



March 13, 2015

FOUNDATION INVESTIGATION AND DESIGN REPORT

**CULVERT REPLACEMENTS, TOWNSHIP OF SHAWANAGA
HIGHWAY 7182 RECONSTRUCTION
FROM THE CARLING/SHAWANAGA TOWNSHIP BOUNDARY, NORTHERLY
7.3 KM
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5163-10-00**

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REPORT





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PART A

**FOUNDATION INVESTIGATION REPORT
HIGHWAY 7182 CULVERTS, TOWNSHIP OF SHAWANAGA
RECONSTRUCTION OF HIGHWAY 7182
FROM THE CARLING/SHAWANAGA TOWNSHIP BOUNDARY,
NORTHERLY 7.3 KM
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5163-10-00**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for one embankment over swamp and two culverts as part of the reconstruction of Highway 7182 (Shebeshekong Road) in the Townships of Shawanaga. The proposed reconstruction of Highway 7182 extends from the boundary of the Township of Carling and Shawanaga northerly for 7.3 km. The locations of the embankment over swamp and proposed culvert replacements are shown on Drawing 1.

The original Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal, dated November 2012. Golder's proposal for foundation engineering services associated with the swamp crossing and culverts is contained in Section 6.8 of MH's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated June 18, 2013. The drawings showing the proposed swamp crossing and culvert alignments were provided to Golder by MH on December 17, 2014.

This report addresses the investigation carried out for the two culverts, both of which have been identified for potential replacement. The foundation investigation for the swamp crossing, which forms part of the Foundation assignment, is presented in a separate report.

The purpose of this investigation is to obtain subsurface information specific to the culvert locations by methods of borehole drilling, bedrock coring, in situ testing and laboratory testing on selected soil samples. The boreholes for these culverts were located in the field by Golder and were surveyed relative to stakes and/or nail pins installed by Tulloch Engineering (Tulloch), a professional surveying company retained by MH. The culvert locations and ground surface elevations at the investigation locations were also surveyed in the field by Tulloch.

2.0 SITE DESCRIPTION

The two existing culverts are located at approximately STA 10+443 and STA 11+290 on Highway 7182 in the Township of Shawanaga and the details (width, height, length, etc.) of which are summarized in Table 1, following the text of this report.

In general, the topography in the area of the overall project limits consists of rolling terrain, including densely treed areas and numerous bedrock outcrops separated by low-lying swamps containing areas of standing water and various types of vegetation and organic soils. The ground surface at the borehole and DCPT locations advanced within the limits of the study area, including through the existing Highway 7182 embankment, varies between Elevations 207.9 m and 205.0 m, referenced to Geodetic datum. Section 4.0 of this report presents a description of the topography in the vicinity of each culvert.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation associated with the two culverts in GWP 5163-10-00 was carried out between June 9 and 16, 2014 during which period a total of seven boreholes and seven Dynamic Cone Penetration Tests (DCPTs) were advanced at, or in the immediate vicinity of, the culvert alignments, as summarized in Table 1 and as shown on Drawings A1 and B1 in Appendices A and B, respectively.



The field investigation was carried out using a truck-mounted CME55 drill rig and portable equipment supplied and operated by Landcore Drilling of Sudbury, Ontario.

The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers, or NW casing with wash boring techniques. In general, soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm O.D. split-spoon sampler operated by an automatic hammer on the drill rig, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Boreholes advanced by portable equipment employed a full-weight hammer lifted manually and dropped from the SPT height. Rock coring to a depth of approximately 3 m beyond the augered/cased borehole was carried out using 'NQ' and 'BQ' core barrels for coring using a drill rig and portable equipment, respectively. All open boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (Wells), as amended.

The boreholes and DCPTs were advanced to depths generally penetrating about 3 m below the culvert invert, terminating on refusal to further auger, casing and/or split spoon advancement likely on, or in proximity to, the bedrock surface. The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendices A and B.

A sample of the creek water was obtained during the field investigation at the culvert locations, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table A1 and B1, included in Appendices A and B, respectively.

The fieldwork was observed by members of our engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples and rock core. The soil samples and rock core were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury geotechnical laboratory where the samples and core underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO Laboratory Standards and/or ASTM Standards, as appropriate. Classification testing (water content, organic content and grain size distribution) was carried out on selected soil samples. Selected samples of the bedrock core were tested for uniaxial compressive strength (UCS). The results of the laboratory testing are provided in Appendices A and B.

Classification of the rock mass quality of the bedrock with respect to the Rock Quality Designation (RQD) is described based on Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006)¹ while the strength of the bedrock core samples is based on Table 3.5 of CFEM, 2006. The degree of weathering of the bedrock core samples and the strength classification of the intact rock mass based on field identification are described in accordance with Table B.3 and Table B.6, respectively of the International Society of Rock Mechanics (ISRM, 1985)² standard classification system.

Survey stakes and/or nail pins were installed by Tulloch at selected locations in the area of each culvert prior to the commencement of drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the applicable stakes and/or nail pins and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the ground surface elevations at applicable survey stakes and/or nail pins installed by Tulloch. The borehole locations given on the Record of Borehole sheets and shown on Drawing A1 and B1 are positioned relative to

¹ Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.

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



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MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and depths drilled are as follows:

Culvert Location	Borehole/DCPT	Location (m)		Ground Surface Elevation (m)	Depth of Borehole/DCPT (m)
		Northing	Easting		
STA 10+443	C1-01	5039724.8	246154.6	205.1	7.8
	C1-02	5039731.2	246164.1	206.9	9.3
	C1-03	5039745.4	246164.6	205.0	4.9 / 6.4
	C1-04	5039720.5	246163.6	205.2	6.3
	C1-DC01	5039721.5	246161.9	205.2	3.0
	C1-DC02	5039733.8	246157.8	206.9	9.1
	C1-DC03	5038743.4	246169.0	205.3	0.8
STA 11+290	C2-01	5040334.6	245640.1	206.7	4.4
	C2-02	5040329.8	245649.2	207.9	7.2
	C2-03	5040341.7	245657.0	206.9	3.6
	C2-DC01	5040327.6	245646.4	207.5	4.0
	C2-DC02A	5040335.3	245647.2	207.9	1.5
	C2-DC02B	5040336.2	245646.9	207.9	1.7
	C2-DC03	5040333.5	245659.8	206.7	0.9

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in The Physiography of Southern Ontario³, this section of Highway 7182 (formerly Highway 69) lies within the physiographic region known as the Georgian Bay Fringe, which extends along the east side of Georgian Bay through the Parry Sound and Muskoka areas, then eastward from Muskoka in patches into the area north of the Kawartha Lakes.

This part of the Georgian Bay Fringe physiographic region was never submerged during periods of glacial recession. As a result, the surficial soils in this area consist of very shallow deposits of sand, silt and clay underlain by metamorphic bedrock; numerous bare knobs and ridges of bedrock are present throughout the area. Localized low-lying swampy areas, containing peat and/or organic soils underlain by soft/loose native soils, are present in valleys between the bedrock knobs and ridges.

The bedrock in the area consists typically of gneisses of the Britt Domain of the Central Gneiss Belt, a subdivision of the Grenville Structural Province, as described in Geology of Ontario, OGS Special Volume 4⁴. Deposition of Paleozoic strata and later erosion during glaciation exposed these Precambrian rocks.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil and bedrock core

³ 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.

⁴ Geology of Ontario, 1991. Ontario Geological Society, Special Volume 4, Part 2. Ministry of Northern Development and Mines, Ontario.



samples, are presented on the Record of Borehole and Drillhole sheets and the laboratory test sheets in Appendices A and B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and in situ testing and are approximate. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the stratigraphy encountered at the culvert locations is similar, however, the thickness of overburden ranges from 0.3 m to 6.3 m. The stratigraphy at the locations of the culverts generally consists of surficial layers of peat or topsoil, or of embankment fill, underlain by interlayers of native organic deposits, non-cohesive soil deposits and cohesive deposits over bedrock. A detailed description of the subsurface conditions at the culvert locations is provided in the following sections of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or stratum.

4.3 Culvert at STA 10+443

The plan and profile along the centreline of the culvert at STA 10+443 showing the borehole locations and interpreted stratigraphy are shown on Drawing A1. The height of the embankment at this location is about 1.9 m and the existing concrete box culvert is about 19.6 m long with dimensions of 2400 mm wide by 1200 mm high. A total of four boreholes and three DCPTs were completed to investigate the subsurface conditions at the culvert location: three boreholes (C1-01, C1-03 and C1-04) and two companion DCPTs (C1-DC01 and C1-DC03) were advanced near the ends of the culvert; and one borehole (C1-02) and one DCPT (C1-DC02) was advanced through the roadway embankment near the midpoint of the culvert. In addition, a DCPT was advanced immediately adjacent to Borehole C1-03 to confirm the depth to refusal recorded in the borehole. In general, the topography in the area of the culvert consists of low-lying swamp areas, bedrock outcrops and treed areas.

4.3.1 Embankment Fill

Asphalt and embankment fill were encountered in Borehole C1-02, advanced immediately adjacent to the culvert. A layer of asphalt 75 mm thick was encountered at ground surface at Elevation 206.9 m and is underlain by a 2.9 m thick deposit of embankment fill consisting of silty sand to sand and gravel. Cobbles are inferred to be present in the fill deposit in Borehole C1-02 below a depth of 2.3 m corresponding to Elevation 203.6 m.

The SPT 'N'-values measured within the embankment fill range between 13 blows and 38 blows per 0.3 m of penetration indicating a compact to dense relative density.

The natural water content measured on one samples of the fill deposit is about 11 per cent.

The result of a grain size distribution test completed on one sample of the silty sand fill is shown on Figure A1 in Appendix A.

4.3.2 Peat (Upper Layer)

A deposit of brown to black amorphous peat was encountered at the ground surface in Boreholes C1-01, C1-03 and C1-04 between Elevations 205.2 m and 205.0 m. Sand seams approximately 0.75 m thick were



encountered in the peat deposit in Borehole C1-03 at a depth of 0.15 m, corresponding to Elevation 204.8 m. The thickness of this upper deposit of peat ranges from 0.5 m to 0.6 m.

The SPT 'N'-values measured within the peat range from 0 blows (weight of hammer) to 1 blow per 0.3 m of penetration suggesting a very soft consistency.

4.3.3 Sand (Interlayer)

An interlayer of brown to grey sand, trace silt, trace organics was encountered underlying the upper peat deposit in Boreholes C1-01, C1-03 and C1-04. The top of the deposit was encountered between Elevations 204.7 m and 204.4 m and the thickness of the interlayer ranges from 0.3 m to 0.6 m.

The SPT 'N'-value measured within the sand interlayer is 1 blow per 0.3 m of penetration indicating a very loose relative density.

The natural water content measured on two samples of the sand deposit range from about 39 per cent to about 56 per cent.

The results of the grain size distribution tests completed on two samples of the sand deposit are shown on Figure A2 in Appendix A.

4.3.4 Peat (Lower Layer)

A deposit of brown to black amorphous peat was encountered below the upper sand layer in Boreholes C1-01, C1-03 and C1-04 between Elevations 204.4 m and 203.9 m, and below the granular fill deposit in Borehole C1-02 at Elevation 203.9 m. The thickness of the deposit ranges from 0.4 m to 1.6 m.

The SPT 'N'-values measured within the organic sand range from 0 blows (weight of hammer) to 2 blows per 0.3 m of penetration suggesting a very soft consistency.

The natural water content measured on two samples of the organic sand range from about 488 per cent and about 611 per cent.

4.3.5 Organic Silt and Clayey Silt

A deposit of brown to grey organic silt and clayey silt was encountered below the lower peat deposit. A deposit of organic silt was encountered in Boreholes C1-01 and C1-03 at Elevations 202.8 m and 203.5 m and the thickness of the deposit is 0.8 m in both boreholes. A clayey silt deposit was encountered in Boreholes C1-02 and C1-04 at Elevations 203.1 m and 202.8 m and the thickness of the deposit is 1.5 m and 0.4 m in the respective boreholes.

The SPT 'N'-values measured within the organic silt are 0 blows (weight of hammer) per 0.3 m of penetration suggesting a very soft consistency. The SPT 'N'-values measured within the clayey silt range from 0 blows (weight of hammer) to 1 blow per 0.3 m of penetration suggesting a very soft consistency. Two in situ field vane tests carried out within the clayey silt measured undrained shear strengths of 14.4 kPa and 16.3 kPa, and a sensitivity of 3. The results of the field vane tests indicate that the clayey silt has a soft consistency.



The natural water content measured on two samples of the organic silt is about 183 per cent and 27 per cent. The natural water content measured on two samples of the clayey silt deposit is about 31 per cent and 43 per cent.

An Atterberg limits test carried out on one sample of the organic silt yielded a liquid limit of about 157 per cent and a plastic limit of about 67 per cent, corresponding to a plastic index of about 90 per cent. Atterberg limits tests carried out on two samples of the clayey silt yielded liquid limits of about 23 per cent and about 24 per cent and plastic limits of about 16 per cent and about 15 per cent, corresponding to plastic indices of about 7 per cent and about 9 per cent, respectively. The results of the Atterberg limits tests are shown on the plasticity chart in Figure A3 in Appendix A, and indicate that the material is classified as organic silt of high plasticity and clayey silt of low plasticity, respectively.

The organic content measured on one sample of the organic silt is about 11 per cent.

4.3.6 Silt and Sand to Gravelly Sand

A deposit of brown to grey silt and sand, silty sand to sand, to gravelly sand was encountered below the organic silt to clayey silt deposits in Boreholes C1-01 to C1-04. The top of the deposit was encountered between Elevations 202.7 m and 201.6 m and the thickness of the deposit ranges from 0.3 m to 2.5 m. Cobbles are inferred to be present in Borehole C1-02 in the gravelly sand deposit below a depth of 2.3 m, corresponding to Elevation 204.6 m.

The SPT 'N'-values measured within the deposit typically range from 4 blows to 7 blows per 0.3 m of penetration indicating a loose relative density. The SPT 'N'-value measured within the gravelly sand deposit in Borehole C1-02 is 13 blows for 0.15 m inferred to be on cobbles as the split-spoon was observed to be bouncing.

The natural water content measured on three samples of the deposit ranged from about 19 per cent to 30 per cent.

The result of the grain size distribution tests completed on a sample of the silt and sand and a sample of the gravelly sand are shown on Figures A4 and A5, respectively, in Appendix A.

4.3.7 Silty Clay to Clay

A deposit of grey silty clay to clay was encountered below the non-cohesive deposit in Boreholes C1-01 and C1-03 at Elevations 205.1 m and 205.0 m and the thickness of the deposit is 2.2 m to 0.8 m in the respective boreholes.

The SPT 'N'-values measured within the deposit are 0 blows (weight of hammer) and 1 blow per 0.3 m of penetration with an SPT 'N'-values of 6 blows per 0.15 m of penetration at the bottom of Borehole C1-01, however, the split-spoon was observed to be bouncing. Two in situ field vane tests carried out within the silty clay to clay deposit measured undrained shear strengths are about 13 kPa and 19 kPa, and the sensitivity is 3 and 5. The results of the field vane tests indicate that the silty clay to clay has a soft consistency.

The natural water content measured on two samples of the clay to silty clay deposit was about 46 per cent and 81 per cent.



Atterberg limits tests carried out on two samples of the cohesive deposit yielded liquid limits of about 52 per cent and 35 per cent, plastic limits of about 24 per cent and 15 per cent and corresponding plastic indexes of about 28 per cent and about 20 per cent. The results of the Atterberg limits tests are shown on the plasticity chart in Figure A6 in Appendix A, and indicate that the material is classified as silty clay of intermediate plasticity and clay of high plasticity, respectively.

4.3.8 Refusal / Bedrock

Refusal to casing and split-spoon advancement in Borehole C1-01 and C1-03 and to further DCPT penetration adjacent to Boreholes C1-03 and DCPTs C1-DC01 to C1-DC03 was encountered at depths ranging from 0.8 m to 9.1 m below ground surface, ranging from Elevations 204.5 m to 197.3 m.

Bedrock was encountered in Boreholes C1-02 and C1-04 at Elevations 200.6 m and 202.1 m and core samples 3.0 m and 3.2 m long were obtained, respectively. Based on a review of the bedrock core samples, the bedrock consists of fine to coarse grained, fresh, dark grey to grey granitic gneiss.

The Total Core Recovery (TCR) for the core samples ranges from 94 per cent to 100 per cent and the Solid Core Recovery (SCR) ranges from 58 per cent to 97 per cent. The Rock Quality Designation (RQD) measured on the recovered bedrock core samples ranges between 53 per cent and 96 per cent, with values typically greater than 85 per cent, indicating the rock is typically of good to excellent quality, according to Table 3.10 in CFEM (2006)¹.

One Unconfined Compression (UC) test (ASTM D7012⁵) was carried out on one core sample of the granitic gneiss bedrock obtained in Borehole C1-04 and measured a Uniaxial Compressive Strength (UCS) value of about 113 MPa, as detailed in Table A2. Based on the laboratory UC test, in accordance with Table 3.5 in CFEM (2006)¹, the gneiss bedrock is classified as very strong (R5, 100 MPa < UCS < 250 MPa).

4.3.9 Groundwater Conditions

The water level was measured in Boreholes C1-01 to C1-04 upon completion of drilling operations at depths between 0.3 m and 3.1 m below ground surface, ranging from Elevations 204.8 m to 203.8 m. Groundwater levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

4.4 Culvert at STA 11+290

The plan and profile along the centreline of the culvert at STA 11+290 showing the borehole locations and interpreted stratigraphy are shown on Drawing B1. The height of the embankment at this location is about 1.2 m and the two existing corrugated steel pipe (CSP) culverts have a diameter of 910 mm and are about 11.9 m and 12.0 m long. A total of three boreholes and four DCPTs were completed to investigate the subsurface conditions at the culvert location: two boreholes (C2-01 and C2-03) and two companion DCPTs (C2-DC01 and C2-DC03) were advanced near the ends of the culvert; and one borehole (C2-02) and two DCPTs (C2-DC02A and C2-DC02B) were advanced through the roadway embankment near the midpoint of the culvert. In general, the topography in the area of the culvert consists of low-lying and swamp areas, bedrock outcrops and treed areas.

⁵ ASTM D7012 - Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens.



4.4.1 Embankment Fill

Asphalt and embankment fill were encountered in Borehole C2-02, advanced immediately adjacent to the culvert. A layer of asphalt 75 mm thick was encountered at ground surface at Elevation 207.9 m and is underlain by a 2.2 m thick deposit of embankment fill comprised of sand and gravel.

The SPT 'N'-values measured within the embankment fill range between 13 blows and 55 blows per 0.3 m of penetration indicating a compact to very dense relative density.

The natural water content measured on one samples of the fill deposit is about 2 per cent.

The results of a grain size distribution test completed on one sample of the embankment fill are shown on Figure B1 in Appendix B.

4.4.2 Topsoil / Peat

A 0.3 m and 0.2 m thick layer of topsoil and peat, respectively, was encountered from ground surface at Boreholes C2-01 and C2-03 drilled near the ends of the culverts.

4.4.3 Clayey Silt to Silty Clay (Upper Deposit)

A 0.5 m to 0.1 m thick upper deposit of clayey silt and silty clay was encountered below the topsoil/peat in Boreholes C2-01 and C2-03, respectively, at Elevations 206.4 m and 206.7 m.

A SPT 'N'-value measured within the clayey silt layer is 3 blows per 0.3 m of penetration indicating a soft consistency.

The natural water content and the organic content measured on a sample of the clayey silt layer is about 20 per cent and about 2 per cent, respectively.

An Atterberg limits test carried out on one sample of the clayey silt yielded a liquid limit of about 25 per cent and a plastic limit of about 16 per cent, corresponding to a plastic index of about 9 per cent. The results of the Atterberg limits tests are shown on the plasticity chart in Figure B2 in Appendix B, and indicate that the material is classified as clayey silt of low plasticity.

4.4.4 Silt and Sand to Sand

A 0.5 m and 0.7 m thick deposit of grey silt and sand to sand was encountered underlying the clayey silt in Borehole C2-01 and below the embankment fill in Borehole C2-02 at Elevations 205.9 m and 205.6 m, respectively.

The SPT 'N'-value measured within the silt and sand deposit is 20 blows per 0.3 m of penetration. A SPT 'N'-value of 8 blows and per 0.15 m of penetration was recorded in Borehole C2-01 where it was observed that the split-spoon was bouncing on inferred cobbles.

The natural water content of two samples of the sand deposit is about 21 per cent and 26 per cent.



The result of a grain size distribution test on a sample of the silt and sand deposit is shown on Figure B3, in Appendix B.

4.4.5 Clayey Silt (Lower Deposit)

A lower deposit of grey clayey silt was encountered underlying the silt and sand to sand deposit in Borehole C2-02. The top of the deposit was encountered at Elevation 204.9 m and the thickness of the deposit is 0.8 m.

The SPT 'N'-value measured within the clayey silt deposit is 4 blow per 0.3 m of penetration. An in situ field vane test carried out within the cohesive deposit measured an undrained shear strength of about 48 kPa, and a sensitivity of 4. The result of the field vane test indicates that the clayey silt has a firm consistency.

The natural water content measured on a sample of the clayey silt deposit is about 38 per cent.

An Atterberg limits test carried out on one sample of the cohesive deposit yielded a liquid limit of about 23 per cent and a plastic limit of about 15 per cent, corresponding to a plastic index of about 8 per cent. The result of the Atterberg limits test is shown on the plasticity chart in Figure B4 in Appendix B, and indicates that the material is classified as clayey silt of low plasticity.

4.4.6 Silty Sand

A layer of silty sand was encountered underlying the clayey silt deposit in Boreholes C2-02. The top of the deposit was encountered at Elevation 204.1 m and the thickness of the deposit is 0.2 m.

The SPT 'N'-value measured at the interface of the bedrock is 4 blows per 0.15 m of penetration.

The natural water content measured on one sample of the silty sand is about 20 per cent.

4.4.7 Refusal / Bedrock

Refusal to further penetration was encountered in DCPTs C2-DC01, C2-DC02A, C2-DC02B and C2-DC03 at depths between 0.9 m and 4.0 m below ground surface ranging from Elevations 206.4 m to 203.5 m.

Bedrock was encountered in Boreholes C2-01 to C2-03 at between Elevations 206.6 m and 203.9 m and core samples between 3.1 m and 3.3 m long were obtained. Based on a review of the bedrock core samples, the bedrock consists of very fine to medium grained, fresh, grey-black to pinkish grey gneiss.

The Total Core Recovery (TCR) for the core samples is 100 per cent and the Solid Core Recovery (SCR) ranges from 89 per cent to 100 per cent. The Rock Quality Designation (RQD) measured on the recovered bedrock core samples ranges between 66 per cent and 100 per cent, with values typically greater than 89 per cent, indicating the rock is of fair to excellent quality, according to Table 3.10 in CFEM (2006)¹.

One Unconfined Compression (UC) test (ASTM D7012⁵) was carried out on one core sample of the granitic gneiss bedrock obtained in Borehole C2-03 and measured a Uniaxial Compressive Strength (UCS) value of about 131 MPa, as detailed in Table B2. Based on the laboratory UC test, in accordance with Table 3.5 in CFEM (2006)¹, the gneiss bedrock is classified as very strong (R5, 100 MPa < UCS < 250 MPa).



4.4.8 Groundwater Conditions

The water level was measured in the open Boreholes C2-01 and C2-02 upon completion of drilling operations at depths of 0.2 m and 1.7 m below ground surface, corresponding to Elevations 206.5 m and 206.2 m, respectively. Groundwater levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

5.0 CLOSURE

Messr. Indulis Dumpis and Gabriel Mathieu, senior technicians with Golder, directed the drilling program. This report was prepared by Ms. Madison Kennedy, B.A.Sc. and reviewed by Mr. Christopher Ng, P.Eng., an Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, carried out a quality control review of the report.



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PART B

FOUNDATION DESIGN REPORT
HIGHWAY 7182 CULVERTS, TOWNSHIP OF SHAWANAGA
RECONSTRUCTION OF HIGHWAY 7182
FROM THE CARLING/SHAWANAGA TOWNSHIP BOUNDARY,
NORTHERLY 7.3 KM
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5163-10-00



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides recommendations on the foundation aspects of design for the proposed work based on the interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation at this site. The recommendations are intended for the guidance of the design engineer. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required during construction. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of Ministry of Transportation, Ontario (MTO) to provide recommendations on foundation aspects for the detail design of two culverts to replace a concrete box culvert and twin corrugated steel pipe (CSP) culverts as part of the reconstruction of Highway 7182 (Shebeshekong Road) in the Township of Shawanaga extending from the boundary of the Township of Carling and Shawanaga northerly for 7.3 km. The proposed culverts are located at STA 10+443 and STA 11+290 in the Township of Shawanaga as shown on Drawing 1. Table 1 summarizes the locations of the proposed culverts, culvert types, dimensions and invert elevations within the project limits that require foundation design. Based on the culvert condition assessment reports prepared by MH, the existing culvert located at STA 10+443 is generally rated as good (i.e. between 10 and 15 years of design life remaining) while the existing double culverts at STA 11+290 is generally rated as fair (i.e. between 5 and 10 years of design life remaining).

This report presents the results of stability and settlement assessments and provides foundation recommendations and recommended geotechnical parameters for the design of the two culverts, both of which have been identified for potential replacements. It provides recommendations for stable embankment geometry and embankment fill materials including implementation of mitigation alternatives that may be required as a means to reduce culvert settlements and to improve embankment stability (if necessary). The report also addresses potential construction concerns and geotechnical problems associated with culvert and embankment construction, sub-excavating soft/organic materials and placement of new fill materials.

It is understood that the present embankment geometry (i.e. height and width) at the culvert locations will remain unchanged and that the proposed work are to rehabilitate the pavement structure and embankment shoulders to improve the overall performance of the highway.

6.2 Mitigation of Time Dependent Settlement and Stability Issues

6.2.1 Culvert at STA 10+443

Given the presence of organic and soft compressible deposits to a depth of up to 3 m below natural ground surface adjacent to the toe of the embankment and up to about 5.3 m below the existing roadway, as inferred from the subsurface (borehole) investigation, founding the new culvert on the existing subgrade (granular fill underlain by soft organic/cohesive deposits and very loose sand deposits) will likely result in poor performance



of the culvert over the long term, potentially resulting in unfavourable drainage/surface water flow conditions. As such, it is recommended that all peat, organic silt and soft clayey silt deposits above about Elevation 201.6 m be sub-excavated and replaced with granular fill to reduce post-construction and differential settlements, improve stability as well as provide a competent founding stratum for the culvert. All sub-excavation and backfilling should be carried out using construction procedures in accordance with OPSS.PROV 209 (Embankment over Swamps and Compressible Soils).

Taking into consideration the height and geometry of the existing embankment (i.e. about 1.9 m high with 2H:1V side slopes), adopting the recommendations to removing the organic and soft compressible soils from below the footprint of the replacement culvert, and reconstructing the embankment adjacent to the culvert with granular fill, stability issues are not anticipated after the culvert replacement. Further post-construction settlement of the foundation soils is estimated to be less than 25 mm.

6.2.2 Culvert at STA 11+290

Taking into consideration that the present embankment geometry adjacent to the existing culvert is to remain unchanged (i.e. no additional load will be imposed on the founding soils), the compact relative density of the existing subsurface deposits under the culvert, stability issues are not anticipated after reconstruction and post-construction settlement is estimated to be less than 10 mm. However, consideration could be given to the sub-excavation and replacement of the native soils (i.e. silt and sand and clayey silt deposits) below the replacement culvert with granular fill to increase the factored geotechnical axial resistance for design.

6.3 Foundations for Culvert Replacements

Pre-cast box culverts and cast-in-place open footing culverts are feasible alternatives for the replacement of the existing concrete box culvert at STA 10+443 and for the replacement of the existing twin CSP culverts at STA 11+290 with a single 1.8 m wide concrete box culvert.

The advantages, disadvantages and risks/consequences associated with replacing the existing culverts with the various culvert alternatives are summarized in Table 2, following the text of this report. Recommendations for replacement of the existing culverts with a pre-cast box culvert as well as cast-in-place open footing culvert are provided in the following sections. From a foundations perspective, pre-cast box culvert replacements are preferred over cast-in-place open footing culvert replacements at these sites based on the following advantages:

- A pre-cast box culvert minimizes the depth of excavation and groundwater control required as compared with an open footing culvert;
- Pre-cast box culvert segments can usually be installed more expeditiously than construction of a cast-in-place open footing culvert, resulting in a shorter duration for dewatering, surface water pumping and road closure; and,
- Pre-cast box culvert segments are more tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site, or movements occur due to freeze-thaw of the founding/adjacent soil.



The simplified stratigraphy together with the associated engineering soil parameters assigned to the different soil types at the culvert locations are presented in Table 3.

6.3.1 Founding Elevations and Frost Protection Requirements

6.3.1.1 Box Culvert Replacements

Box culverts are not required to be founded at or below the standard depth of frost penetration for frost protection given that box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. For a box culvert founded on granular bedding over bedrock, frost penetration measures are not required. Table 3, following the text of this report, provides recommended founding elevations and founding conditions for the replacement culverts.

6.3.1.2 Open Footing Culvert Replacements

The strip footings for an open footing culvert replacement, whether founded on the granular fill or native deposits, should be founded at a minimum depth of 1.8 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.101 (Foundation, Frost Penetration Depths for Southern Ontario). For an open footing culvert founded directly on bedrock, frost penetration measures are not required. Table 3, following the text of this report, provides recommended founding elevations and founding conditions for the replacement culverts.

6.3.2 Geotechnical Axial Resistances and Reactions

Replacement culverts/footings placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 3, should be designed based on the recommended factored geotechnical axial resistances at Ultimate Limit States (ULS) and the geotechnical reactions at Serviceability Limit States (SLS) for 25 mm of settlement, as given in Table 3. The dimensions used in the analysis are given in Table 3.

The factored geotechnical axial resistances at ULS and geotechnical reactions at SLS for 25 mm of settlement are dependent on the culvert/footing dimensions and founding elevation and as such, the geotechnical resistances/reactions should be reviewed if the culvert/footing dimensions or founding elevations differ from those given in Table 3. In addition, geotechnical resistances provided in Table 3 are based on loadings applied perpendicular to the surface of the culverts/footings. Where the load is not applied perpendicular to the surface of the culverts/footings, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the Canadian Highway Bridge Design Code (CHBDC) and its *Commentary*.

6.3.3 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of the box culvert, or strip footings for the open footing culverts, and the granular fill/bedding placed following sub-excavation of organic and cohesive deposits should be calculated in accordance with Section 6.7.5 of the CHBDC. Table 4, following the text of this report,



provides the coefficients of friction ($\tan \delta$) between the base of the culvert/footing and potential interface materials.

6.4 Lateral Earth Pressures for Design

The lateral earth pressures acting on the walls of the culverts will depend on the type and method of placement of backfill materials, the nature of the soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culvert walls. It should be noted that these design recommendations and parameters are for level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II but with less than 5 per cent passing the No. 200 (0.075 mm) sieve should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of not less than 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness and nominally compacted. Weep holes, where applicable, should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.8 m behind the back of the wall (in accordance with Figure C6.20(a) of the *Commentary* to the CHBDC). For unrestrained walls, fill should be placed within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (in accordance with Figure C6.20(b) of the *Commentary* to the CHBDC). The pressures are based on the embankment backfill material and the following parameters (unfactored) may be used:

Fill Type	Soil Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Granular 'A'	22 kN/m ³	0.43	0.27
Granular 'B' Type II	21 kN/m ³	0.43	0.27

If the culvert structures allow for lateral yielding, active earth pressures may be used in the foundation design. If the culvert structures do not allow for lateral yielding, at-rest earth pressures should be assumed for culvert design. The movement to allow active pressures to develop within the backfill, and thereby assume a restrained structure, may be taken as per Table C6.6 of the *Commentary to the CHBDC*.



6.5 Construction Considerations

6.5.1 Temporary Roadway Protection

The temporary excavations for the culverts will be made through the existing embankment fill and into native overburden soils. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects.

Provided that proper groundwater control is in place, temporary open-cut excavations through the embankment fill and native overburden soils should be made with side slopes appropriate for their soil type as defined in the Occupational Health and Safety Act (OHSA). The excavation slope requirements for the various soil types in accordance with OHSA are presented below.

Culvert	Soil	Soil Type	Excavation Slope Requirements
STA 10+443	Silty Sand to Sand and Gravel (Fill)	Type 3	1H:1V
	Peat / Organic Silt to Clayey Silt	Type 4	3H:1V
STA 11+290	Sand and Gravel (Fill)	Type 3	1H:1V
	Silt and Sand	Type 3	1H:1V

Temporary protection systems will be required along the existing highway to facilitate construction staging and maintain traffic during culvert replacement work. Given that the depth to the bedrock surface varies along the embankment, it may not be possible to install sheet pile shoring to facilitate replacement of the existing culverts where bedrock is encountered. In addition, the installation of sheet pile shoring may be difficult given the presence of inferred cobbles in the embankment fill and gravelly sand deposits at the culvert located at STA 10+443.

Temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). The lateral movement of the temporary shoring should meet Performance Level 2 as specified in OPSS 539 provided that any existing adjacent utilities can tolerate this magnitude of deformation.

The selection and design of the protection system is the responsibility of the Contractor.

6.5.2 Excavation and Replacement Below Culvert Bedding

Prior to the placement of any bedding material or granular fill, all organic soils should be stripped from the plan limits of the proposed works. Given the design invert elevations of the replacement culverts summarized in Table 3, excavation of the organic material, embankment fill and very soft/soft cohesive soils up to about 5.3 m and 4.0 m below existing roadway surface will be required for the culverts at STA 10+443 and STA 11+290, respectively.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organic soils or other unsuitable materials have been removed, in accordance with OPSS 422 (Precast



Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for a cast-in-place open footing culvert. Following inspection, the sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II and placed and compacted in accordance with OPSS.PROV 501 (Compacting).

All excavations must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended).

6.5.3 Culvert Bedding and Backfill

6.5.3.1 Box Culverts

The bedding, levelling pad, and granular backfill requirements for the pre-cast box culverts should be in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and potential groundwater seepage through the native overburden soils during excavation to invert and bedding level, it is recommended that at least 300 mm of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material be used for bedding. As the overburden deposit below the bedding is generally fine grained it is recommended that a non-woven geotextile be placed between the overburden soils and the bottom of the bedding. The geotextile should meet the specification for OPSS 1860 (Geotextiles) Class II and have a Fabric Opening Size (FOS) not greater than 212 μm . The bedding should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 95 per cent of the Standard Proctor maximum dry density of the material as specified in OPSS.PROV 501 (Compacting). In addition, a minimum 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 Granular 'A' or concrete fine aggregate meeting the gradation requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided as shown on OPSS 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction in dry conditions.

6.5.3.2 Open Footing Culverts

The backfill requirements for the cast-in-place open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures). The open footing culverts footings should be provided with at least 1.8 m of soil cover for frost protection. Backfill should be placed in lifts not exceeding 200 mm in loose thickness, and compacted as specified in OPSS.PROV 501 (Compacting) to at least 98 per cent of the Standard Proctor maximum dry density of the material.

6.5.3.3 Backfill

Backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II, but with less than 5 per cent passing the No. 200 (0.075 mm) sieve. The granular backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm for a pre-cast box culvert and 500 mm for an open footing culvert, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) and OPSS 902 (Excavating and Backfilling – Structures), respectively.



Backfill placement for reconstruction of the roadway embankments over the culverts should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the existing embankment fill and new fill along the cut faces.

Inspection and field density testing should be carried out by a Quality Verification Engineer during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

6.5.4 Subgrade Protection

The subgrade soils at the culvert sites will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance and as an alternative to the 300 mm compact bedding requirement, a concrete working slab could be placed on the subgrade if the concrete for the footings or the leveling layer and box culverts are not placed within four hours after preparation, inspection and approval of the subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a 28-day compressive strength of not less than 20 MPa.

6.5.5 Erosion Protection

Provision should be made for scour and erosion protection at each culvert location. In order to prevent surface water from flowing either beneath the culverts (potentially causing undermining and scouring), or around the culverts (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the pre-cast box culverts. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level for a pre-cast box culvert and from the ground surface immediately adjacent to an open footing culvert, to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and to a minimum vertical height equivalent to the high water level, including along the embankment slopes. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height of two times the culvert height or the high water level, whichever is greater.

The requirements for and design of erosion protection measures for the inlet and outlet of the culverts should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culverts should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment for Sewer and Culvert Outlets). Erosion protection for the inlet of the culverts should generally follow the standard presented in OPSD 810.010, with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culverts if this clay seal option is adopted.



6.5.6 Surface Water and Groundwater Control

Excavation below the level of the adjacent ground surface at the culvert alignments will be required to remove embankment fill, organics and very soft to soft cohesive overburden soils prior to placement of backfill, bedding material and the actual culvert structures. As a result, groundwater flow into the excavation can be expected to occur due to the relatively permeable nature of the near ground surface fill and native overburden soils. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water flow should be directed away from the excavation.

Depending on the surface water flow conditions and groundwater level at the time of construction, water flow could be passed through the sites by means of a temporary culvert, or diverted by pumping from behind temporary cofferdams.

Groundwater control may be required as the foundation excavation to the culvert invert or footing level will extend below the groundwater level. Excavations will be advanced through the organic deposits, layers of cohesive and non-cohesive deposits; however, seepage into the excavation should be adequately controlled by pumping from properly filtered sumps. Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering).

6.5.7 Analytical Testing for Construction Materials

The results of analytical tests on a sample of water taken adjacent to each culvert site are presented in Tables A1 and B1 in Appendices A and B, respectively. The suite of parameters tested is intended to allow the design engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection of steel reinforcing elements.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Madison Kennedy, B.A.Sc., a member of the geotechnical engineer group. The technical aspects were reviewed by Mr. Christopher Ng, P.Eng., a geotechnical engineer and an Associate with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and a Principal with Golder, carried out an independent quality control review of the report.



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REFERENCES

- Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.
- Canadian Highway Bridge Design Code (CHBDC) and Commentary, 2006. CAN/CSA-S6-06 and CSA Special Publication S6.1 06, Canadian Standards Association.
- Chapman, L.J. and D. F. Putnam, 1984. The Physiography of Southern Ontario, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.
- Geology of Ontario. 1991. Ontario Geological Society, Special Volume 4, Part 2. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.
- 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.
- ASTM International:
- | | |
|------------|--|
| 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 |

Ontario Occupational Health and Safety Act:

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

Ontario Provincial Standard Drawings:

OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Depths for Southern Ontario

Ontario Provincial Standard Specification:

OPSS.PROV 209	Construction Specifications for Embankments Over Swamps and Compressible Soils
OPSS 422	Construction Specifications for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS 517	Construction Specifications for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 902	Construction Specifications for Excavating and Backfilling – Structures
OPSS.PROV 1002	Material Specification for Aggregates – Concrete



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OPSS.PROV 1010	Material Specifications for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material
OPSS 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

Ontario Water Resources Act:

Ontario Regulation Amendment to Ontario Regulation 903



LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a)	Index Properties
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

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

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1
2

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



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w _p	plastic limit
w _l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

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



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING 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° 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	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	



TABLES



**FOUNDATION REPORT - HIGHWAY 7182 RECONSTRUCTION
CULVERTS GWP 5163-10-00**

Table 1: Summary of Culvert Details

Culvert Location (Township)	Culvert ID	Approximate Height of Embankment ¹	Existing Culvert			Approximate Invert Elevation ²		Boreholes	Dynamic Cone Penetration Tests	Reference Appendix
			Type	Approximate Dimension	Approximate Length	North End of Culvert	South End of Culvert			
STA 10+443 (Shawanaga)	C1	1.9 m	Concrete Box	2.4 m wide by 1.2 m high	19.6 m	204.9 m	204.5 m	4 Boreholes (C1-01 to C1-04)	3 DCPTs (C1-DC01 to C1-DC03)	A
STA 11+290 (Shawanaga) ³	C2	1.2 m	CSP Culverts	910 mm diameter	11.9 m / 12.0 m	205.7 m / 206.0 m	205.8 m / 206.1 m	3 Boreholes (C2-01 to C2-03)	4 DCPTs (C2-DC01, C2-DC02A, C2-DC02B and C2-DC03)	B

Notes:

1. Embankment height is relative to existing ground surface level at the toe of embankment adjacent to the culvert.
2. Culvert invert elevations are estimated based on the top of culvert surveys and culvert dimensions provided by MH.
3. At STA. 11+290 the existing culvert structure consists of two parallel CSP culverts.



**FOUNDATION REPORT - HIGHWAY 7182 RECONSTRUCTION
CULVERTS GWP 5163-10-00**

Table 2: Comparison of Foundation Alternatives for Culvert Replacements

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	<ul style="list-style-type: none">■ Minimizes the depth of excavation, excavation support and dewatering requirements.■ Allows for faster construction than for open footing culvert, resulting in shorter duration for dewatering and surface water pumping.■ More tolerant of total and differential settlement than an open footing culvert if the highway embankment is raised or widened at the culvert site.■ Backfill under culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements.■ Can be designed to accommodate movements at the joints in the event of differential settlement or lateral stresses.	<ul style="list-style-type: none">■ Dewatering would be required where excavation extends below the groundwater level if construction is to be carried out in-the-dry.■ Cut-off or clay blanket may be required at inlet to mitigate potential for scour under culvert.	<ul style="list-style-type: none">■ Some risk of disturbance of the founding soils underlying the culvert during construction.
Cast-In-Place Open Footing Culvert	<ul style="list-style-type: none">■ Not limited by the availability of pre-fabricated materials such as for box culverts.	<ul style="list-style-type: none">■ Will require construction of footings in-the-dry which will take a longer time due to requirements for groundwater control system installation, dewatering and surface water pumping.■ Less tolerant of total and differential settlement.■ Excavations for footings will generate additional spoils requiring off-site disposal.	<ul style="list-style-type: none">■ High risk of disturbance of the founding soils underlying the culvert during construction.■ Culvert joints may be required and would have to be designed to accommodate total and differential settlement (if applicable)

Checked by: CN
Reviewed by: JMAC



**FOUNDATION REPORT - HIGHWAY 7182 RECONSTRUCTION
CULVERTS GWP 5163-10-00**

Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box and Cast-In-Place Open Footing Culvert Replacements

Culvert Location (Township)	Approximate Invert Elevation¹ (North End / South End)	Culvert Type	Approximate Founding Elevation (North End / South End)	Founding Soil Stratum	Culvert Dimensions	Factored Geotechnical Axial Resistance at ULS (Embankment Crest / Toe)	Geotechnical Reaction at SLS for 25 mm of Settlement (Embankment Crest / Toe)
STA 10+443 (Shawanaga)	204.9 m / 204.5 m	Pre-Cast Box	204.9 m / 204.5 m	Compacted Granular Fill up to 2 m thick	2.4 m wide / 19.6 m long	200 kPa / 200 kPa	175 kPa / 75 kPa
		Cast-In-Place Open Footing	203.1 m / 202.7 m	Granular fill over loose Silt and Sand to Silty Sand	0.5 m wide footings / 19.6 m long	250 kPa / 250 kPa	250 kPa / 110 kPa
STA 11+290 (Shawanaga)	205.7 m / 205.8 m	Pre-Cast Box	205.7 m / 205.8 m	Compact Sand to Silt and Sand / Gneiss Bedrock	1.8 m wide / 12 m long	175 kPa / 175 kPa	100 kPa / 125 kPa
				Compacted Granular Fill / Gneiss Bedrock	1.8 m wide / 12 m long	650 kPa / 650 kPa	N/A ²
		Cast-In-Place Open Footing	203.9 m / 204.0 m	Gneiss Bedrock	0.5 m wide footings / 12 m long	10,000 kPa / 10,000 kPa	N/A ²

Notes: 1. Culvert invert elevations are based on the top of culvert surveys and culvert dimensions provided by MH.

2. The SLS condition does not apply due to proximity to bedrock or the geotechnical reaction at SLS for 25 mm of settlement will be greater than the factored geotechnical axial resistance at ULS.

Prepared by: MCK
Checked by: CN
Reviewed by: JMAC



**FOUNDATION REPORT - HIGHWAY 7182 RECONSTRUCTION
CULVERTS GWP 5163-10-00**

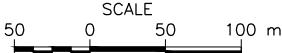
Table 4: Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Cast-In-Place Open Footing Culvert Replacements

Culvert Location (Township)	Pre-Cast Box Culvert		Cast-In-Place Open Footing Culvert	
	Interface Material	Coefficient of Friction (tan δ)	Interface Material	Coefficient of Friction (tan δ)
STA 10+443 (Shawanaga)	Compacted Granular Fill (Bedding)	0.40	Compacted Granular Fill	0.55
STA 11+290 (Shawanaga)	Compacted Granular Fill (Bedding)	0.40	Compact Sand to Silt and Sand/Compacted Granular Fill	0.55
			Gneiss Bedrock	0.70

Prepared by: MCK
Checked by: CN
Reviewed by: JMAC



DRAWINGS



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

CONT No.
GWP No. 5163-10-00

HIGHWAY 7182
CULVERTS STA. 10+443 AND 11+290
INDEX PLAN

SHEET



NOTES

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

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

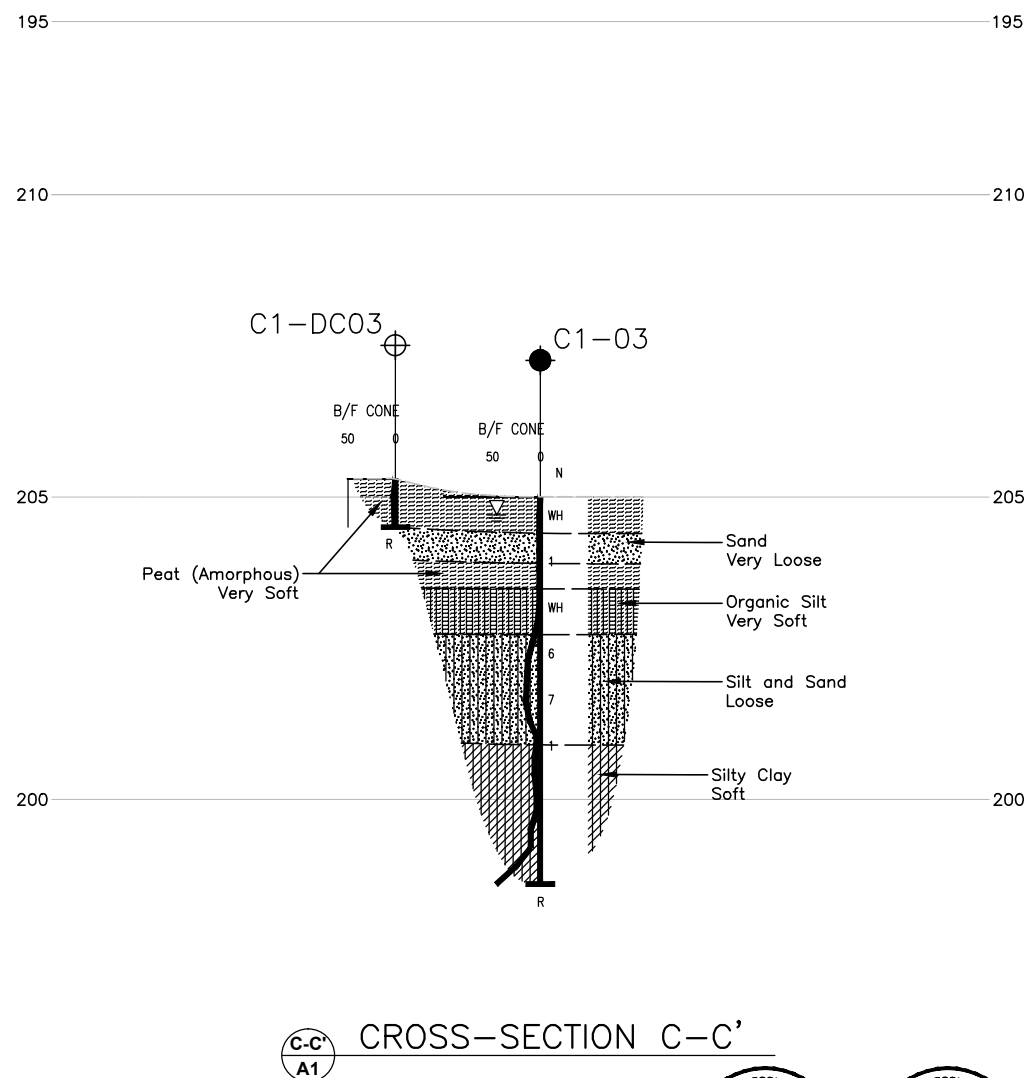
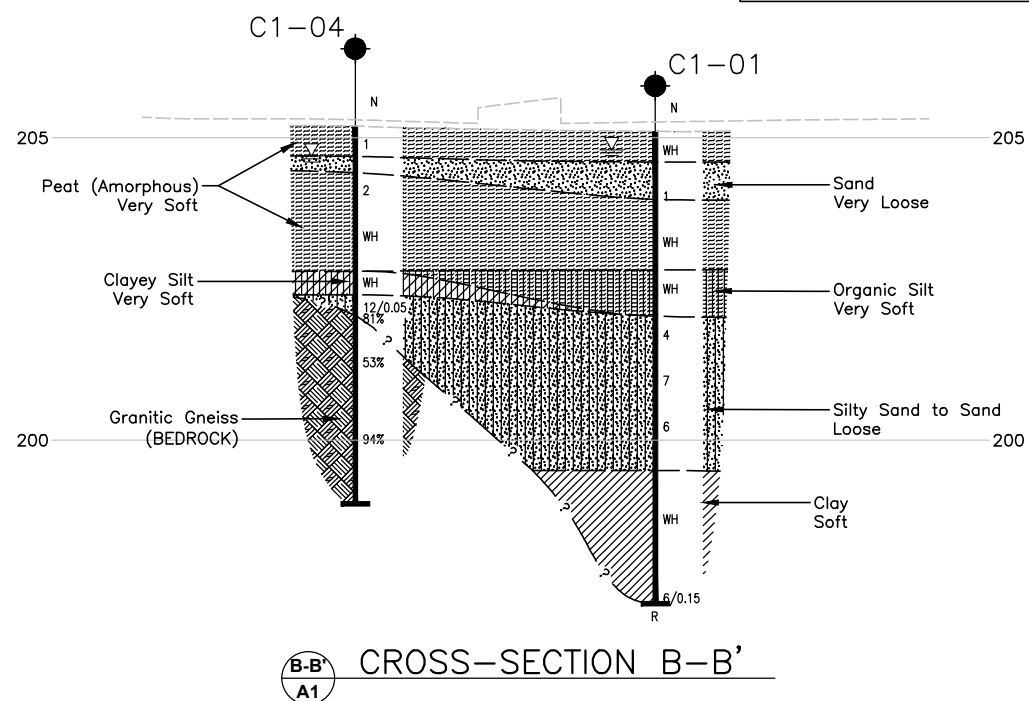
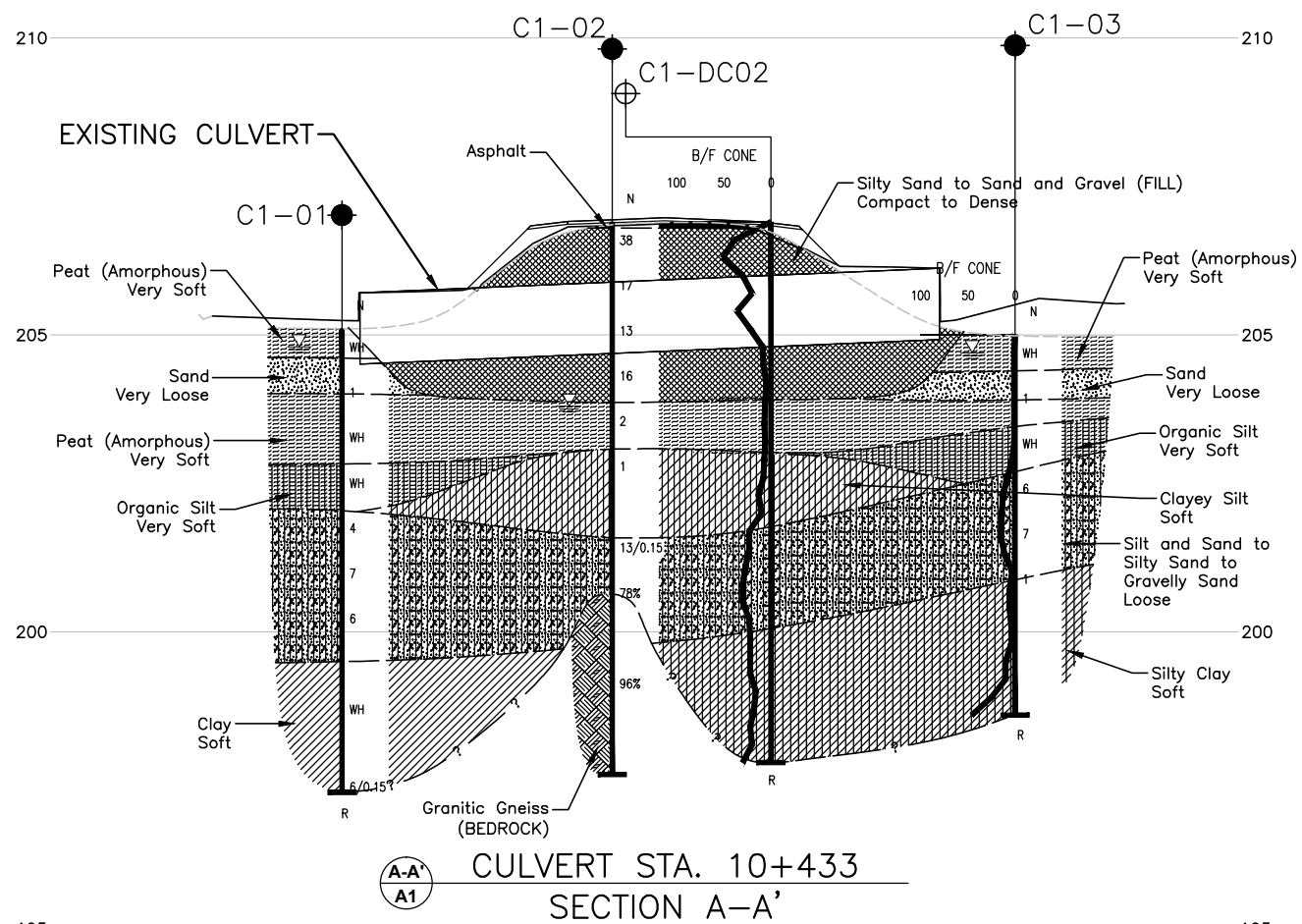
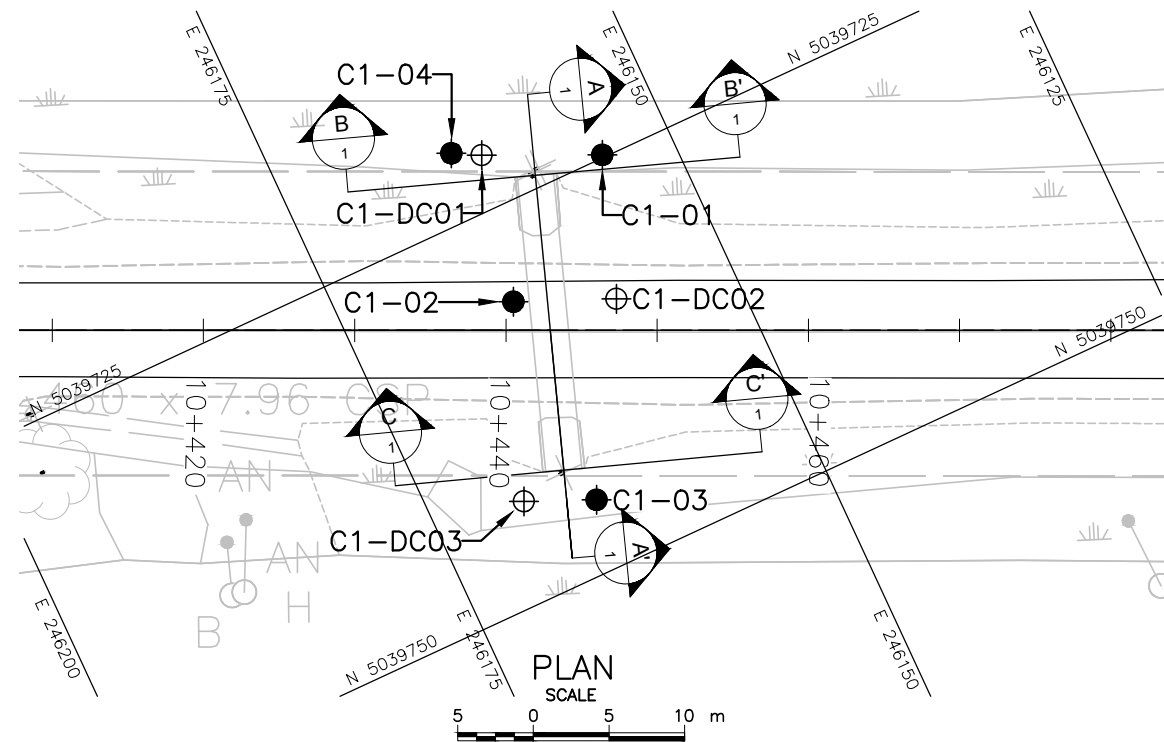
Base plans, profile and topographic data provided in digital format by Morrison Hershfield, drawing file nos. bc04537182001.dwg and Alignment-profile.dwg, dated Dec., 2013, received Dec. 17, 2014

NO.	DATE	BY	REVISION
Geocres No. 41H-148			
HWY. 7182		PROJECT NO. 12-1111-0102	DIST. .
SUBM'D. CN	CHKD. MCK	DATE: 3/13/2015	SITE: .
DRAWN: MR	CHKD. CN	APPD. JMAC	DWG. 1



APPENDIX A

Culvert at STA 10+443 – Highway 7182 – Township of Shawanaga

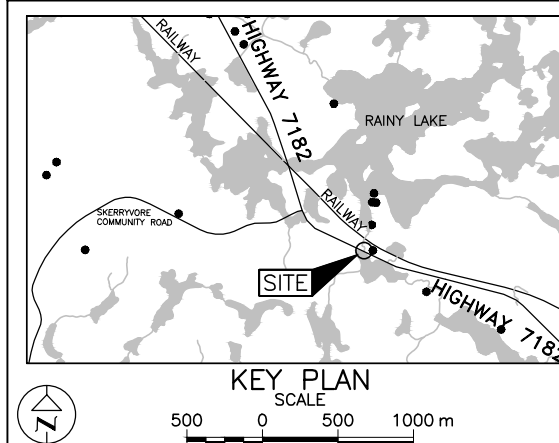


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN
STATIONS IN KILOMETRES + METRES.




CONT No.
GWP No. 5163-10-00



HIGHWAY 7182
CULVERT STA. 10+443 (SBL AND NBL)
BOREHOLE LOCATIONS AND SOIL STRATA



LEGEND

- | | |
|---|--|
|  | Borehole – Current Investigation |
|  | Dynamic Cone Penetration Test |
| N | Standard Penetration Test Value |
| 16 | Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow) |
| 100% | Rock Quality Designation (RQD) |
|  | WL upon completion of drilling |
| R | Refusal |

BOREHOLE CO—ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C1—01	205.1	5039724.8	246154.6
C1—02	206.9	5039731.2	246164.1
C1—03	205.0	5039745.4	246164.6
C1—04	205.2	5039720.5	246163.6
C1—DC01	205.2	5039721.5	246161.9
C1—DC02	206.9	5039733.8	246157.8
C1—DC03	205.3	5039743.4	246169.0

NOTES

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The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans and topographic data provided in digital format by Morrison Hershfield, drawing file nos. bc04537182001.dwg and Alignment-profile.dwg, dated Dec., 2013, received Dec. 17, 2014.
Cross-Section provided in digital format by Morrison Hershfield, drawing file no. Culver x-secs.dwg, received Sept. 30, 2014.

NO.	DATE	BY	REVISION		
Geocres No. 41H-148					
HWY. 7182		PROJECT NO. 12-1111-0102		DIST. .	
SUBM'D. CN		CHKD. MCK		DATE: 1/30/2015	
DRAWN: MR		CHKD. CN		APPD. JMAC	
				DWG. A1	



PROJECT		12-1111-0102		RECORD OF BOREHOLE No C1-01		SHEET 1 OF 1		METRIC								
G.W.P.		5163-10-00		LOCATION		N 5039724.8 ; E 246154.6		ORIGINATED BY		GM						
DIST		HWY 7182		BOREHOLE TYPE		NW Casing, Wash Boring		COMPILED BY		DAM						
DATUM		Geodetic		DATE		June 9, 2014		CHECKED BY		CN						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
205.1	GROUND SURFACE															
0.0	PEAT (Amorphous) Very soft Brown		1	SS	WH		205									0 98 (2)
204.6	Moist to wet															
0.5	SAND, trace silt, trace organics Very loose		2A	SS	1		204									
204.0	Grey Wet		2B													
1.1	PEAT (Amorphous) Very soft Black Wet															
202.8		3	SS	WH	203											
2.3	ORGANIC SILT Very soft Grey Wet	4A	SS	WH												
202.1		4B			202											
3.1	Silty SAND Loose Grey Wet															
			5	SS	4											
			6	SS	7											
			7	SS	6											
199.5																
5.6	CLAY Soft Brown Wet		8	SS	WH											
197.3																
7.8	END OF BOREHOLE CASING AND SPOON REFUSAL (HAMMER BOUNCING)		9	SS	6/0.15											
	NOTE: 1. Water level in open borehole measured at a depth of 0.3 m below ground surface (Elev. 204.8 m) upon completion of drilling.															

GTA-MTO 001 S:\CLIENTS\MTOWHIGHWAY_7182\02_DATA\GINT\1211110102.GPJ GAL-GTA.GDT 03/12/15 TB

PROJECT 12-1111-0102		RECORD OF BOREHOLE No C1-02		SHEET 1 OF 1		METRIC											
G.W.P. 5163-10-00		LOCATION N 5039731.2; E 246164.1		ORIGINATED BY ID													
DIST HWY 7182		BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger		COMPILED BY DAM													
DATUM Geodetic		DATE June 9, 2014		CHECKED BY CN													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL
							20 40 60 80 100	○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED	W _p	W	W _L	20 40 60	kN/m ³			
206.9	GROUND SURFACE																
0.0	ASPHALT (75 mm)																
	Silty sand, some gravel to sand and gravel, trace to some silt (FILL)		1	SS	38												
	Compact to dense		2	SS	17												
	Brown to grey		3	SS	13												
	Moist		4	SS	16												
203.9	Auger grinding below a depth of 2.3 m (cobbles inferred).																
3.0	PEAT (Amorphous)																
	Very soft		5	SS	2												
	Black																
	Wet																
203.1	CLAYEY SILT																
	Soft		6	SS	1												
	Grey																
	Wet																
201.6	Gravelly SAND, some silt, trace clay																
	Grey		7	SS	13/0.15												
	Wet																
200.6	Auger grinding below a depth of 5.3 m (cobbles inferred).																
	Granitic Gneiss (BEDROCK)																
	Bedrock cored from depths of 6.3 m to 9.3 m.		1	RC	REC 100%												
	For bedrock coring details refer to Record of Drillhole C1-02.																
			2	RC	REC 100%												
197.6	END OF BOREHOLE																
	NOTE:																
	1. Water level in open borehole measured at a depth of 3.1 m below ground surface (Elev. 203.8 m) upon completion of drilling.																
	* Split-Spoon Bouncing																

GTA-MTO 001 S:\CLIENTS\MTOWHIGHWAY_7182\02_DATA\GINT\1211110102.GPJ GAL-GTA.GDT 03/12/15 TB

SHEET 1 OF 1

DATUM: Geodetic

DRILLING CONTRACTOR: LANDCORE DRILLING

CHECKED: CN

PROJECT		12-1111-0102		RECORD OF BOREHOLE No C1-03		SHEET 1 OF 1		METRIC							
G.W.P.		5163-10-00		LOCATION		N 5039745.4 ; E 246164.6		ORIGINATED BY		GM					
DIST		HWY 7182		BOREHOLE TYPE		NW Casing, Wash Boring		COMPILED BY		DAM					
DATUM		Geodetic		DATE		June 12, 2014		CHECKED BY		CN					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
205.0	GROUND SURFACE														
0.0	PEAT (Amorphous), some sand Very soft Black Wet		1	SS	WH										
204.4															
0.6															
203.9	Approximately 75 mm thick sand seam encountered at a depth of 0.15 m.		2A	SS	1										
1.1			2B												
203.5	SAND, trace silt, trace organics Very loose Brown Wet		3	SS	WH										
1.5															
202.7	PEAT (Amorphous), some sand Very soft Brown Wet		4	SS	6										
2.3															
	ORGANIC SILT, trace to some clay, trace sand Very soft Brown Wet		5	SS	7										
200.9	SILT and SAND, trace clay Loose Grey Wet		6A	SS	1										
4.1			6B												
	SILTY CLAY, trace sand Soft Grey Wet														
200.1															
4.9															
	END OF BOREHOLE CASING REFUSAL (HAMMER BOUNCING)														
198.6															
6.4	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)														
NOTES: 1. Water level in open borehole measured at a depth of 0.3 m below ground surface (Elev. 204.7 m) upon completion of drilling. 2. A Dynamic Cone Penetration Test was advanced 2.0 m East of Borehole C1-03.															

GTA-MTO 001 S:\CLIENTS\MTOWHIGHWAY_7182\02_DATA\GINT\1211110102.GPJ GAL-GTA.GDT 03/12/15 TB

PROJECT 12-1111-0102		RECORD OF BOREHOLE No C1-04		SHEET 1 OF 1		METRIC														
G.W.P. 5163-10-00		LOCATION N 5039720.5 ; E 246163.6		ORIGINATED BY GM																
DIST _____ HWY 7182		BOREHOLE TYPE NW Casing, Wash Boring		COMPILED BY MT																
DATUM Geodetic		DATE June 12, 2014		CHECKED BY CN																
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL			
								20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100					
205.2	GROUND SURFACE																			
0.0	PEAT (Amorphous) Very soft Black to brown Moist		1	SS	1		205													
204.7																				
0.8	SAND, trace organics Brown Moist		2	SS	2		204													
	PEAT (Amorphous), trace sand Very soft Black Wet		3	SS	WH		203													
202.8																				
202.4	CLAYEY SILT Very soft Grey Wet		4	SS	WH		202													
202.1			5	SS	12/0.05															
3.1	SAND, some silt Brown Wet		1	RC	REC 100%		202										RQD = 81%			
	Granitic Gneiss (BEDROCK)																			
	Bedrock cored from depths of 3.1 m to 6.3 m.		2	RC	REC 94%		201										RQD = 53%			
	For bedrock coring details refer to Record of Drillhole C1-04.		3	RC	REC 100%		200										RQD = 94%			
198.9							199													
6.3	END OF BOREHOLE																			
NOTE: 1. Water level in open borehole measured at a depth of 0.5 m below ground surface (Elev. 204.7 m) upon completion of drilling. * Split-Spoon Bouncing																				

GTA-MTO 001 S:\CLIENTS\MTOWHIGHWAY_7182\02_DATA\GINT\1211110102.GPJ GAL-GTA.GDT 03/12/15 TB

SHEET 1 OF 1

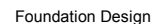
DATUM: Geodetic

DRILLING CONTRACTOR: LANDCORE DRILLING

CHECKED: CN

PROJECT 12-1111-0102				RECORD OF DCPT No C1-DC01				SHEET 1 OF 1				METRIC				
G.W.P. 5163-10-00				LOCATION N 5039721.5; E 246161.9				ORIGINATED BY GM								
DIST _____ HWY 7182				BOREHOLE TYPE Dynamic Cone Penetration Test				COMPILED BY TB								
DATUM Geodetic				DATE June 9, 2014				CHECKED BY DAM								
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W _p	W		
205.2	GROUND SURFACE						20	40	60	80	100					
0.0	Dynamic Cone Penetration Test (DCPT)						20	40	60	80	100					
202.2	END OF DCPT															
3.0	Refusal to Further Penetration (HAMMER BOUNCING)															

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

PROJECT 12-1111-0102		RECORD OF DCPT No C1-DC03				SHEET 1 OF 1		METRIC								
G.W.P. 5163-10-00		LOCATION N 5039743.4 ;E 246169.0				ORIGINATED BY GM										
DIST _____ HWY 7182		BOREHOLE TYPE Dynamic Cone Penetration Test				COMPILED BY TB										
DATUM Geodetic		DATE June 12, 2014				CHECKED BY DAM										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
205.3	GROUND SURFACE						20	40	60	80	100					
0.0	Dynamic Cone Penetration Test (DCPT)					205										
204.5	END OF DCPT															
0.8	Refusal to Further Penetration (HAMMER BOUNCING)															

GTA-MTO 001 S:\CLIENTS\MTOWHIGHWAY_7182\02_DATA\GINT\1211110102.GPJ GAL-GTA.GDT 03/12/15 TB



FOUNDATION REPORT - HIGHWAY 7182 RECONSTRUCTION
CULVERTS GWP 5163-10-00

Table A1: Summary of Analytical Testing of Surface Water

Culvert Location Highway 7182 (Township)	Parameter (Units, Detection Limit)				
	Chloride (mg/L, 1)	Sulfate (mg/L, 1)	Conductivity (μS/cm, 1.0)	Resistivity (Ω-cm)	pH
STA 10+443 (Shawanaga Township)	38	1	150	6,600	6.87

Notes: 1. Samples obtained June 16, 2014
2. Analytical testing carried out by Maxxam Analytics.

Prepared by: MCK
Checked by: CN
Reviewed by: JMAC

Golder Associates Ltd.

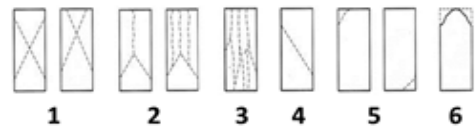
1010 Lorne Street
Sudbury, Ontario, Canada P3C 4R9
Telephone: (705) 524-6861
Fax: (705) 524-1984

**TABLE A2 - SUMMARY OF ROCK CORE TEST DATA**

PROJECT NO.: 12-1111-0102
JOB NAME: Culvert at Station 10+443 - Highway 7182/Shawanaga
TYPE OF UNIT: Bedrock Core

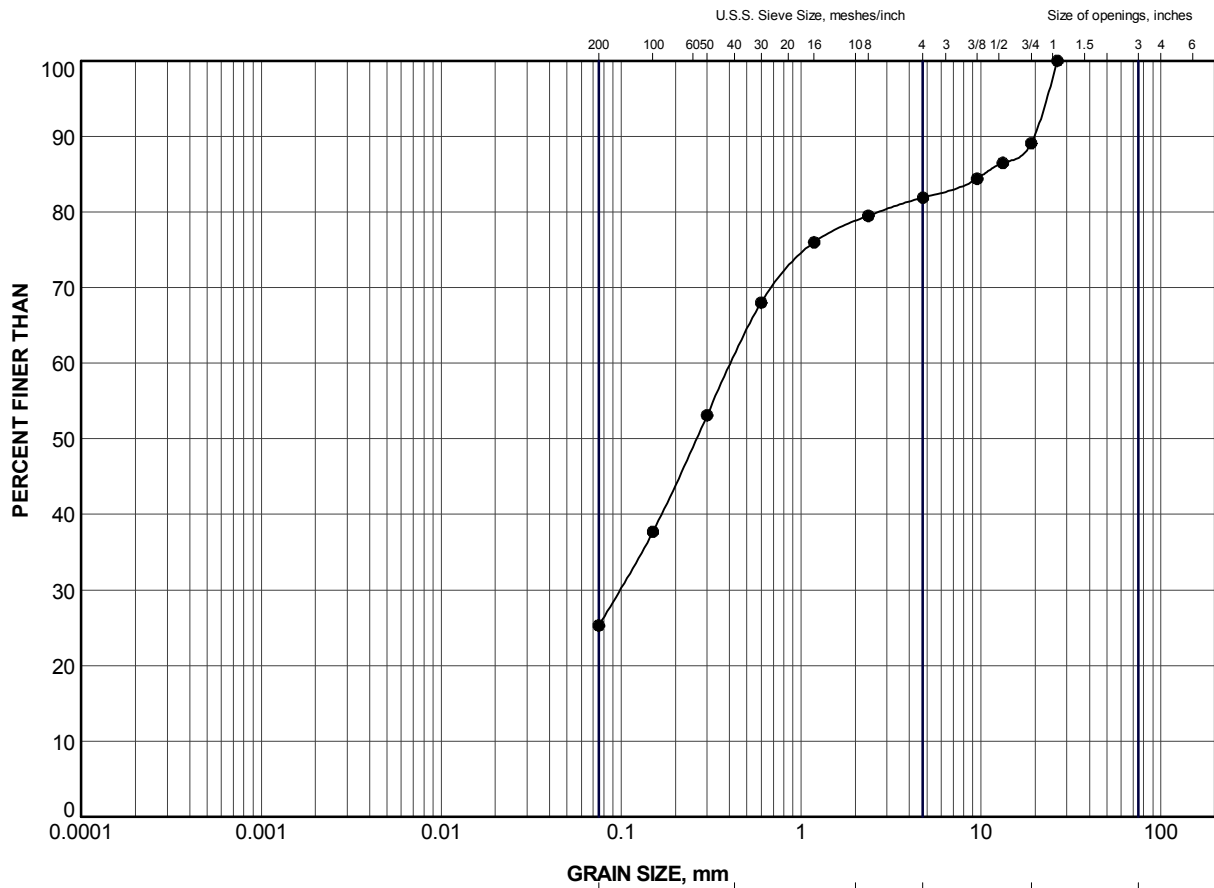
GOLDER LAB NUMBER	G0732
BOREHOLE	C1-04
DATE TESTED	Aug. 12, 2014
DEPTH OF TESTED CORE (m)	4.9
LENGTH AS CUT (mm)	90.0
DIAMETER (mm)	42.6
DENSITY (kg/m3)	2778
UNIAXIAL COMPRESSIVE STRENGTH (MPa)	112.5
TYPE OF FRACTURE	2

Type of Fracture



Tested by: SA

Reviewed by: CN



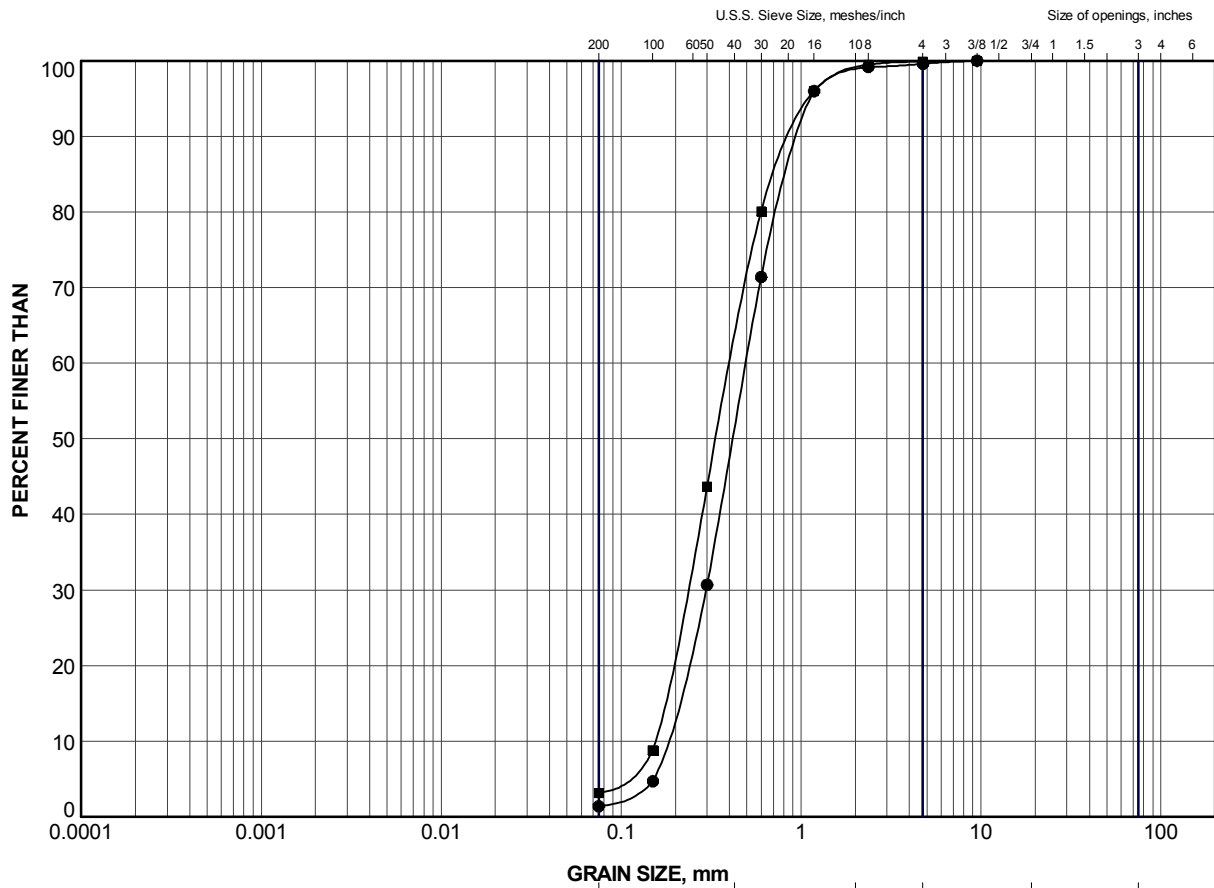
CLAY AND SILT	GRAVEL SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C1-02	3	205.1

PROJECT					HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 10+443				
TITLE					GRAIN SIZE DISTRIBUTION SILTY SAND (FILL)				
PROJECT No.		12-1111-0102			FILE No.		1211110102.GPJ		
DRAWN	TB	Mar 2015			SCALE	N/A	REV.		
CHECK	MCK	Mar 2015			FIGURE A1				
APPR	CN	Mar 2015							





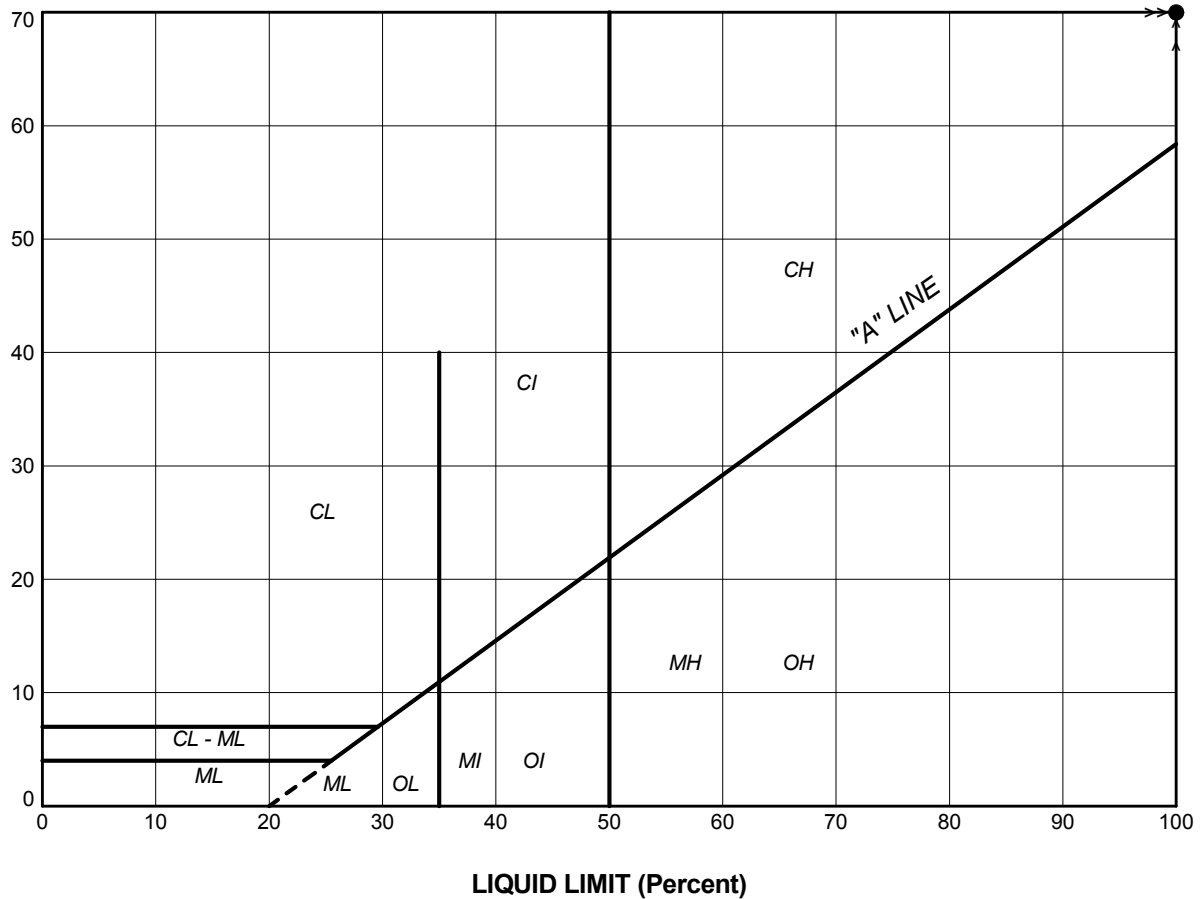
CLAY AND SILT	GRAVEL SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C1-01	2A	204.2
■	C1-03	2A	204.1

PROJECT					HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 10+443				
TITLE					GRAIN SIZE DISTRIBUTION SAND (INTERLAYER)				
PROJECT No.			12-1111-0102		FILE No.			1211110102.GPJ	
DRAWN	TB	Mar 2015	SCALE	N/A	REV.				
CHECK	MCK	Mar 2015							
APPR	CN	Mar 2015							
 Golder Associates SUDBURY, ONTARIO			FIGURE A2						

PLASTICITY INDEX (Percent)



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

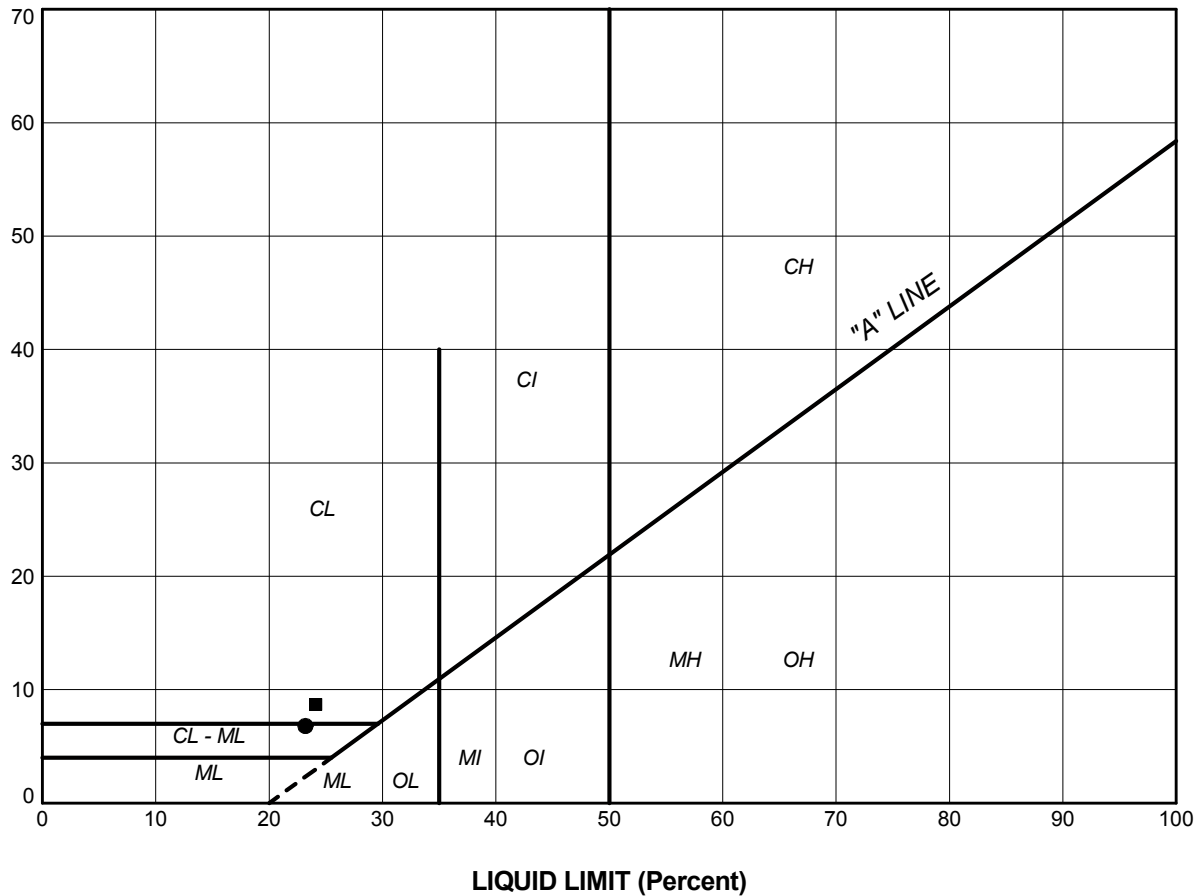
LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C1-01	4A	156.5	67.0	89.5

PROJECT			HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 10+443		
TITLE			PLASTICITY CHART ORGANIC SILT		
PROJECT No.		12-1111-0102	FILE No.		1211110102.GPJ
DRAWN	TB	Mar 2015	SCALE	N/A	REV.
CHECK	MCK	Mar 2015	FIGURE A3A		
APPR	CN	Mar 2015			



PLASTICITY INDEX (Percent)




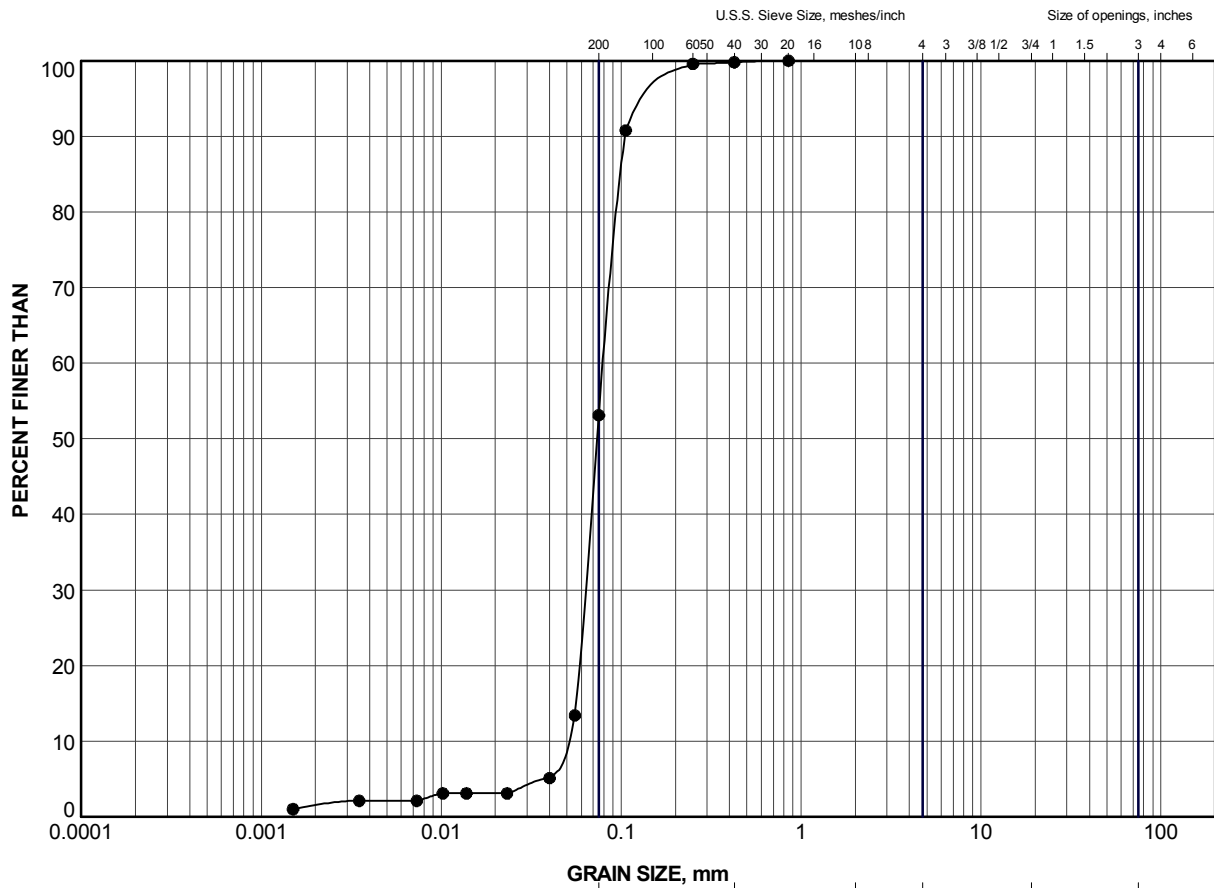
SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND


SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C1-02	6	23.2	16.4	6.8
■	C1-04	4	24.1	15.4	8.7

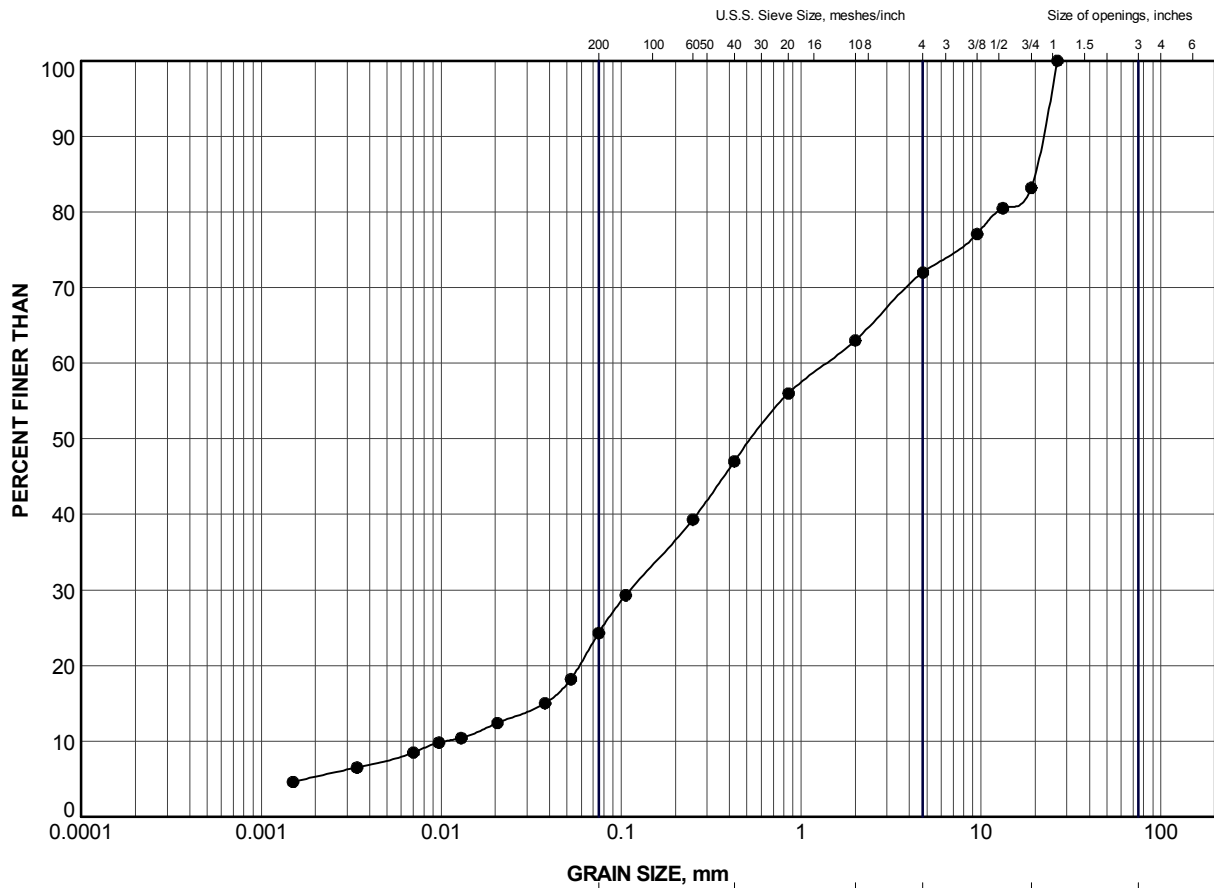
PROJECT			HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 10+443		
TITLE			PLASTICITY CHART CLAYEY SILT		
PROJECT No.		12-1111-0102	FILE No.		1211110102.GPJ
DRAWN	TB	Mar 2015	SCALE	N/A	REV.
CHECK	MCK	Mar 2015			
APPR	CN	Mar 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE A3B		



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C1-03	4	202.4

PROJECT						HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 10+443					
TITLE						GRAIN SIZE DISTRIBUTION SILT and SAND					
PROJECT No.			12-1111-0102			FILE No.			1211110102.GPJ		
DRAWN	TB	Mar 2015	SCALE	N/A	REV.						
CHECK	MCK	Mar 2015									
APPR	CN	Mar 2015									
 Golder Associates SUDBURY, ONTARIO			FIGURE A4								

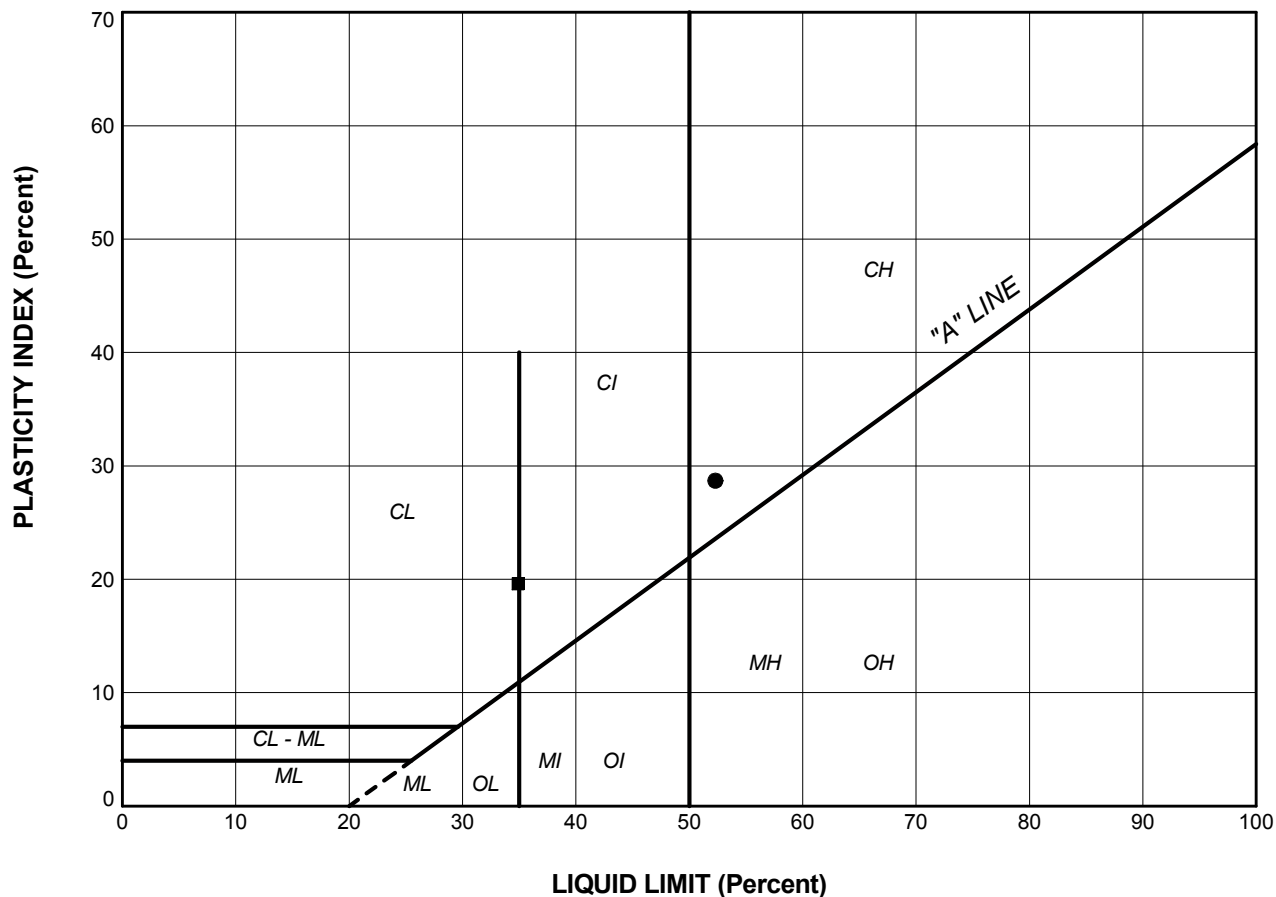


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C1-02	7	201.5

PROJECT						HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 10+443									
TITLE						GRAIN SIZE DISTRIBUTION GRAVELLY SAND									
 Golder Associates SUDBURY, ONTARIO			PROJECT No.			12-1111-0102			FILE No.			1211110102.GPJ			
			DRAWN		TB		Mar 2015		SCALE		N/A		REV.		
			CHECK		MCK		Mar 2015								
			APPR		CN		Mar 2015								
												FIGURE A5			



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C1-01	8	52.3	23.6	28.7
■	C1-03	6B	34.9	15.3	19.6

PROJECT			HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 10+443		
TITLE			PLASTICITY CHART SILTY CLAY to CLAY		
PROJECT No.		12-1111-0102	FILE No.		1211110102.GPJ
DRAWN	TB	Mar 2015	SCALE	N/A	REV.
CHECK	MCK	Mar 2015	FIGURE A6		
APPR	CN	Mar 2015			






APPENDIX B

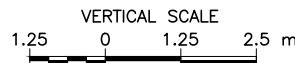
Culvert at STA 11+290 – Highway 7182 – Township of Shawanaga



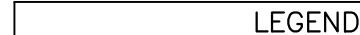
HORIZONTAL SCALE






A horizontal scale bar with markings at 2.5, 0, 2.5, and 5 m.



**Golder
Associates**



- | | |
|---|--|
|  | Borehole |
|  | Dynamic Cone Penetration Test |
| N | Standard Penetration Test Value |
| 16 | Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow) |
| 100% | Rock Quality Designation (RQD) |
|  | WL upon completion of drilling |
| R | Refusal |

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C2-01	206.7	5040334.6	245640.1
C2-02	207.9	5040329.8	245649.2
C2-03	206.9	5040341.7	245657.0
C2-DC01	207.5	5040327.6	245646.4
C2-DC02A	207.9	5040335.3	245647.2
C2-DC02B	207.9	5040336.2	245646.9
C2-DC03	206.7	5040333.5	245659.8

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

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

Base plans and topographic data provided in digital format by Morrison Hershfield, drawing file nos. bc04537182001.dwg and Alignment-profile.dwg dated Dec., 2013, received Dec. 17, 2014.

Cross-Section provided in digital format by Morrison Hershfield, drawing file no. Culver x-secs.dwg, received Sept. 30, 2014.

-	-	-	-	-	-
NO.	DATE	BY	REVISION		
Geocres No. 41H-148					
HWY. 71B2		PROJECT NO. 12-1111-0102		DIST. .	
SUBM'D. MCK		CHKD. MCK		DATE: 1/30/2015	
DRAWN: MR		CHKD. CN		APPD. JM/CAC	
				DWG. B1	

PROJECT 12-1111-0102		RECORD OF BOREHOLE No C2-01		SHEET 1 OF 1		METRIC							
G.W.P. 5163-10-00		LOCATION N 5040334.6; E 245640.1		ORIGINATED BY GM									
DIST _____ HWY 7182		BOREHOLE TYPE NW Casing, Wash Boring		COMPILED BY MT									
DATUM Geodetic		DATE June 10, 2014		CHECKED BY CN									
SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					
206.7	GROUND SURFACE						20 40 60 80 100						
0.0	TOPSOIL		1A	SS	3								
206.4			1B										
0.3	CLAYEY SILT, some sand, trace organics												
205.9	Soft		2	SS	*8/0.15								
0.8	Brown to grey												
205.4	Moist												
1.3	SAND, some silt, trace organics		1	RC	REC 100%								
	Grey												
	Wet												
	Granitic Gneiss (BEDROCK)		2	RC	REC 100%								
	Bedrock cored from depths of 1.3 m to 4.4 m.												
	For bedrock coring details refer to Record of Drillhole C2-01.		3	RC	REC 100%								
			4	RC	REC 100%								
			5	RC	REC 100%								
202.3	END OF BOREHOLE												
4.4	NOTE: 1. Water level in open borehole measured at a depth of 0.2 m below ground surface (Elev. 206.5 m) upon completion of drilling. * Split-Spoon Bouncing												

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PROJECT: 12-1111-0102

RECORD OF DRILLHOLE: C2-01

SHEET 1 OF 1

LOCATION: N 5040334.6 ;E 245640.1

DRILLING DATE: June 10, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Portable Tripod

DRILLING CONTRACTOR: LANDCORE DRILLING

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth RO - Rough VR - Very Rough MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.																NOTES	
							FLUSH	RECOVERY		R.Q.D. %	FRACT. INDEX PER 0.3 m	B Angle	DIP w.r.t CORE AXIS	DISCONTINUITY DATA			HYDRAULIC CONDUCTIVITY K, cm/sec			Diametral Point Load Index (MPa)	RMC -Q AVG			
								TOTAL CORE %	SOLID CORE %					TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	10 ⁰	10 ¹			10 ²		
		Continued from Record of Borehole C2-01		205.43																				
	BQ Thin-walled Coring Double-Tube Sampling	Fresh, foliated, grey, medium to coarse crystalline, faintly to moderately porous, strong to very strong GRANITIC GNEISS		1.27	1	GREY 100%																		
2																								
3																								
4																								
		END OF DRILLHOLE		202.31 4.39	5	GREY 100%																		
5																								
6																								
7																								
8																								
9																								
10																								
11																								

DEPTH SCALE

1 : 50



LOGGED: GM

CHECKED: CN

PROJECT 12-1111-0102		RECORD OF BOREHOLE No C2-02		SHEET 1 OF 1		METRIC																		
G.W.P. 5163-10-00		LOCATION N 5040329.8 ; E 245649.2		ORIGINATED BY ID																				
DIST HWY 7182		BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger		COMPILED BY MT																				
DATUM Geodetic		DATE June 10, 2014		CHECKED BY CN																				
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			ELEVATION SCALE			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																			
207.9	GROUND SURFACE																							
0.0	ASPHALT (75 mm)		1	SS	55																			
	Sand and gravel, trace to some silt (FILL) Compact to very dense Grey Moist to wet		2	SS	17																			
			3	SS	13																			
205.6																								
2.3	SILT and SAND, trace gravel, trace clay Compact Grey Wet		4	SS	20																			
204.9																								
3.0	CLAYEY SILT Firm Grey Wet		5	SS	4																			
204.1			6	SS	4/0.15																			
4.0	Silty SAND, some gravel, trace clay Grey Wet																							
	Granitic Gneiss (BEDROCK)		1	RC	REC 100%																			
	Bedrock cored from depths of 4.0 m to 7.2 m. For bedrock coring details refer to Record of Drillhole C2-02.		2	RC	REC 100%																			
200.7																								
7.2	END OF BOREHOLE																							
NOTES:																								
1. Water level in open borehole measured at a depth of 1.7 m below ground surface (Elev. 206.2 m) upon completion of drilling.																								
2. An additional borehole was advanced approximately 1.1 m North of Borehole C2-02 to carry out an in situ field vane test at a depth of 3.4 m.																								
* Split-Spoon Bouncing																								

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SHEET 1 OF 1

DATUM: Geodetic

DRILLING CONTRACTOR: LANDCORE DRILLING

CHECKED: CN

PROJECT 12-1111-0102		RECORD OF BOREHOLE No C2-03		SHEET 1 OF 1		METRIC											
G.W.P. 5163-10-00		LOCATION N 5040341.7 ; E 245657.0		ORIGINATED BY GM													
DIST _____ HWY 7182		BOREHOLE TYPE NW Casing, Wash Boring		COMPILED BY MT													
DATUM Geodetic		DATE June 11, 2014		CHECKED BY CN													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL
							20 40 60 80 100	○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED	W _p	W	W _L	20 40 60	kN/m ³			
206.9	GROUND SURFACE		1A	SS	1/0.15												
0.0	PEAT (Fibrous)		1B														
0.3	Soft Black Moist																
	SILTY CLAY with sand, trace organics Grey to brown Wet		1	RC	REC 100%		206									RQD = 100%	
	Granitic Gneiss (BEDROCK)																
	Bedrock cored from depths of 0.3 m to 3.6 m.		2	RC	REC 100%		205									RQD = 66%	
	For bedrock coring details refer to Record of Drillhole C2-03.																
			3	RC	REC 100%		204									RQD = 93%	
203.3	END OF BOREHOLE																
3.6	NOTE: 1. Water level in open borehole was not recorded.																

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PROJECT: 12-1111-0102

RECORD OF DRILLHOLE: C2-03

SHEET 1 OF 1

LOCATION: N 5040341.7 ;E 245657.0

DRILLING DATE: June 11, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Portable Tripod

DRILLING CONTRACTOR: LANDCORE DRILLING

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth RO - Rough VR - Very Rough	MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.	NOTES
		Continued from Record of Borehole C2-03		206.60									
1		Fresh, foliated, grey, medium to coarse crystalline, faintly to moderately porous, strong to very strong GRANITIC GNEISS		0.30	1	GREY	100%						
2	BQ Thin-walled Coring Double-Tube Sampling				2	GREY	100%						
3					3	GREY	100%						
4		END OF DRILLHOLE		203.32									
5				3.58									
6													
7													
8													
9													
10													

UCS = 131 MPa

DEPTH SCALE

1 : 50

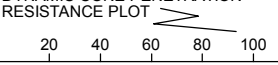


LOGGED: GM

CHECKED: CN

PROJECT		12-1111-0102		RECORD OF DCPT No C2-DC01		SHEET 1 OF 1		METRIC									
G.W.P.		5163-10-00		LOCATION		N 5040327.6 ; E 245646.4		ORIGINATED BY									
DIST		HWY 7182		BOREHOLE TYPE		Dynamic Cone Penetration Test		COMPILED BY									
DATUM		Geodetic		DATE		June 10, 2014		CHECKED BY									
DAM																	
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
207.5	GROUND SURFACE																
0.0	Dynamic Cone Penetration Test (DCPT)																
207																	
206																	
205																	
204																	
203.5	END OF DCPT																
4.0	Refusal to Further Penetration (HAMMER BOUNCING)																

GTA-MTO 001 S:\CLIENTS\MTOWHIGHWAY_7182\02_DATA\GINT\1211110102.GPJ GAL-GTA.GDT 03/12/15 TB

PROJECT 12-1111-0102		RECORD OF DCPT No C2-DC02A		SHEET 1 OF 1		METRIC				
G.W.P. 5163-10-00		LOCATION N 5040335.3 ; E 245647.2		ORIGINATED BY ID						
DIST _____ HWY 7182		BOREHOLE TYPE Dynamic Cone Penetration Test		COMPILED BY TB						
DATUM Geodetic		DATE June 10, 2014		CHECKED BY DAM						
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE						
207.9 0.0	GROUND SURFACE Dynamic Cone Penetration Test (DCPT)									
206.4 1.5	END OF DCPT Refusal to Further Penetration (HAMMER BOUNCING)									

GTA-MTO 001 S:\CLIENTS\MTOWHIGHWAY_7182\02_DATA\GINT\1211110102.GPJ GAL-GTA.GDT 03/12/15 TB

PROJECT		12-1111-0102		RECORD OF DCPT No C2-DC02B		SHEET 1 OF 1		METRIC								
G.W.P.		5163-10-00		LOCATION		N 5040336.2 ; E 245646.9		ORIGINATED BY								
DIST		HWY 7182		BOREHOLE TYPE		Dynamic Cone Penetration Test		COMPILED BY								
DATUM		Geodetic		DATE		June 10, 2014		CHECKED BY								
DAM																
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
							20	40	60	80	100					
207.9	GROUND SURFACE															
0.0	Dynamic Cone Penetration Test (DCPT)															
206.2																
1.7	END OF DCPT Refusal to Further Penetration (HAMMER BOUNCING)															

PROJECT 12-1111-0102		RECORD OF DCPT No C2-DC03				SHEET 1 OF 1		METRIC									
G.W.P. 5163-10-00		LOCATION N 5040333.5 ; E 245659.8				ORIGINATED BY GM											
DIST _____ HWY 7182		BOREHOLE TYPE Dynamic Cone Penetration Test				COMPILED BY TB											
DATUM Geodetic		DATE June 10, 2014				CHECKED BY DAM											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
206.7	GROUND SURFACE						20	40	60	80	100						
0.0	Dynamic Cone Penetration Test (DCPT)																
205.8						206											
0.9	END OF DCPT Refusal to Further Penetration (HAMMER BOUNCING)																

GTA-MTO 001 S:\CLIENTS\MTOWHIGHWAY_7182\02_DATA\GINT\1211110102.GPJ GAL-GTA.GDT 03/12/15 TB



**FOUNDATION REPORT - HIGHWAY 7182 RECONSTRUCTION
CULVERTS GWP 5163-10-00**

Table B1: Summary of Analytical Testing of Surface Water

Culvert Location Highway 7182 (Township)	Parameter (Units, Detection Limit)				
	Chloride (mg/L, 1)	Sulfate (mg/L, 1)	Conductivity (μS/cm, 1.0)	Resistivity (Ω-cm)	pH
STA 11+290 (Shawanaga Township)	3	<1	24	41,000	5.84

Notes: 1. Samples obtained June 16, 2014
2. Analytical testing carried out by Maxxam Analytics.

Prepared by: MCK
Checked by: CN
Reviewed by: JMAC

Golder Associates Ltd.

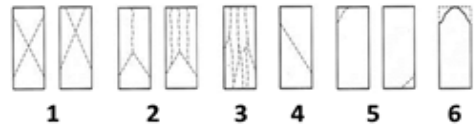
1010 Lorne Street
Sudbury, Ontario, Canada P3C 4R9
Telephone: (705) 524-6861
Fax: (705) 524-1984

**TABLE B2 - SUMMARY OF ROCK CORE TEST DATA**

PROJECT NO.: 12-1111-0102
JOB NAME: Culvert at Station 11+290 - Highway 7182/Shawanaga
TYPE OF UNIT: Bedrock Core

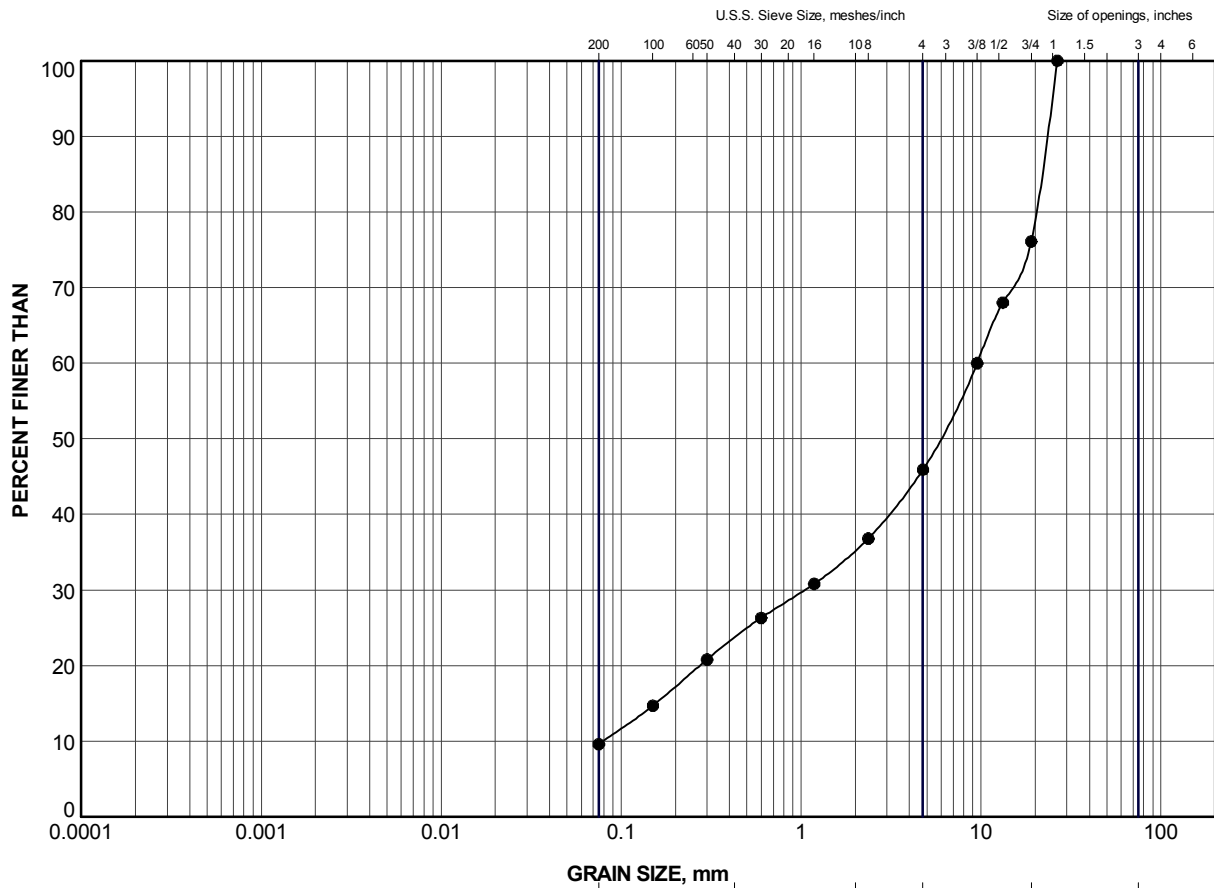
GOLDER LAB NUMBER	G0733
BOREHOLE	C2-03
DATE TESTED	Aug. 12, 2014
DEPTH OF TESTED CORE (m)	2.3
LENGTH AS CUT (mm)	93.0
DIAMETER (mm)	43.5
DENSITY (kg/m3)	2717
UNIAXIAL COMPRESSIVE STRENGTH (MPa)	131.4
TYPE OF FRACTURE	3

Type of Fracture



Tested by: SA

Reviewed by: CN



CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

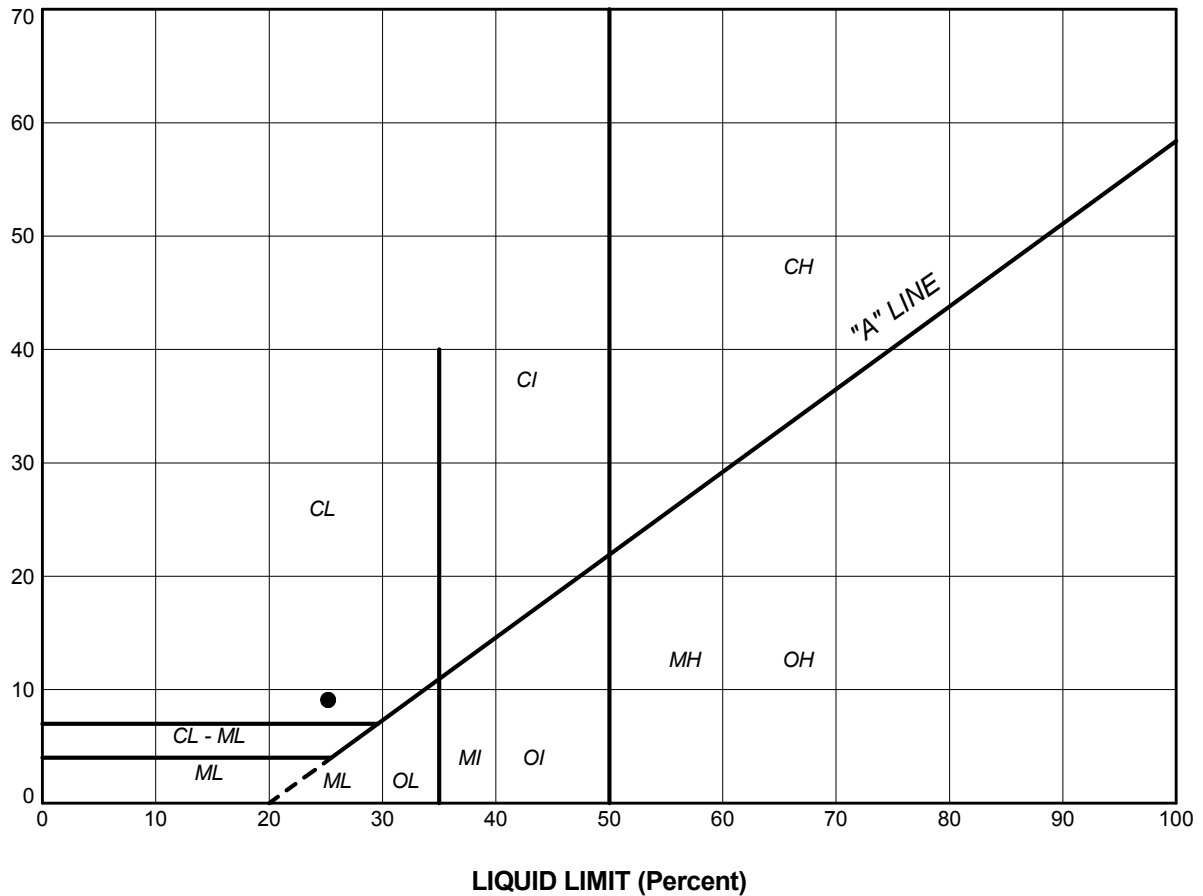
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C2-02	1	207.6

PROJECT					HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 11+290				
TITLE					GRAIN SIZE DISTRIBUTION SAND and GRAVEL (FILL)				
PROJECT No.		12-1111-0102			FILE No.		1211110102.GPJ		
DRAWN	TB	Mar 2015			SCALE	N/A	REV.		
CHECK	MCK	Mar 2015			FIGURE B1				
APPR	CN	Mar 2015							



PLASTICITY INDEX (Percent)



SOIL TYPE
C = Clay
M = Silt
O = Organic

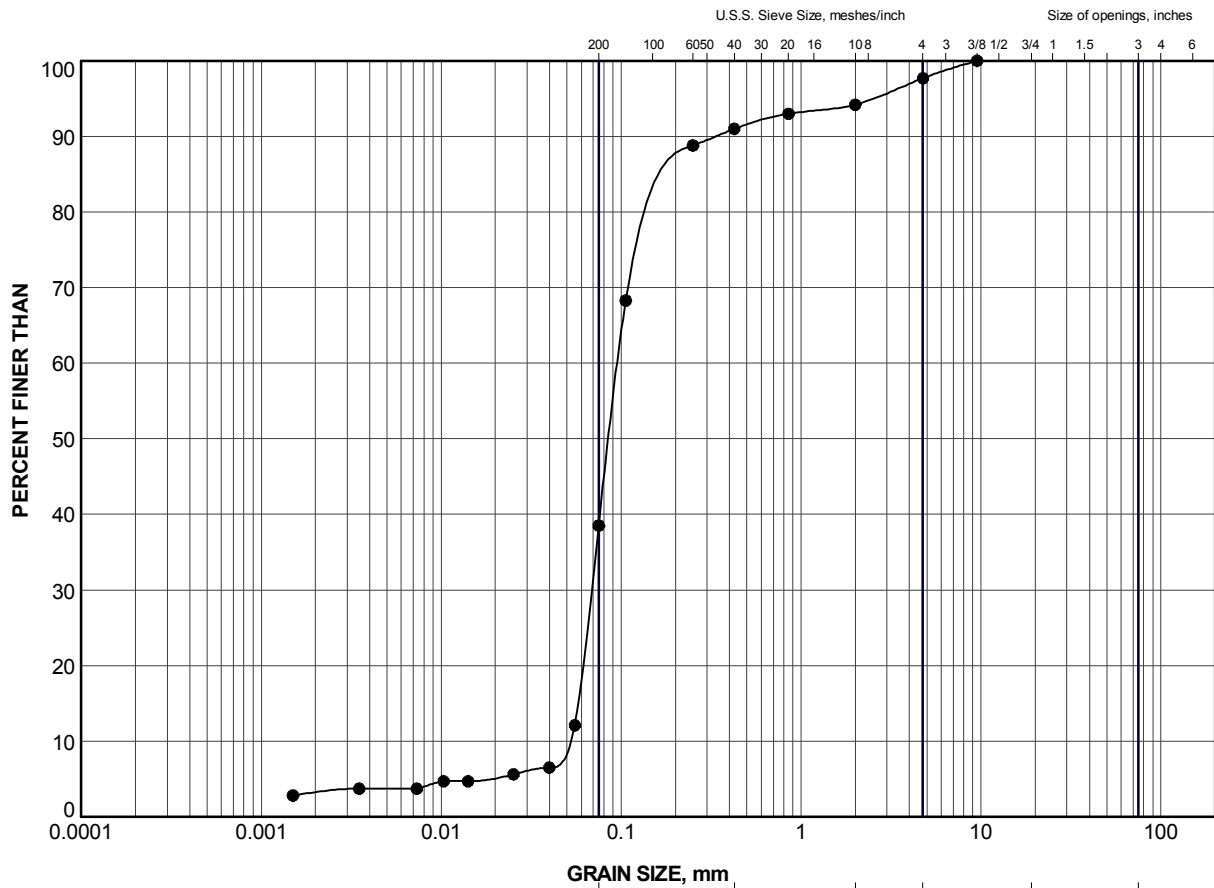
PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C2-01	1B	25.2	16.1	9.1

PROJECT			HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 11+290		
TITLE			PLASTICITY CHART CLAYEY SILT (UPPER DEPOSIT)		
PROJECT No.		12-1111-0102	FILE No.		1211110102.GPJ
DRAWN	TB	Mar 2015	SCALE	N/A	REV.
CHECK	MCK	Mar 2015	FIGURE B2		
APPR	CN	Mar 2015			




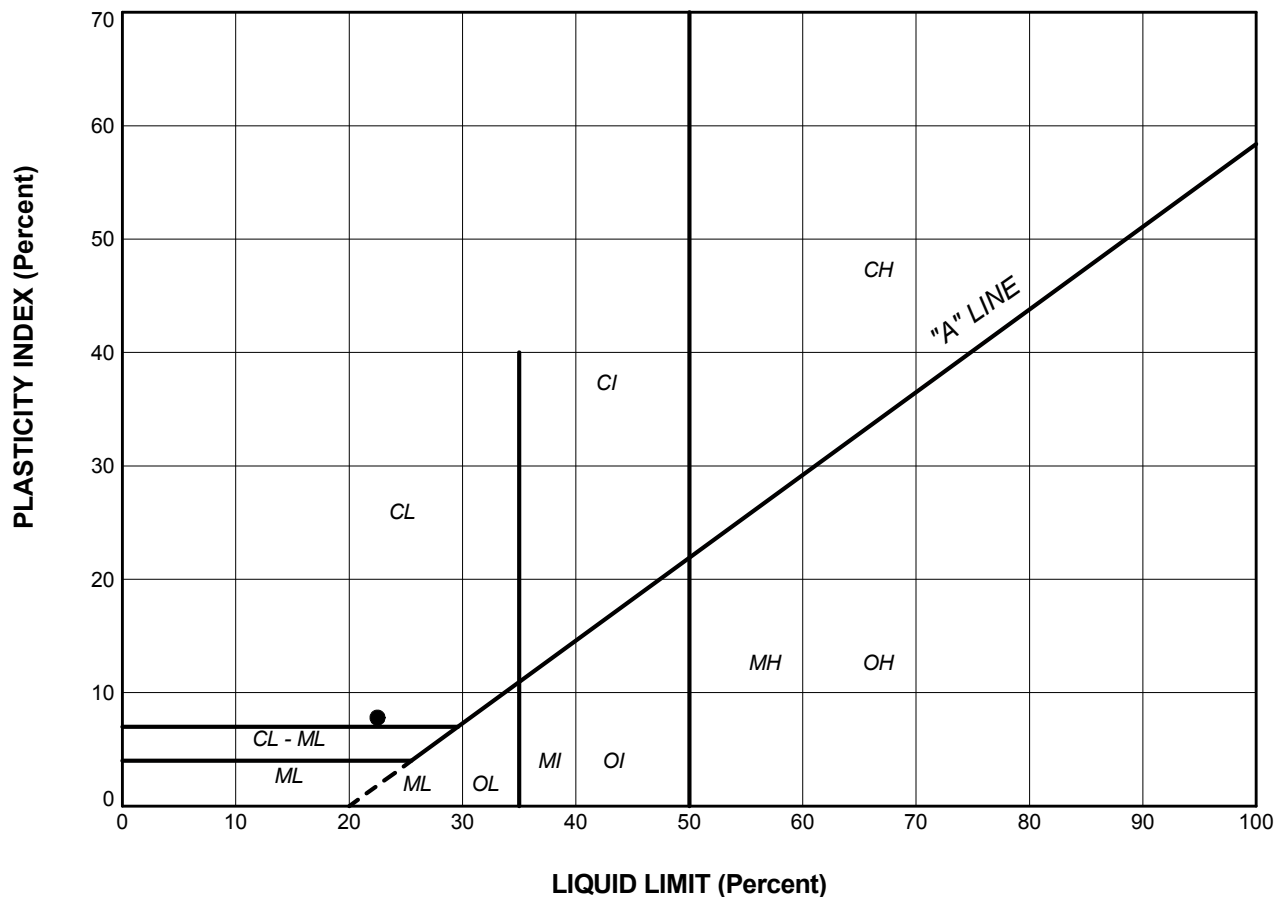


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C2-02	4	205.3

PROJECT					HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 11+290				
TITLE					GRAIN SIZE DISTRIBUTION SILT and SAND				
 Golder Associates SUDBURY, ONTARIO		PROJECT No. 12-1111-0102			FILE No. 1211110102.GPJ				
		DRAWN	TB	Mar 2015	SCALE	N/A	REV.		
		CHECK	MCK	Mar 2015	FIGURE B3				
		APPR	CN	Mar 2015					



LEGEND					
SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C2-02	5	22.5	14.7	7.8

PROJECT			HIGHWAY 7182 RECONSTRUCTION HIGHWAY 7182 (SBL and NBL) CULVERT 11+290		
TITLE			PLASTICITY CHART CLAYEY SILT (LOWER DEPOSIT)		
PROJECT No.		12-1111-0102	FILE No.		1211110102.GPJ
DRAWN	TB	Mar 2015	SCALE	N/A	REV.
CHECK	MCK	Mar 2015	FIGURE B4		
APPR	CN	Mar 2015			



At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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South America	+ 55 21 3095 9500

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