



November 12, 2013

FOUNDATION INVESTIGATION AND DESIGN REPORT

**HIGHWAY 11 - SIX MILE CREEK CULVERT AT STATION 16+381
TOWNSHIP OF DEVITT, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 164-98-00, WP 5244-05-01, SITE NUMBER 39W-124**

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REPORT





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**FOUNDATION REPORT
HIGHWAY 11 SIX MILE CREEK CULVERT**

PART A

FOUNDATION INVESTIGATION REPORT

HIGHWAY 11 – SIX MILE CREEK CULVERT AT STATION 16+381

TOWNSHIP OF DEVITT, ONTARIO

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Ltd. (MMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the Highway 11 Six Mile Creek culvert at STA 16+381 in the Township of Devitt, Ontario. The Key Plan showing the general location of this section of Highway 11 and the location of the investigated area are shown on Drawing 1. The purpose of this investigation is to establish the subsurface conditions at the location of the proposed culvert by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The Six Mile Creek culvert is located east side of Val Côté, Ontario, approximately 19.5 km east of the east junction of Highway 583. In general, the topography in the area of the overall project limits consists of flat terrain utilized as farmland, with moderate tree cover. The existing highway grade is at about Elevation 245 m and the water surface at the culvert inlet was measured by Golder at Elevation 240.3 m on October 21, 2011. The existing culvert is a three-cell timber culvert with two cell sizes at 2.1 m and the third cell at 1.7 m. In addition, a single 1.8 m Structural Plate Corrugated Steel Pipe culvert is located on the east side of the timber culvert. The existing culverts are about 30 m long.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between October 20 to 22, 2011, on March 20, 2012 and on July 3, 2013, during which time a total of ten (10) boreholes (6M-1 to 6M-9 and 6M-4a) were advanced for the proposed culvert replacement as shown on Drawing 1. Boreholes 6M-1 to 6M-7 and 6M-4a were advanced using a track-mounted CME 45 supplied and operated by KC Drilling Ltd. of Belle Ewart, Ontario, including Borehole 6M-2 to a depth of 6.8 m. Borehole 6M-2, below a depth of 6.8 m, and Boreholes 6M-8 and 6M-9 were advanced using a track-mounted CME 55 supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. The Record of Boreholes sheets are provided in Appendix A.

The boreholes were advanced to depths ranging between 3.0 m and 13.2 m below existing ground. Each of the boreholes for the investigation were advanced using either 150 mm outer diameter (O.D.) continuous flight solid stem augers or 108 mm inner diameter continuous flight hollow stem augers, except below a depth of 6.8 m in Borehole 6M-2, below which NW casing and NQ coring were used to advance the borehole from 6.8 m to the bottom of the borehole at 13.2 m depth. Soil samples were generally obtained at intervals of depth of about 0.75 m to 1.5 m, using a 50 mm O.D. split-spoon sampler, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). A total of 3.3 m of bedrock was cored in Borehole 6M-2. 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 Appendix A. The boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The fieldwork was supervised throughout by members of our 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 and rock samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury Geotechnical



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Laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are included in Appendix B.

A sample of the creek water was obtained on October 22, 2011, 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 B1 in Appendix B, together with the detailed analytical laboratory test results.

The as-drilled borehole locations for the current investigation were measured in the field relative to stakes installed by MMM. Golder referenced as-drilled borehole ground surface elevations to the stakes. The ground surface elevations at the borehole locations are referenced to Geodetic datum. The as-drilled borehole locations for the investigation, the ground elevations and borehole depths at the drilled locations are shown in the table below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
6M-1	5 500 521.4	348 446.0	241.9	3.3
6M-2	5 500 527.4	348 466.5	244.7	13.2
6M-3	5 500 553.3	348 455.2	242.5	3.3
6M-4	5 500 554.3	348 428.6	243.5	3.0
6M-4a	5 500 561.9	348 430.3	241.7	3.1
6M-5	5 500 564.1	348 400.8	243.4	4.6
6M-6	5 500 526.8	348 494.3	245.1	5.8
6M-7	5 500 525.2	348 528.4	245.5	8.0
6M-8	5 500 534.3	348 448.1	244.5	7.7
6M-9	5 500 536.1	348 478.8	244.2	4.4

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Published literature indicates that the site is located in the Quetico Subprovince of the Superior Province (Geology of Ontario; OGS Special Volume 4)¹. The bedrock in a large area within and surrounding the Town of Hearst consists of muscovite-bearing granitic rocks (peraluminous), and may include biotite granite. Beyond the muscovite-bearing granitic boundary, bedrock consists of metasedimentary rocks.

Based on terrain mapping by the Ontario Geological Survey², the subsurface soils in the vicinity of the site consist of ground moraine deposits of clayey till.

¹ Geology of Ontario, 1991. Ontario Geological Survey, special Volume 4, Part 1. Eds P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott, Ministry of Northern Development and Mines, Ontario.

² Northern Ontario Engineering Geology Terrain Study, OGS Electronic Map, printed July 2011



4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions, as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the Record of Boreholes sheets attached in Appendix A. Detailed results of the laboratory testing of the soil samples are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations of drilling progress and cuttings. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations. The inferred soil stratigraphy based on the results of the boreholes at the culvert location is shown on Drawings 1 and 2.

In general, the subsoils at the structure site consist of embankment fill (gravel to clayey silt) and underlain by an organic layer, which in turn is underlain sand and silt layer transitioning into glacial till. Possible bedrock, cobbles or boulders were encountered in eight of the boreholes around the culvert; whereas, bedrock was confirmed in one borehole at the centreline of the culvert. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

Various fill materials were encountered from ground surface at each of the boreholes advanced at the site. For each borehole, the following provides a summary of the fill types and thicknesses.

- Borehole 6M-1 was advanced near the south embankment toe on the west side of the creek and encountered 0.1 m of topsoil fill from ground surface (Elevation 241.9 m) underlain by 0.7 m of sand and silt fill with trace gravel and some organics.
- Borehole 6M-2 was advanced through the existing highway embankment in the eastbound lane on the east side of the culvert and encountered 140 mm of asphalt from ground surface (Elevation 244.7 m) underlain by 4.3 m of sand and gravel to sand fill.
- Borehole 6M-3 was advanced near the north embankment toe on the west side of the creek and encountered 0.1 m of topsoil fill from ground surface (Elevation 242.5 m) underlain by 1.5 m of clayey silt fill with some organics.
- Borehole 6M-4 was advanced about 40 m west of the culvert through the north shoulder and encountered 3.0 m of sand fill from surface (Elevation 243.5 m). Clay pockets were encountered within the fill material and the borehole was terminated within the fill material likely on cobbles and boulders near the surface of the native sand and silt till.
- Borehole 6M-4a was advanced approximately 8 m north of Borehole 6M-4 and encountered 1.7 m of sand fill from ground surface (Elevation 241.7 m) underlain by 0.6 m of clayey topsoil fill.
- Borehole 6M-5 was advanced about 70 m west of the culvert through the north shoulder and encountered 1.5 m of sand fill from ground surface (Elevation 243.4 m) underlain by 1.5 m of sand and silt fill with an organic pocket encountered within the sample obtained at about Elevation 241.0 m.



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- Borehole 6M-6 was advanced about 30 m east of the culvert through the north shoulder and encountered 2.3 m of sand and gravel to sand from ground surface (Elevation 245.1 m).
- Borehole 6M-7 was advanced about 60 m east of the culvert north of the north embankment toe and encountered 0.6 m of gravel fill from ground surface (Elevation 245.5 m).
- Borehole 6M-8 was advanced through the existing highway embankment in the eastbound lane on the west side of the culvert and encountered 200 mm of asphalt from ground surface (Elevation 244.5 m) underlain by 4.3 m of sand and gravel to sand fill.
- Borehole 6M-9 was advanced near the north embankment toe on the east side of the creek and encountered 0.3 m of topsoil fill from ground surface (Elevation 244.2 m) underlain by 1.5 m of clayey silt to silty clay fill.

SPT 'N'-values measured within the cohesionless fill (gravel, sand, silt) range between 2 blows and 39 blows per 0.3 m of penetration, indicating a very loose to dense relative density. SPT 'N'-values measured within the clayey silt to silty clay fill in Borehole 6M-3 and 6M-9 range between 7 blows and 17 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency. One SPT 'N'-value measured in the clayey topsoil in Borehole 6M-4a is 15 blows per 0.3 m of penetration, suggesting a very stiff consistency.

A grain size distribution test was carried out on four samples of the gravelly sand to sand fill and the results are shown on Figure B1 in Appendix B.

A grain size distribution test was carried out on one sample of the clayey silt to silty clay fill and the results are shown on Figure B2 in Appendix B.

Atterberg limits testing carried out on one sample of the clayey silt to silty clay fill yielded liquid limits of about 41 per cent, plastic limits of about 20 per cent and a plasticity index of about 22 per cent. The results of the Atterberg limits testing are shown on the plasticity chart on Figure B3 in Appendix B and indicate that the deposit consists of silty clay of intermediate plasticity. The natural water content measured on samples of the gravelly sand to sand fill range between about 4 per cent and 13 per cent; whereas, the natural water content measured on one sample of the clayey silt to silty clay fill was about 26 per cent.

4.2.2 Peat

A deposit of black amorphous peat was encountered beneath the sand and silt fill in Borehole 6M-1 at a depth of 0.8 m (Elevation 241.1 m) and below the clayey silt fill in Borehole 6M-3 at a depth of 1.6 m (Elevation 240.9 m) with thicknesses of 0.7 m at both locations.

Two SPT 'N'-value measured within the peat are 5 blows and 13 blows per 0.3 m of penetration, suggesting a firm to stiff consistency.

The natural water content measured on two samples of the peat are about 34 per cent and 43 per cent.



4.2.3 Silty Clay to Clay

A deposit of grey silty clay to clay was encountered below the sand and gravel fill in Borehole 6M-6 at a depth of 2.3 m (Elevation 242.8 m) and below the gravel fill in Borehole 6M-7 at a depth of 0.6 m (Elevation 2.3 m) with thicknesses of 0.6 m and 2.3 m in the respective boreholes.

SPT 'N'-values recorded within the silty clay to clay range from 10 blows to 20 blows per 0.3 m of penetration, suggesting the cohesive deposit has a stiff to very stiff consistency.

Atterberg limits testing carried out on two samples of the silty clay to clay deposit yielded liquid limits of about 51 per cent and 41 per cent, plastic limits of about 22 per cent and 19 per cent and plasticity indices of about 29 per cent and 21 per cent. The results of the Atterberg limits testing are shown on the plasticity chart on Figure B4 in Appendix B and indicate that the deposit consists of silty clay of intermediate plasticity to a clay of high plasticity.

The natural water content measured on two samples of the silty clay to clay were about 22 per cent and 33 per cent.

4.2.4 Silt to Sand and Silt

A deposit of grey silt to sand and silt, trace gravel, trace to some clay was encountered below the peat in Borehole 6M-1 and 6M-2, below the silty clay to clay deposit in Boreholes 6M-6 and 6M-7 and below the fill in Borehole 6M-9. The silt to sand and silt deposit was encountered between Elevation 242.6 m and Elevation 239.4 m. The thickness of the deposit is between 0.7 m and 2.6 m.

SPT 'N'-values recorded within the silt to sand and silt range from 8 blows and 38 blows per 0.3 m of penetration, indicating the cohesionless deposit has a loose to dense relative density.

Grain size distribution tests carried out for two samples of the silt to sand and silt deposit are shown on Figure B5, in Appendix B.

The natural water content measured on samples of the silt to sand and silt are about 22 per cent.

4.2.5 Sand and Silt to Gravelly Silt (Till)

A deposit of grey sand and silt to gravelly silt till, trace clay was encountered below the silt to sand and silt in Borehole 6M-2 at Elevation 239.4 m, with a thickness of 4.6 m. Cobbles were encountered within this deposit as split-spoon refusal was encountered at a depth of 6.1 m (Elevation 238.6 m) and auger refusal was encountered at a depth of 6.8 m (Elevation 237.9 m). Boreholes 6M-1, 6M-3, 6M-4a, 6M-5, 6M-6, 6M-7, 6M-8 and 6M-9 were terminated within the glacial till after penetrating between about 0.8 m and 3.2 m into the deposit, with the surface of the deposit encountered at these boreholes between about Elevation 239.4 m and 241.2 m.

Three SPT 'N'-values measured within the sand and silt to gravelly silt till range between 22 blows and greater than 100 blows per 0.3 m of penetration (split-spoon refusal where applicable).

A grain size distribution for eleven samples of the sand and silt to gravelly silt till deposit is shown on Figure B6, in Appendix B.



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Atterberg limits testing carried out on one sample of the deposit yielded a liquid limit of about 16 per cent, a plastic limit of about 11 per cent and a plasticity index of about 5 per cent. The results of the Atterberg limits testing are shown on the plasticity chart on Figure B7 in Appendix B and indicate that the deposit is classified as a clayey silt to silt.

The natural water content measured on two samples of the sand and silt till are between about 10 per cent and 17 per cent.

4.2.6 Bedrock/Refusal

Bedrock was encountered below the sand and silt till in Borehole 6M-2 at a depth of 9.9 m below ground surface, corresponding to Elevation 234.8 m, and a 3.4 m length of bedrock core was recovered. The upper 1.5 m of bedrock is described as a fine grained, slightly weathered, white quartz and the lower 1.9 m of bedrock is described as a fine grained, slightly weathered to fresh, grey metasediment. The total core recovery measured on the recovered core samples is 100 per cent, the Solid Core Recovery ranges from 52 per cent to 90 per cent and the Rock Quality Designation (RQD) values range between 54 per cent and 88 per cent, indicating that the bedrock is of fair to good quality, as per CFEM (2006).

Refusal to split spoon, auger and/or DCPT advancement was encountered in and adjacent to Boreholes 6M-1 and 6M-3 to 6M-9 at depths from 3.1 m to 8.0 m below ground surface, with elevations from Elevation 236.8 m to Elevation 240.5 m.

4.2.7 Groundwater Conditions

Boreholes 6M-2, 6M-4, 6M-4a and 6M-5 were dry upon completion of drilling. In Boreholes 6M-1, 6M-3, 6M-6, 6M-7, 6M-8 and 6M-9, unstabilized water levels measured upon the completion of drilling range from depths of 1.0 m to 3.5 m, between Elevation 239.9 m to 242.1 m. On October 21, 2011 the water level in Six Mile Creek was surveyed by Golder to be at Elevation 240.3 m. Groundwater and creek water levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The field personnel supervising the drilling program were Mr. Indulis Dumpis and Mr. Matthew Thibeault, EIT. This report was prepared by Mr. Matthew Thibeault, EIT, and was reviewed by Mr. Andre Bom, P.Eng. A quality control review of the report was provided by Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project.



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**FOUNDATION REPORT
HIGHWAY 11 SIX MILE CREEK CULVERT**

PART B

FOUNDATION DESIGN REPORT

HIGHWAY 11 – SIX MILE CREEK CULVERT AT STATION 16+381

TOWNSHIP OF DEVITT, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 164-98-00, WP 5244-05-01, SITE NUMBER 39W-124



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides design recommendations on the foundation aspects for the proposed Highway 11 culvert replacement at Six Mile Creek. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigations at the site.

The interpretation and recommendations presented are intended only to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the proposed structure and approach embankments at this site. As such, where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

The existing Six Mile Creek three-cell timber culvert will be replaced with a precast concrete box culvert with a width of 6.0 m, a height of 3.5 m and length of 28 m. The existing CSP culvert will remain in place for drainage during construction and will be removed when the new culvert is installed. The proposed culvert outlet (north) and inlet (south) inverts will be Elevation 239.07 m and 239.22 m, respectively. The existing embankment is constructed of granular fill material and is approximately 4.5 m high relative to the creek.

The subsoils at the culvert midpoint generally consist of embankment fill materials (sand and gravel to gravelly sand) and at the inlet and outlet a thin peat layer was found, with the fill and peat underlain by silt to sand and silt. Near the culvert midpoint, the silt to sand and silt was underlain by sand and silt till at a depth of 5.3 m (Elevation 239.4 m) and bedrock at 9.9 m depth (Elevation 234.8 m). Details of the subsurface conditions along this culvert are presented Section 4.2 and shown in profile on Drawing 1.

The culvert will be replaced in stages using a temporary roadway protection system. Foundation investigation and design was completed for a detour on the north side of the culvert but we understand that the detour will not be required. In the potential case that a detour is required, our discussion and recommendations below address the detour.

6.2 Culvert Types

The analysis and recommendations presented in this report assume that the new Six Mile Creek culvert will consist of a precast concrete box culvert. Alternatively, an open footing culvert could be constructed at this site. Table 1 presents a comparison of the alternatives. From a foundations perspective, a concrete precast box culvert is preferred to limit the depth of excavation and dewatering.

6.3 Stability, Settlement and Horizontal Strain

The following sections summarize stability, settlement horizontal strains along the culvert beneath the influence of the proposed embankment loading.



The recommendations provided below assume that all organics soils beneath the culvert alignment will be removed prior to construction as discussed in Section 6.6 and that granular fill (i.e., Granular 'B' Type II) will be used for replacement of sub-excavated material.

6.3.1 Stability

Based on the subsurface conditions encountered in the boreholes advanced at this site, the Highway 11 embankment following culvert replacement and the proposed detour embankment should be stable at side slopes not steeper than 2 Horizontal to 1 Vertical (2H:1V) provided all organic materials are excavated prior to embankment construction.

6.3.2 Settlement

Following the proposed culvert replacement, the Highway 11 embankment geometry is anticipated to remain relatively consistent with the existing embankment geometry. If a grade raise or widening is proposed, settlement analysis should be carried out, however, based on the subsurface conditions encountered at the boreholes, negligible settlements (i.e., less than 25 mm) are anticipated for a minor grade raise.

It is recommended that consideration be given to the use of OPSS.PROV.1010 (Aggregates) Granular 'B' Type I or II for Highway 11 embankment reconstruction at the culvert location. Where granular fill will be placed below the water level, Granular 'B' Type II should be used. The material placed below the water level will compress/settle under its self-weight as additional fill is placed over it. The material placed above the water level should be compacted in accordance with OPSS 501 (Compacting). Compression settlement of the fill placed below water and from properly compacted embankment fill above water is expected to occur during construction.

6.3.3 Horizontal Strain

Based on the limited vertical settlements at this site (less than 25 mm), horizontal strain along the culvert is not expected to occur. As a result, culvert construction concurrent with the embankment construction can be carried out without the need for any foundation mitigation measures or culvert camber.

6.4 Geotechnical Resistance

For a box culvert bearing on the loose to dense silt to sand and silt or on the sand and silt till, a factored geotechnical axial resistance at Ultimate Limit States (ULS) of 200 kPa may be used for design for an assumed 6.0 m wide box culvert. Alternatively, for an open bottom footing culvert founded on the dense to very dense sand and silt till, a factored axial resistance at ULS of 400 kPa may be used for design for an assumed 1 m wide footing.

The loading on the foundation soils below the culvert and the associated total settlement at the culvert extensions will be governed by the embankment widening, if required. As such, it is recommended that the structural engineer exercise caution when utilizing the value(s) of the geotechnical axial resistance at



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Serviceability Limit States (SLS) in the design of the culverts and that consideration be given to the sequence and staging of construction. Based on the above, the geotechnical resistance at SLS (for 25 mm settlement) for a 6.0 m wide box culvert constructed on the properly prepared silt to sand and silt subgrade may be taken as 150 kPa. The geotechnical resistance at SLS (for 25 mm settlement) for a 1 m wide footing constructed on the properly prepared till subgrade may be taken as 275 kPa.

The geotechnical resistances are given for loads applied perpendicular to the surface of the base of the culvert. Where loads are not applied perpendicular to the base of the culvert, inclination of the loads should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the Canadian Highway Bridge Code (CHBDC) and its Commentary.

Dewatering will be required to construct a cast-in-place culvert in the dry, as discussed further in Section 6.6.3.

6.4.1 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of a concrete box closed bottom culvert and the granular fill/bedding or footings for the open box culvert on the sand and silt till should be calculated in accordance with Section 6.7.5 of the CHBDC. The following summarizes the coefficient of friction for the interface materials for a precast and cast-in-place concrete or footings.

Interface Materials	Coefficient of Friction
Precast Concrete on Compacted Granular 'B' Type II	$\tan \delta = 0.45$
Cast-in-Place Concrete on Compacted Granular 'B' Type II or sand and silt till	$\tan \delta = 0.58$

The values are unfactored.

6.4.2 Frost Protection

The estimated frost penetration depth in the Hearst area is 2.6 m, as per OPSD 3090.100 (Foundation Frost Penetration Depths for Northern Ontario). Footings for an open footing culvert should be provided with a minimum of 2.6 m of soil cover for frost protection.

Closed bottom box culverts are typically not provided with the standard depth for frost protection as close bottom box culverts are tolerant to small magnitudes related to freeze-thaw cycles should these occur. The box culvert should, however, be founded below any existing fill and surficial organic materials. It is recommended that the box culvert segments be placed on a minimum thickness of 300 mm of OPSS.PROV.1010 Granular 'B' Type II.



6.5 Lateral Earth Pressures

The lateral earth pressures acting on the side walls (or head/wing walls if required) of the culverts will depend on the type and method of placement of backfill materials, the nature of 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 culverts and any wing or head walls. It should be noted that these design recommendations and parameters are applicable to 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 requirements of OPSS.PROV.1010 (Aggregates) Granular 'A' or Granular 'B' Type II but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culverts. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper should be in accordance with OPSD 3101.150 (Walls, Abutment, Backfill) and OPSD 3121.150 (Walls Retaining, Backfill).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culverts and retaining walls, in accordance with CHBDC Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS 501 (Compaction). Other surcharge loadings should be accounted for in the design as required.
- Granular fill may be placed either in a zone with the width equal to at least 2.6 m behind the back of the walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5 H:1V extending up and back from the rear face of the base of the walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC).
- For a restrained wall condition, the pressures are based on the proposed embankment fill materials and the existing overburden soils and the following parameters (unfactored) may be used assuming the use of granular fill or rock fill:

	Granular Fill	Rock Fill
Soil unit weight:	21 kN/m ³	19 kN/m ³
Coefficients of static lateral earth pressure:		
Active, K_a	0.31	0.22
At rest, K_o	0.47	0.36

- For an unrestrained wall condition, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:



FOUNDATION REPORT HIGHWAY 11 SIX MILE CREEK CULVERT

	Granular 'A'	Granular 'B' Type II
Soil unit weight:	22 kN/m ³	21 kN/m ³
Coefficients of static lateral earth pressure:		
Active, K_a	0.27	0.27
At rest, K_o	0.43	0.43

If the wing/head walls and culvert structures allow for lateral yielding, active earth pressures may be used in the geotechnical design of the structures. If the wing/retaining walls and culvert structures do not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the Commentary to the CHBDC.

6.6 Culvert Construction Considerations

6.6.1 Excavations, Subgrade Preparation, Bedding and Backfill above Base of Culvert

All excavations must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended by Ontario Regulation 443). In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of the existing Highway 11. Temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems) and is discussed further in Section 6.6.4.

Prior to the placement of any bedding material and fill for new construction, all organic soils where encountered should be stripped from the plan limits of the proposed works. The native subgrade soils may be susceptible to disturbance from construction traffic and/or ponded water. In order to limit this degradation, it is recommended that a concrete working slab be placed on the subgrade if culvert construction is not carried out within four (4) hours after preparation, inspection and approval of the subgrade. A sample Non-Standard Special Provision (NSSP) to address this requirement is included in Appendix C.

The precast box culvert should be constructed in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) and could be installed in wet conditions depending on the season of construction and water level at the time of installation. As an alternative to a working slab discussed above, the box culvert could be constructed on a layer of OPSS.PROV.1010 (Aggregates) Granular 'B' Type II material for bedding purposes, which will likely be placed in the wet and nominally compacted by the construction equipment.

For the open footing culvert, dewatering will be required to construct the cast-in-place elements in-the-dry, as discussed further in Section 6.6.3.

The fill depth during placement should be maintained equal on both sides of the culvert with one side not exceeding the other by more than 500 mm.

The culvert should be designed for the full overburden stress and appropriate live loads, assuming a fill unit weight of 22 kN/m³ for Granular 'A' and 21 kN/m³ for Granular 'B' Type II backfill above and surrounding the



culvert. Inspection and field density testing should be carried out by qualified personnel during fill placement operations to ensure that appropriate materials are used and that adequate levels of compaction have been achieved.

6.6.2 Erosion Protection

If the culvert is placed on a granular blanket, provisions should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a concrete cut-off wall or clay seal should be provided at the upstream end of the culvert. 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 to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including along the embankment slope. 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 culvert should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culvert 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 follow the standard presented in OPSD 810.010 similar to the outlet but 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 culvert.

6.6.3 Control of Groundwater and Surface Water

Excavation within the plan limits of the proposed Six Mile Creek alignment will be required to remove organics, existing granular fill prior to construction of the footings, placement of backfill/embankment fill, bedding material and the actual culvert structure. The existing culvert flows will need to be diverted/piped during construction. Surficial water seepage into the excavation should be expected and will be heavier during periods of sustained precipitation. Seepage from the granular fills and near surface native granular materials should be expected, particularly after precipitation events. It is anticipated that this surficial seepage can be controlled by using properly filtered sumps within the excavation.

For cast-in-place culvert elements, dewatering will be required for construction in-the-dry. The excavations will be advanced through or into water-bearing cohesionless soils and appropriate unwatering of the water-bearing granular soil deposits will be required to maintain the water level below the founding level for the culvert during excavation and construction. It is recommended that an NSSP be included in the Contract to address unwatering for the culvert site; a sample NSSP is included in Appendix C.



6.6.4 Temporary Shoring

Temporary shoring along the centreline will be required to facilitate culvert replacement to support the embankment fill, instead of a detour. The temporary support systems could consist of driven steel sheet piling where suitable depth of embedment is available. However, due to the presence of the cobbles and boulders within the sand and silt till, driven sheet piling may not penetrate into the till material. Based on the presence of the sand and silt till generally within 1 m of the culvert invert, soldier piles and lagging may be more practical at this site, where the H-piles would be driven or pre-drilled to a suitable depth and horizontal lagging installed as the excavation proceeds. Support to the system could be in the form of struts and walers or rakers and anchors. The Contractor should be alerted to the cobbles and boulders within the sand and silt till; an example NSSP (or Notice to Contractor) to be included in the Contract is presented in Appendix C.

The temporary excavation support system should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2, as specified in OPSS 539. The contractor is responsible for the complete detailed design of the protection system.

The design of braced soldier pile and lagging walls should be based on a rectangular earth pressure distribution using the design parameters given below. Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The anchor/raker support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system. Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter.

The unfactored triangular earth pressure distribution (p in kN/m^2 ; increasing with depth), can be calculated as follows:

$$\begin{array}{lll} p & = & K_a (\gamma H + q) \\ \text{where } H & = & \text{the depth of the excavation at any point (m)} \\ K_a & = & \text{active coefficient of earth pressure} \\ \gamma & = & \text{soil unit weight (kN/m}^3\text{)} \\ q & = & \text{surcharge for traffic and other loading (kN/m}^2\text{)} \end{array}$$

For a braced excavation in granular fill and native cohesionless soils, the unfactored rectangular earth pressure distribution (p in kN/m^2 ; constant with depth), can be calculated as follows:

$$\begin{array}{lll} p & = & 0.65 K_a (\gamma H + q) \\ \text{where } H & = & \text{the total depth of the excavation (m)} \\ K_a & = & \text{active coefficient of earth pressure} \\ \gamma & = & \text{soil unit weight (kN/m}^3\text{)} \\ q & = & \text{surcharge for traffic and other loading (kN/m}^2\text{)} \end{array}$$

The support systems may be designed using the following parameters:



FOUNDATION REPORT HIGHWAY 11 SIX MILE CREEK CULVERT

SOIL TYPE	COEFFICIENT OF EARTH PRESSURE			INTERNAL ANGLE OF FRICTION (ϕ , degrees)	UNIT WEIGHT (γ , kN/m ²)
	Active, K_a	At Rest, K_o	Passive, K_p		
Existing					
Embankment Fill	0.33	0.50	3.0	30	20
Silt to Sand and Silt	0.36	0.53	2.8	28	19
Sand and Silt Till	0.28	0.44	3.6	34	19

The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficients should be adjusted accordingly.

6.6.5 Detour Construction

If a detour is considered for culvert replacement, based on the grade of the detour alignment as shown on Drawing 2, up to about 2 m of filling is required on either side the creek crossing area, minimal filling is required east of the creek and about 1 m of filling is required west of the creek. The subgrade generally consists of sand or sand and gravel fill over stiff clay east of the culvert followed by compact to dense silt to sand and silt, which also exists below the fill west of the culvert. Peat exists in the creek valley which if present below the detour embankment, should be sub excavated.

Settlement from new fill placement above the existing fill subgrade should be minor, and should take place during filling or immediately afterwards. For side slopes at 2H:1V, the detour embankment stability will be adequate.

The detour embankment construction should consider the presence and protection or relocation of the existing utilities.

Foundations for the temporary modular bridge should be carried through the existing fill and organic peat material to found preferably on the sand and silt till. The foundations on the till can be designed of a ULS value of 400 kPa and a SLS value of 275 kPa.

6.6.6 Analytical Testing for Construction Materials

The analytical test results on a sample of creek water taken adjacent to the culvert site are presented in Table B1. The suite of parameters tested is intended to allow the structural engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection.

7.0 CLOSURE


This report was prepared by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.



FOUNDATION REPORT HIGHWAY 11 SIX MILE CREEK CULVERT

Report Signature Page

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N:\Active\2010\1190 Sudbury\1191\10-1191-0038 MMM Hwy 11 Mattawishkvia River\Reporting\Final Report\R02 - 6 Mile Creek\10-1191-0038-R02 Final FIDR 13Nov12 6 Mile Creek.Docx



FOUNDATION REPORT HIGHWAY 11 SIX MILE CREEK CULVERT

REFERENCES

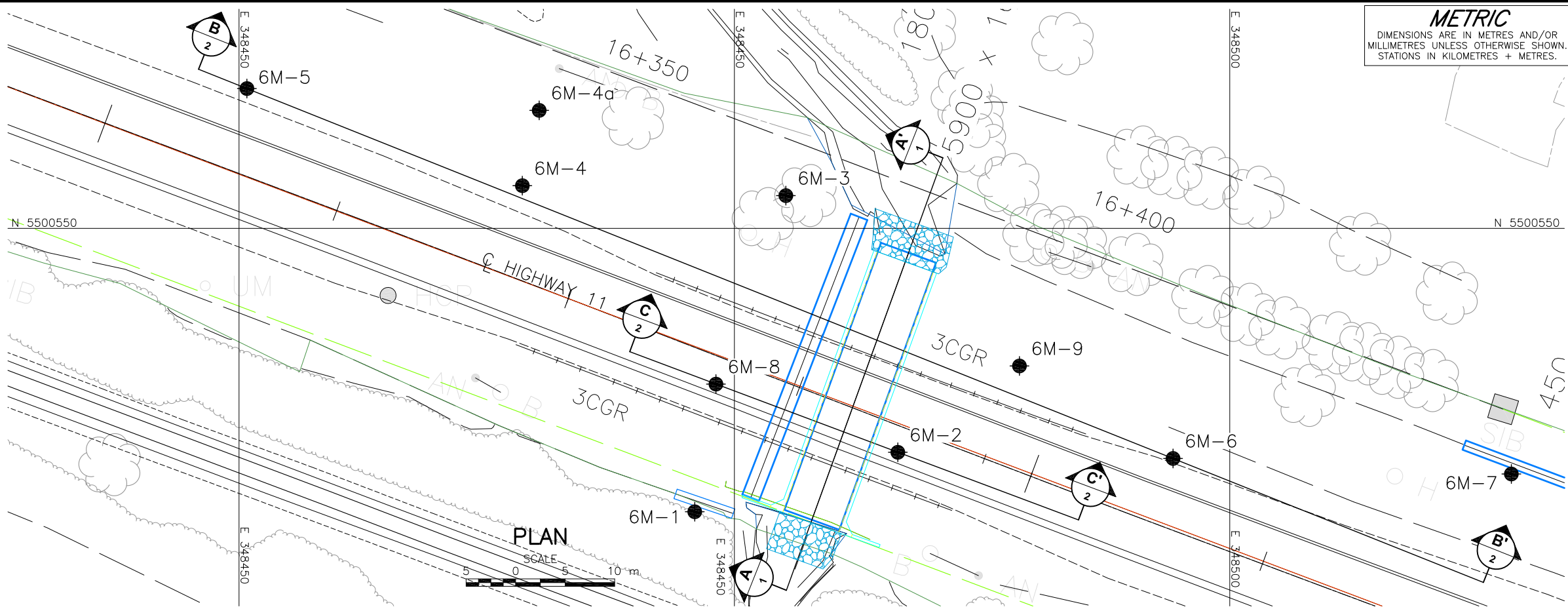
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- Northern Ontario Engineering Geology Terrain Study, OGS Electronic Map, printed July 2011
- Occupational Health and Safety Act and Regulation for Construction Projects, January 2006.
- ASTM International
- ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
- Ontario Provincial Standard Drawings
- | | |
|---------------|---|
| OPSD 802.034 | Rigid Pipe Bedding and in Embankment |
| OPSD 810.010 | Rip Rap Treatment for Sewer and Culvert Outlets |
| OPSD 3090.100 | Foundation, Frost Penetration Depths for Northern Ontario |
| OPSD 3101.150 | Walls, Abutment, Backfill |
| OPSD 3121.150 | Walls, Retaining, Backfill, Minimum Granular Requirement |
- Ontario Provincial Standard Specifications
- | | |
|----------------|--|
| OPSS 422 | Construction Specification for Precast Reinforced Concrete Box Culverts |
| OPSS 501 | Construction Specification for Compacting |
| OPSS 539 | Construction Specification for Temporary Protection Systems |
| OPSS 1205 | Material Specification for Clay Seal |
| OPSS PROV.1010 | Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material |
- Ontario Water Resources Act
- | | |
|---------------------------|-------------------------------------|
| Ontario Regulation 372/97 | Amendment to Ontario Regulation 903 |
|---------------------------|-------------------------------------|



FOUNDATION REPORT HIGHWAY 11 SIX MILE CREEK CULVERT

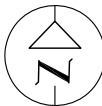
Table 1: Evaluation of Culvert Types

Options	Ranking	Advantages	Disadvantages	Relative Costs
Precast Box Concrete Culvert	1	<ul style="list-style-type: none">■ Straightforward construction.■ Dewatering/unwatering may not be required for pre-cast option.	<ul style="list-style-type: none">■ Bedding material required for a pre-cast closed bottom culvert.■ Closed bottom culvert less suitable for sites where reduced impact to creeks bed is required.	<ul style="list-style-type: none">■ Additional transportation costs for pre-cast option.
Cast-In-Place Concrete Open Footing Culvert	2	<ul style="list-style-type: none">■ Bedding material not required for footings placed directly on the sand and silt till.■ Open bottom culvert suitable for sites where reduced impact to creek bed is required.	<ul style="list-style-type: none">■ Dewatering required for cast-in-place concrete.■ Sub-excavation of very dense sand and silt till material for footing frost cover.	<ul style="list-style-type: none">■ Additional cost for dewatering.■ Additional cost for concrete form work for cast-in-place option.



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

CONT No.
GWP No.164-98-00

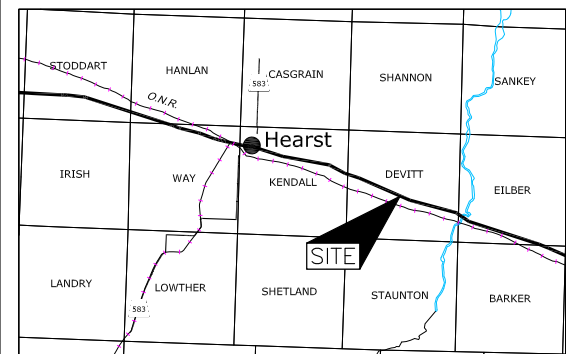


HIGHWAY 11
CULVERT AT STA. 16+381
BOREHOLE LOCATIONS AND
SOIL STRATA

SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



KEY PLAN

SCALE
10 0 10 km

LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
6M-1	241.9	5500521.4	348446.0
6M-2	244.7	5500527.4	348466.5
6M-3	242.5	5500553.3	348455.2
6M-4	243.5	5500554.3	348428.6
6M-4a	241.7	5500561.9	348430.3
6M-5	243.4	5500564.1	348400.8
6M-6	245.1	5500526.8	348494.3
6M-7	245.5	5500525.2	348528.4
6M-8	244.5	5500534.3	348448.1
6M-9	244.2	5500536.1	348478.8

NOTES

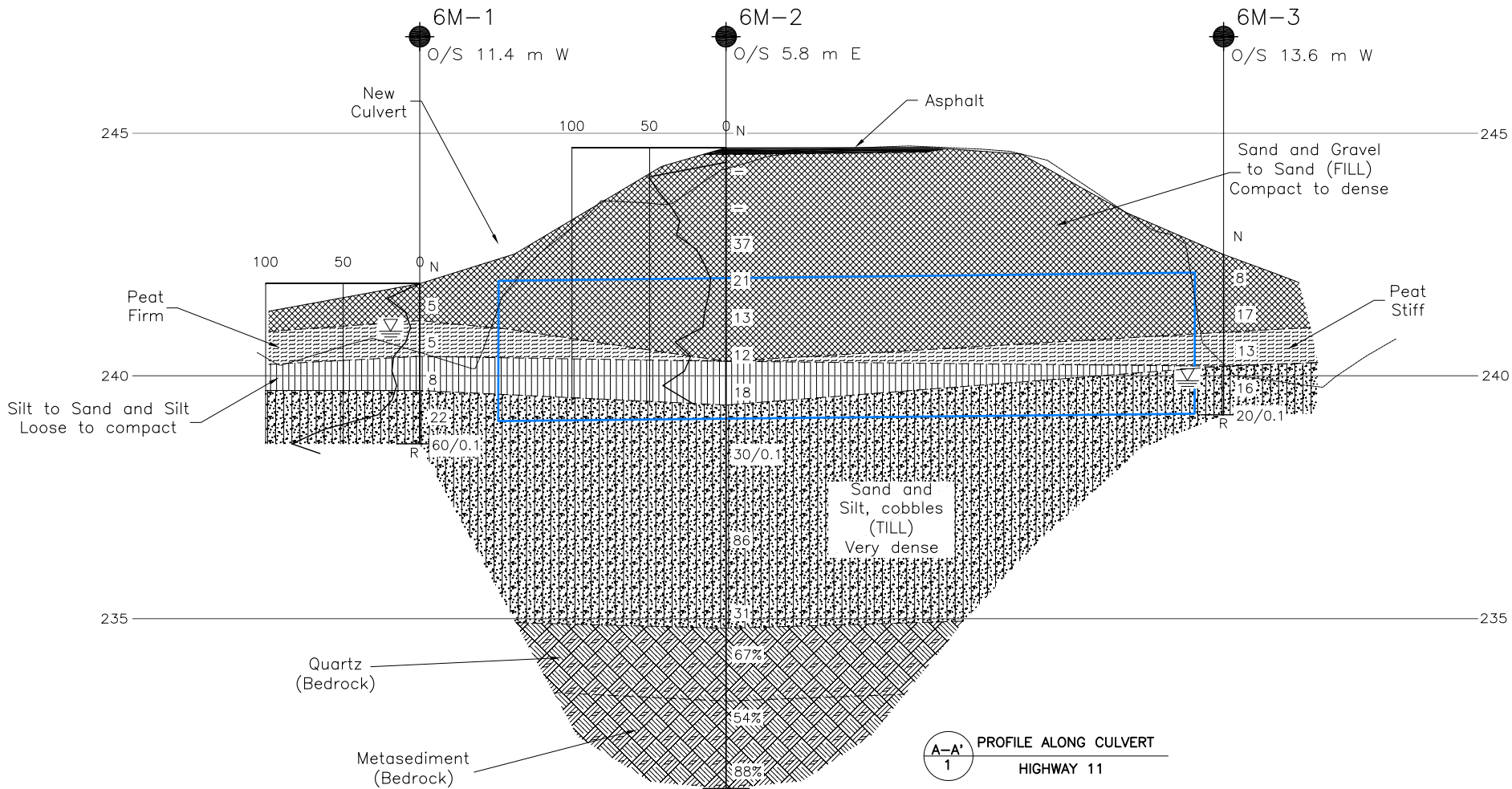
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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 provided in digital format by MMM, drawing file BASE-PLAN.dwg and Hwy 11 - Align-C2.dwg, received NOV 2013 and updated culvert invert elevations in profile on Sept. 24, 2013.



A-A'
1
PROFILE ALONG CULVERT
HIGHWAY 11
HORIZONTAL SCALE
2.5 0 2.5 5 m
1.25 0 1.25 2.5 m

NO.	DATE	BY	REVISION
Geocres No. 42G-42			
HWY. 11	PROJECT NO. 10-1191-0038		DIST.
SUBM'D. MT	CHKD. AB	DATE: NOV 2013	SITE: 39W-124/C
DRAWN: TB	CHKD. FJM	APPD.	DWG. 1

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

CONT No.
GWP No.164-98-00

HIGHWAY 11
CULVERT AT STA. 16+385
SOIL STRATA

SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA

LEGEND

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

BOREHOLE CO-ORDINATES

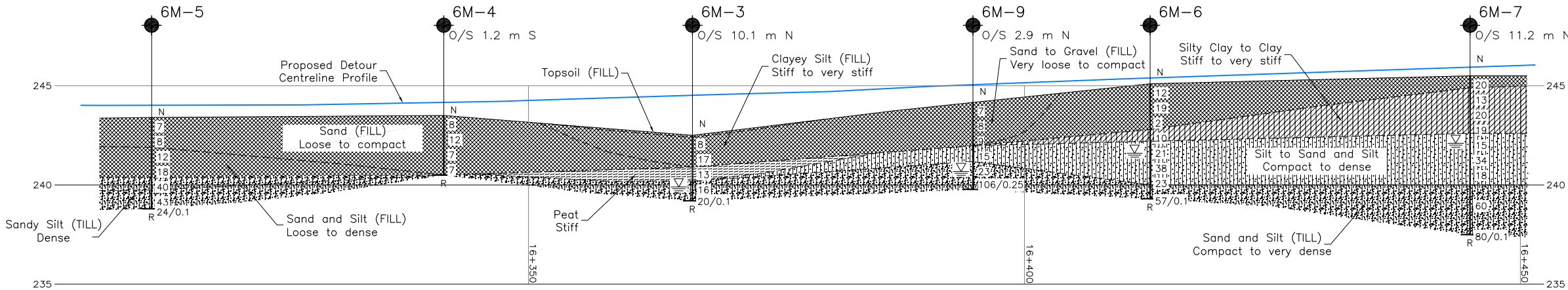
No.	ELEVATION	NORTHING	EASTING
6M-3	242.5	5500553.3	348455.2
6M-4	243.5	5500554.3	348428.6
6M-5	243.4	5500564.1	348400.8
6M-6	245.1	5500526.8	348494.3
6M-7	245.5	5500525.2	348528.4
6M-8	244.5	5500534.3	348448.1

NOTES

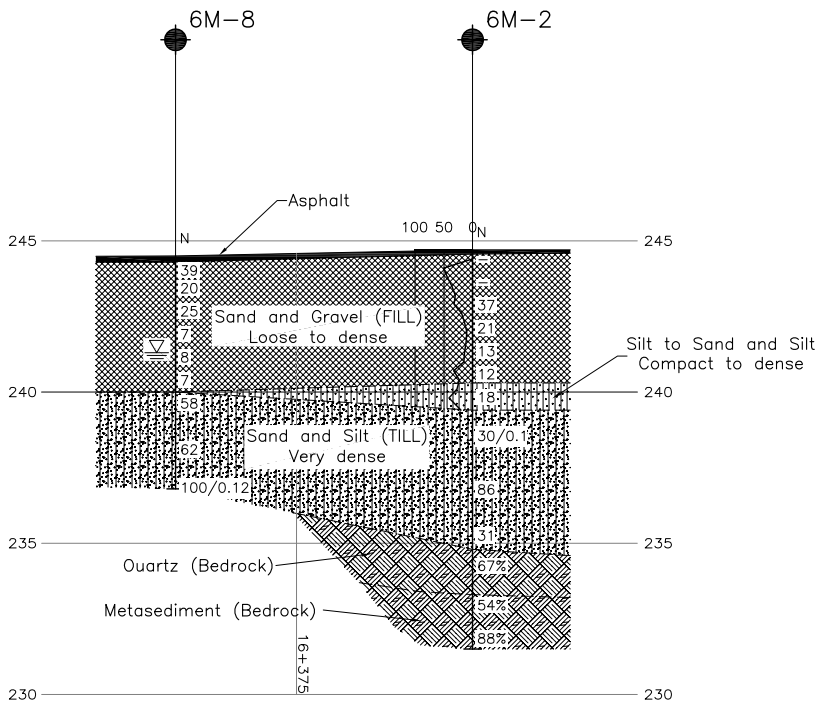
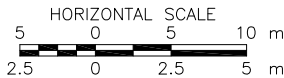
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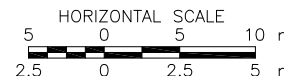
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS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



B-B'
1
PROFILE ALONG DETOUR
HIGHWAY 11



C-C'
1
CENTRELINE PROFILE
HIGHWAY 11



NO.	DATE	BY	REVISION
Geocres No. 42G-42			
HWY. 11	PROJECT NO. 10-1191-0038		DIST.
SUBM'D. MT	CHKD. AB	DATE: NOV 2013	SITE: 39W-124/C
DRAWN: TB	CHKD. FJM	APPD.	DWG. 2



**FOUNDATION REPORT
HIGHWAY 11 SIX MILE CREEK CULVERT**

APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

Notes: 1
2

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



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

WEATHERINGS STATE

Fresh: no visible sign of weathering

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

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

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

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

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

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

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

GRAIN SIZE

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

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

CORE CONDITION

Total Core Recovery (TCR)

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

Solid Core Recovery (SCR)

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

Rock Quality Designation (RQD)

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

DISCONTINUITY DATA

Fracture Index

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

Dip with Respect to Core Axis

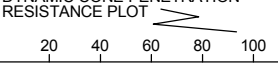







The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

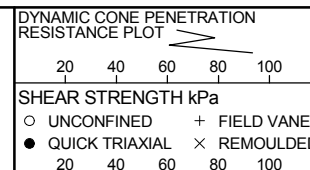
Description and Notes

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	

PROJECT		10-1191-0038		RECORD OF BOREHOLE No 6M-1		1 OF 1 METRIC					
W.P.		164-98-00		LOCATION		N 5500521.4; E 348446.0					
DIST		HWY 11		BOREHOLE TYPE		150 mm O.D. Solid Stem Augers					
DATUM		Geodetic		DATE		October 20, 2011					
				ORIGINATED BY		MT					
				COMPILED BY		MT					
				CHECKED BY		AB					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p — W — W _L WATER CONTENT (%)	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
241.9	GROUND SURFACE										
0.0	Topsoil (FILL) Black Moist		1	SS	5	 241					4 33 52 11
241.1	Sand and silt, trace gravel, some organics (FILL) Loose Brown / Black Moist to wet		2	SS	5						
240.4	PEAT (Amorphous) Firm Black Moist to wet		3	SS	8						
239.7	SILT to SAND and SILT, trace to some clay, trace gravel Loose Grey Moist to wet		4	SS	22						
238.6	SAND and SILT (TILL) Compact to very dense Grey Wet		5	SS	60/0.1						
3.3	END OF BOREHOLE SPOON AND AUGER REFUSAL										
Note: 1. Water level at a depth of 1.0 m below ground surface (Elev. 240.9 m) upon completion of drilling. 2. Advanced DCPT 1 m west of Borehole 6M-1. Refusal at a depth of 3.5 m.											

PROJECT		10-1191-0038		RECORD OF BOREHOLE No 6M-2		1 OF 2 METRIC							
W.P.		164-98-00		LOCATION		N 5500527.4; E 348466.5							
DIST		HWY 11		BOREHOLE TYPE		150 mm O.D. Solid Stem Augers, NW Casing, NQ Coring							
DATUM		Geodetic		DATE		October 21, 2011 and March 20, 2012.							
						ORIGINATED BY MT/ID							
						COMPILED BY MT							
						CHECKED BY AB							
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								
244.7	GROUND SURFACE												
0.0	ASPHALT (140mm)		1	AS	-								
0.1	Sand and gravel to sand, trace to some silt (FILL) Compact to dense Brown Moist		2	AS	-								
			3	SS	37								
			4	SS	21								
			5	SS	13								
			6	SS	12								
240.3	SILT to SAND and SILT Compact Grey Moist		7	SS	18								
239.4	SAND and SILT, trace to some clay, trace gravel, cobbles (TILL) Very dense Grey Moist		8	SS	30/0/1								
	Augered through cobbles at 6.1 m depth.												
	Auger refusal at 6.8 m depth, NW Casing and NQ Coring below 6.8 m depth.												
			9	SS	86								
			10	SS	31								
234.8	QUARTZ (BEDROCK)		1	RC	REC 100%								
	Bedrock cored from 9.9 m depth to 13.2 m depth.												
	For coring details see Record of Drillhole 6M-2.												
233.3	METASEDIMENT (BEDROCK)		2	RC	REC 100%								
			3	RC	REC 100%								
231.5	END OF BOREHOLE												
13.2													

Continued Next Page

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

SUD-MTO 001 1011910038 6MI.GPJ GAL-MISS.GDT 25/10/13 DATA INPUT:

PROJECT <u>10-1191-0038</u>		RECORD OF BOREHOLE No 6M-2				2 OF 2 METRIC											
W.P. <u>164-98-00</u>		LOCATION <u>N 5500527.4; E 348466.5</u>				ORIGINATED BY <u>MT/ID</u>											
DIST <u> </u> HWY <u>11</u>		BOREHOLE TYPE <u>150 mm O.D. Solid Stem Augers, NW Casing, NQ Coring</u>				COMPILED BY <u>MT</u>											
DATUM <u>Geodetic</u>		DATE <u>October 21, 2011 and March 20, 2012.</u>				CHECKED BY <u>AB</u>											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT 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			W _L
	--- CONTINUED FROM PREVIOUS PAGE ---																
	Notes: 1. Borehole dry upon completion of drilling. 2. Advanced DCPT 1 m east of Borehole 6M-2. Refusal at a depth of 5.3 m. 3. On October 21, 2011, auger refusal encountered at 6.8 m depth (Elev. 237.9 m). Returned to site on March 20, 2012 and advanced NW Casing and NQ Coring below 6.8 m depth.																

SUD-MTO 001 1011910038 6M.GPJ GAL-MISS.GDT 25/10/13 DATA INPUT:

PROJECT: 10-1191-0038

RECORD OF DRILLHOLE: 6M-2

SHEET 1 OF 1

LOCATION: N 5500527.4 ; E 348466.5

DRILLING DATE: October 21, 2011 and March 20, 2012.

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 45

DRILLING CONTRACTOR: Landcore

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV.		RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - 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 MB - Mechanical Break	BR - Broken Rock	NOTE: For additional abbreviations refer to list of abbreviations & symbols.	NOTES WATER LEVELS INSTRUMENTATION													
				DEPTH (m)	FLUSH																						
															RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY		Diametral Point Load Index (MPa)	RMC -Q'	AVG.
															TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn			
10	NW Casing March 20, 2012	REFER TO PREVIOUS PAGE		234.8 9.9																							
11		QUARTZ Fine grained Slightly weathered White		1	Grey 100%																						
12		METASEDIMENT Fine grained Slightly weathered to 12.2 m depth, fresh below 12.2 m Grey		233.3 11.4	2	Grey 100%																					
13				231.5 13.2	3	Grey 100%																					
14		END OF DRILLHOLE																									
15		Note: 1. Joints generally undulating and rough.																									
16																											
17																											
18																											
19																											

DEPTH SCALE



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LOGGED: MT/ID

CHECKED: AB


SUD-RCK 1011910038 6MIGPJ GAL-MISS.GDT 25/10/13 DATA INPUT:

PROJECT		10-1191-0038				RECORD OF BOREHOLE No 6M-3				1 OF 1 METRIC							
W.P.		164-98-00		LOCATION		N 5500553.3; E 348455.2				ORIGINATED BY		MT					
DIST		HWY 11		BOREHOLE TYPE		150 mm O.D. Solid Stem Augers				COMPILED BY		MT					
DATUM		Geodetic		DATE		October 21, 2011				CHECKED BY		AB					
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									
242.5	GROUND SURFACE							20	40	60	80	100					
0.0	Topsoil (FILL) Black Moist		1	SS	8		242										
	Clayey silt, some organics (FILL) Stiff to very stiff Grey Moist		2	SS	17		241										
240.9	PEAT (Amorphous) Stiff Black Moist	3	SS	13	240												
240.2	SAND and SILT, trace gravel, trace clay (TILL) Compact to dense Grey Moist to wet	4	SS	16													
239.2	END OF BOREHOLE SPOON AND AUGER REFUSAL	5	SS	20/0.1													
3.3	Note: 1. Water level at a depth of 2.6 m below ground surface (Elev. 239.9 m) upon completion of drilling.																

SUD-MTO 001 1011910038 6M.GPJ GAL-MISS.GDT 25/10/13 DATA INPUT:

PROJECT		10-1191-0038				RECORD OF BOREHOLE No 6M-4				1 OF 1 METRIC							
W.P.		164-98-00		LOCATION		N 5500554.3; E 348428.6				ORIGINATED BY				MT			
DIST		HWY 11		BOREHOLE TYPE		150 mm O.D. Solid Stem Augers				COMPILED BY				MT			
DATUM		Geodetic		DATE		October 20, 2011				CHECKED BY				AB			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			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					WATER CONTENT (%)				
243.5	GROUND SURFACE																
0.0	Sand, trace to some gravel, trace to some silt (FILL) Loose to compact Brown Moist Clay pockets encountered in Samples 1 and 4.		1	SS	8												
			2	SS	12												
			3	SS	7												
			4	SS	7												
240.5	END OF BOREHOLE AUGER REFUSAL																
3.0	Note: 1. Borehole dry upon completion of drilling. 2. Attempted to advance borehole 1 m west of Borehole 6M-4. Auger refusal encountered at a depth of 3.2 m (Elev 240.3 m).																



SUD-MTO 001 1011910038 6M.GPJ GAL-MISS.GDT 25/10/13 DATA INPUT:

PROJECT		10-1191-0038				RECORD OF BOREHOLE No 6M-4a				1 OF 1 METRIC								
W.P.		164-98-00		LOCATION		N 5500561.9; E 348430.3				ORIGINATED BY				MT				
DIST		HWY 11		BOREHOLE TYPE		150 mm O.D. Solid Stem Augers				COMPILED BY				MT				
DATUM		Geodetic		DATE		October 20, 2011				CHECKED BY				AB				
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)					
241.7	GROUND SURFACE							20	40	60	80	100						
0.0	Sand, trace gravel (FILL) Loose Brown Moist		1	SS	6													
			2	SS	6													
240.0																		
1.7	Clayey topsoil, some sand, some gravel (FILL) Very stiff Black Moist		3	SS	15													
239.4																		
2.3																		
	SAND and SILT, trace to some clay, trace gravel (TILL) Loose to dense Grey Moist		4	SS	7													
238.6																		
3.1	END OF BOREHOLE SPOON AND AUGER REFUSAL		5	SS	20/0.1													
	Note: 1. Borehole dry upon completion of drilling. 2. Advanced borehole approximately 8.0 m north of Borehole 6M-4.																	

SUD-MTO 001 1011910038 6M.GPJ GAL-MISS.GDT 25/10/13 DATA INPUT:

PROJECT		10-1191-0038				RECORD OF BOREHOLE No 6M-5				1 OF 1 METRIC							
W.P.		164-98-00		LOCATION		N 5500564.1; E 348400.8				ORIGINATED BY							
DIST		HWY 11		BOREHOLE TYPE		150 mm O.D. Solid Stem Augers				COMPILED BY							
DATUM		Geodetic		DATE		October 20, 2011				CHECKED BY							
AB																	
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			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					WATER CONTENT (%)				
243.4	GROUND SURFACE																
0.0	Sand, some gravel, trace to some silt (FILL) Loose Brown Moist		1	SS	7												
			2	SS	8												
241.9																	
1.5	Sand and silt, trace to some clay, trace gravel (FILL) Loose to dense Grey / brown / black Moist		3	SS	12												
			4	SS	18												
240.4	Organic pockets encountered in Sample 4.																
3.0	Sandy SILT, trace to some clay, trace to some gravel (TILL) Dense Grey Moist		5	SS	40												
			6	SS	43												
238.8			7	SS	24/0.1												
4.6	END OF BOREHOLE SPOON AND AUGER REFUSAL																
	Note: 1. Borehole dry upon completion of drilling.																



PROJECT 10-1191-0038			RECORD OF BOREHOLE No 6M-6			1 OF 1 METRIC										
W.P. 164-98-00			LOCATION N 5500526.8; E 348494.3			ORIGINATED BY MT										
DIST HWY 11			BOREHOLE TYPE 150 mm O.D. Solid Stem Augers			COMPILED BY MT										
DATUM Geodetic			DATE October 21, 2011			CHECKED BY AB										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
245.1	GROUND SURFACE															
0.0	Sand and gravel to sand, trace silt (FILL) Very loose to compact Brown Moist		1	SS	12											
			2	SS	19											23 65 (12)
			3	SS	2											
242.8																
2.3	CLAY, some silt, trace gravel, trace sand Stiff Grey Moist		4	SS	10											
242.2																
2.9	SILT to SAND and SILT, trace clay Compact to dense Grey Moist to wet		5	SS	21											
			6	SS	38											0 2 94 4
			7	SS	23											
240.0																
5.1	SAND and SILT (TILL) Very dense Grey Wet		8	SS	57/0 1											
239.3																
5.8	END OF BOREHOLE SPOON AND AUGER REFUSAL															
Note: 1. Water level at a depth of 3.5 m below ground surface (Elev. 241.6 m) upon completion of drilling.																

PROJECT 10-1191-0038			RECORD OF BOREHOLE No 6M-7			1 OF 1 METRIC													
W.P. 164-98-00			LOCATION N 5500525.2; E 348528.4			ORIGINATED BY MT													
DIST _____ HWY 11			BOREHOLE TYPE 150 mm O.D. Solid Stem Augers			COMPILED BY MT													
DATUM Geodetic			DATE October 20, 2011			CHECKED BY AB													
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 (%)	
245.5	GROUND SURFACE							20	40	60	80	100							
0.0	Gravel, trace to some silt, some organics (FILL) Compact		1	SS	20		245												
244.9	Brown / Black Moist						244												
0.6	SILTY CLAY, trace sand Stiff to very stiff Brown to grey Moist		2	SS	13		243												
			3	SS	20		242												
		4	SS	19	241														
242.6	SILT to SAND and SILT, trace clay Compact to dense Grey Moist to wet	5	SS	15	240														
2.9		6	SS	34	239														
		7	SS	18	238														
		8	SS	60															
240.0	SAND and SILT, some gravel, trace clay (TILL) Very dense Grey Moist to wet																		
5.5		9	SS	80/10.1															
237.5	END OF BOREHOLE SPOON AND AUGER REFUSAL																		
8.0	Note: 1. Water level at a depth of 3.4 m below ground surface (Elev. 242.1 m) upon completion of drilling.																		

SUD-MTO 001 1011910038 6M.GPJ GAL-MISS.GDT 25/10/13 DATA INPUT:

PROJECT		10-1191-0038				RECORD OF BOREHOLE No 6M-8				1 OF 1 METRIC							
W.P.		164-98-00		LOCATION		N 5500534.3; E 348448.1				ORIGINATED BY ID							
DIST		HWY 11		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY MT							
DATUM		Geodetic		DATE		July 3, 2013				CHECKED BY AB							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
244.5	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT (200 mm)																
0.2	Sand and gravel to sand (FILL) Loose to dense Brown Moist		1	SS	39	▽	244										
			2	SS	20		243										
			3	SS	25		242										
			4	SS	7		241										
			5	SS	8		240										
			6	SS	7		239										
240.0	SAND and SILT, trace to some clay, trace gravel (TILL) Very dense Grey Moist		7	SS	58		240										6 34 50 10
							239										
			8	SS	62		238										
							237										
236.8	END OF BOREHOLE SPOON REFUSAL		9	SS	100/12												3 40 49 8
7.7	Note: 1. Water level at a depth of 3.2 m below ground surface (Elev. 241.3 m) upon completion of drilling.																

SUD-MTO 001 1011910038 6M/GPJ GAL-MISS.GDT 25/10/13 DATA INPUT:

PROJECT		10-1191-0038				RECORD OF BOREHOLE No 6M-9				1 OF 1 METRIC							
W.P.		164-98-00		LOCATION		N 5500536.1; E 348478.8				ORIGINATED BY ID							
DIST		HWY 11		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY MT							
DATUM		Geodetic		DATE		July 3, 2013				CHECKED BY AB							
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									
244.2	GROUND SURFACE							20	40	60	80	100					
0.0 243.9 0.3	Topsoil (FILL) Black Moist		1	SS	7		244										0 4 48 48
	Clayey silt to silty clay, trace to some sand (FILL) Stiff Brown Moist to wet		2	SS	8		243										
			3	SS	9												
242.0					242												
2.2	SILT, some sand Compact Grey Moist to wet	4	SS	15													
241.2					241												
3.0	Gravely SILT, some sand, trace clay (TILL) Compact to very dense Grey Wet	5	SS	23											25 18 52 5		
		6	SS	106/0.25		240											
239.8 4.4	END OF BOREHOLE AUGER REFUSAL																
Note: 1. Water level at a depth of 3.5 m below ground surface (Elev. 240.7 m) upon completion of drilling.																	

SUD-MTO 001 1011910038 6M.GPJ GAL-MISS.GDT 25/10/13 DATA INPUT:



APPENDIX B

Laboratory Test Results



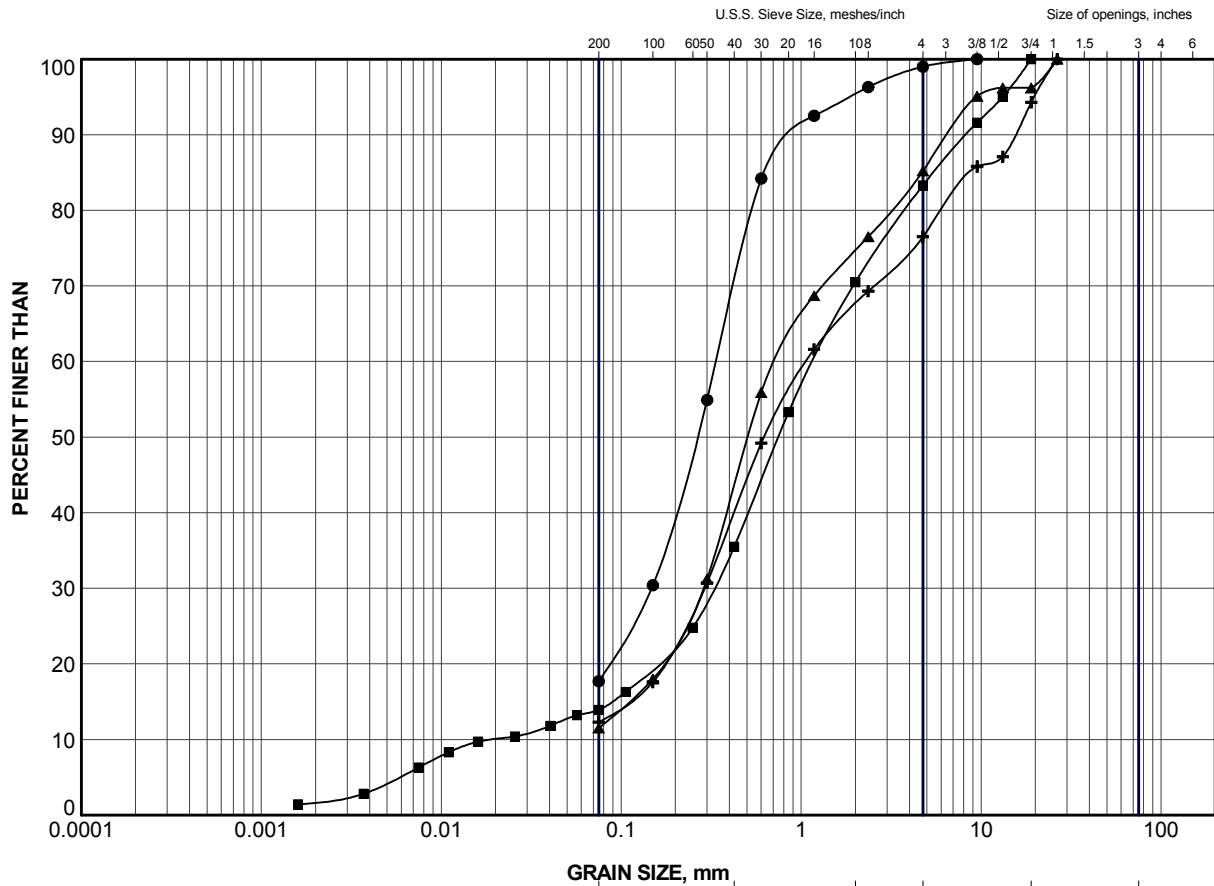
FOUNDATION REPORT HIGHWAY 11 SIX MILE CREEK CULVERT

Table B1 - Summary of Analytical Testing of Six Mile Creek Water Sample

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	9
Dissolved Sulphate	mg/L	1	Not Detected
Conductivity	mS/cm	0.001	0.130
Resistivity	ohm-cm	n/a	7700
pH	n/a	n/a	7.58

Notes: 1. Sample obtained on October 22, 2011.
2. Analytical testing carried out by Maxxam Analytics.


Checked by: AB

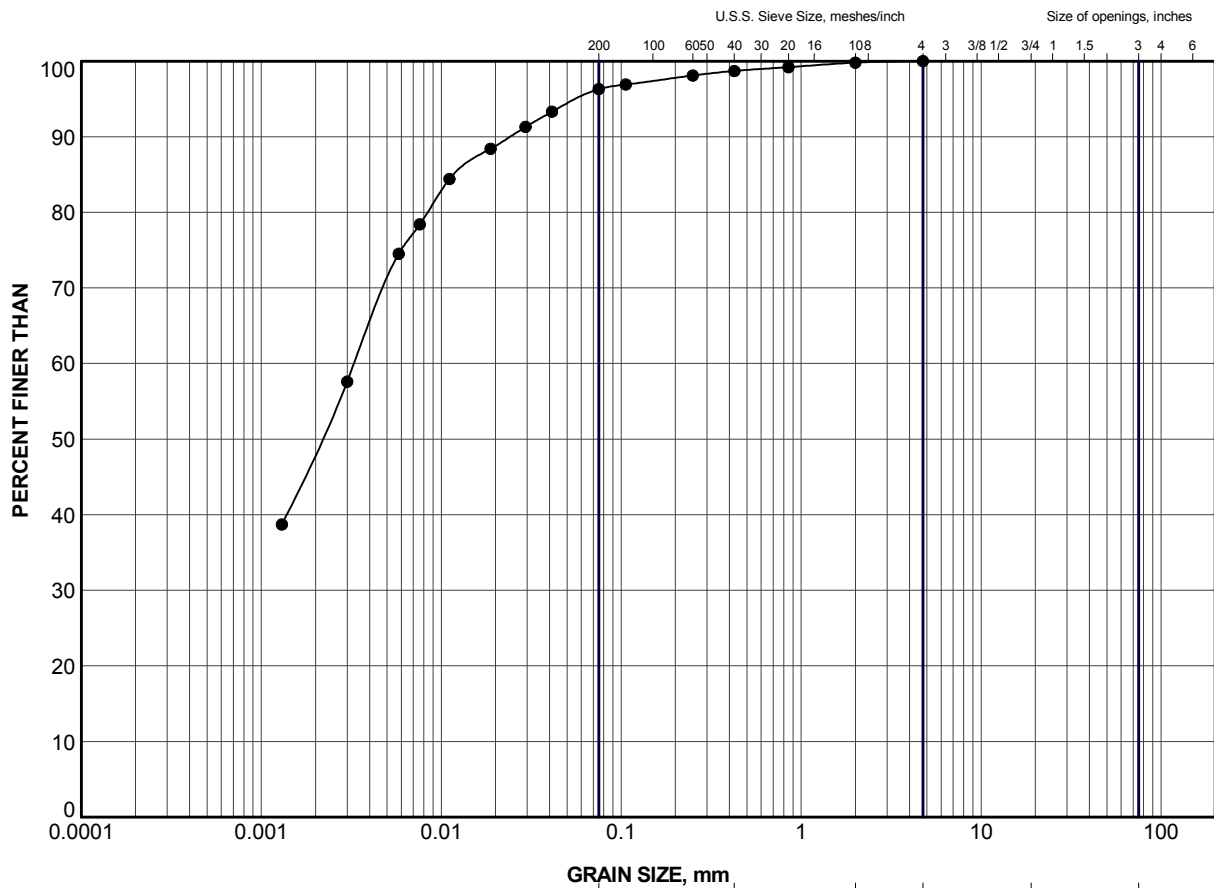


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	6M-2	4	242.1
■	6M-4	4	240.9
▲	6M-5	2	242.3
+	6M-6	2	244.0


PROJECT						HIGHWAY 11 SIX MILE CREEK CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION GRAVELLY SAND TO SAND (FILL)					
PROJECT No.			10-1191-0038			FILE No.			1011910038 6MILGPJ		
DRAWN	TB	Aug 2013	SCALE	N/A	REV.						
CHECK	AB	Aug 2013									
APPR		Aug 2013				FIGURE B1					
 Golder Associates SUDBURY, ONTARIO											

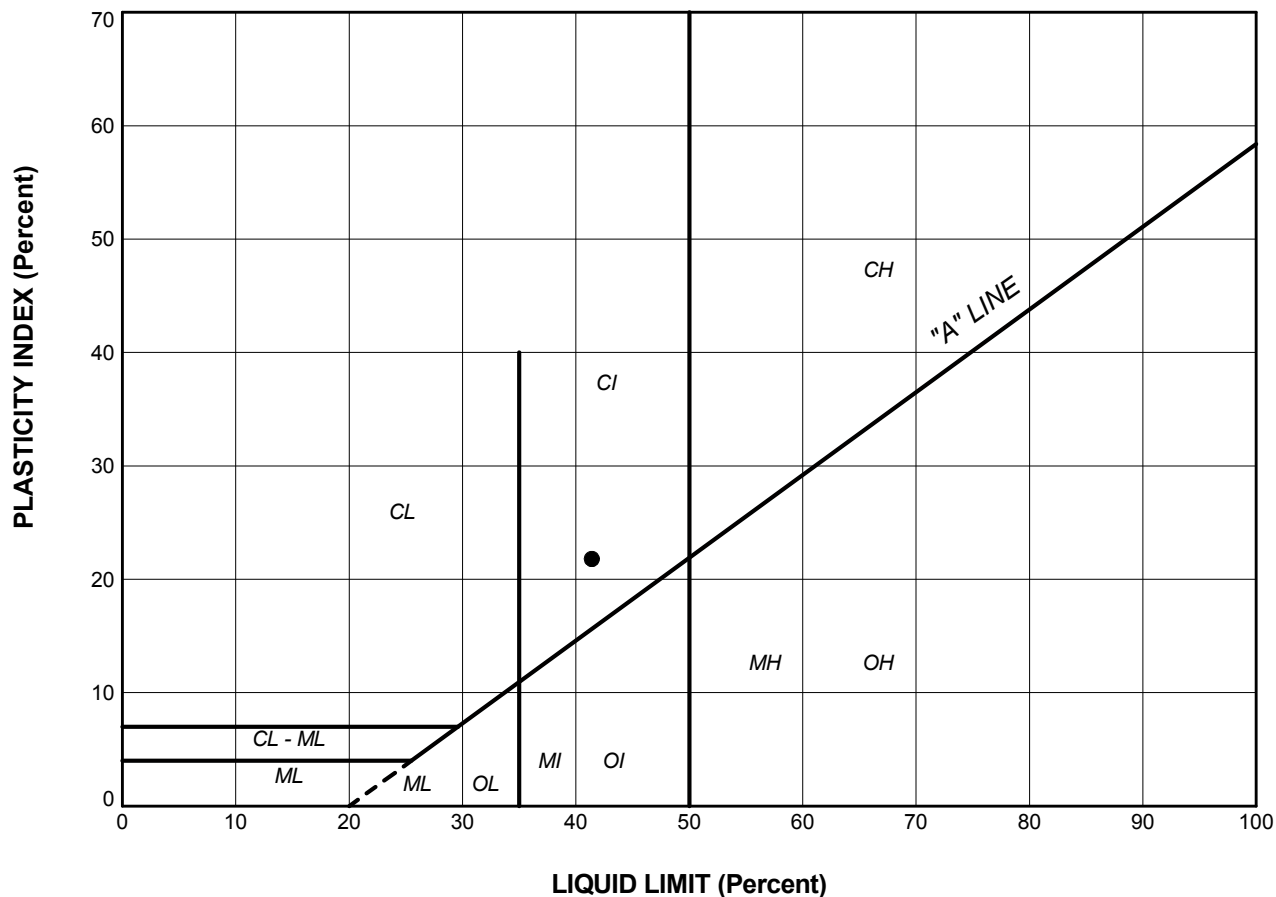


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

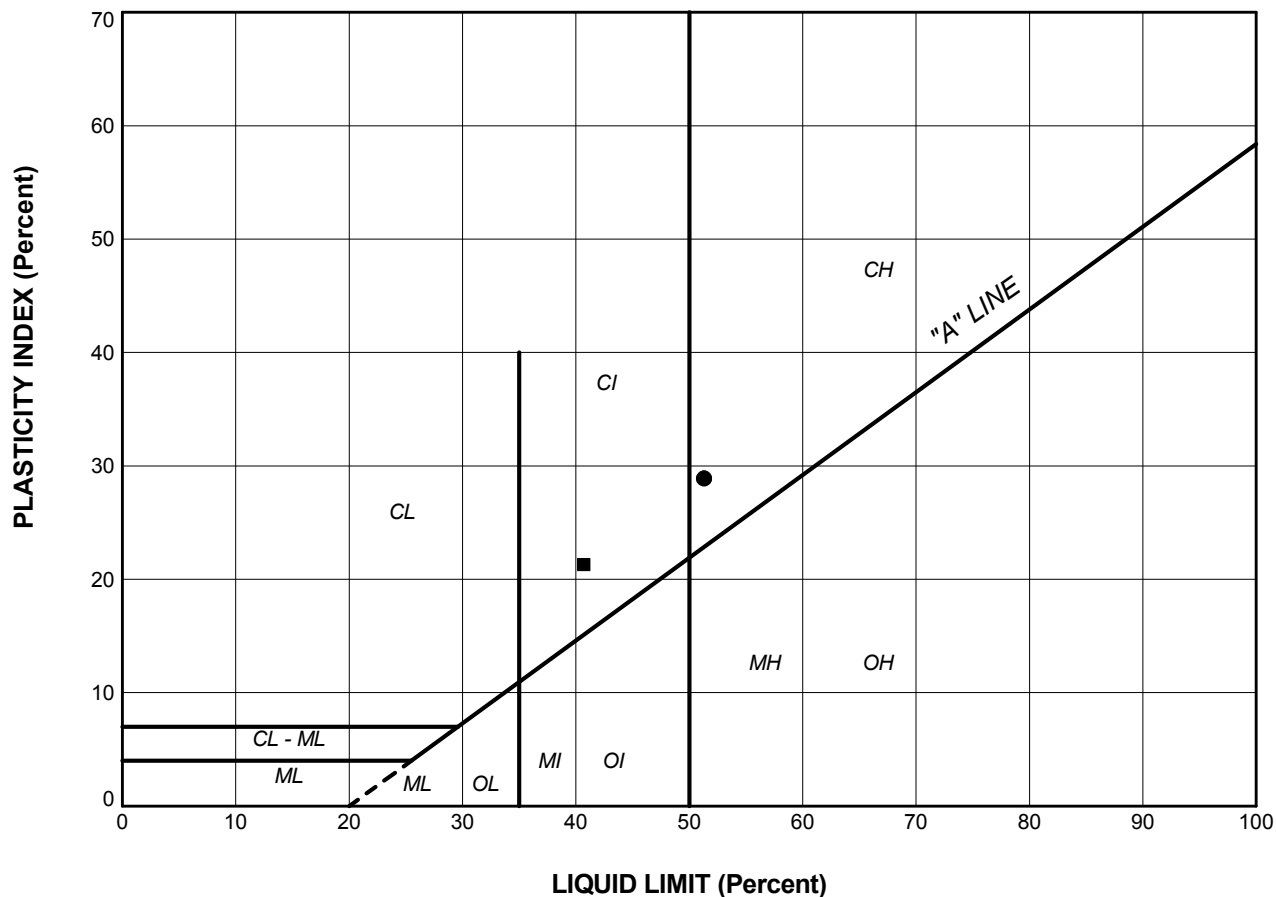
LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	6M-9	3	242.4

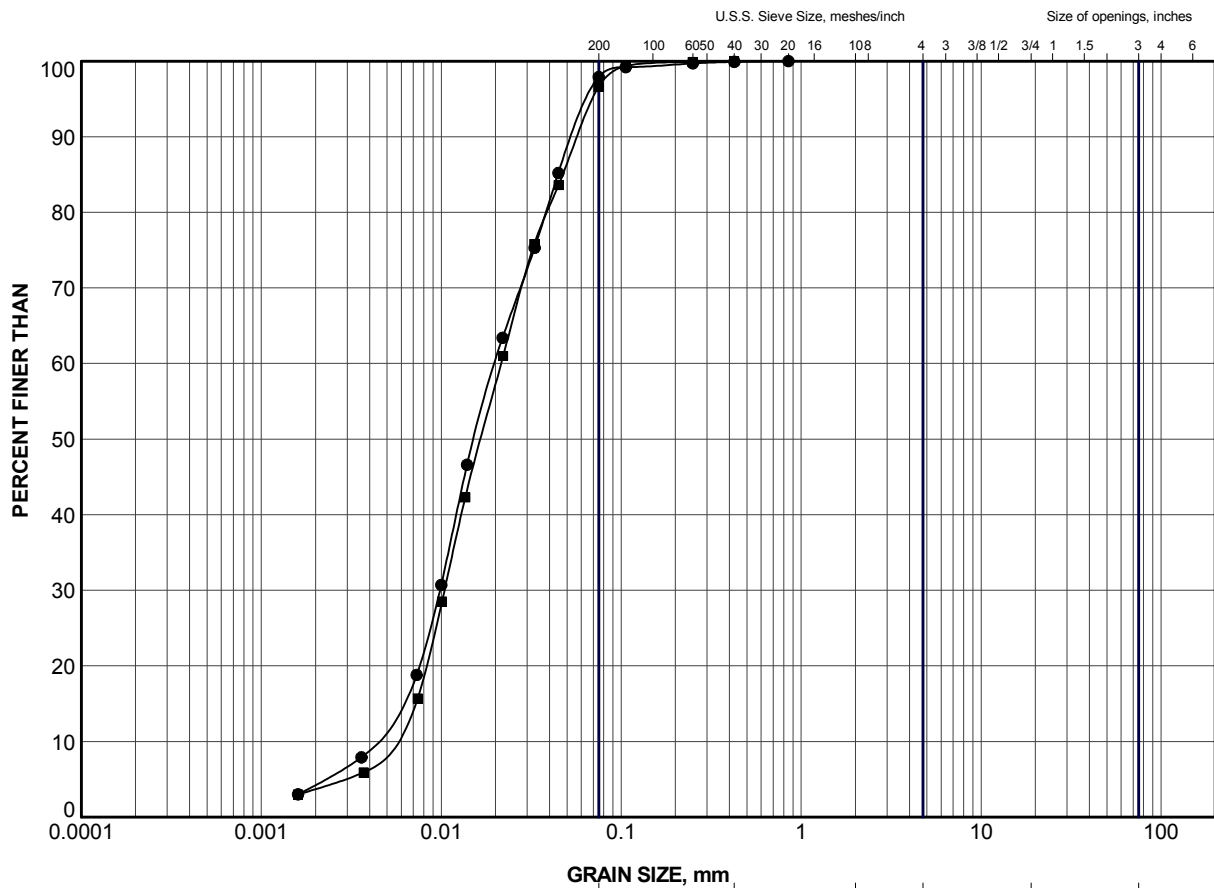
PROJECT					HIGHWAY 11 SIX MILE CREEK CULVERT				
TITLE					GRAIN SIZE DISTRIBUTION SILTY CLAY (FILL)				
PROJECT No.		10-1191-0038		FILE No.		1011910038 6M/GPJ			
DRAWN	TB	Aug 2013		SCALE	N/A	REV.			
CHECK	AB	Aug 2013							
APPR		Aug 2013							
 Golder Associates SUDBURY, ONTARIO				FIGURE B2					



PROJECT					
HIGHWAY 11 SIX MILE CREEK CULVERT					
TITLE					
PLASTICITY CHART SILTY CLAY (FILL)					
PROJECT No. 10-1191-0038			FILE No. 1011910038 6MLGPJ		
DRAWN	TB	Aug 2013	SCALE	N/A	REV.
CHECK	AB	Aug 2013	FIGURE B3		
APPR		Aug 2013			




PROJECT		HIGHWAY 11 SIX MILE CREEK CULVERT						
TITLE		PLASTICITY CHART SILTY CLAY TO CLAY						
 Golder Associates SUDBURY ONTARIO	PROJECT No.		10-1191-0038		FILE No.		1011910038 6MLGPJ	
	DRAWN	TB	Aug 2013		SCALE	N/A	REV.	
	CHECK	AB	Aug 2013		FIGURE B4			
	APPR		Aug 2013					

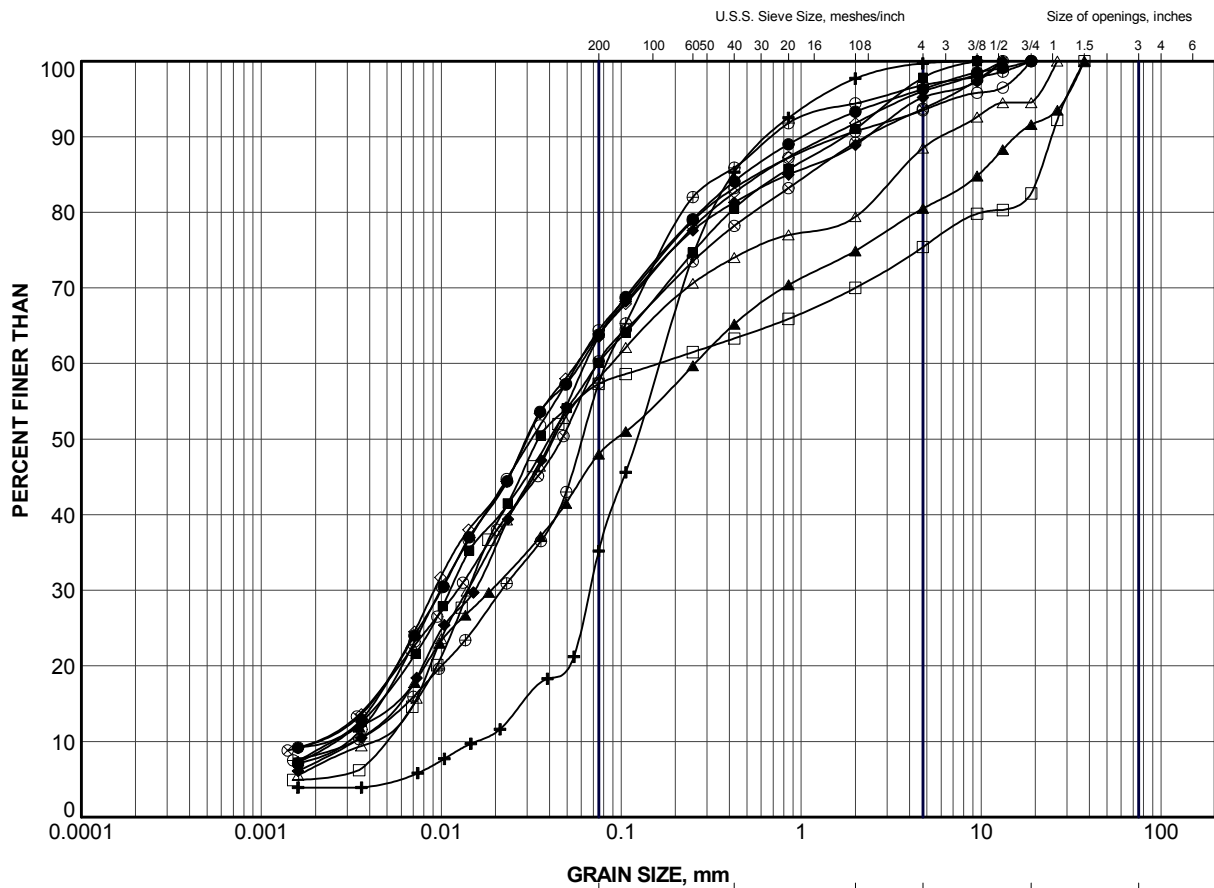


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	6M-6	6	241.0
■	6M-7	6	241.4

PROJECT						HIGHWAY 11 SIX MILE CREEK CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.			10-1191-0038			FILE No.			1011910038 6MILGPJ		
DRAWN	TB	Aug 2013	SCALE	N/A	REV.						
CHECK	AB	Aug 2013				FIGURE B5					
APPR		Aug 2013									
 Golder Associates SUDBURY, ONTARIO											



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	6M-1	4	239.3
■	6M-2	8	238.6
▲	6M-2	9	236.8
+	6M-2	10	235.3
◆	6M-3	4	239.9
◇	6M-4a	4	239.1
○	6M-5	6	239.3
△	6M-7	8	239.1
⊗	6M-8	7	239.6
⊕	6M-8	9	236.8
□	6M-9	5	240.9

PROJECT

HIGHWAY 11
SIX MILE CREEK CULVERT

TITLE

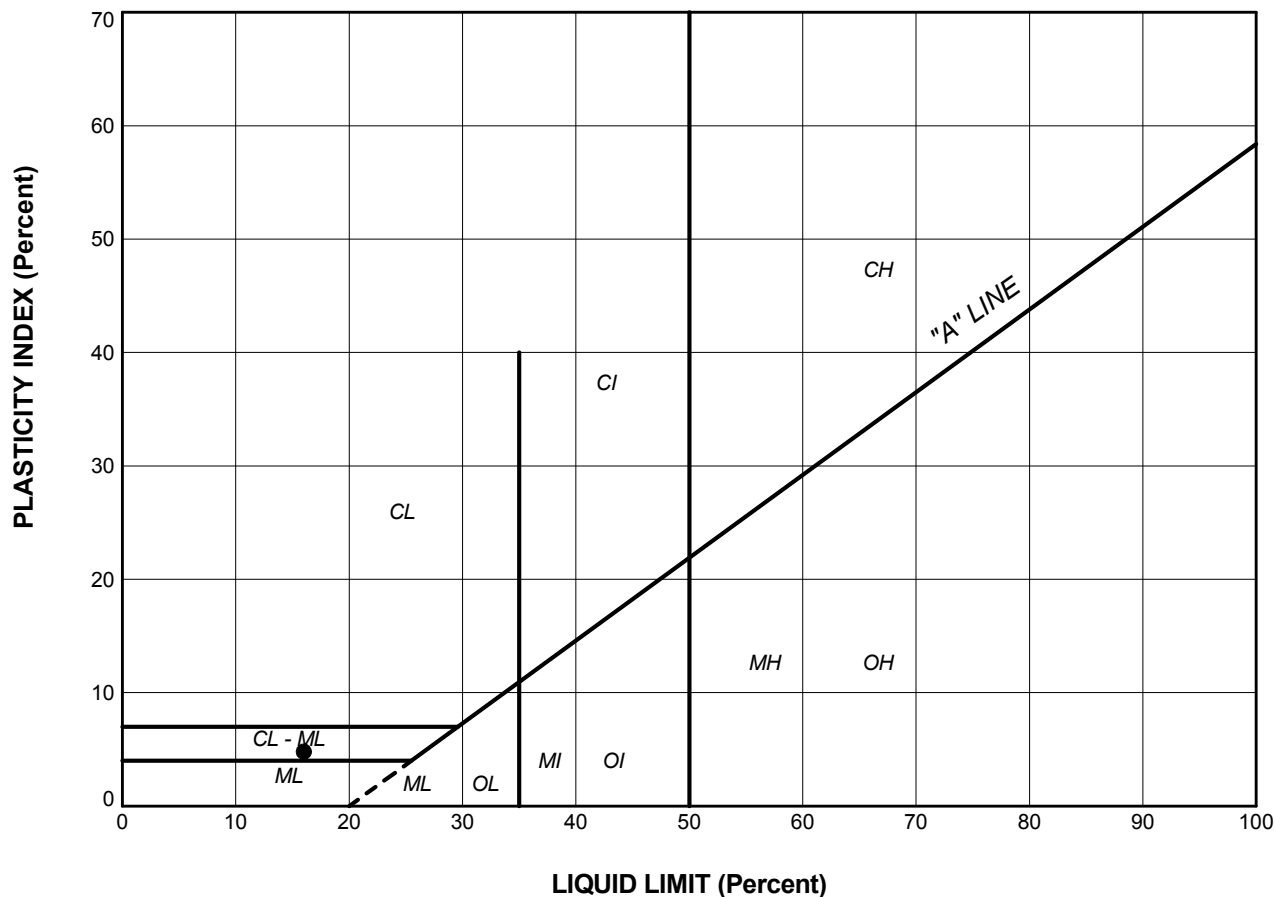
GRAIN SIZE DISTRIBUTION
SAND AND SILT (TILL)




Golder Associates
SUDBURY, ONTARIO

PROJECT No.	10-1191-0038	FILE No.	1011910038 6MILGPJ
DRAWN	TB	Aug 2013	SCALE N/A
CHECK	AB	Aug 2013	REV.
APPR		Aug 2013	

FIGURE B6



PROJECT		HIGHWAY 11 SIX MILE CREEK CULVERT					
TITLE PLASTICITY CHART SAND AND SILT (TILL)							
 Golder Associates SLIDBURY ONTARIO	PROJECT No.		10-1191-0038		FILE No.	1011910038 6MLGPJ	
	DRAWN	TB	Aug 2013		SCALE	N/A	REV.
	CHECK	AB	Aug 2013		FIGURE B7		
	APPR		Aug 2013				





APPENDIX C

Non-Standard Special Provisions

GROUNDWATER CONTROL - Item No.

Non-Standard Special Provision

Foundations for the new Six Mile Creek culvert will require excavations to extend below the groundwater level at the site. Cohesionless soils (silty, sandy gravelly) that are present below the groundwater table will slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate dewatering system for the culvert site to enable construction in dry conditions, and prevent disturbance to the founding soils.

Basis of Payment

Payment at the lump sum contract price for this Tender Item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

WORKING SLAB - Item No.

Non-Standard Special Provision

Scope of Work

This Special Provision covers the requirements for the supply and placement of a concrete working slab for the Six Mile Creek culvert. The purpose of the working slab is to protect the subgrade from disturbance and loosening due to construction traffic and ponded water and also to provide a level working surface.

Construction

Protection of Founding Soil

- Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as per the contract drawings and documents. The concrete shall have a minimum 28 day compressive strength of 20 MPa.

Unwatering of the excavation for the culvert construction may be required, including the construction of the working slab.

Basis of Payment

Payment at the Contract Price for the above tender item includes full compensation for all labour, equipment and material to do the required work.

END OF SECTION

OBSTRUCTIONS

Non-Standard Special Provision

As part of the work for the culvert installation, the Contactor shall be alerted to the presence of cobbles and boulders within the sand and silt till.

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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