



**Foundation Investigation and  
Design Report**

Mariposa Brook Culvert Replacement  
Site No. 32-161/C  
Highway 7  
Station 13+322 Township of Mariposa

G.W.P. 4066-10-00

Geocres No. 31D-534

Project No. 165000795

March 2012

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**FOUNDATION INVESTIGATION REPORT**

For

G.W.P 4066-10-00

Mariposa Brook Culvert Replacement

Station 13+322

Site No. 32-161/C

Highway 7, Township of Mariposa

## **1.0 Introduction**

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Stantec Consulting Ltd. (Stantec) was retained by the Ministry of Transportation, Ontario (MTO) to undertake the detailed design for the proposed replacement of the Mariposa Brook Structural Culvert. This culvert is located on Highway 7 in the Township of Mariposa.

This Foundation Investigation Report has been prepared specifically and solely for the proposed replacement of the Mariposa Brook Culvert site.

Project Number: G.W.P.: 4066-10-00

Project Location: Highway 7, Mariposa Brook Culvert Replacement, Township of Mariposa

The work was carried out under MTO Agreement Number 4010-E-0026 with Stantec Consulting Ltd., the Detailed Design Consultant for this project.

## **2.0 Site Description and Geology**

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### Site Location

The site location is shown on the Key Plan inset to Drawing No. 1, provided in Appendix A. The existing Mariposa Brook Culvert crosses beneath Highway 7 at Station 13+322, approximately 260 m east of County Road 46.

### General Site Description

General site photographs showing the roadway cross-section and culvert are provided in Appendix A.

Highway 7 is oriented in the east-west direction at the project location with chainage increasing from west to east. In the vicinity of the culvert, Highway 7 has a two lane rural cross-section with approximately 3 m wide gravel shoulders.

The culvert conveys flow from Mariposa Brook which flows north at the project site, eventually draining into Sturgeon Lake. Drainage of the highway is provided via ditches leading to the brook.

At the time of field investigation for this assignment, the area on either side of the Highway 7 embankment was covered with high grass (see Photo Nos. 1 and 3).

The horizontal alignment of Highway 7 at the project site is within a tangent section and includes guardrails on both sides. The vertical alignment is within a slight sag in the profile. No signs of pavement distresses associated with the underlying culvert were observed at the site.

At both the inlet and the outlet, the Highway 7 shoulder is approximately 1.9 m higher than the culvert invert and the embankment has 2H:1V side slopes.

Limited scour protection was observed below the water surface at the upstream end. Scour protection was not observed at the downstream end. Although some erosion of the banks was observed, no signs of scour or erosion adjacent to the foundations were noted.

#### Existing Culvert

The approximate alignment of the existing culvert is shown on Drawing No. 1 in Appendix A. The existing culvert is an open footing concrete culvert. The culvert has an approximate span of 3.1 m, a height of 1.4 m, and a length of 25 m. The water level in culvert was noted at approximately 50% of the culvert height, the water level is shown in Photos 1 through 4 in Appendix A. Flow in the culvert is from south to north.

This culvert consists of four sections with the top slab of the original sections supported by steel beams that are braced with timber beams and supports. The inlet and outlet sections are also showing signs of deterioration and weathering (see Photo 4). This culvert has been identified as requiring replacement.

A Stone-filled gabion wall is present on the south end of the culvert. The gabion wall is approximately 0.5 m high and is located on top of the culvert. The gabion wall is shown on Photo No. 2.

#### Physiographic Description

The site is located within a physiographic region known as the Peterborough Drumlin Field (Chapman and Putnam, 1984). The drumlins in this region are generally composed of highly calcareous till with local differences. In Mariposa Township, bedrock is generally shallow with the till containing great quantities of angular limestone rubble. In some areas of the region, the till contains approximately 0.6 to 0.9 m diameter boulders, especially near the surface.

The underlying bedrock in the region is limestone of the Lindsay and Verulam Formations. The terrain is generally rolling with a series of deep valleys leading northward which break the continuity of the till plain.

### **3.0 Investigation Procedures**

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#### **3.1 FIELD INVESTIGATION**

Prior to carrying out the investigation, Stantec made arrangements to obtain utility clearances for the proposed borehole locations.

A field investigation with four boreholes was carried out between September 22 and 28, 2011. The boreholes were designated BH11-1 through BH11-4 and their locations are shown on the Borehole Location Plan, Drawing No.1 in Appendix A.

Boreholes BH11-2 and BH11-3 were advanced through the roadway platform near the pavement edges with a truck mount CME 75 drill rig with solid stem augers and soil and bedrock sampling equipment. Boreholes BH11-1 and BH11-4 were advanced near the culvert inlet and outlet using portable drilling equipment with casing, a split-spoon sampler, and a full-weight SPT hammer.

The subsurface stratigraphy encountered in each borehole was recorded in the field. Split spoon samples were collected at regularly spaced intervals (typically every 760 mm) during the course of Standard Penetration Testing (ASTM, 1999). In addition, one Shelby tube sample was recovered from Borehole BH11-3. All samples recovered were returned to Stantec's Ottawa laboratory for detailed classification and testing. Boreholes were backfilled with auger cuttings mixed with bentonite and road holes were topped with cold patch asphalt.

A Groundwater monitoring well was installed in Borehole BH11-1 near the culvert outlet. The monitoring well consisted of 50 mm diameter PVC pipe with perforations along the lower 3 m length.

#### **3.2 LOCATION AND ELEVATION SURVEY**

Elevation and location survey of the borehole locations was performed by Stantec personnel. The ground surface elevation at each borehole location was surveyed with reference to a Geodetic Benchmark provided by MTO. The bench mark consisted of a cut cross on northwest corner of the existing culvert which has a geodetic elevation of 276.114 m.

Table 3.1 summarizes the location and elevation information for the boreholes included in this report.

**Table 3.1: Borehole Information Summary**

	Boreholes			
	BH11-1	BH11-2	BH11-3	BH11-4
MTM Zone 10 Coordinates				
Northing	4908788	4908778	4908766	4908759
Easting	348716	348724	348710	348724
Station	13+327	13+331	13+314	13+325
Offset (m)	4.0 Rt	4.0 Lt	15.5 Lt	14.5 Rt
Ground Surface Elevation, m	275.4	277.8	277.8	275.1
Total Depth Drilled, m	5.5	7.9	13.1	5.2
End of Borehole Elevation, m	269.9	269.9	264.7	269.9
Number of Soil Samples	10	11	17	9

Note: Stations are measured along Hwy 7 Centerline. Offsets are measured with respect to Centerline of Hwy 7.

### 3.3 LABORATORY TESTING

All samples were subjected to a detailed visual examination by a Geotechnical Engineer. The following geotechnical laboratory tests were carried out:

<u>Test</u>	<u>No. of Tests</u>
Moisture Content	40
Grain Size Analysis	10
Atterberg Limits	1
Organic Matter Content	4

In addition, two samples were tested for pH, soluble sulphate content, chloride content and resistivity.

Samples remaining after testing will be stored for one year after issuance of the final report. After the storage period, the samples will be discarded.

## 4.0 Subsurface Conditions

### 4.1 GENERAL

The subsurface conditions observed in the boreholes are presented in detail on the Borehole Records provided in Appendix B. An explanation of the symbols and terms used to describe the Borehole Records is also provided.

In general, the subsurface stratigraphy consisted of a pavement structure over an embankment fill over variable layers of organic silt, cohesive clay till, and non-cohesive till.

A borehole location plan and a stratigraphic section of the soils encountered within the boreholes are provided on Drawing No. 1 in Appendix A.

## **4.2 OVERBURDEN**

### **4.2.1 Pavement Structure**

The top of road elevation at both Boreholes BH 11-2 and BH 11-3 was 277.8 m.

The pavement structure consisted of the following:

HM Asphalt	180 to 200 mm
Base/Sub Base Gravel	870 to 1030 mm

The base/sub base material consisted of a brown gravelly sand.

It is noted that a buried layer of asphalt approximately 50 mm thick was encountered in BH11-3 approximately 100 mm beneath the road surface.

The moisture content testing on base/sub base samples yielded results ranging from 4 to 5%.

### **4.2.2 Embankment Fill**

The embankment fill was encountered in Boreholes BH11-2 and BH11-3. The fill, including the pavement structure, was approximately 2.1 and 3.1 m thick and extended to bottom elevation of approximately 275.7 to 274.8 m.

The fill generally consisted of variable amounts of sand, gravel and silt. Trace quantities of organic material and brick pieces were observed in Borehole BH11-2.

The Standard Penetration Test (SPT) N-values observed within the embankment fill ranged from 6 to 9 blows per 0.3 m suggesting a loose state of compactness.

Moisture content and grain size distribution tests carried out on representative samples of the embankment fill yielded the following results:

Gravel:	17 and 26%
Sand:	49 and 57%
Fines (silt & clay):	25 and 26%
Moisture content:	4 to 24%

The embankment fill material is classified as a silty sand to a silty sand with gravel (SM). The grain size distribution curves for the fill layer are provided on Figure 1 in Appendix C.

### **4.2.3 Topsoil and Organic Silt**

Approximately 100 mm thick topsoil was encountered in BH11-4.

A 900 mm thick organic silt layer was encountered at ground surface in BH11-1, extending to a bottom elevation of 274.5 m.



A 2.6 m thick organic silt layer was encountered beneath the roadway embankment in BH 11-3, extending to a bottom elevation of 273.1 m.

The organic silt is light brown, slightly fibrous, relatively dry and in a compressed state.

SPT N-values of 3 to 4 were measured within the organic silt layer.

Three moisture content tests and two organic matter content tests carried out on representative samples from this layer yielded the following results:

Moisture Content:	30 to 99%
Organic Matter:	6.7 to 17.1%

#### **4.2.4 Clayey Silt Till**

A cohesive clayey silt till layer, containing various amounts of sand, was encountered in Boreholes BH11-1, BH11-2 and BH11-4. This layer was 0.6 to 2.3 m thick and extended to bottom elevations of 274.0 to 272.7 m.

The SPT N-values for this deposit ranged from 3 to 55 suggesting a firm to hard consistency.

Moisture content and grain size distribution tests carried out on representative samples of the clay deposit yielded the following results:

Gravel:	0%
Sand:	27 and 32%
Fines (silt & clay):	68 and 73%
Moisture Content:	16 to 24%

An Atterberg limits test carried out on a sample of this layer indicated a low plastic soil. This layer is classified as clayey silt till (CL) with various amounts of sand. The grain size distribution curves for the material of this layer are provided on Figure 2 in Appendix C.

#### **4.2.5 Non-cohesive Glacial Till**

A non-cohesive glacial till deposit was encountered beneath the clayey silt till at BH11-1, BH11-2 and BH11-4, and directly beneath organic silt in Borehole BH11-3. In all boreholes, drilling was terminated within this deposit, the actual thickness was not confirmed. The penetrated thickness of the till ranged from 2.8 to 8.4 m, corresponding to bottom of borehole elevations ranging from 264.7 m to 269.9 m.

Frequent cobbles and boulders were encountered in this layer. In BH11-3, NQ-size coring was carried out to advance through a layer of boulders.

The SPT N-values for this deposit ranged from 16 to greater than 100 per 0.3 m suggesting a compact to very dense state.

Moisture content and grain size distribution tests carried out on representative samples of the till deposit yielded the following results:

Gravel:	17 to 34%
Sand:	37 to 70%
Fines (silt & clay):	13 to 43%
Moisture Content:	4 to 16%

The non-cohesive till deposit is classified as silty sand with gravel (SM). Representative grain size distribution plots for the material of this layer are indicated on Figure 3 in Appendix C.

### 4.3 CHEMICAL TEST RESULTS

One soil sample from each till layer was tested for pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are provided in Table 4.1.

**Table 4.1: Results of Chemical Analysis**

Borehole No	Sample No.	Depth (m)	pH	Chloride (µg/g)	Sulphate (µg/g)	Resistivity (Ohm-m)
BH11-2	SS-6	3.8 to 4.4	7.9	397	52	19.4
BH11-4	SS-4	1.8 to 2.4	7.7	17	38	67.3

### 4.4 GROUNDWATER

The depth to groundwater was inferred in all four boreholes at the time of drilling between September 22 and September 28, 2011. A groundwater monitoring well was installed in BH11-1; the depth to groundwater was measured in a standpipe well on September 28, 2011. The measured and inferred (i.e., at the time of drilling) groundwater levels are summarized in Table 4.2.

**Table 4.2: Groundwater Levels**

Table 4.2: Groundwater Levels			
Borehole No	Ground Surface Elevation (m)	Groundwater	
		Depth (m)	Elevation (m)
Measured on September 28, 2011			
BH11-1	275.4	2.0	273.4
Inferred (time of drilling)			
BH11-2	277.8	4.1	273.7
BH11-3	277.8	4.9	272.9
BH11-4	275.1	0.6	274.5

Fluctuations in the groundwater and culvert water level due to seasonal variations or in response to a particular precipitation event should be anticipated.

## **5.0 Miscellaneous**

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The field work was carried out under the supervision of Messrs. Dan Stunden and Jeff Forrester, Geotechnical Engineering Technologists, under the direction of Mr. Chris McGrath, P.Eng.

MultiVIEW Locates Inc. of Mississauga, Ontario, carried out the private and public utility locates for the boreholes.

The CME 75 drilling equipment was supplied and operated by Strong Soil Search Inc. of Claremont, Ontario. The portable drilling equipment was supplied and operated by OGS Inc. of Almonte, Ontario.

Elevation and approximate location survey of the borehole locations was carried out by Stantec personnel.

Geotechnical laboratory testing was carried out at Stantec's Ottawa laboratory. Chemical testing for pH, soluble sulphate and chloride content, and resistivity was carried out by Paracel Laboratories of Ottawa.

This report was prepared by Simon Gudina and Chris McGrath, and reviewed by Raymond Haché.

## 6.0 Closure

A subsurface investigation is a limited sampling of a site. The subsurface conditions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information.

Respectfully Submitted;

**STANTEC CONSULTING LTD.**



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**FOUNDATION DESIGN REPORT**

For

G.W.P 4066-10-00

Mariposa Brook Culvert Replacement

Station 13+322

Site No. 32-161/C

Highway 7, Township of Mariposa

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**7.0 Discussion and Engineering Recommendations**

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**7.1 GENERAL**Project Purpose/Justification

The Mariposa Brook culvert crosses beneath Highway 7. It is an open footing culvert with a span of 3.1 m and a length of 25 m. This culvert consists of four sections with the top slab of the original sections supported by steel beams that are braced with timber beams and supports. This culvert has been identified for replacement.

Performance of Existing Foundations

The outside sections of the culvert were observed to be generally in a fair condition. Spalling of the concrete was noted at the culvert outlet and is shown on Photo No. 4 in Appendix A. The water level in culvert was noted at approximately 50% of the culvert height, the water level is shown in Photos 1 through 4. The gabion wall located on the top of the inlet was observed to be in a fair condition; slight bulging of the gabion was noted.

No contract documents or foundation investigation and design reports were reviewed for the existing culvert section; however, it is understood that the footings are founded at approximate elevation 273.5 m. Based on the borehole data, it appears likely that the culvert is supported on strip footings bearing on the till deposits ranging from a clayey silt to a silty sand with gravel at the footing level.

Visual inspection of the culvert inlet and outlet sections at the time of the investigation did not reveal any indications of significant settlement or cracking. The pavement surface at the location of the culvert was generally in a fair condition, no significant dips or bumps were observed.

Proposed Structures

It is understood that the replacement culvert is proposed to be a rigid frame box culvert with a concrete cut-off wall at the inlet and outlet. The new culvert design is anticipated to have a span of 3.0 m, a length of 24.4 m, and a height of 1.8 m.

Key elevations associated with the proposed culvert replacement are as follows:

Pavement Elevation: 277.93 m (approximately near C/L of Highway 7)

Invert Elevation: 274.13 m

Streambed Elevation: 274.43 m

Water Elevation: 274.6 m July 2010

25 Year Water Level: 276.20 m

Founding Elevation: 273.5 m existing culvert (assumed)  
 274.0 m proposed box culvert replacement  
 273.0 m proposed concrete cut-off wall

### Construction Staging & Detours

It is understood that the culvert replacement work is to be carried out without the use of a traffic detour.

A two stage construction approach is proposed in order to keep one lane operational to traffic at all times. Highway traffic is to be controlled using temporary traffic signals.

## **7.2 GEOTECHNICAL DESIGN PARAMETERS**

The soil conditions at this site generally consist of a pavement structure over an embankment fill over layers of organic silt, cohesive clay till, and non-cohesive till.

For design purposes, the following soils profile will be used:

**Table 7.1: Geotechnical Model**

Elevation (m)		Soil Type	Design Properties
From	To		
277.9	274.8	FILL: Silty Sand (SM) with gravel, loose to compact	Total Unit Weight = 20.0 kN/m <sup>3</sup> Friction Angle, $\phi = 32^\circ$ $E' = 35$ MPa
274.8	274.0	Cohesive Till: Clayey silt with sand (CL), firm to stiff	Total Unit Weight = 19 kN/m <sup>3</sup> Friction Angle, $\phi' = 28^\circ$ $E' = 10$ MPa $C = 100$ kPa $C' = 8$ kPa
274.0	<264.7	Non-Cohesive Till: Silty sand (SM) with gravel, frequent cobbles and boulders, compact to very dense	Total Unit Weight = 20 kN/m <sup>3</sup> Friction Angle, $\phi = 35^\circ$ $E' = 50$ MPa

- Note:
- 1) A design water level elevation of 274.6 m was assumed.
  - 2) The organic silt is not included in the geotechnical model since it is recommended to be removed from beneath the culvert foundations.
  - 3) The cohesive till at BH 11-4 extends down to elevation 272.7 m, however, below elevation 274.0 m SPT N-values of 31 and 55 were observed indicating the till to be hard. Representing this portion of the cohesive till using the non-cohesive till parameters is considered to be conservative.

### **7.3 FROST PENETRATION**

The design frost penetration depth for foundations,  $f$ , at the site is 1.6 m based on OPSD 3090.101.

Spread footings should be provided with 1.6 m of earth cover or equivalent insulation for frost protection; this would apply to an open footing rigid frame culvert option as well as retaining walls associated with both open footing and box culvert options. Frost protection is not required for the box culvert.

The depth of frost penetration should also be used in the design of frost tapers for the culvert backfill.

### **7.4 SEISMIC DESIGN CONSIDERATIONS**

#### **7.4.1 Soil Profile Type**

It is recommended that a Soil Profile I as defined in CHBDC (CHBDC, 2006) Section 4.4.6 be used in the seismic design of this site.

#### **7.4.2 Zonal Acceleration Ratio**

Table A3.1.1 of the CHBDC indicates that the Zonal Acceleration Ratio (ZAR) for the Township of Mariposa (Peterborough, Ontario) is 0.05.

Even though it is not likely very significant, seismically induced lateral earth pressures should be considered for this project with a Zonal Acceleration Ratio of 0.05.

#### **7.4.3 Liquefaction Potential**

Liquefaction of the foundation soils is not a concern for this project due to the compact to very dense soil conditions and the relatively low Zonal Acceleration Ratio.

## 7.5 STRUCTURE/FOUNDATION OPTIONS

The following optional structure types are being considered for the culvert replacement on this project:

- Rigid Frame Box Culvert (precast and cast in place)
- Rigid Frame Open Footing Culvert

The soil conditions at this site are suitable to support these culvert options on shallow foundations.

It is noted that regardless of the option selected, the existing 25 m long culvert is to be removed. This will require excavation down to the existing founding elevation of 273.5 m for both options. This suggests the need for groundwater control as detailed in Section 8.3. The existing footings will need to be removed; otherwise, they will be in conflict with the proposed box culvert. The proposed box culvert founding level is 500 mm above the existing culvert footing founding levels.

Given the length of the proposed culvert and that the 25 year high water level is close to the culvert obvert, it is anticipated that retaining walls will be incorporated in the design to both support the embankment slope and to protect the culvert backfill from scour. Retaining walls will require foundations founded below the frost penetration level.

Table 7.2 compares the culvert structure options considered from a foundations design and constructability perspective for the replacement options for the original culvert.

**Table 7.2: Comparison of the Replacement Options for Robbins Municipal Drain Culvert**

Option	Advantages	Disadvantages	Relative Cost	Risk/Consequences
Precast Rigid Frame Box	<ul style="list-style-type: none"> <li>• Shorter construction period</li> <li>• Shorter traffic management period</li> <li>• Reduced water control period</li> <li>• Reduced environmental impact</li> </ul>	<ul style="list-style-type: none"> <li>• needs heavy lifting equipment</li> </ul>	Medium	
Cast-in-Place Rigid Frame Box	<ul style="list-style-type: none"> <li>• Suitable if site is not conducive to heavy equipment for installing precast sections</li> </ul>	<ul style="list-style-type: none"> <li>• slower construction process</li> <li>• greater unwatering volume required</li> </ul>	Low	<ul style="list-style-type: none"> <li>• higher risk of unwatering related issues</li> </ul>
Rigid Frame Open Footing	<ul style="list-style-type: none"> <li>• maintains the natural streambed</li> </ul>	<ul style="list-style-type: none"> <li>• slower construction process</li> <li>• greater unwatering volume required</li> <li>• deeper founding required for frost protection of footings</li> </ul>	High	<ul style="list-style-type: none"> <li>• higher risk of unwatering related issues due to deeper excavation</li> </ul>

The use of trenchless construction techniques were also considered. Due to the large span of the culvert, trenchless construction is not appropriate.



The foundation soils at the site are generally good and can provide adequate support for all options listed in Table 7.2 above. Precast concrete box culverts would be the preferred option due to the anticipated reduced construction period.

The following design recommendations are provided based on the foundation options discussed above.

## 7.6 FOUNDATION RECOMMENDATIONS

### 7.6.1 Geotechnical Resistances

The following geotechnical resistances are provided for the possible options described above. It is recommended that the replacement culvert be founded on the native till deposit or on compacted OPSS Granular A placed on the native till. The footing of the existing culvert will require removal. The layer of organic silt should be entirely removed from beneath the footprint of the culvert. The excavations should be backfilled with structural fill consisting of compacted OPSS Granular A. For the case of a pre-cast rigid frame box culvert, a 75 mm layer of uncompacted OPSS Granular A should be placed beneath the culvert for bedding purposes.

The edges of the pad should extend at least 1 m horizontally away from the footing in all directions. Where the granular also forms the foreslope it should be constructed no steeper than 2H:1V. A sketch illustrating the Granular pad with the required distances and slopes is included in Appendix F.

The geotechnical resistances provided in Table 7.3 may be used in the design provided the footings are placed on undisturbed native till or granular bedding over undisturbed native till as described above.

**Table 7.3: Recommended Footing Design Parameters**

Founding Element	Founding Elev. (m)	Footing Size (m x m)		Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Reaction at SLS (kPa)
		Width (m)	Length (m)		
Rigid Frame Box Culvert on Till	273.9	2.5	25	850	350
		3.0	25	900	350
		3.5	25	950	350
		4.0	25	1000	350
Rigid Frame Open Footing on Till (footing soil cover for frost = 1.6 m)	272.8	0.75	25	375	350
		1.0	25	400	350
		1.5	25	425	350
Retaining Wall Foundations on Till	272.8	0.75	25	375	350
		1.0	25	400	350
		1.5	25	425	350

Notes:

- (1) In accordance with Section 6.6.1 of the CHBDC, a resistance factor of 0.5 has been applied to calculate the factored geotechnical resistance at ULS.

- (2) The geotechnical reaction at SLS corresponds to a maximum settlement of 25 mm.
- (3) In the case of the rigid frame box culvert, the very high geotechnical resistances at ULS reflect the large width of the theoretical footing and the overall depth of embedment measured from the top of road. For the box culvert option the geotechnical reaction at SLS will govern the design.

It is noted that there is a potential for organic silt being within the footprint of the new culvert. This material, if encountered, will need to be removed entirely. An NSSP is provided in Appendix E outlining the removal of the organic silt.

### **7.6.2 Sliding Resistance**

The unfactored horizontal resistance of spread footings may be calculated using the following unfactored coefficients of friction:

0.55 between OPSS Granular A and pre-cast concrete

0.50 between silty sand till and cast-in-place concrete

In accordance with Table 6.1 of the CHBDC CAN/CSA-S6-06, a resistance factor against sliding of 0.8 should be applied to obtain the resistance at ULS.

## **7.7 LATERAL EARTH PRESSURES**

### **7.7.1 Lateral Earth Pressures under Static Conditions**

Earth pressures will need to be considered in the design of the culvert walls, culvert retaining walls (if proposed), as well as for roadway protection systems.

Computation of earth pressures should be in accordance with Section 6.9 of the CHBDC. For retaining walls that are designed to allow rotation, active earth pressure may be used for design. For rigidly tied and unyielding structures, the at-rest earth pressure should be used for design. For a Rigid Frame Box Culvert and a Rigid Frame Open Footing Culvert, the walls are considered to be unyielding and the at-rest earth pressure should be used for design. The unfactored soil parameters provided in Table 7.4 may be used for design of walls with a horizontal backfill. The effects of compaction should be accounted for by applying a compaction surcharge as shown in Figure 6.6 of the CHBDC.

The total active ( $P_A$ ), at-rest ( $P_O$ ) and passive ( $P_P$ ) thrusts can be calculated using the following equations:

$$P_A = \frac{1}{2} K_a \gamma H^2$$

$$P_O = \frac{1}{2} K_o \gamma H^2$$

$$P_P = \frac{1}{2} K_p \gamma H^2$$

where H is the height of the wall. Values for  $K_a$ ,  $K_o$ ,  $K_p$ , and  $\gamma$  are provided in Table 7.4. The thrust acts at a point one third up the height of the wall.

**Table 7.4: Recommended Non-Seismic Earth Pressure Parameters (Horizontal Backfill)**

Parameter	OPSS Gran B Type I	OPSS Gran A and Gran B Type II	Existing Embankment Fill	Silty/Sandy Clay Till	Silty Sand Till
Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	21.2	22.0	20.0	19.0	20.0
Effective Friction Angle	32°	35°	32°	28°	35°
Coefficient of Earth Pressure at Rest ( $K_o$ )	0.47	0.43	0.47	0.53	0.43
Coefficient of Active Earth Pressure ( $K_a$ )	0.31	0.27	0.31	0.36	0.27
Coefficient of Passive Earth Pressure ( $K_p$ )	3.25	3.69	3.25	2.77	3.69

### 7.7.2 Lateral Earth Pressures under Seismic Conditions

The culvert walls and wingwalls should also be designed to resist the earth pressures induced under seismic loading conditions. The seismic earth pressures may be calculated using the parameters detailed in Tables 7.5 below.

The total active and passive thrusts under seismic loading conditions can be calculated using the following equations:

- $P_{AE} = \frac{1}{2} K_{AE} \gamma H^2 (1 - k_v)$
- $P_{PE} = \frac{1}{2} K_{PE} \gamma H^2 (1 - k_v)$

where:

- $K_{AE}$  = active earth pressure coefficient (combined static and seismic)
- $K_{PE}$  = passive earth pressure coefficient (combined static and seismic)
- H = height of wall
- $k_h$  = horizontal acceleration coefficient
- $k_v$  = vertical acceleration coefficient
- $\gamma$  = total unit weight

For this site, the following design parameters were used to develop the recommended  $K_{AE}$  and  $K_{PE}$  values:

- Zonal Acceleration Ratio, A or PGA 0.05
- Horizontal Acceleration Coefficient,  $k_h$  0.025 yielding 0.075 non-yielding
- Vertical Acceleration Coefficient,  $k_v$  0.017 yielding 0.05 non-yielding
- Horizontal Backslope to wall
- Vertical back of wall

The above  $k_h$  value corresponds to  $\frac{1}{2}$  of the A value for yielding walls and 1.5 times for non-yielding walls. The  $k_v$  value corresponds to 0.67 of the  $k_h$  value. The angle of friction between the soil and the wall has been set at 0° to provide a conservative estimate.

**Table 7.5: Recommended Seismic Earth Pressure Parameters (Horizontal Backfill)**

Parameter	OPSS Gran B Type I		OPSS Gran A and Gran B Type II		Existing Road Embankment Fill		Sandy/Silty Clay Till		Silty Sand Till	
Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	21.2		22.0		19.0		19.0		20	
Effective Friction Angle	32°		35°		32°		28°		35°	
	Yielding wall	Non-yielding	Yielding wall	Non-yielding	Yielding wall	Non-yielding	Yielding wall	Non-yielding	Yielding wall	Non-yielding
Active Earth Pressure ( $K_{AE}$ )	0.32	0.35	0.28	0.31	0.32	0.35	0.38	0.41	0.28	0.31
Height of Application of $P_{AE}$ from base as a ratio of wall height, (H)	0.341	0.356	0.342	0.358	0.341	0.356	0.34	0.354	0.342	0.358
Passive Earth Pressure ( $K_{PE}$ )	3.21	3.11	3.64	3.54	3.21	3.11	2.73	2.63	3.64	3.54
Height of Application of $P_{PE}$ from base as a ratio of wall height, (H)	0.325	0.306	0.325	0.307	0.325	0.306	0.325	0.305	0.325	0.307

## 7.8 STABILITY OF SLOPES

A preliminary slope stability evaluation was carried out using commercial program Slope/W (Geo-Slope, 2010). The analysis considered seismic loading using one-half of the ZAR. The permanent configuration includes a 3 m wide shoulder which results in the traffic loads being outside the influence of slope stability for a 2.7 m tall embankment. Traffic loads have not been incorporated in the design, however, should the platform configuration change to include reduced shoulder widths, the influence of traffic loading will need to be reassessed.

A 2H:1V permanent embankment slope was considered. The slope stability analysis results are presented in Figures 5 to 7 in Appendix D. The slope stability evaluation results indicate that the failure planes generally tend to be relatively shallow. Based on this preliminary slope stability analysis, the factor of safety against the shallow critical failure plane meets the required target value of 1.3 for highway embankments.

## 7.9 EMBANKMENT SETTLEMENT

The existing roadway profile will be maintained, no grade raises are proposed at the culvert location. Negligible settlement of the embankments is anticipated.

## 7.10 TEMPORARY ROADWAY PROTECTION

The total width of the roadway platform is estimated to be approximately 12 to 13 m. The depth of excavation for the culvert replacement is expected to be in the order of 4.5 m. Therefore, the use of an open trenching approach with 1H:1V slopes is not considered feasible at this site without widening the roadway platform to support a single lane of detoured traffic.

Temporary roadway protection is anticipated to form part of a staged construction approach that will be required to maintain traffic flow during construction. The configuration of the temporary roadway protection has not yet been finalized but will likely be placed near the centerline of the road area at a length of approximately 20 m.

Assuming that the precast rigid box option is carried forward and provided an appropriate unwatering system is in place, a soldier pile and lagging system may be feasible. Due to the presence of cobbles and boulders within the till and the continuous refusal to Standard Penetration Test (N-Values >100), the use of sheet piling is not likely practical at this site. Soldier pile and lagging are preferred but will likely require bracing for support.

Computation of earth pressures should be in accordance with Section 6.9 of the Canadian Highway Bridge Design Code (CHBDC). For roadway protection with a horizontal backfill, the unfactored soil parameters provided in Table 7.4 may be used for design. For the second stage of excavation the effects of backfill compaction should be accounted for by estimating the compaction-induced load in accordance with the methodology described in Figure 6.6 of the CHBDC.

The total active ( $P_A$ ) and passive ( $P_P$ ) thrusts can be calculated using the following equations.

$$P_A = \frac{1}{2} K_a \gamma H^2$$

$$P_P = \frac{1}{2} K_p \gamma H^2$$

Where  $H$  is the height of the wall and the values for  $K_a$ ,  $K_p$ , and  $\gamma$  are provided in Table 7.4. The thrust typically acts at a point one third up the height of the wall, however, roadway protection types and materials will dictate the actual pressure distribution.

Shoring design should meet the requirements of Performance Level 2 as per OPSS 539 and should consider traffic loading. Performance Level 2 specifies a Maximum Angular Distortion of 1:200 and a Maximum Horizontal Displacement of 25 mm.

Due to the very dense nature of the glacial till, the contractor may choose to pre-auger holes as part of the soldier pile installation procedure. An NSSP has been provided in Appendix E to alert the contractor of the presence of cobbles and boulders in the till and that there is a risk of cave-in and raveling within preaugered holes due to the cobbles and boulders being displaced and due to augering below the water table within a non-cohesive till.

## **7.11 EROSION AND SCOUR PROTECTION**

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes and adjacent stream banks. All slopes within 3 m of the culvert inlet and outlet should be surfaced with rip-rap at least 300 mm thick placed on a Class II non-woven filter fabric; the rip-rap should extend up the slope to 0.3 m above the design high water level. Where embankment construction includes earth fill, normal slope vegetation should be established as soon as possible after completion of the embankment fills in order to control surficial erosion.

The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site.

The General Arrangement (GA) drawing for the proposed box culvert includes a cut-off wall extending down to elevation 273.0 m which is within the till layer. Retaining walls are proposed at the south end of the culvert which will act as a barrier to water flow within the granular backfill outside of the culvert walls. Therefore, a clay seal within the culvert backfill is not required for this project.

## **7.12 CEMENT TYPE AND CORROSION PROTECTION**

Two samples of the native soil were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The testing was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are summarized in the Table 4.1.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The soluble sulphate concentrations for the two samples were 52 and 38 µg/g. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU (General Use) Portland Cement should therefore be suitable for use in concrete at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH values were 7.7 and 7.9 which are within what is considered the normal range for soil pH of 5.5 to 9.0. The pH levels of the tested soil do not indicate a highly corrosive environment. The test results provided in the Table 4.1 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

## **8.0 Construction Considerations**

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### **8.1 CONSTRUCTION STAGING**

The partial replacement of the culvert in this project is anticipated to involve a staged construction. This will involve closure of one lane of the road for a short duration by using appropriate traffic control and would require the use of temporary roadway protection near the centerline of the highway.

### **8.2 EXCAVATION AND BACKFILLING**

Excavation and backfill for the new culvert should be carried out in accordance with OPSS 902 Construction Specification for Excavation and Backfilling applicable to the rigid frame open

footing culvert and cast in place Rigid Frame Box Culvert options and SP 422S01 for the Precast Rigid Frame Box Culverts option.

All vegetation, fill, organic silt and other deleterious materials must be removed from beneath the proposed box culvert foundation. The footings of the existing culvert should be removed. Where deleterious materials are encountered, the material should be excavated, wasted and replaced. The lateral extent of such excavation should include all deleterious materials within the influence zone of the foundations.

Side slopes for open cut excavations should conform to Occupational Health and Safety Act (OHSA) regulations for Construction Projects. The soils encountered at the site may be classified as Type 3 Soil.

Generally, it is anticipated that construction requirements for temporary open excavations will include 1H:1V side slopes extending from the base of the excavation.

Grading work for reinstatement of the highway embankment along the existing culvert alignment should be carried out in accordance with OPSS 206 Construction Specification for Grading and SP 206S03. Backfilling of the culvert should be carried in accordance with MTOD 803.021.

### **8.3 TEMPORARY CONSTRUCTION UNWATERING AND DEWATERING**

The underside of the culvert is anticipated to be lower than the observed groundwater and creek water levels. Furthermore, removal of the underside of the existing foundations of the original culvert will require excavation to 273.5 m or 1.1 m below the creek water level observed in July 2010.

Control of the water flow in the stream will require a cofferdam or an aquadam to prevent stream flow into the excavations. Note that cobbles and boulders were encountered. For this reason, aquadam provides a less risky option. It is anticipated that flow will be diverted using pumps to allow construction of the replacement culvert.

The estimated hydraulic conductivity for the native soil at the site is expected to be in the order of  $1 \times 10^{-7}$  to  $1 \times 10^{-5}$  m/s. Unwatering of the structure excavation using conventional sump and pump techniques should be adequate.

The excavation level anticipated to remove the existing footings is close to the observed groundwater level and as noted above it is anticipated that conventional unwatering practices will suffice for this project. Notwithstanding, a Dewatering NSSP should be included in the contract to cover the possibility that the groundwater level increases during construction to the point where some dewatering effort is required to provide a stable earth platform for construction purposes. A copy of the NSSP is provided in Appendix E.

## **9.0 Specifications**

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The following specifications are referenced in this report:

**Table 9.1: Specifications Referenced in Report**

<b>Document</b>	<b>Title</b>
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
MTOD 803.021	Bedding and Backfill for Precast Concrete Box Culverts
OPSS 206	Construction Specification for Grading
SP 206S03	Earth Excavation, Grading
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cuts
SP 422S01	Precast Concrete Box Culvert
OPSS 539	Construction Specification for Temporary Protection System
OPSS 902	Construction Specification for Excavation and Backfilling - Structures
NSSP	Dewatering
NSSP	Removal of Organic Silt
NSSP	Risk of Cave-In with Pre-Augered Holes
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 518	Construction Specification for Control of Water from Dewatering Operations



## **10.0 References**

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ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

Chapman, L.J., and Putnam, D.F. 1984. The physiography of Southern Ontario, Ontario Geological Survey Special Volume 2. Ontario Research Foundation, Toronto, Ontario.

CHBDC. 2006. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

Geo-Slope International, Ltd. 2010. GeoStudio 2007 (Slope/W 2007), Calgary, Alberta.

## 11.0 Closure

A soil investigation is a limited sampling of a site. The conclusions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information and its effects on the above recommendations.

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

This report was prepared by Simon Gudina and Chris McGrath, and Reviewed by Raymond Haché.

Respectfully submitted,

**STANTEC CONSULTING LTD.**



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Geotechnical Engineer



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Associate, Geotechnical Engineer



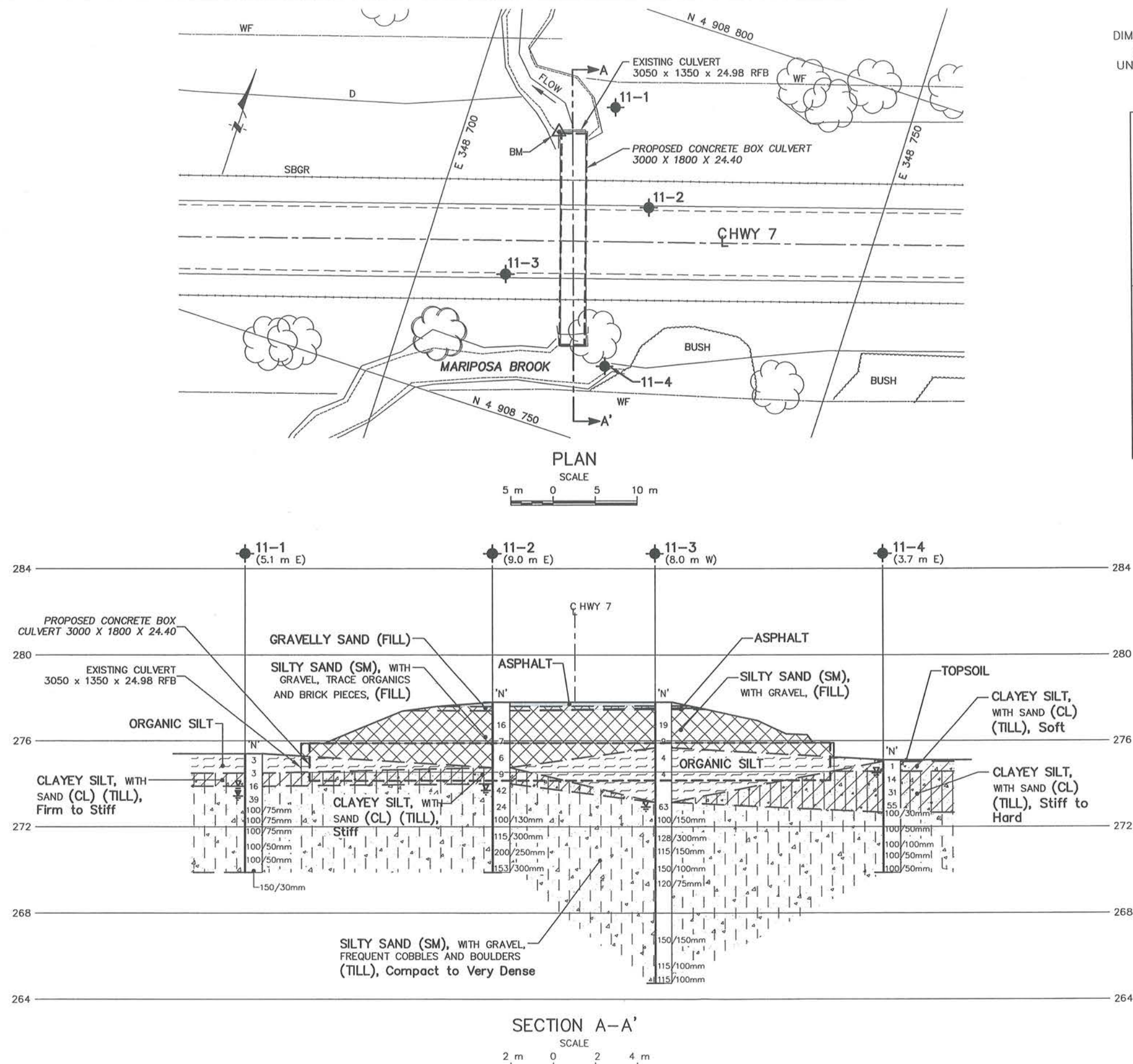
Raymond Haché, M.Sc., P.Eng.  
Designated Principal MTO Foundation Contact



# **APPENDIX A**

Drawing No. 1 – Borehole Location Plan and Soil Strata

Site Photos



METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN




PLATE	No
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CONT	
WP	4066-10-00

MARIPOSA BROOK CULVERT  
HIGHWAY 7  
BOREHOLE LOCATIONS & SOIL STRATA



### LEGEND

- |   |   |
|---|---|
|   | Borehole  |
| N   | Blows/0.3m (Std Pen Test, 475 J/blow)                                       |
|  | WL at time of investigation<br>(September 28, 2011)                         |
|  | WL at time of investigation,<br>(September, 2011)                           |
|  | Temporary benchmark<br>(Cut cross on Culvert)<br>Elev. = 276.114 m Geodetic |
| (5.1 m E)   | Offset from culvert centreline in<br>meters                                 |

No	ELEVATION	MTM_ZONE 10 NORTH	COORDINATES EAST
11-1	275.4	4 908 788.0	348 716.4
11-2	277.8	4 908 778.3	348 723.6
11-3	277.8	4 908 765.7	348 709.9
11-4	275.1	4 908 759.2	348 724.3

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=NOTES=

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

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REVIEWS				
	DATE	BY	DESCRIPTION	
GEOCRES No				
HWY No 7			DATE 2011-10-26	DIST MARIPOSA
SUBM'D SG	CHECKED		APPROVED	SITE
DRAWN GBB	CHECKED			DWG 1





**Photo No. 1: Looking west at culvert inlet near BH11-4**



**Photo No. 2: Close-up view of culvert at the inlet**





**Photo No. 3: Looking north at culvert outlet near BH11-1**



**Photo No. 4: Culvert at outlet showing signs of deterioration**



# **APPENDIX B**

Symbols and Terms Used on Borehole Records

Borehole Records

## SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

### SOIL DESCRIPTION

#### Terminology describing common soil genesis:

<i>Topsoil</i>	- mixture of soil and humus capable of supporting vegetative growth
<i>Peat</i>	- mixture of visible and invisible fragments of decayed organic matter
<i>Till</i>	- unstratified glacial deposit which may range from clay to boulders
<i>Fill</i>	- material below the surface identified as placed by humans (excluding buried services)

#### Terminology describing soil structure:

<i>Desiccated</i>	- having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
<i>Fissured</i>	- having cracks, and hence a blocky structure
<i>Varved</i>	- composed of regular alternating layers of silt and clay
<i>Stratified</i>	- composed of alternating successions of different soil types, e.g. silt and sand
<i>Layer</i>	- > 75 mm in thickness
<i>Seam</i>	- 2 mm to 75 mm in thickness
<i>Parting</i>	- < 2 mm in thickness

#### Terminology describing soil types:

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488). The classification excludes particles larger than 76 mm (3 inches). The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

#### Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present:

<i>Trace, or occasional</i>	Less than 10%
<i>Some</i>	10-20%
<i>Frequent</i>	> 20%

#### Terminology describing compactness of cohesionless soils:

The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test N-Value (also known as N-Index). A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
<i>Very Loose</i>	<4
<i>Loose</i>	4-10
<i>Compact</i>	10-30
<i>Dense</i>	30-50
<i>Very Dense</i>	>50

#### Terminology describing consistency of cohesive soils:

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests.

Consistency	Undrained Shear Strength	
	kips/sq.ft.	kPa
<i>Very Soft</i>	<0.25	<12.5
<i>Soft</i>	0.25 - 0.5	12.5 - 25
<i>Firm</i>	0.5 - 1.0	25 - 50
<i>Stiff</i>	1.0 - 2.0	50 - 100
<i>Very Stiff</i>	2.0 - 4.0	100 - 200
<i>Hard</i>	>4.0	>200





## ROCK DESCRIPTION

### Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	<i>Very Poor</i>
25-50	<i>Poor</i>
50-75	<i>Fair</i>
75-90	<i>Good</i>
90-100	<i>Excellent</i>

Rock quality classification is based on a modified core recovery percentage (RQD) in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. RQD was originally intended to be done on NW core; however, it can be used on different core sizes if the bulk of the fractures caused by drilling stresses are easily distinguishable from *in situ* fractures. The terminology describing rock mass quality based on RQD is subjective and is underlain by the presumption that sound strong rock is of higher engineering value than fractured weak rock.

### Terminology describing rock mass:

Spacing (mm)	Joint Classification	Bedding, Laminations, Bands
> 6000	<i>Extremely Wide</i>	-
2000-6000	<i>Very Wide</i>	<i>Very Thick</i>
600-2000	<i>Wide</i>	<i>Thick</i>
200-600	<i>Moderate</i>	<i>Medium</i>
60-200	<i>Close</i>	<i>Thin</i>
20-60	<i>Very Close</i>	<i>Very Thin</i>
<20	<i>Extremely Close</i>	<i>Laminated</i>
<6	-	<i>Thinly Laminated</i>

### Terminology describing rock strength:

Strength Classification	Unconfined Compressive Strength (MPa)
<i>Extremely Weak</i>	< 1
<i>Very Weak</i>	1 – 5
<i>Weak</i>	5 – 25
<i>Medium Strong</i>	25 – 50
<i>Strong</i>	50 – 100
<i>Very Strong</i>	100 – 250
<i>Extremely Strong</i>	> 250

### Terminology describing rock weathering:

Term	Description
<i>Fresh</i>	No visible signs of rock weathering. Slight discolouration along major discontinuities
<i>Slightly Weathered</i>	Discolouration indicates weathering of rock on discontinuity surfaces. All the rock material may be discoloured.
<i>Moderately Weathered</i>	Less than half the rock is decomposed and/or disintegrated into soil.
<i>Highly Weathered</i>	More than half the rock is decomposed and/or disintegrated into soil.
<i>Completely Weathered</i>	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.



## STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders  
Cobbles  
Gravel



Sand



Silt



Clay



Organics



Asphalt



Concrete



Fill



Bedrock

## SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
DP	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

## WATER LEVEL MEASUREMENT



measured in standpipe, piezometer, or well



inferred

## RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

## N-VALUE





Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (64 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (305 mm) into the soil. For split spoon samples where insufficient penetration was achieved and N-values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N value corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

## DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to A size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (305 mm) into the soil. The DCPT is used as a probe to assess soil variability.

## OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
$\gamma$	Unit weight
$G_s$	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
$Q_u$	Unconfined compression
$I_p$	Point Load Index ( $I_p$ on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer



Stantec

# RECORD OF BOREHOLE No BH 11-1

1 OF 1

METRIC

W.P. 4066-10-00 LOCATION Mariposa Brook Culvert, Hwy 7, Kawartha Lakes, ON ORIGINATED BY JF  
 DIST Eastern HWY 7 BOREHOLE TYPE Portable Drilling Equipment, Splitspoon Sampler COMPILED BY JF  
 DATUM Geodetic DATE 2011 09 27 - 2011 09 28 CHECKED BY CM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa		WATER CONTENT (%)			
275.4	Tall grass						20   40   60   80   100						
0.0	ORGANIC SILT - brown - compressed		1	SS	3								
274.5	CLAYEY SILT with sand (CL), TILL		2	SS	3								
0.9	Firm to stiff												
273.9	Grey, moist		3	SS	16								
1.5	SILTY SAND (SM) with gravel, TILL												
	Compact to very dense												
	Grey, moist		4	SS	39								28   45   20   7
	- frequent cobbles and boulders												
			5	SS	100/ 75mm								31   46   (23)
			6	SS	100/ 75mm								
			7	SS	100/ 75mm								
			8	SS	100/ 50mm								
			9	SS	100/ 50mm								
269.9	End of Borehole		10	SS	150/ 30mm								
5.5	Groundwater measured on September 28, 2011												

ONTARIO MTO STANTEC 165000795 - HWY 7-35 KAWARTHA GPJ ONTARIO MOT GDT 13/3/12

# RECORD OF BOREHOLE No BH 11-2

1 OF 1

METRIC

W.P. 4066-10-00 LOCATION Mariposa Brook Culvert, Hwy 7, Kawartha Lakes, ON ORIGINATED BY DS  
 DIST Eastern HWY 7 BOREHOLE TYPE Solid Stem Augers, Splitspoon Sampler COMPILED BY JF  
 DATUM Geodetic DATE 2011 09 22 - 2011 09 22 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
								○ UNCONFINED	● QUICK TRIAXIAL	✕ FIELD VANE	✕ LAB VANE	WATER CONTENT (%)					
277.8	Asphalt																
0.0 277.6	200 mm ASPHALT																
0.2	FILL: Gravelly sand, brown		1	BS													
276.7																	
1.1	FILL: Silty sand (SM) with gravel - trace organics and brick pieces		2	SS	16												
			3	SS	7												
			4	SS	6												
274.8																	
3.1	CLAYEY SILT with sand (CL), TILL  Stiff  Grey, moist		5	SS	9												
274.0	SILTY SAND (SM) with gravel, TILL  Compact to very dense  Grey, moist to wet  - frequent cobbles and boulders		6	SS	42												
3.8																	
			7	SS	24												
			8	SS	100/ 130mm												
			9	SS	115/ 300mm												
			10	SS	200/ 250mm												
			11	SS	153/ 300mm												
269.9																	
7.9	End of Borehole																
	Groundwater observed at 4.1 m depth during drilling																

# RECORD OF BOREHOLE No BH 11-3

1 OF 2

METRIC

W.P. 4066-10-00 LOCATION Mariposa Brook Culvert, Hwy 7, Kawartha Lakes, ON ORIGINATED BY DS  
 DIST Eastern HWY 7 BOREHOLE TYPE Solid Stem Augers, Splitspoon Sampler COMPILED BY JF  
 DATUM Geodetic DATE 2011 09 22 - 2011 09 22 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
277.8	Asphalt							20 40 60 80 100						GR SA SI CL
0.0	180 mm ASPHALT													
277.6														
277.5	FILL: gravelly sand, brown													
277.5	ASPHALT													
0.3	FILL: Gravelly sand Brown		1	BS						10	20	30		
			2	SS	19									
276.4														
1.4	FILL :Silty Sand (SM) Brown		3	SS	9									17 57 (26)
275.7														
2.1	ORGANIC SILT - brown - compressed		4	SS	4									7.7% Organic Matter
			5	SS	4									6.7% Organic Matter
			6	ST										17.1 Organic Matter
273.1														
4.7	SILTY SAND (SM) with gravel, TILL  Compact to very dense  Grey, moist to wet  - frequent cobbles and boulders		7	SS	63									
			8	SS	100/ 150mm									27 37 26 10
			9	SS	128/ 300mm									
			10	SS	115/ 150mm									
			11	SS	150/ 100mm									
			12	SS	120/ 75mm									
			13	NQ										

Continued Next Page

Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE



# RECORD OF BOREHOLE No BH 11-4

1 OF 1

METRIC

W.P. 4066-10-00 LOCATION Mariposa Brook Culvert, Hwy 7, Kawartha Lakes, ON ORIGINATED BY JF  
DIST Eastern HWY 7 BOREHOLE TYPE Portable Drilling Equipment, Splitspoon Sampler COMPILED BY JF  
DATUM Geodetic DATE 2011 09 22 - 2011 09 23 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	× FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	20						40	60	80
275.1	Tall grass																			
274.9	TOPSOIL with PEAT						275													
0.1	CLAYEY SILT with sand (CL), TILL		1	SS	1															
274.6	Soft																			
0.5	Grey, moist																			
	CLAYEY SILT with sand (CL), TILL																			
	Stiff to hard		2	SS	14		274													
	Brown																			
	- all samples wet		3	SS	31												0 32 (68)			
			4	SS	55		273													
272.7	SILTY SAND with gravel (SM), TILL		5	SS	100/ 30mm															
2.4	Compact to very dense																			
	Grey, moist																			
	- frequent cobbles and boulders		6	SS	100/ 50mm		272										17 70 10 3			
			7	SS	100/ 100mm		271										34 48 (18)			
			8	SS	100/ 50mm															
269.9	End of Borehole		9	SS	100/ 50mm		270													
5.2	Groundwater observed at 0.6 m depth during drilling																			

ONTARIO MTO STANTEC 165000795 - HWY 7-35 KAWARTHA GPJ ONTARIO MOT GDT 13/3/12

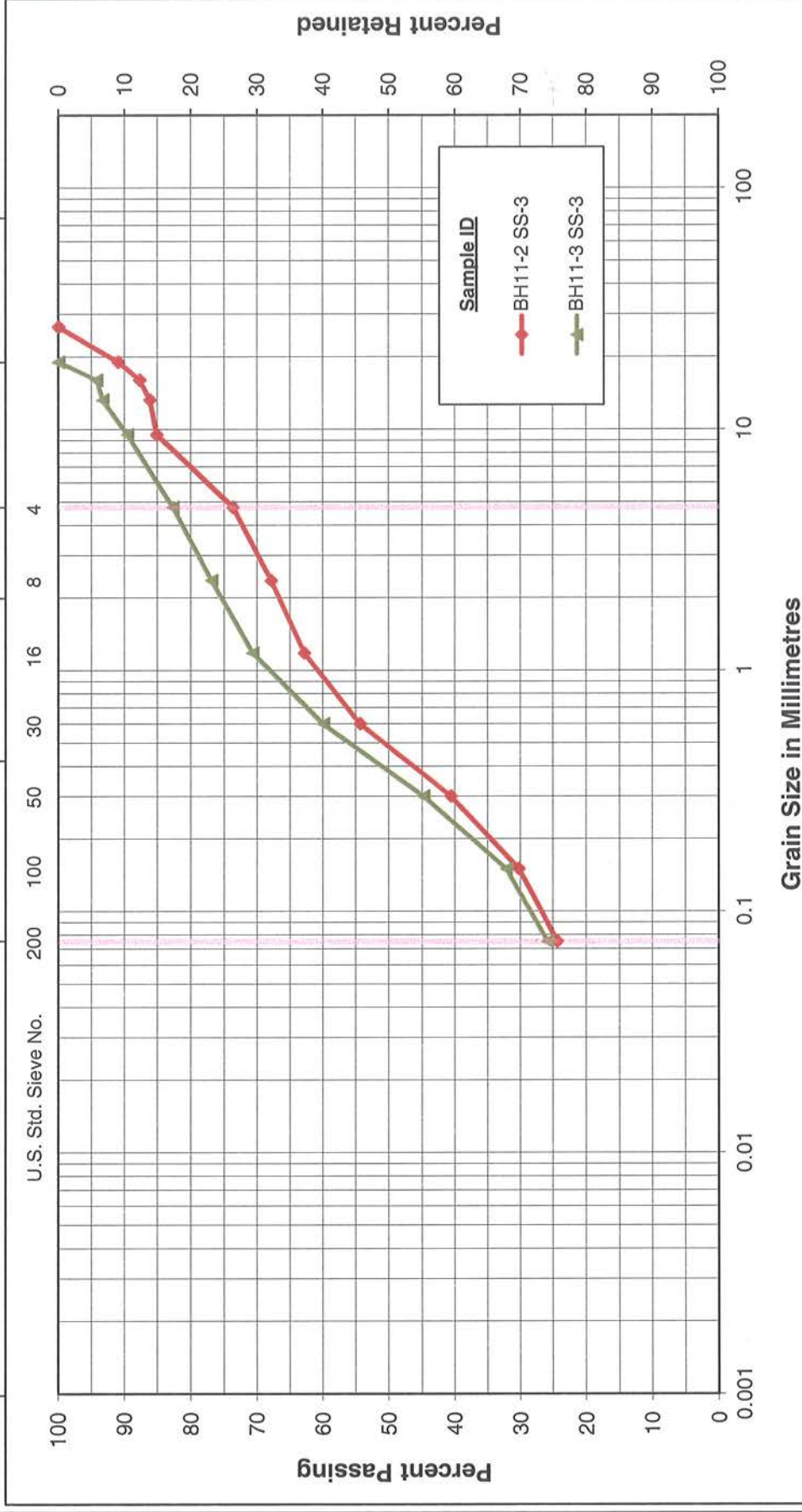
# **APPENDIX C**

Laboratory Test Results



# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

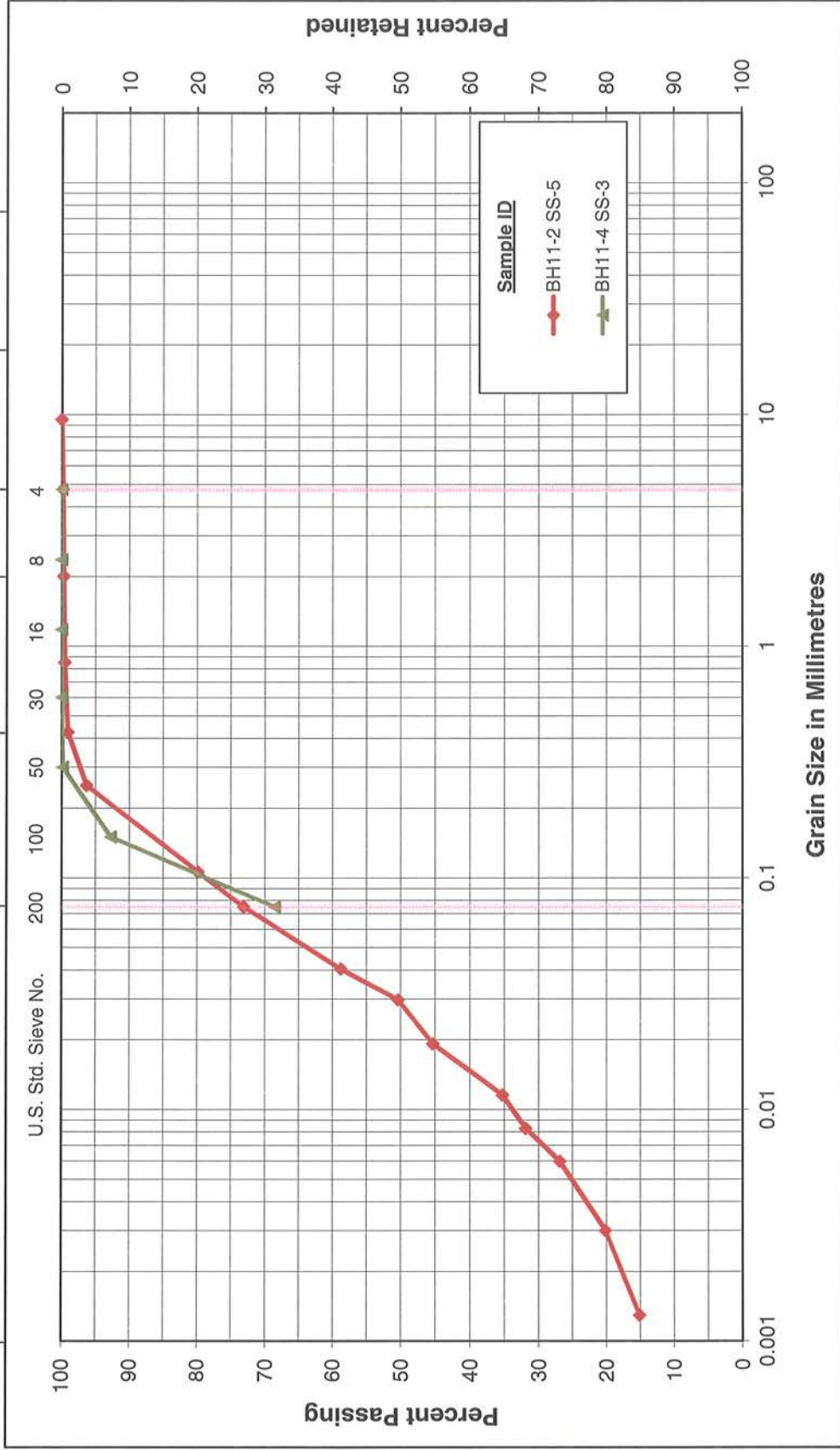
FILL: Silty Sand with gravel (SM)

Figure No. 1

Project No. 165000795

# Unified Soil Classification System

CLAY & SILT		SAND			Gravel	
		Fine	Medium	Coarse	Fine	Coarse



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## GRAIN SIZE DISTRIBUTION

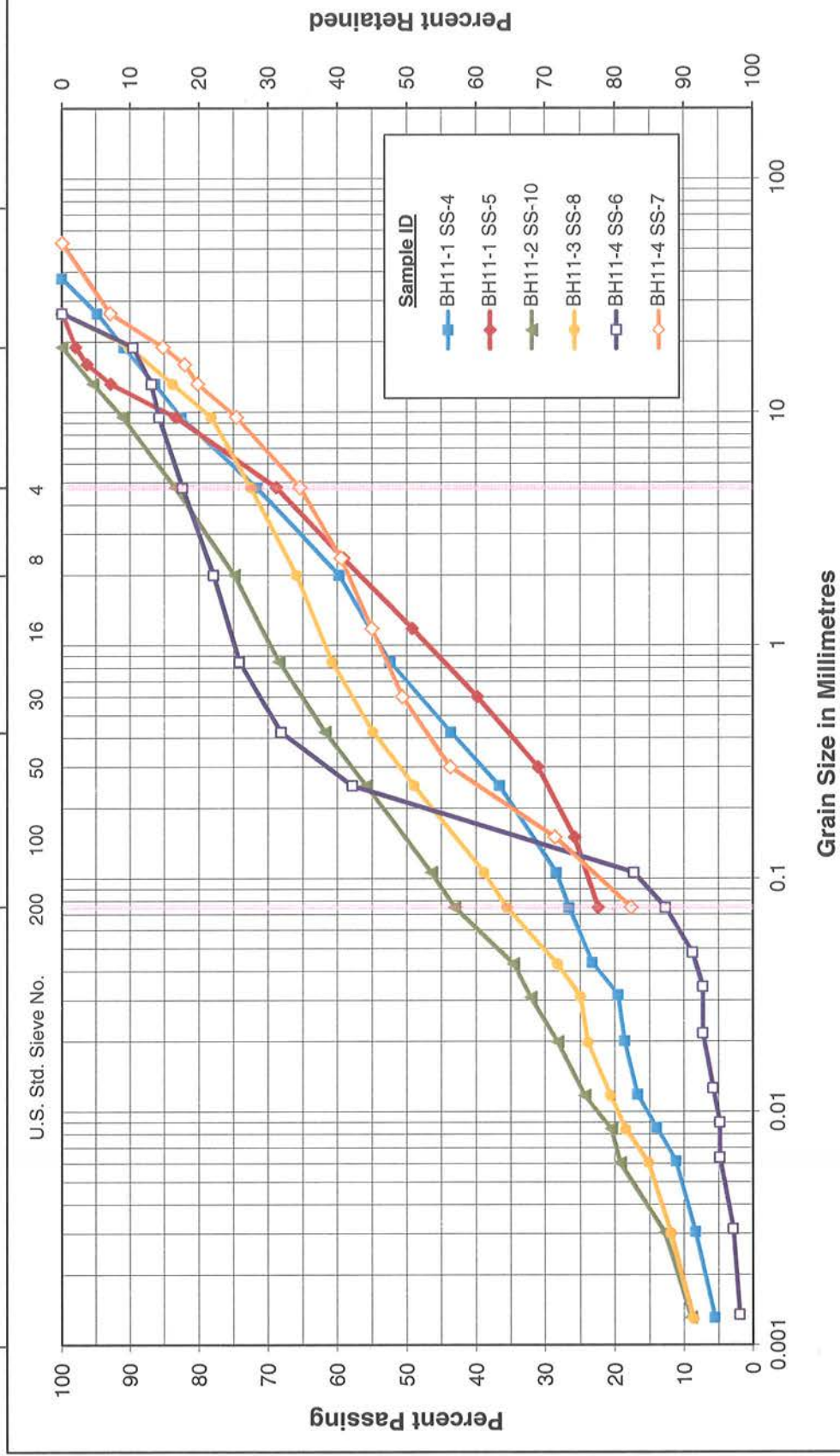
TILL: Clayey Silt with Sand (CL)

Figure No. 2

Project No. 165000795

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



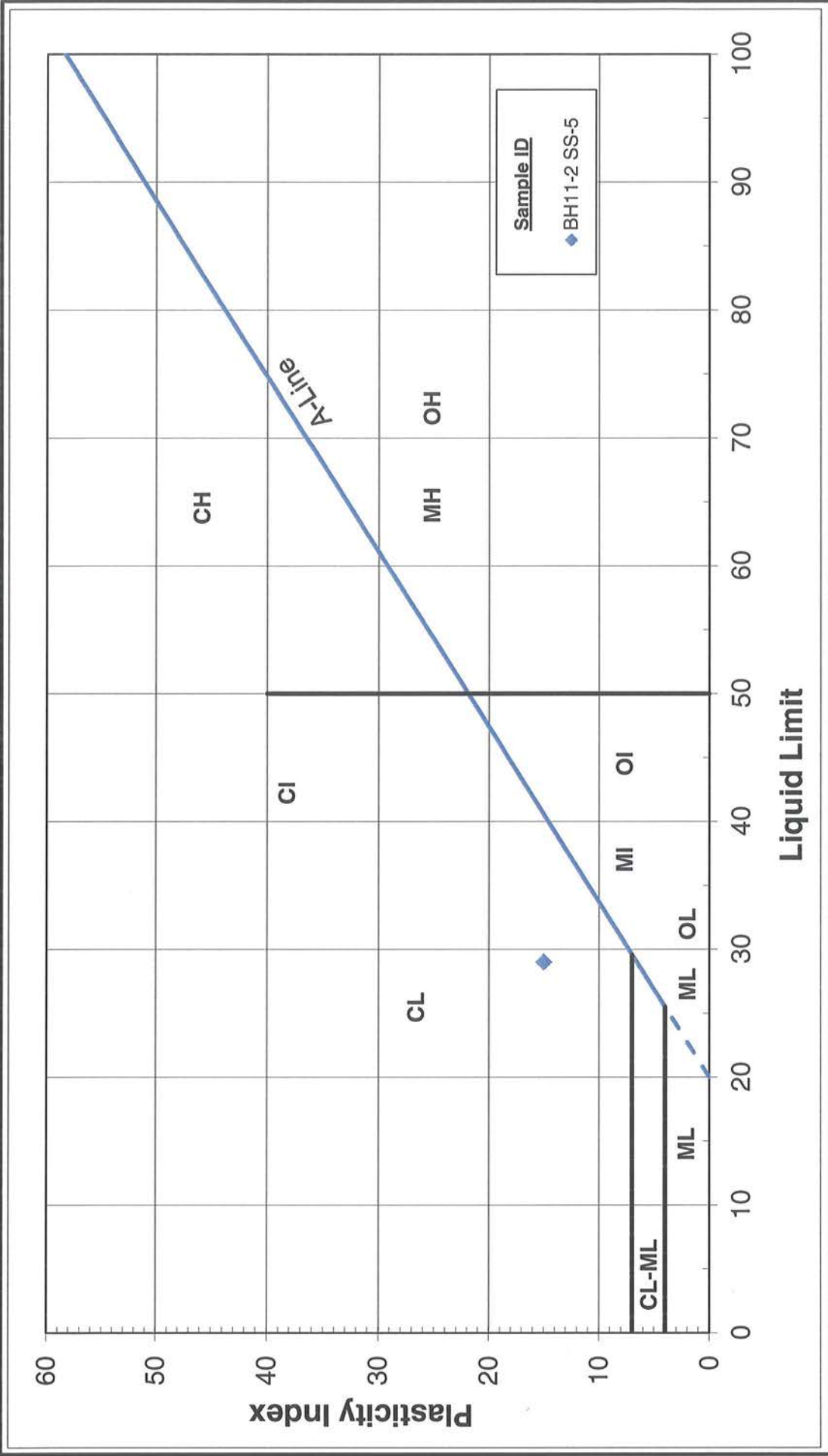
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## GRAIN SIZE DISTRIBUTION

TILL: Silty sand with gravel (SM)

Figure No. 3

Project No. 165000795



# PLASTICITY CHART

Figure No. 4

Project No. 165000795

# **APPENDIX D**

Slope Stability Results



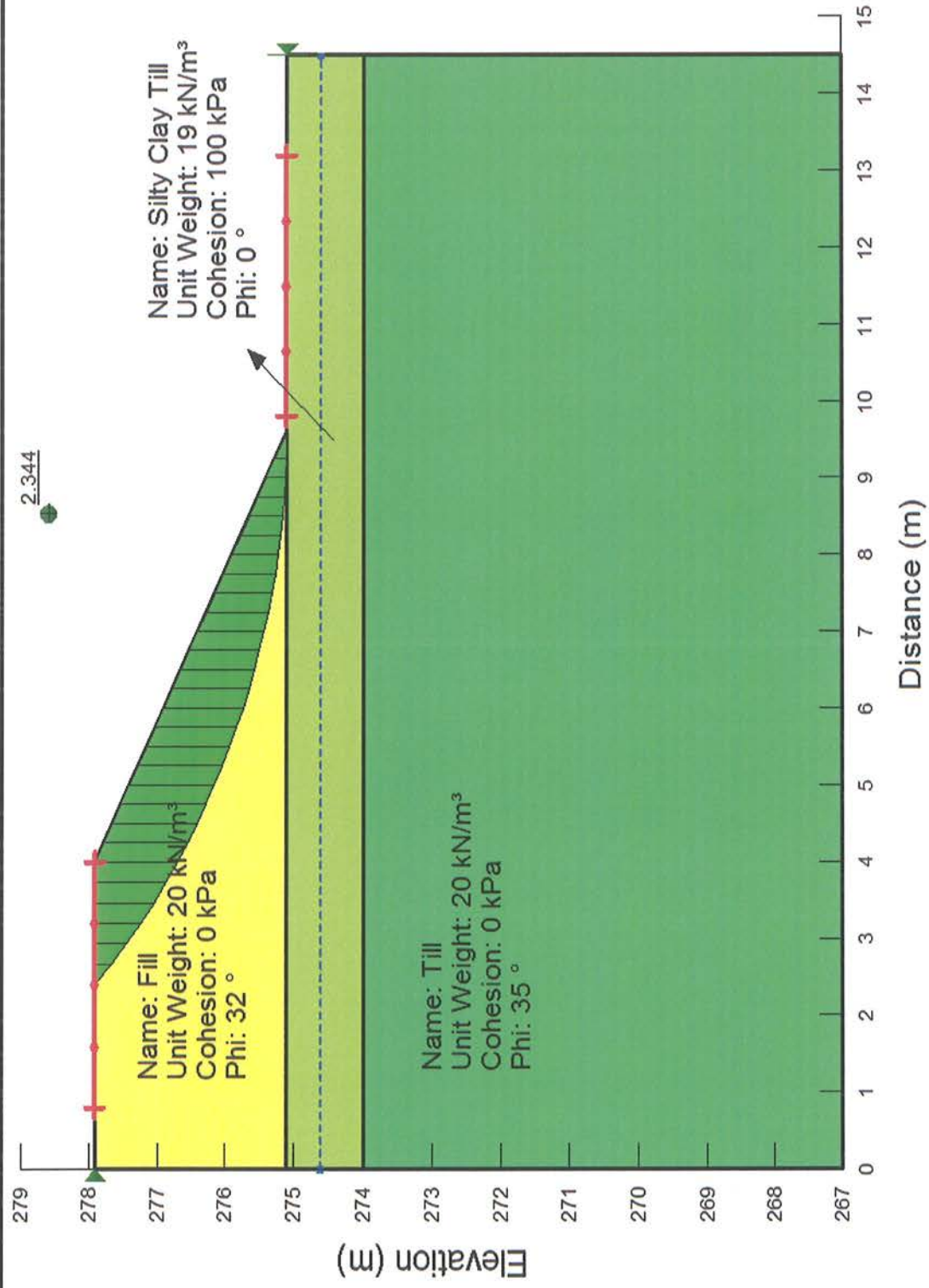


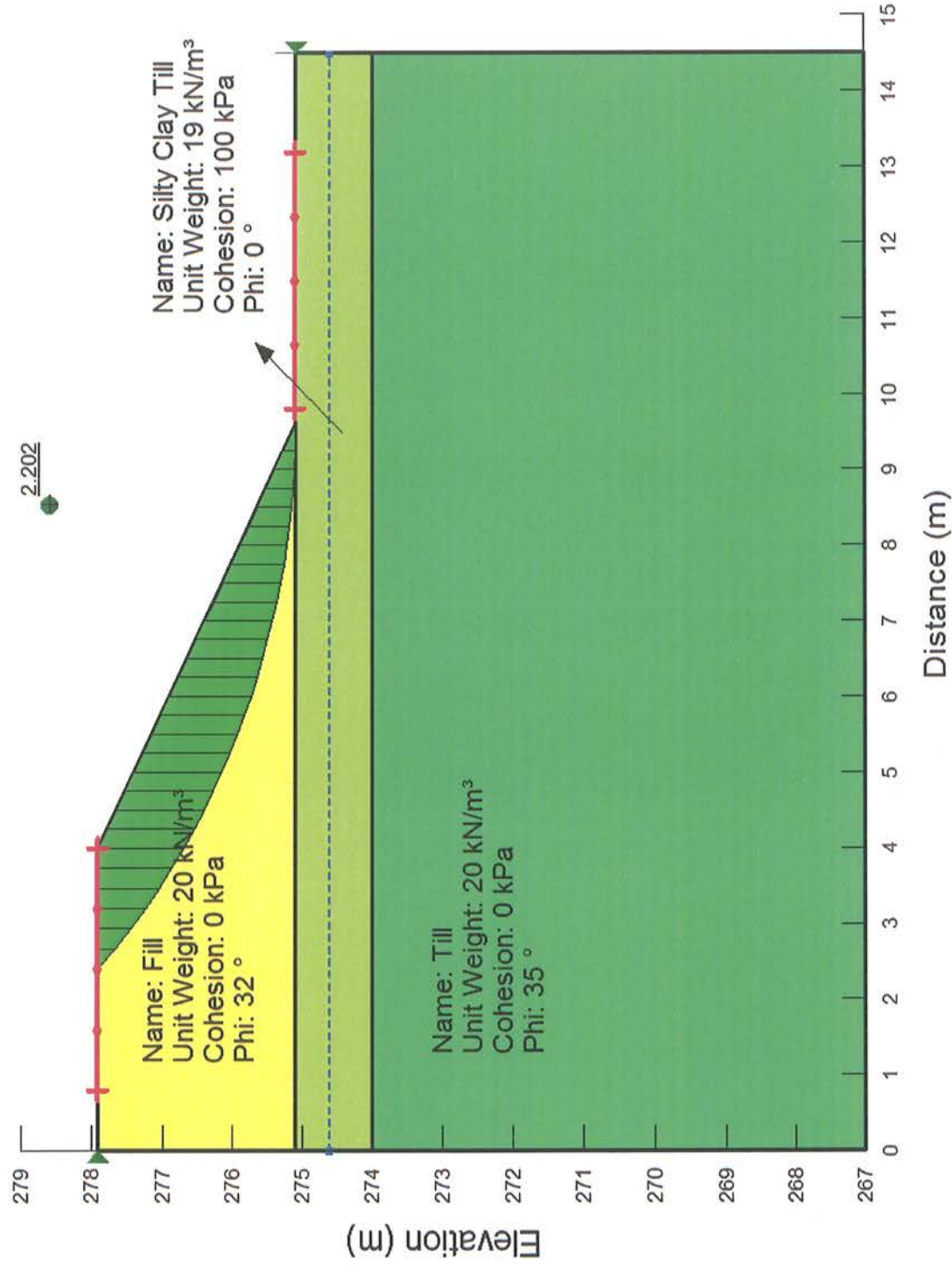
Figure 5

# Static Undrained Slope Stability Analysis Mariposa Brook Culvert Replacement Highway 7



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Project No. 165000795



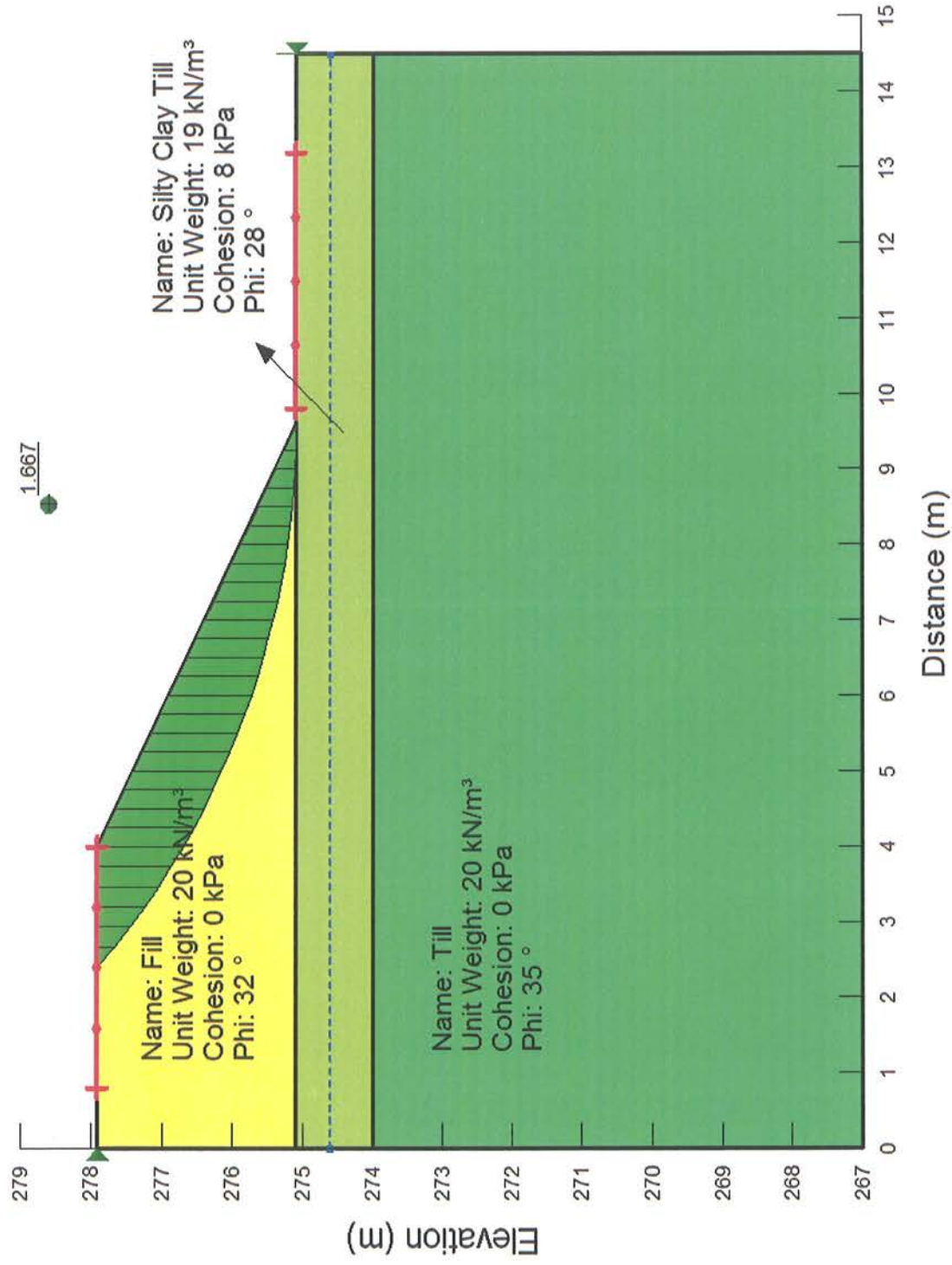
**Seismic Slope Stability Analysis**  
 Mariposa Brook Culvert Replacement  
 Highway 7

Figure 6

Project No. 165000795



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# Static Drained Slope Stability Analysis

## Mariposa Brook Culvert Replacement

### Highway 7

Figure 7

Project No. 165000795



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# **APPENDIX E**

Dewatering NSSP

Removal of Organic Silt NSSP

Risk of Cave-In with Pre-Augered Holes NSSP

## **DEWATERING—Item No.**

---

### **Special Provision**

---

#### **SCOPE**

The work required for the above tender item shall include consideration of dewatering to provide stable earth platform.

#### **CONSTRUCTION**

The contractor is advised of the following:

- Excavation is required to remove the existing culvert and for the construction of a new culvert.
- The groundwater level was measured at elevation 273.4 m in Borehole BH11-1 on September 28, 2011.
- The water level in Mariposa Brook was measured at elevation 274.6 m in July 2010.
- The contractor shall consider that seasonal groundwater fluctuations may result in higher groundwater levels than observed and that higher groundwater levels may result in an unstable working earth platform.
- The anticipated excavation level is approximately 273.5 m which is close to the observed groundwater level noted above.
- The presence of cohesionless till can render the soils susceptible to unbalanced hydrostatic head, soil sloughing and cave-in.
- The contractor shall consider the site conditions, sequence of work and schedule when assessing requirements for dewatering.

Requirements for dewatering are contained in OPSS 517.

Requirements for the control of water during construction are contained in OPSS 518.

#### **BASIS OF PAYMENT**

Payment at the Contract price for the appropriate tender items associated with dewatering shall include full compensation for all labour, Equipment and Material to do the work.

## **REMOVAL OF ORGANIC SILT—Item No.**

---

Special Provision

---

### **SCOPE**

The work required for the above tender item shall include consideration of the removal of organic silt at this site.

### **CONSTRUCTION**

The Contractor is advised that organic silt was encountered at the site during the site investigation and that the excavation for the new culvert may encounter this layer. This weak layer shall be excavated and removed entirely from within the culvert footprint/influence zone down to the native till. The influence zone is defined as the area beneath the culvert plus 1 m in all horizontal directions and the area below an imaginary line projecting downward away from the edges of the culvert footing at a slope of 1H:1V.

The Contractor shall consider the observed conditions, including the depth of the organic silt or weak material encountered, sequence of work and schedule when devising excavation and removal of the weak layer.

### **BASIS OF PAYMENT**

Payment at the contract price for the tender item shall be full compensation for all labour, equipment and material to do the work.

## **RISK OF CAVE-IN WITH PRE-AUGERED HOLES—Item No.**

---

Special Provision

---

### **SCOPE**

The work required for the above tender item shall include consideration of the potential for soil cave-in during installation of soldier piles as part of the temporary roadway protection at this site.

### **CONSTRUCTION**

The observed glacial till at the site during geotechnical drilling is generally very dense and contains frequent cobbles and boulders. Due to the very dense nature of the glacial till, the Contractor may choose to pre-auger holes as part of the soldier pile installation procedure. The Contractor is advised that there is a risk of cave-in and ravelling within pre-augered holes due to the cobbles and boulders being displaced and due to augering below the groundwater table within a non-cohesive till.

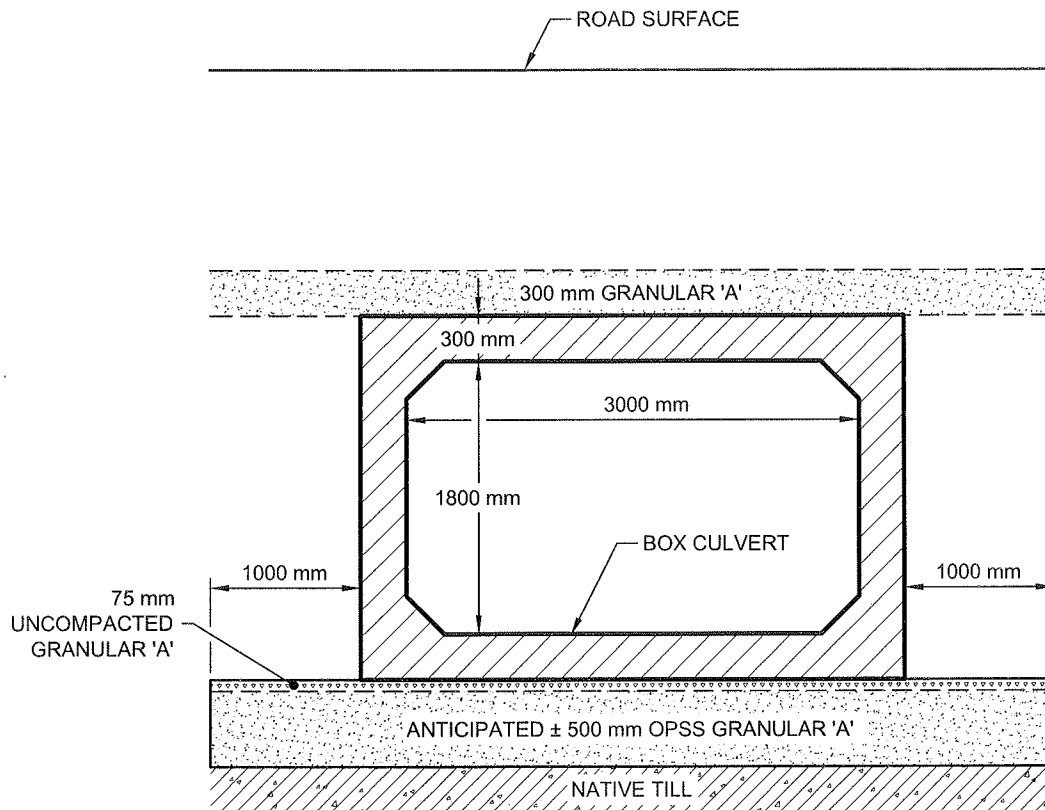
The Contractor shall carefully monitor the observed conditions during augering and shall accordingly devise appropriate procedures when constructing the temporary protection system.

### **BASIS OF PAYMENT**

Payment at the contract price for the tender item shall be full compensation for all labour, equipment and material to do the work.

## **APPENDIX F**

Sketch Showing Granular Pad Beneath the Box Culvert



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC CONSULTING LTD. REPORT AND MUST NOT BE USED FOR OTHER PURPOSES.

## SKETCH OF GRANULAR PAD BENEATH THE BOX CULVERT

MARIPOSA BROOK CULVERT  
HIGHWAY 7, KAWARTHA LAKES, ONTARIO

Job No.: 165000795

Scale: 1 : 50

Date: 12/03/15

Dwn. By: GBB

App'd By:

Dwg. No.:

2



**Stantec**

Client: MTO