



November 17, 2011

## FOUNDATION INVESTIGATION AND DESIGN REPORT

**HIGHWAY 11 SBL CULVERT REPLACEMENT AT STATION 21+319  
TOWNSHIP OF SOUTH HIMSWORTH, ONTARIO  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5416-06-00**

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REPORT





## Table of Contents

### **PART A – FOUNDATION INVESTIGATION REPORT**

<b>1.0 INTRODUCTION.....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION.....</b>	<b>1</b>
<b>3.0 INVESTIGATION PROCEDURES .....</b>	<b>2</b>
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS .....</b>	<b>3</b>
4.1 Regional Geology .....	3
4.2 Subsurface Conditions.....	3
4.2.1 Fill .....	4
4.2.2 Organics.....	4
4.2.3 Silt to Clayey Silt .....	4
4.2.4 Clayey Silt to Silty Clay .....	5
4.2.5 Silty Sand to Sand .....	5
4.2.6 Sand and Gravel .....	5
4.2.7 Bedrock/ Refusal.....	6
4.2.8 Groundwater Conditions .....	6
<b>5.0 CLOSURE .....</b>	<b>6</b>

### **PART B – FOUNDATION DESIGN REPORT**

<b>6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS.....</b>	<b>9</b>
6.1 General .....	9
6.2 Culvert Types .....	10
6.3 Culvert Construction Options.....	10
6.4 Stability, Settlement and Horizontal Strain.....	10
6.4.1 Stability .....	11
6.4.1.1 Methodology .....	11
6.4.1.2 Parameter Selection .....	11
6.4.1.3 Results of Analysis .....	12
6.4.2 Settlement .....	12
6.4.3 Horizontal Strain .....	12



## FOUNDATION REPORT - HIGHWAY 11 SBL STA 21+319 CULVERT REPLACEMENT

6.5	Design recommendations for Concrete Box Culvert .....	12
6.5.1	Geotechnical Resistance .....	12
6.5.2	Resistance to Lateral Loads/Sliding Resistance .....	13
6.5.3	Lateral Earth Pressures – Culvert .....	13
6.6	Culvert Construction Considerations .....	14
6.6.1.1	Removal of Organics .....	14
6.6.1.2	Replacement/Backfill below Base of Culvert .....	14
6.6.1.3	Temporary Shoring .....	14
6.6.2	Bedding and Backfill above Base of Culvert .....	15
6.6.3	Erosion Protection.....	16
6.6.4	Control of Surface Water .....	16
7.0	CLOSURE .....	17

### DRAWINGS

Drawing 1      Borehole Locations and Soil Strata

### APPENDICES

#### Appendix A      Record of Boreholes

List of Symbols and Abbreviations

Record of Boreholes BH09-25, BH09-26, BH09-27 and BH09-28

#### Appendix B      Laboratory Test Results

Figure B1      Grain Size Distribution – Gravelly Sand to Sand (Fill)

Figure B2      Grain Size Distribution – Silty Sand (Fill)

Figure B3      Plasticity Chart – Silt to Clayey Silt

Figure B4      Grain Size Distribution – Silt to Clayey Silt

Figure B5      Plasticity Chart – Clayey Silt to Silty Clay

Figure B6      Grain Size Distribution – Silty Sand to Sand

Figure B7      Grain Size Distribution – Sand and Gravel



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**FOUNDATION REPORT - HIGHWAY 11 SBL STA 21+319  
CULVERT REPLACEMENT**

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# **PART A**

**FOUNDATION INVESTIGATION REPORT**

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**TOWNSHIP OF SOUTH HIMSWORTH, ONTARIO**

**MINISTRY OF TRANSPORTATION, ONTARIO**

**GWP 5416-06-00**



### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed rehabilitation of the Highway 11 Southbound Lanes (SBL), including the culvert replacement at Station 21+319. This project is part of the detail design for the rehabilitation of Highway 11 Northbound Lanes (NBL) and Southbound Lanes (SBL) from 5.0 km south of Highway 534 northerly 3.5 km. The general location of this section of the Highway 11 alignment is shown on the Key Plan on Drawing 1 following the text of this report.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal dated July 23, 2009. Golder's proposal (P9-1191-0042, dated August 14, 2009) for foundation engineering services associated with the rehabilitation/replacement of culverts is contained in Section 6.8 of URS's Technical Proposal that forms part of the Consultant's Agreement (Purchase Order Number 5008-E-0061) for this project. The work was carried out in accordance with Golder's Supplemental Specialty Quality Control Plan for this project dated August 17, 2010.

This report addresses the investigation carried out for the replacement of the culvert on Highway 11 SBL at Station 21+319 only. Separate reports will be submitted detailing the foundation investigations for other culverts for this project. The General Arrangement (GA) drawing for the proposed culvert alignment was provided to Golder by URS on June 4, 2010. Cross-sections showing invert information were provided on August 25, 2010.

Based on the information from URS, the culvert at Station 21+319 will be concrete and will have an opening of 1.2 m. The existing culvert is about 36 m long. The inverts at the west and east ends of the culvert will be Elevation 269.2 m and 270.5 m, respectively. The height of the embankment in the culvert area is about 5 m (median) to 6 m (west side) and we understand that neither a grade raise nor embankment widening are required at this culvert location.

The purpose of this investigation is to establish the subsurface conditions at the location of the proposed culvert replacement by borehole drilling, in situ testing and laboratory testing on selected samples.

The culvert alignment was located in the field by Golder relative to stakes installed by Callon Dietz Inc. (Callon Dietz), a professional surveying company retained by URS, and referencing plan drawings provided by URS. The investigated area is shown in plan on Drawing 1 following the text of this report.

### 2.0 SITE DESCRIPTION

The replacement culvert will be located on the same alignment as the existing culvert that is in the Township of South Huron near Powassan, Ontario, on Highway 11 approximately 700 m south of Purdon Line and Main Street.

The existing culvert at Station 21+319 is a 900 millimetre diameter corrugated steel pipe (CSP) culvert. The Preliminary Design Report (PDR) dated December 2008 indicates that the condition of the culvert is below minimum tolerable as it is rotted out. Water flow through the culvert was not observed during our investigation.

In general, the topography in the area of the overall project limits consists of rolling terrain separated by creeks and swamps. The ground surface elevation on the west side of the Highway 11 embankment is about Elevation 269 m and the roadway surface at the top of the embankment is at about Elevation 275 m.



### **3.0 INVESTIGATION PROCEDURES**

The fieldwork for the investigation associated with this culvert replacement at Station 21+319 was carried out on November 8, 9, 15 and 19, 2010, during which time a total of four (4) Boreholes (BH09-25 to BH09-28) and four (4) Dynamic Cone Penetration Tests (DCPTs) were advanced at the culvert location. The field investigation was carried out using a Track Mounted D-50 supplied and operated by Walker Drilling Ltd., of Utopia, Ontario for boreholes advanced near the toes of the embankment and using a truck mounted CME 55 supplied and operated by Landcore Drilling of Sudbury, Ontario for the boreholes advanced at the top of the embankment. The location of the boreholes is shown on Drawing 1 following the text of this report.

The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers. Soil samples were obtained continuously or at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573-08). The DCPTs were advanced within 2.5 m of each borehole to determine the depth to refusal and to provide additional information on the density of the soil strata. All boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The boreholes were advanced to depths ranging between 5.3 m and 11.3 m below existing ground surface. In Borehole BH09-28, a total of 3.2 m of bedrock was cored. Boreholes BH09-25 and BH09-27 were advanced to auger refusal and all four DCPTs were terminated on refusal to cone penetration. These depths to refusal do not confirm bedrock surface elevations, but may be inferred to indicate potential proximity to the bedrock surface. Borehole BH09-26 was terminated within a silty sand to sand deposit.

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. It should be noted that groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

The fieldwork was supervised throughout by a member 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 samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury geotechnical 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 and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are included in Appendix B.

Survey stakes were installed near the SBL embankment east toe by Callon Dietz prior to drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the stakes and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the ground surface elevations at the stakes. The borehole locations shown on Drawing 1 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum.



## FOUNDATION REPORT - HIGHWAY 11 SBL STA 21+319 CULVERT REPLACEMENT

The as-drilled borehole locations, ground surface elevations at the drilled locations and borehole depths are summarized below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
09-25	5 102 387.3	316 336.0	270.9	5.3
09-26	5 102 379.1	316 325.5	275.5	11.3
09-27	5 102 381.3	316 314.6	275.4	10.0
09-28	5 102 371.0	316 296.3	268.9	8.5

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

As delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)<sup>1</sup>, this section of Highway 11 lies within the physiographic region known as the Number 11 Strip, which extends along Highway 11 from Gravenhurst to North Bay. This part of the Number 11 Strip physiographic region is near the southwest shoreline of glacial Lake Algonquin. As a result, the streams entering Lake Algonquin deposited sand as delta features and silt and clay settled in deeper offshore water. Sand and gravel was also deposited as an esker which follows the strip from Bondfield to Gravenhurst.

The bedrock in the area consists typically of crystalline granite gneisses of the Powassan Domain of the Central Gneiss Belt, a subdivision of the Grenville Structural Province, as described in *Geology of Ontario, OGS Special Volume 4*<sup>2</sup>.

### 4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets in Appendix A. The results of the laboratory testing are provided in Appendix B. The inferred stratigraphy as encountered in the boreholes is shown on Drawing 1. The stratigraphic boundaries shown on the Record of Borehole sheets and in profile on Drawing 1 are inferred from non continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. 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.

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

<sup>2</sup> *Geology of Ontario*, 1991. Ontario Geological Society Special Volume 4, Part 2. Ministry of Northern Development and Mines, Ontario.





## FOUNDATION REPORT - HIGHWAY 11 SBL STA 21+319 CULVERT REPLACEMENT

It should be noted that the orientation (i.e. north, south, east, west) stated in the text of the report is typically referenced to project north (along the Highway 11 alignment) and therefore may differ from that shown on the drawing which represents magnetic north.

In general, the subsurface stratigraphy along the culvert alignment consists of embankment fill or organic materials underlain by silt to clayey silt, clayey silt to silty clay, silty sand to sand and sand and gravel (where encountered). As discussed in Section 3, bedrock was cored at one borehole location.

### 4.2.1 Fill

Boreholes BH09-26 and BH09-27 were drilled through the embankment and encountered about 130 mm and 150 mm of asphalt at ground surface, respectively. Sand and gravel to sand was found beneath the asphalt in Boreholes BH09-26 and BH09-27 having a thickness of 1.7 and 2.9 m, respectively, and the surface of the layer was at Elevation 275.3 and 275.4 m, respectively. Silty sand to sandy silt fill was encountered below the upper fill at Elevation 272.5 m and 273.6 m in Boreholes BH09-26 and BH08-27, respectively, and was 2.6 m and 4.0 m thick, respectively.

The upper predominantly sand and gravel to sand fill is compact with 'N'-values ranging from 12 blows to 24 blows per 0.3 m of penetration. The lower silty sand to sandy silt fill is very loose to compact with 'N'-values of 0 (weight of hammer) blows at depth to 16 blows per 0.3 m of penetration near the surface of this fill.

The grain size distributions of two samples of the upper fill are presented on Figure B1 in Appendix B and the gradation of two samples of the lower fill is shown on Figure B2.

The water content in the fill ranged from 10 percent to 28 percent.

### 4.2.2 Organics

Organic silt was encountered at the surface of Boreholes BH09-25 and BH09-28, with a thickness of approximately 0.7 m.

The organic silt in Boreholes BH09-28 was inferred to be very loose based on a SPT result of 1 blow per 0.3 m of penetration in Borehole BH09-28.

Water contents of two samples of this material are 42 percent and 47 percent and two organic content tests yielded 5 percent and 7 percent.

### 4.2.3 Silt to Clayey Silt

A deposit of silt to clayey silt was encountered below the organic silt in Borehole BH09-25 and below the embankment fill in Borehole BH09-26 and the deposit was between about 1.0 m and 2.6 metres thick. The surface of the silt to clayey silt ranged between Elevation 269.9 m and 270.2 m. A lower deposit of silt to clayey silt was encountered below the clayey silt to silty clay (discussed below) in Boreholes BH09-26 and BH09-27. The surface of the lower layer was at about Elevation 268.3 m and 268.2 m in Boreholes BH09-26 and BH09-27, respectively, and about 1.3 m and 0.9 m thick, respectively.





SPT 'N'-values of 4 blows to 12 blows per 0.3 m of penetration were obtained in the silt to clayey silt indicating a firm to very stiff consistency. An in situ vane test gave a shear strength value of in excess of 100 kPa.

The silt to clayey silt is of low plasticity based on four Atterberg Limits determinations with plastic limits of 17 and 18 percent, liquid limits of 21 to 23 percent and a plasticity index of 4 to 6 percent. The results of the Atterberg Limit determination are shown on Figure B3.

Grain size distributions of three samples of silt to clayey silt are shown on Figure B4.

The natural water content of the silt to clayey silt layer varied between 32 percent and 45 percent, which is well above the liquid limit values.

#### **4.2.4 Clayey Silt to Silty Clay**

About 0.8 m and 1.3 m thick clayey silt to silty clay layers were encountered in Boreholes BH09-26 and BH09-27, respectively, and the surface of the layers were encountered at about Elevation 269.0 m and 269.6 m, respectively.

One SPT N value of 6 blows per 0.3 m of penetration was obtained during the SPT testing in the clayey silt to clayey silt layer. In situ field shear vane testing was conducted within the deposit in Boreholes BH09-26 and the shear strength was approximately 87 kPa indicating a stiff consistency.

Two Atterberg Limits tests on samples of the layer yielded plastic limits of 18 percent and 20 percent, liquid limits of 35 percent and 39 percent and plasticity indices of 17 percent and 19 percent. The results of the Atterberg Limit determination are shown on Figure B5.

The natural water content of two samples of this layer is 39 percent and 43 percent which is near the liquid limit value.

#### **4.2.5 Silty Sand to Sand**

The silt and silty clay in all four boreholes was underlain by silty sand to sand trace to some gravel with the surface ranging from Elevation 266.8 to 267.6 m. The silty sand to sand was about 1.3 m to 3.2 m thick in Boreholes BH09-25, BH09-27 and BH09-28. Borehole BH09-26 was terminated after exploring the deposit for about 3.1 m. The sands are compact to very dense based on measured SPT 'N'-values of 10 blows to 64 blows per 0.3 m of penetration. The gradation of three samples of the silty sand to sand encountered is presented on Figure B6. The natural water content of samples of silty sand to sand is 9 percent to 10 percent.

#### **4.2.6 Sand and Gravel**

The silty sand encountered in BH09-25 was underlain by a sand and gravel layer of 0.7 m thickness. The surface elevation of the sand and gravel layer is at Elevation 266.3 m.

The grain size distribution of the sand and gravel layer is presented on Figure B7 in Appendix B.



#### **4.2.7 Bedrock/ Refusal**

In Borehole BH09-28, bedrock was encountered at a depth of 5.3 m (Elevation 263.6 m) and cored for 3.2 m. Based on the cored bedrock samples, the bedrock generally consists of gneiss, and may be described as fresh, medium grained and grey. The Rock Quality Designation (RQD) measured on the two core runs is 88 percent and 100 percent, generally indicating a rock mass of excellent quality. The Total Core Recovery (TCR) of the samples recovered is 100 percent.

In Borehole BH09-25, refusal to auger and DCPT cone penetration occurred at a depth of 5.3 m and 5.1 m, respectively, corresponding to Elevation 265.6 m and 265.8 m, respectively. In Borehole BH09-26, refusal to auger and DCPT cone penetration occurred at a depth of 11.3 m and 10.2 m, respectively, corresponding to Elevation 264.2 m and 265.3 m, respectively. In Borehole BH09-27, refusal to auger and DCPT cone penetration occurred at a depth of 10.0 m and 9.3 m, respectively, corresponding to Elevation 265.4 m and 266.1 m, respectively. Where bedrock was not cored, the depths to refusal, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface.

#### **4.2.8 Groundwater Conditions**

Boreholes BH09-25 and BH09-28 were noted to be dry upon completion of drilling. Water levels observed in Boreholes BH09-26 and BH09-27 upon completion of drilling were 6.0 m and 6.8 m below existing ground surface corresponding to Elevation 268.7 m and 269.4 m, respectively. Groundwater/surface water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

### **5.0 CLOSURE**

The field personnel supervising the drilling program were Mr. Ed Savard and Mr. Mathew Riopelle. This report was prepared by Mr. Matthew Thibeault in conjunction with Mr. André Bom, P.Eng. Mr. Fintan Heffernan, one of Golder's MTO Designated Contacts, carried out a quality control review and reviewed the technical aspects of the report on behalf of Mr. Jorge M. A. Costa, P.Eng., the Designated MTO Contact for this project.



## FOUNDATION REPORT - HIGHWAY 11 SBL STA 21+319 CULVERT REPLACEMENT

### Report Signature Page

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# **PART B**

**FOUNDATION DESIGN REPORT**

**HIGHWAY 11 SBL CULVERT REPLACEMENT AT STATION 21+319**

**TOWNSHIP OF SOUTH HIMSWORTH, ONTARIO**

**MINISTRY OF TRANSPORTATION, ONTARIO**

**GWP 5416-06-00**



## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

This section of the report provides an interpretation of the factual geotechnical data obtained during the investigation and recommendations on the foundation aspects of design of the proposed works. The recommendations provided are intended for the guidance of the design engineer. Where comments are made on construction, they are provided to highlight aspects of construction that could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the subsurface information provided as such interpretation may affect their proposed construction methods, costs, equipment selection, scheduling and the like.

### **6.1 General**

The project involves the rehabilitation of a 3.5 km section of Highway 11 (NBL and SBL) south of Powassan under GWP 323-00-00, including foundation investigation and design for the replacement of a three (3) SBL culverts. In a separate contract for the rehabilitation of 13.0 km of Highway 11 (NBL only) north of Powassan under GWP 5416-06-00, five (5) NBL culverts will be replaced including the culvert crossing Windsor Creek and a new NBL and SBL wildlife crossing will be constructed.

This section of the report provides foundation design recommendations for the proposed culvert replacement on Highway 11 SBL at Station 21+319. The scope of work includes an assessment of stability and settlement of the embankment for the culvert replacement and providing recommendations on a preferred mitigation option that may be required as a means to minimize total and differential settlements (if applicable), geotechnical resistances (as applicable), and estimates of horizontal and vertical strains and maximum joint opening allowances along the culvert. The work also includes addressing foundation aspects for the final design and construction of head walls and wing walls associated with the culvert (where applicable), construction concerns and potential geotechnical problems associated with the culvert, including localized sub-excavation of soft/organic materials, placement of new fill and requirements for erosion protection and bedding materials.

We understand from URS that the culvert to be constructed under the SBL embankment at Station 19+545 will be a concrete pipe 1.2 m in diameter. The replacement culvert will be installed at approximately the same invert elevation as the existing culvert. No grade raises or embankment widening are planned in the area of this culvert. The existing culvert is 900 mm diameter CSP about 36 m in length. The existing inverts at the inlet (east side) and outlet (west side) are Elevation 270.5 m and 269.2 m, respectively. Head walls and wing walls will not be required.

The subsoils along the culvert alignment generally consist of embankment fill materials and surficial organic silt (where encountered), underlain by silt to clayey silt, clayey silt to silty clay and silty sand to sand. Bedrock was encountered at Elevation 263.6 m at Borehole BH09-28 and auger and DCPT refusal was encountered between Elevation 265 m and 266 m at the remaining boreholes (except Borehole BH09-26, which did not encounter auger refusal). Details of the subsurface conditions along this culvert are presented in Section 4.2 and shown in profile on Drawing 1 following the text of this report.



## **6.2 Culvert Types**

The analysis and recommendations in this report assume that a concrete circular culvert will be installed at the site. However, foundation design recommendations for a concrete box culvert are also provided in the event that an alternative culvert type is considered.

## **6.3 Culvert Construction Options**

We understand that the existing embankment will not be widened or raised. Should a widening or grade raise of the embankment be required, the timing of culvert construction will be an essential factor in determining the preferred mitigation option as the foundation strata at the culvert crossing will undergo settlement as a result of any additional loading from widening of the embankment or raising the embankment grade. The following alternatives for culvert construction can be considered (where applicable, giving due consideration to the recommended foundation mitigation option for the embankment):

- concurrent with phased embankment construction between the two sides of the roadway; or
- following full sub-excavation of any soft soils along the culvert alignment and concurrent with embankment reconstruction.

Where relatively small settlements are estimated to occur as a result of the embankment construction, culvert construction may be carried out concurrently with the embankment. The provision of camber for the culvert replacement is not required since the foundation soils are such that excessive post-construction or differential settlements are not anticipated. Should an embankment widening or grade raise be identified at this location, additional analysis will be required to address settlement and stability for the revised embankment geometry and to provide recommendations for possible alternatives for culvert construction to mitigate settlements and improve long-term performance.

At this site, the recommended construction alternative is to remove any organic materials, backfill the sub-excavated area with Granular 'B' Type II material and bedding and construct the culvert concurrent with embankment reconstruction.

## **6.4 Stability, Settlement and Horizontal Strain**

The following sections summarize the methods utilized to carry out analyses of stability and settlement of the culvert and methods utilized to evaluate horizontal strains along the culvert beneath the influence of the proposed embankment loading.

The analyses assume that any organic soils beneath the culvert alignment will be removed prior to construction as discussed in Section 6.7.1.1 and that granular fill (i.e. sand and gravel material such as Granular 'B' Type II) will be used for replacement of sub-excavated material. The piezometric conditions required in the analyses were based on the unstabilized groundwater levels observed during drilling, which were noted to be at depth; the analysis also took into consideration an assumed water level at the outlet ground surface elevation.



### 6.4.1 Stability

The methodology used to evaluate embankment stability at the culvert location is described below and the results of the analyses are discussed in Section 6.4.1.3.

#### 6.4.1.1 Methodology

Limit equilibrium slope stability analyses were performed using the commercially available program GeoStudio 2007 (Version 7.13), produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. For all analyses, the Factor of Safety of numerous potential failure surfaces was computed in order to establish the minimum Factor of Safety. The Factor of Safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. A target minimum Factor of Safety of 1.3 is normally adopted for the design of embankment slopes under static conditions. This Factor of Safety is considered adequate for the embankment at this site considering the design requirements and the field data available and is based on deep-seated, global failure surfaces that would affect the operation of the roadway. The stability analyses were performed to check that the target minimum Factor of Safety was achieved for the embankment height and geometry at the culvert location.

#### 6.4.1.2 Parameter Selection

The embankment cross-section modelled in the analyses is assumed to be constructed of granular fill (such as MTO Special Provision (SP) 110S13 (Aggregates) Granular 'B' Type I or Type II), having a unit weight of 21 kN/m<sup>3</sup> above the water level and 20 kN/m<sup>3</sup> below the water level and an effective friction angle of 35° and is constructed with 2H:1V side slopes to 2.5 m high above the surrounding ground surface.

The subsoils encountered below the culvert alignment are composed of both cohesive and cohesionless soils.

For the cohesive layers, total stress parameters were employed in the analysis. The total stress parameters (i.e. undrained shear strength –  $s_u$ ) for the cohesive soils were assessed based on the results of the in situ field vane tests and from correlations with the SPT results.

For the cohesionless layers, effective stress parameters were employed in the analyses assuming drained conditions.

The simplified stratigraphy together with the associated strength and unit weight employed for the different native soil types for the culvert are summarized below.

Soil Type	Unit Weight (kN/m <sup>3</sup> )	Undrained Shear Strength (kPa)	Angle of Internal Friction (°)
Silt to Clayey Silt	18	-	28
Clayey Silt to Silty Clay	18	100	-
Silty Sand to Sand	19	-	30
Sand and Gravel	19	--	35





### **6.4.1.3 Results of Analysis**

The stability analysis performed on the proposed embankment at the culvert location indicates that after completion of construction, the embankment will have a Factor of Safety of 1.3 or greater for deep-seated, global failure surfaces that would impact the operation of the roadway.

### **6.4.2 Settlement**

As the existing embankment will not be raised or widened at the location of the culvert replacement, settlement of the foundation soils is not anticipated. Should the embankment require widening or an increase to the grade, settlement analysis will be required and recommendations provided for mitigation as appropriate.

It is recommended that consideration be given to the use of SP 110S13 (Aggregates) Granular 'B' Type I or II for 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. It is recommended that the fines content of the Granular 'B' Type II fill used for embankment construction below the water be restricted to a maximum of 5 percent passing the No. 200 sieve, to reduce the potential for segregation of fines during placement and to reduce the potential post-construction settlement and associated maintenance needs.

### **6.4.3 Horizontal Strain**

Horizontal strain along the culvert is not expected to occur provided the proposed embankment geometry does not change from the current geometry. Should the embankment be widened or raised compared with the existing geometry, a reassessment of the potential magnitude of horizontal strain will be required.

## **6.5 Design recommendations for Concrete Box Culvert**

### **6.5.1 Geotechnical Resistance**

If a concrete box culvert is considered, a factored geotechnical axial resistance at Ultimate Limits States (ULS) of 200 kPa is recommended for design for an assumed 1.2 m wide box culvert founded on a properly prepared subgrade of granular fill overlying the native firm to very stiff silt/clayey silt/silty clay soils. The geotechnical resistance given is 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*.

It is noted that at this site, the loading on the foundation soils below the culverts and the associated total settlement at the culvert locations will be governed by the design height of the overlying and adjacent widening embankment fills. As such, it is recommended that the structural engineer exercise caution when utilizing the value(s) of the geotechnical axial resistance at 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 1.2 m wide box culvert constructed on the properly prepared granular subgrade overlying the native soils may be taken as 125 kPa.

### 6.5.2 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of a concrete box culvert and the granular fill/bedding placed following sub-excavation 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 culvert.

Interface Materials	Coefficient of Friction
Precast Concrete Box Culvert on Compacted Granular 'A' or 'B' Type II	$\tan \delta = 0.45$
Cast-in-Place Concrete Box Culvert on Compacted Granular 'A' or 'B' Type II	$\tan \phi' = 0.58$

### 6.5.3 Lateral Earth Pressures – Culvert

The lateral earth pressures acting on the side walls of the culvert (head walls and/or wing walls will not be required) 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 culvert walls.

The following recommendations are made concerning the design of the box culvert.

- Select, free draining granular fill meeting the specifications of SP 110S13 (Aggregates) Granular 'A' or Granular 'B' Type II but with less than 5 percent passing the No. 200 (0.075 mm) sieve should be used as backfill behind the culvert. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS 501 (Compacting). Backfill should be placed with a maximum of 200 mm loose lift thickness. Other aspects of the granular backfill requirements for concrete culverts should be in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culvert, in accordance with *CHBDC* Section 6.9.3 and Figure 6.6. Other surcharge loadings should be accounted for in the design, as required.
- For a box culvert, granular fill should be placed in a zone with the width equal to at least 2.0 m behind the back of the culvert (in accordance with Figure C6.20(a) of the *Commentary* to the *CHBDC*).
- For a box culvert, 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:



	Granular Fill
Soil unit weight:	21 kN/m <sup>3</sup>
Coefficients of static lateral earth pressure:	
Active, $K_a$	0.31
At rest, $K_o$	0.47

If the box culvert allows for lateral yielding, active earth pressures may be used in the geotechnical design of the structure design. If the culvert does 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 a restrained structure, may be taken as presented in Table C6.6 of the *Commentary* to the CHBDC.

## 6.6 Culvert Construction Considerations

The following sections discuss general aspects of subgrade preparation and embankment construction at the culvert site, including removal of organic materials.

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 Type 3 soil. In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of the existing Highway 11 and any associated side roads and detours during excavation operations, where applicable.

### 6.6.1.1 Removal of Organics

Based on the information from the boreholes advanced during the field investigation, the thickness of organic deposits (i.e. peat or organic silt) at the culvert location is up to about 0.7 m thick at the toes of the embankment adjacent to the creek. Prior to the placement of any bedding material and fill for new construction, all organic soils should be stripped from the plan limits of the proposed works. Construction of the embankment section in sub-excavation areas should be in accordance with OPSP 203.010 (Embankments Over Swamp, New Construction).

### 6.6.1.2 Replacement/Backfill below Base of Culvert

For replacement of sub-excavated material below the water level along the culvert alignment, it is recommended that Granular 'B' Type II be used to backfill the excavation. In addition, in this instance (i.e. typically backfill below the water table), the granular fill should to be end-dumped simultaneously as the excavation advances in accordance with OPSS 209 (Embankments Over Swamps and Compressible Soils).

### 6.6.1.3 Temporary Shoring

We understand that the culvert will be replaced in stages with traffic routed to a single lane during culvert construction on each side of the embankment. Temporary excavation support systems for staged construction should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems) and should be designed to Performance Level 2 for any excavation adjacent to existing roadways.



## FOUNDATION REPORT - HIGHWAY 11 SBL STA 21+319 CULVERT REPLACEMENT

The support systems may be designed using the following parameters:

SOIL TYPE	COEFFICIENT OF EARTH PRESSURE			INTERNAL ANGLE OF FRICTION (degrees)	UNIT WEIGHT (kN/m <sup>2</sup> )
	Active, K <sub>a</sub>	At Rest, K <sub>o</sub>	Passive, K <sub>p</sub>		
Existing Granular Fill	0.33	0.50	3.0	30	20
Silt/Clayey Silt/Silty Clay	0.40	0.55	2.7	27	18
Silty Sand to Sand	0.30	0.50	3.0	30	19

The support system should also be checked with an undrained shear strength of 100 kPa for the silt/clayey silt/silty clay.

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.

### 6.6.2 Bedding and Backfill above Base of Culvert

The bedding, levelling pad and backfill requirements for a circular concrete pipe culvert should be in accordance with OPS D 802.031 (Rigid Pipe, Bedding Cover and Backfill, Type 3 Soil - Earth Excavation) and culvert construction should be in accordance with OPSS 421 (Pipe Culvert Installation in Open Cut). It is important that the backfill at the haunches be well compacted.

A precast box culvert, if used as an alternative to the circular concrete pipe culvert, should be constructed in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). The box culvert should be constructed on a minimum 300 mm thick layer of SP 110S13 (Aggregates) Granular 'B' Type II material for bedding purposes and partial frost protection. In addition, a minimum 75 mm thick uncompacted levelling pad consisting of concrete fine aggregate meeting the grading requirements specified in OPSS 1002 (Aggregates for Concrete) should be provided in both dry and wet conditions as shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

In dry conditions, the bedding should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 95 percent of the Standard Proctor maximum dry density (SPMDD) of the material as specified in OPSS 501 (Compacting). Where bedding material is placed in wet conditions, Granular 'B' Type II should be used. The structural design of the culvert should take into consideration the conditions for bedding placement and compaction in accordance with the requirements of Section 7.8.3.6 of the CHBDC. For culverts where the invert level is located at or below the groundwater table, the structural design should assume that the bedding material will only achieve 90 percent of the SPMDD during placement.

The culvert should be designed for the full overburden stress and appropriate live loads, assuming a fill unit weight of 22 kN/m<sup>3</sup> for Granular 'A' and 21 kN/m<sup>3</sup> for Granular 'B' Type II backfill above and surrounding the culvert.



Inspection should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used, and that field density testing is carried out on fills placed above the water level to check that adequate levels of compaction have been achieved.

### **6.6.3 Erosion Protection**

Provision 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 clay seal or concrete cut-off wall 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 (3) times the culvert height and along the adjacent slopes to a height of two (2) 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.

### **6.6.4 Control of Surface Water**

Excavation within the plan limits of the proposed culvert alignment will be required to remove organic soils prior to 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 seepage can be controlled by using properly filtered sumps at the base of the excavation. Sumps should be maintained outside the footing areas.

A precast concrete box culvert may be placed and the associated bedding materials constructed 'in-the-wet' and, as such, control of surface water and groundwater would not be required at this culvert location under such conditions.



## **7.0 CLOSURE**

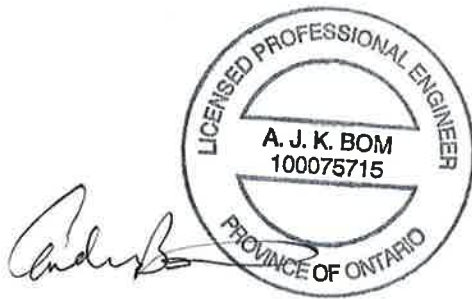
This report was prepared by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, one of Golder's MTO Designated Contacts, carried out a quality control review and reviewed the technical aspects of the report on behalf of Mr. Jorge M. A. Costa, P.Eng., the Designated MTO Contact for this project.



## FOUNDATION REPORT - HIGHWAY 11 SBL STA 21+319 CULVERT REPLACEMENT

### Report Signature Page

GOLDER ASSOCIATES LTD.



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Designated MTO Contact



MT/AB/FJH/lb/cl

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### REFERENCES

- Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-06. 2006. CSA Special Publication, S6.1-06. Canadian Standard Association.
- Chapman, L.J., and Putnam, D.F., 1984. The Physi ography of Southern Ontario. Ontario Geological Survey, Special Volume 2, 3<sup>rd</sup> Edition. Ontario Ministry of Natural Resources.
- Geology of Ontario, 1991. Ontario Geological Society, Special Volume 4, Part 2. Eds . P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.

### STANDARDS:

#### ASTM International:

- |                |   |
|----------------|---|
| ASTM D1586-08a | Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils |
| ASTM D2573     | Standard Test Method for Field Vane Shear Test in Cohesive Soil                             |

#### Contract Design Estimating and Documentation (CDED):

- |                          |   |
|--------------------------|---|
| Special Provision 110S13 | Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material. May 2010. Amendment to OPSS 1010. |
|--------------------------|---|

#### Ontario Occupational Health and Safety Act:

- |                           |                                     |
|---------------------------|-------------------------------------|
| Ontario Regulation 213/91 | Construction Projects               |
| Ontario Regulation 443/09 | Amendment to Ontario Regulation 213 |

#### Ontario Provincial Standard Drawing:

- |              |  |
|--------------|--|
| OPSD 203.010 | Embankments Over Swamp – New Construction.                                       |
| OPSD 802.031 | Rigid Pipe Bedding, Cover and Backfill Type 3 Soil - Earth Excavation.           |
| OPSD 803.010 | Backfill and Cover for Concrete Culverts With Spans less than or equal to 3.0 m. |
| OPSD 810.010 | Rip-Rap Treatment for Sewer and Culvert Outlets.                                 |

#### Ontario Provincial Standard Specification:

- |          |   |
|----------|---|
| OPSS 209 | Construction Specification for Embankments Over Swamps and Compressible Soils.                      |
| OPSS 421 | Construction Specification For Pipe Culvert Installation In Open Cut.                               |
| OPSS 422 | Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut. |
| OPSS 501 | Construction Specification for Compacting.  |



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## FOUNDATION REPORT - HIGHWAY 11 SBL STA 21+319 CULVERT REPLACEMENT

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OPSS 539	Construction Specification for Temporary Protection Systems.
OPSS 1002	Material Specification for Aggregates – Concrete.
OPSS 1205	Material Specification for Clay Seal.

Ontario Water Resources Act:

Ontario Regulation 372/97    Amendment to Ontario Regulation 903

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

CONT No.  
WP No. 5416-06-00

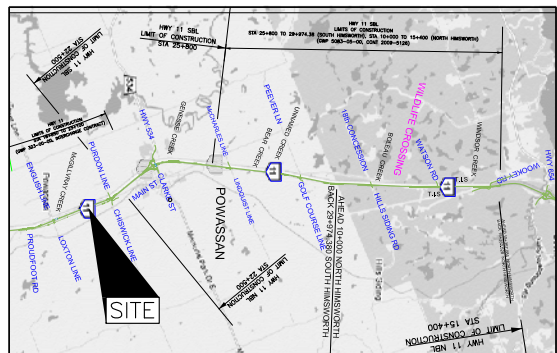


HIGHWAY 11  
CULVERT AT STA 21+319 SBL  
BOREHOLE LOCATIONS AND  
SOIL STRATA

SHEET



**Golder Associates Ltd.**  
SUDBURY, ONTARIO, CANADA



KEY PLAN  
SCALE  
2.5 0 2.5 km

LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
BH09-25	270.9	5102387.3	316336.0
BH09-26	275.5	5102379.1	316325.5
BH09-27	275.4	5102381.3	316314.6
BH09-28	268.9	5102371.0	316296.3

NOTES

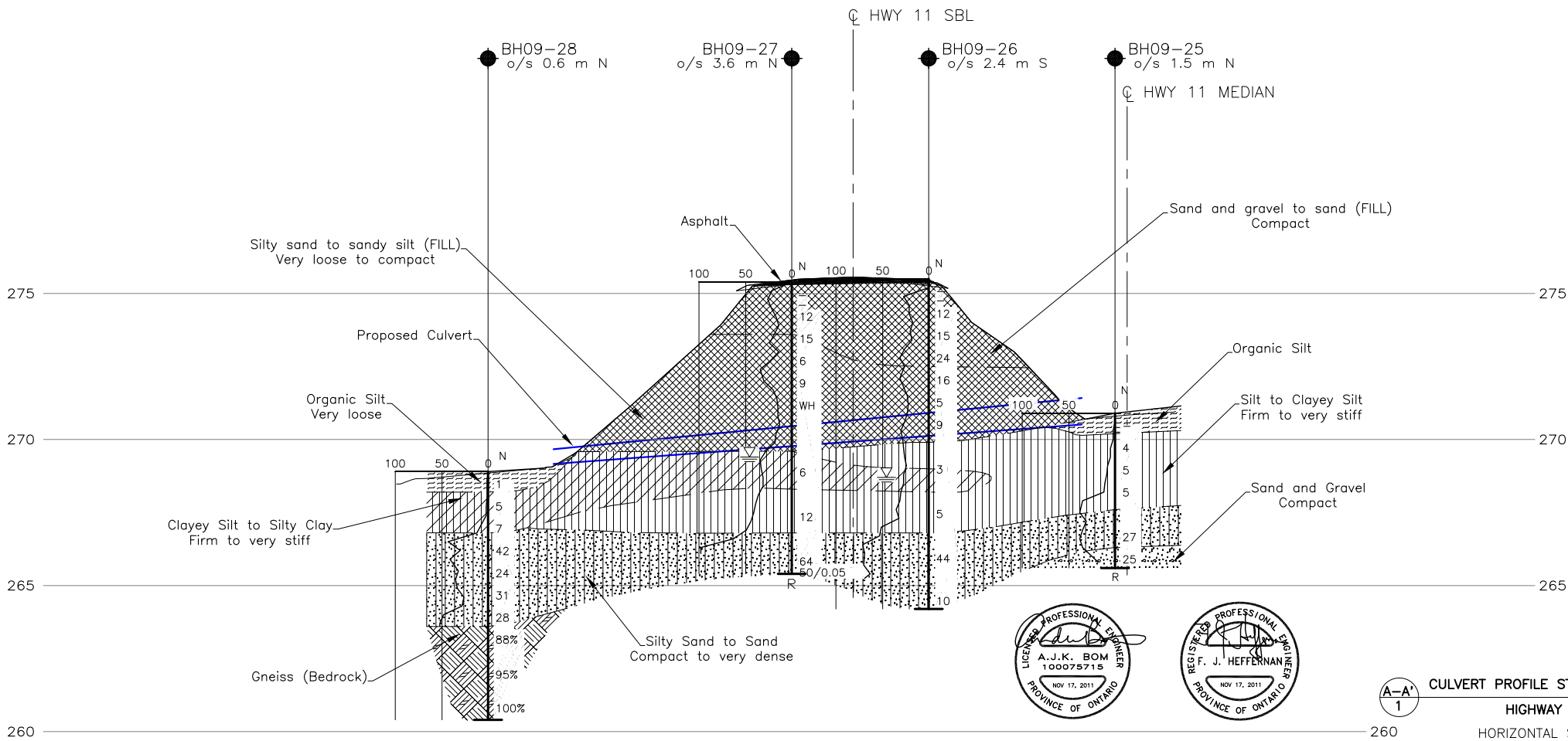
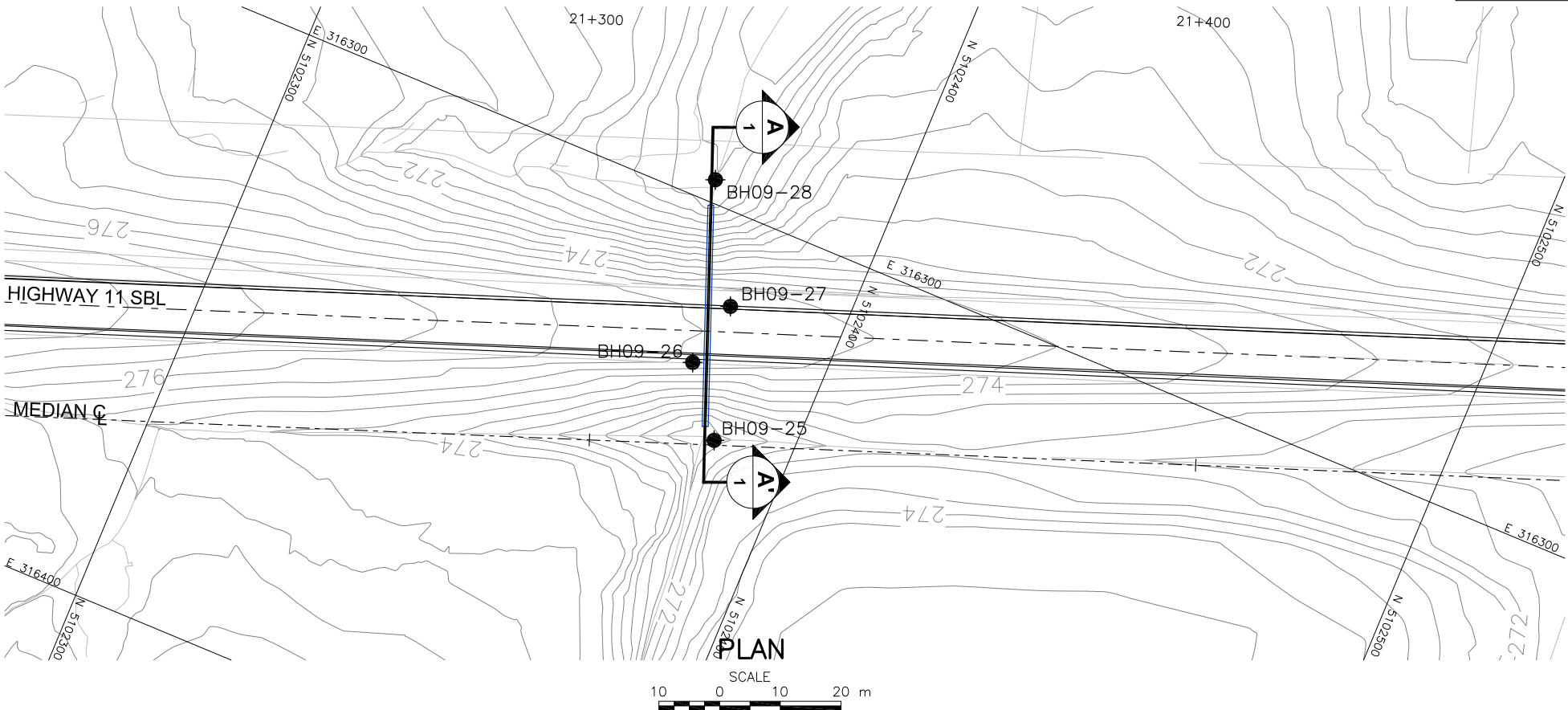
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

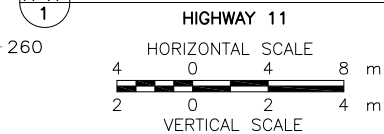
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS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

REFERENCE

Base plans provided in digital format by URS, drawing file nos. BasePlan HWY 11.dwg dated June 4, 2010, received June 4, 2010. Keyplan provided in digital format by URS, Keyplan received June 3, 2011.



CULVERT PROFILE STA. 21+319 (SBL)



NO.	DATE	BY	REVISION
Geocres No. 31L-155			
HWY. 11		PROJECT NO. 09-1191-0042	DIST.
SUBM'D.	CHKD. AB	DATE: NOV 2011	SITE:
DRAWN: JJJ	CHKD.	APPD. FJH	DWG. 1



# **APPENDIX A**

## **Record of Boreholes**



## LIST OF SYMBOLS

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

### 1. GENERAL

$\pi$	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
V	volume
W	weight

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. stress: $\Delta\sigma$
$\epsilon$	linear strain
$\epsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s/\rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

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

#### (a) Index Properties (continued)

w	water content
$w_l$	liquid limit
$w_p$	plastic limit
$I_p$	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
$C_a$	coefficient of secondary consolidation
$m_v$	coefficient of volume change
$c_v$	coefficient of consolidation
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

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

Notes: 1  $\tau = c' + \sigma' \tan \phi'$   
2 Shear strength = (Compressive strength)/2



## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

AS Auger sample  
BS Block sample  
CS Chunk sample  
SS Split-spoon  
DS Denison type sample  
FS Foil sample  
RC Rock core  
SC Soil core  
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 cm<sup>2</sup> O 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.

### V. MINOR SOIL CONSTITUENTS

Percent 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 (cohesionless) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

### III. SOIL DESCRIPTION

#### (a) 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<sup>1</sup>  
CIU consolidated isotropically undrained triaxial test with porewater pressure measurement<sup>1</sup>  
 $D_R$  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  
C 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)  
 $\gamma$  unit weight

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

PROJECT		RECORD OF BOREHOLE		No BH09-25		1 OF 1		METRIC					
W.P.		LOCATION		ORIGINATED BY		DIST		BOREHOLE TYPE					
DATE		COMPILED BY		CHECKED BY		BOREHOLE TYPE		BOREHOLE TYPE					
09-1191-0042		N 5102387.3; E 316336.0		MR		11		108 mm I.D. Continuous Flight, Hollow Stem Augers					
Geodetic		November 19, 2010		JL		AB							
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	GR SA SI CL
270.9	GROUND SURFACE												
0.0	ORGANIC SILT, trace to some sand, trace gravel Brown to black Moist to wet		1	AS	-							OC = 5.0%	
270.2													
0.7	SILT to CLAYEY SILT, trace sand, trace organics in upper samples Firm to very stiff Grey Moist to wet		2	SS	4		270						
			3	SS	5		269						0 2 55 43
			4	SS	5		268						
267.6													
3.3	Silty SAND, some gravel, trace clay Compact Grey Moist		5	SS	27		267						
266.3													
4.6	SAND and GRAVEL, some silt Compact Grey Moist		6	SS	25		266						42 40 (18)
265.6													
5.3	END OF BOREHOLE AUGER REFUSAL  Note:  1. Attempted vane at 3.3 m depth, could not turn vane.  2. Borehole dry upon completion of drilling.  3. Advanced DCPT 1.0 m south of Borehole BH09-25. Refusal at a depth of 5.1 m (Elev. 265.8 m).												



PROJECT		09-1191-0042		<b>RECORD OF BOREHOLE No BH09-26</b>		1 OF 1 <b>METRIC</b>								
W.P.		5416-06-00		LOCATION		N 5102379.1; E 316325.5								
DIST		HWY 11		BOREHOLE TYPE		108 mm I.D. Continuous Flight, Hollow Stem Augers								
DATUM		Geodetic		DATE		November 9, 2010								
						ORIGINATED BY MR								
						COMPILED BY JJJ								
						CHECKED BY AB								
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						
275.5	GROUND SURFACE							20 40 60 80 100						
0.0	ASPHALT (130 mm)		1	AS	-									
	Sand and gravel to sand, some silt (FILL)		2	AS	-									
	Compact													
	Brown													
	Moist		3	SS	12									
			4	SS	15									
			5	SS	24									
272.5														
3.0	Silty sand to sandy silt, trace to some gravel (FILL)		6	SS	16									25 50 18 7
	Loose to compact		7	SS	5									10 50 27 13
	Brown to grey													
	Moist		8	SS	9									
269.9														
5.6	SILT, some sand, trace clay, trace organics													
	Brown to grey		9a	SS	3									
269.0														
6.5	CLAYEY SILT to SILTY CLAY		9b											
	Stiff													
	Grey													
	Wet													
268.2														
7.3	SILT to CLAYEY SILT		10	SS	5									
	Firm													
	Grey													
	Wet													
267.3														
8.2	Augers grinding below 8.2 m depth.													
	Silty SAND to SAND, trace gravel													
	Compact to dense		11	SS	44									
	Grey													
	Wet													
			12	SS	10									4 84 (12)
264.2														
11.3	END OF BOREHOLE													
	Note:													
	1. Water level at a depth of 6.8 m below ground surface (Elev. 268.7 m) upon completion of drilling.													
	2. Advanced DCPT 2.5 m south of Borehole BH09-26. Refusal at a depth of 10.2 m (Elev. 265.3 m).													

PROJECT 09-1191-0042			RECORD OF BOREHOLE No BH09-27			1 OF 1 METRIC							
W.P. 5416-06-00			LOCATION N 5102381.3; E 316314.6			ORIGINATED BY MR							
DIST HWY 11			BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers			COMPILED BY JJL							
DATUM Geodetic			DATE November 8 and 9, 2010			CHECKED BY AB							
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
275.4	GROUND SURFACE					20	40	60	80	100			
0.0	ASPHALT (150 mm)		1	AS	-								
0.1	Sand and gravel to sand, trace silt (FILL) Compact Brown Moist		2	AS	-								
			3	SS	12							3 93 (4)	
273.6			4	SS	15								
1.8	Silty sand to sandy silt, trace clay, some gravel (FILL) Very loose to loose Brown to grey Moist		5	SS	6								
			6	SS	9								
			7	SS	WH							12 57 (31)	
			8	SS	1								
269.6													
5.8	SILTY CLAY, trace sand Stiff to very stiff Brown Moist to wet		9	SS	6								
268.3													
7.1	SILT to CLAYEY SILT Stiff Brown to grey Moist to wet		10	SS	12							0 7 73 20	
267.2	Slower augering and grinding below 8.2 m depth. Silty SAND, trace to some clay, trace to some gravel Very dense Brown to grey Moist to wet		11	SS	64								
8.2													
265.4			12	SS	50/0.05							16 56 (28)	
10.0	END OF BOREHOLE SPOON AND AUGER REFUSAL												
Note: 1. Water level at a depth of 6.0 m below ground surface (Elev. 269.4 m) upon completion of drilling. 2. Advanced DCPT 1.5 m north of Borehole BH09-27. Refusal at a depth of 9.3 m (Elev. 266.1 m).													

PROJECT		09-1191-0042		RECORD OF BOREHOLE No BH09-28		1 OF 1 METRIC											
W.P.		5416-06-00		LOCATION		N 5102371.0; E 316296.3											
DIST		HWY 11		BOREHOLE TYPE		108 mm I.D. Continuous Flight, Hollow Stem Augers											
DATUM		Geodetic		DATE		November 15, 2010											
				ORIGINATED BY		MR											
				COMPILED BY		JJL											
				CHECKED BY		AB											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60	W <sub>p</sub> W W <sub>L</sub>	γ	GR SA SI CL					
268.9	GROUND SURFACE																
0.0	ORGANIC SILT Very loose Brown Moist to wet		1	SS	1						OC = 7.1%						
268.2																	
0.7	SILT to CLAYEY SILT, some sand Firm to stiff Brown to grey Moist to wet		2	SS	5		268										
			3	SS	7		267					0 12 74 14					
266.8																	
2.1	Silty SAND, some gravel Compact to dense Brown Moist		4	SS	42		266					22 51 (27)					
			5	SS	24		265										
	Augers grinding at 3.8 m depth.																
			6	SS	31		264					18 56 (26)					
			7	SS	28		263										
263.6																	
5.3	GNEISS (BEDROCK)  Bedrock cored from 5.3 m depth to 8.5 m depth.  For coring details see Record of Drillhole BH09-28.		1	RC	REC 100%		262					RQD = 88%					
			2	RC	REC 100%		261					RQD = 95%					
			3	RC	REC 100%							RQD = 100%					
260.4																	
8.5	END OF BOREHOLE  Note: 1. Borehole dry upon completion of drilling. 2. Advanced DCPT 1.0 m south of Borehole BH09-28. Refusal at a depth of 5.3 m (Elev. 263.6 m).																

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 16/11/11 DATA INPUT:

PROJECT: 09-1191-0042

**RECORD OF DRILLHOLE: BH09-28**

SHEET 1 OF 1

LOCATION: N 5102371.0 ;E 316296.3

DRILLING DATE: November 15, 2010

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: D-50

DRILLING CONTRACTOR: Walker Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	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	
							RECOVERY			R.Q.D. %	FRACT INDEX METRES	DISCONTINUITY DATA						HYDRAULIC CONDUCTIVITY k, cm/s				Diametral Point Load Index (MPa)		RMC -Q AVG
							FLUSH	TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	10 <sup>0</sup>	10 <sup>1</sup>	10 <sup>2</sup>	10 <sup>3</sup>			

		Refer to Previous Page		263.6																										
6	D-50 NQ Coring	GNEISS Fresh Grey Medium grained		5.3	1	GREY 100%																								
7					2	GREY 100%																								
8					3	GREY 100%																								
					260.4																									
9		END OF DRILLHOLE		8.5																										
10																														
11																														
12																														
13																														
14																														
15																														

DEPTH SCALE

1 : 50



LOGGED: MR

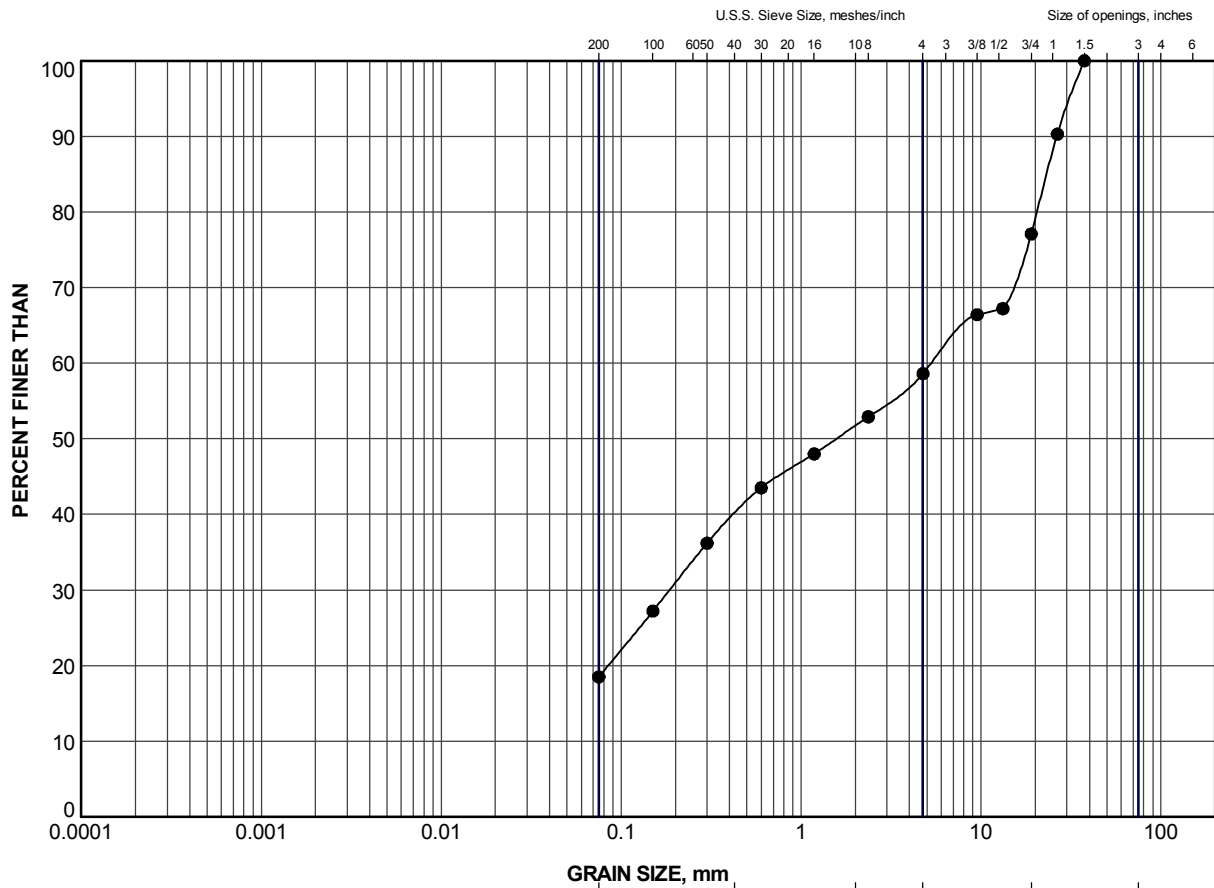
CHECKED: AB

SUD-RCK 09-1191-0042-4000.GPJ GAL-MISS.GDT 16/11/11 DATA INPUT:



# **APPENDIX B**


## **Laboratory Test Results**

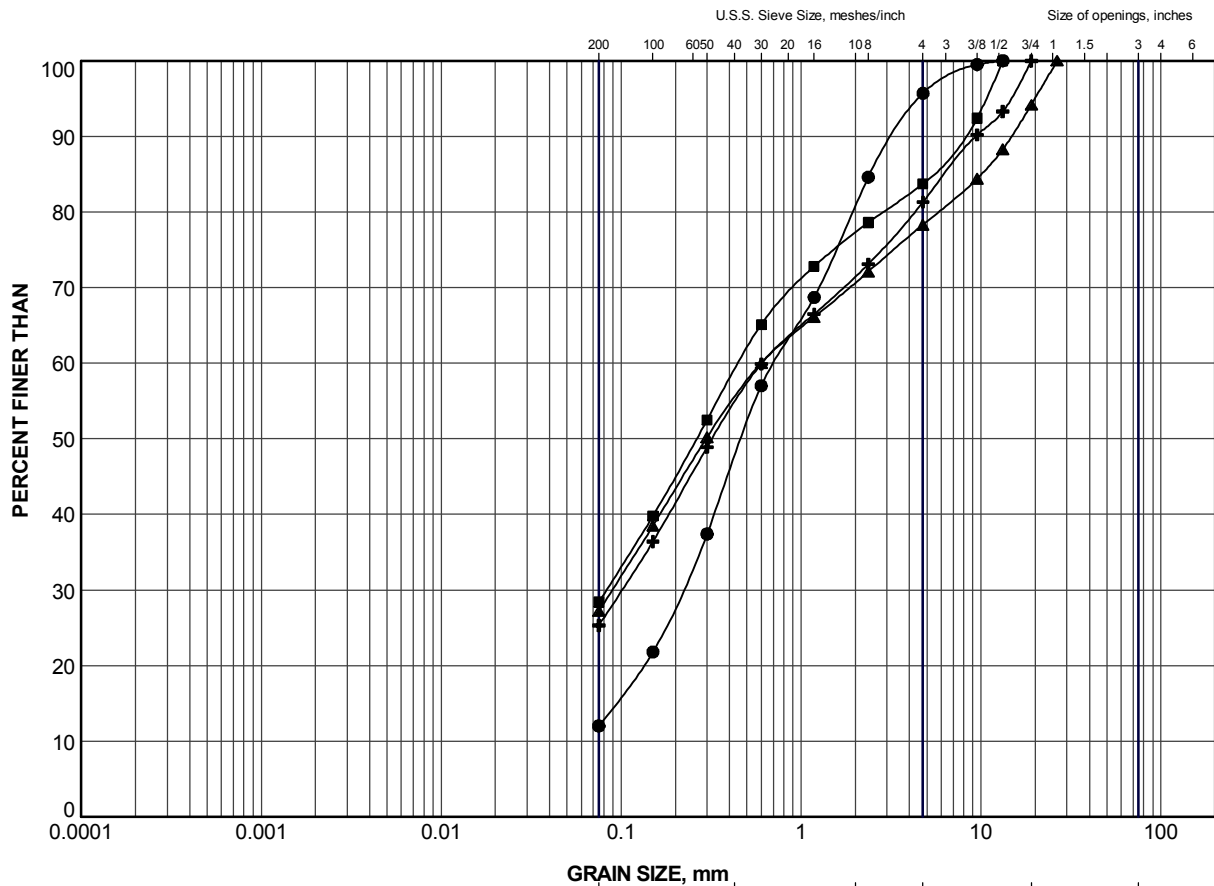


CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-25	6	266.0


PROJECT				
HIGHWAY 11 SBL CULVERT 21+319				
TITLE				
GRAIN SIZE DISTRIBUTION				
SAND AND GRAVEL				
PROJECT No.		09-1191-0042		FILE No. 09-1191-0042-4000.GPJ
DRAWN	JJL	Nov 2011	SCALE	N/A
CHECK	AB	Nov 2011	REV.	
APPR	FJH	Nov 2011		
 <b>Golder Associates</b> SUDBURY, ONTARIO				<b>FIGURE B7</b>



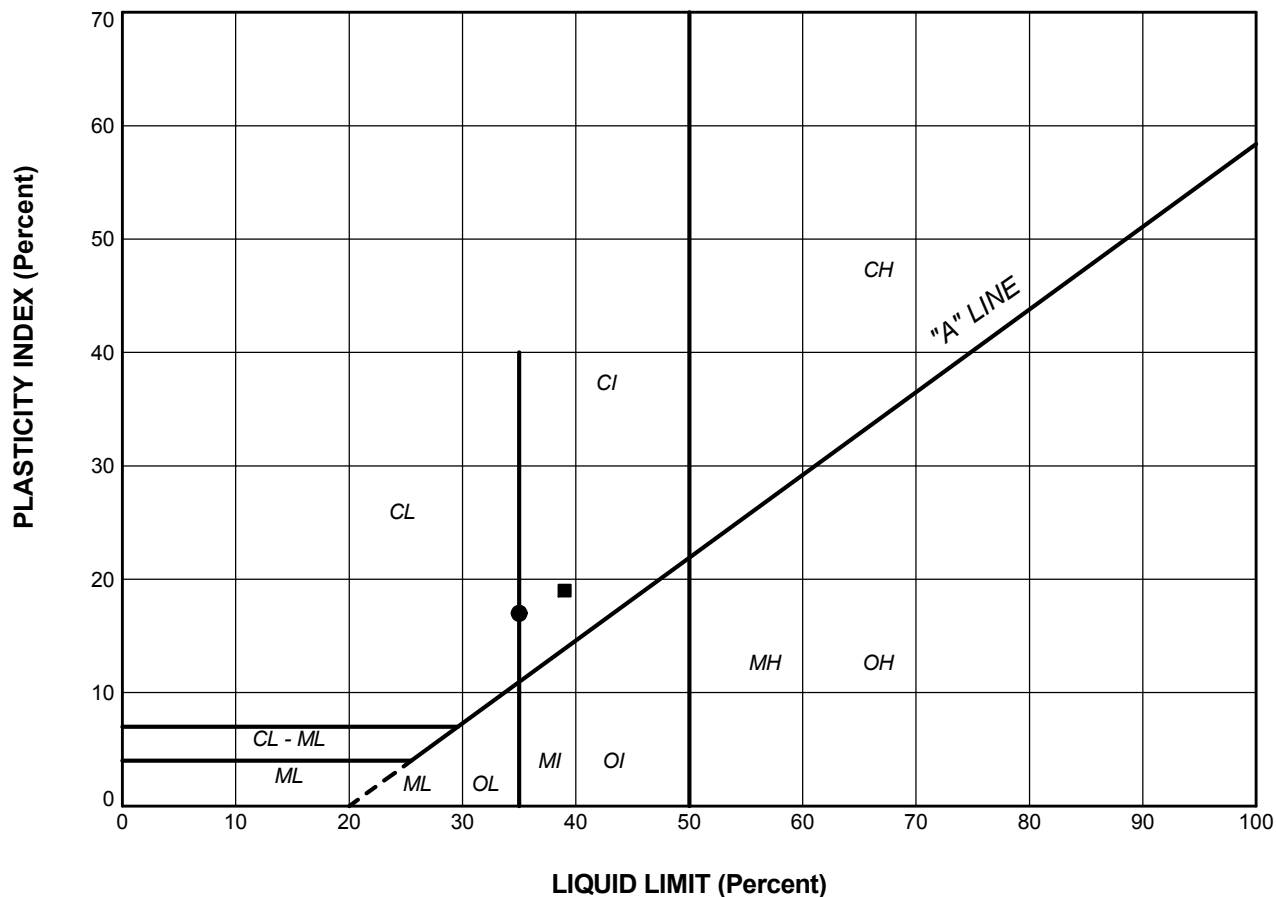
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-26	12	264.5
■	BH09-27	12	265.5
▲	BH09-28	4	266.3
+	BH09-28	7	264.0


PROJECT				
HIGHWAY 11 SBL CULVERT 21+319				
TITLE				
GRAIN SIZE DISTRIBUTION				
SILTY SAND TO SAND				
PROJECT No.		09-1191-0042		FILE No. 09-1191-0042-4000.GPJ
DRAWN	JJL	Nov 2011	SCALE	N/A
CHECK	AB	Nov 2011	REV.	
APPR	FJH	Nov 2011		
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B6</b>	

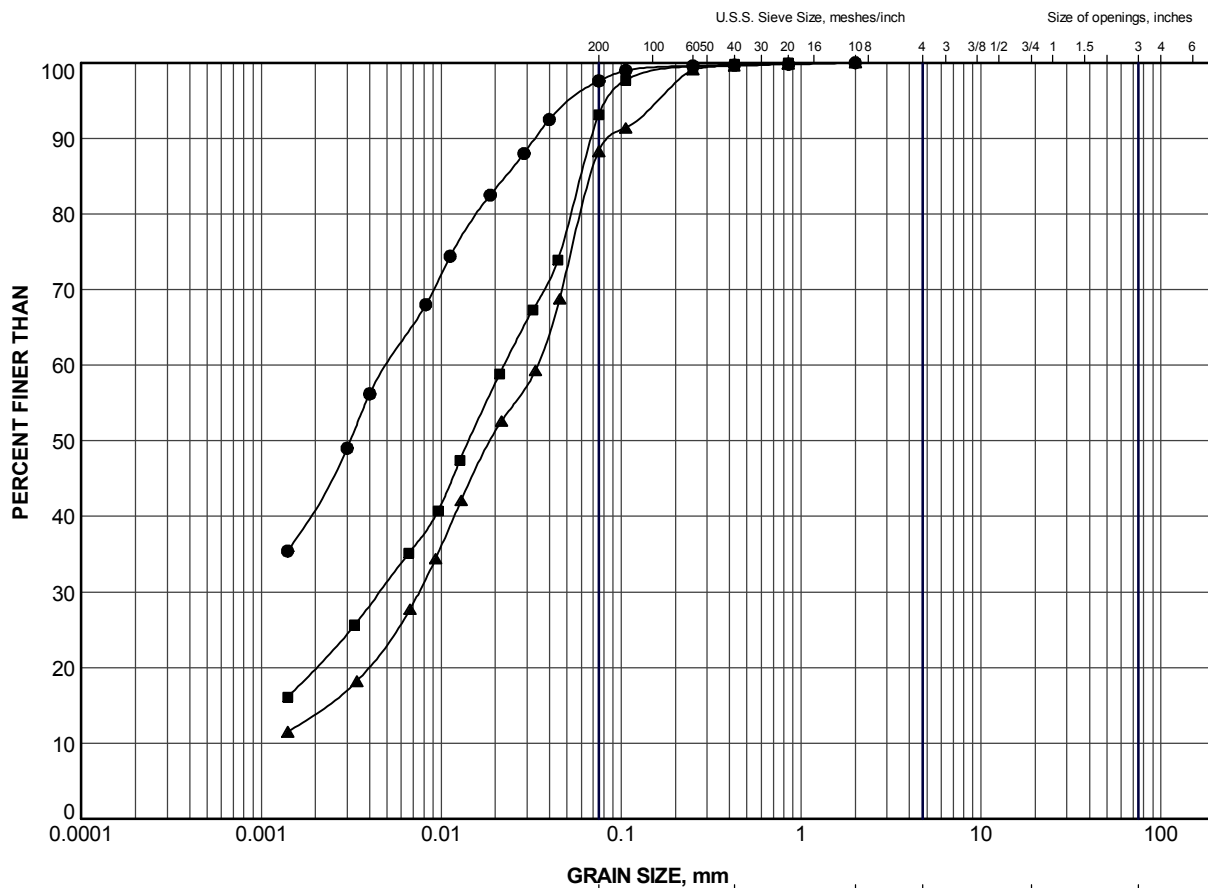




### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH09-26	9b	35.0	18.0	17.0
■	BH09-27	9	39.0	20.0	19.0


PROJECT					
HIGHWAY 11 SBL CULVERT 21+319					
TITLE					
<b>PLASTICITY CHART</b> CLAYEY SILT TO SILTY CLAY					
PROJECT No.		09-1191-0042		FILE No.	09-1191-0042-4000.GPJ
DRAWN	JJL	Nov 2011	SCALE	N/A	REV.
CHECK	AB	Nov 2011			
APPR	FJH	Nov 2011			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B5</b>		

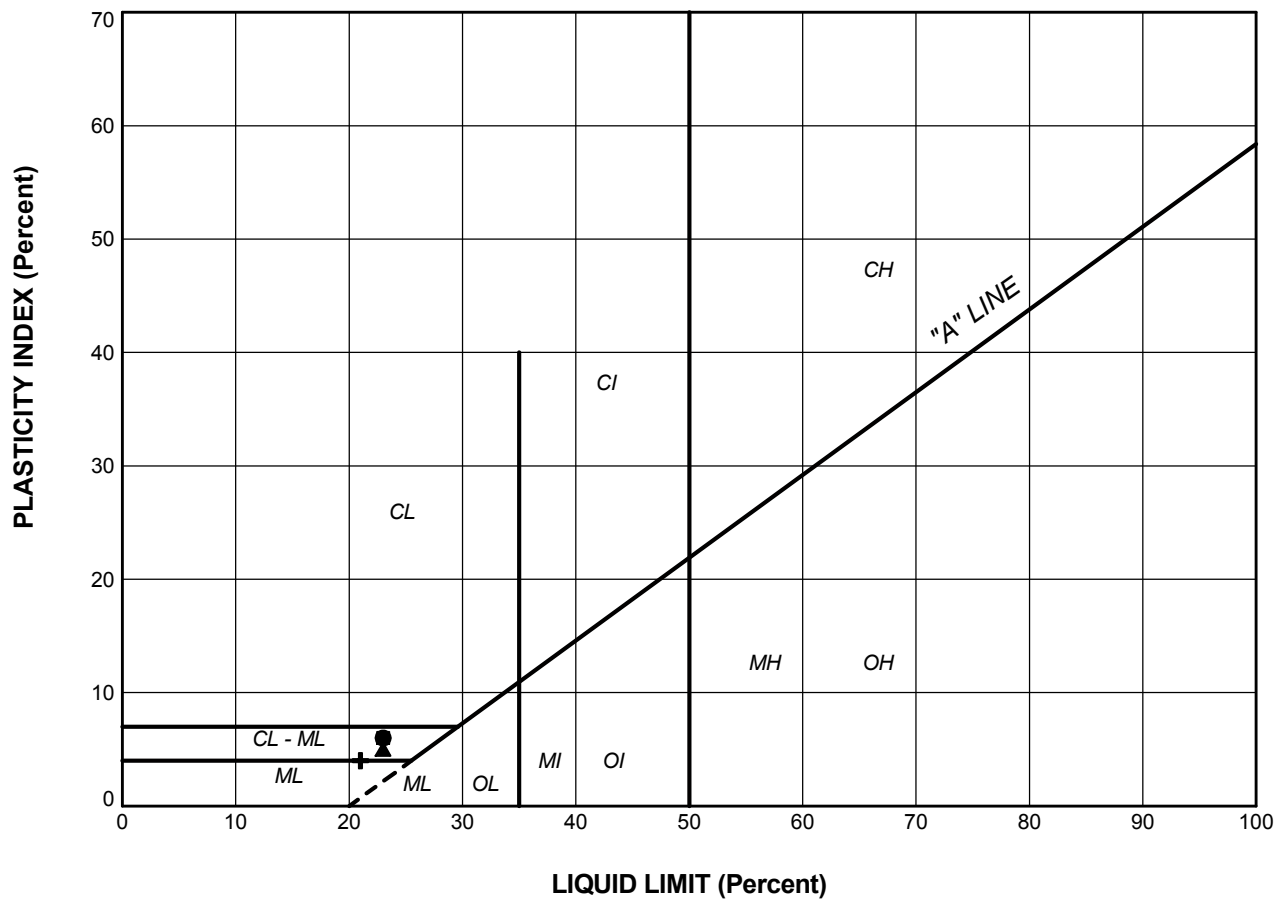



GRAVEL SIZE, mm						Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

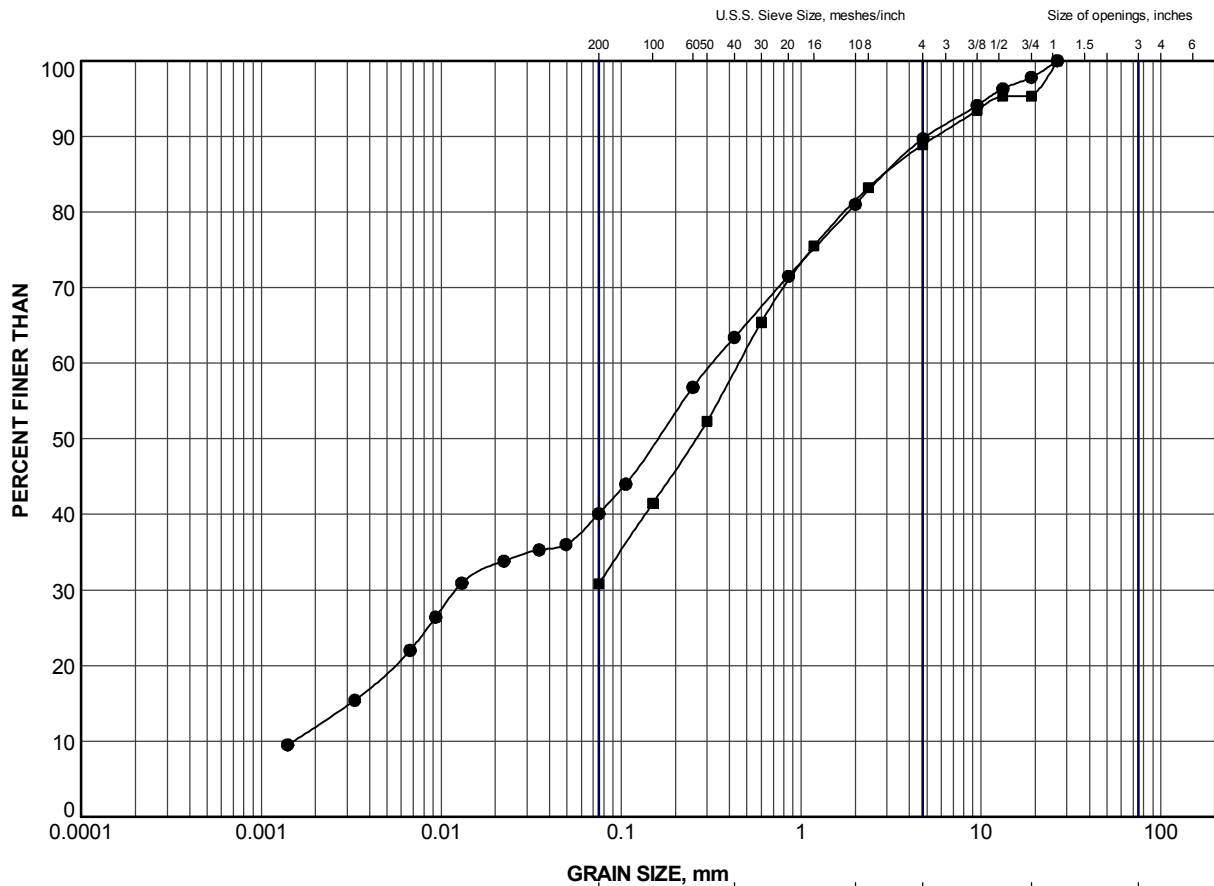
#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-25	3	269.1
■	BH09-27	10	267.5
▲	BH09-28	3	267.1

PROJECT					
HIGHWAY 11 SBL CULVERT 21+319					
TITLE					
GRAIN SIZE DISTRIBUTION					
SILT TO CLAYEY SILT					
PROJECT No.		09-1191-0042		FILE No. 09-1191-0042-4000.GPJ	
DRAWN	JJL	Nov 2011	SCALE	N/A	REV.
CHECK	AB	Nov 2011			
APPR	FJH	Nov 2011			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B4</b>		




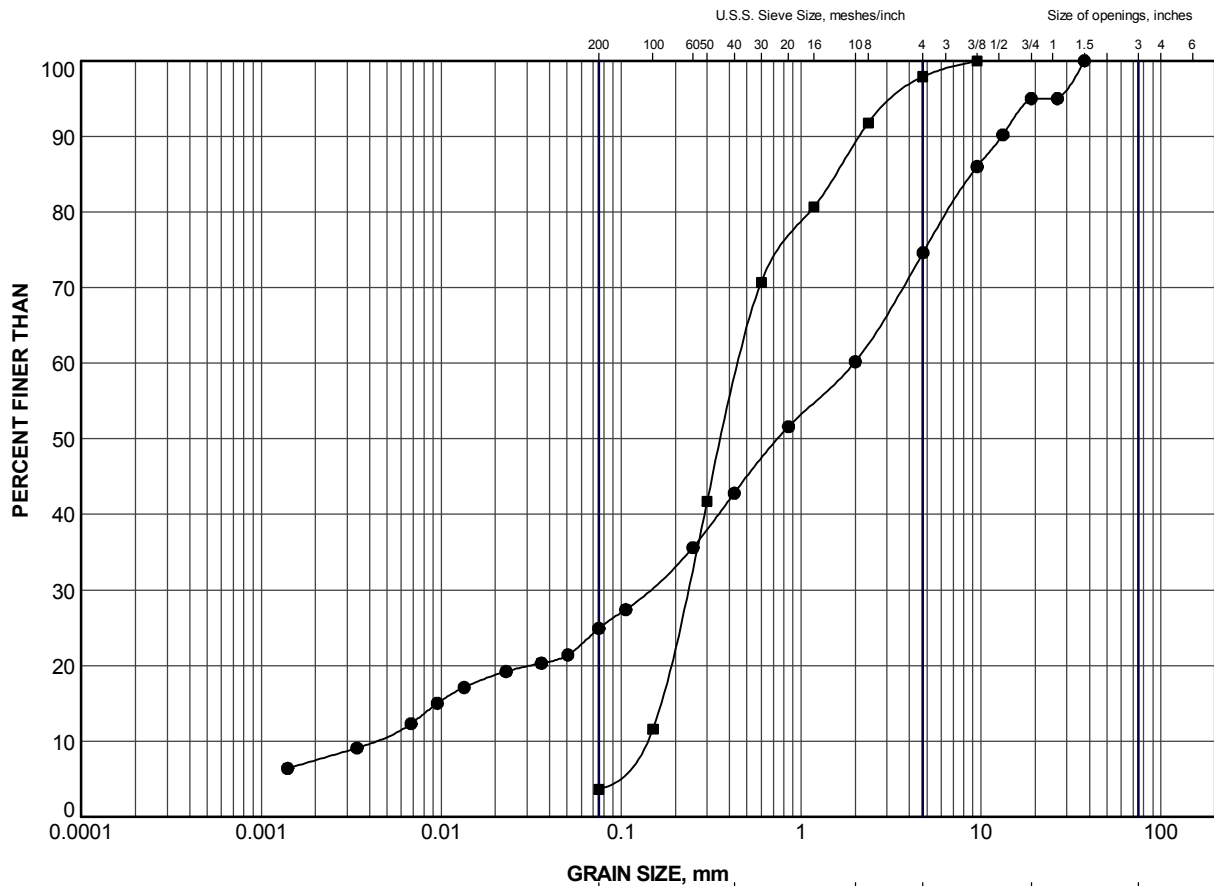
PROJECT				
HIGHWAY 11 SBL CULVERT 21+319				
TITLE				
<b>PLASTICITY CHART</b> SILT TO CLAYEY SILT				
PROJECT No. 09-1191-0042		FILE No. 09-1191-0042-4000.GPJ		
DRAWN	JJL	Nov 2011	SCALE	N/A
CHECK	AB	Nov 2011	REV.	
APPR	FJH	Nov 2011		
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B3</b>	



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-26	6	272.1
■	BH09-27	7	271.3


PROJECT					
HIGHWAY 11 SBL CULVERT 21+319					
TITLE					
GRAIN SIZE DISTRIBUTION					
SILTY SAND (FILL)					
PROJECT No.		09-1191-0042		FILE No. 09-1191-0042-4000.GPJ	
DRAWN	JJL	Nov 2011	SCALE	N/A	REV.
CHECK	AB	Nov 2011			
APPR	FJH	Nov 2011			
			<b>FIGURE B2</b>		



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

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-26	5	272.9
■	BH09-27	3	274.3

PROJECT				
HIGHWAY 11 SBL CULVERT 21+319				
TITLE				
GRAIN SIZE DISTRIBUTION				
GRAVELLY SAND TO SAND (FILL)				
PROJECT No.		09-1191-0042		FILE No. 09-1191-0042-4000.GPJ
DRAWN	JJL	Nov 2011	SCALE	N/A
CHECK	AB	Nov 2011	REV.	
APPR	FJH	Nov 2011		
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B1</b>	

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