



November 17, 2011

## FOUNDATION INVESTIGATION AND DESIGN REPORT

**HIGHWAY 11 SBL CULVERT REPLACEMENT AT STATION 19+545  
TOWNSHIP OF SOUTH HIMSWORTH, ONTARIO  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5416-06-00**

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REPORT





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# **PART A**

**FOUNDATION INVESTIGATION REPORT**

**HIGHWAY 11 SBL CULVERT REPLACEMENT AT STATION 19+545**

**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 19+545. This project is part of the detail design for the rehabilitation of Highway 11 Northbound Lanes (NBL) and 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 19+545 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 19+545 will be concrete and will have an opening of 1.2 m. The existing culvert is about 41 m long. The inverts at the west and east ends of the culvert will be Elevation 260.0 m and 260.6 m, respectively. The embankment in the culvert area is about 6 m high 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 Himsworth near Powassan, Ontario, on Highway 11 approximately 500 m north of Proudfoot Road.

The existing culvert at Station 19+545 is an 800 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 and the culvert has no bottom now. 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 at about Elevation 260 m and the ground surface of the shoulder of the embankment is at Elevation 266 m.



### 3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation associated with this culvert replacement at Station 19+545 was carried out on November 10, 11, 24 and 25, 2010, during which time a total of four (4) Boreholes (BH09-17 to BH09-20) 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). The DCPTs were advanced within 1.5 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 10.2 m and 17.4 m below existing ground surface. Boreholes BH09-17 and BH09-20 were terminated on auger refusal and the associated DCPTs at these locations were terminated on refusal to further cone penetration. These depths to refusal do not confirm bedrock surface elevations, but may be inferred to indicate potential proximity to the bedrock surface. Boreholes BH09-18 and BH09-19 and associated DCPT were terminated within the sand to gravelly 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.

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



## FOUNDATION REPORT - HIGHWAY 11 SBL STA 19+545 CULVERT REPLACEMENT

| Borehole | Location (m) |           | Ground Surface Elevation (m) | Borehole Depth (m) |
|----------|--------------|-----------|------------------------------|--------------------|
|          | Northing     | Easting   |                              |                    |
| 09-17    | 5 100 745.9  | 316 983.2 | 261.3                        | 11.2               |
| 09-18    | 5 100 737.3  | 316 969.7 | 265.8                        | 17.4               |
| 09-19    | 5 100 741.0  | 316 958.8 | 265.5                        | 14.3               |
| 09-20    | 5 100 729.8  | 316 943.8 | 260.0                        | 10.2               |

## 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.

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 sandy silt and/or sand to gravelly sand at depth.

<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.





#### **4.2.1 Fill**

Boreholes BH09-18 and BH09-19 were advanced through the embankment and encountered asphalt 210 mm and 180 mm thick from ground surface, respectively. Below the asphalt in Boreholes BH09-18 and BH09-19, sand and gravel to silty sand and fill was encountered having a thickness of about 1.9 m and 3.9 m, respectively, and the surface of the upper fill was encountered at Elevation 265.6 m and 265.3 m, respectively. Sand and silt to silt fill was encountered below the sand and gravel to silty sand fill at Elevation 263.7 m and 261.4 m in Boreholes BH09-18 and BH09-19, respectively, and was about 3.5 m and 1.5 m thick, respectively.

The upper sand and gravel to silty sand fill is compact to dense with 'N'-values ranging from 11 blows to 41 blows per 0.3 m of penetration. The lower sand and silt to silt fill is loose to compact with 'N'-values of 4 blows to 26 blows per 0.3 m of penetration.

The grain size distributions of three samples of the upper sand and gravel to silty sand fill are presented on Figure B1 in Appendix B and three samples of the lower sand and silt to silt fill are shown on Figure B2.

The water content of selected sand and gravel to silty sand fill samples ranged from 4 percent to 13 percent and the water content of samples of the sand and silt to silt fill ranged from 11 percent to 26 percent.

#### **4.2.2 Organic Soil**

Organics were found at the surface of Borehole BH09-17 about 0.1 m thick (Elevation 261.3 m), about 0.8 m of organic silt was encountered beneath the fill in Borehole BH09-18 (Elevation 260.2 m) and about 0.7 m of organic silt was encountered at the surface of Borehole BH09-20 (Elevation 260.0 m).

The organic silt in Borehole BH09-18 was inferred to be loose based on the SPT sample obtained near Elevation 259.5 m. A sample retrieved from the standard penetration testing in the borehole had a water content of 40 percent and an organic content of 5.7 percent.

#### **4.2.3 Silt to Sandy Silt**

A deposit of silt was encountered below the organics in Borehole BH09-17, below the organic silt in Boreholes BH09-18 and BH09-20 and below the embankment fill in Borehole 09-19 and ranged in thickness from 7.7 m to 8.6 m. The silt contained seams and layers of clayey silt in Borehole BH09-17 and was found to be sandy in the lower samples of the deposit in Borehole BH09-19. The surface of the silt ranged between Elevation 259.3 and 261.2 m.

'N'-values of 2 blows to 22 blows per 0.3 m of penetration were obtained during the SPT testing, indicating a very loose to compact relative density.

The grain size distributions of eight samples of the silt to sandy silt are shown on Figure B3.

The clayey silt seams/layers are of low plasticity based on a single Atterberg Limits determination with a plastic limit of 19 percent, a liquid limit of 30 percent and a plasticity index of 11 percent. The results of the Atterberg Limit determination are shown on Figure B4.





The natural water content varied between 18 percent and 40 percent. The organic content of the silt near Elevation 259 m in Borehole BH09-18 is 2.2 percent.

#### **4.2.4 Sand to Gravelly Sand**

The silt to sandy silt in all four boreholes was underlain by sand to gravelly sand from Elevation 251.2 to 252.6 m. Each of the boreholes was terminated in the sand to gravelly sand deposit after exploring the deposit for 1.0 m to 2.8 m.

The sands are loose to dense based on measured SPT 'N'-values of 4 blows to 35 blows per 0.3 m of penetration.

The gradation of a sample of gravelly sand from BH09-18 is presented on Figure B5.

The natural water content of samples of sand to gravelly sand is 13 percent to 27 percent.

#### **4.2.5 Refusal**

In Borehole BH09-17, refusal to augering and DCPT cone penetration occurred at a depth of 11.2 m and 11.8 m, respectively, corresponding to Elevation 250.1 m and 249.5 m, respectively. In Borehole BH09-20, refusal to augering and DCPT cone penetration occurred at a depth of 10.2 m and 11.7 m, respectively, corresponding to Elevation 249.8 m and 248.3 m, respectively. These depths to refusal, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface.

#### **4.2.6 Groundwater Conditions**

Water levels observed in the boreholes upon completion of drilling range from 2.9 m to 8.9 m below existing ground surface, ranging between Elevation 256.9 m and 257.8 m. These water levels may represent the water level in the underlying sand stratum. The water level in the silt to sandy silt stratum may be close to the surface of the stratum at about Elevation 259.0 m. 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. The report was written by Ms. Dirka Prout, P.Eng., and reviewed 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 19+545 CULVERT REPLACEMENT

### Report Signature Page

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# **PART B**

**FOUNDATION DESIGN REPORT**

**HIGHWAY 11 SBL CULVERT REPLACEMENT AT STATION 19+545**

**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 report provides foundation design recommendations for the proposed culvert replacement on Highway 11 SBL at Station 19+545. 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 an 800 millimetre diameter CSP and about 40.5 m in length. The existing inverts at the inlet (east side) and outlet (west side) are Elevation 260.6 m and 260.0 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 cohesionless deposits of silt to sandy silt and sand to gravelly sand to Elevation 251 m to 253 m. Auger and DCPT refusal was encountered between Elevation 248 m and 250 m in the inlet and outlet areas. 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. If required, the culvert design could include a camber. 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 culvert construction as discussed in Section 6.6.1.1 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 6.0 m high above the surrounding ground surface.

The subsoils encountered below the culvert alignment are composed of cohesionless soils. For the cohesionless layers, effective stress parameters were employed in the analyses assuming drained conditions. The silt to sandy silt was assumed to have a unit weight of 18 kN/m<sup>3</sup> and an effective friction angle of 28° and the sand to gravelly sand was assumed to have a unit weight of 20 kN/m<sup>3</sup> and an effective friction angle of 30°.

#### **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, significant settlement of the foundation soils is not anticipated and as such camber of the culvert is not considered necessary. 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 re-assessment 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 250 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 loose to compact silt to sandy silt. 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 150 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.





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| 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

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 0.8 m thick below the embankment and at the toe 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 OPSD 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.

The support systems may be designed using the following parameters:

| SOIL TYPE              | COEFFICIENT OF EARTH PRESSURE |                |                | INTERNAL<br>ANGLE OF<br>FRICTION<br>(degrees) | UNIT<br>WEIGHT<br>(kN/m <sup>2</sup> ) |
|------------------------|-------------------------------|----------------|----------------|---|--|
|                        | Active, $K_a$                 | At Rest, $K_o$ | Passive, $K_p$ |   |  |
| Existing Granular Fill | 0.33                          | 0.50           | 3.0            | 30  | 20                                     |
| Silt to Sandy Silt     | 0.35                          | 0.53           | 3.0            | 28  | 18                                     |



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 OPSS 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 OPSS 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, in that case, 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 Ms. Dirka U. Prout, P.Eng. 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.

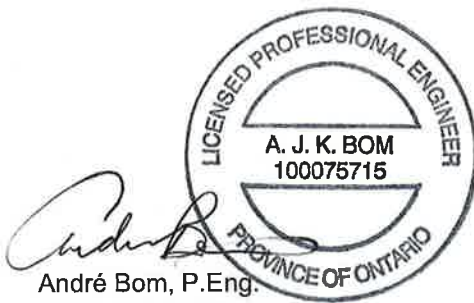


## FOUNDATION REPORT - HIGHWAY 11 SBL STA 19+545 CULVERT REPLACEMENT

### Report Signature Page

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DUP/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 Onta rio. Ontari o Geological Survey, Special Volume 2, 3<sup>rd</sup> Edition. Ontario Ministry of Natural Resources.
- Geology of Ontario, 1991. Ontari o Geological Societ y, Spec ial Volume 4, Part 2. Eds . P.C. Thurs ton, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.

### STANDARDS:

#### ASTM International:

- |                |   |
|----------------|---|
| ASTM D1586-08a | Standard T est Meth od fo r Stand ard P enetration T est (SPT ) a nd Split-Barrel Sampling of Soils |
|----------------|---|

#### 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 a nd Cover fo r Concrete Culverts With Sp ans le ss tha n or e qual t o 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 Compress ible Soils.                      |
| OPSS 421 | Construction Specification For Pipe Culvert Installation In Open Cut.                                |
| OPSS 422 | Construction Spec ification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut. |
| OPSS 501 | Construction Specification for Compacting.   |
| OPSS 539 | Construction Specification for Temporary Protection Systems.   |



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## FOUNDATION REPORT - HIGHWAY 11 SBL STA 19+545 CULVERT REPLACEMENT

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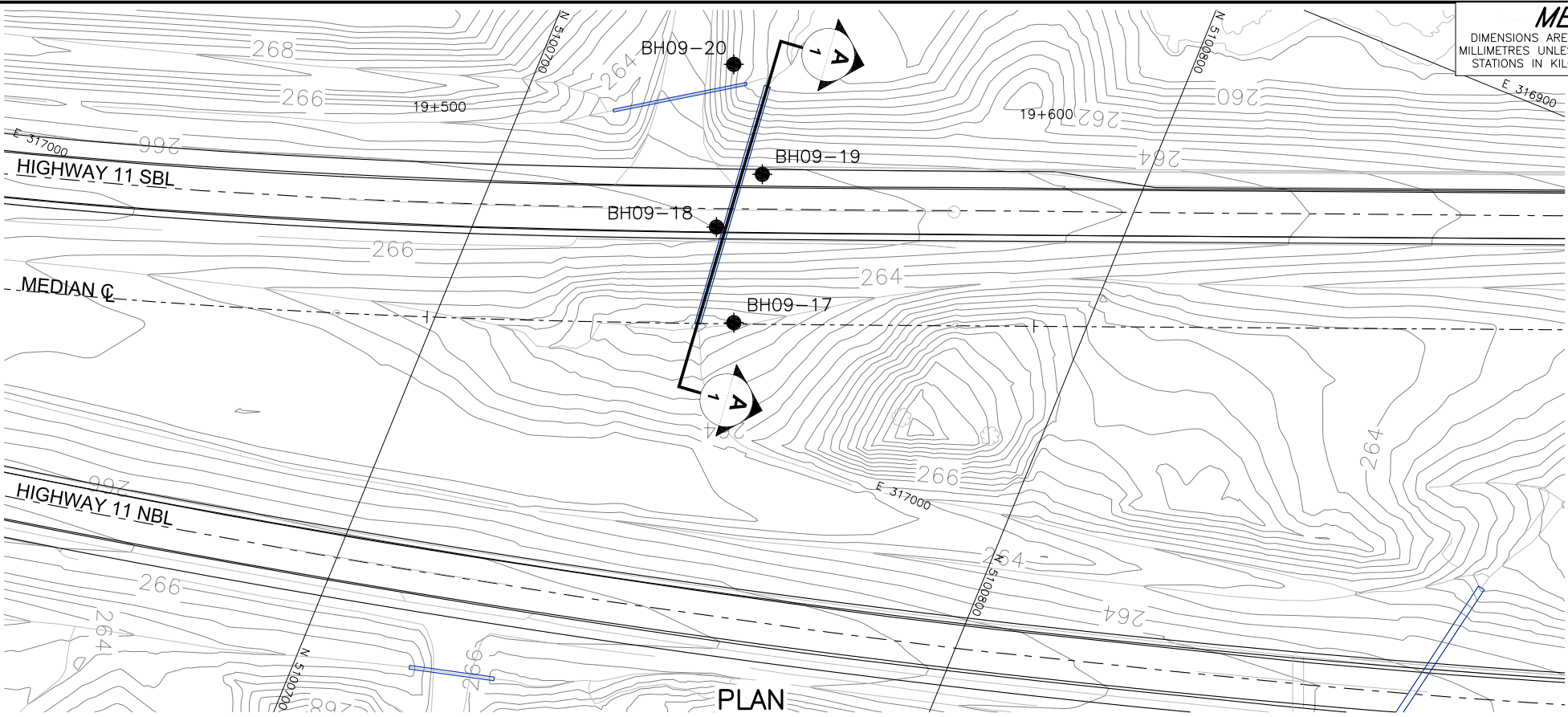
OPSS 1002                      Material Specification for Aggregates – Concrete.

OPSS 1205                      Material Specification for Clay Seal.

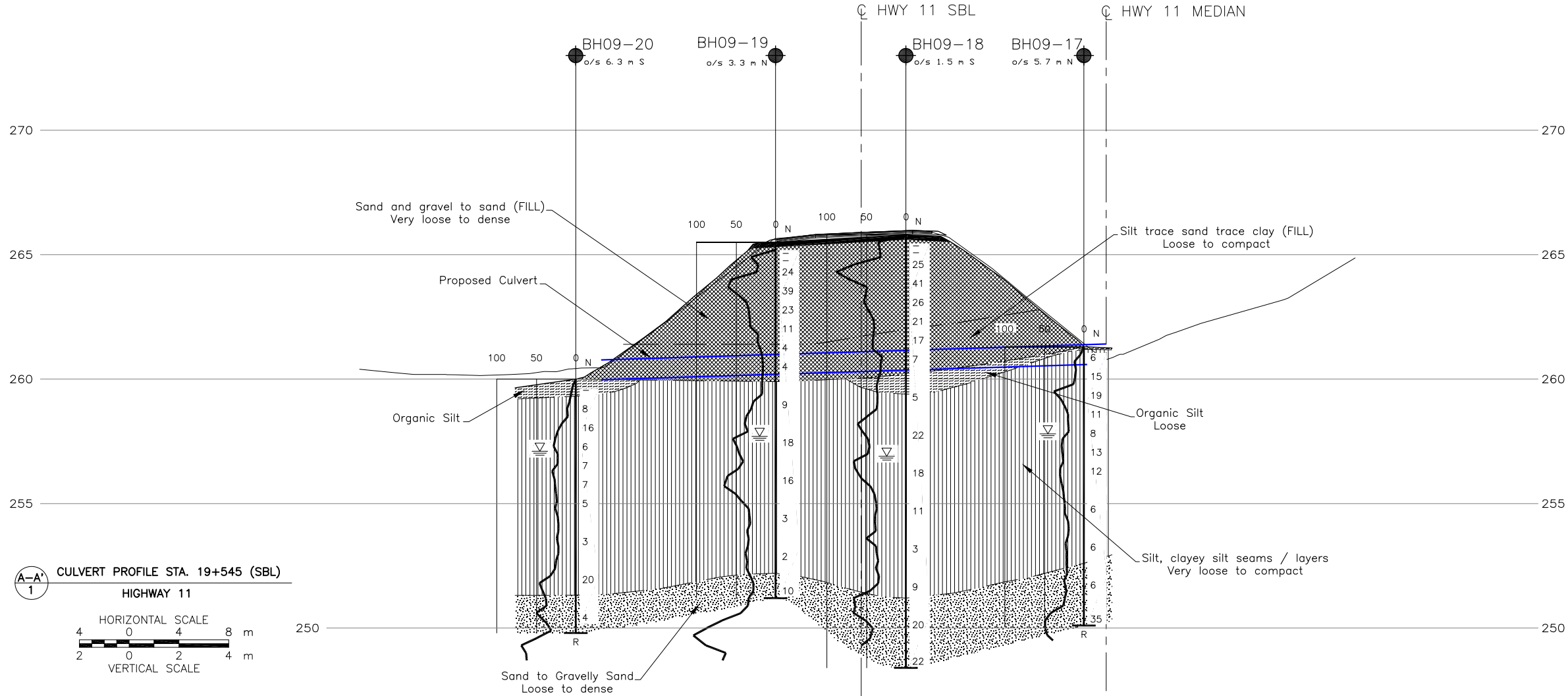
Ontario Water Resources Act:

Ontario Regulation 372/97    Amendment to Ontario Regulation 903





PLAN  
SCALE  
10 0 10 20 m



A-A'  
1  
CULVERT PROFILE STA. 19+545 (SBL)  
HIGHWAY 11  
HORIZONTAL SCALE  
4 0 4 8 m  
VERTICAL SCALE  
2 0 2 4 m

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

CONT No.  
WP No. 5416-06-00

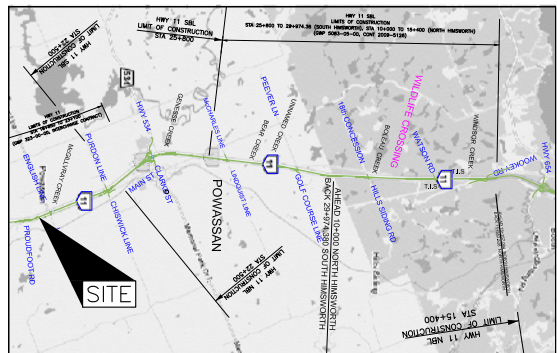
HIGHWAY 11  
CULVERT AT STA 19+545 SBL  
BOREHOLE LOCATIONS AND  
SOIL STRATA



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
- R Refusal

### BOREHOLE CO-ORDINATES

| No.     | ELEVATION | NORTHING  | EASTING  |
|---------|-----------|-----------|----------|
| BH09-17 | 261.3     | 5100745.9 | 316983.2 |
| BH09-18 | 265.8     | 5100737.3 | 316969.7 |
| BH09-19 | 265.5     | 5100741.0 | 316958.8 |
| BH09-20 | 260.0     | 5100729.8 | 316943.8 |

### NOTES

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

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

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

### REFERENCE

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

| NO.         | DATE                     | BY             | REVISION |
|-------------|--------------------------|----------------|----------|
| Geocres No. |                          |                |          |
| HWY. 11     | PROJECT NO. 09-1191-0042 |                | DIST.    |
| SUBM'D. LG  | CHKD. AB                 | DATE: NOV 2011 | SITE:    |
| DRAWN: JJL  | 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<br>$= (\sigma_1 + \sigma_2 + \sigma_3)/3$ |
| $\tau$                         | 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 $= (e_{max} - e) / (e_{max} - e_{min})$<br>(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.

### 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

|            | $C_u, S_u$ | psf            |
|------------|------------|----------------|
|            | kPa        |                |
| 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.

### 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<br>Silty Clay with sand / Clayey Silt with sand |

| PROJECT 09-1191-0042 |  |            | RECORD OF BOREHOLE No BH09-17                                   |      |            | 1 OF 1 METRIC                            |                 |   |   |  |  |             |  |  |                                       |   |             |
|----------------------|--|------------|---|------|------------|--|-----------------|---|---|--|--|-------------|--|--|---------------------------------------|---|-------------|
| W.P. 5416-06-00      |  |            | LOCATION N 5100745.9; E 316983.2                                |      |            | ORIGINATED BY MR                         |                 |   |   |  |  |             |  |  |                                       |   |             |
| DIST HWY 11          |  |            | BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers |      |            | COMPILED BY JLL                          |                 |   |   |  |  |             |  |  |                                       |   |             |
| DATUM Geodetic       |  |            | DATE November 25, 2010  |      |            | 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<br>DEPTH        | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE | "N" VALUES | GROUND WATER<br>CONDITIONS               | ELEVATION SCALE | SHEAR STRENGTH kPa<br>○ UNCONFINED + FIELD VANE<br>● QUICK TRIAXIAL × REMOULDED |   |  |  |             | W <sub>p</sub> W W <sub>L</sub><br>WATER CONTENT (%) |  |                                       | γ | GR SA SI CL |
| 261.3                | GROUND SURFACE   |            |   |      |            |  |                 | 20 40 60 80 100   |   |  |  |             |  |  |                                       |   |             |
| 0.0                  | ORGANICS<br>Black to brown<br>Moist  |            | 1   | SS   | 6          |  | 261             |   |   |  |  |             |  |  |                                       |   |             |
|                      | SILT, trace to some clay, trace to some sand, clayey silt seams / layers<br>Loose to compact<br>Brown to grey<br>Moist to wet  |            | 2   | SS   | 15         |  | 260             |   |   |  |  |             |  |  |                                       |   |             |
|                      |  |            | 3   | SS   | 19         |  | 259             |   |   |  |  |             |  |  |                                       |   |             |
|                      |  |            | 4   | SS   | 11         |  | 258             |   |   |  |  |             |  |  |                                       |   | 0 2 73 25   |
|                      |  |            | 5   | SS   | 8          |  | 257             |   |   |  |  |             |  |  |                                       |   |             |
|                      |  |            | 6   | SS   | 13         |  | 256             |   |   |  |  |             |  |  |                                       |   |             |
|                      |  |            | 7   | SS   | 12         |  | 255             |   |   |  |  |             |  |  |                                       |   | 0 7 72 21   |
|                      |  |            | 8   | SS   | 6          |  | 254             |   |   |  |  |             |  |  |                                       |   |             |
|                      |  |            | 9   | SS   | 6          |  | 253             |   |   |  |  |             |  |  |                                       |   |             |
| 252.6                | SAND to Gravelly SAND, some silt<br>Loose to dense<br>Brown<br>Wet   |            | 10  | SS   | 6          |  | 252             |   |   |  |  |             |  |  |                                       |   |             |
|                      |  |            | 11  | SS   | 35         |  | 251             |   |   |  |  |             |  |  |                                       |   |             |
| 250.1                | END OF BOREHOLE<br>AUGER REFUSAL   |            |   |      |            |  |                 |   |   |  |  |             |  |  |                                       |   |             |
| 11.2                 | Note:<br><br>1. Water level at a depth of 3.5 m below ground surface (Elev. 257.8 m) upon completion of drilling.<br><br>2. Advanced DCPT 1.0 m south of Borehole BH09-17. Refusal at a depth of 11.8 m (Elev. 249.5 m). |            |   |      |            |  |                 |   |   |  |  |             |  |  |                                       |   |             |

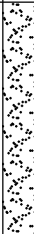
SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 16/11/11 DATA INPUT:

| PROJECT       |   | 09-1191-0042 |         | <b>RECORD OF BOREHOLE No BH09-18</b> |            | 1 OF 2 <b>METRIC</b>                              |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
|---------------|---|--------------|---------|--------------------------------------|------------|---|-----------------|-----------------|---|---------------------------------|---|-------------|--|--|---------------------------------------|--|--|
| W.P.          |   | 5416-06-00   |         | LOCATION                             |            | N 5100737.3; E 316969.7                           |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
| DIST          |   | HWY 11       |         | BOREHOLE TYPE                        |            | 108 mm I.D. Continuous Flight, Hollow Stem Augers |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
| DATUM         |   | Geodetic     |         | DATE                                 |            | November 11, 2010                                 |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
|               |   |              |         |                                      |            | ORIGINATED BY MR                                  |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
|               |   |              |         |                                      |            | COMPILED BY JLL                                   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
|               |   |              |         |                                      |            | 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<br>DEPTH | DESCRIPTION                                     | STRAT PLOT   | NUMBER  | TYPE                                 | "N" VALUES | GROUND WATER<br>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 |  |  |                                       |  |  |
| 265.8         | GROUND SURFACE                                  |              |         |                                      |            |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
| 0.0           | ASPHALT (210 mm)                                |              |         |                                      |            |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
| 0.2           | Sand and gravel to sand, trace some silt (FILL) |              | 1       | AS                                   | -          |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
|               | Compact to dense                                |              | 2       | AS                                   | -          |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
|               | Brown   |              | 3       | SS                                   | 25         |   | 265             |                 |   |                                 |   | 18 75 (7)   |  |  |                                       |  |  |
|               | Moist   |              | 4       | SS                                   | 41         |   | 264             |                 |   |                                 |   |             |  |  |                                       |  |  |
| 263.6         | Sand and silt to silt, trace clay (FILL)        |              |         |                                      |            |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
| 2.2           | Loose to compact                                |              | 5       | SS                                   | 26         |   | 263             |                 |   |                                 |   | 2 40 52 6   |  |  |                                       |  |  |
|               | Brown to grey                                   |              | 6       | SS                                   | 21         |   | 262             |                 |   |                                 |   |             |  |  |                                       |  |  |
|               | Moist   |              | 7       | SS                                   | 17         |   | 261             |                 |   |                                 |   | 0 1 95 4    |  |  |                                       |  |  |
|               |   |              | 8       | SS                                   | 7          |   | 260             |                 |   |                                 |   |             |  |  |                                       |  |  |
| 260.2         | ORGANIC SILT                                    |              |         |                                      |            |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
| 5.6           | Loose   |              | 9a      | SS                                   | 5          |   | 259             |                 |   |                                 |   | OC = 5.7%   |  |  |                                       |  |  |
|               | Brown to grey                                   |              | 9b      |                                      |            |   | 258             |                 |   |                                 |   | OC = 2.2%   |  |  |                                       |  |  |
|               | Wet   |              |         |                                      |            |   | 257             |                 |   |                                 |   |             |  |  |                                       |  |  |
| 259.4         | SILT, some clay, trace to some sand             |              |         |                                      |            |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
| 6.4           | Very loose to compact                           |              | 10      | SS                                   | 22         |   | 256             |                 |   |                                 |   |             |  |  |                                       |  |  |
|               | Brown to grey                                   |              |         |                                      |            |   | 255             |                 |   |                                 |   |             |  |  |                                       |  |  |
|               | Moist to wet                                    |              |         |                                      |            |   | 254             |                 |   |                                 |   |             |  |  |                                       |  |  |
|               |   |              | 11      | SS                                   | 18         |   | 253             |                 |   |                                 |   | 0 18 67 15  |  |  |                                       |  |  |
|               |   |              | 12      | SS                                   | 11         |   | 252             |                 |   |                                 |   |             |  |  |                                       |  |  |
|               |   |              | 13      | SS                                   | 3          |   | 251             |                 |   |                                 |   |             |  |  |                                       |  |  |
|               |   |              | 14      | SS                                   | 9          |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
| 251.2         |   |              |         |                                      |            |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |
| 14.6          |   |              |         |                                      |            |   |                 |                 |   |                                 |   |             |  |  |                                       |  |  |

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

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

| PROJECT <u>09-1191-0042</u>          |  | <b>RECORD OF BOREHOLE No BH09-18</b>  |        |      |                            | 2 OF 2 <b>METRIC</b>    |  |                    |  |  |  |   |                                     |                                   |   |  |            |  |  |  |  |
|--------------------------------------|--|---|--------|------|----------------------------|-------------------------|--|--------------------|--|--|--|---|-------------------------------------|-----------------------------------|---|--|------------|--|--|--|--|
| W.P. <u>5416-06-00</u>               |  | LOCATION <u>N 5100737.3; E 316969.7</u>   |        |      |                            | ORIGINATED BY <u>MR</u> |  |                    |  |  |  |   |                                     |                                   |   |  |            |  |  |  |  |
| DIST <u>          </u> HWY <u>11</u> |  | BOREHOLE TYPE <u>108 mm I.D. Continuous Flight, Hollow Stem Augers</u>            |        |      |                            | COMPILED BY <u>JJL</u>  |  |                    |  |  |  |   |                                     |                                   |   |  |            |  |  |  |  |
| DATUM <u>Geodetic</u>                |  | DATE <u>November 11, 2010</u>   |        |      |                            | CHECKED BY <u>AB</u>    |  |                    |  |  |  |   |                                     |                                   |   |  |            |  |  |  |  |
| SOIL PROFILE                         |  | SAMPLES   |        |      | GROUND WATER<br>CONDITIONS | ELEVATION SCALE         | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT  |                    |  |  |  | PLASTIC<br>LIMIT<br>W <sub>p</sub>  | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |            |  |  |  |  |
| ELEV<br>DEPTH                        | DESCRIPTION  | STRAT PLOT  | NUMBER | TYPE |                            |                         | "N" VALUES   | SHEAR STRENGTH kPa |  |  |  |   |                                     |                                   |   |  |            |  |  |  |  |
|                                      | --- CONTINUED FROM PREVIOUS PAGE ---   |   |        |      |                            |                         | <div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div> |                    |  |  |  | <div style="display: flex; justify-content: space-between;"> <span>20 40 60</span> <span>20 40 60</span> </div> |                                     |                                   |   |  |            |  |  |  |  |
| 248.4                                | SAND to Gravelly SAND, some silt,<br>trace clay<br>Compact<br>Brown<br>Wet   |  | 15     | SS   | 20                         |                         |  |                    |  |  |  |   |                                     |                                   |   |  | 25 57 16 2 |  |  |  |  |
| 17.4                                 | END OF BOREHOLE  |   |        |      |                            |                         |  |                    |  |  |  |   |                                     |                                   |   |  |            |  |  |  |  |
|                                      | Note:<br><br>1. Water level at a depth of 8.9 m<br>below ground surface (Elev. 256.9 m)<br>upon completion of drilling.<br><br>2. Advanced DCPT 1.5 m south of<br>Borehole BH09-18. End of DCPT at a<br>depth of 16.5 m (Elev. 249.3 m). |   |        |      |                            |                         |  |                    |  |  |  |   |                                     |                                   |   |  |            |  |  |  |  |

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

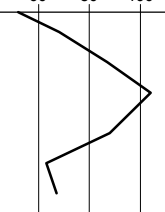


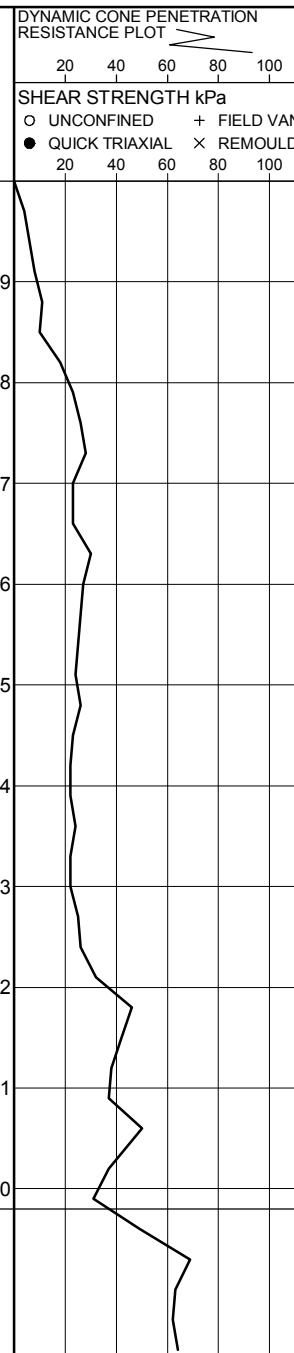



| PROJECT      |  | 09-1191-0042 |         | <b>RECORD OF BOREHOLE No BH09-19</b> |            | 1 OF 2 <b>METRIC</b>                              |                 |   |                                 |                               |                                |                  |                                       |
|--------------|--|--------------|---------|--------------------------------------|------------|---|-----------------|---|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|
| W.P.         |  | 5416-06-00   |         | LOCATION                             |            | N 5100741.0; E 316958.8                           |                 |   |                                 |                               |                                |                  |                                       |
| DIST         |  | HWY 11       |         | BOREHOLE TYPE                        |            | 108 mm I.D. Continuous Flight, Hollow Stem Augers |                 |   |                                 |                               |                                |                  |                                       |
| DATUM        |  | Geodetic     |         | DATE                                 |            | November 10, 2010                                 |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              |         |                                      |            | ORIGINATED BY MR                                  |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              |         |                                      |            | COMPILED BY JJL                                   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              |         |                                      |            | CHECKED BY AB                                     |                 |   |                                 |                               |                                |                  |                                       |
| SOIL PROFILE |  |              | SAMPLES |                                      |            | GROUND WATER CONDITIONS                           | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT<br><div style="display: flex; justify-content: space-around; font-size: small;"> <span>20 40 60 80 100</span> </div> | PLASTIC LIMIT<br>W <sub>p</sub> | NATURAL MOISTURE CONTENT<br>W | LIQUID LIMIT<br>W <sub>L</sub> | UNIT WEIGHT<br>γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
| ELEV DEPTH   | DESCRIPTION  | STRAT PLOT   | NUMBER  | TYPE                                 | "N" VALUES |   |                 |   |                                 |                               |                                |                  |                                       |
| 265.5        | GROUND SURFACE   |              |         |                                      |            |   |                 |   |                                 |                               |                                |                  |                                       |
| 0.0          | ASPHALT (180 mm)   |              |         |                                      |            |   |                 |   |                                 |                               |                                |                  |                                       |
| 0.2          | Sand and gravel to silty sand (FILL)<br>Compact to dense<br>Brown<br>Moist                       |              | 1       | AS                                   | -          |   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              | 2       | AS                                   | -          |   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              | 3       | SS                                   | 24         |   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              | 4       | SS                                   | 39         |   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              | 5       | SS                                   | 23         |   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              | 6       | SS                                   | 11         |   |                 |   |                                 |                               |                                |                  |                                       |
| 261.4        | Silt, trace sand, trace clay (FILL)<br>Loose<br>Brown and grey<br>Moist                          |              | 7       | SS                                   | 4          |   |                 |   |                                 |                               |                                |                  |                                       |
| 4.1          |  |              | 8       | SS                                   | 4          |   |                 |   |                                 |                               |                                |                  |                                       |
| 259.9        | SILT to Sandy SILT, trace to some clay<br>Very loose to compact<br>Brown to grey<br>Moist to wet |              | 9       | SS                                   | 9          |   |                 |   |                                 |                               |                                |                  |                                       |
| 5.6          |  |              | 10      | SS                                   | 18         |   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              | 11      | SS                                   | 16         |   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              | 12      | SS                                   | 3          |   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              | 13      | SS                                   | 2          |   |                 |   |                                 |                               |                                |                  |                                       |
|              |  |              | 14      | SS                                   | 10         |   |                 |   |                                 |                               |                                |                  |                                       |
| 252.2        | SAND, trace silt<br>Compact<br>Brown<br>Wet  |              |         |                                      |            |   |                 |   |                                 |                               |                                |                  |                                       |
| 13.3         |  |              |         |                                      |            |   |                 |   |                                 |                               |                                |                  |                                       |
| 251.2        |  |              |         |                                      |            |   |                 |   |                                 |                               |                                |                  |                                       |
| 14.3         |  |              |         |                                      |            |   |                 |   |                                 |                               |                                |                  |                                       |

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

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

| PROJECT <u>09-1191-0042</u>          |   | <b>RECORD OF BOREHOLE No BH09-19</b>                                   |        |      |                            | 2 OF 2 <b>METRIC</b>    |  |                    |                                    |                                     |                                   |   |  |
|--------------------------------------|---|--|--------|------|----------------------------|-------------------------|--|--------------------|------------------------------------|-------------------------------------|-----------------------------------|---|--|
| W.P. <u>5416-06-00</u>               |   | LOCATION <u>N 5100741.0; E 316958.8</u>                                |        |      |                            | ORIGINATED BY <u>MR</u> |  |                    |                                    |                                     |                                   |   |  |
| DIST <u>          </u> HWY <u>11</u> |   | BOREHOLE TYPE <u>108 mm I.D. Continuous Flight, Hollow Stem Augers</u> |        |      |                            | COMPILED BY <u>JJL</u>  |  |                    |                                    |                                     |                                   |   |  |
| DATUM <u>Geodetic</u>                |   | DATE <u>November 10, 2010</u>  |        |      |                            | CHECKED BY <u>AB</u>    |  |                    |                                    |                                     |                                   |   |  |
| SOIL PROFILE                         |   | SAMPLES  |        |      | GROUND WATER<br>CONDITIONS | ELEVATION SCALE         | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT  |                    | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br><br><b>γ</b><br><br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br><br>GR SA SI CL |
| ELEV<br>DEPTH                        | DESCRIPTION   | STRAT PLOT   | NUMBER | TYPE |                            |                         | "N" VALUES   | SHEAR STRENGTH kPa |                                    |                                     |                                   |   |  |
|                                      | --- CONTINUED FROM PREVIOUS PAGE ---  |  |        |      |                            |                         | <div style="display: flex; justify-content: space-between; font-size: small;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="font-size: x-small;">             ○ UNCONFINED      + FIELD VANE<br/>             ● QUICK TRIAXIAL    × REMOULDED           </div> |                    |                                    |                                     |                                   |   |  |
|                                      | END OF BOREHOLE<br><br>Note:<br><br>1. Water level at a depth of 7.8 m below ground surface (Elev. 257.7 m) upon completion of drilling.<br><br>2. Advanced DCPT 1.5 m north of Borehole BH09-19. End of DCPT at a depth of 16.8 m (Elev. 248.7 m). |  |        |      |                            |                         |    |                    |                                    |                                     |                                   |   |  |

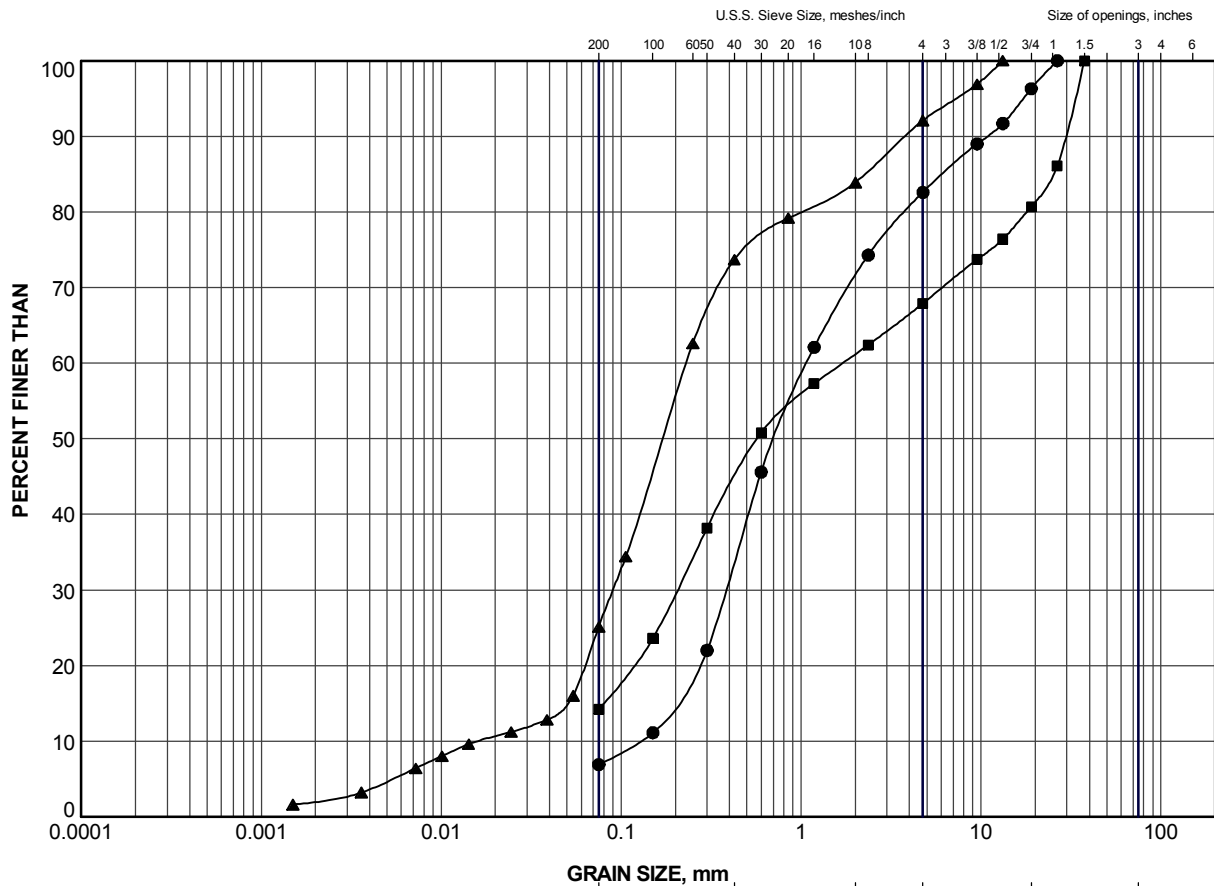
| PROJECT       |   | 09-1191-0042  |         | <b>RECORD OF BOREHOLE No BH09-20</b> |            | 1 OF 1 <b>METRIC</b>                              |                 |  |                                    |                                     |                                   |   |  |
|---------------|---|---|---------|--------------------------------------|------------|---|-----------------|--|------------------------------------|-------------------------------------|-----------------------------------|---|--|
| W.P.          |   | 5416-06-00  |         | LOCATION                             |            | N 5100729.8; E 316943.8                           |                 |  |                                    |                                     |                                   |   |  |
| DIST          |   | HWY 11  |         | BOREHOLE TYPE                        |            | 108 mm I.D. Continuous Flight, Hollow Stem Augers |                 |  |                                    |                                     |                                   |   |  |
| DATUM         |   | Geodetic  |         | DATE                                 |            | November 24, 2010                                 |                 |  |                                    |                                     |                                   |   |  |
|               |   |   |         |                                      |            | ORIGINATED BY MR                                  |                 |  |                                    |                                     |                                   |   |  |
|               |   |   |         |                                      |            | COMPILED BY JJL                                   |                 |  |                                    |                                     |                                   |   |  |
|               |   |   |         |                                      |            | CHECKED BY AB                                     |                 |  |                                    |                                     |                                   |   |  |
| SOIL PROFILE  |   |   | SAMPLES |                                      |            | GROUND WATER<br>CONDITIONS                        | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT<br> | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |
| ELEV<br>DEPTH | DESCRIPTION   | STRAT PLOT  | NUMBER  | TYPE                                 | "N" VALUES |   |                 |  |                                    |                                     |                                   |   |  |
| 260.0         | GROUND SURFACE  |   | 1       | AS                                   | -          |   |                 |  |                                    |                                     |                                   |   |  |
| 0.0           | ORGANIC SILT<br>Greenish grey<br>Moist  |    |         |                                      |            |   |                 |  |                                    |                                     |                                   |   |  |
| 259.3         |   |   | 2       | SS                                   | 8          |   | 259             |  |                                    |                                     |                                   |   | 0 2 78 20  |
| 0.7           | SILT, trace to some sand, trace to<br>some clay<br>Very loose to compact<br>Brown to grey<br>Moist to wet   |    | 3       | SS                                   | 16         |   | 258             |  |                                    |                                     |                                   |   |  |
|               |   |   | 4       | SS                                   | 6          |   | 257             |  |                                    |                                     |                                   |   | 0 12 74 14   |
|               |   |   | 5       | SS                                   | 7          |   | 256             |  |                                    |                                     |                                   |   |  |
|               |   |   | 6       | SS                                   | 7          |   | 255             |  |                                    |                                     |                                   |   | 0 9 74 17  |
|               |   |   | 7       | SS                                   | 5          |   | 254             |  |                                    |                                     |                                   |   |  |
|               |   |   | 8       | SS                                   | 3          |   | 253             |  |                                    |                                     |                                   |   |  |
|               |   |   | 9       | SS                                   | 20         |   | 252             |  |                                    |                                     |                                   |   |  |
| 251.3         |   |   |         |                                      |            |   | 251             |  |                                    |                                     |                                   |   |  |
| 8.7           | SAND, some gravel, trace silt<br>Loose<br>Brown<br>Wet<br>Note: About 0.3 m of heaving sand in<br>augers below 9.1 m depth.   |  | 10      | SS                                   | 4          |   | 250             |  |                                    |                                     |                                   |   |  |
| 249.8         |   |   |         |                                      |            |   |                 |  |                                    |                                     |                                   |   |  |
| 10.2          | END OF BOREHOLE<br>AUGER REFUSAL<br><br>Note:<br>1. Water level at a depth of 2.9 m<br>below ground surface (Elev. 257.1 m)<br>upon completion of drilling.<br>2. Advanced DCPT 1.3 m east of<br>Borehole BH09-20. Refusal at a<br>depth of 11.7 m (Elev. 248.3 m). |   |         |                                      |            |   |                 |  |                                    |                                     |                                   |   |  |

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




# **APPENDIX B**

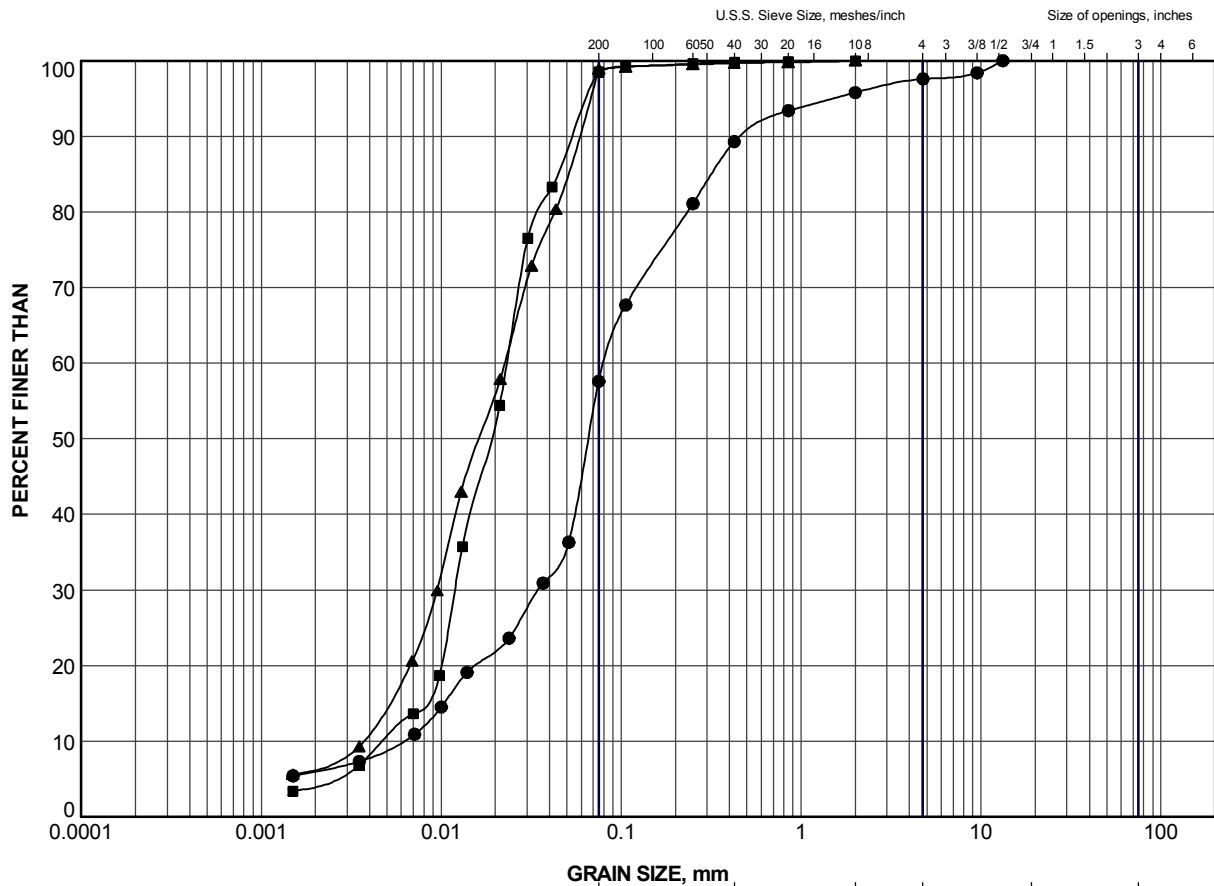
## **Laboratory Test Results**



### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | BH09-18  | 3      | 264.7    |
| ■      | BH09-19  | 4      | 263.7    |
| ▲      | BH09-19  | 6      | 262.1    |


|  |     |              |                  |                                |      |
|--|-----|--------------|------------------|--------------------------------|------|
| PROJECT  |     |              |                  |                                |      |
| HIGHWAY 11 SBL CULVERT 19+545  |     |              |                  |                                |      |
| TITLE  |     |              |                  |                                |      |
| <b>GRAIN SIZE DISTRIBUTION</b><br>SAND AND GRAVEL TO 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>Golder Associates</b><br>SUDBURY, ONTARIO |     |              | <b>FIGURE B1</b> |                                |      |

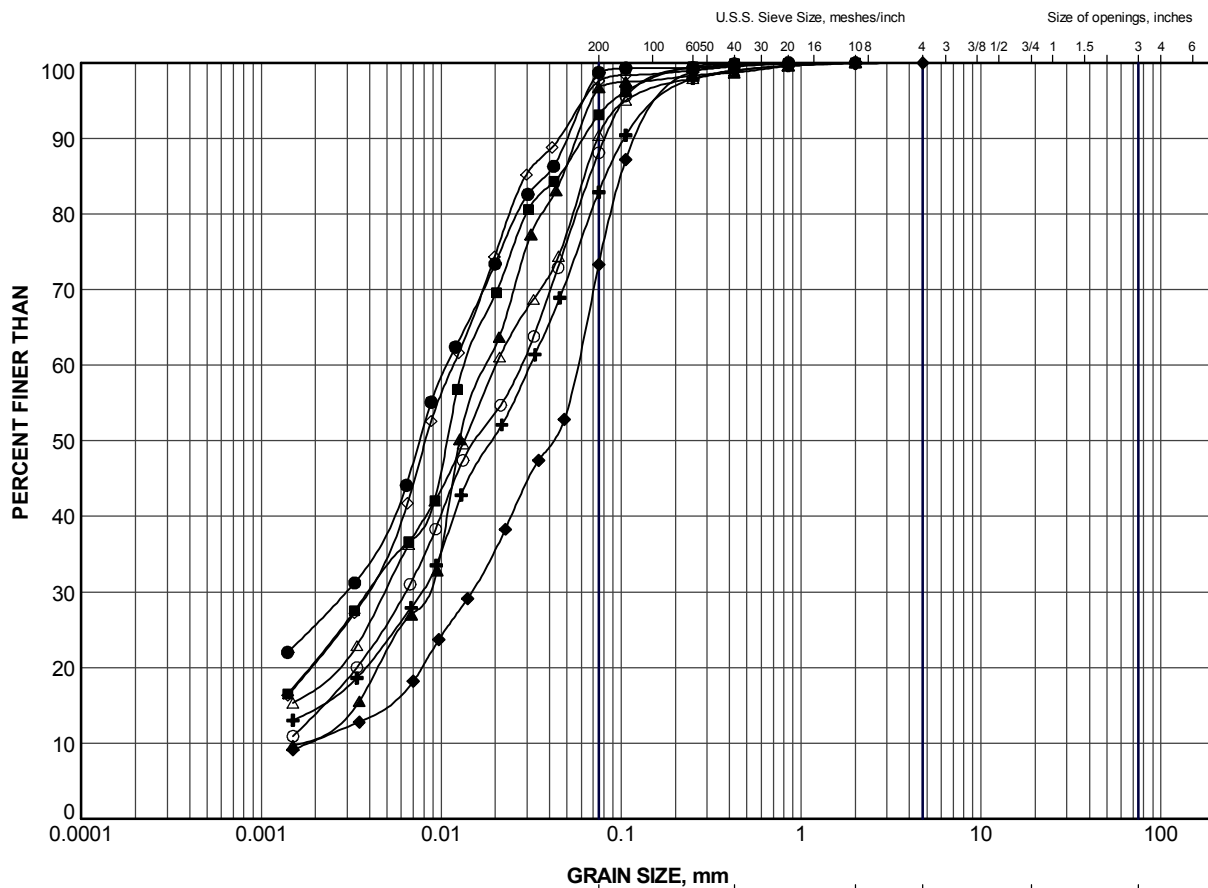


|               |                 |        |        |             |        |  |                |
|---------------|-----------------|--------|--------|-------------|--------|--|----------------|
| CLAY AND SILT | GRAVEL SIZE, mm |        |        |             |        |  | Cobble<br>Size |
|               | fine            | medium | coarse | fine        | coarse |  |                |
|               | SAND SIZE       |        |        | GRAVEL SIZE |        |  |                |

### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | BH09-18  | 5      | 263.2    |
| ■      | BH09-18  | 7      | 261.7    |
| ▲      | BH09-19  | 8      | 260.6    |

|   |     |              |                  |                                |
|---|-----|--------------|------------------|--------------------------------|
| PROJECT   |     |              |                  |                                |
| HIGHWAY 11 SBL CULVERT 19+545   |     |              |                  |                                |
| TITLE   |     |              |                  |                                |
| GRAIN SIZE DISTRIBUTION   |     |              |                  |                                |
| SAND AND SILT TO SILT (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><br>SUDBURY, ONTARIO |     |              | <b>FIGURE B2</b> |                                |



| GRAVEL SIZE, mm |           |        |        |             |        | Cobble<br>Size |
|-----------------|-----------|--------|--------|-------------|--------|----------------|
| CLAY AND SILT   | fine      | medium | coarse | fine        | coarse |                |
|                 | SAND SIZE |        |        | GRAVEL SIZE |        |                |

#### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | BH09-17  | 4      | 258.7    |
| ■      | BH09-17  | 8      | 254.9    |
| ▲      | BH09-18  | 9b     | 259.2    |
| +      | BH09-18  | 11     | 256.4    |
| ◆      | BH09-19  | 13     | 253.0    |
| ◇      | BH09-20  | 2      | 258.9    |
| ○      | BH09-20  | 4      | 257.4    |
| △      | BH09-20  | 7      | 255.1    |

PROJECT

HIGHWAY 11 SBL CULVERT 19+545

TITLE

**GRAIN SIZE DISTRIBUTION**

SILT TO SANDY SILT

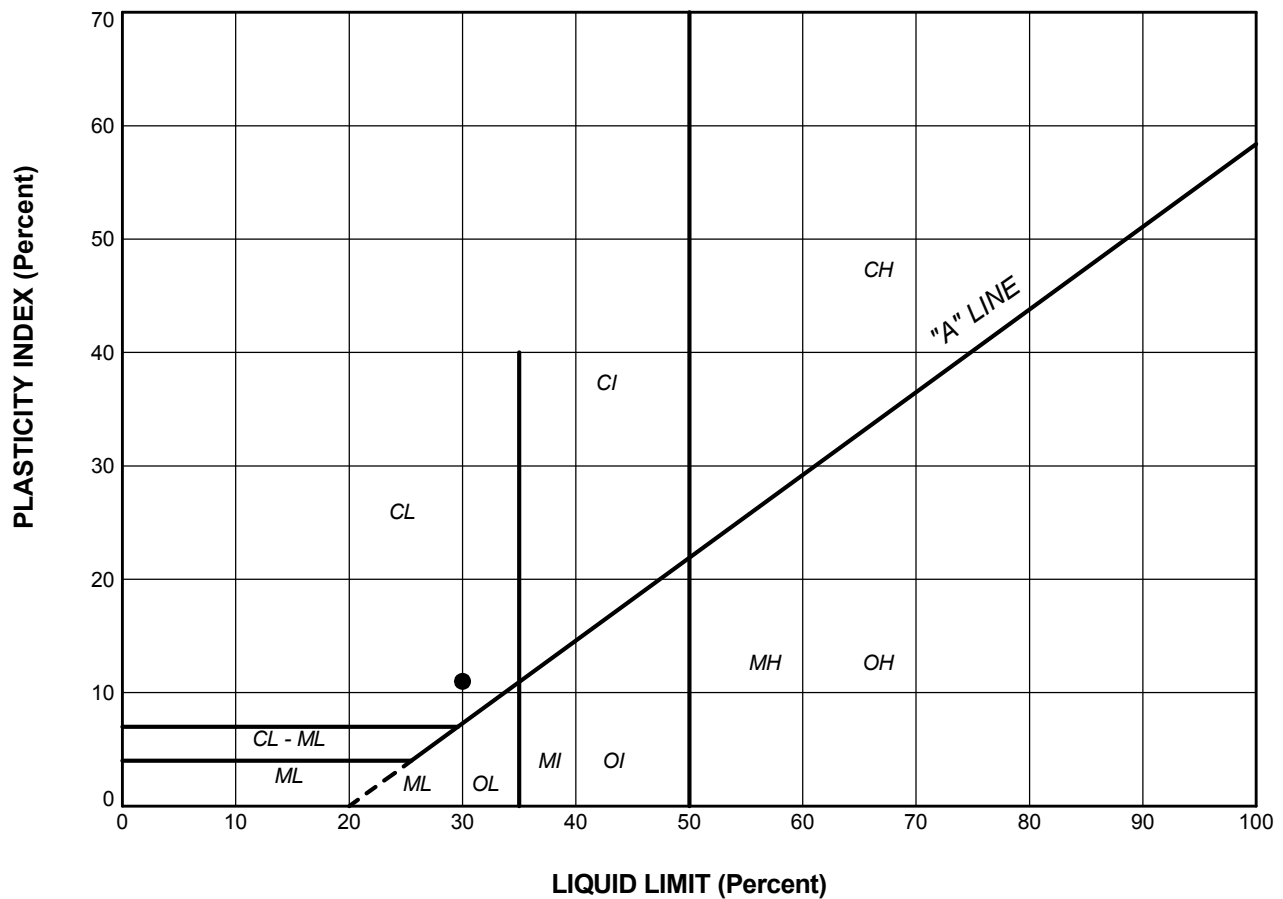


**Golder Associates**  
SUDBURY, ONTARIO

|                          |     |                                |           |
|--------------------------|-----|--------------------------------|-----------|
| 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                       |           |

**FIGURE B3**

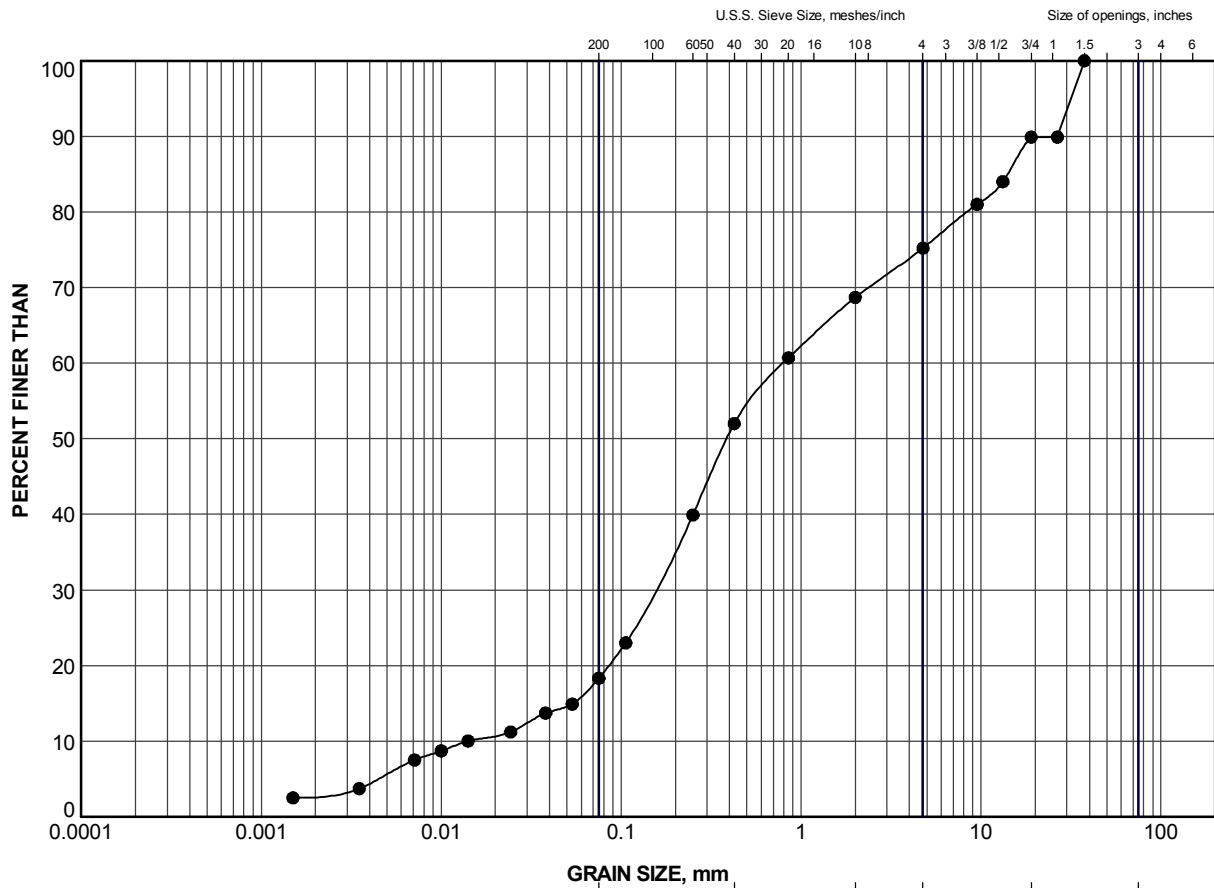




| <b>LEGEND</b> |          |        |       |       |      |
|---------------|----------|--------|-------|-------|------|
| SYMBOL        | BOREHOLE | SAMPLE | LL(%) | PL(%) | PI   |
| ●             | BH09-17  | 5      | 30.0  | 19.0  | 11.0 |

|   |     |          |                                |     |      |
|---|-----|----------|--------------------------------|-----|------|
| PROJECT   |     |          |                                |     |      |
| HIGHWAY 11 SBL CULVERT 19+545                         |     |          |                                |     |      |
| TITLE   |     |          |                                |     |      |
| <b>PLASTICITY CHART</b><br>CLAYEY SILT SEAMS / LAYERS |     |          |                                |     |      |
| PROJECT No. 09-1191-0042                              |     |          | FILE No. 09-1191-0042-4000.GPJ |     |      |
| DRAWN   | JJL | Nov 2011 | SCALE                          | N/A | REV. |
| CHECK   | AB  | Nov 2011 | <b>FIGURE B4</b>               |     |      |
| APPR  | FJH | Nov 2011 |                                |     |      |






|               |           |        |        |             |        |                |
|---------------|-----------|--------|--------|-------------|--------|----------------|
| CLAY AND SILT | fine      | medium | coarse | fine        | coarse | Cobble<br>Size |
|               | SAND SIZE |        |        | GRAVEL SIZE |        |                |

### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | BH09-18  | 15     | 250.3    |

|  |  |                          |     |                                |           |
|--|--|--------------------------|-----|--------------------------------|-----------|
| PROJECT  |  |                          |     |                                |           |
| HIGHWAY 11 SBL CULVERT 19+545  |  |                          |     |                                |           |
| TITLE  |  |                          |     |                                |           |
| GRAIN SIZE DISTRIBUTION  |  |                          |     |                                |           |
| GRAVELLY 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>FIGURE B5</b>   |  |                          |     |                                |           |

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