



September 25, 2015

## PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

TURNER CREEK CULVERT - SITE NO. 45-279/C  
HIGHWAY 602, DISTRICT OF RAINY RIVER  
TOWNSHIP OF AYLSWORTH  
MINISTRY OF TRANSPORTATION, ONTARIO  
G.W.P 6341-14-00

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REPORT





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# **PART A**

**PRELIMINARY FOUNDATION INVESTIGATION REPORT  
TURNER CREEK CULVERT – SITE NO. 45-279/C  
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G.W.P. 6341-14-00**



## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by Hatch Mott MacDonald (HMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the replacement of the Turner Creek culvert (Site No. 45-279/C). The Turner Creek culvert is located in the District of Rainy River, in the Township of Aylsworth on Highway 602 at STA 10+031, approximately 18.4 km southeast of the junction of Highway 602 and Highway 11. The key plan showing the general location of this section of Highway 602 and the location of the investigated area are shown on Drawing 1.

## **2.0 SITE DESCRIPTION**

The Turner Creek culvert is an open footing concrete structure, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

In general, the topography in the area of the culvert is relatively flat with agricultural land use beyond the highway right-of-way and mature trees in the immediate vicinity of the culvert. Highway 602 runs in a west-east direction with the culvert in a north-south orientation perpendicular to the roadway. At the culvert location, Turner Creek flows southerly. The highway grade is at Elevation 335.6 m and the culvert invert is at approximately Elevation 329.1 m and 328.9 m at the inlet (north end) and outlet (south end), respectively. The creek water level was at Elevations 331.5 m as measured by others on June 18, 2014. The creek ice level was at Elevation 330.4 m as measured by Golder on March 13, 2015. Surface conditions at the culvert inlet and outlet areas are shown on Photographs 1 to 3, attached.

## **3.0 INVESTIGATION PROCEDURES**

The field work for this subsurface investigation was carried out between March 13 and 15 and on March 22, 2015, during which time four (4) boreholes (Boreholes TR-1 to TR-4) were advanced at approximate the locations shown on Drawing 1. Boreholes TR-1 and TR-4 were advanced at the toe of slope near the culvert inlet and outlet, respectively, and Boreholes TR-2 and TR-3 were advanced from the existing highway platform. Boreholes TR-1 to TR-3 were advanced with a track-mounted CME 55 drill rig using 108 mm inside diameter hollow stem augers and Borehole TR-4 was advanced with a portable tripod drill rig using NW casing and wash boring techniques. All drilling equipment was supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec.

Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using an MTO Standard 'N' size vane. The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The field work was supervised on a full-time basis by a member of Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in



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Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions and Atterberg limits were carried out on selected soil samples. The geotechnical laboratory testing was completed according to MTO LS standards.

A sample of the creek water was obtained at the culvert site on February 24, 2015, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters, including pH, resistivity, conductivity, sulphates and chlorides.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by member of our technical staff, referenced to the highway centerline and existing culvert and converted into northing/easting on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile provided by MTO on drawing E14876021.dwg. The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum, and borehole depth at each borehole location are presented on the Record of Borehole sheets in Appendix A and summarized below.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
TR-1	5376181.0	249406.7	331.5	6.7
TR-2	5376164.7	249408.0	335.6	23.9
TR-3	5376160.8	249398.4	335.5	23.5
TR-4	5376149.2	249408.8	332.2	6.7

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)<sup>1</sup> mapping, the subsoils in the vicinity of the Turner Creek culvert site generally consist of glaciolacustrine plain deposits comprised of clay and silt bordering with areas of organic terrain comprised of peat/muck.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)<sup>2</sup>, the site is underlain by metasedimentary bedrock of the Archean Era, comprised of wacke, arkose, argillite, slate, chert and iron formations bordering with areas of massive granodiorite to granite bedrock.

### 4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ tests (i.e., SPT 'N'-values and undrained shear strengths from field vanes) as presented on the Record of Borehole sheets and in

<sup>1</sup> Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52CNW.

<sup>2</sup> Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542.



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Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

### Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt, sand fill, and silty clay to clay fill, underlain by cohesive deposits of silty clay to clayey silt (till) and clay. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows) / Shear Strength	Laboratory Testing
				Consistency or Relative Density	
<b>Asphalt</b>	TR-2, TR-3	0.025	335.6 – 335.5	n/a	n/a
<b>(FILL)</b> Sand, some gravel; brown; frozen	TR-2, TR-3	0.7	335.6 – 335.5	n/a	w = 5%
<b>(FILL)</b> <sup>1</sup> Silty Clay with sand, trace gravel, trace wood, trace organics to Clay, trace sand; brown to grey; frozen to wet	TR-1 to TR-3	1.4 – 4.2	334.9 – 331.5	N = 3 – 8 <sup>2</sup> S <sub>u</sub> = 91 - >100 S = 1  <b>Soft to very stiff</b>	w = 32% - 38% w <sub>L</sub> = 85% - 88% w <sub>p</sub> = 27% - 29% I <sub>p</sub> = 56% - 61% 2 - MH (Fig. B1) 2 - AL (Fig. B2)
<b>Clayey Silt (TILL)</b> with sand to sandy <b>Silty Clay (TILL)</b> , trace gravel; brown to grey, frozen to wet	TR-1 to TR-4	5.3 – 17.6	332.2 – 330.1	N = 4 – 16 <sup>3</sup> S <sub>u</sub> = 72 - >100 S = 1  <b>Stiff to very Stiff</b>	w = 19% - 23% w <sub>L</sub> = 30% - 42% w <sub>p</sub> = 14% - 25% I <sub>p</sub> = 13% - 27% 9 - MH (Fig. B3) 9 - AL (Fig. B4)
<b>Clay</b> , trace sand; grey; wet	TR-2, TR-3	2.2 – 3.8 (Boreholes terminated in this deposit)	315.5 – 314.2	N = 6 – 8 S <sub>u</sub> = 89 - 96 S = 1 - 2  <b>Stiff</b>	w = 57% w <sub>L</sub> = 81% w <sub>p</sub> = 29% I <sub>p</sub> = 52% 1 - MH (Fig. B5) 1 - AL (Fig. B6)

#### Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration

S<sub>u</sub> = Undrained Shear Strength (kPa)

S = Sensitivity

w = Natural Moisture Content (%)

w<sub>p</sub> = Plastic Limit (%)

w<sub>L</sub> = Liquid Limit (%)

I<sub>p</sub> = Plasticity Index (%)

MH = Combined Sieve and Hydrometer analysis

AL = Atterberg Limits Test



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### Notes:

<sup>1</sup> Wood fragments were noted within the silty clay fill in Borehole TR-1 advanced at the toe of the embankment slope.

<sup>2</sup> SPT 'N'-values ranging from 11 to 76 blows per 0.3 m were measured in the silty clay to clay fill, however, these values are likely indicative of the frozen state of the material and not representative of the consistency of the fill material.

<sup>3</sup> SPT 'N'-values of 16 and 17 blows per 0.3 m were measured in the near surface sections of the sandy silty clay till deposit, however, these values are likely indicative of the frozen state of the material and not representative of the relative density of the till material.

### Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The creek ice level was measured at Elevation 330.4 m on March 13, 2015. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
TR-1	Dry	-
TR-2	4.8	330.8
TR-3	5.0	330.5
TR-4	0.0	332.2 <sup>1</sup>

Note:

<sup>1</sup> Borehole TR-4 was advanced using NW casing and wash boring techniques. As such, the water level may not be representative of in situ groundwater conditions.

## 5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle, under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Tibor Berecz, and Mr. David Muldowney, P.Eng. provided a technical review of the report. Mr. Jorge M. A. Costa, P.Eng., the Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.





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## Report Signature Page

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## **PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT  
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## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides preliminary foundation design recommendations for the proposed replacement of the Turner Creek culvert. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation.

The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the culvert replacement. Further investigation and analysis may be required during detail design, once the configuration of the proposed culvert and replacement strategy is finalized, to confirm and expand on the preliminary foundation recommendations provided in this report.

Where comments are made on construction, they are provided to highlight those aspects that could affect the future detail design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

Based on discussions with HMM, it is assumed that the concrete culvert will be replaced with a culvert of similar dimensions, along the same alignment as well at similar invert elevations to those of the existing culvert. In addition, it is assumed that there will be no embankment grade raises or widening in the area of the culvert as part of the Hwy 602 reinstatement.

### **6.2 Foundations**

#### **6.2.1 Foundation Options**

The existing Turner Creek culvert is located in the District of Rainy River, in the Township of Aylsworth on Highway 602 at STA 10+031, approximately 18.4 km south of the junction of Highway 602 and Highway 11. The highway embankment is constructed of granular and cohesive fill material and is approximately 6.5 m high relative to the culvert invert and the fill covering the existing structure is approximately 3.0 m thick. The existing culvert is a concrete open footing structure, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

Based on discussions with HMM and as indicated on the preliminary General Arrangement (GA) drawings prepared by HMM, we understand that the following culvert types are being considered at this location:

- A pre-cast concrete box;
- A pre-cast open footing with either a pre-cast concrete arch or metal box; and
- A pre-cast concrete cap on sheet-pile abutments.

In this report we have considered the following options:

- A pre-cast concrete box;



- An open footing (box or arch) culvert supported on either cast-in-place or pre-cast footings;
- A pre-cast concrete cap on sheet-pile abutments; and
- A pipe culvert(s).

Pipe culverts, including elliptical culverts and/or flexible arch culverts are considered feasible but would provide less flow-through capacity compared to a box culvert option with a similar span and would likely require multiple, parallel pipes. If a pipe culvert is selected, a concrete pipe would be preferred as a structural plate or corrugated steel pipe generally has a shorter design life. A pre-cast concrete slab supported on sheet-pile abutments is also considered feasible at this site but the sheet-piles may need to be advanced to a significant depth to develop sufficient frictional forces or to penetrate into a competent stratum to develop sufficient toe resistance to meet the geotechnical axial and lateral resistance requirements. Open footing arch culverts could be considered but the overall performance of such structures over the longer term is not known. From a foundation perspective, a box culvert sufficiently wide to accommodate the creek flow is preferred. A pre-cast concrete box culvert is recommended over an open footing culvert as the subsurface conditions at the foundation level are suitable for the support of such a box foundation; it can accommodate an accelerated construction schedule; and there are reduced excavation, dewatering and shoring requirements. Other culvert types may be preferred due to construction staging or other considerations such as fisheries requirements related to natural channel substrate. A comparison of culvert types based on advantages, disadvantages and risks/consequences is presented in Table 2.

## **6.2.2 Foundation Elevations and Frost Protection**

### **6.2.2.1 Box Culvert**

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as a box structure is tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the replacement box culvert be founded on a granular bedding/levelling pad placed on the stiff to very stiff clayey silt to silty clay (till) stratum as encountered in the boreholes. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3.

### **6.2.2.2 Open Footing Culvert**

Strip footings for an open footing culvert should be founded on the stiff to very stiff clayey silt to silty clay (till) stratum at a minimum depth of 2.3 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation, Frost Penetration Depths for Northern Ontario). In addition, the footings should extend below any existing fill and/or organics (if encountered). Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

### **6.2.2.3 Pre-Cast Concrete Slab on Sheet-Pile Abutments**

Sheet-pile abutments supporting a concrete slab, if utilized at this site as the culvert replacement option, will penetrate well below the frost depth to bear within the stiff to very stiff clay deposit encountered in Boreholes



TR-2 and TR-3. Therefore, such a foundation should not be subject to frost induced heave per se but adhesion of the subsoils to the sheet-pile walls along the depth of the frost penetration zone would have to be considered in the overall assessment of the sheet-pile depths in order to resist uplift (heave). An estimate of the additional depth required to resist uplift should be provided at the detail design stage if this culvert replacement option is selected.

#### **6.2.2.4     *Pipe Culvert(s)***

It is not necessary to found pipe culvert(s) at the standard depth for frost protection purposes, as such culverts are tolerant to small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the replacement culvert(s), if adopted, be founded on a bedding layer of granular material placed over the stiff to very clayey silt to stiff clay (till) stratum. Recommended foundation elevation and foundation conditions for circular pipe culverts are provided in Table 3.

### **6.2.3     Geotechnical Resistances**

#### **6.2.3.1     *Box Culvert***

A box culvert, placed on the properly prepared subgrade and/or properly placed granular pad/backfill at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement, as provided in Table 3. These recommendations are based on an assumed 5 m wide box culvert as noted in Table 3.

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS are dependent on the foundation size, configuration and applied loads; the geotechnical resistance/reaction should, therefore, be reviewed if the culvert width or founding elevation differs from those given in Table 3.

The geotechnical resistance/reaction provided in Table 3 are based on loading applied perpendicular to the base of the culvert; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the Canadian Highway Bridge Design Code (CHBDC 2006) and its Commentary.

The loading on the foundation soils below the culvert and the associated settlements of the culvert will be governed by the design height of the overlying and adjacent embankment fill, however it is assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is to take place as the magnitude of settlement that will occur under the culvert will be impacted by any additional soil loading both on and adjacent to the culvert.

#### **6.2.3.2     *Open Footing Culvert***

Strip footings placed on the properly prepared subgrade, at or below the founding elevation recommended in Table 3, should be designed based on the factored geotechnical axial resistance at ULS and geotechnical



reaction at SLS, for 25 mm of settlement, as provided in Table 3. These recommendations are based on the assumed footing widths of 0.6 m and 1.2 m as noted in Table 3.

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS are dependent on the foundation size, configuration and applied loads; the geotechnical axial resistance/reaction should, therefore, be reviewed if the culvert footing widths or founding elevation differs from those given in Table 3.

The geotechnical resistance/reaction provided in Table 3 are based on loading applied perpendicular to the base of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the CHBDC and its Commentary.

The loading on the foundation soils below the culvert and the associated settlements of the culvert will be governed by the design height of the overlying and adjacent embankment fill, however it is assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is to take place as the magnitude of settlement that will occur under the culvert will be impacted by any additional soil loading both on and adjacent to the culvert.

### **6.2.3.3     *Pre-Cast Slab and Sheet-Pile Abutments***

The sheet-piles should be driven through the silty clay to clay (till) and into the stiff to very stiff clay deposit to or below the founding elevations given in Table 3, and should be designed based on the factored unit geotechnical resistances at ULS and unit geotechnical reaction at SLS (for 25 mm of settlement) provided in Table 3. These values do not include downdrag forces, which may need to be considered if the grade is raised or the embankments are widened, nor do the estimated depths of sheet-pile embedment account for the uplift (heave) stresses due to adhesion to frozen ground.

The units of unfactored geotechnical axial resistance/reaction provided in Table 3 are primarily based on frictional forces between the sheet-pile and the subgrade soil interface material. If a higher geotechnical resistance/reaction is required for design, the sheet-piles may need to be driven to a greater depth to increase frictional resistance, or penetrate into a more competent soil stratum if such a structure is present at depth, to develop higher toe resistances; however, additional drilling would be required to confirm the subgrade soil conditions at greater depth.

### **6.2.4     *Resistance to Lateral Loads / Sliding Resistance***

Resistance to lateral forces/sliding resistance between the base of the box culvert and granular bedding material or between the base of the strip footing and subgrade soil should be calculated in accordance with Section 6.7.5 of the CHBDC. Table 4 provides the coefficients of friction between the base of the culvert/footing and potential interface materials.



## **6.2.5 Stability and Settlement**

Given that an embankment grade raise or widening is not proposed as part of the culvert replacement and highway embankment reconstruction, the existing native soils will not experience additional load, and therefore, settlement of the culvert after embankment reconstruction is estimated to be less than 25 mm.

For the subsurface conditions and the reconstructed embankments height up to about 6.5 m relative to the existing/proposed culvert invert, granular fill embankments at this site will be stable at side slopes inclined at 2 Horizontal to 1 Vertical (2H:1V) or flatter.

Given the height of the existing embankment and the presence of the cohesive soil deposits at this site, additional analysis of stability and long-term settlement will be required if a grade raise and/or widening is proposed. Further, depending on the magnitude of the grade raise and/or widening, additional field work and/or specialized laboratory testing may be required.

## **6.3 Lateral Earth Pressures**

The lateral earth pressures acting on the side walls (or head/wing walls if required) of the culvert will depend on the type and method of placement of backfill materials, the nature of soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

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

- Select, free draining granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of up to 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness. Weep holes should be installed to allow for positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).
- The granular fill may be placed either in a zone with the width equal to at least 2.3 m behind the back of the walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5 H:1V extending up and back from the rear face of the base of the walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC).
- The following parameters (unfactored) may be used to calculate the lateral earth pressures acting on the culvert or sheet-piles:



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Fill Type	Internal Angle of Friction ( $\phi$ )	Unit Weight	Coefficients of Static Lateral Earth Pressure	
			At-Rest, $K_o$	Active, $K_a$
Granular 'A'	35°	22 kN/m <sup>3</sup>	0.43	0.27
Granular 'B' Type II	35°	21 kN/m <sup>3</sup>	0.43	0.27
Granular 'B' Type I or III	32°	21 kN/m <sup>3</sup>	0.47	0.30
Clayey Silt to Silty Clay (Till)	28°	18 kN/m <sup>3</sup>	0.53	0.36
Clay	27°	17 kN/m <sup>3</sup>	0.55	0.38

If the structure allows for lateral yielding, active earth pressures may be used in the design of the structure. If the structure does not allow for lateral yielding, at-rest earth pressures should be assumed for design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the Commentary to the CHBDC.

## 6.4 Construction Considerations

### 6.4.1 Temporary Roadway Protection

The temporary excavation for the culvert replacement will be made through the existing granular and cohesive embankment fill and into native soils comprised of stiff to very stiff clayey silt to silty clay (till). All excavations must be carried out in accordance with Ontario Regulation 213, Ontario Occupational Health and Safety Act for Construction Projects (as amended). The granular and generally stiff to very stiff cohesive fill material and the native soil are considered to be Type 3 and Type 2 soil, respectively, above the groundwater table and Type 4 soil below the groundwater table. Temporary open-cut excavations in Type 2 and Type 3 soils should remain stable if side slopes are formed no steeper than 1H:1V, including for vertical sides for the lower 1.2 m of the excavation in Type 2 soil. In Type 4 soils, the side slopes should be formed no steeper than 3H:1V.

Temporary protection support systems may be required along the highway to facilitate construction staging and maintain traffic during culvert replacement work. The temporary support systems could consist of either driven sheet-piling extended to suitable depth, or soldier piles and lagging where H-piles are driven to a suitable depth and horizontal lagging is installed as the excavation proceeds. Support to the temporary protection system could be in the form of struts and walers and rakers or anchors. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways.

The installation of the sheet-piles for culvert construction and/or temporary shoring may be impeded by the presence of wood, such as was encountered within the fill material in Borehole TR-1 and the potential presence of corduroy road material, which may have been used locally based on anecdotal information. It may be necessary to excavate and replace the existing fill material in the areas of sheet-pile installation in a series of narrow trenches of limited length. In general, the narrowest suitable excavator bucket should be used. The replacement fill could consist of excavated fill material or imported granular material such as OPSS.PROV 1010





Granular 'A' or Granular 'B' Type I, II or III provided that 100 per cent of the material passes the 75 mm size and less than 5 per cent passes the 75  $\mu$ m size. The excavated spoil pile may be re-used to backfill the excavation after removing the wood (and any cobbles and boulders, if encountered) that would otherwise impede the sheet-pile installation. Excavation and replacement should be carried out on the same day to avoid leaving any trench open overnight. Consideration should be given to including an NSSP in the contract to address obstructions. A sample NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

#### **6.4.2 Excavation and Replacement Below Culvert**

Prior to placement of any bedding/levelling course material, engineered fill or concrete, all existing fill, organics (if encountered) and any softened or disturbed soils, should be sub-excavated from below the plan limits of the proposed works to the founding levels provided in Table 3.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organics and other unsuitable materials have been removed as noted above, in accordance with OPSS 422 (Pre-cast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for an open footing culvert. Following inspection, the sub-excavated area should be backfilled with granular material meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II or III that is placed and compacted in accordance with OPSS.PROV 501 (Compacting). The use of Granular 'B' Type II is recommended in wet ground conditions or below water and placement should be in accordance with OPSS.PROV 209 (Embankments over Swamps and Compressible Soils).

#### **6.4.3 Culvert Bedding and Backfill**

##### **6.4.3.1 Box Culvert**

The levelling layer pad, and the bedding if required, for a pre-cast box culvert should be accordance with OPSS 422 (Pre-cast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the native soils during excavation to the invert and level of the levelling layer and hence for softening of the subgrade, if the excavation has to be deepened as a result of removal of unsuitable material, it is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material be used for bedding purposes. As the native soil below the bedding are generally fine grained, it is recommended that a non-woven geotextile be placed between the native soil and the bottom of the bedding. The geotextile should meet the specifications for OPSS 1860 (Geotextiles) Class II, and have a fabric opening size (FOS) not greater than 212  $\mu$ m. Above the water table, the bedding should be placed in maximum 200 mm thick loose lifts and compacted to at least 98 per cent of the standard Proctor maximum dry density (SPMDD) of the materials as specified in OPSS.PROV 501 (Compacting). In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided with a geometry similar to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts), whether placed on the native subgrade material or on the bedding layer, and should be placed in dry conditions.



If the top of the box culvert is located above the frost penetration depth, depending on the embankment thickness over the culvert and the final size and founding elevation of the culvert, a frost taper should be constructed in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts). Although OPSD 803.010 relates to box culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 5 m wide box culvert replacement option.

If the top of the box culvert is located below the frost penetration depth, a frost taper may not be required from a foundation perspective but may be required from a pavement restoration perspective due to the presence of the moderate to highly frost susceptible clay embankment fill.

#### **6.4.3.2     *Open Footing Culvert***

The excavation and backfilling requirements for the open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures) and also in similar configuration to that shown on OPSD 803.010 as noted in Section 6.4.3. The open footing culvert should be provided with at least 2.3 m of soil cover for frost protection.

Should a pre-cast open footing culvert be the selected replacement option, a bedding layer and levelling pad will be required above the native soil. The bedding layer and levelling pad for the pre-cast open footings should follow the recommendations as discussed in Section 6.4.3.1 for the box culvert replacement option.

If the top of the open footing culvert is located above the frost penetration depth, depending on the embankment thickness over the culvert and the final size and founding elevation of the culvert, a frost taper should be constructed in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts). Although OPSD 803.010 relates to an open footing culvert with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 7 m wide open footing culvert replacement option shown on the preliminary GA drawings.

If the top of the open footing culvert is located below the frost penetration depth, a frost taper may not be required from a foundation perspective but may be required from a pavement restoration perspective due to the presence of the moderately frost susceptible silty clay to clay embankment fill.

#### **6.4.3.3     *Pipe Culvert(s)***

The bedding, levelling and backfill for a concrete pipe, CSP or SP CSPA culvert should be in accordance with OPSD 802.034 (Rigid Pipe Bedding and Cover in Embankment), OPSD 802.014 (Flexible Pipe Embedment in Embankment) or OPSD 802.024 (Flexible Pipe Arch, Embedment in Embankment), respectively, 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. The pipe culvert should be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II material for bedding purposes, however this layer thickness should be confirmed at the detail design stage for the actual culvert type and size selected.

If the top of the pipe culvert(s) is located above the frost penetration depth, depending on the final size and founding elevation, a frost taper should be constructed with geometry similar to that provided on OPSD 803.031 (Frost Treatment).



If the top of the pipe culvert is located below the frost penetration depth, a frost taper may not be required from a foundation perspective but may be required from a pavement restoration perspective due to the presence of the moderate to highly frost susceptible clay embankment fill.

#### **6.4.3.4 Backfill**

Backfill behind the culvert walls (including the sheet-pile abutments, if selected as the preferred culvert replacement option) should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the No. 200 (0.075 mm) sieve. The backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMD in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm.

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

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

#### **6.4.4 Subgrade Protection**

The native clayey silt to silty clay (till) subgrade will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance it may be necessary to sub-excavate deeper and place a 300 mm thick compacted bedding layer on the prepared subgrade, or alternatively construct a concrete working slab on the subgrade if the concrete footings, or the box culvert, is not placed within four hours after preparation, inspection, and approval of the foundation subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28 day compressive strength of 20 MPa. Consideration should be given to include an NSSP in the contract to address subgrade protection at this site. A sample NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

#### **6.4.5 Erosion Protection**

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the box/pipe culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a concrete cut-off wall or clay seal should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum thickness of 1 m. The clay seal should extend from a depth of 1 m below the scour level to a minimum vertical height equivalent to the high water level. The seal should also extend a minimum horizontal



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distance of 2 m on either side of the culvert inlet opening. Alternatively, a 0.6 m thick clay blanket may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height of two times the culvert height or the high water level, whichever is greater.

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

### 6.4.6 Control of Groundwater and Surface Water

Excavation along the culvert alignment will be required to remove the existing fill, organic soils where present and a portion of the native soil where required to achieve the design invert/bedding level prior to placement of bedding, the actual culvert, backfill and the roadway pavement structure. Groundwater flow into the excavation can be expected due to the depth of the excavation and the presence of existing relatively permeable embankment fill. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

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

Excavations for the box, open footing and pipe culvert options will extend below the creek water level and will therefore require temporary shoring with dewatering to allow for construction/placement of the footings and/or placement of engineered fill in dry conditions, where required. Temporary shoring and dewatering could be in the form of a sheet-pile cut-off wall or cofferdam advanced to an appropriate depth to control groundwater inflow from the creek and to prevent base heaving of the foundation subgrade. As discussed in Section 6.4.2, sub-excavation replacement backfill, if required, can be placed subaqueously, if comprised of Granular B Type II materials, however, dewatering may still be required for footing/culvert placement as the culvert invert is at or below the creek water level.

Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering). Consideration should be given to include an NSSP in the contract to address unwatering at this site. A sample NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

At this preliminary stage, an accurate prediction of the groundwater pumping volumes cannot be made, as the flow rate would be dependent on construction methods adopted by the contractor. However, given the subsurface conditions at the culvert site, it is considered that with prudent control of surface water flows and adequate diversion around the work area minimizing surface water filtration, groundwater pumping volumes likely would not exceed 50 m<sup>3</sup>/day during initial drawdown stages and/or during periods of precipitation. For this site, a Permit to Take Water (PTTW) is likely not required.



#### **6.4.7 Obstructions**

Based on anecdotal information, we understand that corduroy roads were commonly used during culvert construction in the Northwest Region. The Contractor should be alerted to the potential for buried wood within the fill material, as encountered in Borehole TR-1. An NSSP should be developed at the detail design stage for inclusion into the Contract Documents to alert the contractor to the potential presence of such obstructions.

#### **6.4.8 Analytical Testing for Construction Materials**

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

### **6.5 Recommendations for Further Work During Detail Design**

During the detail design phase, additional field investigation and testing may be required, depending on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., staging). In particular, consideration should be given to drilling additional boreholes advanced to a suitable depth for design of temporary works if the culvert is to be constructed in stages while maintaining one open lane of traffic or if the pre-cast concrete cap supported on sheet-pile abutments option is selected and additional resistance to that presented in Table 3 is needed. The scope and results of this investigation must be reviewed at the time of the detail design to determine if they meet the then-current MTO requirements for the culvert type or staging strategy under consideration, and if additional investigation and analysis is necessary. If a grade raise or widening of the roadway is required at this site, additional settlement and stability analysis will be required. Further, an assessment of the need for an application for a PTTW should be defined early in the detail design phase of the project as not to delay the start of construction.

## **7.0 CLOSURE**

This Preliminary Foundation Design Report was prepared by Mr. Adam Core, P. Eng. and the technical aspects were reviewed by Mr. David Muldowney, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.



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TURNER CREEK CULVERT - SITE NO. 45-279/C**

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## Report Signature Page

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## PRELIMINARY FOUNDATION REPORT TURNER CREEK CULVERT - SITE NO. 45-279/C

### REFERENCES

Canadian Standards Association (CSA), 2006. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6 06. CSA Special Publication, S6.1 06.

Occupational Health and Safety Act and Regulation for Construction Projects (as amended).

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542.

Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52CNW.

ASTM International:

ASTM D1586                      Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

ASTM D2573                      Standard Test Method for Field Vane Shear Test in Cohesive Soil

Ontario Provincial Standard Specifications (OPSS)

OPSS 421                         Construction Specification for Pipe Sewer Installation in Open Cut

OPSS 422                         Construction Specification for Pre-cast Reinforced Concrete Box Culverts and Box Sewers in Open Cut

OPSS 517                         Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation

OPSS 902                         Construction Specification for Excavating and Backfilling – Structures

OPSS 1205                        Material Specification for Clay Seal

OPSS 1860                        Material Specification for Geotextiles

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 209                 Construction Specification for Embankments over Swamps and Compressible Soils

OPSS.PROV 501                 Construction Specification for Compacting

OPSS.PROV 539                 Construction Specification for Temporary Protection Systems

OPSS.PROV 1002                Material Specification for Aggregates - Concrete

OPSS.PROV 1010                Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010                  Benching of Earth Slopes

OPSD 802.014                  Flexible Pipe, Embedment in Embankment, Original Ground: Earth or Rock

OPSD 802.024                  Flexible Pipe Arch, Embedment in Embankment, Original Ground: Earth or Rock

OPSD 802.034                  Rigid Pipe Bedding and Cover in Embankment, Original Ground: Earth or Rock





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## PRELIMINARY FOUNDATION REPORT TURNER CREEK CULVERT - SITE NO. 45-279/C

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OPSD 803.010	Backfill and Cover for Concrete Culverts With Spans Less Than or Equal to 3.0 m
OPSD 803.031	Frost Treatment – Pipe Culverts, Frost Penetration Line between Top of Pipe and Bedding Grade.
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario

Ontario Water Resource Act:

Regulation 903	Wells (as amended)
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Table 1: Summary of Culvert Details

Culvert Location (Township)	Site #	Approximate Height of Embankment <sup>1</sup> (m)	Existing Culvert			Approximate Invert Elevation <sup>2</sup>	
			Type	Approximate Dimension <sup>2</sup>	Approximate Length (m)	North End of Culvert (m)	South End of Culvert (m)
Hwy 602 STA 10+031 (Township of Aylsworth)	45-279/C	6.5	Concrete open footing	3.0 m wide by 3.5 m high	27	329.1	328.9

- Notes:
1. Embankment height is relative to existing ground surface at the centreline of the roadway and the invert elevation of the culvert.
  2. Culvert dimensions and invert elevations are based on the plan and profile drawings provided by MTO (Drawing E14876021.dwg).

Prepared by: TB/AC  
Checked by: DAM  
Reviewed by: JMAC



## PRELIMINARY FOUNDATION REPORT TURNER CREEK CULVERT - SITE NO. 45-279/C

**Table 2: Comparison of Foundation Alternatives**

Option	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	<ul style="list-style-type: none"> <li>■ Minimizes depth of excavation, protection system (if required) and dewatering requirements compared to open footing option. Minor excavation required for the bedding/levelling course.</li> <li>■ Allows faster construction resulting in shorter duration for dewatering and surface water pumping.</li> <li>■ More tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site or if heave/settlement occurs resulting from freeze/thaw of the subgrade.</li> <li>■ Backfill/bedding under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements.</li> </ul>	<ul style="list-style-type: none"> <li>■ May not satisfy fisheries requirements related to natural channel substrate, if applicable.</li> <li>■ Cut-off wall (or clay seal/blanket) required at inlet to mitigate potential scour under culvert.</li> <li>■ Transportation to and on-site lifting of large pre-cast sections will be required.</li> <li>■ May require water diversion of the creek channel to accommodate construction of the new culvert.</li> </ul>	<ul style="list-style-type: none"> <li>■ Some risk of disturbance of the native clayey silt to silty clay (till) deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad or bedding layer.</li> <li>■ Low risk related to settlement performance.</li> </ul>
Open Footing Culvert	<ul style="list-style-type: none"> <li>■ May be feasible to construct the culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering/unwatering (pumping) of surface water.</li> <li>■ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable.</li> <li>■ Suitable footing founding subgrade at/below the depth of frost penetration (existing structure is also an open footing structure).</li> <li>■ Existing culvert can be used for water diversion while new footings are being constructed adjacent to the existing culvert depending on the width of the new culvert.</li> </ul>	<ul style="list-style-type: none"> <li>■ Excavation depths are greater than for a box culvert option, resulting in increased excavation support requirements and additional spoil material to be disposed off-site.</li> <li>■ Constructing footings in the dry will take longer due to requirements for installation of a groundwater and surface water control system, dewatering and surface water pumping and excavation in a confined space.</li> <li>■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site. Concrete or metal arch sections supported on concrete open (strip) footings but the long-term performance of such structures is not known.</li> <li>■ Would require two parallel sheet pile walls along each footing to allow for excavation to the footing founding level and for control of the groundwater water inflow.</li> </ul>	<ul style="list-style-type: none"> <li>■ High risk of disturbance of the native clayey silt to silty clay (till) deposit during construction; can be somewhat mitigated with use of a concrete working slab or granular working pad but would require greater depth of dewatering for footing construction.</li> <li>■ Culvert joints may be required to accommodate total and differential settlement (if applicable).</li> </ul>



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Option	Advantages	Disadvantages	Risks/Consequences
Pre-cast concrete cap on Sheet-Pile Abutment	<ul style="list-style-type: none"> <li>Existing culvert can be used for water diversion while the sheet-pile abutments are installed adjacent to the existing culvert depending on the width of the new culvert. Minimizes excavation depths and does not require dewatering.</li> <li>Would satisfy fisheries requirements related to natural channel substrate, if applicable.</li> <li>Minimizes or eliminates requirement for excavation and dewatering</li> </ul>	<ul style="list-style-type: none"> <li>May require additional deeper boreholes to assess adequacy of subsurface soils for potentially higher bearing and lateral resistances.</li> <li>Relatively long lengths/sections of sheet-piles required to achieve given bearing and lateral resistances.</li> <li>Potential difficulties in achieving lateral resistances upon driving/vibrating sheet-piles due to the sensitivity of the subgrade soils.</li> <li>Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site (i.e. potential for downdrag and/or heave due to adhesion, including during frozen ground conditions, on the sheet-piles).</li> <li>Steel sheet-piles may not have as long of a design life compared to concrete options.</li> </ul>	<ul style="list-style-type: none"> <li>Joints may need to be incorporated into the slab to accommodate total and differential settlement.</li> <li>Some risk that additional sheet-pile lengths may be required due to disturbance of the subsurface soils during sheet-pile installation.</li> </ul>
Pipe Culvert(s)	<ul style="list-style-type: none"> <li>Allows for faster construction resulting in shorter duration for dewatering and surface pumping.</li> <li>More tolerant of total and differential settlement if the highway embankment is raised or widened.</li> <li>Backfill under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements.</li> </ul>	<ul style="list-style-type: none"> <li>Reduced flow through capacity, unless multiple pipe culverts are considered.</li> <li>Cut-off wall or clay seal/blanket may be required at inlet to mitigate potential scour under culvert.</li> <li>CSP does not have as long of design life compared to concrete options.</li> <li>Difficulty in compacting backfill materials to level of culvert springline.</li> </ul>	<ul style="list-style-type: none"> <li>Some risk of disturbance of the native clayey silt to silty clay (till) subgrade during construction can be mitigated with the use of a tremie concrete working slab or Granular 'B' Type II working pad.</li> <li>Limited risk related to settlement performance.</li> </ul>



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**Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box, Open Footing and Pre-cast Concrete Cap on Sheet-Pile Abutment**  
**Culvert Replacements**

Culvert Location (Township)	Approximate Invert Elevation <sup>1</sup> (North End / South End)	Culvert Type	Approximate Backfill/Bedding Founding Elevation (North End / South End)	Founding Condition	Factored Geotechnical Axial Resistance at ULS <sup>2</sup>	Geotechnical Reaction at SLS for 25 mm of Settlement <sup>2</sup>
Hwy 602 STA 10+031 (Township of Aylsworth)	329.1 m / 328.9 m	Pre-Cast Box <sup>2</sup>	328.7 m / 328.5 m	Bedding/Levelling Pad over Stiff to Very Stiff Clayey Silt with Sand to Sandy Silty Clay (Till)	200 kPa	100 kPa
		Open Footing <sup>2</sup> (0.6 m wide)	326.8 m / 326.6 m	Stiff to Very Stiff Clayey Silt with Sand to Sandy Silty Clay (Till)	200 kPa	200 kPa
		Open Footing <sup>2</sup> (1.2 m wide)			200 kPa	200 kPa
		Pipe Culvert <sup>3</sup>	328.8 m / 328.6 m	Bedding layer over Stiff to Very Stiff Clayey Silt with Sand to Sandy Silty Clay (Till)	N/A	N/A
	N/A	Pre-Cast Slab on Sheet-Pile Abutments <sup>4</sup>	~312.0 m	Stiff Clay	200 kN/m	180 kN/m

- Notes:
1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing E14876021.dwg).
  2. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an assumed 5.0 m wide box culvert and a 0.6 m or 1.2 m wide open footing. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the foundation widths differ from those given above.
  3. The founding elevation may need to be adjusted based on the type and size of the pipe culvert and required bedding thickness.
  4. The factored geotechnical resistance at ULS and geotechnical reaction at SLS (for 25 mm of settlement) are provided per horizontal metre of EZ88 series sheet-piling. The recommended geotechnical resistance/reaction should be reviewed once more information becomes available in terms of the final sheet-piling configuration.

Prepared by: AC  
 Checked by: DAM  
 Reviewed by: JMAC



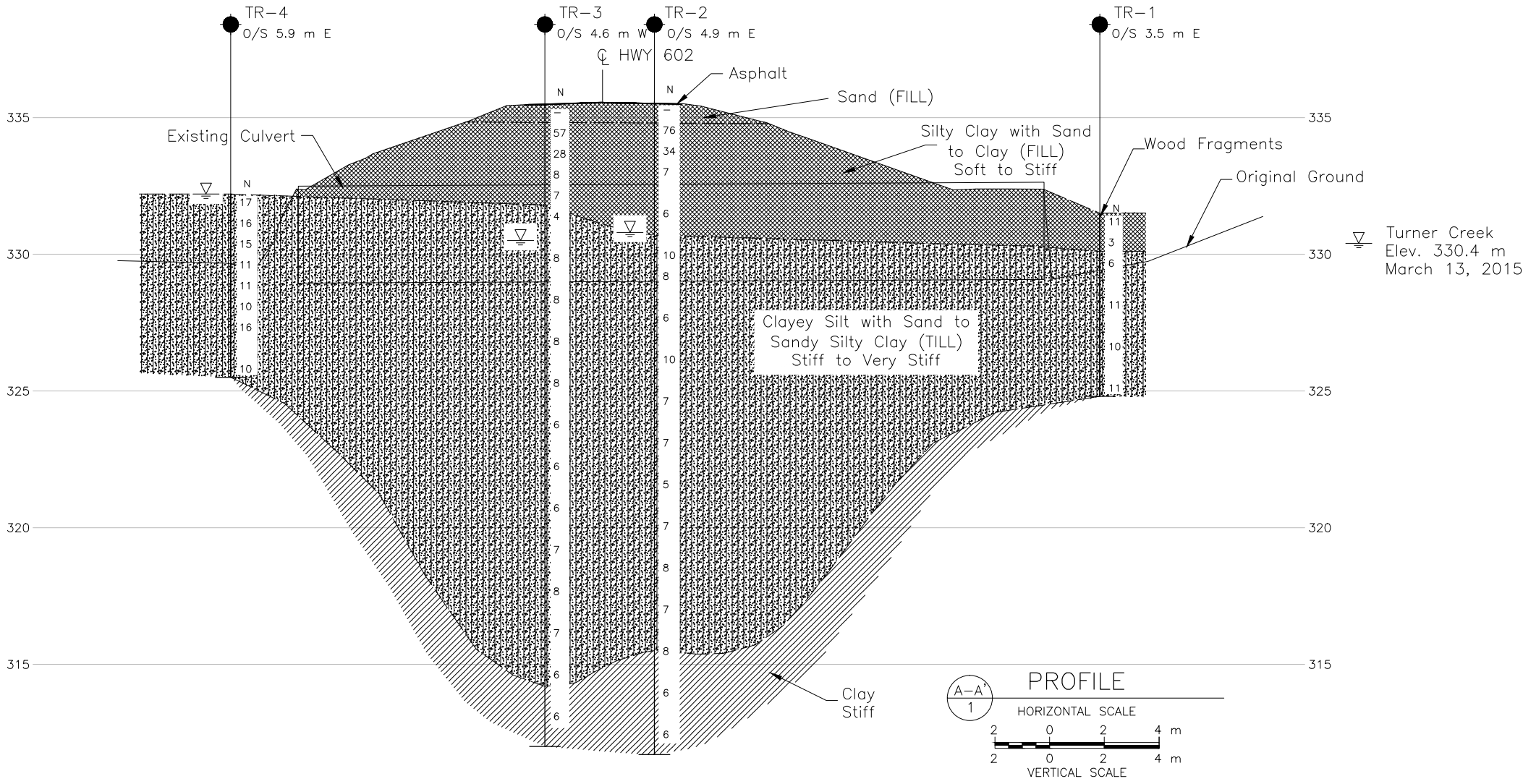
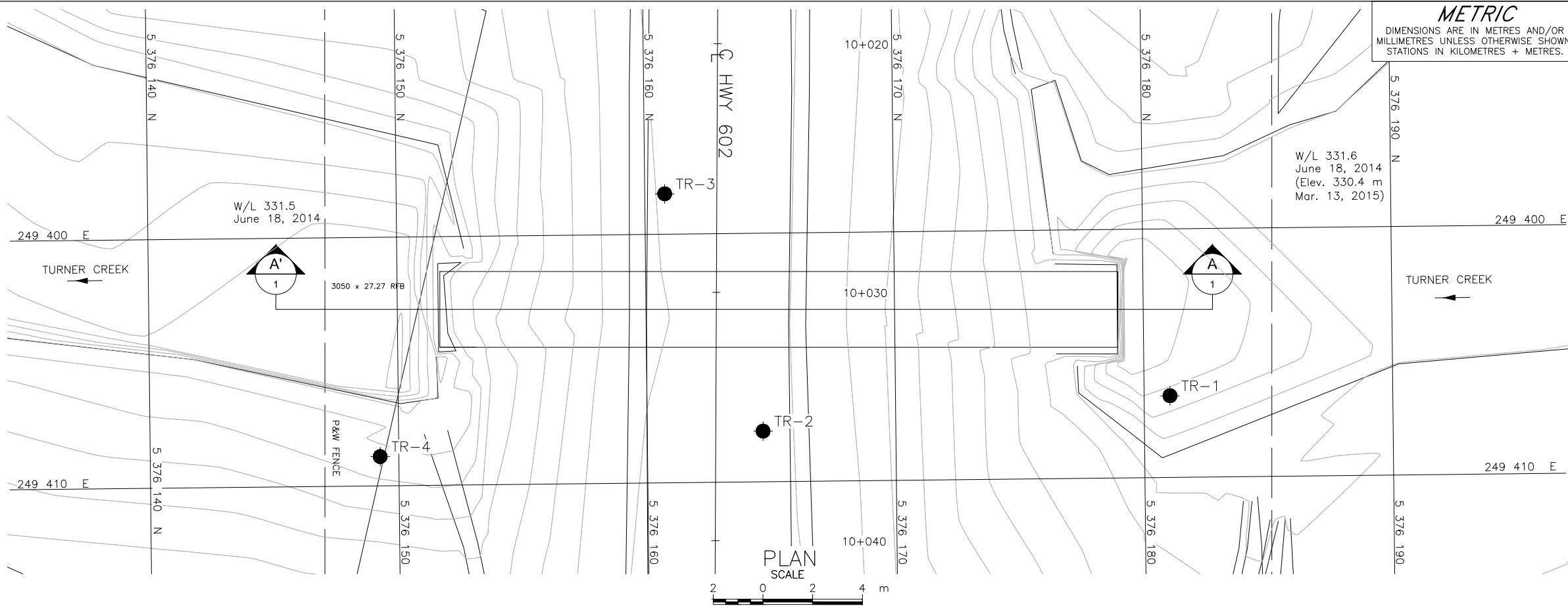
## PRELIMINARY FOUNDATION REPORT TURNER CREEK CULVERT - SITE NO. 45-279/C

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

Culvert Location (Township)	Pre-Cast Box Culvert or Open Footing		Cast-in-place Open Footing	
	Interface Material	Coefficient of Friction <sup>1</sup> (tan $\delta$ )	Interface Material	Coefficient of Friction <sup>1</sup> (tan $\delta$ )
Hwy 602 STA 10+031 (Township of Alysworth)	Compacted Granular Fill (Bedding or Levelling Pad)	0.45	Stiff to Very Stiff Clayey Silt with Sand to Sandy Silty Clay(Till)	0.35

Notes: 1. These values are unfactored. In accordance with CHBDC, a factor of 0.8 to be applied in calculated the horizontal resistances.

Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC



CONT No. GWP No. 6341-14-00

HIGHWAY 602  
TURNER CREEK CULVERT STA 10+031  
BOREHOLE LOCATION PLAN AND  
SOIL STRATA

**Golden Associates**

KEY PLAN

1 0 1 2 km

1:50,000 m

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

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
TR-1	331.5	5376181.0	249406.7
TR-2	335.6	5376164.7	249408.0
TR-3	335.5	5376160.8	249398.4
TR-4	332.2	5376149.2	249408.8

NOTES

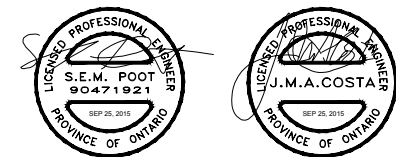
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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 MTO, drawing file no. E14876021, dated JUN 2014, received JAN 27, 2015.



NO.	DATE	BY	REVISION
1	9/28/2015	JLL/TB	1
Geocres No. 52C-42			
HWY. 602	PROJECT NO. 1411526	DIST.	
SUBM'D. AC	CHKD.	DATE: 9/28/2015	SITE: 45-279/C
DRAWN: JLL/TB	CHKD. SEMP	APPD. JMAC	DWG. 1





## PHOTOGRAPHS

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**Photograph 1: Turner Creek Culvert  
North Side - Inlet (Golder – March 12, 2015)**



**Photograph 2: Turner Creek Culvert  
South Side - Outlet (Golder – March 12, 2015)**





## PHOTOGRAPHS

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**Photograph 3: Turner Creek Culvert  
North Side – Inlet (Golder – March 12, 2015)**







# **APPENDIX A**

## **Record of Boreholes**



## LIST OF SYMBOLS

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

### I. 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

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

<b>(a)</b>	<b>Index Properties</b>
$\rho(\gamma)$	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

### (a) Index Properties (continued)

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

### (b) Hydraulic Properties

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

### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_\alpha$	secondary compression index
$m_v$	coefficient of volume change
$C_v$	coefficient of consolidation (vertical direction)
$C_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
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

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

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

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

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

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

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

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

#### (b) Cohesive Soils Consistency

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



### IV. SOIL TESTS

w	water content
w <sub>p</sub>	plastic limit
w <sub>l</sub>	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 <sub>R</sub>	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <sub>4</sub>	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

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

PROJECT 1411523		<b>RECORD OF BOREHOLE No TR-1</b>				1 OF 1 <b>METRIC</b>													
G.W.P. 6341-14-00		LOCATION N 5376181.0; E 249406.7				ORIGINATED BY MR													
DIST _____ HWY 602		BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers				COMPILED BY AC													
DATUM GEODETIC		DATE March 15, 2015				CHECKED BY SEMP													
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)	
331.5	GROUND SURFACE							20	40	60	80	100							
0.0	Silty clay with sand, trace gravel, trace wood and organics (FILL) Soft Brown to grey Frozen* to wet		1	SS	11*		331												
			2	SS	3														
330.1							330												
1.4	Sandy SILTY CLAY, trace gravel (TILL) Very stiff Brown to grey Wet		3	SS	6		329												
			4	SS	11		328												
			5	SS	10		327												
							326												
			6	SS	11		325												
324.8	END OF BOREHOLE																		
6.7	Note:  1. Borehole dry upon completion of drilling.																		

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 16/09/15 DATA INPUT:

# RECORD OF BOREHOLE No TR-2

1 OF 2 **METRIC**

PROJECT 1411523

G.W.P. 6341-14-00

LOCATION N 5376164.7; E 249408.0

ORIGINATED BY MR

DIST \_\_\_\_\_ HWY 602

BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers

COMPILED BY AC

DATUM GEODETIC

DATE March 13, 2015



CHECKED BY SEMP

[illegible]

Continued Next Page

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

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/09/15 DATA INPUT:

PROJECT 1411523			RECORD OF BOREHOLE No TR-2			2 OF 2 METRIC												
G.W.P. 6341-14-00			LOCATION N 5376164.7; E 249408.0			ORIGINATED BY MR												
DIST _____ HWY 602			BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers			COMPILED BY AC												
DATUM GEODETIC			DATE March 13, 2015			CHECKED BY SEMP												
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ kN/m <sup>3</sup>	GR SA SI CL	
							20 40 60 80 100	○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED	W <sub>p</sub>	W	W <sub>L</sub>	20 40 60					
	--- CONTINUED FROM PREVIOUS PAGE ---																	
	Sandy SILTY CLAY, trace gravel (TILL) Very stiff Grey Wet		13	SS	7		320											
								319										
				14	SS	8												
								318										
				15	SS	7		317										
315.5							316											
20.1	CLAY, trace sand Stiff Grey Wet		16	SS	8		315											
								314										
								313										
				17	SS	6												
								312										
311.7																		
23.9	END OF BOREHOLE																	
	Note:  1. Water level at a depth of 4.8 m below ground surface (Elev. 330.8 m) upon completion of drilling.																	

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/09/15 DATA INPUT:

PROJECT 1411523			RECORD OF BOREHOLE No TR-3			1 OF 2 METRIC															
G.W.P. 6341-14-00			LOCATION N 5376160.8; E 249398.4			ORIGINATED BY MR															
DIST HWY 602			BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers			COMPILED BY AC															
DATUM GEODETIC			DATE March 14, 2015			CHECKED BY SEMP															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) W <sub>p</sub> — W — W <sub>L</sub>			γ			GR SA SI CL		
335.5	GROUND SURFACE							20 40 60 80 100													
0.0	ASPHALT (25 mm)		1	AS	-		335														
334.8	Sand, some gravel (FILL) Brown Frozen		2	SS	57*		334														
0.7	Clay, trace sand (FILL) Firm to stiff Brown to grey Frozen* to wet		3	SS	28*		333														
	Trace organics noted from 2.3 m to 3.7 m depth.		4	SS	8		332														
			5	SS	7		331														
331.8	CLAYEY SILT with sand to Sandy SILTY CLAY, trace gravel (TILL) Stiff to very stiff Grey Wet		6	SS	4		330														
			7	SS	8		329														
			8	SS	8		328														
			9	SS	8		327														
			10	SS	8		326														
			11	SS	6		325														
			12	SS	6		324														
			13	SS	6		323														
							322														
							321														

Continued Next Page

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

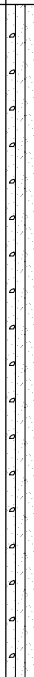
SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/09/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No TR-3				2 OF 2 METRIC									
G.W.P. 6341-14-00		LOCATION N 5376160.8; E 249398.4				ORIGINATED BY MR									
DIST _____ HWY 602		BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers				COMPILED BY AC									
DATUM GEODETIC		DATE March 14, 2015				CHECKED BY SEMP									
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa							
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100				
	CLAYEY SILT with sand to Sandy SILTY CLAY, trace gravel (TILL) Stiff to very stiff Grey Wet		14	SS	7										
			15	SS	8										
			16	SS	7										
			17	SS	6										
314.2															
21.3	CLAY Stiff Grey Wet		18	SS	6										
312.0															
23.5	END OF BOREHOLE														
	Note:  1. Water level at a depth of 5.0 m below ground surface (Elev. 330.5 m) upon completion of drilling.														

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/09/15 DATA INPUT:



PROJECT <u>1411523</u>		<b>RECORD OF BOREHOLE No TR-4</b>		1 OF 1 <b>METRIC</b>	
G.W.P. <u>6341-14-00</u>		LOCATION <u>N 5376149.2; E 249408.8</u>		ORIGINATED BY <u>MR</u>	
DIST <u>          </u> HWY <u>602</u>		BOREHOLE TYPE <u>Portable Equipment - NW Casing and Wash Boring</u>		COMPILED BY <u>AC</u>	
DATUM <u>GEODETIC</u>		DATE <u>March 22, 2015</u>		CHECKED BY <u>SEMP</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>						
332.2	GROUND SURFACE																				
0.0	Sandy SILTY CLAY, trace gravel (TILL) Stiff to very stiff Grey Frozen* to wet		1	SS	17*																
			2	SS	16*																
	Trace organics encountered in upper 1.5 m.		3	SS	15																
			4	SS	11																
			5	SS	11																
			6	SS	10																
			7	SS	16																
			8	SS	10																
325.5	END OF BOREHOLE																				
6.7	Note:  1. Water level at ground surface (Elev. 332.2 m) upon completion of drilling.																				

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 16/09/15 DATA INPUT:



# **APPENDIX B**

## **Laboratory Test Results**



## PRELIMINARY FOUNDATION REPORT TURNER CREEK CULVERT - SITE NO. 45-279/C

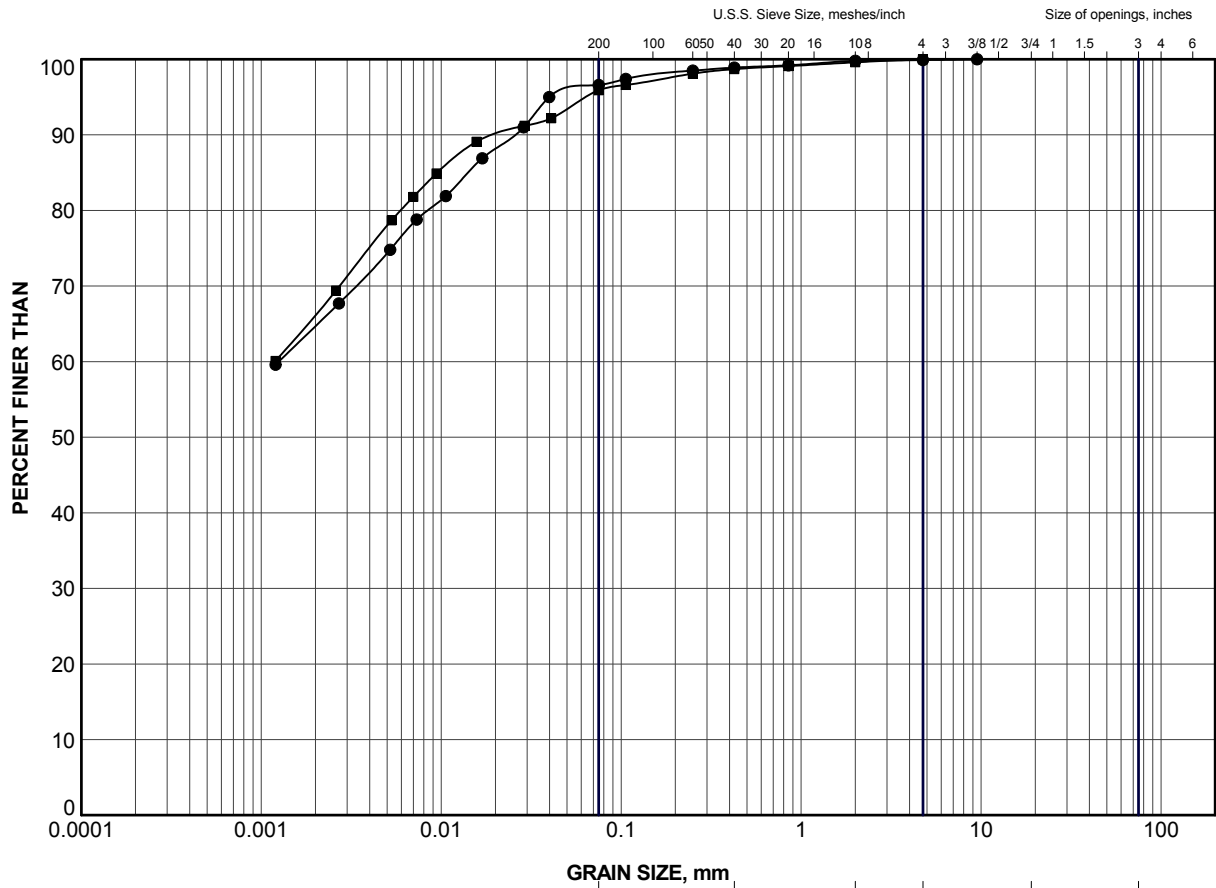
**Table B1: Summary of Analytical Testing of Turner Creek Water Sample**

Parameter	Units	Result
Chloride (CL)	mg/L	20.3
Sulphate (SO4)	mg/L	363
Conductivity (EC)	µS/cm	1480
Resistivity	µohm-cm	<0.33
pH	n/a	7.43

Notes:

1. Sample obtained on February 24, 2015.
2. Analytical testing carried out by ALS Canada Ltd.


Prepared by: TB  
Checked by: DAM  
Reviewed by: JMAC

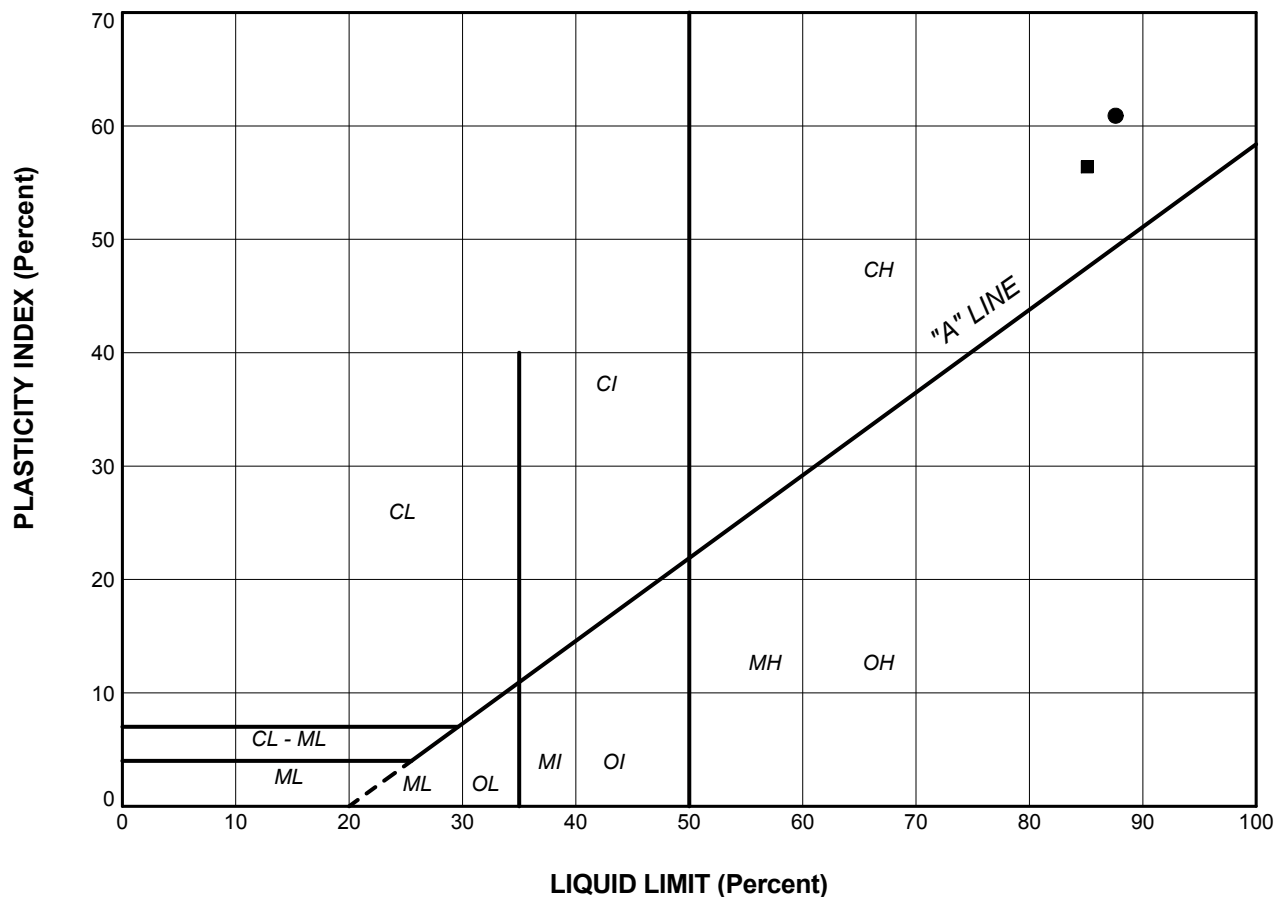


CLAY AND SILT	SAND SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

### LEGEND

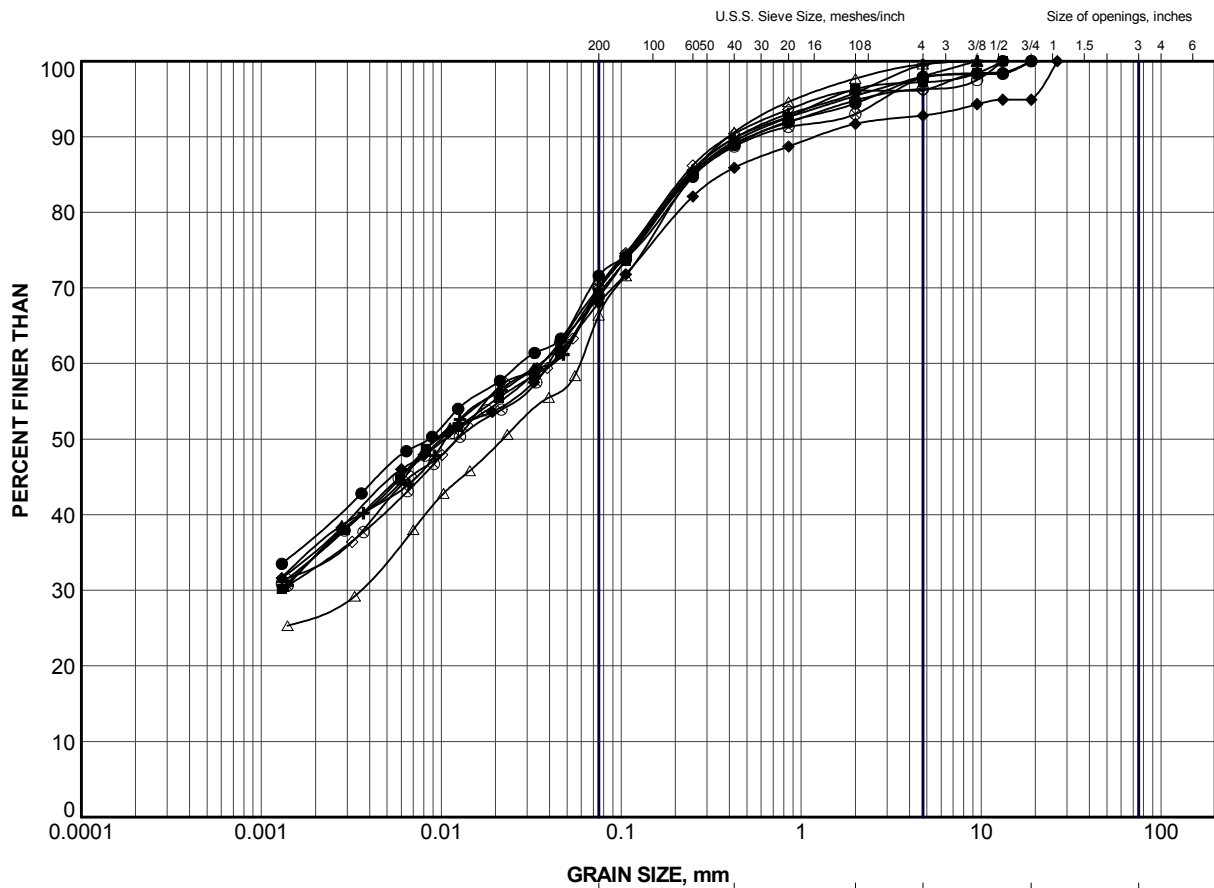
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	TR-2	3	333.8
■	TR-3	3	333.7

PROJECT						HIGHWAY 602 TURNER CREEK CULVERT STA 10+031					
TITLE						GRAIN SIZE DISTRIBUTION CLAY (FILL)					
PROJECT No.				1411523		FILE No.				1411523.GPJ	
DRAWN		JJL		Sep 2015		SCALE		N/A		REV.	
CHECK		SEMP		Sep 2015		APPR		JMAC		Sep 2015	
 <b>Golder Associates</b> SUDBURY, ONTARIO						<b>FIGURE B1</b>					




PROJECT					
HIGHWAY 602 TURNER CREEK CULVERT STA 10+031					
TITLE					
PLASTICITY CHART CLAY (FILL)					
PROJECT No. 1411523			FILE No. 1411523.GPJ		
DRAWN	JJL	Sep 2015	SCALE	N/A	REV.
CHECK	SEMP	Sep 2015	FIGURE B2		
APPR	JMAC	Sep 2015			

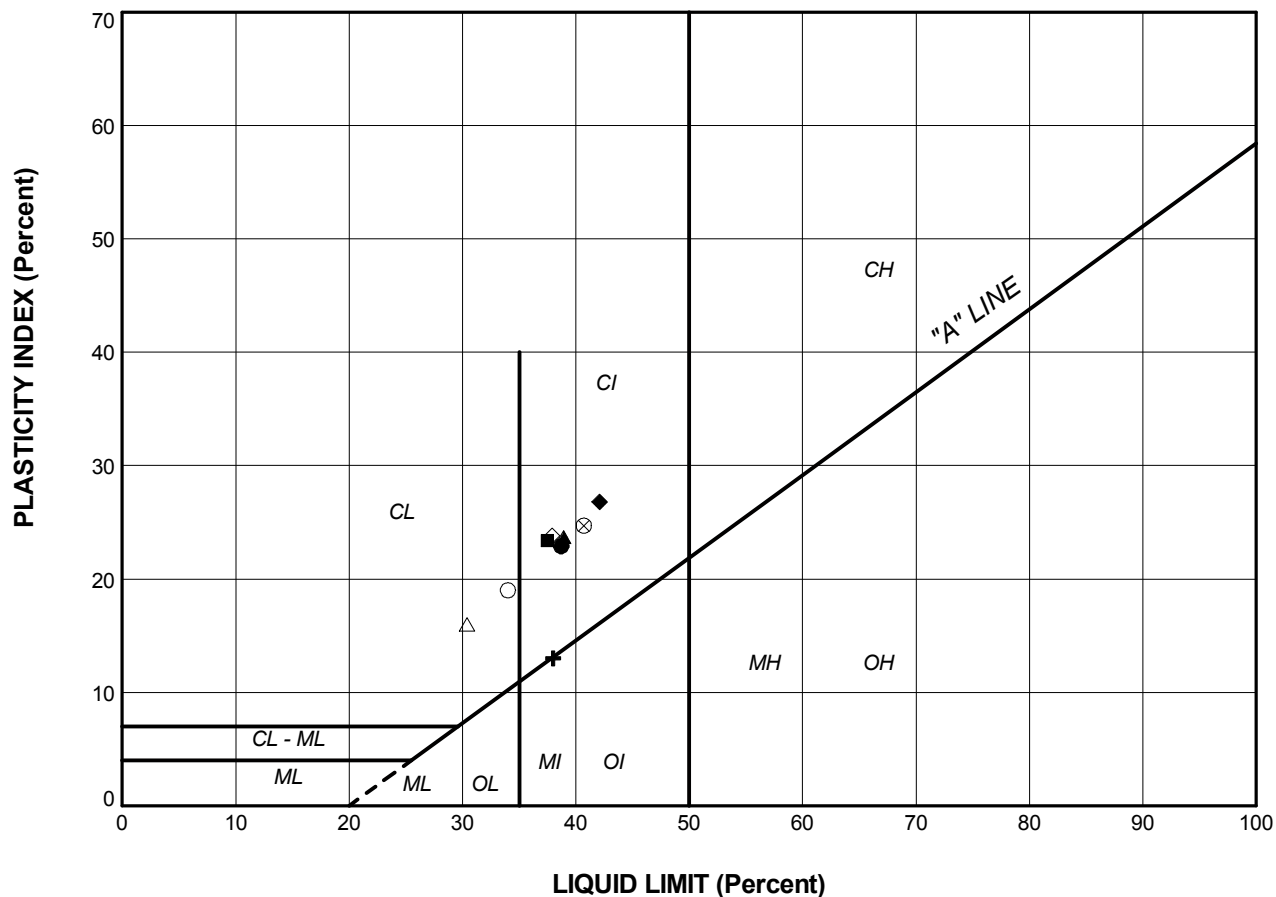




### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	TR-1	3	329.7
■	TR-1	6	325.1
▲	TR-2	7	329.2
+	TR-2	12	321.6
◆	TR-2	14	318.5
◇	TR-3	7	329.9
○	TR-3	9	326.8
△	TR-3	15	317.7
⊗	TR-4	6	328.1

PROJECT				
HIGHWAY 602 TURNER CREEK CULVERT STA 10+031				
TITLE				
GRAIN SIZE DISTRIBUTION CLAYEY SILT with SAND to SANDY SILTY CLAY (TILL)				
PROJECT No.		1411523		FILE No.
DRAWN		JJL	Sep 2015	SCALE N/A
CHECK		SEMP	Sep 2015	REV.
APPR		JMAC	Sep 2015	
 <b>Golder Associates</b> SUDBURY, ONTARIO		<b>FIGURE B3</b>		



**SOIL TYPE**  
 C = Clay  
 M = Silt  
 O = Organic

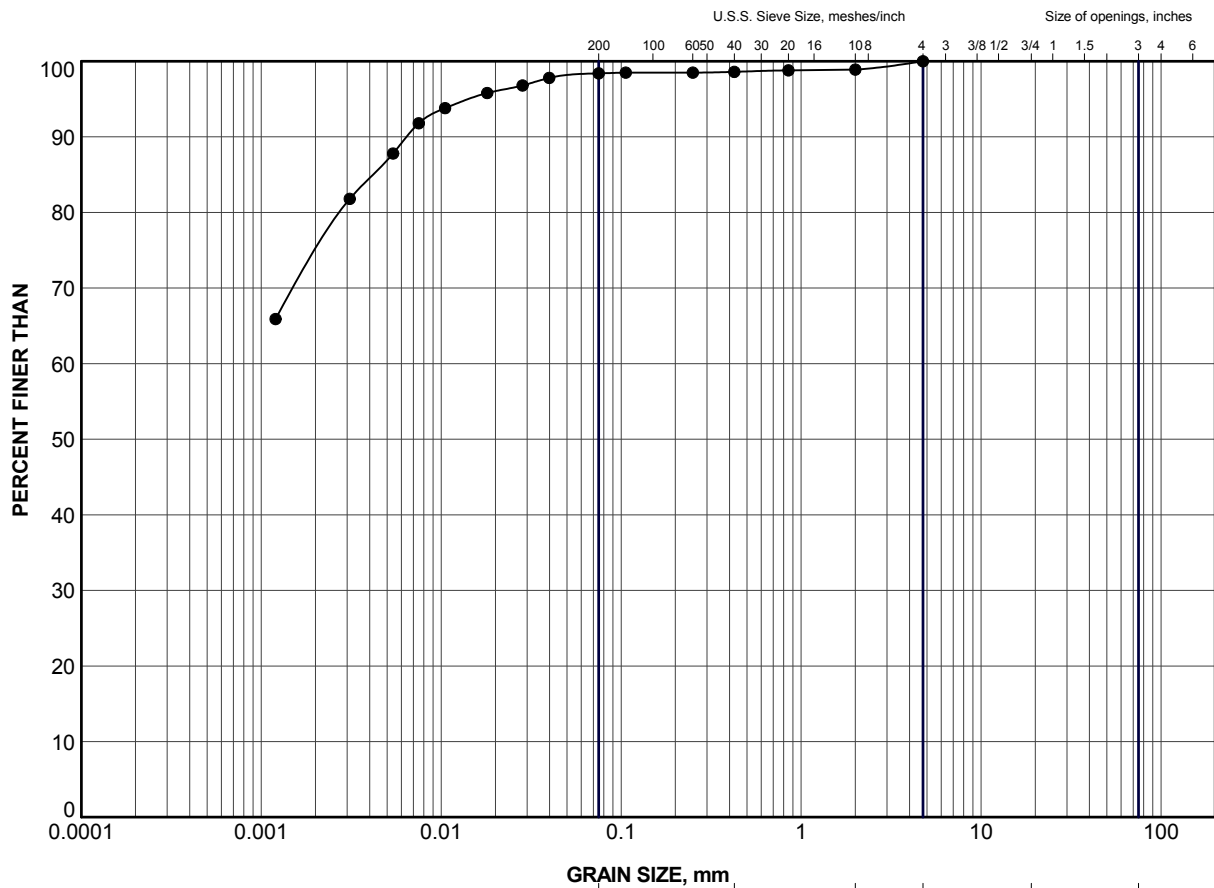
**PLASTICITY**  
 L = Low  
 I = Intermediate  
 H = High

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	TR-1	3	38.7	15.8	22.9
■	TR-1	6	37.5	14.1	23.4
▲	TR-2	7	38.9	15.2	23.7
+	TR-2	12	38.0	25.0	13.0
◆	TR-2	14	42.1	15.3	26.8
◇	TR-3	7	37.9	14.1	23.8
○	TR-3	9	34.0	15.0	19.0
△	TR-3	15	30.4	14.4	16.0
⊗	TR-4	6	40.7	16.0	24.7


PROJECT					
HIGHWAY 602 TURNER CREEK CULVERT STA 10+031					
TITLE					
PLASTICITY CHART CLAYEY SILT with SAND to SANDY SILTY CLAY (TILL)					
PROJECT No. 1411523			FILE No. 1411523.GPJ		
DRAWN	JJL	Sep 2015	SCALE	N/A	REV.
CHECK	SEMP	Sep 2015	FIGURE B4		
APPR	JMAC	Sep 2015			



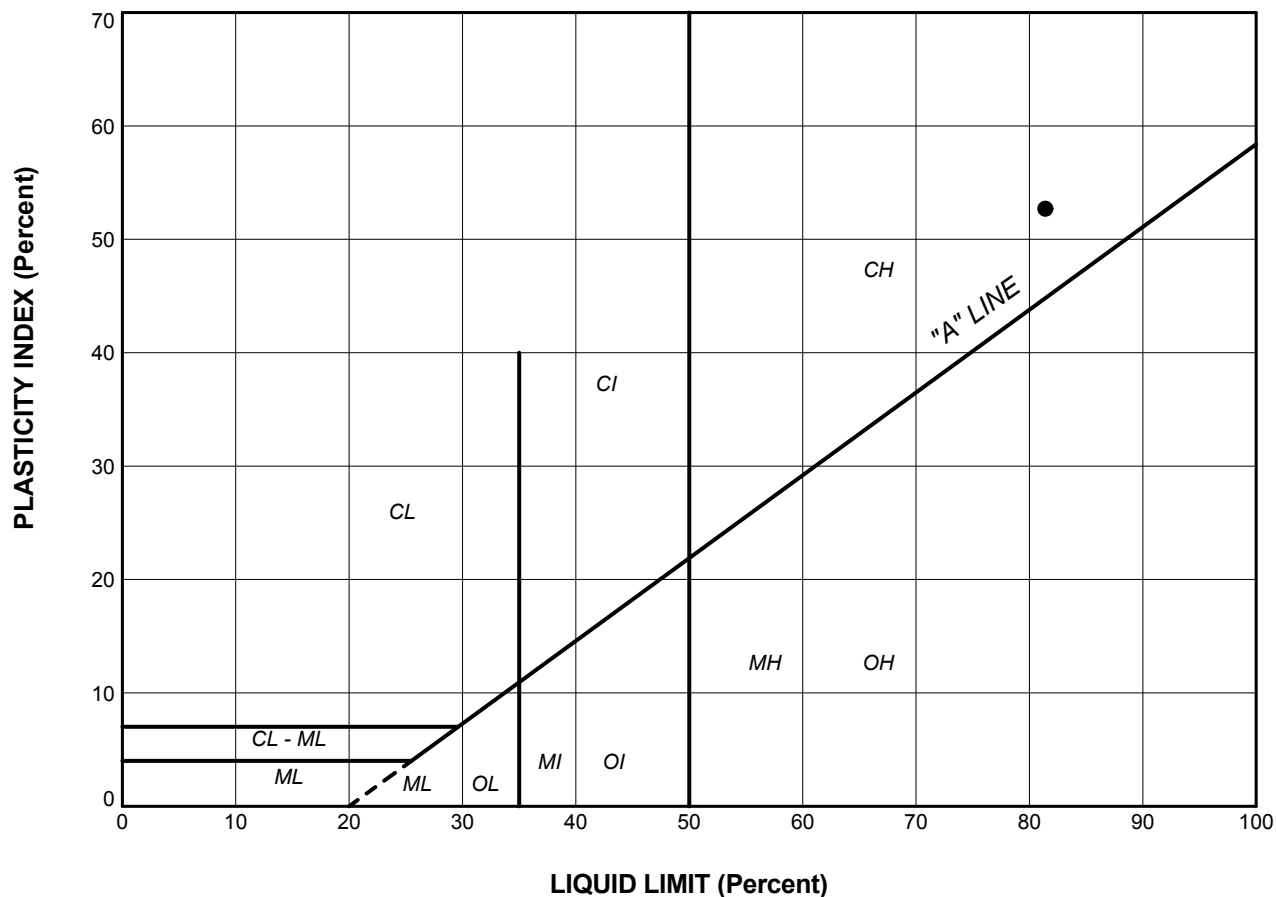


### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	TR-2	17	314.0

PROJECT					
HIGHWAY 602 TURNER CREEK CULVERT STA 10+031					
TITLE					
GRAIN SIZE DISTRIBUTION CLAY					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Sep 2015	SCALE	N/A	REV.
CHECK	SEMP	Sep 2015			
APPR	JMAC	Sep 2015			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B5</b>		





PROJECT					
HIGHWAY 602 TURNER CREEK CULVERT STA 10+031					
TITLE					
PLASTICITY CHART CLAY					
PROJECT No. 1411523			FILE No. 1411523.GPJ		
DRAWN	JJL	Sep 2015	SCALE	N/A	REV.
CHECK	SEMP	Sep 2015	FIGURE B6		
APPR	JMAC	Sep 2015			



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