



**June 16, 2015**

## **DRAFT PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT**

**GERHARD CREEK CULVERTS - SITE NO. 45-154/C  
HIGHWAY 619, DISTRICT OF RAINY RIVER  
TOWNSHIP OF SUTHERLAND  
MINISTRY OF TRANSPORTATION, ONTARIO  
G.W.P 6327-14-00**

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1 Copy: Golder Associates Ltd., Sudbury, Ontario

**DRAFT REPORT**





## Table of Contents

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

<b>1.0 INTRODUCTION.....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION.....</b>	<b>1</b>
<b>3.0 INVESTIGATION PROCEDURES .....</b>	<b>1</b>
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS .....</b>	<b>2</b>
4.1 Regional Geology .....	2
4.2 Subsurface Conditions.....	2
<b>5.0 CLOSURE.....</b>	<b>4</b>

### **PART B - PRELIMINARY FOUNDATION DESIGN REPORT**

<b>6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS.....</b>	<b>6</b>
6.1 General.....	6
6.2 Foundations .....	6
6.2.1 Foundation Options.....	6
6.2.2 Foundation Elevations and Frost Protection .....	7
6.2.2.1 Box Culvert .....	7
6.2.2.2 Open Footing Culvert.....	7
6.2.2.3 Pipe Culverts .....	7
6.2.3 Geotechnical Resistances.....	8
6.2.3.1 Box Culvert .....	8
6.2.3.2 Open Footing Culvert.....	8
6.2.4 Resistance to Lateral Loads / Sliding Resistance .....	9
6.2.5 Stability and Settlement .....	9
6.3 Lateral Earth Pressures .....	9
6.4 Construction Considerations.....	10
6.4.1 Temporary Roadway Protection.....	10
6.4.2 Excavation and Replacement Below Culvert .....	11
6.4.3 Culvert Bedding and Backfill .....	11
6.4.3.1 Box Culvert .....	11



## DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/C

6.4.3.2	Open Footing Culvert.....	11
6.4.3.3	Pipe Culverts .....	12
6.4.3.4	Backfill .....	12
6.4.4	Subgrade Protection .....	12
6.4.5	Erosion Protection.....	13
6.4.6	Control of Groundwater and Surface Water .....	13
6.4.7	Analytical Testing for Construction Materials .....	14
6.5	Recommendations for Further Work During Detail Design .....	14
<b>7.0</b>	<b>CLOSURE.....</b>	<b>14</b>

### REFERENCES

#### TABLES

Table 1	Summary of Culvert Details
Table 2	Comparison of Foundation Alternatives
Table 3	Geotechnical Axial Resistance and Reaction for Pre-Cast Box, Open Footing and Pre-Cast Concrete Slab on Sheet-Pile Abutments Replacement Culverts
Table 4	Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Open Footing Replacement Culverts

#### DRAWING

Drawing 1	Borehole Locations and Soil Strata
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#### PHOTOGRAPHS

#### APPENDIX A RECORD OF BOREHOLES

Lists of Abbreviations and Symbols
Record of Boreholes GR-1 to GR-4

#### APPENDIX B LABORATORY TEST RESULTS

Table B1	Summary of Analytical Testing of Surface Water
Figure B1	Grain Size Distribution – Sand and Gravel (Fill)
Figure B2	Grain Size Distribution – Silty Clay to Clay
Figure B3	Plasticity Chart – Silty Clay to Clay



# **PART A**

**PRELIMINARY FOUNDATION INVESTIGATION REPORT  
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## **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 Gerhard Creek culverts (Site No. 45-154/C). The Gerhard Creek culverts are located in the District of Rainy River in the Township of Sutherland on Highway 619 at STA 10+070, approximately 4.3 km south of the junction of Highway 600 and Highway 619. The key plan showing the general location of this section of Highway 619 and the location of the investigated area are shown on Drawing 1.

## **2.0 SITE DESCRIPTION**

The Gerhard Creek culverts consist of twin Steel Plate Corrugated Steel Pipes (SP CSP) 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 culvert area is a relatively flat low-lying swampy area, covered with long grass and shrubs. Highway 619 runs in a north-south direction with the culvert perpendicular to the highway in a west-east orientation. At the culvert location, Gerhard Creek flows easterly. The highway grade is at Elevation 334.8 m and the culvert inverts, as provided by MTO, at the inlet end is at Elevation 331.4 m with the outlet end being slightly higher at Elevation 331.5 m. The creek water level was at Elevation 333.2 m as measured by others on May 7, 2014 and the creek ice level was at Elevation 333.0 m as measured by Golder on January 28, 2015. Surface conditions at the culvert inlet and outlet are as shown on Photographs 1 to 4, attached.

## **3.0 INVESTIGATION PROCEDURES**

The field work for this subsurface investigation was carried out on January 28 and March 17, 2015, during which time four boreholes (Boreholes GR-1 to GR-4) were advanced at approximately the locations shown on Drawing 1. Boreholes GR-1 and GR-4 were advanced at the toe of slope near the culvert inlet/outlet, using 108 mm inside diameter hollow stem augers. Boreholes GR-2 and GR-3 were advanced from the existing highway platform using NW casing and wash boring techniques. All boreholes were advanced using a track-mounted CME 55 drill rig 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). Samples of the cohesive soils were obtained using 76 mm outside diameter thin walled Shelby Tubes (ASTM D1587) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using MTO Standard 'N' size vanes. 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



## DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/C

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 Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content, 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 during the field investigation (on January 28, 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 a 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 drawing provided by MTO (Drawing E13976191.dwg). The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths 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)
GR-1	5419242.5	209901.9	333.9	6.7
GR-2	5419256.0	209910.6	334.7	10.1
GR-3	5419244.1	209913.8	334.7	11.0
GR-4	5419255.3	209928.2	333.5	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 Gerhard Creek culverts generally consist of glaciolacustrine plain deposits of clays and silts.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)<sup>2</sup>, the site is underlain by bedrock of the Archean Era, comprised of a foliated tonalite suite consisting of tonalite to granodiorite.

### 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 52DNE.

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



## DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/C

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 culvert site consist of granular fill (for boreholes advanced through the embankment) and organics comprised of silty peat (for boreholes advanced at the toe of slope) underlain by a deposit of silty clay to 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 (kPa)	Laboratory Testing
				Consistency or Relative Density	
(FILL) Sand and Gravel, trace to some silt; brown; frozen to wet	GR-2, GR-3	2.2	334.7	N = 10 <sup>1</sup>  Compact	w = 10% 1 - M (Fig. B1)
Silty Peat, trace sand, trace gravel, black; frozen	GR-1, GR-4	0.7	333.9 – 333.5	N/A <sup>2</sup>	w = 49%
Silty Clay to Clay <sup>3</sup> , grey; wet	GR-1 to GR-4	6.0 – 8.8 (boreholes terminated in this deposit)	333.2 – 332.5	N = 2 – 9 s <sub>u</sub> = 38 - >100 S = 1 - 5  Firm to Very Stiff	w = 26% - 45% w <sub>l</sub> = 34% - 78% <sup>4</sup> w <sub>p</sub> = 14% - 30% I <sub>p</sub> = 20% - 48% 2 – MH (Fig. B2) 6 – AL (Fig. B3)

#### Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration  
w = Natural Moisture Content (%)  
MH = Combined Sieve and Hydrometer analysis  
M = Sieve analysis  
AL = Atterberg Limits Test  
s<sub>u</sub> = Undrained Shear Strength (kPa)  
S = Sensitivity  
w<sub>p</sub> = Plastic Limit (%)  
w<sub>l</sub> = Liquid Limit (%)  
I<sub>p</sub> = Plasticity Index (%)



**Notes:**

<sup>1</sup> In the granular fill, three SPT 'N'-values ranging from 67 blows to 91 blows per 0.3 m of penetration were recorded, however, these are likely indicative of the frozen state of the material and are not representative of the relative density of this material.

<sup>2</sup> In the silty peat deposit, two SPT 'N'-values of 14 blows and 19 blows per 0.3 m of penetration were recorded, however, these are likely indicative of the frozen state of the material and are not representative of the relative density of this deposit.

<sup>3</sup> Sandy silt laminations and thinly bedded sand layers were noted within the silty clay to clay deposit at various depths as indicated on the Record of Borehole sheets.

<sup>4</sup> One Atterberg limit test on a sample of the cohesive deposit that contained the sand layers returned a result of clayey silt of low plasticity.

## **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 333.0 m on January 28, 2015. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

<b>Borehole No.</b>	<b>Depth to Groundwater Level (m)</b>	<b>Groundwater Elevation (m)</b>
GR-1	Dry	-
GR-2	1.5	333.2 <sup>1</sup>
GR-3	1.6	333.1 <sup>1</sup>
GR-4	Dry	-

**Note:**

<sup>1</sup> Boreholes GR-2 and GR-3 were advanced using NW casing and wash boring techniques. As such, water levels 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. Adam Core, E.I.T., 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.





## Report Signature Page

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AC/DAM/SEMP/kp

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# **PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT  
GERHARD CREEK CULVERTS – SITE NO. 45-154/C  
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G.W.P. 6327-14-00**



## **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 Gerhard Creek culverts. 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 replacements. Further investigation and analysis may be required during detail design, once the configuration of the proposed culvert(s) and replacement strategy are 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.

It is assumed that the existing twin SP CSP culverts will be replaced with a culvert(s) of similar dimensions, along the same alignment as well at similar invert elevations to those of the existing culverts. In addition, it is assumed that there will be no embankment grade raises or widening in the area of the culverts as part of the Hwy 619 reinstatement.

### **6.2 Foundations**

#### **6.2.1 Foundation Options**

The existing Gerhard Creek culverts are located in the District of Rainy River in the Township of Sutherland on Highway 619 at STA 10+070, approximately 4.3 km south of the junction of Highway 600 and Highway 619. The highway embankment is constructed of granular fill material and is approximately 3.4 m high relative to the culvert invert. The existing culverts consist of twin SP CSPs, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

Based on discussions with HMM and the preliminary General Arrangement drawings prepared by HMM, we understand that the following culvert types are being considered for replacement of the existing culvert at this location:

- Twin pre-cast concrete boxes; and
- A pre-cast open footing culvert with either a pre-cast concrete arch or metal box.

In this report we have considered the following options:

- A pre-cast concrete box (or twin boxes);
- An open footing or arch culvert supported on either cast-in-place or pre-cast footings; and



■ Pipe culverts.

Given the limited thickness of soil cover (i.e., less than 1 m) over the existing or proposed culvert compared to that normally required for installation of guide rail posts and/or pavement structure, a sheet-pile abutment and concrete cap option is not considered practical at this location. Open footing arch culvert could be considered but the flow through capacity could be limited or restricted due to the need to provide adequate soil cover (including the roadway pavement structure) and the overall performance of such structures over the long term is not known. Pipe culverts (similar to the existing culvert configuration) are considered feasible but would provide less flow-through capacity compared to a box culvert option with a similar span. If pipe culverts are selected, concrete pipes would be preferred as a CSP culvert generally has a shorter design life. 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 it can accommodate an accelerated construction schedule and there are reduced excavation, dewatering and shoring requirements. Further, if twin boxes are considered, one of the existing SP CSP culverts can likely be used as the diversion channel during construction. 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(s) be founded on the generally stiff to very stiff silty clay to clay 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 generally stiff to very stiff silty clay to clay 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 (i.e., peat), where present. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

### **6.2.2.3 Pipe Culverts**

It is not necessary to found pipe culverts 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 culverts, if adopted, be founded on the generally stiff to very stiff silty clay to clay 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 bedding/engineered fill 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 the assumed box culvert width of 10 m as provided 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 it's Commentary.

The loading on the foundation soils below the culvert and the associated settlements at the culvert location 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 applicable as the settlement under the culvert will be governed by the soil loading and not the culvert loading.

### **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 width of 0.6 m as provided 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 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 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 footings and the associated settlements at the culvert location 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 applicable as the settlement under the culvert will likely be governed by both the soil loading and culvert footing loading.

#### **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 proposed embankments height, up to about 3.4 m above the existing ground surface relative to the 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 presence of the silty clay to clay deposit at this site, additional long term settlement and stability analysis 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).



## DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/C

- 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:

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

If the structure allows for lateral yielding, active earth pressures may be used in the design of the structure(s). 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 embankment granular fill comprised of compact sand and gravel and into the native soils, which are comprised of silty peat and generally stiff to very stiff silty clay to clay. 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 fills and native soils are considered to be Type 3 soil above the groundwater table and Type 4 soil below. Temporary open-cut excavations in Type 3 soils should remain stable if side slopes are formed no steeper than 1H:1V. 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 driven sheet-piling extended to a suitable depth or may consist of 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 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.





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

Prior to placement of any bedding material, engineered fill or concrete, all organics (including topsoil, peat or mixed organic materials) 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).

## **6.4.3 Culvert Bedding and Backfill**

### **6.4.3.1 Box Culvert**

The bedding and levelling pad requirements 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 adjacent granular fill during excavation to the invert and bedding level, 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 is 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 µm. The bedding should be placed in maximum 200 mm thick loose lifts and compacted to at least 98 per cent of the SPMD 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 concrete fine aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided with a geometry similar to that presented on OPSD 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction in dry conditions.

A frost taper should be constructed in in a similar configuration as that shown in OPSD 803.010. 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 10 m wide box culvert replacement option.

### **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 (Backfill and Cover for Concrete Culverts). 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 above in Section 6.4.3.1 for the box culvert replacement option.

A frost taper should be constructed in accordance with OPSD 803.010. Although OPSD 803.010 also relates to concrete culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 10 m wide open footing culvert replacement option.

### **6.4.3.3 Pipe Culverts**

The bedding, levelling and backfill for concrete pipe, CSP or CSP arch culverts 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 culverts 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.

A frost taper should be constructed in accordance with OPSD 803.031 (Frost Treatment).

### **6.4.3.4 Backfill**

Backfill behind the culvert walls 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 granular backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD 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 over and adjacent to 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 clay to clayey silt subgrade will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance and as an alternative to the 300 mm compacted bedding layer, a concrete working slab should be placed 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 can 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 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, if constructed of natural clay or soil bentonite mix. 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 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. Given the low-lying swampy nature of the terrain in the vicinity of the culvert and the poorly defined creek channel, a clay blanket will likely not be practical at this culvert site.

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 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 if a clay blanket is adopted.

#### **6.4.6 Control of Groundwater and Surface Water**

Excavation along the culvert alignment will be required to remove existing fill and organics and some of the native silty clay to clay stratum to achieve the required 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 excavations and the presence of 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, using one or both of the existing twin-cell SP CSP culverts or diverted by pumping from behind a temporary cofferdam.

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, engineered fill for sub-excavation and replacement below the culvert invert/bedding layer can be placed subaqueously, however, dewatering may still be required for footing/box 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 can 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, it is considered that groundwater pumping volumes could exceed 50 m<sup>3</sup>/day during initial drawdown stages and/or during periods of heavy precipitation. For this pumping volume, a Permit to Take Water (PTTW) would be required.

#### **6.4.7 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, based 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 for design of temporary protection works if the culvert is to be constructed in stages while maintaining one lane of open traffic during construction. 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, 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, E.I.T. and the technical aspects were reviewed by Mr. David Muldowney, P.Eng. 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.



## Report Signature Page

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AC/DAM/SEMP/kp

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n:\active\2014\1190 sudbury\1191\1411523 - hmm 26 culverts thunder bay\reporting\preliminary design\r15 - gerhard creek\draft\1411523 rpt r15 jun16 draft prelim fidr gerhard creek.docx



## 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, January 2006.

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 52DNE.

ASTM International:

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

ASTM D1587 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

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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## **DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/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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## DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/C

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)	West End of Culvert (m)	East End of Culvert (m)
Hwy 619 STA 10+070 (Township of Sutherland)	45-154/C	3.4	Twin SP CSP	2.4 m diameter (each)	20	331.4	331.5

- 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 E13976191.dwg).

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



## DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/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.</li> <li>■ Allows for faster construction resulting in shorter duration for dewatering and surface water pumping.</li> <li>■ More tolerant of total and differential settlement due to frost penetration into the subgrade soils and if the highway embankment is raised or widened at the culvert site, or remnants of the peat deposit are not fully removed.</li> <li>■ Backfill/bedding under the culvert may be placed underwater (i.e., Granular 'B' Type II) minimizing or eliminating water pumping requirements.</li> <li>■ Span width can be increased to accommodate the required flow volume while still allowing for adequate cover to be placed and maintain the existing road grade.</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) required at inlet to mitigate potential scour under culvert.</li> <li>■ Transportation to and on-site lifting of large pre-cast sections may be required.</li> <li>■ May require water diversion of the creek channel to accommodate construction using a full width culvert section, unless the culvert is comprised of multiple parallel box sections.</li> </ul>	<ul style="list-style-type: none"> <li>■ Some risk of disturbance of the native silty clay to clay subgrade 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>■ May be able to use one or both of the existing culverts for water diversion while new footings are being constructed adjacent to the culverts.</li> </ul>	<ul style="list-style-type: none"> <li>■ Excavation depths are greater than for 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 control system, dewatering and surface water pumping and excavation in a constrained space.</li> <li>■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site.</li> <li>■ Concrete or metal arch sections supported on concrete open (strip) footings must provide for adequate flow-through capacity and allow for adequate soil cover to be placed including the roadway pavement structure.</li> </ul>	<ul style="list-style-type: none"> <li>■ High risk of disturbance of the native silty clay to clay subgrade 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>■ Higher risk of additional settlement for footings due to the smaller foundation footprint.</li> <li>■ Culvert joints may be required to accommodate total and differential settlement (if applicable).</li> </ul>





## DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/C

Option	Advantages	Disadvantages	Risks/Consequences
Circular Pipe	<ul style="list-style-type: none"><li>■ Allows for 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.</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.</li><li>■ Cut-off wall or clay blanket 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></ul>	<ul style="list-style-type: none"><li>■ Some risk of disturbance of the native silty clay to clay subgrade during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad.</li><li>■ Limited risk related to settlement performance.</li></ul>



**DRAFT PRELIMINARY FOUNDATION REPORT  
GERHARD CREEK CULVERTS - SITE NO. 45-154/C**

**Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box, Open Footing and Pre-Cast Concrete Slab on Sheet-Pile Abutments  
Replacement Culverts**

<b>Culvert Location (Township)</b>	<b>Approximate Invert Elevation <sup>1</sup></b>	<b>Culvert Type</b>	<b>Approximate Backfill/Bedding or Footing Founding Elevation</b>	<b>Founding Condition</b>	<b>Factored Geotechnical Axial Resistance at ULS <sup>2</sup></b>	<b>Geotechnical Reaction at SLS for 25 mm of Settlement <sup>2</sup></b>
Hwy 619 STA 10+070 (Township of Sutherland)	331.4 m	Pre-Cast Box	331.0 m	Levelling/Bedding over the Firm to Very Stiff Silty Clay to Clay Deposit	150 kPa	100 kPa
		Open Footing	329.1 m	Firm to Very Stiff Silty Clay to Clay Deposit	150 kPa	100 kPa
		Pipe Culvert	331.1 m <sup>3</sup>	Bedding over the Firm to Very Stiff Silty Clay to Clay Deposit	N/A	N/A

- Notes:
1. Culvert invert elevation is based on the invert at the inlet end as shown on the profile drawings provided by MTO (Drawing BC13976191.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 10 m wide box culvert and a 0.6 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 foundation elevation may need to be adjusted based on the type and size of pipe culvert and the required bedding thickness.

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



## DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/C

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

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 619 STA 10+070 (Township of Sutherland)	Compacted Granular Fill (Levelling Pad)	0.45	Firm to Very Stiff Silty Clay to Clay	0.30

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

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

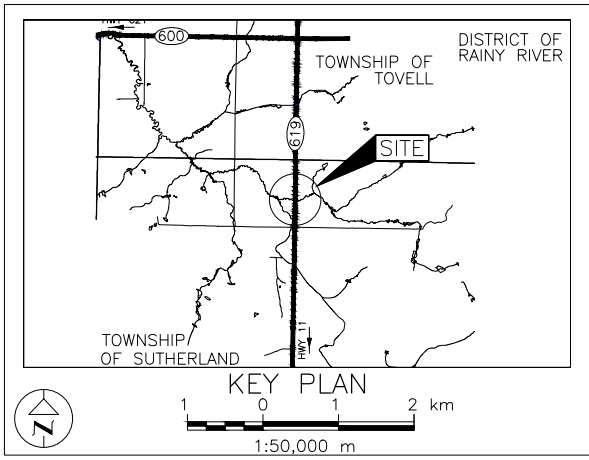


**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No. GWP No. 6327-14-00

HIGHWAY 619  
GERHARD CREEK CULVERTS STA 10+070  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



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
GR-1	333.9	5419242.5	209901.9
GR-2	334.7	5419256.0	209910.6
GR-3	334.7	5419244.1	209913.8
GR-4	333.5	5419255.3	209928.2

**NOTES**

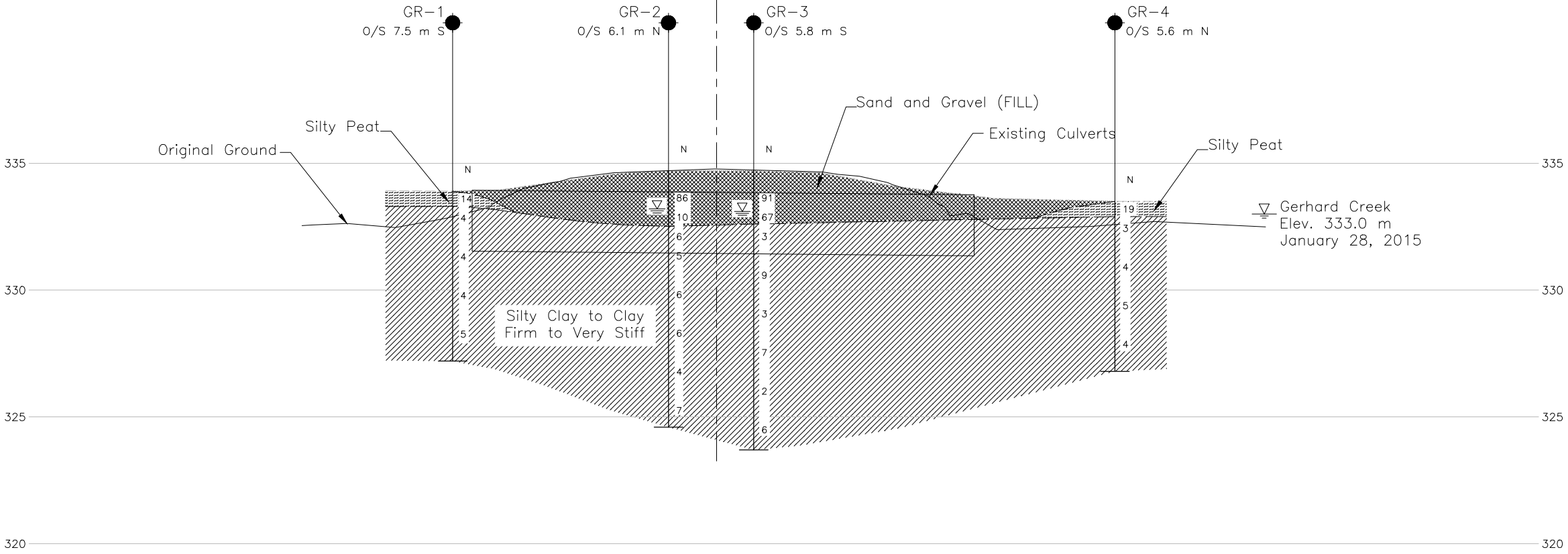
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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. E13976191, received FEB 15, 2015.



PROFILE

A-A' 1

HORIZONTAL SCALE

2 0 2 4 m

VERTICAL SCALE

2 0 2 4 m

**DRAFT**

NO.	DATE	BY	REVISION
Geocres No. PROJECT NO. 1411523 DIST. SUBM'D. AC CHKD. DATE: 5/20/2015 SITE: 45-154/C DRAWN: JJL CHKD. SEMP APPD. JMAC DWG. 1			





## PHOTOGRAPHS

**Photograph 1: Gerhard Creek Culverts  
West Side - Inlet (Taken from MTO, OSIM\_12-03-2013)**



**Photograph 2: Gerhard Creek Culverts  
East Side - Outlet (Taken from MTO, OSIM\_12-03-2013)**







## PHOTOGRAPHS

**Photograph 3: Gerhard Creek Culverts  
West Side - Inlet (Golder – January 28, 2015)**



**Photograph 4: Gerhard Creek Culverts  
East Side - Outlet (Golder – January 28, 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

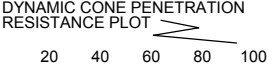



### IV. SOIL TESTS

w	water content
$w_p$	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
OC	organic content test
$SO_4$	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	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 GR-1</b>				1 OF 1 <b>METRIC</b>					
G.W.P. 6327-14-00		LOCATION N 5419242.5; E 209901.9				ORIGINATED BY MR					
DIST _____ HWY 619		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC					
DATUM GEODETIC		DATE March 17, 2015				CHECKED BY DAM					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W <sub>p</sub> — W — W <sub>L</sub> WATER CONTENT (%)	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						
333.9	GROUND SURFACE										
0.0	Silty PEAT, trace sand Black Frozen		1	SS	14						
333.2	SILTY CLAY to CLAY Stiff to very stiff Grey Wet		2	SS	4		333				
0.7	Sandy silt laminations between 0.6 m and 5.0 m depth.						332				
			3	SS	4		331				
			4	SS	4		330				
			5	SS	5		329				
							328				
327.2	END OF BOREHOLE										
6.7	Note: 1. Borehole dry upon completion of drilling. 2. Advanced additional borehole 1 m south of Borehole GR-1 to obtain a Shelby Tube sample at 2.5 m depth and additional field vanes at 3.4 m and 3.7 m depth ( <i>Italics</i> ).										

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 20/05/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No GR-2				1 OF 1 METRIC								
G.W.P. 6327-14-00		LOCATION N 5419256.0; E 209910.6				ORIGINATED BY MR								
DIST _____ HWY 619		BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY AC								
DATUM GEODETIC		DATE January 28, 2015				CHECKED BY DAM								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
334.7	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	Sand and gravel, some silt (FILL) Compact Brown Frozen* to wet		1	SS	86*									
			2	SS	10									
332.5	CLAY Stiff to very stiff Grey Wet  Trace organics in upper 0.8 m.  Sandy silt laminations between 2.2 m and 4.1 m depth.		3	SS	6									
2.2			4	SS	5									
			5	SS	6									
			6	SS	6									
			7	SS	4									
			8	SS	7									
324.6	END OF BOREHOLE													
10.1	Note: 1. Water level at a depth of 1.5 m below ground surface (Elev. 333.2 m) upon completion of drilling.													

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 20/05/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No GR-3				1 OF 1 METRIC						
G.W.P. 6327-14-00		LOCATION N 5419244.1; E 209913.8				ORIGINATED BY MR						
DIST HWY 619		BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY AC						
DATUM GEODETIC		DATE January 28, 2015				CHECKED BY DAM						
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID UNIT WEIGHT REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60	W <sub>p</sub> W W <sub>L</sub>	γ	GR SA SI CL
334.7	GROUND SURFACE											
0.0	Sand and gravel, trace silt (FILL) Brown Frozen		1	SS	91		334					
			2	SS	67		333					55 39 (6)
332.5	CLAY Firm to very stiff Grey Wet		3	SS	8		332					
2.2							331					
	Sandy silt laminations between 5.3 m and 6.5 m depth.		4	SS	9		330					
			5	SS	3		329					
							328					
			6	SS	7		327					
	Thinly bedded sand layers below 8.4 m depth. Clay/sand mix exhibits clayey silt consistency.		7	SS	2		326					2 17 43 38
			8	SS	6		325					
							324					
323.7	END OF BOREHOLE											
11.0	Note:  1. Water level at a depth of 1.6 m below ground surface (Elev. 333.1 m) upon completion of drilling.											

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 25/05/15 DATA INPUT:

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

PROJECT 1411523		<b>RECORD OF BOREHOLE No GR-4</b>				1 OF 1 <b>METRIC</b>								
G.W.P. 6327-14-00		LOCATION N 5419255.3; E 209928.2				ORIGINATED BY MR								
DIST _____ HWY 619		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC								
DATUM GEODETIC		DATE March 17, 2015				CHECKED BY DAM								
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						
333.5	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	Silty PEAT, trace sand, trace gravel Black Frozen		1	SS	19		333							
332.8														
0.7	CLAY Stiff to very stiff Grey Wet  Trace organics in upper 0.6 m.  Sandy silt laminations below 2.3 m depth.		2	SS	3		332							
							331							0 5 34 61
			3	SS	4									
							330							
			4	SS	5									
							329							
			5	SS	4		328							
326.8	END OF BOREHOLE						327							
6.7	Notes:  1. Borehole dry upon completion of drilling.  2. Advanced additional borehole 1 m north of Borehole GR-4 to obtain a Shelby Tube sample at 3.3 m depth and additional field vanes at 4.1 m and 4.4 m depth ( <i>Italics</i> ).													

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 20/05/15 DATA INPUT:



# **APPENDIX B**

## **Laboratory Test Results**



## DRAFT PRELIMINARY FOUNDATION REPORT GERHARD CREEK CULVERTS - SITE NO. 45-154/C

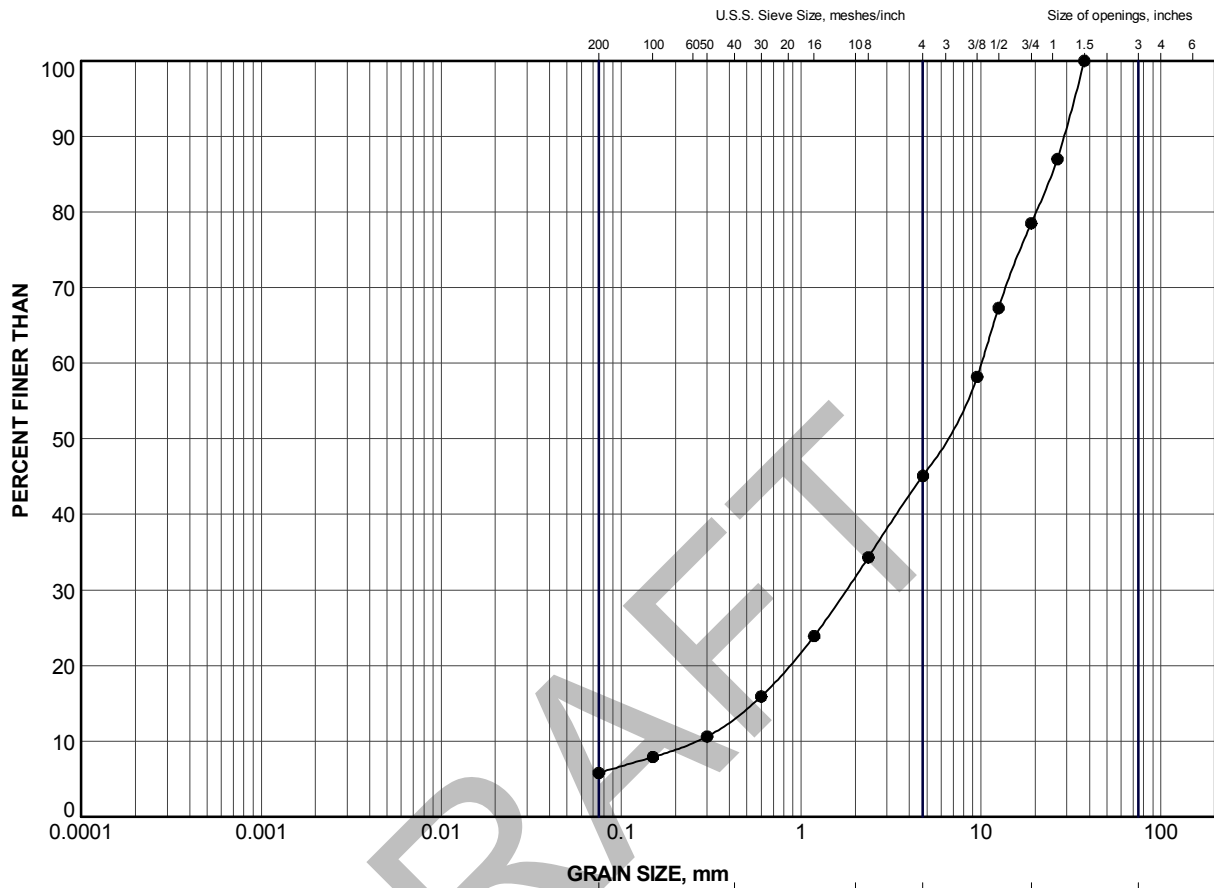
**Table B1: Summary of Analytical Testing of Gerhard Creek Water Sample**

Parameter	Units	Result
Chloride (CL)	mg/L	2.59
Sulphate (SO4)	mg/L	0.42
Conductivity (EC)	µS/cm	380
Resistivity	µohm-cm	<0.33
pH	n/a	7.3

Notes:

1. Sample obtained on January 28, 2015.
2. Analytical testing carried out by ALS Canada Ltd.


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



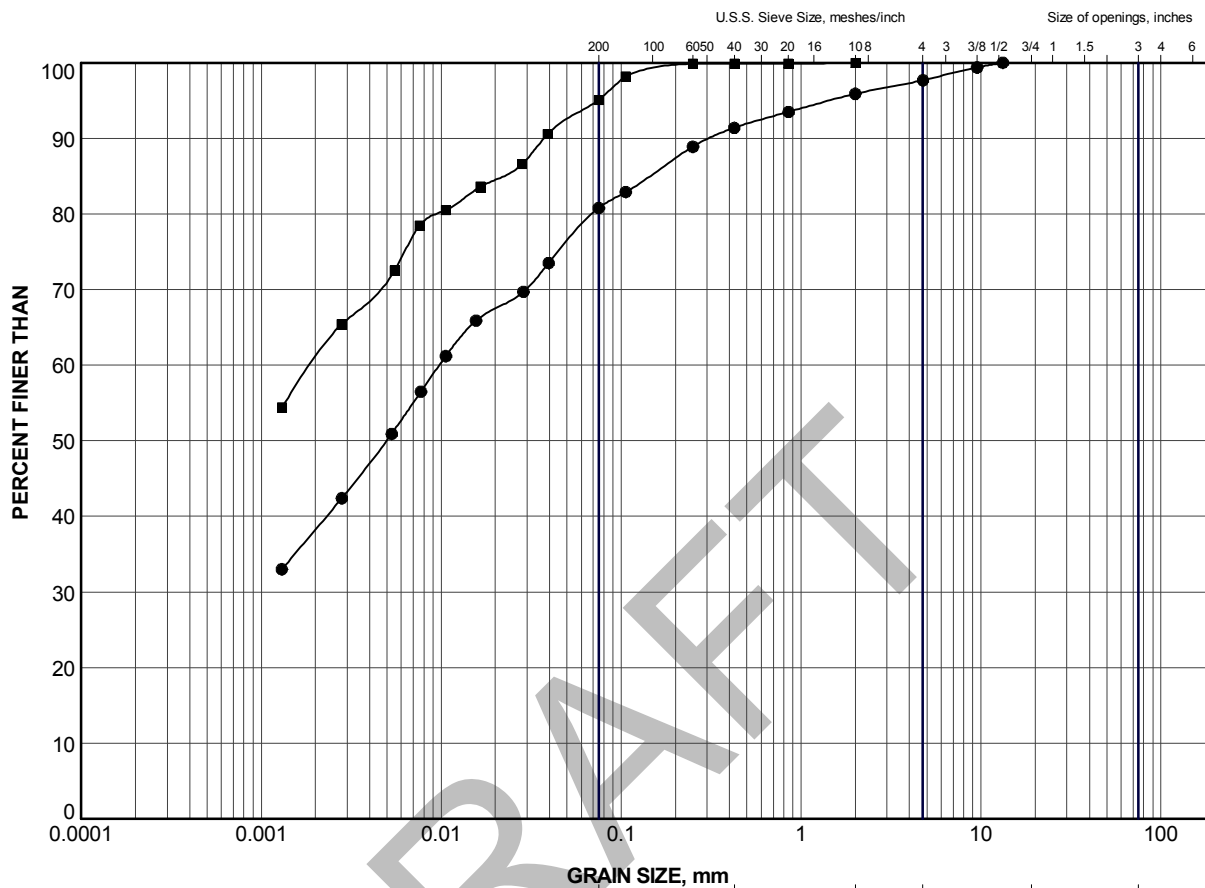
CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	GR-3	2	332.9

PROJECT					HIGHWAY 619 GERHARD CREEK CULVERTS STA 10+070				
TITLE					<b>GRAIN SIZE DISTRIBUTION</b> SAND and GRAVEL (FILL)				
PROJECT No.			1411523		FILE No.			1411523.GPJ	
DRAWN	JJL	May 2015	SCALE	N/A	REV.				
CHECK	DAM	May 2015							
APPR	JMAC	May 2015							
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B1</b>						




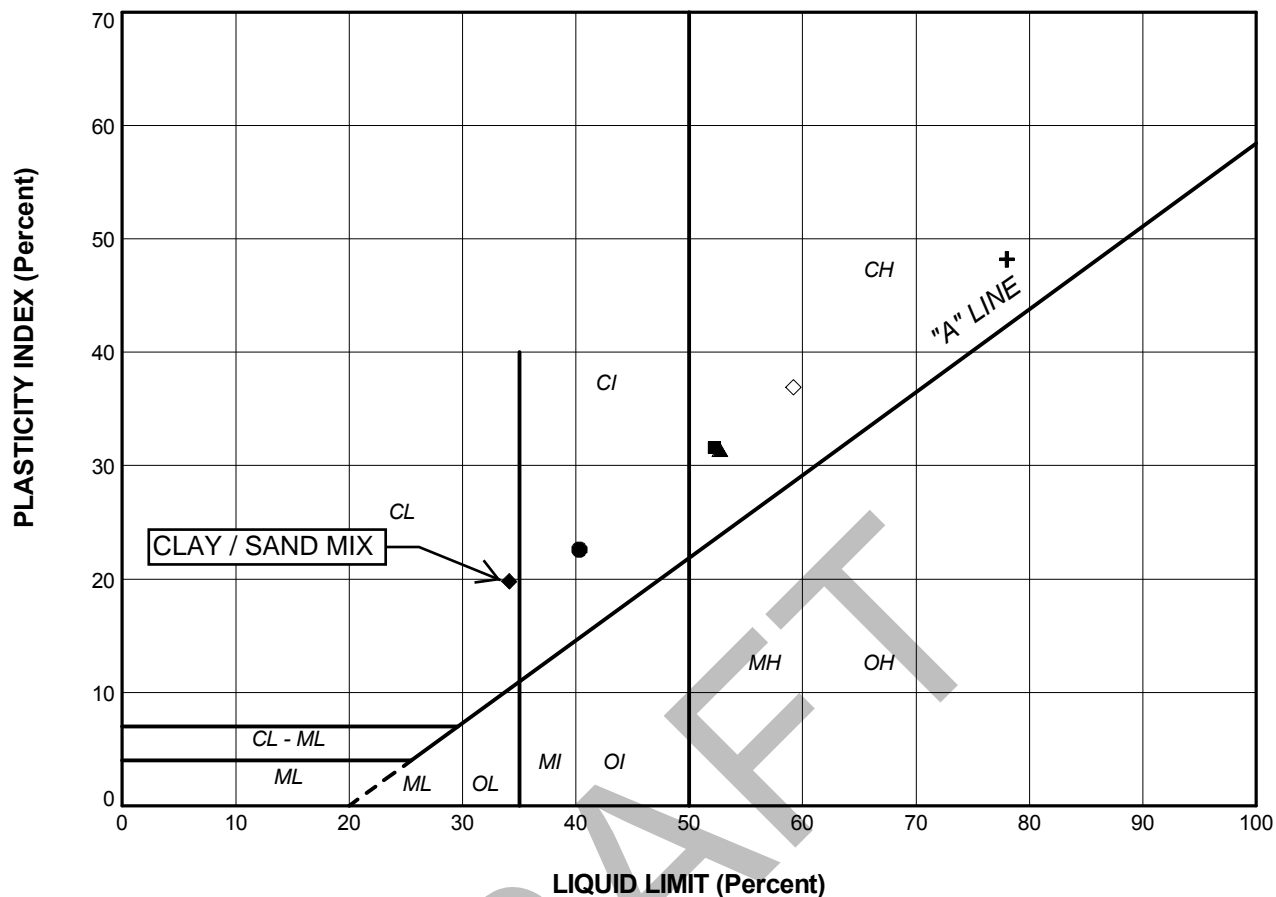


CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

#### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	GR-3	7	326.0
■	GR-4	3	330.9

PROJECT					HIGHWAY 619 GERHARD CREEK CULVERTS STA 10+070				
TITLE					GRAIN SIZE DISTRIBUTION SILTY CLAY to CLAY				
PROJECT No. 1411523			FILE No. 1411523.GPJ		DRAWN J.J.L. May 2015			SCALE N/A	
CHECK DAM May 2015			APPR JMAC May 2015		REV.			FIGURE B2	
 <b>Golder Associates</b> SUDBURY, ONTARIO									



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	GR-1	2	40.3	17.7	22.6
■	GR-1	4	52.2	20.6	31.6
▲	GR-2	3	52.7	21.3	31.4
+	GR-2	6	78.0	29.8	48.2
◆	GR-3	7	34.1	14.3	19.8
◇	GR-4	3	59.2	22.3	36.9

PROJECT				
HIGHWAY 619 GERHARD CREEK CULVERTS STA 10+070				
TITLE				
PLASTICITY CHART SILTY CLAY to CLAY				
PROJECT No.		1411523		FILE No.
DRAWN		JJL	May 2015	SCALE
CHECK		DAM	May 2015	REV.
APPR		JMAC	May 2015	
 <b>Golder Associates</b> SUDBURY, ONTARIO		<b>FIGURE B3</b>		

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