



February 28, 2018

FOUNDATION INVESTIGATION AND DESIGN REPORT

**REPLACEMENT OF UNNAMED CREEK CULVERT - SITE NO. 39W-121/C
HIGHWAY 581, FAQUIER TOWNSHIP, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5164-13-00, WP 5164-13-01**

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REPORT

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PART A

**FOUNDATION INVESTIGATION REPORT
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MINISTRY OF TRANSPORTATION, ONTARIO
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by LEA Consulting Ltd. (LEA) on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation engineering services for the replacement of the Unnamed Creek Culvert (Site No. 39W-121/C), located on Highway 581, 2.5 km north of Highway 11 in the Township of Fauquier, Ontario. The key plan showing the general location of this section of Highway 581 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the existing culvert location by borehole drilling and laboratory testing on selected soil samples.

The Terms of Reference and Scope of Work for the Foundation Investigation are outlined in MTO's Request for Proposal dated April, 2016. Golder's proposal for foundation engineering services associated with replacement of Unnamed Creek Culvert structure is contained in Section 17.8 of LEA's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundations engineering services for this project, dated November 1, 2016.

2.0 SITE DESCRIPTION

The existing Unnamed Creek Culvert consists of a three cell timber culvert that is 14 m long, 4.2 m wide (each cell is 1.4 m wide). The approximate invert of the culvert is Elevation 230 m. In general, the topography at the culvert site is relatively flat, the ground surface being covered/vegetated with grass, shrubs and trees in the vicinity of the culvert. At the culvert location, the highway grade is at Elevation 232.0 m with the embankment up to about 2 m relative to the surrounding grade which is at about Elevation 230 m to 231 m.

Photographs at the culvert are shown on Photographs 1 to 4, following the text of this report.

3.0 INVESTIGATION PROCEDURES

The field work was carried out between May 27 and June 17, 2017, during which time six boreholes (Boreholes UN-1 to UN-6) were advanced at approximately the locations shown on Drawing 1. Borehole UN-1 was advanced from the roadway using a truck-mounted CME-55 drill rig supplied and operated by Landcore Drilling of Sudbury, Ontario. Borehole UN-2 was advanced from the roadway using a track-mounted CME-55 drill rig supplied and operated by Downing Drilling Inc. (Downing) of Grenville-sur-la-Rouge, Quebec. Boreholes UN-3 to UN-6 were advanced at the toe of the Highway 581 embankment near the culvert inlet/outlet using a portable tripod drill rig supplied and operated by Downing. The borehole records are presented in Appendix A.

The boreholes were advanced using 108 mm inside diameter hollow-stem augers and/or NW casing with wash boring techniques with a Dynamic Cone Penetration Test (DCPT) was advanced from the bottom of each borehole except at Borehole UN-2. 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 on the CME-55 drill rig and a manual half-weight hammer (Acker) on the portable drill rigs, in accordance with the Standard Penetration Test (SPT) procedure (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 levels in the



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open boreholes were observed during the drilling operations as described on the borehole records in Appendix A. All boreholes were backfilled upon completion in accordance with Ontario Regulation 903 (Wells, as amended).

The fieldwork 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, and logged the boreholes. 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. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable. Index and classification testing, consisting of water content determinations, grain size distributions and Atterberg limits tests were carried out on selected soil samples. The results of the laboratory testing on samples from the boreholes are presented on the borehole records in Appendix A, and shown on Figures B1 to B5 in Appendix B.

A soil sample was obtained on June 17, 2017, in Borehole UN-4, 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 results of the analytical testing are summarized in Table B1 included in Appendix B.

The borehole locations and elevations were measured in the field by Golder personnel, relative to existing site features and surveyed to point HCP-101. The borehole locations (referenced to the MTM NAD83 co-ordinate system), ground surface elevations (referenced to Geodetic datum) and borehole depths are presented on the borehole records in Appendix A, and are summarized below.

Borehole	Location (MTM NAD 83, Zone12)		Location (World Geodetic System 84)		Ground Surface Elevation (m)	Borehole (DCPT) Depth (m)
	Northing	Easting	Latitude	Longitude		
UN-1	5470438.2	220528.8	49.366053	-82.160343	232.0	18.9 (20.2)
UN-2	5470421.2	220523.0	49.365899	-82.160420	232.0	16.2
UN-3	5470431.1	220534.2	49.365990	-82.160268	231.0	10.1 (12.0)
UN-4	5470420.6	220533.3	49.365895	-82.160278	231.1	9.8 (13.0)
UN-5	5470430.5	220515.3	49.365982	-82.160528	230.9	9.8 (12.5)
UN-6	5470421.6	220514.8	49.365902	-82.160532	230.7	9.8 (12.4)

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based NOEGTS¹, the subsoils in the vicinity of Unnamed Creek Culvert the site comprise ground moraine deposits consisting primarily of clayey till materials.

Based on geological mapping, the site is located in the Superior Province (OGS, 1991)² with bedrock consisting of massive to foliated granodiorite to granite rocks.

¹ Digital Northern Ontario Engineering Geology Terrain Study (NOEGTS). Ontario Geological Survey, Miscellaneous Release – Date 160.

² Ontario Geological Survey, 1991, Bedrock geology of Ontario, east-central sheet; Map 2543.



4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil samples, are presented on the borehole records in Appendix A and the laboratory test sheets in Appendix B. The results of the in situ field tests (i.e., SPT 'N'-values and undrained shear strengths from the vanes) as presented on the borehole records and in Section 4 are uncorrected. The stratigraphic boundaries shown on the borehole records 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. A summary of the subsurface conditions as encountered in Boreholes UN-1 to UN-6 is presented below.

4.2.1 Subsoil Conditions

A description of the soil deposits encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows)	Laboratory Testing
				Field Vane Results (kPa)	
				Consistency or Relative Density	
Asphalt	UN-1, UN-2	0.03	232.0	n/a	n/a
(FILL) Sand and Gravel; Sand	UN-1, UN-2, UN-4	0.3 – 1.8	232.0 – 231.1	N = 11 and 15 (sand)	w = 3% and 6% 2 – M (Fig. B1)
				n/a	
				Compact (sand)	
Peat (Amorphous/Fibrous), Organic Silty Sand and/or Organic Silt	UN-2 to UN-6	0.7 – 1.5	231.0 – 230.5	N = 1 – 4	w = 42% – 60% 3 Oc = 4.7%, 7.4% and 8.5%
				n/a	
				Very soft to soft, (loose, organic silty sand)	
Silt, Silty Sand; Clayey Sand and Sandy Silt Interlayers (Upper Deposit)	UN-1 and UN-3 to UN-6	0.4 – 6.5	230.2 – 229.5	N = 2 – 7	w = 22% – 31% 2 – MH (Fig. B2) 1 – AL (NP)
				n/a	
				Very loose to loose	
Clayey Silt to Silty Clay (Upper Deposit) ¹	UN-1 to UN-4	0.8 – 3.7	229.8 – 228.8	N = 3 – 7	w = 25% – 29% 3 – AL (Fig. B3) 3 – MH (Fig. B4) w _l = 24% – 46% w _p = 15% – 18% I _p = 9% – 29%
				S _u = 38 – 62 S = 2 – 3	
				Firm to stiff	



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Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows)	Laboratory Testing
				Field Vane Results (kPa)	
				Consistency or Relative Density	
Silt (Middle Deposit)²	UN-1 to UN-4	2.6 – 6.1	228.1 – 226.1	N = WH - 10	w = 23% – 39% 7 – MH (Fig. B2) 2 – AL (NP)
				Very loose to compact	
Silty Clay to Sandy Clayey Silt (Lower Deposit)¹	UN-1 to UN-6	>0.7 - 9.2	225.1 – 221.8	N = WH - 14	w = 16% – 31% 5 – AL (Fig. B3) 4 – MH (Fig. B4) w _l = 21% – 38% w _p = 13% – 17% I _p = 9% – 21%
				s _u = 57 – >100 S = 1 – 2	
				Soft to very stiff	
Silt and Sand (Lower Deposit)	UN-1	>0.8	213.9	N = 10	w = 24% 1 – MH (Fig. B5)
				Compact	

Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration
s_u = undrained shear strength from in situ field 'N'-vane (kPa)
S = calculated sensitivity
w = natural moisture content (%)
M = sieve analysis for particle size
MH = combined sieve and hydrometer analysis
AL = Atterberg limits test
w_p = plastic limit (%)
w_l = liquid limit (%)
I_p = plasticity index (%)
NP = non-plastic test result in Atterberg limits
Oc = organic content test

Notes:

¹ Silt laminations were encountered at various depths within the clayey silt to silty clay deposit.

² Silty clay laminations were encountered at various depths within the silt deposit.

4.3 Refusal

Refusal to further split spoon or DCPT advancement was recorded in all boreholes at the depths/elevations presented below.



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Borehole No.	Depth to DCPT /Split-Spoon Refusal (below ground surface at borehole location) (m)	DCPT/Slit-Spoon Refusal Elevation (m)	DCPT Refusal Condition
UN-1	20.2	211.8	Refusal to further DCPT penetration
UN-2	16.2	215.8	Refusal to Split-spoon
UN-3	12.0	219.0	Refusal to further DCPT penetration
UN-4	13.0	218.1	Refusal to further DCPT penetration
UN-5	12.5	218.4	Refusal to further DCPT penetration
UN-6	12.4	218.3	Refusal to further DCPT penetration

4.4 Groundwater Conditions

The depths to/elevations of unstabilized groundwater levels measured in the open boreholes upon completion of drilling are presented below. It should be noted that the introduction of drilling water to advance NW casing in the boreholes may have impacted the measured groundwater levels. Water levels should be expected to vary depending on the time of year and precipitation events.

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
UN-1	3.4	228.6
UN-2	At ground surface	232.0
UN-3	0.2	230.8
UN-4	0.2	230.9
UN-5	At ground surface	230.9
UN-6	At ground surface	230.7

The water level in the creek water was measured by Golder on May 28, 2017, at Elevation 230.5 m.

5.0 CLOSURE

The field drilling program was supervised by Mr. Mat Riopelle and Mr. Shane Albert. This Foundation Investigation Report was prepared by Mr. Tibor Berecz, and the technical aspects were reviewed by Mr. André Bom, P.Eng., a geotechnical engineer and Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Designated MTO Foundations Contact and Senior Consultant of Golder, conducted an independent quality control review and technical audit of this report.

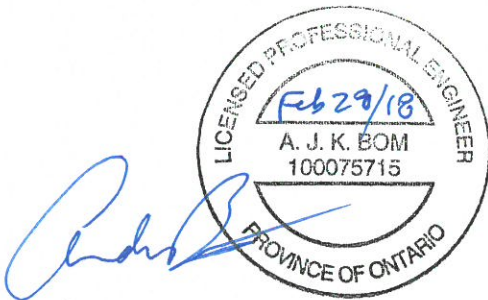


Report Signature Page

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PART B

**FOUNDATION DESIGN REPORT
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed replacement of the Unnamed Creek Culvert (Site 39W-121/C) located on Highway 581. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation. The discussion and recommendations presented in this Foundation Design Report (Part B) are intended to provide MTO's designers with sufficient information to assess the feasible foundation alternatives and to design the proposed culvert.

The discussion and recommendations contained in this Foundation Design Report (Part B) shall not be used or relied upon for any other purpose or by any other parties, including the construction contractor. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. The contractor must make their own interpretation based on the factual data in the Foundation Investigation Report (Part A), as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

Golder Associates Ltd. (Golder) has been retained by LEA Consulting Ltd. (LEA) on behalf of MTO to provide recommendations on the foundation aspects for the design of the replacement of the Unnamed Creek Culvert on Highway 581.

A box culvert and open footing culvert are both considered feasible alternatives for replacement of the existing culvert at this site. However, from a foundations perspective, an open footing culvert presents greater challenges due to the existing subsoils at this site and the open footing culvert will have an extended construction schedule and increase the excavation, dewatering and shoring requirements compared to a box culvert; therefore, a box culvert sufficiently wide to handle the creek flow is the preferred culvert type alternative for this site. As a different culvert type, including a pipe culvert, may be considered due to other constraints (e.g. fisheries requirements related to natural channel substrate), a comparison of culvert types based on advantages, disadvantages and risks/consequences is presented in Table 1.

Based on the General Arrangement (GA) drawing dated October 2017 provided by LEA, we understand that the proposed replacement culvert is to consist of a single precast concrete box culvert barrels approximately 3.6 m wide by 1.8 m high (exterior dimensions), with the invert at Elevations 229.9 m and 229.8 m at the inlet and outlet ends, respectively. Given the minimal thickness (about 0.6 m) of fill cover over the proposed culverts, we understand that a distribution slab is not required.

We further understand that the proposed culvert barrel is to be constructed along the current (existing) culvert alignment, and understand that a grade raise or widening is not required for the culvert replacement, relative to the existing embankment. Based on the existing subsurface conditions, if a grade raise or widening is required in the future, we recommend that a geotechnical engineer be retained to assess the embankment stability and settlement.



6.2 Consequence and Site Understanding Classification

The replacement culvert is being designed in accordance with the current Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC 2014).

In accordance with Section 6.5 of CHBDC (2014) and its Commentary, the proposed culvert and its foundation system is considered to be classified as having a "typical consequence level" associated with exceeding limits states design. This consequence classification should be confirmed by LEA. The degree of site and prediction of our understanding, based on the scope of the current foundation investigation and design, is considered "typical" as described in Clause 6.5.3.2 of CHBDC (2014). The appropriate corresponding ultimate limit states (ULS) and serviceability limit states (SLS) consequence factors, Ψ , and geotechnical resistance factors at ULS (ϕ_{gu}) and SLS (ϕ_{gs}), from Tables 6.1 and 6.2, respectively, of the CHBDC have been used for design in this report.

6.3 Culvert Foundation Design Recommendations

6.3.1 Founding Level and Geotechnical Resistance

Prior to placing the bedding/levelling pad for the replacement culvert, it is recommended that all organic material (i.e., peat and/or mixed organic soils) encountered below the culvert footprint be sub-excavated and replaced with Ontario Provincial Standard Specification, Provincial Oriented (OPSS.PROV) 1010 (Aggregates) Granular 'B' Type II, which is suitable for placement/use in wet ground conditions, as discussed further in Section 6.6.3.

For the proposed 3.6 m wide culvert, with the underside of the concrete slab at approximately Elevation 229.5 m (for an assumed 0.5 m thick slab) and the underside of the compacted granular bedding at approximately Elevation 229.0 m (for a 0.5 m thick bedding layer), a factored ultimate geotechnical resistance at ULS of 170 kPa and a factored serviceability geotechnical resistance at SLS (corresponding to 25 mm of settlement) of 20 kPa, may be used in design. Alternatively, if the culvert can tolerate 50 mm of settlement, a factored serviceability geotechnical resistance at SLS of 40 kPa, may be used in design.

The factored geotechnical resistances provided above are based on the loading applied perpendicular to the base of the culvert/footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of CHBDC (2014) and associated Commentary. The factored geotechnical resistances should be reviewed if the founding elevation and/or the foundation widths differ from those given above.

The loading on the foundation soils below the culvert and the associated settlement at the culvert location will be impacted by loading from the embankment fill immediately adjacent to the culvert. The factored geotechnical serviceability resistance provided above assumes there will not be a temporary and/or permanent grade raise at or adjacent to the culvert location (including during the course of construction).



6.3.2 Frost Protection

Provided that the box culvert is tolerant of small magnitudes or movement related to freeze-thaw cycles, the culvert can be founded above the depth of frost penetration, which is 2.5 m as interpreted from OPSD 3090.100 (Frost Protection Depths for Northern Ontario).

6.3.3 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance should be calculated in accordance with Section 6.10.5 of CHBDC (2014), applying the appropriate consequence and degree of site understanding factors as noted above in Section 6.2. A coefficient of friction, $\tan \delta'_i$, of 0.4 may be used at the interface between the base of the box culvert and the granular bedding.

6.4 Stability, Settlement and Horizontal Strain

6.4.1 Embankment Stability

The proposed 2.4 m high embankment sections adjacent to the new culvert are stable from a geotechnical perspective if reconstructed of granular material at inclinations of 2 horizontal to 1 vertical (2H:1V). As discussed in Section 6.1, given the existing subsurface conditions, if a grade raise or widening is required in future relative to the proposed/existing embankment, a stability analysis should be completed for the enlarged geometry.

6.4.2 Settlement and Horizontal Strain

Negligible settlement is expected to occur as a result of the culvert replacement as the proposed embankment geometry will match the existing geometry. Provided sustained loading from the culvert on the founding soils remains below the factored SLS values presented in Section 6.3.1. Assuming the loading will be relatively uniform across the footprint of the culvert, settlement of the founding soils is anticipated to similarly be uniform; however, areas previously loaded by the open footing timber structure may experience less settlement. A culvert camber is not considered necessary for this site. If the culvert is placed above the frost penetration depth, less than 25 mm of differential settlement may seasonally occur between the culvert centre and ends.

6.5 Lateral Earth Pressures

The lateral earth pressures acting on the side walls of the box culverts will depend on the type and method of placement of backfill materials, the nature of the 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. It should be noted that these design recommendations and parameters assume level (horizontal) backfill and ground surface behind the walls.

Select, free draining granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II should be used as backfill behind the culvert walls. Longitudinal drains and weep holes should



be installed to provide positive drainage of the granular backfill. Backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting).

The soil parameters provided below for the embankment fill, including at-rest earth pressures may be used in the design of the box culvert, assuming that the box culvert walls will not allow for lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition). For restrained walls, granular fill should be placed in a zone with the width equal to at least 2.6 m behind the back of the wall (in accordance with Figure C6.20 (a) of the Commentary to the CHBDC).

Fill Type	Unit Weight	Coefficients of Static Lateral Earth Pressure
		At-Rest, K_o
Granular 'A'	22 kN/m ³	0.43
Granular 'B' Type II	21 kN/m ³	0.43

6.6 Construction Considerations

6.6.1 Excavations and Control of Groundwater and Surface Water

Removal of fill and organic soils from below the footprint of the proposed culvert is recommended. Excavations will extend to approximately Elevation 228.5 m for the proposed precast concrete cut-off wall at both ends of the culvert and to approximately Elevation 229.1 m below the length of the culvert between the two cut-off walls, assuming that 500 mm of granular bedding will be placed under the culvert. Excavations may extend deeper in select areas to remove the organic soil.

Open-cut excavations must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA 2016) and Regulation for Construction Activities. The existing fill and organic soils are classified as Type 4 soil according to the OHSA. Temporary excavations (i.e., those that are open for a relatively short time period) should be made with side slopes no steeper than 1H:1V above the water level. Open excavations below the water level are not recommended or should be minimized.

Temporary protection systems will be required for staged culvert replacement. Recommendations for temporary protection systems are provided in Section 6.6.2.

Creek flows through the existing culvert will need to be diverted/pumped away from the excavation areas during the construction period. 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.

As a result of the excavation, groundwater flow into the excavation can be expected due to the relatively permeable nature of the adjacent granular embankment fill and non-cohesive native soils.

Excavations for the precast cut-off wall and bedding for the culvert will extend below the groundwater level. Due to the existing creek, a groundwater cut-off (cofferdam or similar measure) is recommended at the ends of the



culvert to minimize dewatering requirements and the occurrence of potential environmental impacts, as discussed further in Section 6.6.2. Dewatering of all excavations should be carried out in accordance with OPSS.PROV 517 (Dewatering). A Notice to Contractor should be included in the Contract to alert the contractor to the potential issues associated with cofferdams and unwatering of the soils at the site and that the excavation must be unwatered and kept stable during placement of cut-off wall and bedding; an example Notice to Contractor is included in Appendix C.

The silt/clayey silt/silty clay that will be exposed within the excavation may be susceptible to disturbance from construction traffic and/or ponded water and the exposed surface should be protected from construction traffic and water flow.

6.6.2 Temporary Protection Systems and Cofferdams

Temporary protection systems may be required for traffic staging to remove existing fill and organic soil below the new culvert footprint and for bedding and culvert placement. Temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems), provided that any existing adjacent structures or utilities can tolerate this magnitude of deformation. The lateral movement of the temporary shoring systems should meet Performance Level 2 as specified in OPSS.PROV 539.

It is considered that either a driven, interlocking sheet pile system or a soldier pile and timber lagging system would be suitable for the temporary excavation support at the site, based on the subsurface soil and groundwater conditions. An interlocking sheet pile system would contribute to both ground and, where applicable, groundwater control – it would provide for control of seepage of groundwater from the non-cohesive soils. For a soldier pile and lagging system, it would be necessary to control seepage or include measures to mitigate loss of soil particles through the lagging boards. If dewatering operations are carried out for construction of the culvert in dry conditions, the groundwater level should be lowered to at least 0.3 m below the base of the excavation.

The sheet piles or soldier piles would have to be driven or socketted to sufficient depth to provide the necessary passive resistance for the retained soil height, including any surcharge loads behind the protection system within at least a 1H:1V zone relative to the base of the excavation. Lateral support to the sheet piles or soldier piles could be provided in the form of rakers or temporary anchors.

The selection and design of the protection system will be the responsibility of the Contractor.

6.6.3 Subgrade, Bedding and Backfill

The culvert should be constructed consistent with elements shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts) and in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). The subgrade should be inspected following sub-excavation to ensure that all organics and other unsuitable materials have been removed.



The box culvert should be constructed on a minimum 500 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II Material for bedding purposes, with an OPSS 1860 non-woven Class II geotextile, with a filtration opening size not greater than 150 µm separation layer between the granular material and the native subgrade. The granular material should be nominally compacted by the construction equipment. The design of the culvert should be based on the bedding having achieved a moderate level of compaction – if a degree of compaction is needed for design, a relative density of 90 per cent of the standard Proctor maximum dry density (SPMDD) should be assumed.

Backfill above/behind the culvert walls, including in the space between the two culvert barrels, should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III. The granular backfill should be placed in maximum 300 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD of the materials in accordance with OPSS.PROV 501 (Compacting).

Backfill placement for reconstruction of the roadway embankments along 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.

6.6.4 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 cut-off wall comprised of concrete, natural clay or a soil-bentonite mix should be provided at the upstream and downstream end of the culvert. The concrete or clay cut-off wall should extend to a depth of 1 m below the scour level. If a clay cut-off is adopted, the clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal). In addition, depending on hydraulic conditions resulting in ponding of water against the upstream embankment side slopes, a clay seal/blanket should also be considered on the side slopes up to the high water level. The clay seal/blanket should be a minimum of 1 m thick constructed of natural clay or soil-bentonite mix. The seal should also extend a minimum horizontal distance of 2 m on either side of the culvert inlet opening. If a geosynthetic clay liner (GCL) is utilized as a seal/blanket in lieu of the natural clay, the GCL should be constructed within the embankment slope to allow for a minimum 0.3 m thick granular (embankment) fill cover to be placed over the GCL to provide for protection from the requisite overlying erosion protection material.

Subject to confirmation and modifications as necessary based on the hydrology reports (by others), erosion protection could consist of a 0.6 m thick layer of rip rap treatment for the inlet and outlet of the culvert consistent with the standard presented in OPSD 810.010 (Rip Rap Treatment). We understand LEA only requires 0.4 m of rip rap for this site. The rip-rap at the inlet of the culvert should be placed up to the toe of slope level, in combination



with the cut-off measures noted in Section 6.6.1. Similarly, rip rap should be provided over the full extent of the clay seal or GCL, if applied.

6.6.5 Analytical Testing for Construction Materials

The results of an analytical test carried out on a soil sample from Borehole UN-4 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.

For potential sulphate attack on concrete, the results of the soil analysis were compared to Table 3 in CSA A23.1, and indicate that the relative degree of sulphate attack is low (less than the Moderate range). However, given that the location of the culvert will be exposed to de-icing salts it is recommended that C-1 class exposure concrete be considered for the pre-cast culvert units. Further, the resistivity results indicate that the soil has a low corrosiveness potential based on the Transportation Research Board Guidelines (1998) as referenced in the MTO Gravity Pipe Manual (2014).

It should be noted that the creek water level in the area is subject to seasonal fluctuations and variations due to precipitation events and the water chemistry could also be variable. These recommendations are provided as guidance only; the structural designer should take the results of the laboratory testing, the potential for corrosion and the ultimate selection of materials into consideration.

7.0 CLOSURE

This detail Foundation Design Report was prepared by Mr. Matthew Thibeault, P. Eng. and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., a Designated MTO Foundations Contact and Senior Consultant of Golder, conducted an independent quality control review and technical audit of this report.

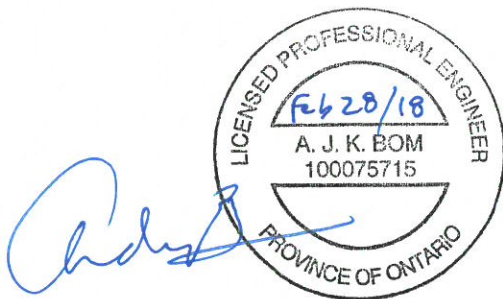


Report Signature Page

GOLDER ASSOCIATES LTD.

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MT/AB/LCC/JMAC/kp

n:\active\2016\3 proj\1661607 lea_5015-e-0049_ne region\foundations\reporting\r02-unnamed\final\1661607-r-r02-rev0 lea mto unnamed creek fdr 28feb_18.docx



REFERENCES

Canadian Standards Association (CSA), 2014. *Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-14*.

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2543.

Ministry of Transportation, *MTO Gravity Pipe Design Guidelines*, MTO Drainage and Hydrology Design and Contract Standards Office, May 2014

Ministry of Natural Resources. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society. Transportation Research Board, National Research Council, 1998. *Service Life Drainage Pipe*, National Cooperative Highway Research Program (NCHRP) Synthesis 254.

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 Drawings (OPSD)

OPSD 208.010 Benching of Earth Slopes

OPSD 803.010 Backfill and Cover for Concrete Culverts with Spans less than or Equal to 3 m

OPSD 810.010 General Rip-Rap Layout for Sewer and Culvert Outlets

OPSD 3090.100 Foundation Frost Penetration Depths for Northern Ontario

Ontario Provincial Standard Specifications (OPSS)

OPSS 422 Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 517 Construction Specification for Dewatering

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

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

OPSS.PROV 1205 Material Specification for Clay Seal

OPSS.PROV 1860 Material Specification for Geotextiles

Ontario Water Resource Act

Ontario Regulation 903 Wells (as amended)

Ontario Occupational Health and Safety Act:

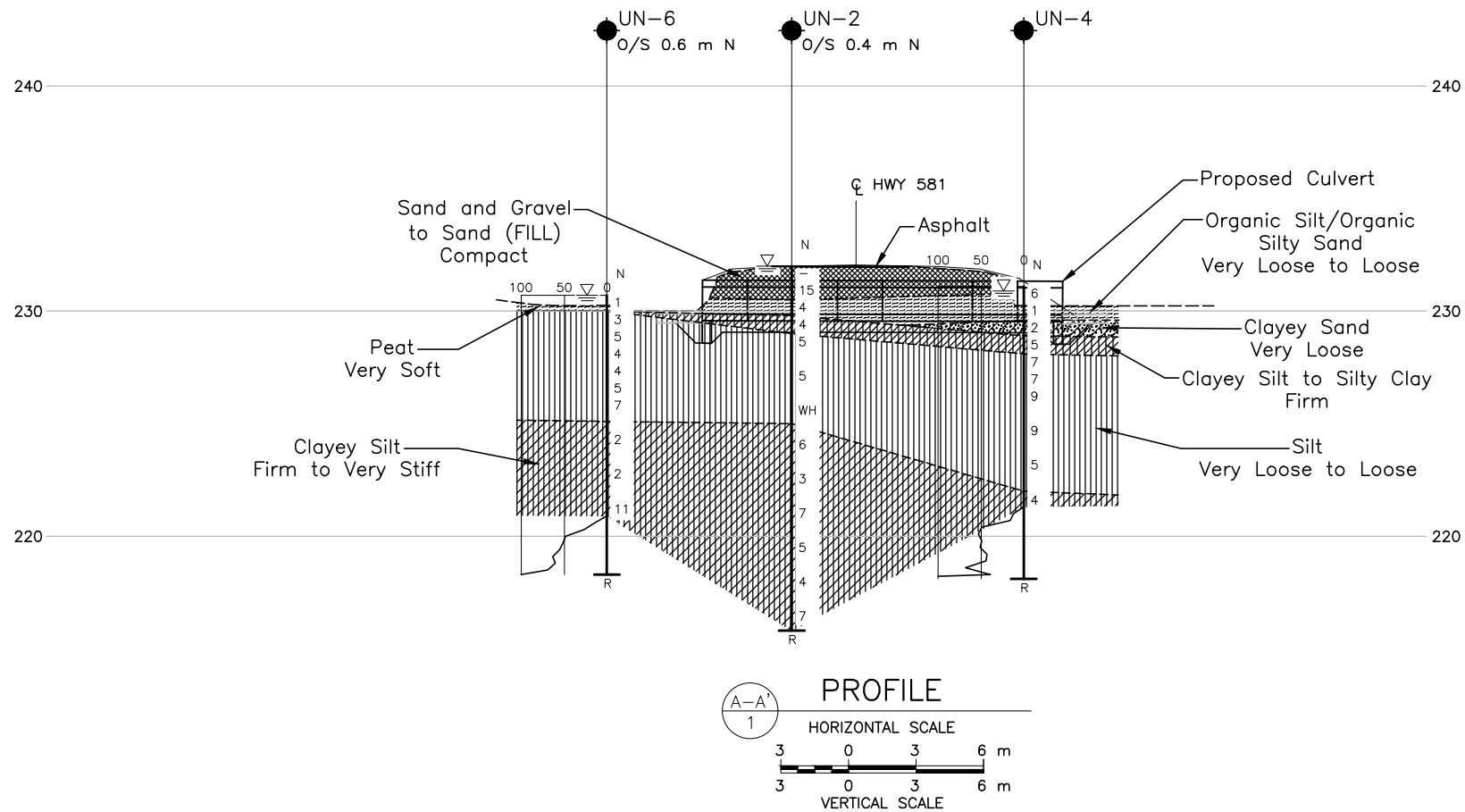
Ontario Regulation 213/91 Construction Projects (as amended)



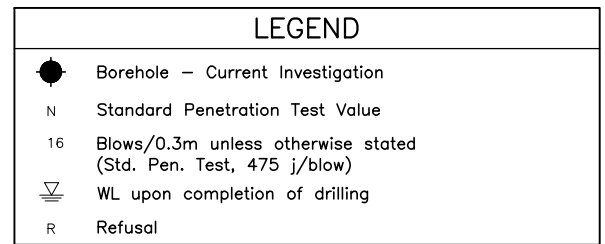
FOUNDATION REPORT, REPLACEMENT OF UNNAMED CREEK CULVERT, HIGHWAY 581, SITE NO. 39W-121/C
GWP 5164-13-00, WP 5164-13-01

Table 1: Comparison of Alternative Culvert Types

Option (Ranking)	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert (1)	<ul style="list-style-type: none"> Minimizes depth of excavation, protection system (if required) and unwatering requirements compared to open footing option. Allows for faster construction resulting in shorter duration for unwatering and surface water pumping. More tolerant of total and differential settlement. Backfill/bedding under the culvert may be placed underwater (i.e., Granular 'B' Type II) minimizing water pumping requirements. 	<ul style="list-style-type: none"> May not satisfy fisheries requirements related to natural channel substrate, if applicable. Cut-off wall (or clay seal) likely required at inlet to mitigate potential scour under the culvert. Transportation to and on-site lifting of large pre-cast sections will be required. Will require diversion of the creek channel. 	<ul style="list-style-type: none"> Risk of disturbance of the native silt to clayey silt deposit at subgrade level during construction, which will be mitigated by Granular 'B' Type II bedding. Lower risk related to settlement performance as box segments can accommodate some total and differential settlement.
Open Footing Culvert (2)	<ul style="list-style-type: none"> May be feasible to construct the culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for unwatering (pumping) of surface water. Readily suitable for construction using concrete or metal sections. Would likely satisfy fisheries requirements related to natural channel substrate, if applicable. 	<ul style="list-style-type: none"> Excavation depths are greater than for a box culvert option, resulting in increased excavation support and dewatering requirements and additional spoil material to be disposed off-site. 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. Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site. 	<ul style="list-style-type: none"> Moderate risk of disturbance of the native silt to clayey silt deposit during construction; can be mitigated with use of a tremie concrete. May require greater depth of dewatering for footing construction. Culvert joints may be required to accommodate the anticipated total and differential settlement.
Pipe Culvert (3)	<ul style="list-style-type: none"> Allows for faster construction resulting in shorter duration for unwatering and surface pumping compared to an open footing culvert. More tolerant of total and differential settlement. Backfill under the culvert may be placed underwater (i.e., Granular 'B' Type II) minimizing or eliminating water pumping requirements. 	<ul style="list-style-type: none"> Reduced flow-through capacity compared to box culvert and open footing options with a similar span – additional flow through capacity may have to be provided by multiple pipes. Cut-off wall or clay seal may be required at inlet to mitigate potential scour under the culvert(s). Difficult to compact backfill materials to level of culvert springline. CSP does not have as long a design life as compared to concrete options. 	<ul style="list-style-type: none"> Moderate risk of disturbance of the native silt to clayey silt deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular 'B' Type II working pad. Moderate risk related to anticipated total and differential settlement; but lower risk compared to box or open footing option.



GOLDER

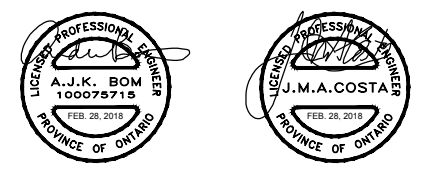


NOTES

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.

REFERENCE	
Base plans provided in digital format by LEA, drawing file nos. Unnamed.dwg, received MAY 05, 2017, and 17197-Unnamed Culvert-S1-General Arrangement.dwg, received FEB 12, 2018.	



NO.	DATE	BY	REVISION
Geocres No. 42G-068			
HWY. 581		PROJECT NO. 1661607	DIST. .
SUBM'D.		CHKD. AC	DATE: 2/27/2018
DRAWN: TB		CHKD. AB	SITE: 39W-121/ APPD. JMAC
			DWG. 1



PHOTOGRAPHS

Photograph 1: Unnamed Creek Bridge
South approach and west side of culvert, looking north (May 2017)



Photograph 2: Unnamed Creek Bridge
West end of culvert, looking north-east (May 2017)





PHOTOGRAPHS

**Photograph 3: Unnamed Creek Bridge
North approach, looking south (May 2017)**



**Photograph 4: Unnamed Creek Bridge
East side of culvert, looking east (May 2017)**





APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

I. GENERAL

π	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

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a)	Index Properties
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	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_{α}	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
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	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 ρ . Unit weight symbol is γ 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 cm² 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

Condition	N 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

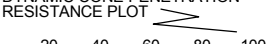
w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific 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)
γ	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

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

PROJECT 1661607			RECORD OF BOREHOLE No UN-1				2 OF 2 METRIC					
G.W.P. 5164-13-00		LOCATION N 5470438.2; E 220528.8 MTM ZONE 12 (LAT. 49.366053; LONG. -82.160343)				ORIGINATED BY SAMR						
DIST _____ HWY 581		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, Wash Boring				COMPILED BY TB/MT						
DATUM GEODETIC		DATE May 27, 2017				CHECKED BY AB						
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 _p — W — W _L WATER CONTENT (%)	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES							
--- CONTINUED FROM PREVIOUS PAGE ---												
	SILTY CLAY, trace to some gravel, trace sand Stiff to very stiff Grey Wet		10	SS	6		219					
	150 mm thick silt seam encountered at 12.6 m depth.											
			11	SS	8		218					
							217					
			12	SS	WH		216					
							215					
			13	SS	14		214					
213.9 18.1	SILT and SAND, trace gravel, trace clay Compact Grey Wet		14	SS	10		213					4 39 55 2
213.1 18.9	END OF BOREHOLE START OF DCPT						212					
211.8 20.2	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING) (100 BLOWS/0.05 m) Note: 1. Water level at a depth of 3.4 m below ground surface (Elev. 228.6) upon completion of drilling.											

SUD-MTO 001 MTM ZN INC LAT/LONG S:\CLIENTS\SMTO\1661607 LEA_5015-E-0049_NE REGION02_DATA\GINT\1661607.GPJ GAL-MISS.GDT 9/12/17 TB\JUL

PROJECT 1661607		RECORD OF BOREHOLE No UN-2				1 OF 2 METRIC								
G.W.P. 5164-13-00		LOCATION N 5470421.2; E 220523.0 MTM ZONE 12 (LAT. 49.365899; LONG. -82.16042)				ORIGINATED BY MR								
DIST _____ HWY 581		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing, Wash Boring				COMPILED BY TB/MT								
DATUM GEODETIC		DATE May 28, 2017				CHECKED BY AB								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
232.0	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	ASPHALT (25 mm)		1	AS	-									30 59 (11)
231.4	Sand and gravel to sand (FILL) Brown Moist													
0.6	Reclaimed asphalt encountered between 0.1 m and 0.3 m depths.		2	SS	15									
230.5	Sand (FILL) Compact Brown Moist													
1.5	ORGANIC SILTY SAND Loose Dark brown Wet		3	SS	4								OC = 7.4%	
229.8	CLAYEY SILT to SILTY CLAY Firm Grey Wet		4	SS	4									
2.2														
			5	SS	5									0 2 72 26
227.6	SILT, trace sand Very loose to loose Grey Wet		6	SS	5									
4.4														
			7	SS	WH									0 1 96 3
225.0	CLAYEY SILT, trace gravel, trace sand Stiff to very stiff Grey Wet		8	SS	6									
7.0														
			9	SS	3									
			10	SS	7									4 18 51 27

Continued Next Page

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

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[illegible]

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

PROJECT 1661607		RECORD OF BOREHOLE No UN-3				1 OF 2 METRIC								
G.W.P. 5164-13-00		LOCATION N 5470431.1; E 220534.2 MTM ZONE 12 (LAT. 49.36599; LONG. -82.160268)				ORIGINATED BY MR								
DIST _____ HWY 581		BOREHOLE TYPE Portable Tripod, NW Casing, Wash Boring				COMPILED BY TB/MT								
DATUM GEODETIC		DATE June 12, 2017				CHECKED BY AB								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
231.0	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	PEAT (Amorphous), trace wood pieces Soft Black Wet		1	SS	3									
230.3														
0.7	ORGANIC SILT, trace sand, trace to some clay Soft Dark brown to black Wet		2	SS	3		230						OC= 4.7%	
229.5														
1.5	SILT, trace sand, trace organics Loose Grey Wet		3	SS	5		229							
228.8														
2.2	SILTY CLAY, silt laminations throughout Firm Grey Wet		4	SS	5		228							1 3 38 58
228.0														
3.0	SILT Loose to compact Grey Wet Approximately 10 mm to 20 mm thick silty clay seams were encountered in Sample 5.		5	SS	8		227							
			6	SS	7									
			7	SS	8		226						NP	0 0 95 5
			8	SS	10		225							
							224							
			9	SS	6		223							
222.6														
8.4	Sandy CLAYEY SILT, trace gravel Soft Grey Wet		10	SS	2		222							3 25 54 18
220.9														
10.1	END OF BOREHOLE START OF DCPT						221							
219.0														

Continued Next Page

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

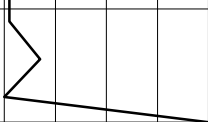
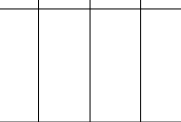
SUD-MTO 001 MTM ZN INC LAT/LONG S:\CLIENTS\MTM\1661607 LEA_5015-E-0049_NE REGION02_DATA\GINT\1661607.GPJ GAL-MISS.GDT 9/12/17 TB/JUL

PROJECT 1661607		RECORD OF BOREHOLE No UN-3				2 OF 2 METRIC										
G.W.P. 5164-13-00		LOCATION N 5470431.1; E 220534.2 MTM ZONE 12 (LAT. 49.36599; LONG. -82.160268)				ORIGINATED BY MR										
DIST _____ HWY 581		BOREHOLE TYPE Portable Tripod, NW Casing, Wash Boring				COMPILED BY TB/MT										
DATUM GEODETIC		DATE June 12, 2017				CHECKED BY AB										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
	--- CONTINUED FROM PREVIOUS PAGE ---															
12.0	END OF DCPT REFUSAL TO FURTHER PENETRATION (100 BLOWS/0.13 m) Note: 1. Water level at a depth of 0.2 m below ground surface (Elev. 230.8 m) upon completion of drilling. 2. Split Spoon samples obtained by driving with a 1/2 weight hammer. SPT 'N' - values have been adjusted to the inferred values that would be obtained using a standard weight hammer.															

SUD-MTO 001 MTM ZN INC LAT/LONG S:\CLIENTS\MTM\1661607 LEA_5015-E-0049_NE REGION02_DATA\GINT\1661607.GPJ GAL-MISS.GDT 9/12/17 TB\JUL

SUD-MTO 001 MTM ZN INC LAT/LONG S:\CLIENTS\MTO\1661607 LEA 5015-E-0049 NE REGION\02 DATA\GINT\1661607.GPJ GAL-MISS.GDT 9/12/17 TB/JJL

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

PROJECT <u>1661607</u>		RECORD OF BOREHOLE No UN-4				2 OF 2 METRIC											
G.W.P. <u>5164-13-00</u>		LOCATION <u>N 5470420.6; E 220533.3 MTM ZONE 12 (LAT. 49.365895; LONG. -82.160278)</u>				ORIGINATED BY <u>MR</u>											
DIST <u> </u> HWY <u>581</u>		BOREHOLE TYPE <u>Portable Tripod, NW Casing, Wash Boring</u>				COMPILED BY <u>TB/MT</u>											
DATUM <u>GEODETIC</u>		DATE <u>June 17, 2017</u>				CHECKED BY <u>AB</u>											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED </div>					<div style="display: flex; justify-content: space-between;"> W_p W W_L </div>					
218.1 13.0	END OF DCPT REFUSAL TO FURTHER PENETRATION (100 BLOWS/0.25 m) Note: 1. Water level at a depth of 0.2 m below ground surface (Elev. 230.9 m) upon completion of drilling. 2. Split Spoon samples obtained by driving with a 1/2 weight hammer. SPT 'N' - values have been adjusted to the inferred values that would be obtained using a standard weight hammer.					219											

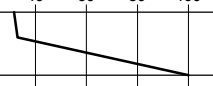
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PROJECT 1661607		RECORD OF BOREHOLE No UN-5				1 OF 2 METRIC								
G.W.P. 5164-13-00		LOCATION N 5470430.5; E 220515.3 MTM ZONE 12 (LAT. 49.365982; LONG. -82.160528)				ORIGINATED BY MR								
DIST _____ HWY 581		BOREHOLE TYPE Portable Tripod, NW Casing, Wash Boring				COMPILED BY TB/MT								
DATUM GEODETIC		DATE June 16, 2017				CHECKED BY AB								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
230.9	GROUND SURFACE													
0.0	PEAT (Fibrous) Very soft Black Wet		1	SS	1									
230.2	SILT, trace clay Very loose to loose Grey Wet Trace organics in Samples 2 and 3.		2	SS	3	230								
0.7			3	SS	6	229							NP	0 0 94 6
			4	SS	5	228								
			5	SS	4	227								
			6	SS	4	226								
	Sandy silt in Sample 7.		7	SS	7	225								
			8	SS	2	224								
223.7	CLAYEY SILT, some sand, trace gravel Firm to stiff Grey Wet		9	SS	2	223								1 15 45 39
7.2			10	SS	11	222								
221.1	END OF BOREHOLE START OF DCPT					221								
9.8						220								
						219								

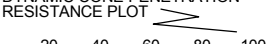



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+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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PROJECT 1661607		RECORD OF BOREHOLE No UN-5				2 OF 2 METRIC											
G.W.P. 5164-13-00		LOCATION N 5470430.5; E 220515.3 MTM ZONE 12 (LAT. 49.365982; LONG. -82.160528)				ORIGINATED BY MR											
DIST _____ HWY 581		BOREHOLE TYPE Portable Tripod, NW Casing, Wash Boring				COMPILED BY TB/MT											
DATUM GEODETIC		DATE June 16, 2017				CHECKED BY AB											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE </div> <div style="display: flex; justify-content: space-between;"> ● QUICK TRIAXIAL × REMOULDED </div>					<div style="display: flex; justify-content: space-between;"> W_p W W_L </div>					
218.4 12.5	END OF DCPT REFUSAL TO FURTHER PENETRATION (100 BLOWS/0.05 m) Note: 1. Water level at ground surface (Elev. 230.9 m) upon completion of drilling. 2. Split Spoon samples obtained by driving with a 1/2 weight hammer. SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer.																

SUD-MTO 001 MTM ZN INC LAT/LONG S:\CLIENTS\MTM\1661607 LEA_5015-E-0049_NE REGION02_DATA\GINT\1661607.GPJ GAL-MISS.GDT 9/12/17 TB\JUL

PROJECT 1661607			RECORD OF BOREHOLE No UN-6				1 OF 2 METRIC				
G.W.P. 5164-13-00		LOCATION N 5470421.6; E 220514.8 MTM ZONE 12 (LAT. 49.365902; LONG. -82.160532)				ORIGINATED BY MR					
DIST _____ HWY 581		BOREHOLE TYPE Portable Tripod, NW Casing, Wash Boring				COMPILED BY TB/MT					
DATUM GEODETIC		DATE June 16, 2017				CHECKED BY AB					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
230.7	GROUND SURFACE										
0.0	PEAT (Amorphous) Very soft Black Wet		1	SS	1						
230.0							230				
0.7	SILT, trace clay, trace sand Very loose to loose Grey Wet Trace organics in Sample 2 and 3.		2	SS	3						
							229				
			3	SS	5						
							228				0 0 92 8
			4	SS	4						
							227				
			5	SS	4						
							226				0 4 93 3
			6	SS	5						
							225				
			7	SS	7						
							224				
225.1	CLAYEY SILT, some sand Stiff Grey Wet		8	SS	2						0 18 64 18
5.6							223				
							222				
			9	SS	2						
							221				
			10	SS	11						
220.9	END OF BOREHOLE START OF DCPT						220				
9.8							219				

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

SUD-MTO 001 MTM ZN INC LAT/LONG S:\CLIENTS\MTM\1661607 LEA_5015-E-0049_NE REGION02_DATAGINT\1661607.GPJ GAL-MISS.GDT 9/12/17 TB/JUL

PROJECT 1661607		RECORD OF BOREHOLE No UN-6				2 OF 2 METRIC											
G.W.P. 5164-13-00		LOCATION N 5470421.6; E 220514.8 MTM ZONE 12 (LAT. 49.365902; LONG. -82.160532)				ORIGINATED BY MR											
DIST _____ HWY 581		BOREHOLE TYPE Portable Tripod, NW Casing, Wash Boring				COMPILED BY TB/MT											
DATUM GEODETIC		DATE June 16, 2017				CHECKED BY AB											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE </div> <div style="display: flex; justify-content: space-between;"> ● QUICK TRIAXIAL × REMOULDED </div>					<div style="display: flex; justify-content: space-between;"> W_p W W_L </div>					
218.3 12.4	END OF DCPT REFUSAL TO FURTHER PENETRATION (100 BLOWS/0.18 m) Note: 1. Water level at ground surface (Elev. 230.7 m) upon completion of drilling. 2. Split Spoon samples obtained by driving with a 1/2 weight hammer. SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer.																

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APPENDIX B

Laboratory Testing



**FOUNDATION REPORT, REPLACEMENT OF UNNAMED CREEK CULVERT,
HIGHWAY 581, SITE NO. 39W-121/C
GWP 5164-13-00, WP 5164-13-01**

Table B1: Summary of Analytical Testing of Soil Sample (Borehole UN-4 Sample 4)

Parameter	Units	Result
Chloride (CL)	mg/L	26
Sulphate (SO4)	mg/L	ND
Conductivity (EC)	µS/cm	217
Resistivity	ohms*cm	4,600
pH	n/a	7.79

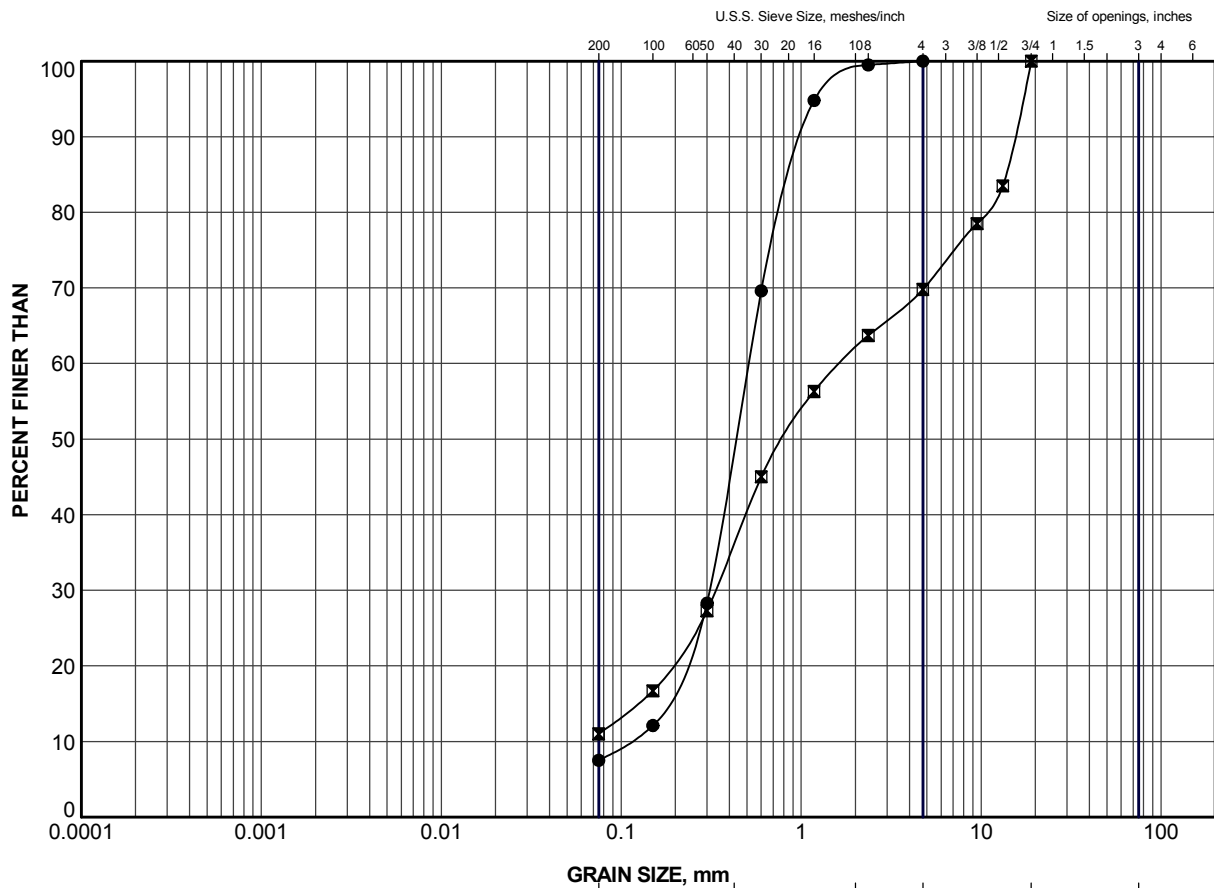
Notes: 1. Sample obtained on June 17, 2017.

2. Analytical testing carried out by Maxxam Analytics International Corporation.

3. ND = Not detected

Prepared by: TB

Reviewed by: AB



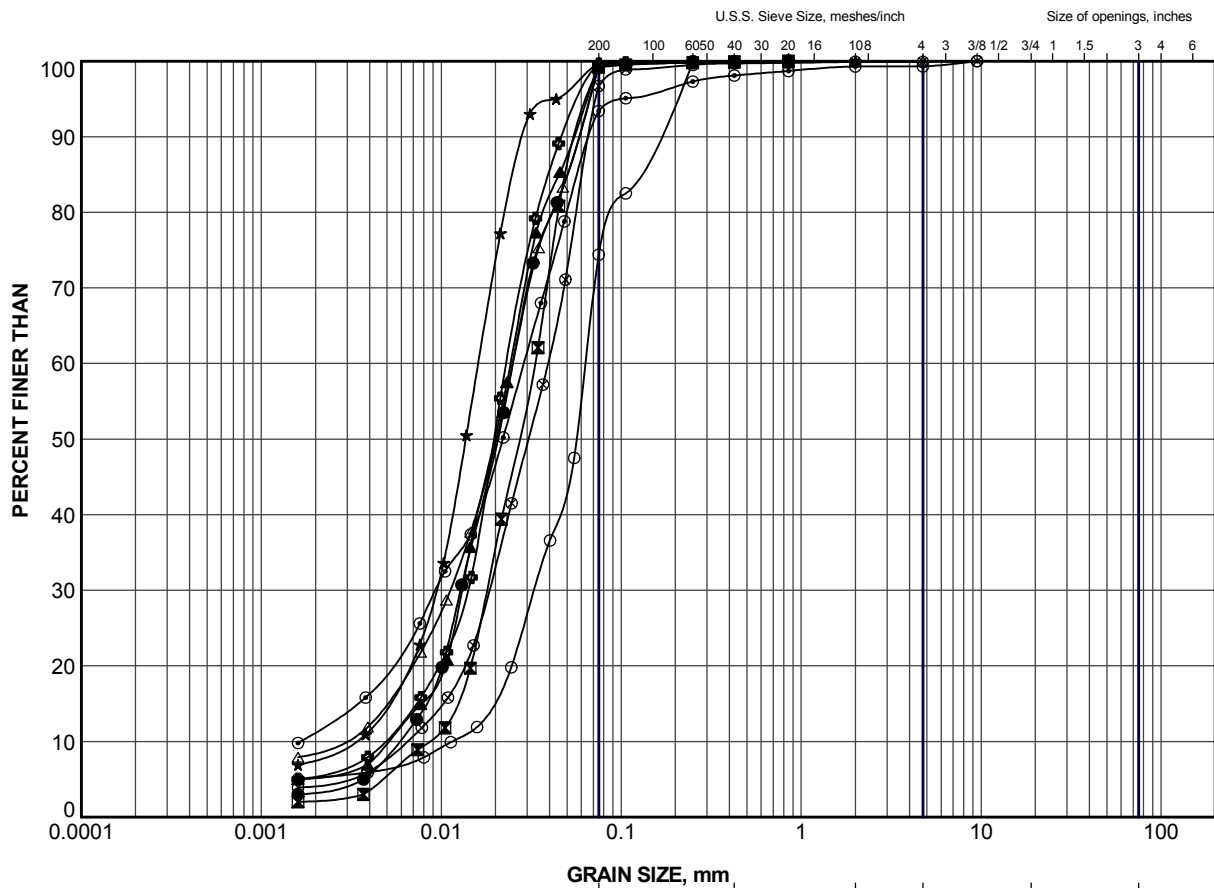
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	UN-1	1	230.9
■	UN-2	1	231.7

PROJECT						HIGHWAY 581 UNNAMED CREEK CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SAND; SAND and GRAVEL (FILL)					
PROJECT No.				1661607		FILE No.				1661607.GPJ	
DRAWN	TB	Feb 2018		SCALE	N/A	REV.					
CHECK	AB	Feb 2018									
APPR	JMAC	Feb 2018									
				FIGURE B1							





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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	UN-1	7	224.1
■	UN-2	7	225.6
▲	UN-3	7	226.1
★	UN-4	6	227.0
⊙	UN-4	9	223.2
⊕	UN-5	3	229.1
○	UN-5	7	226.0
△	UN-6	4	228.1
⊗	UN-6	6	226.6

PROJECT

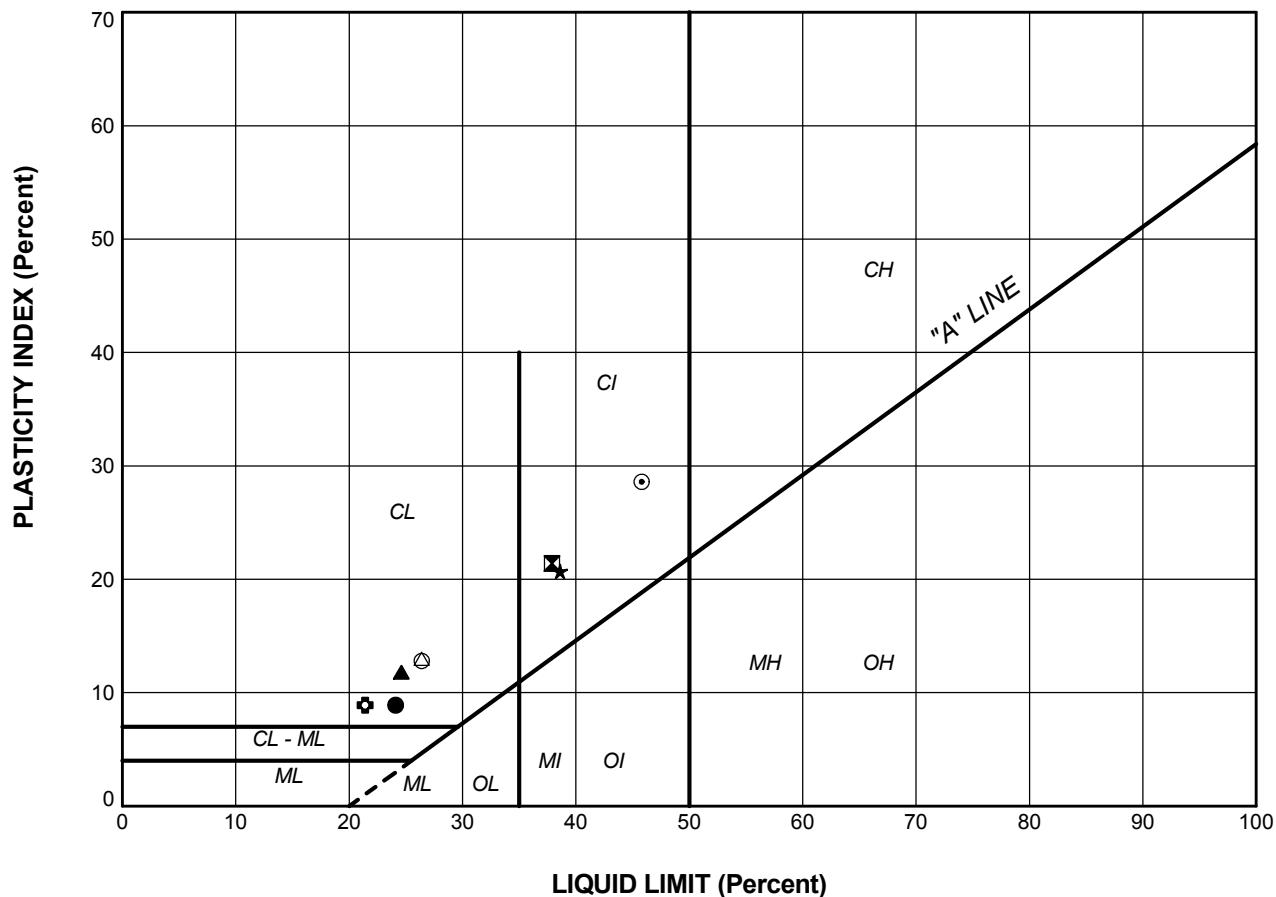
HIGHWAY 581
UNNAMED CREEK CULVERT

TITLE

GRAIN SIZE DISTRIBUTION
SILT




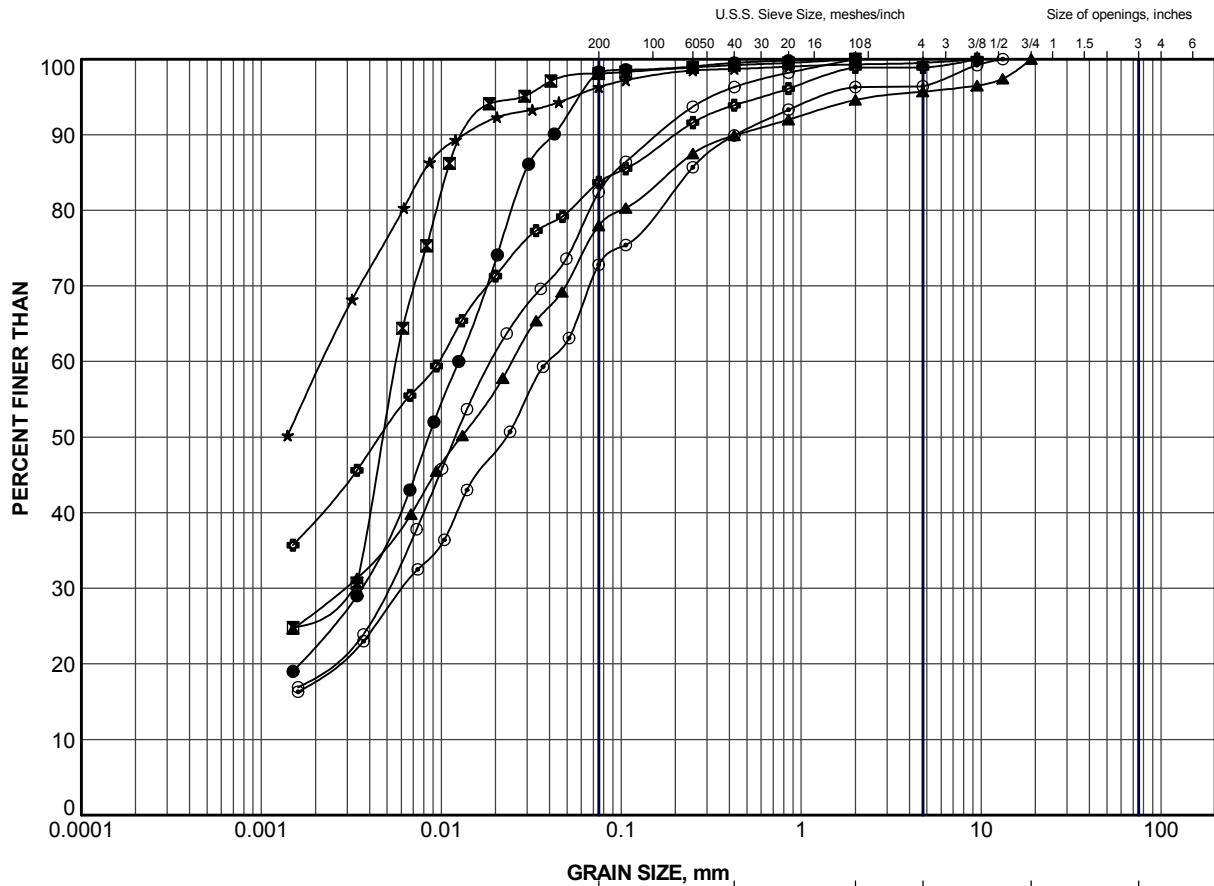
PROJECT No.		1661607	FILE No.		1661607.GPJ
DRAWN	TB	Feb 2018	SCALE	N/A	REV.
CHECK	AB	Feb 2018	FIGURE B2		
APPR	JMAC	Feb 2018			



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	UN-1	3	24.1	15.2	8.9
⊠	UN-1	11	37.9	16.5	21.4
▲	UN-2	10	24.6	12.8	11.8
★	UN-3	4	38.6	17.9	20.7
⊙	UN-4	4	45.8	17.2	28.6
⊕	UN-4	10	21.4	12.5	8.9
○	UN-5	9	26.4	13.6	12.8
△	UN-6	8	26.4	13.4	13.0

PROJECT					
HIGHWAY 581 UNNAMED CREEK CULVERT					
TITLE					
PLASTICITY CHART CLAYEY SILT to SILTY CLAY					
PROJECT No.		1661607		FILE No.	1661607.GPJ
DRAWN	TB	Feb 2018	SCALE	N/A	REV.
CHECK	AB	Feb 2018			
APPR	JMAC	Feb 2018			
 Golder Associates SUDBURY, ONTARIO			FIGURE B3		



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	UN-1	3	229.4
■	UN-2	5	228.7
▲	UN-2	10	221.0
★	UN-3	4	228.4
⊙	UN-3	10	221.6
⊕	UN-5	9	223.0
○	UN-6	8	224.3

PROJECT

HIGHWAY 581
UNNAMED CREEK CULVERT

TITLE

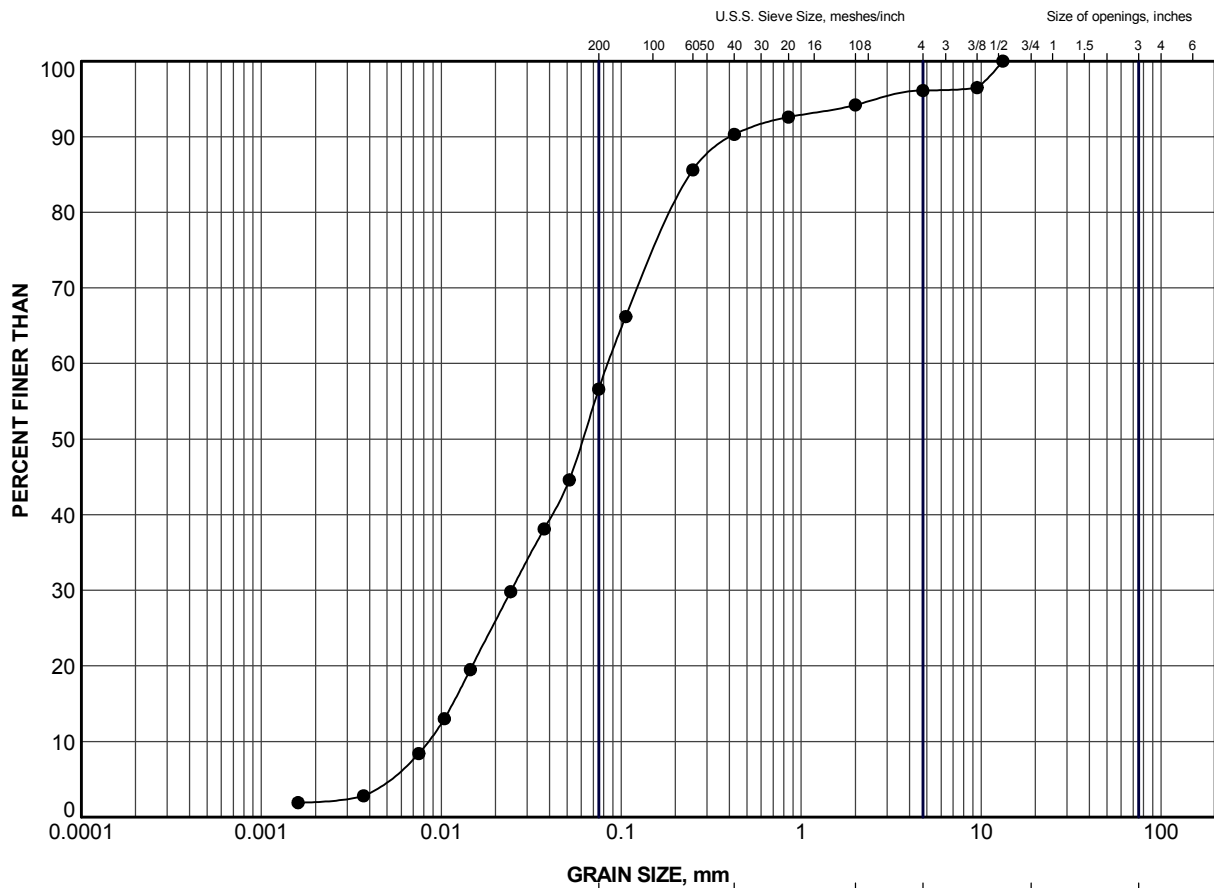
GRAIN SIZE DISTRIBUTION
CLAYEY SILT to SILTY CLAY



Golder Associates
SUDBURY, ONTARIO

PROJECT No. 1661607		FILE No. 1661607.GPJ	
DRAWN	TB	Feb 2018	SCALE N/A
CHECK	AB	Feb 2018	REV.
APPR	JMAC	Feb 2018	

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	UN-1	14	213.4

PROJECT						HIGHWAY 581 UNNAMED CREEK CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SILT and SAND					
PROJECT No.				1661607		FILE No.				1661607.GPJ	
DRAWN	TB	Feb 2018		SCALE	N/A	REV.					
CHECK	AB	Feb 2018									
APPR	JMAC	Feb 2018									
								FIGURE B5			





APPENDIX C

Notice to Contractor

UNWATERING OF STRUCTURE EXCAVATION - Item No.

Notice to Contractor

Construction of the culvert will require excavations to extend below the groundwater level and the adjacent creek water level. The embankment fill, organic soil and silt/clayey silt deposits within the excavation may slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate excavation protection and unwatering system to enable construction and prevent disturbance to the founding soils.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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