



FOUNDATION INVESTIGATION AND DESIGN REPORT

Bear Creek Culvert Replacement - Site 44X-0209/C0
Highway 518, Station 17+932 Monteith Township
District of Parry Sound
Ministry of Transportation, Ontario
GWP 5202-13-00, WP 5202-13-01

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PART A

FOUNDATION INVESTIGATION REPORT
BEAR CREEK CULVERT REPLACEMENT
SITE 44X-0209/C0 - HIGHWAY 518, STA. 17+932 MONTEITH
TOWNSHIP DISTRICT OF PARRY SOUND
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5202-13-00, WP 5202-13-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by GHD, on behalf of the Ministry of Transportation, Ontario (MTO), to provide detail design Foundation Engineering services for the replacement of the Bear Creek Culvert (Site No. 44X-0209/C0). The existing Bear Creek Culvert is located on Highway 518 at about Station 17+932 Monteith Township in the District of Parry Sound, Ontario (approximately 27.7 km west of Highway 11). The key plan showing the general location of this section of Highway 518 and the location of the investigated area is presented on Drawing 1.

The Terms of Reference (TOR) for the Foundation investigation are outlined in MTO's Request for Proposal (RFP) for Assignment 5016-E-0037 (dated March 2017) and the subsequent clarifications and addenda. Golder's Scope of Work is outlined in our proposal, dated June 14, 2017, which is included in Section 17.8 of GHD's technical proposal for this assignment.

This work has been carried out in accordance with Golder's Supplementary Specialty Plan for Foundation Engineering services for this project, dated September 13, 2017.

2.0 SITE DESCRIPTION

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on the drawing. For the purpose of this report, Highway 518 is oriented in a west-east direction with the culvert aligned perpendicular to the highway, generally in a north-south orientation.

In general, the topography within the vicinity of the culvert consists of relatively flat terrain, which is heavily forested beyond the highway right-of-way (ROW), with visible bedrock outcrops located about 50 m and 150 m east of the culvert on the south and north sides of the highway, respectively. The topography along the south side of the highway in the culvert area is relatively flat and covered with grass and small shrubs; and appears to be an old highway alignment or previous detour alignment.

At the culvert location, the highway grade is at approximately Elevation 299.5 m and the existing highway embankment is approximately 1.6 m to 2.5 m high relative to the ground surface at the toe of embankment slope borehole locations (or about 5.8 m to 5.9 m high relative to the existing culvert inverts). The existing embankment side slopes are generally inclined at about 2.5 horizontal to 1 vertical (2.5H:1V) above approximately Elevation 297 m, and are locally steepened to about 0.25H:1V and 0.4H:1V below about Elevation 297 m (i.e., about 2.5 m below the road surface) along the north and south side slopes, respectively, to the toe of slope.

The existing culvert consists of a 4.4 m wide by 2.8 m high structural plate corrugated steel pipe arch (SPCSPA). Based on the survey drawing (E1086518.dwg) provided by GHD, the existing culvert invert is at about Elevation 295.2 m and 295.1 m at the north (inlet) and south (outlet) ends, respectively. The creek water level, as surveyed by Golder on December 11, 2017, was Elevation 296.8 m. The ground surface conditions in the area around the culvert location are shown on Photographs 1 to 4.

Based on the Ontario Structure Inspection Manual (OSIM) report, dated June 22, 2018, the existing culvert is generally in poor condition, with some minor deterioration of several elements, including more significant deterioration of the structural steel coatings and culvert barrel. The existing highway embankment is also noted to be in good condition. Based on our site observations at the time of the field investigation and a review of the

available site photographs/satellite images, the existing embankment in the culvert area generally appears to be performing satisfactorily with little to no evidence of soil movement, tilted vegetation, or tension cracks; however, it is noted that the highway was resurfaced in 2013.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface exploration was carried out between December 4 and 11, 2017, and February 8, 2018, during which time, four boreholes (Boreholes BC-1 to BC-4) were advanced at approximately the locations shown on Drawing 1. Boreholes BC-1 and BC-4 were advanced at the toe of the embankment side slopes near the culvert inlet and outlet, respectively, while Boreholes BC-2 and BC-3 were advanced from the roadway platform. Boreholes BC-2, BC-3, and BC-4 were advanced using a rubber tire ATV- (or “buggy”) mounted CME-55 drilling rig and Borehole BC-1 was advanced using portable tripod drilling equipment and a portable Hilti core drill to facilitate bedrock coring. The ATV-mounted drilling rig and portable tripod equipment were supplied and operated by Landcore Drilling Inc, of Chelmsford, Ontario, and the Hilti core drill was supplied and operated by Golder. Traffic control was performed in accordance with the Ontario Traffic Control Manual Book 7 – Temporary Conditions by Fowler Construction Company Limited of Bracebridge, Ontario.

The boreholes were advanced using 108 mm inside diameter hollow-stem augers, NW casing with wash boring techniques, and NQ coring (as required). Water from the local creek was used for wash boring and coring operations. 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 or a cathead hammer (for the borehole advanced using the portable tripod) in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The groundwater levels in the open boreholes were observed during and upon completion of the drilling/coring 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 field work was supervised on a full-time basis by a member of Golder’s technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; and logged the boreholes. The soil and rock 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 determinations, grain size distributions, and Atterberg Limits were carried out on selected soil samples. In addition, an unconfined compression (UC) test was carried out on a specimen of the retrieved bedrock core for determination of its uniaxial compression strength (UCS). The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable.

The as-drilled borehole locations were measured by a member of our technical staff relative to the existing culvert and roadway centreline, using a measuring tape and converted into northing/easting coordinates on the plan drawing. Given the relatively short distances between the boreholes and the existing structure, the measurements are considered to be accurate to within 0.5 m horizontally. The ground surface elevations at the borehole locations were obtained using a survey level and rod and the survey loop was closed to within 0.1 m vertically. The boreholes were surveyed relative to the highway centerline at the culvert location, the elevation of which was obtained from the plan drawing (E10865181.dwg) provided by GHD. The NAD 83 MTM CSRS CBNv6-2010.0 (Zone 10) northing and easting coordinates, World Geodetic System 1984 (WGS 84) geographical coordinates,

ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below.

Borehole Number	Location (NAD 83, MTM Zone 10)		Location (WGS 84)		Ground Surface Elevation (m)	Borehole Depth ¹ (m)
	Northing	Easting	(Latitude)	(Longitude)		
BC-1	5032757.9	295322.6	45.434699	-79.621135	297.0	4.6
BC-2	5032765.4	295344.0	45.434767	-79.620862	299.6	7.0
BC-3	5032752.1	295335.7	45.434647	-79.620968	299.5	9.9
BC-4	5032754.8	295351.2	45.434671	-79.620769	297.9	7.1

Note(s): 1. Borehole depths include between 3.2 m and 3.3 m of bedrock coring.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on the Surficial Geology of Southern Ontario mapping by the Ministry of Natural Resources and Forestry (MNRF)¹, the subsoils in the vicinity of the Bear Creek Culvert site consist of alluvial deposits comprised of clay, silt, sand, gravel, and may contain organic remains; bordered by Precambrian bedrock-drift complexes and glaciolacustrine deposits primarily comprised of sand and gravel with minor silt and clay deposits.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)², the site is underlain by bedrock of the central gneiss belt, including mafic rock comprised of amphibolite, gabbro, diorite, and mafic gneisses; bordered by migmatites rocks and gneisses of undetermined protolith commonly comprised of layered biotite gneisses and migmatites with localized quartzofeldspathic gneisses, orthogneisses, and paragneisses.

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 and Record of Drillhole sheets contained in Appendix A. The detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT 'N'-values), as presented on the Record of Boreholes and in Section 4, are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profiles 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.

In summary, the subsurface conditions encountered at the site consist of surface treatment and granular embankment fill (for boreholes advanced through the roadway platform) and topsoil (for boreholes advanced near

¹ Ontario Ministry of Natural Resources and Forestry, Surficial Geology of Southern Ontario. Ontario Geological Society Electronic Mapping.

² Ontario Ministry of Northern Development of Mines. Bedrock Geology of Ontario – Southern Sheet, Ontario Geological Survey - Map 2544

the embankment toe of slope) underlain by interlayered deposits of gravelly sand, silty clay, silt, and silty sand to silt and sand underlain by bedrock at relatively shallow depth below ground surface. A detailed description of the soil deposits, bedrock, and groundwater conditions encountered in the boreholes is provided in the following sections.

4.2.1 Surface Treatment

A 15 mm and 20 mm thick layer of surface treatment was encountered at ground surface in Boreholes BC-2 and BC-3, respectively.

4.2.2 Topsoil

A 50 mm thick deposit of topsoil was encountered from ground surface in Boreholes BC-1 and BC-4.

4.2.3 Granular Embankment Fill

A 3.8 to 4.5 m thick layer of granular embankment fill was encountered below the surface treatment in Boreholes BC-2 and BC-3, respectively, which were advanced from the roadway platform. A 1.5 m thick layer of granular fill was encountered below the topsoil in Borehole BC-4, which was advanced near the north toe of the embankment side slope. The granular fill consists an upper 0.3 m thick layer of sand and gravel in Boreholes BC-2 and BC-3, underlain by brown to grey, moist to wet, gravelly sand to sand and gravel, trace to some silt. The granular fill was noted to contain cobbles and boulders (ranging in size from 175 mm to 400 mm) in Borehole BC-2 and trace organics in Borehole BC-4.

Standard Penetration Test (SPT) 'N'-values measured within the granular fill range from 3 blows to 30 blows per 0.3 m of penetration, indicating a very loose to compact compactness condition. In two instances, the split-spoon sampler encountered refusal (i.e., hammer bouncing): one SPT 'N'-value of 18 blows for 0.3 m of penetration was recorded with a subsequent 30 blows for 0.05 m of penetration (and hammer bouncing) in the lower portion of the sample interval, due to the presence of cobbles and boulders; and one SPT 'N'-value of 33 blows for 0.28 m of penetration was recorded at the top of the underlying bedrock.

The moisture content measured on two samples of the sand and gravel to gravelly sand fill are 6 per cent and 14 per cent.

The results of the grain size distribution tests completed on two samples of the granular fill are shown on Figure B-1 in Appendix B.

4.2.4 Silt and Sand

A deposit of brown to grey, moist to wet, silt and sand, trace to some gravel, trace to some organics was encountered below the topsoil in Borehole BC-1. The surface of the silt and sand deposit was encountered at Elevation 296.9 m and the deposit is 1.3 m thick.

The SPT 'N'-values within the silt and sand deposit are 5 blows and 2 blows per 0.3 m of penetration indicating a very loose to loose compactness condition.

The moisture content measure on two samples of the silt and sand is 26 per cent and 38 per cent.

The result of a grain size distribution test completed on one selected sample of the silt and sand deposit is shown on Figure B-2A in Appendix B.

Atterberg limits tests were carried out on the two samples of the silt and sand deposit: one test indicated a non-plastic condition; and one test measured a liquid limit of 26 per cent, a plastic limit of 22 per cent, and a plasticity index of 4 per cent, indicating that the silt and sand deposit is slightly plastic, as shown on Figure B-2B. The other Atterberg limit test returned a non-plastic test result.

4.2.5 Gravelly Sand

A deposit of grey, wet, gravelly sand, trace to some silt was encountered underlying the granular fill in Borehole BC-3. The surface of the gravelly sand deposit was encountered at Elevation 295.0 m and the deposit is 1.1 m thick.

The SPT 'N'-value measured within the gravelly sand deposit is 23 blows per 0.3 m of penetration indicating a compact compactness condition.

The moisture content measured on one sample of the gravelly sand deposit is 9 per cent.

The result of the grain size distribution test completed on a sample of the gravelly sand is shown on Figure B-3 in Appendix B.

4.2.6 Silty Clay

A deposit of brown to grey, wet, silty clay was encountered underlying the granular fill in Borehole BC-4. The surface of the silty clay deposit was encountered at Elevation 296.4 m and the deposit is 0.7 m thick.

The SPT 'N'-value measured within the silty clay deposit is 5 blows per 0.3 m of penetration suggesting a firm consistency.

4.2.7 Silt

A deposit of brown to grey, wet, silt, trace sand, trace to some clay was encountered underlying the silty clay deposit in Borehole BC-4. The surface of the silt was encountered at Elevation 295.7 m and the deposit was 0.7 m thick.

The SPT 'N'-value measured within the silt deposit is 7 blows per 0.3 m of penetration indicating a loose compactness condition.

The moisture content measured on one sample of the silt deposit is 33 per cent.

The result of the grain size distribution tests completed on one sample of the silt deposit is shown on Figure B-4 in Appendix B.

An Atterberg limit test was carried out on one sample of the silt deposit, which indicated a non-plastic condition.

4.2.8 Silty Sand

A deposit of brown to grey, wet, silty sand, trace gravel was encountered below the gravelly sand deposit in Borehole BC-3 and underlying the silt deposit in Borehole BC-4. The surface of the silty sand deposit was encountered at Elevations 293.9 m and 295.0 m in the respective boreholes, and the deposit is 1.1 and 0.9 m thick, respectively. A boulder of about 300 mm in size was encountered at the interface of the silty sand deposit within the silt deposit at about 2.9 m depth (i.e., Elev. 295.0 m) in Borehole BC-4.

Standard Penetration Test (SPT) 'N'-values measured in the silty sand deposit are 7 blows and 19 blows per 0.3 m of penetration indicating a loose to compact compactness condition.

The natural moisture content measured on one sample of the silty sand deposit is 15 per cent.

The result of the grain size distribution test completed on one sample of the silty sand deposit is shown on Figure B-5 in Appendix B.

4.2.9 Bedrock

Bedrock was encountered below the overburden soils in Boreholes BC-1 to BC-4. The bedrock surface elevations and cored lengths in each borehole are presented below.

Borehole No.	Bedrock Surface Elevation (m)	Core Length (m)
BC-1	295.6	3.2
BC-2	295.8	3.2
BC-3	292.8	3.2
BC-4	294.1	3.3

The retrieved bedrock core in Boreholes BR-1 to BR-4 is described as a fresh, fine to medium grained, strongly foliated, strong, dark grey to black to pink granite biotite gneiss. More detailed descriptions of the bedrock cores are presented on the Record of Drillhole sheets in Appendix A. Photographs of the bedrock core samples and the result of an unconfined compression (UC) test are presented on Figures B-5 and B-6, respectively, which are included in Appendix B. The bedrock properties from the retrieved cores are summarized below.

Borehole No.	Total Core Recovery (%)	Solid Core Recovery (%)	Rock Quality Designation (%)	Quality Classification (Table 3.10 of CFEM 2006 ³)	Uniaxial Compressive Strength (MPa)	Strength Classification (Table 3.5 of CFEM 2006 ³)
BC-1	100	29 - 85	69 - 98	Fair to Excellent	-	
BC-2	100	72 - 96	92 - 96	Excellent	97	(R4 – Strong)
BC-3	100	91 - 100	79 - 100	Good to Excellent	-	
BC-4	100	94 - 100	94 - 100	Excellent	-	

4.2.10 Groundwater Conditions

The unstabilized groundwater levels measured in the open boreholes upon completion of drilling/coring are summarized below. The creek water level, as surveyed by Golder on December 11, 2017, was Elevation 296.8 m. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
BC-1	0.2	296.8
BC-2	3.3	296.3
BC-3	2.8	296.7
BC-4	2.3	295.6

The water levels in Boreholes BC-1 to BC-4 would have been affected by water introduced into the boreholes during washing boring for NW casing advancement and/or during NQ coring operations; however, the water levels in the open boreholes are generally consistent with the surveyed creek water level at the time of the investigation.

4.3 Analytical Test Results of Soil Sample

A sample of the silty sand deposit from Borehole BC-3 (i.e., Sample No. 8) was obtained during the field investigation using appropriate sampling protocols and submitted to Maxxam Analytics under chain of custody procedures and tested for a suite of corrosivity indicator parameters including: pH, resistivity, conductivity, sulphates, and chlorides. The results of the analytical testing are presented in Appendix C and are summarized below.

³ Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.

Parameter	Units	Results Borehole BC-3, Sample No. 8 (Elevation 293.1 m)
Resistivity	ohm-cm	11,000
Conductivity	µmho/cm	91
pH	pH	6.59
Sulphate	µg/g	ND ¹
Chloride	µg/g	35

Note(s): 1. ND = Not Detected (i.e., the sulphate concentration is below the reportable detection limit of 20 µg/g).

5.0 CLOSURE

The field drilling program was supervised by Mr. Matthew Riopelle and Mr. Shane Albert under the overall direction of Mr. David Muldowney, P.Eng. This Foundation Investigation Report was prepared by Mr. Adam Core, P. Eng., and Mr. David Muldowney, P.Eng., provided a technical review of the report. Mr. Jorge M. A. Costa, P. Eng., an MTO Foundations Designated Contact and Senior Consultant for Golder, conducted an independent quality control review of this report.

Signature Page

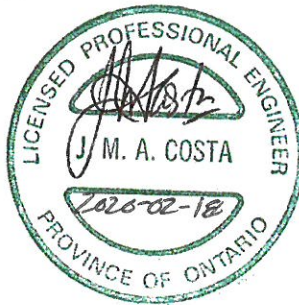
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PART B

FOUNDATION DESIGN REPORT
BEAR CREEK CULVERT REPLACEMENT
SITE 44X-0209/C0 - HIGHWAY 518, STA. 17+932 MONTEITH
TOWNSHIP DISTRICT OF PARRY SOUND
MINISTRY OF TRANSPORTATION, ONTARIO
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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 Bear Creek Culvert on Highway 518. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface exploration. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible foundation alternatives and carry out the design of the structure foundations, as may be required. The Foundation Investigation Report, discussion, and recommendations are intended for the use of the MTO and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in the Foundation Investigation Report (Part A of this report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided, as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

6.1 General

The Bear Creek Culvert is located on Highway 518 at about Station 17+932 Monteith Township in the District of Parry Sound, Ontario (approximately 27.7 km west of Highway 11). The existing culvert consists of a 4.4 m wide by 2.8 m high structural plate corrugated steel pipe arch (SPCSPA) and based on the information provided in the 2014 OSIM report, as well as our site observations at the time of the field investigation, the existing culvert generally appears to be performing satisfactorily.

A concrete box culvert, open footing culvert, or corrugated steel pipe (CSP) culvert are all considered feasible alternatives for replacement of the existing culvert at this site. Given the presence of bedrock at shallow depth, a like-for-like replacement strategy with a similar sized SPCSPA placed on the existing alignment and at the same (or potentially higher) invert elevation, if such can still accommodate hydraulic requirements, would be preferred from a Foundation perspective, in an effort to eliminate (or at least minimize) bedrock excavation/blasting requirements. Although concrete structures generally have higher initial costs, they typically have a longer design life; and if a lower invert elevation or a larger span culvert is required to satisfy hydrology requirements, a concrete structure would be preferred over a CSP culvert. Further, a cast-in-place open footing culvert, which has a smaller foundation footprint and can more readily accommodate variations in the bedrock surface, would be preferred over a precast box culvert. Consideration could be given to utilizing precast open-box segments in conjunction with cast-in-place footings to expedite the construction schedule. A comparison of culvert types based on advantages, disadvantages, and risks/consequences is presented in Table 1.

Based on the preliminary General Arrangement (GA) drawing provided by GHD on August 22, 2019, we understand that the replacement culvert is to consist of a 4.5 m wide by 3.0 m high (interior dimensions) precast concrete box culvert with invert Elevations of 295.1 m and 295.0 m at the inlet and outlet ends, respectively (i.e., about 0.1 m below the existing SPCSPA). We also understand that the roadway platform is to be widened and the embankment side slopes are to be flattened. Given the limited right-of-way (ROW), precast retaining walls are being proposed at the north end of the culvert to accommodate the proposed widening. Based on the GA drawing, the stepped retaining wall footings will be founded at about Elev. 294.2 m (adjacent to the culvert walls) and 295.2 m (farther end from the culvert).

6.2 Consequence and Site Understanding Classification

A “typical consequence level” is considered appropriate for the foundation design at this site, as outlined in Section 6.5 of the Canadian Highway Bridge Design Code (CHBDC 2014) and its Commentary. Further, given the scope of work of the Foundation field investigation and laboratory testing program, as presented in Sections 3.0 and 4.0, a “typical degree of site and prediction model understanding” has been utilized. Accordingly, the appropriate corresponding ULS and SLS consequence factor, Ψ , and geotechnical resistance factors, Φ_{gu} and Φ_{gs} , from Tables 6.1 and 6.2 of the CHBDC (2014) have been used for design.

6.3 Culvert Foundation Design Recommendations

6.3.1 Founding Level and Geotechnical Resistance

Prior to placing the bedding/levelling pad, replacement culvert, and precast retaining wall footings, it is recommended that all organic material (i.e., topsoil, peat, and/or mixed organic soils) and existing fill encountered below the footprint of the culvert and retaining wall footings be sub-excavated and replaced with Ontario Provincial Standard Specification, Provincial Oriented (OPSS.PROV) 1010 Granular ‘A’ or Granular ‘B’ Type II material. Granular ‘B’ Type II material is recommended for placement in wet conditions.

Based on the proposed culvert invert elevations and taking into account a 350 mm thick bottom slab, a 75 mm thick levelling pad, and a minimum 150 mm thick bedding layer (as discussed further in Section 6.6.4), the precast box culvert will be founded on a combination of bedrock and native soil (i.e., gravelly sand to silty sand) at about Elevations 294.5 m and 294.4 m at the inlet and outlet ends, respectively. Similarly, the precast retaining wall footings will be founded on bedrock at about Elevation 294.0 m (adjacent to the culvert walls) and 295.0 m (far end of the retaining walls) assuming a 75 mm thick levelling pad and a minimum 150 mm thick bedding layer.

For a proposed 5.2 m wide box culvert (exterior dimension) founded on a properly prepared granular bedding/levelling pad, overlying the native subgrade soils and bedrock at this site, a factored ultimate geotechnical axial resistance of 400 kPa and a factored serviceability geotechnical resistance of 150 kPa (for 25 mm of settlement) may be used for design. If higher geotechnical resistances are required, consideration could be given to sub-excavating the native soils to the exposed bedrock surface and replacing with OPSS.PROV 1010 Granular ‘A’ or Granular ‘B’ Type II material.

For an assumed 0.6 m wide precast retaining wall footing founded on properly prepared granular bedding/levelling pad overlying bedrock, a factored geotechnical resistance of 200 kPa at both ULS and SLS (for 25 mm of settlement) may be used for design. Alternatively, consideration could be given to utilizing cast-in-place open footings founded directly on bedrock for the culvert replacement and/or the proposed retaining walls. A factored geotechnical resistance of 1 MPa at both ULS and SLS may be used for design purposes for a culvert/retaining wall footing founded directly on bedrock. These resistances can be reviewed, and likely increased once more details became available, if a cast-in-place footing option is selected.

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 its 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 governed by the thickness/height of the overlying and adjacent embankment fill. The factored geotechnical serviceability resistances provided above assume there will not be any temporary and/or permanent grade raise at the culvert location (including during the course of construction).

6.3.2 Frost Protection

The frost penetration depth in the area of the Bear Creek Culvert is 1.9 m, as interpreted from OPSD 3090.101 (Foundation Frost Penetration Depths for Southern Ontario). However, it is not necessary to found the replacement box culvert below the frost penetration depth, as box culverts are tolerant of small magnitudes of movement related to freeze-thaw cycles.

Although the native gravelly sand and silty sand subgrade underlying the proposed culvert (southern portion) invert elevation is considered to have a low susceptibility to frost heaving (based on the MTO Pavement Design and Rehabilitation Manual, 2013), if an open footing culvert is selected, we recommend that the footings be placed directly on the exposed bedrock, as open footings are typically less tolerant of differential movement.

Given that the proposed precast concrete retaining wall footings are to be founded on a non-frost susceptible granular bedding/levelling pad over bedrock (or directly on the bedrock surface if cast-in-place concrete is utilized) as discussed in Section 6.3.1, it is not necessary to found the retaining wall footings below the depth of frost penetration.

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 0.45 may be used at the interface between the base of the precast concrete box culvert and retaining wall footings and the granular bedding material. If cast-in-place concrete is utilized for an open footing culvert or for the retaining wall footings, a coefficient of friction, $\tan \delta'_i$, of 0.55 may be used at the interface between the cast-in-place concrete and the granular bedding material. If the culvert or retaining wall foundations are founded directly on clean, sound (i.e., slightly weathered to fresh) bedrock, the coefficient of friction ($\tan \delta'_i$) may be taken as 0.7 for cast-in-place concrete as interpreted from NAVFAC (1986).

Dowels should be incorporated into the design where bedrock is found to be sloping at greater than 10 degrees and/or if additional horizontal resistance is required. The horizontal resistance of the dowels is dependent on the strength of the bedrock, grout, and steel. Where the rock mass is stronger than the concrete (as is the case at this site), the design of the dowels into the rock may be handled in the same way as the dowel embedment into concrete for a uniaxial compressive strength of grout similar to that of the concrete. Dowels should have a minimum 1 m embedment into fair quality (i.e., RQD >50 per cent) bedrock and the structural strength of the dowels and the compressive strength of the grout should not be exceeded. If dowels are incorporated into the design, a Non-Standard Special Provision (NSSP) for Dowels into Rock should be included in the Contract Documents; an example NSSP is provided in Appendix D.

6.4 Stability, Settlement and Horizontal Strain

The existing embankment is about 1.6 m and 2.5 m high, relative to the ground surface at the toes of the embankment slope borehole locations adjacent to the culvert. The existing embankment side slopes are inclined at about 2.5H:1V in the upper portion of the embankment and locally steepened to about 0.25H:1V and 0.4H:1V in the lower portion of the embankment along the north and south toes of the side slopes, respectively. Based on our site observations at the time of the current subsurface exploration and available site photographs/satellite images, the existing highway embankment in the culvert area appears to be performing satisfactorily. There was no evidence of instability or settlement (i.e., soil movement) of the embankment side slopes and no visible signs of previous embankment rehabilitation. It is noted in GHD's draft Structural Design Report (dated June 10, 2019) that there is a history of sinkhole development within the highway embankments at the culvert location; however, the sinkholes are inferred to be a result of embankment material composition as selected for initial construction, construction practices, and/or inadequate surface water management practices (i.e., leading to localized erosion and transport of embankment materials) rather than embankment instability.

Based on the GA drawing provided by GHD, we understand that the roadway platform is to be widened by about 3 m to accommodate wider shoulders and shoulder roundings. We also understand that the side slopes are to be flattened to about 3H:1V on both sides of the embankment, which will result in a widening along the embankment south toe of slope; whereas, retaining walls are being proposed to accommodate the proposed widening due to the limited ROW.

Given the relatively low embankment height, gravelly sand to sand and gravel embankment composition, generally cohesionless overburden/native soils, and the presence of bedrock at shallow depth, slope stability, and/or settlement issues are not anticipated at this site as a result of the proposed embankment re-instatement and widening. Although, a firm but still compressible silty clay deposit was encountered in Borehole BC-4, the deposit was not encountered within the roadway platform (i.e., within Boreholes BC-2 and BC-3) and as such, is not anticipated to impact performance of the final paved roadway surface. Also, given that the deposit was encountered above the proposed culvert invert elevation, the silty clay deposit is not anticipated to impact culvert performance. There could, however, be some localized impacts to the side slope of the widened embankment south side slope, potentially requiring post-construction maintenance (i.e., regrading). To reduce the width of the widening at the toe of embankment slope and to reduce the potential encroachment onto the silty clay deposit, consideration should be given to using 2H:1V side slopes as typically utilized for granular embankments in MTO's Northeast Region.

Due to the limited extent of the silty clay deposit (as encountered in one of the four boreholes), the limited thickness of the deposit (i.e., 0.7 m), and our experience with similar deposits in northeastern Ontario, it is considered that the post-construction settlement of the silty clay deposit, as a result of the proposed widening, will be relatively minor (i.e., less than 25 mm). As such, stability and/or settlement mitigation measures are not considered to be required at the site of the proposed embankment widening and local reconstruction. Consideration could be given to sub-excavating the silty clay deposit below the footprint of the widened embankment to mitigate the potential risk of post-construction settlement; however, the costs associated with the additional sub-excavation, soil disposal, and importation of new replacement granular fill is not considered to be warranted from a Foundation perspective, given the relatively low risks associated with post-construction settlement.

Given the subsurface conditions underlying the culvert foundation footprint at this site, horizontal strain along the culvert is anticipated to be relatively minor. As such, culvert construction concurrent with the embankment construction can be carried out without the need for any foundation mitigation measures or culvert camber.

However, if the replacement culvert and/or retaining wall footings are founded on a combination of bedrock and native soil, consideration should be given to incorporating additional reinforcing steel within the concrete elements in the vicinity of the bedrock/native soil transition(s) to mitigation differential movements. For a precast concrete culvert, the additional reinforcement could be in the form of dowels and/or steel strapping between the box culvert segments. For the precast concrete retaining wall footings, the additional reinforcement (if required) could consist of additional reinforcing steel bars.

6.5 Lateral Earth Pressures

The lateral earth pressures acting on the side walls of the culvert and retaining walls 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.

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

Select, free draining, non-frost susceptible granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' (Type I or II), should be used as backfill for the sub-excavated areas behind the culvert walls and on top of the culvert for a minimum thickness of 300 mm in a similar geometry to that shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

For a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), backfill behind the culvert walls and/or retaining walls should be placed within a zone with the width equal to or greater than the equivalent depth of frost penetration, which for this site is 1.9 m. For an unrestrained wall, the backfill behind the back of the culvert walls and/or retaining walls should be placed within a wedge shaped zone defined by a line drawn flatter than 1H:<1V extending up and back from the base of the culvert/footings (see Figure C6.20(b) of the Commentary to the CHBDC). However, as outlined in Section 6.6.1, temporary excavation side slopes no steeper than 1H:1V above the groundwater level and 3H:1V below the groundwater level will be required in accordance Ontario Regulation 213, Ontario *Occupational Health and Safety Act* (OHSa) for Construction Projects (as amended). Consideration could be given to backfilling the full open-cut excavation area with OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' (Type I or II) in order to satisfy both the backfilling requirements outlined in the Commentary to the CHBDC and the open-cut excavation requirements outlined in the OHSa.

A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culvert and retaining walls, in accordance with CHBDC Section 6.12 and Figure 6.6. All backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting), as amended by SP 105S22. In wet conditions, it is recommended that Granular B Type II be used.

The lateral earth pressures acting against the culvert walls and retaining walls are based on the proposed backfill materials and the following parameters (unfactored) may be used:

Fill Type	Unit Weight (γ , kN/m ³)	Internal Angle of Friction (ϕ , degrees)	Coefficients of Static Lateral Earth Pressure		
			Active, K_a	At-Rest, K_o	Passive, K_p
Granular 'A' (compacted)	22	35°	0.27	0.43	3.69
Granular 'B' (Type I or II) (compacted)	21	35°	0.27	0.43	3.69

If the culvert walls/retaining walls do not allow lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition), at-rest earth pressures (plus any compaction surcharge) should be assumed for geotechnical design.

If the culvert walls/retaining walls allow for lateral yielding, active earth pressures may be used in the geotechnical design of the structure. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.6 of the Commentary to the 2014 CHBDC.

6.6 Construction Considerations

6.6.1 Construction Staging and Temporary Roadway Protection

Temporary excavations for the culvert replacement and retaining wall construction will extend through the existing embankment granular fill, into the native soils, and in some areas extending to/into bedrock. The granular fill and native soils are considered to be Type 3 soil above the groundwater table and Type 4 soil below the groundwater table. 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. Excavations into the bedrock, where required, may be cut vertically or near vertically depending on the degree of weathering. All excavations must be carried out in accordance with Ontario Regulation 213, Ontario OHSA for Construction Projects (as amended).

Based on discussions with GHD, we understand that a temporary roadway protection system is being proposed to facilitate a staged construction approach at this site. The temporary roadway protection system could consist of either driven steel sheet piling or soldier piles and lagging. The installation of sheet-piles for temporary roadway protection could potentially be impeded by the presence of cobbles and/or boulder obstructions and may require pre-drilling through the obstructions and/or the use of a heavier sheet pile section. It is recommended that a Notice to Contractor for Existing Subsurface Conditions be included in the Contract Documents to alert the Contractor to the presence of obstructions. A sample Notice to Contractor is provided in Appendix D. Further, given the shallow depth to bedrock at this site, sheet pile installations would require the drilling/placement of toe-pins to fix the base of the sheeting to the top of the bedrock. Support to the sheet-pile system, if required, could be in the form of struts and wales and rakers or anchors.

Soldier piles and lagging would likely be more suitable to penetrate through the cobble and boulder obstructions but would still require pre-drilling to socket the H-piles into bedrock. Support to the soldier pile and lagging system could also be in the form of struts and wales and rakers or anchors.

Although the contractor is responsible for the selection and complete detail design of the temporary protection roadway system (and temporary support/dewatering systems), the following parameters are provided to enable the structural designer(s) to develop a conceptual design and assess the approximate construction costs for the temporary protection system. As noted in Section 4.2.10, groundwater conditions measured with the four boreholes ranged from Elevation 295.6 m to 296.8 m and the creek water level at the time of the Foundation investigation was measured at Elevation 296.8 m. These groundwater and creek water levels should be considered by the structural designer(s) when determining the appropriate design groundwater elevation for the conceptual design of the temporary protection system.

Soil Type	Unit Weight (γ , kN/m ³)	Internal Angle of Friction (ϕ , degrees)	Undrained Shear Strength (s_u , kPa)	Coefficient of Earth Pressure		
				Active, K_a	At Rest, K_o	Passive, K_p
New Granular 'A' (compacted)	22	35	-	0.27	0.43	3.69
New Granular 'B' (Type I or II) (compacted)	21	35	-	0.27	0.43	3.69
Existing Granular Fill (very loose to compact)	20	32	-	0.31	0.47	3.25
Silt and Sand (very loose to loose)	19	30	-	0.33	0.50	3.00
Gravelly Sand (compact)	20	32	-	0.31	0.47	3.25
Silty Clay (firm)	17	27	30	0.38	0.55	2.66
Silt (loose)	18	28	-	0.36	0.53	2.77
Silty Sand (loose to compact)	19	29	-	0.35	0.52	2.88

Note(s):

1. The temporary shoring design should be assessed for both the drained (ϕ) and undrained (s_u) cases and the design should be based on the more conservative earth pressure conditions.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
3. The total passive resistance below the base of the excavation adjacent to the temporary protection system may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

The temporary protection system(s) shall be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary protection system(s) shall be designed to Performance Level 2 for any excavation adjacent to existing roadway.

The silty clay and silt deposits at this site are potentially sensitive to disturbance and loosening from vibration and/or sheet pile/pile driving operations, which should be considered in the design and installation of the temporary protection systems. A Notice to Contractor for Existing Subgrade Conditions should be included in the Contract Documents to alert the contractor to the potential for subgrade disturbance. A sample Notice to Contractor is included in Appendix D. Additionally, the design of the temporary excavation and roadway support system should include an evaluation of base stability ("base heave" or "soil squeezing" stability) and hydraulic uplift stability, as defined in the CFEM (2006).

Consideration could be given to either partial or full removal of the temporary protection system(s) upon completion of construction, as noted in OPSS.PROV 539. Although there is some potential risk that full removal of the temporary protection system(s) could result in subgrade softening of the silty clay and/or silt deposits and some risk of soil adhesion along the sheet pile (or H-pile) walls (CFEM 2006), which could create a void below the excavation, these risks are considered to be relatively low given the limited thickness/extent of the silty clay and silt deposits.

6.6.2 Control of Groundwater and Surface Water

Temporary excavations along the culvert alignment will be required to remove the existing embankment fill, organic material (where present) and a portion or all of the native soil deposits, and the upper portion of the exposed bedrock (at the north end). Groundwater seepage into the excavation should be expected from the relatively permeable adjacent embankment fill and native soils, as well as from joints/fractures within the bedrock. Therefore, control of groundwater will be necessary to allow for levelling of the bedrock surface (where required), placement of the levelling/bedding and replacement culvert, and construction of the retaining wall footings in dry conditions.

As noted in Section 6.6.1, given the potential presence of cobbles and boulder obstructions along the temporary protection system alignment and the presence bedrock at relatively shallow depth, a sheet pile cofferdam would require the drilling/placement of toe-pins to fix the base of the sheeting to the top of the bedrock. In addition, sandbags or a concrete plug would likely be required to develop a seal between the base of the sheeting and the uneven bedrock surface in order to facilitate unwatering.

As such, consideration could be given to the use of a sandbag or inflatable bladder cofferdam to isolate the excavations from the creek channel and allow unwatering and construction in dry conditions. To minimize groundwater seepage, further consideration may need to be given to sub-excavating the native soils to allow placement of the sandbag or inflatable bladder cofferdam directly on the bedrock surface. Groundwater seepage should still be anticipated between the base of the cofferdam system and the exposed bedrock surface and from fractures within the bedrock. As such, a tremie concrete plug may be required to seal the base of excavation prior to dewatering; however, additional effort would be required by the Contractor to demonstrate that no overburden soils are trapped between the tremie plug and the top of bedrock, which could compromise the geotechnical resistances of the culvert/retaining wall footings.

Depending on the surface water and groundwater conditions at the time of construction, the creek water flow could be passed through the area by means of a temporary by-pass culvert or be diverted by pumping from

behind the temporary dewatering system; however, it should be noted that pumping from within the excavation will likely be required as water flow into the excavation is anticipated to occur from below the base of the system and/or the base of the excavation.

Surface water should be directed away from the excavation areas to prevent ponding of water that could impede culvert/footing construction. Unwatering of all excavations should be carried out in accordance with OPSS 902 (Excavating and Backfilling – Structures), as modified by NSSP FOUN0003 (Dewatering Structure Excavations), a copy of which is included in Appendix D. Given the apparent lack of infrastructure in the vicinity of the culvert, a preconstruction survey is not considered to be required at this site. As such, the foundation designer fill-in in Section 902.04.02.02 of NSSP FOUN0003 should indicate that the preconstruction survey distance is not applicable. Further, considering the generally non-cohesive overburden, the relatively shallow depth to bedrock at this site, and the relatively minor groundwater lowering that is anticipated to be required to facilitate the culvert replacement and retaining wall construction, the risk of settlement impacts to nearby infrastructure (if present) is considered to be low from a Foundation perspective, so long as pumping is carried out from properly filtered sumps/well points. The recommended preconstruction survey distance should, however, be reviewed by a professional hydrogeologist.

Based on the GA drawing provided GHD, we understand that the conceptual dewatering system for this site consists of a sandbag cofferdam, in combination with temporary by-pass pipe to divert the surface/creek water flows, with localized with pumping to facilitate unwatering of the excavations areas within the cofferdam enclosure. Based on subsurface conditions at this site, and the conceptual dewatering system being proposed by GHD, we anticipate that an Environmental Activity Section Registry (EASR) will be required as per the *Environmental Protection Act* by the Ontario Ministry of the Environment, Conservation and Parks (MECP), but given that the surface water flows will be redirected through a temporary by-pass pipe, a permit to take water (PTTW) is not. However, the Contractor should be required to evaluate the estimated seepage and groundwater removal quantity, based on their proposed construction methods/procedures, to make the final assessment/determination whether an EASR or PTTW is ultimately required.

6.6.3 Subgrade Preparation

Prior to placing the levelling pad/bedding layer material and/or precast culvert/retaining wall footings, all existing fill, organic materials (including topsoil, peat, and/or mixed organic soil), and any disturbed/loosened native soils should be sub-excavated from below the plan limits of the proposed works to expose the undisturbed native subgrade soil and/or bedrock within the plan limits of the culvert and/or retaining wall footings.

The subgrade should be inspected following sub-excavation to ensure that all organics (if encountered) and other unsuitable materials have been removed, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) and/or OPSS 902 (Excavating and Backfilling – Structures). Where bedrock is encountered, the exposed bedrock surface should be inspected by a Foundation Engineering Specialist following sub-excavation, to ensure that the rock mass integrity was preserved during excavation and that the bedrock surface is properly cleaned, scaled, and loosened debris removed prior to placing the levelling/bedding materials in accordance with OPSS 902 (Excavating and Backfilling Structures). At this site, the bedrock is classified as strong (bordering very strong) and pre-drilling and hoe ramming techniques alone may not be adequate to break-up the bedrock, depending on the amount of bedrock excavation that is required. It is recommended that a Notice to Contractor be included in the Contract Documents to alert the Contractor of the presence of strong (Grade R4) bedrock at this site. A sample Notice to Contractor for Existing Subsurface Conditions is included in Appendix D. Consideration may need to be given to controlled blasting/excavation techniques, as per OPSS.PROV 120 (Explosives) and

OPSS.PROV 202 (Rock Removal – Manual or Blasting). Pre-shearing, line-drilling, or other specialized techniques may be required to maintain the excavation lines and preserve the integrity of the rock mass along the footprint of the replacement culvert and/or retaining wall footings. The effect of blasting on the existing roadway and temporary protection systems should be considered by the designer and by the blasting contractor.

Following inspection and approval, the sub-excavated area should be backfilled with granular material meeting the requirements of an OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II, that is placed and compacted in accordance with OPSS.PROV 501 (Compacting), as amended by SP 105S22. The use of Granular 'B' Type II fill is recommended in wet conditions or below water.

6.6.4 Bedding

The bedding layer and levelling pad requirements for a precast box culvert should be accordance with OPSS 422 (Pre-cast Reinforced Concrete Box Culverts), with a geometry similar to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts). Where the precast box culvert segments and/or retaining wall footings are founded entirely on bedrock, it is recommended that a minimum 150 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II be used for bedding purposes. Where the precast culvert segments or retaining wall footings are founded on a combination of bedrock and native soil, it is recommended that a minimum 300 mm thick bedding layer be used to mitigate the potential for differential performance. Given the potential presence of groundwater/surface water, we do not recommend that Granular 'B' Type I or III, nor any materials from the Group II list in OPSS 422, be used for bedding purposes. In addition to the recommended bedding layer, the 75 mm thick uncompacted levelling pad to be provided between the bedding layer and the precast culvert/retaining wall footings should consist of OPSS.PROV 1010 (Aggregates) Granular 'A' or fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete).

6.6.5 Backfill

Backfill above/behind the culvert walls and retaining walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' (Type I or II). The use of Granular 'B' Type II is recommended in wet ground conditions or below water. The granular backfill should compacted to at least 98 per cent of the SPMD of the materials, in accordance with OPSS.PROV 501 (Compacting), as amended by SP 105S22.

As the existing granular embankment fill material, which is considered to have a low susceptibility to frost heaving (based on MTO Pavement Design and Rehabilitation Manual, 2013), extends below the estimated 1.9 m depth of frost penetration, a frost taper as per OPSD 803.010 is not required at this site.

6.6.6 Erosion Protection

Provision should be made for scour and erosion protection at the culvert location. Based on the GA drawing provided by GHD, we understand that concrete retaining walls and a concrete cut-off wall are being proposed at the culvert inlet to prevent surface/creek water 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).

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 could 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 base of the retaining wall and/or toe of slope level. We would further suggest that the erosion protection should consist of R-50 Rip Rap or Rock Protection meeting the requirements of OPSS.PROV 1004 (Aggregates – Miscellaneous). The ultimate selection of the erosion protection material is, however, the responsibility of the hydraulics design engineer.

6.6.7 Obstructions

The contractor should be alerted to the presence of cobbles and boulders within the embankment fill, as encountered in Borehole BC-2, and within the native subgrade soils, as encountered in BC-4, which could affect the installation of the temporary roadway protection systems and/or temporary cofferdams (if required). As such, it is recommended that a Notice to Contractor be included in the Contract Documents to alert the Contractor the presence of cobble/boulder obstructions. A sample Notice to Contractor is included in Appendix D. Note that the extent and depth of the cobble and boulder obstructions may vary beyond and between the borehole locations.

6.6.8 Corrosion Assessment and Protection

The results of an analytical test on a soil sample taken from one borehole advanced at the Bear Creek culvert site, are summarized in Section 4.3 and presented in Appendix C. The potential for sulphate attack and corrosion are discussed in the following sub-sections; however, it is ultimately up to the structural designer to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 “Durability Requirements” are followed when designing the concrete elements. The culvert should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Guidelines (2014).

6.6.8.1 Potential for Sulphate Attack

The analytical test results were compared to CSA Standard, CAN/CSA-A23.1-14 Table 3 (“Additional requirements for concrete subjected to sulphate attack”) for potential sulphate attack on concrete. The sulphate concentration measured in the tested sample is less than the reportable detection limit of 0.002 per cent (20 ug/g), which is below the S-3 (Moderate) exposure class and is considered negligible according to Table 7.2 in the MTO Gravity Pipe Guidelines (2014). Therefore, based on the one soil sample tested, when the designer is selecting the exposure class for the structure, the effects of sulphates may not need to be considered.

6.6.8.2 Potential for Corrosion

According to the MTO Gravity Pipe Design Guidelines (2014), a pH <5.5 is considered strongly acidic, while a pH >8.5 is considered strongly alkaline, both of which are indicative of an increased potential for corrosion. The test result from the sample obtained at this site measured a pH of about 6.6 and as such, additional corrosion protection is not anticipated to be required. The resistivity is about 11,000 ohm-cm, which indicates that the soil corrosiveness is less than very low (10,000 > R > 2,000 ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design

Guidelines (2014). However, the culvert and retaining walls will be located within the roadway and adjacent to the roadway shoulders, respectively, and will be exposed to de-icing salt. As such, the concrete should be designed for a “C” type exposure class, as defined by CSA A23.1 Table 1.

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

7.0 CLOSURE

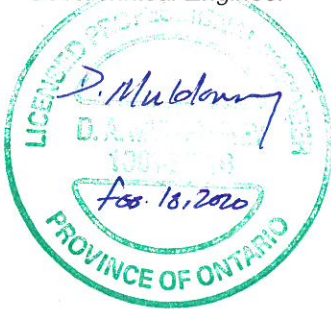
This Foundation Design Report was prepared by Mr. Adam Core, P. Eng., and the technical aspects were reviewed by Mr. David Muldowney, P.Eng. Mr. Jorge M. A. Costa, P.Eng., a Designated MTO Foundations Contact and Senior Consultant for Golder, conducted an independent quality control review and technical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

Signature Page

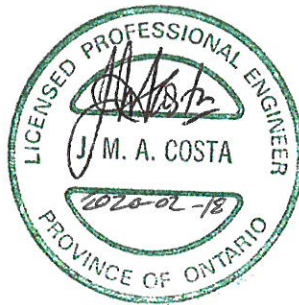
Golder Associates Ltd.



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AC/DAM/JMAC/ca/sm

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https://golderassociates.sharepoint.com/sites/13313g/deliverables/foundations/2_reporting/r01_bear_creek_culvert/3_final/1776446-r01-r-rev0-ghd_bear_creek_hwy_518_fidr_18feb_2020.docx

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- Occupational Health and Safety Act and Regulation, Ontario Regulation 213 for Construction Projects (as amended).
- Unified Facilities Criteria, NAVFAC, 1986. Foundations and Earth Structures Design Manual 7.02.

ASTM International

ASTM D1586	Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils
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Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 120	General Specification for the Use of Explosives
OPSS.PROV 202	Construction Specification for Rock Removal by Manual Scaling, Machine Scaling, Trim Blasting or Controlled Blasting
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 902	Construction Specification for Excavating and Backfilling - Structures
OPSS.PROV 1002	Material Specification for Aggregates - Concrete
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS.PROV 1004	Material Specification for Aggregate – Miscellaneous

Ontario Provincial Standard Drawings (OPSD)

OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario

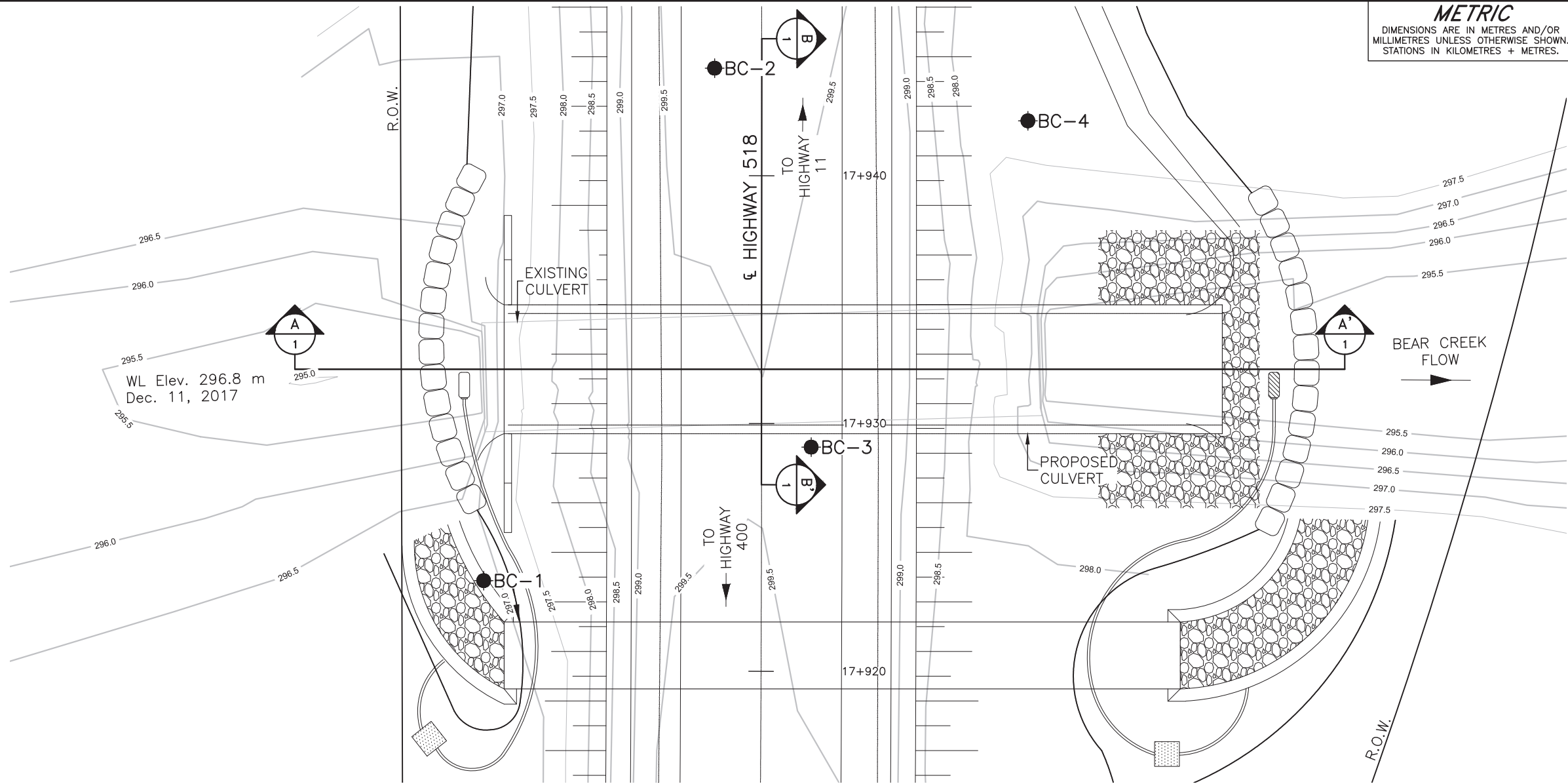
Ontario Water Resource Act

Regulation 903	Wells (as amended)
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Table 1: Comparison of Alternative Culvert Replacement Types

Option	Advantages	Disadvantages	Risks/Consequences
Circular/ Arch CSP	<ul style="list-style-type: none"> Potentially minimizes depth of excavation, protection system, and dewatering requirements compared to open footing option (unless footings are constructed on bedrock). Allows faster construction resulting in shorter duration for dewatering and surface water pumping. Most tolerant of total and differential settlements. Backfill under the culvert may be placed in wet conditions (i.e., for Granular 'B' Type II material) potentially reducing dewatering and 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 or a larger arch. Does not accommodate variations in bedrock elevation and would require additional excavation (or blasting) quantities to accommodate a larger footprint. Excavation quantities could be quite minimal if a like-for-like replacement strategy is adopted. Difficult to compact backfill materials to level of culvert springline if not done in dry conditions. CSP has a shorter design life compared to concrete options; however, asphalt coatings or polymer linings can be incorporated to increase design life (but also at increasing cost). 	<ul style="list-style-type: none"> Moderate risk of dewatering issues to allow construction in-the-dry to facilitate proper placement and compaction of the backfill below the culvert springline. Can be completed in wet conditions if bedding is comprised of Granular 'B' Type II material. Higher risk of additional bedrock excavations, due to the larger foundation footprint (if required). CSP culverts have a lower risk of poor performance related to total and differential settlements compared to concrete culvert options.
Open Footing Culvert	<ul style="list-style-type: none"> Cast-in-place construction can more readily accommodate variations in bedrock surface. Reduced bedrock excavation (or blasting) quantities compared to CSP and box culvert options due to the smaller foundation footprint. 	<ul style="list-style-type: none"> Excavation depths are greater than for box or CSP (pipe or arch) culvert options, resulting in increased excavation support and dewatering requirements and additional spoil material to be disposed off-site. Longer anticipated schedule for construction; however, precast footings and/or open box 	<ul style="list-style-type: none"> Higher risk of dewatering issues to allow for construction in dry conditions. Lowest risk of additional bedrock excavations, due to small foundation footprint and ability to accommodate variations in bedrock elevation.

Option	Advantages	Disadvantages	Risks/Consequences
	<ul style="list-style-type: none"> Allows for greater flow volume than circular/arch CSP with similar span. Concrete culverts have a longer design life compared to CSP options. 	<p>segments can be used to expedite the schedule.</p> <ul style="list-style-type: none"> Transportation to and on-site lifting of large precast sections (if adopted) will be required. Less tolerant of differential movement related to frost heave, unless constructed on bedrock. 	<ul style="list-style-type: none"> Less tolerant of total and differential settlement but risk is negligible if footings are placed directly on bedrock. Culvert joints and/or additional reinforcement may be required to accommodate the anticipated total and differential settlement if placed on a combination of bedrock and native soil.
Pre-Cast Box Culvert	<ul style="list-style-type: none"> Minimizes depth of excavation, protection system and dewatering requirements compared to open footing option. Allows faster construction resulting in shorter duration for dewatering and surface water pumping. More tolerant of total and differential settlement compared to an open-footing culvert. Backfill under the culvert may be placed in wet conditions (i.e., for Granular 'B' Type II materials) potentially reducing dewatering and water pumping requirements. Allows for greater flow volume than circular/arch CSP with similar span. Concrete culverts have a longer design life compared to CSP options. 	<ul style="list-style-type: none"> Does not accommodate variations in bedrock elevation and may require additional bedrock excavation (or blasting) quantities, due to the larger foundation footprint. Transportation to and on-site lifting of large pre-cast sections will be required. 	<ul style="list-style-type: none"> Lower risk of dewatering issues as backfill can be placed in wet conditions and does not require as much effort to shape/compact the bedding compared to a CSP option. Higher risk of additional bedrock excavations due to the larger foundation footprint. Low risk related to settlement performance as box segments can accommodate some total and differential settlement; however, additional reinforcement (i.e., dowels and/or strapping) may be required if the culvert is founded on a combination of bedrock and native soil.

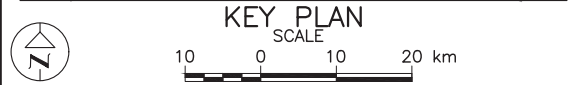
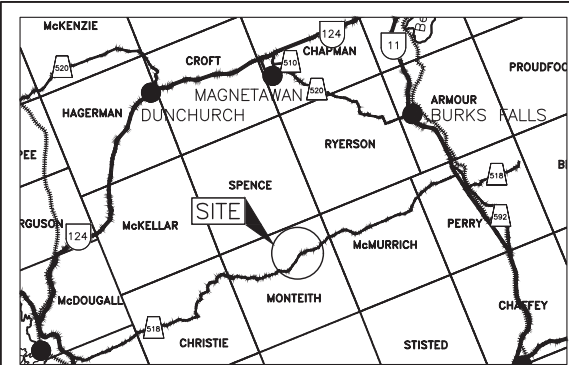


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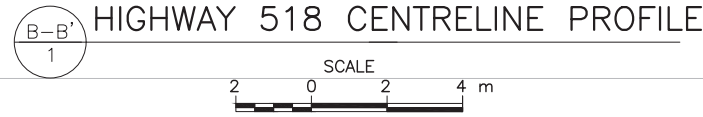
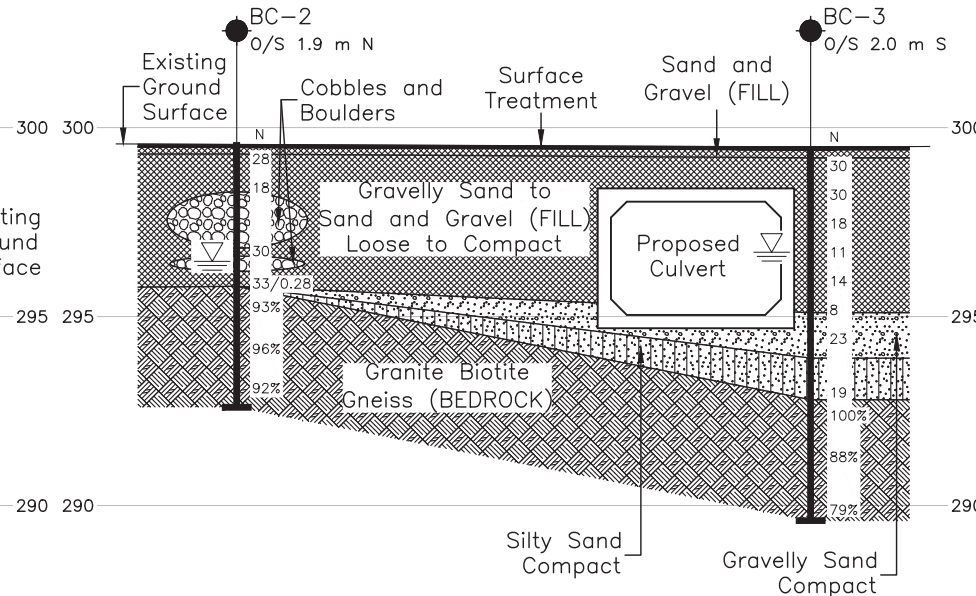
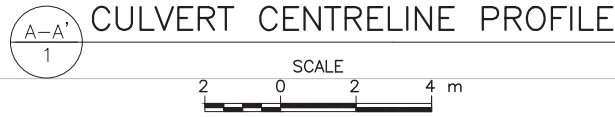
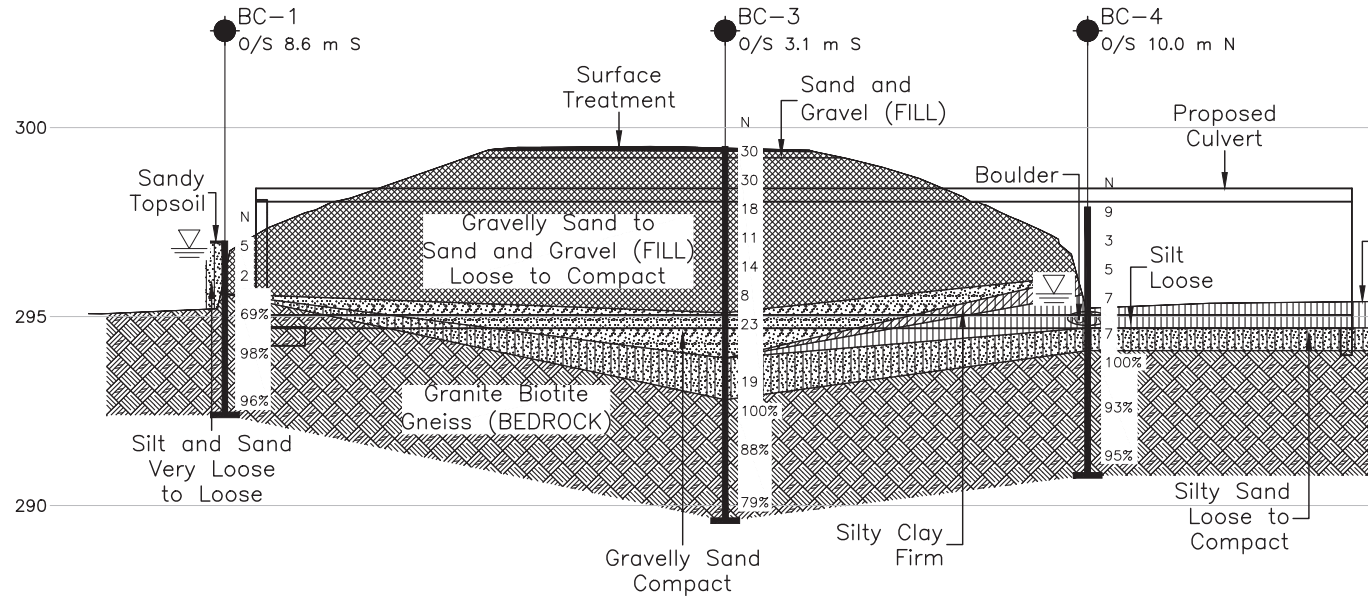
CONT No.
WP No. 5202-13-01

HIGHWAY 518
BEAR CREEK CULVERT
STA. 17+932 MONTEITH TOWNSHIP
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
BC-1	297.0	5032757.9	295322.6
BC-2	299.6	5032765.4	295344.0
BC-3	299.5	5032752.1	295335.7
BC-4	297.9	5032754.8	295351.2



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.

REFERENCE

Base plans provided in digital format by GHD, drawing file No. E10865181.dwg, received APRIL 17, 2018 and drawing file No. 44-209-C-HWY 518 - Ret Wall on N end.dwg, received AUGUST 22, 2019

NO.	DATE	BY	REVISION
1	2/12/2020	JMAC	ISSUED FOR CONSTRUCTION
Geocres No. 31E-402			
HWY. 518	PROJECT NO. 1776446	DIST.	
SUBM'D.	CHKD. AC	DATE: 2/12/2020	SITE: 44X-0209/CO
DRAWN: TR	CHKD. DAM	APPD. JMAC	DWG. 1



Photograph 1: Highway 518 at Bear Creek Culvert, Facing West (December 2017)



Photograph 2: Highway 518 at Bear Creek Culvert, Facing East (December 2017)



Photograph 3: Bear Creek at Culvert Inlet, Facing North (December 2017)



Photograph 4: Culvert Outlet, Facing North (December 2017)

APPENDIX A

Record of Boreholes and Drillholes

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

$\tau = c' + \sigma' \tan \phi'$
shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
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

Compactness	N
Condition	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

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing</u>
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT 1776446		RECORD OF BOREHOLE No BC-1				1 OF 2 METRIC								
W.P. 5202-13-01		LOCATION N 5032757.9; E 295322.6 NAD83 MTM ZONE 10 (LAT. 45.434699; LONG. -79.621135)				ORIGINATED BY MR								
DIST HWY 518		BOREHOLE TYPE NW Casing and NQ Coring				COMPILED BY AC								
DATUM GEODETIC		DATE December 11, 2017 and February 8, 2018				CHECKED BY DAM								
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						
297.0	GROUND SURFACE													
0.9	Sandy TOPSOIL (50 mm) Frozen		1	SS	5									
	SILT and SAND, trace to some gravel, trace to some clay, trace organics Very loose to loose Brown to grey Moist to wet		2	SS	2									
295.6	Split-spoon refusal (i.e. hammer bouncing) at 1.3 m depth. GRANITE BIOTITE GNEISS (BEDROCK)		1	RC	REC 100%									
1.4	Bedrock cored from 1.4 m depth to 4.6 m depth. For coring details see Record of Drillhole BC-1.		2	RC	REC 100%									
			3	RC	REC 100%									
292.4	END OF BOREHOLE													
4.6	Notes: 1. Water level at a depth of 0.2 m below ground surface (Elev. 296.8 m) upon completion of drilling. 2. Three DCPTs advanced 1 m north (shown above), 1 m southwest (shown above), and 1 m east (not shown) of Borehole BC-1. DCPT refusal (i.e. cone bouncing) encountered at depths of 1.32 m, 1.30 m, and 1.27 m, respectively. 3. Bedrock coring completed February 8, 2018 utilizing a Hilti core drill in a separate borehole advanced 0.3 m west of Borehole BC-1.													

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INCLINATION: -90° AZIMUTH: —

DRILLING CONTRACTOR: Landcore Drilling

DATUM: GEODETIC

1 : 60



CHECKED: DAM

SUD-MTO-RCK S:\CLIENTS\MTO\HWY 124 400 518\02 DATA\GIN\1776446.GPJ GAL-MISS.GDT 11-29-19 TB

PROJECT <u>1776446</u>		RECORD OF BOREHOLE No BC-2				1 OF 2 METRIC											
W.P. <u>5202-13-01</u>		LOCATION <u>N 5032765.4; E 295344.0 NAD83 MTM ZONE 10 (LAT. 45.434767; LONG. -79.620862)</u>				ORIGINATED BY <u>SA</u>											
DIST <u> </u> HWY <u>518</u>		BOREHOLE TYPE <u>NW Casing and NQ Coring</u>				COMPILED BY <u>AC</u>											
DATUM <u>GEODETIC</u>		DATE <u>December 5, 2017</u>				CHECKED BY <u>DAM</u>											
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									
299.6	GROUND SURFACE																
0.0	SURFACE TREATMENT (15 mm)																
299.3	Sand and gravel, trace silt (FILL)		1	SS	28												
0.3	Brown Moist																
	Gravelly sand, trace to some silt (FILL)																
	Compact		2	SS	18												
	Brown to grey																
	Moist to wet																
	Split-spoon refusal (i.e. hammer bouncing) at 1.3 m depth. Switched to NQ Coring.		-	RC	REC 41%												
	Cobbles and boulders encountered as follows:																
	Depth (m) Diameter (mm)																
	1.3 200		3	SS	30												
	1.6 175																
	3.0 400																
			-	RC	REC 100%												
295.8	GRANITE BIOTITE GNEISS (BEDROCK)		4	SS	33/0.28												
3.8	Bedrock cored from 3.8 m depth to 7.0 m depth.																
	For coring details see Record of Drillhole BC-2.																
			1	RC	REC 100%												RQD = 93%
			2	RC	REC 100%												RQD = 96%
			3	RC	REC 100%												RQD = 92%
292.6	END OF BOREHOLE																
7.0	Note: 1. Water level at a depth of 3.3 m below ground surface (Elev. 296.3 m) upon completion of coring.																

PROJECT: 1776446

LOCATION: N 5032765.4; E 295344.0

NAD83 MTM ZONE 10 (LAT. 45.434767; LONG. -79.620862)

INCLINATION: -90° AZIMUTH: —

RECORD OF DRILLHOLE: BC-2

SHEET 2 OF 2

DRILLING DATE: December 5, 2017

DATUM: GEODETIC

DRILL RIG: CME 55

DRILLING CONTRACTOR: Landcore Drilling

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	RECOVERY		R.Q.D. %	FRACT INDEX METRES	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q AVG					
								FLUSH	TOTAL CORE %			SOLID CORE %	TYPE AND SURFACE DESCRIPTION	Jr	Ja				Jn				
																				JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break
4	NW	BEDROCK SURFACE		295.8																			
		GRANITE BIOTITE GNEISS		3.8																			
		Fresh																					
		Fine to medium grained																					
		Strongly foliated																					
		Strong																					
		Dark grey to black to pink																					
5																							
	CME 55																						
	NQ Coring																						
6																							
7		- Broken rock below 6.9 m depth		292.6																			
		END OF DRILLHOLE		7.0																			
8																							
9																							
10																							
11																							
12																							
13																							
14																							
15																							

DEPTH SCALE

1 : 60

**GOLDER**

LOGGED: SA

CHECKED: DAM

SUD-MTO-RCK S:\CLIENTS\IMTOHWY_124_400_518\02_DATA\GINT\1776446.GPJ GAL-MISS.GDT 11-29-19 TB

PROJECT 1776446		RECORD OF BOREHOLE No BC-3				1 OF 2 METRIC														
W.P. 5202-13-01		LOCATION N 5032752.1; E 295335.7 NAD83 MTM ZONE 10 (LAT. 45.434647; LONG. -79.620968)				ORIGINATED BY SA														
DIST _____ HWY 518		BOREHOLE TYPE NW Casing and NQ Coring				COMPILED BY AC														
DATUM GEODETIC		DATE December 5, 2017				CHECKED BY DAM														
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										WATER CONTENT (%)		
								20	40	60	80	100						20	40	60
299.5	GROUND SURFACE																			
0.0	SURFACE TREATMENT (20 mm)																			
299.2	Sand and gravel, trace silt (FILL)		1	SS	30															
0.3	Brown to grey Moist																			
	Sand and gravel, trace to some silt (FILL)		2	SS	30															
	Loose to compact Brown to grey Moist to wet																			
			3	SS	18															
			4	SS	11															
			5	SS	14															
			6	SS	8															
295.0																				
4.5	Gravelly SAND, trace to some silt Compact Grey Wet		7	SS	23															
293.9	SILTY SAND, trace gravel Compact Brown to grey Wet		8	SS	19															
292.8	GRANITE BIOTITE GNEISS (BEDROCK)		1	RC	REC 100%															
	Bedrock cored from 6.7 m depth to 9.9 m depth.																			
	For coring details see Record of Drillhole BC-3.		2	RC	REC 100%															
			3	RC	REC 100%															
289.6	END OF BOREHOLE																			
9.9	Note: 1. Water level at a depth of 2.8 m below ground surface (Elev. 296.7 m) upon completion of coring.																			

SUD-MTO 001 S:\CLIENTS\MT\Hwy_124_400_518\02_DATA\GINT\1776446.GPJ GAL-MISS.GDT 12-3-19 TB

PROJECT: 1776446

LOCATION: N 5032752.1; E 295335.7

NAD83 MTM ZONE 10 (LAT. 45.434647; LONG. -79.620968)

INCLINATION: -90° AZIMUTH: —

RECORD OF DRILLHOLE: BC-3

SHEET 2 OF 2

DRILLING DATE: December 5, 2017

DATUM: GEODETIC

DRILL RIG: CME 55

DRILLING CONTRACTOR: Landcore Drilling

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR- Shear VN - Vein CJ - Conjugate BD- Bedding FO- Foliation CO- Contact OR- Orthogonal CL - Cleavage PL - Planar CU- Curved UN - Undulating ST - Stepped IR - Irregular PO- Polished K - Slickensided SM- Smooth Ro - Rough MB- Mechanical Break BR - Broken Rock <div>NOTE: For additional abbreviations refer to list of abbreviations & symbols.</div>										DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY				Diametral Point Load Index (MPa)	RMC -Q AVG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
								FLUSH	RECOVERY		R.Q.D. %	FRACT. INDEX METRES	B Angle	DIP w.r.t CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	k ₁ cm/s	k ₂ cm/s	k ₃ cm/s	k ₄ cm/s																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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7	CME 55 NQ Coring	BEDROCK SURFACE		292.8																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													</

DEPTH SCALE

1 : 60


GOLDER

LOGGED: SA

CHECKED: DAM

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PROJECT 1776446		RECORD OF BOREHOLE No BC-4				1 OF 2 METRIC											
W.P. 5202-13-01		LOCATION N 5032754.8; E 295351.2 NAD83 MTM ZONE 10 (LAT. 45.434671; LONG. -79.620769)				ORIGINATED BY SA											
DIST HWY 518		BOREHOLE TYPE NW Casing and NQ Coring				COMPILED BY AC											
DATUM GEODETIC		DATE December 4, 2017				CHECKED BY DAM											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL
								20 40 60 80 100	20 40 60 80 100	20 40 60	W _p W W _L	20 40 60					
297.9	GROUND SURFACE																
0.9	TOPSOIL (50 mm)		1	SS	9												
	Gravelly sand to sand and gravel, trace to some silt, trace organics (FILL) Very loose to compact Brown Moist		2	SS	3												
296.4																	
1.5	SILTY CLAY, trace to some sand, trace gravel Firm Brown to grey Wet		3	SS	5												
295.7																	
2.2	Poor recovery in Sample No. 5 SILT, trace sand, trace to some clay Loose Brown to grey Wet		4	SS	7												
295.0																	
2.9	SILTY SAND, trace gravel Loose Brown Wet		-	RC	REC 100%												
			5	SS	7												
294.1																	
3.8	A 300 mm boulder was encountered at 2.9 m depth. GRANITE BIOTITE GNEISS (BEDROCK) Bedrock cored from 3.8 m depth to 7.1 m depth. For coring details see Record of Drillhole BC-4.		1	RC	REC 100%												
			2	RC	REC 100%												
			3	RC	REC 100%												
290.8	END OF BOREHOLE																
7.1	Note: 1. Water level at a depth of 2.3 m below ground surface (Elev. 295.6 m) upon completion of coring.																

SUD-MTO 001 S:\CLIENTS\MT\TOHWY_124_400_518\02_DATA\GINT\1776446.GPJ GAL-MISS.GDT 12-3-19 TB

SHEET 2 OF 2

DATUM: GEODETIC

DRILL RIG: CME 55

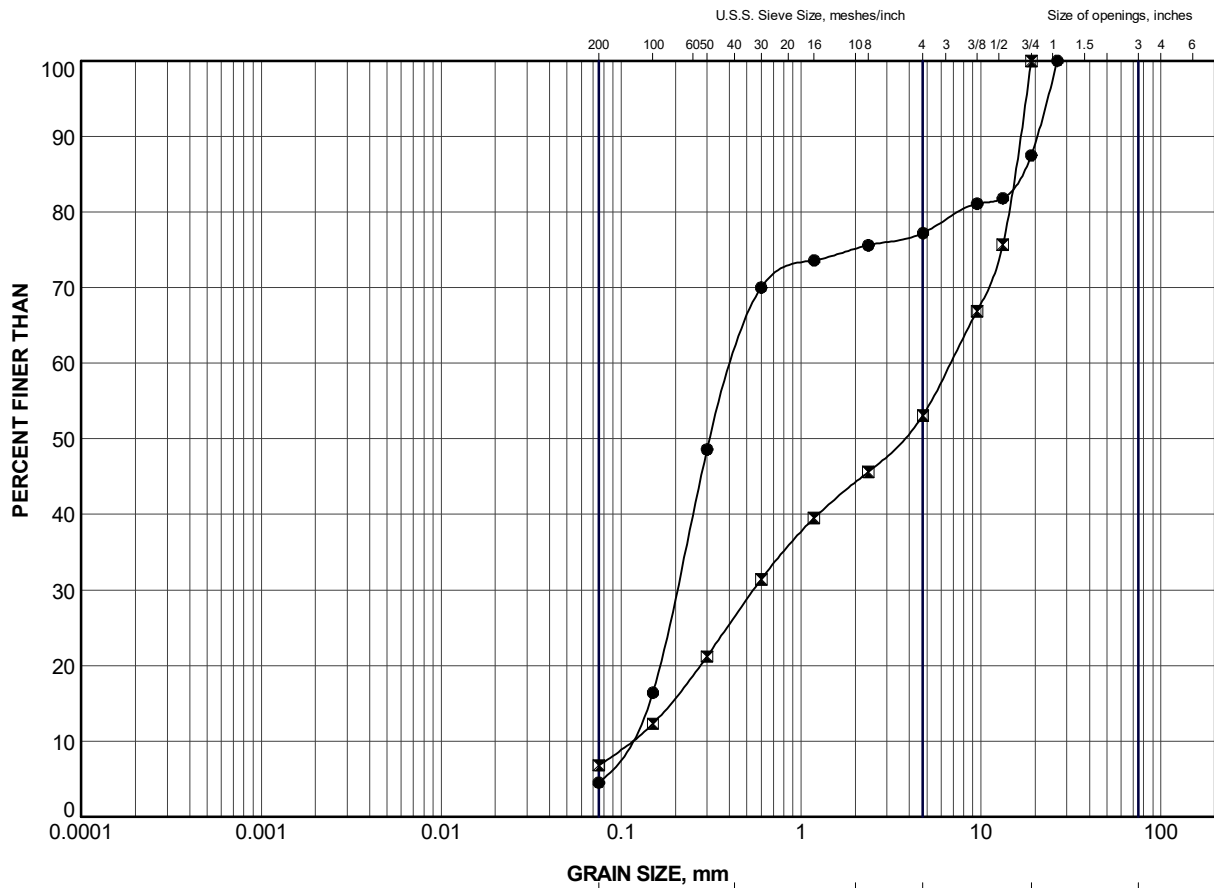
DRILLING CONTRACTOR: Landcore Drilling

CHECKED: DAM

SUD-MTO-RCK S:\CLIENTS\MTO\HWY 124 400 518\02 DATA\GIN\1776446.GPJ GAL-MISS.GDT 11-29-19 TB

APPENDIX B

Geotechnical Laboratory Test Results

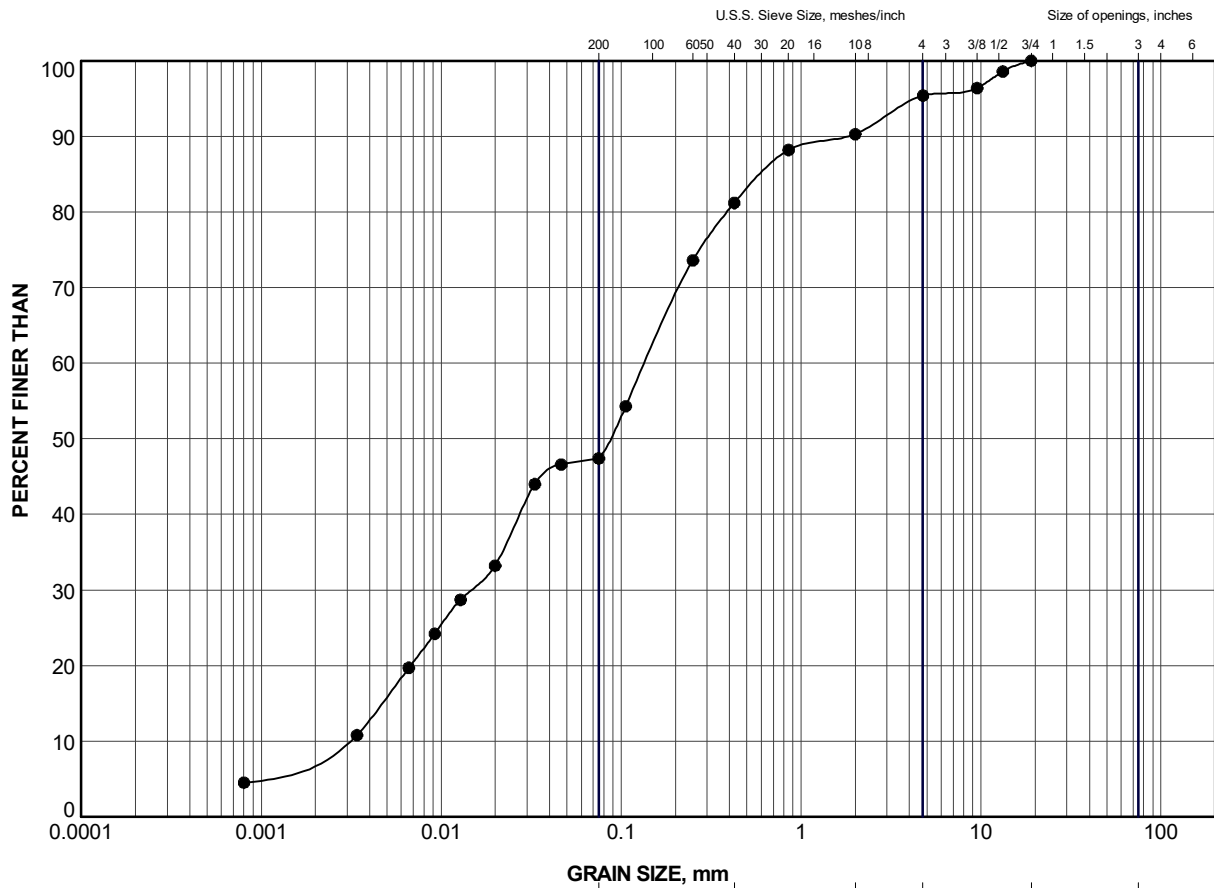


CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BC-2	2	298.6
×	BC-3	3	297.7

PROJECT					
HIGHWAY 518 BEAR CREEK CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION Gravelly Sand to Sand and Gravel (FILL)					
PROJECT No.		1776446		FILE No. 1776446.GPJ	
DRAWN	TR	Nov 2019	SCALE	N/A	REV.
CHECK	DAM	Nov 2019			
APPR	JMAC	Nov 2019			
GOLDER SUDBURY, ONTARIO			FIGURE B-1		



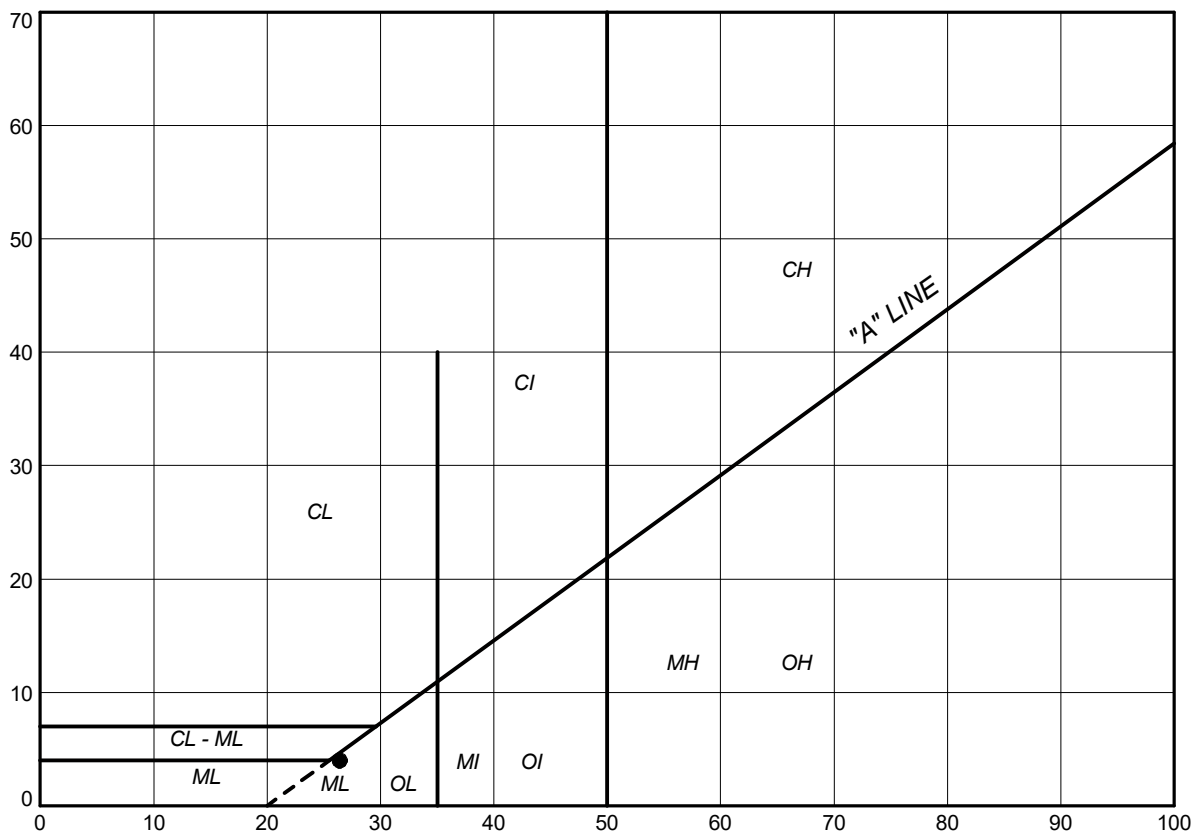
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BC-1	2	295.9

PROJECT					
HIGHWAY 518 BEAR CREEK CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION Silt and Sand					
PROJECT No. 1776446			FILE No. 1776446.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.
CHECK	DAM	Nov 2019			
APPR	JMAC	Nov 2019			
GOLDER SUDBURY, ONTARIO			FIGURE B-2A		

PLASTICITY INDEX (Percent)



LIQUID LIMIT (Percent)

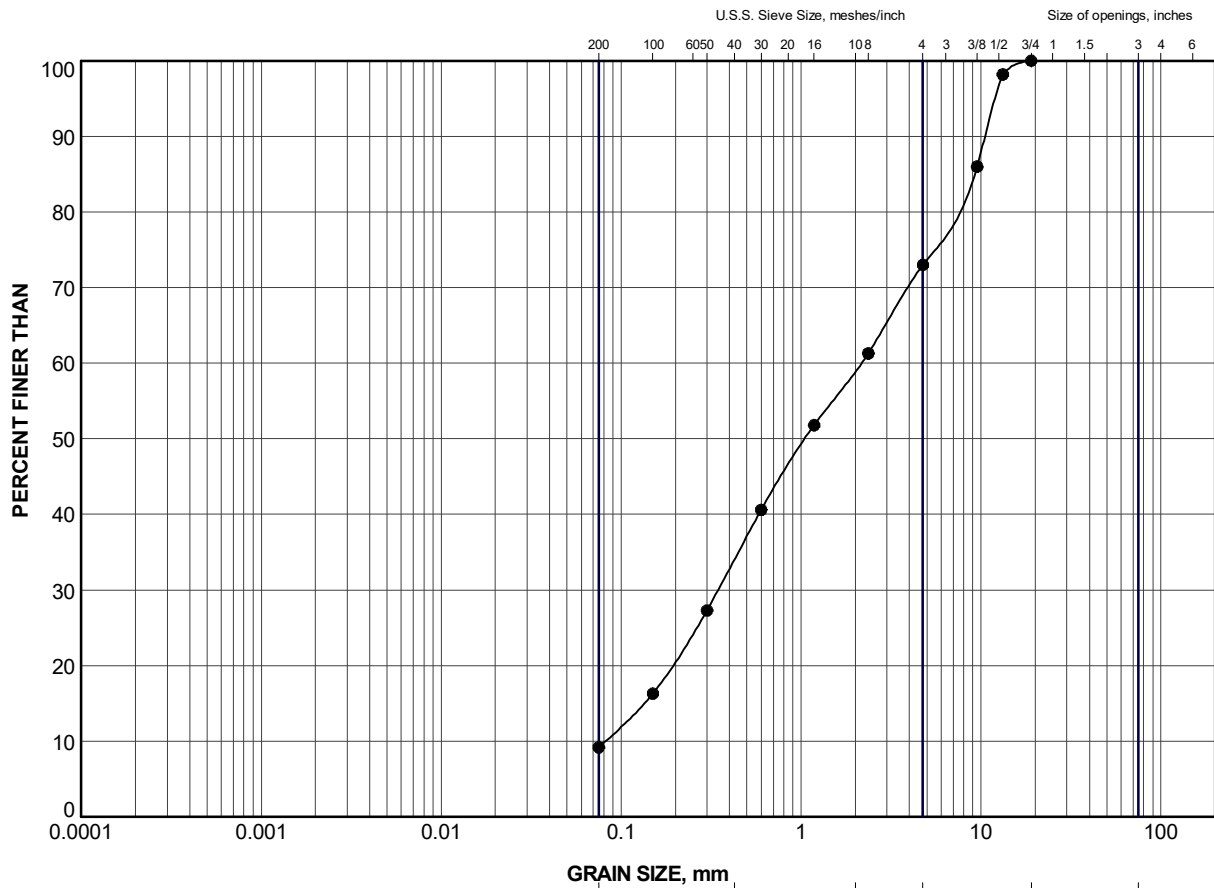
SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BC-1	1	26.4	22.4	4.0

PROJECT					
HIGHWAY 518 BEAR CREEK CULVERT					
TITLE					
PLASTICITY CHART Silt and Sand					
PROJECT No. 1776446			FILE No. 1776446.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.
CHECK	DAM	Nov 2019	FIGURE B-2B		
APPR	JMAC	Nov 2019			
SUDBURY, ONTARIO					

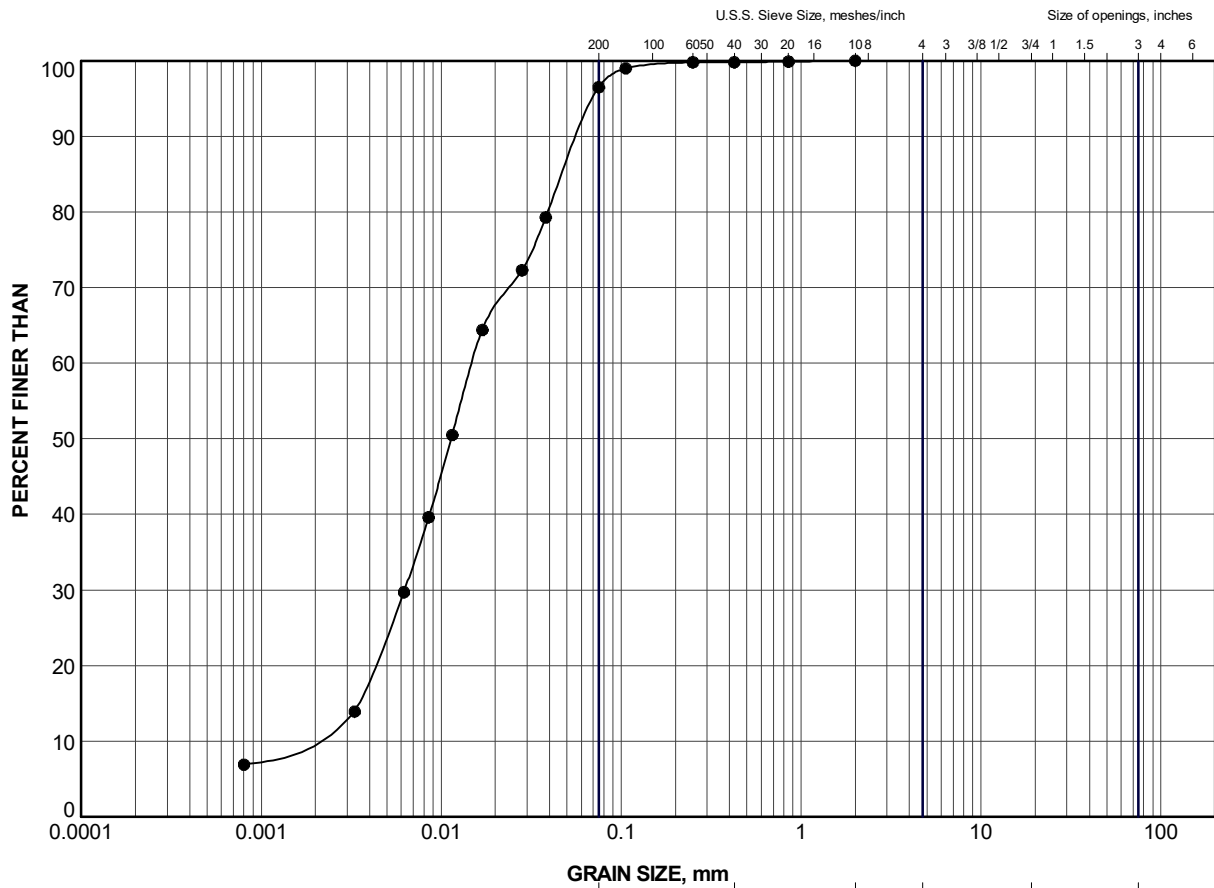


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BC-3	7	294.6

PROJECT					
HIGHWAY 518 BEAR CREEK CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION Gravelly Sand					
PROJECT No. 1776446			FILE No. 1776446.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.
CHECK	DAM	Nov 2019	FIGURE B-3		
APPR	JMAC	Nov 2019			
SUDBURY, ONTARIO					

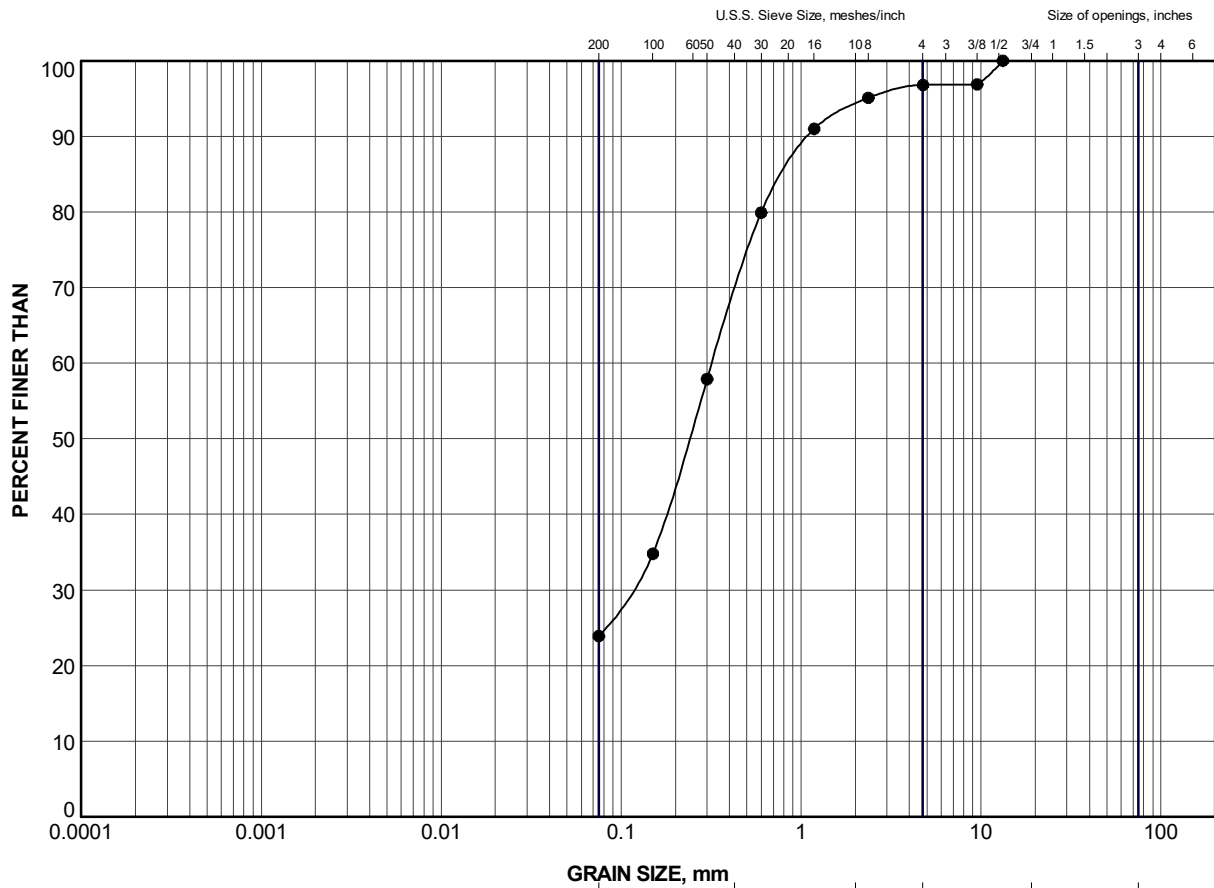


GRAVEL SIZE, mm							Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BC-4	4	295.3

PROJECT					
HIGHWAY 518 BEAR CREEK CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION Silt					
PROJECT No. 1776446			FILE No. 1776446.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.
CHECK	DAM	Nov 2019			
APPR	JMAC	Nov 2019			
GOLDER SUDBURY, ONTARIO			FIGURE B-4		



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

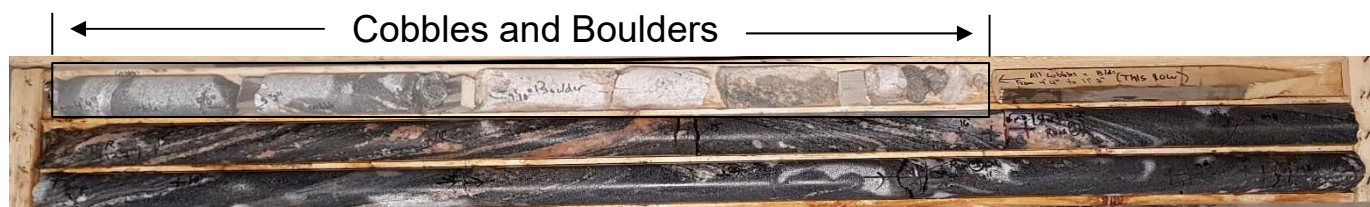
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BC-4	5	294.6

PROJECT					
HIGHWAY 518 BEAR CREEK CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION Silty Sand					
PROJECT No. 1776446			FILE No. 1776446.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.
CHECK	DAM	Nov 2019	FIGURE B-5		
APPR	JMAC	Nov 2019			
SUDBURY, ONTARIO					



Borehole BC-1: Elevation 295.6 m to 292.4 m



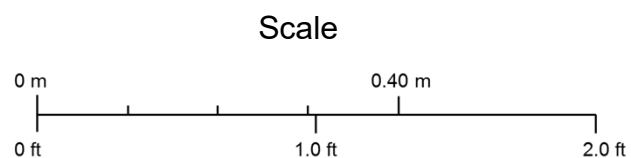
Borehole BC-2: Elevation 295.8 m to 292.6 m




Borehole BC-3: Elevation 292.8 m to 289.6 m



Borehole BC-4: Elevation 294.1 m to 290.8 m



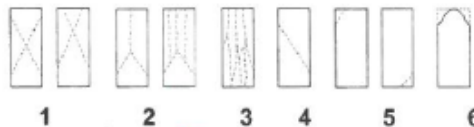
PROJECT		HIGHWAY 518 BEAR CREEK CULVERT			
TITLE		BEDROCK CORE PHOTOGRAPHS			
	PROJECT No. 1776446			FILE No.	
	DESIGN	AC	Dec. 19	SCALE	As Shown
	CADD	--		FIGURE B-6	
	CHECK	DAM	Dec. 19		
	REVIEW	JMAC	Dec. 19		

SUMMARY OF ROCK CORE TEST DATA

PROJECT NO.: 1776446/2300
 PROJECT NAME: MTO/5016-E-0037/Hwys 124,400,518
 TYPE OF UNIT: Rock Core
 TESTED BY: JM
 DATE TESTED: April 20, 2018

GOLDER LAB NUMBER	S276				
BOREHOLE NUMBER:	BC-2				
SAMPLE NUMBER:	N/A				
DEPTH OF TESTED CORE (ft)	15'1/4"-15' 4 2/3"				
LENGTH AS CUT (mm)	99.0				
DIAMETER (mm)	47.7				
DENSITY (kg/m3)	2718				
COMPRESSIVE STRENGTH (KN)	173.4				
CORRECTED STRENGTH (MPa)	97.2				
TYPE OF FRACTURE	3				

Type of Fracture



COMMENTS:

PROJECT

**HIGHWAY 518
BEAR CREEK CULVERT**

TITLE

Summary of Rock Core Test Data



PROJECT No. 1776446

FILE No.

DESIGN AC Dec. 19

SCALE As Shown VER. 1.

CADD --

CHECK DAM Dec. 19

REVIEW JMAC Dec. 19

FIGURE B-7

APPENDIX C

Analytical Laboratory Test Results

Your Project #: 1776446 T2200/MTP/GHD HWY124/5
Site Location: HWY 124 HARRIS CREEK
Your C.O.C. #: 641586-01-01

Attention: David Muldowney

Golder Associates Ltd
33 Mackenzie Street
Suite 100
Sudbury, ON
Canada P3C 4Y1

Report Date: 2018/01/03
Report #: R4927509
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B755485

Received: 2017/12/15, 14:01

Sample Matrix: Soil
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	3	N/A	2017/12/27	CAM SOP-00463	EPA 325.2 m
Conductivity	3	N/A	2017/12/27	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl ₂ EXTRACT	3	2017/12/28	2017/12/28	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	3	2017/12/20	2017/12/27	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	3	N/A	2017/12/27	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

Your Project #: 1776446 T2200/MTP/GHD HWY124/5
Site Location: HWY 124 HARRIS CREEK
Your C.O.C. #: 641586-01-01

Attention: David Muldowney

Golder Associates Ltd
33 Mackenzie Street
Suite 100
Sudbury, ON
Canada P3C 4Y1

Report Date: 2018/01/03
Report #: R4927509
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B7S5485

Received: 2017/12/15, 14:01

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Fatemeh Habibagahi, Project Manager Assistant
Email: FHabibagahi@maxxam.ca
Phone# (905) 817-5700

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

RESULTS OF ANALYSES OF SOIL

Maxxam ID		FTW859	FUN106	FUN107		
Sampling Date		2017/12/14 13:00	2017/12/05 12:00	2017/12/07 13:30		
COC Number		641586-01-01	641586-01-01	641586-01-01		
	UNITS	HC-1(HARRIS CREEK CULVERT HWY 121)	BC-3(BEWR CREEK HWY 518)	C27-2(CULVERT27 HWY124)	RDL	QC Batch
Calculated Parameters						
Resistivity	ohm-cm	5100	11000	2300		5325054
Inorganics						
Soluble (20:1) Chloride (Cl)	ug/g	56	35	210	20	5329429
Conductivity	umho/cm	197	91	444	2	5330818
Available (CaCl2) pH	pH	7.44	6.59	6.66		5333167
Soluble (20:1) Sulphate (SO4)	ug/g	ND	ND	ND	20	5329488
RDL = Reportable Detection Limit QC Batch = Quality Control Batch ND = Not detected						

Maxxam ID		FUN107		
Sampling Date		2017/12/07 13:30		
COC Number		641586-01-01		
	UNITS	C27-2(CULVERT27 HWY124) Lab-Dup	RDL	QC Batch
Inorganics				
Available (CaCl2) pH	pH	6.71		5333167
Soluble (20:1) Sulphate (SO4)	ug/g	ND	20	5329488
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate ND = Not detected				

TEST SUMMARY

Maxxam ID: FTW859
Sample ID: HC-1(HARRIS CREEK CULVERT HWY 121)
Matrix: Soil

Collected: 2017/12/14
Shipped:
Received: 2017/12/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5329429	N/A	2017/12/27	Deonarine Ramnarine
Conductivity	AT	5330818	N/A	2017/12/27	Tahir Anwar
pH CaCl2 EXTRACT	AT	5333167	2017/12/28	2017/12/28	Tahir Anwar
Resistivity of Soil		5325054	2017/12/27	2017/12/27	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5329488	N/A	2017/12/27	Deonarine Ramnarine

Maxxam ID: FUN106
Sample ID: BC-3(BEWR CREEK HWY 518)
Matrix: Soil

Collected: 2017/12/05
Shipped:
Received: 2017/12/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5329429	N/A	2017/12/27	Deonarine Ramnarine
Conductivity	AT	5330818	N/A	2017/12/27	Tahir Anwar
pH CaCl2 EXTRACT	AT	5333167	2017/12/28	2017/12/28	Tahir Anwar
Resistivity of Soil		5325054	2017/12/27	2017/12/27	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5329488	N/A	2017/12/27	Deonarine Ramnarine

Maxxam ID: FUN107
Sample ID: C27-2(CULVERT27 HWY124)
Matrix: Soil

Collected: 2017/12/07
Shipped:
Received: 2017/12/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5329429	N/A	2017/12/27	Deonarine Ramnarine
Conductivity	AT	5330818	N/A	2017/12/27	Tahir Anwar
pH CaCl2 EXTRACT	AT	5333167	2017/12/28	2017/12/28	Tahir Anwar
Resistivity of Soil		5325054	2017/12/27	2017/12/27	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5329488	N/A	2017/12/27	Deonarine Ramnarine

Maxxam ID: FUN107 Dup
Sample ID: C27-2(CULVERT27 HWY124)
Matrix: Soil

Collected: 2017/12/07
Shipped:
Received: 2017/12/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
pH CaCl2 EXTRACT	AT	5333167	2017/12/28	2017/12/28	Tahir Anwar
Sulphate (20:1 Extract)	KONE/EC	5329488	N/A	2017/12/27	Deonarine Ramnarine

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	6.0°C
Package 2	7.0°C

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1776446 T2200/MTP/GHD HWY124/5
Site Location: HWY 124 HARRIS CREEK
Sampler Initials: SA

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5329429	Soluble (20:1) Chloride (Cl)	2017/12/27	116	70 - 130	104	70 - 130	ND, RDL=20	ug/g	NC	35
5329488	Soluble (20:1) Sulphate (SO4)	2017/12/27	115	70 - 130	110	70 - 130	ND, RDL=20	ug/g	NC	35
5330818	Conductivity	2017/12/27			100	90 - 110	ND,RDL=2	umho/cm	0.40	10
5333167	Available (CaCl2) pH	2017/12/28			100	97 - 103			0.70	N/A

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

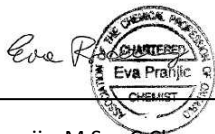
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference $\leq 2 \times \text{RDL}$).

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Ewa Pranjić, M.Sc., C.Chem, Scientific Specialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



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CHAIN OF CUSTODY RECORD

Page of

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name: #7575 Golder Associates Ltd		Company Name:		Quotation #: B70916		Maxxam Job #:	
Attention: David Muldowney		Attention:		P.O. #:		Bottle Order #:	
Address: 33 Mackenzie Street Suite 100		Address:		Project: 1776446 P2200		COC #:	
Sudbury ON P3C 4Y1		Address:		Project Name: MTO/GHD Hwy 124/518		Project Manager:	
Tel: (705) 524-6861 x		Tel:		Site #: Hwy 124 Harris Creek		Alison Cameron	
Fax: (705) 524-1984 x		Fax:		Sampled By: S Albert		C#641586-01-01	
Email:		Email:					

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011)		Other Regulations		Special Instructions
<input type="checkbox"/> Table 1	<input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine	<input type="checkbox"/> CCME	<input type="checkbox"/> Sanitary Sewer Bylaw	
<input type="checkbox"/> Table 2	<input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse	<input type="checkbox"/> Reg 558	<input type="checkbox"/> Storm Sewer Bylaw	
<input type="checkbox"/> Table 3	<input type="checkbox"/> Agri/Other <input type="checkbox"/> For RSC	<input type="checkbox"/> MISA	Municipality	
<input type="checkbox"/> Table		<input type="checkbox"/> PWQO		
		<input type="checkbox"/> Other		

Include Criteria on Certificate of Analysis (Y/N)?

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered (please circle):	Metals / Hg / Cr / VI	Corrosivity on Water
1	HC-1	Harris Creek Culvert Hwy 124	17/12/14	13:00	Soil			X
2								
3								
4								
5								
6								
7								
8								
9								
10								

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

Turnaround Time (TAT) Required:

Please provide advance notice for rush projects

Regular (Standard) TAT:

(will be applied if Rush TAT is not specified):

Standard TAT = 5-7 Working days for most tests.

Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)

Date Required: Time Required:

Rush Confirmation Number: (call lab for #)

of Bottles

Comments

15-Dec-17 14:01

Alison Cameron

B7S5485

URE ENV-1215

Received in Sudbury

* RELINQUISHED BY: (Signature/Print)		Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)		Date: (YY/MM/DD)	Time	# jars used and not submitted	Laboratory Use Only		
Shane Albert / Shane Albert		17/12/15	2:01 PM	J. Clement		17/12/15	2:01 PM		Time Sensitive	Temperature (°C) on Receipt	Custody Seal
				Sudbury / Sudbury		2017/12/16	10:20			6/6/16	Present
											Intact
											Yes
											No

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

** SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT HTTP://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

White: Maxxa Yellow: Client

CHAIN OF CUSTODY RECORD

62087

Page 1 of 1

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required	
Company Name: #3575 Golden Associates	Company Name:	Quotation #: 370916	<input checked="" type="checkbox"/> Regular TAT (5-7 days) Most analyses				
Contact Name: David Mukherjee	Contact Name:	P.O. # / AFE#:	PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS				
Address: 88 McKenzie St. Suite 100	Address:	Project #: 1176446 P.3200	Rush TAT (Surcharges will be applied)				
Sudbury ON P3C 0H1	Address:	Site Location: N70/G40 Hwy 124/518	<input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days				
Phone: (705) 524-6861 Fax: (705) 524-1984	Phone:	Site #:	Date Required:				
Email:	Email:	Sampled By: S. Albest	Rush Confirmation #:				
MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY							
Regulation 153		Other Regulations		Analysis Requested		LABORATORY USE ONLY	
<input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Med/ Fine	<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw	REFER TO BACK OF COC		CUSTODY SEAL Y / N		COOLER TEMPERATURES	
<input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse	<input type="checkbox"/> MISA <input type="checkbox"/> Storm Sewer Bylaw			Present Intact		7.7, 7.7°C	
<input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/ Other	<input type="checkbox"/> PWQO Region			N N			
<input type="checkbox"/> Table <input type="checkbox"/> FOR RSC (PLEASE CIRCLE) Y / N	<input type="checkbox"/> Other (Specify)						
<input type="checkbox"/> REG 558 (MIN. 3 DAY TAT REQUIRED)							
Include Criteria on Certificate of Analysis: Y / N							
SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM							
SAMPLE IDENTIFICATION	DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CVI	RTX / PHC F1	PHCS F2 - F4
1 BC-3 & Bear Creek Hwy 5183	2017/12/05	12:00	Sol	3			
2 C 27-28 Culvert 27 Hwy 1243	2017/12/07	13:30	Sol	3			
3 HL-1 & Harris Creek Culvert Hwy 1243	2017/12/14	13:00	Sol	3			
4							
5							
6							
7							
8							
9							
10							
RELINQUISHED BY: (Signature/Print)				DATE: (YYYY/MM/DD)		TIME: (HH:MM)	
A. De Souza DE Souza				2017/12/19		13:20	
RECEIVED BY: (Signature/Print)				DATE: (YYYY/MM/DD)		TIME: (HH:MM)	
B. G. / Bradley Frappier				2017/12/19		13:20	
A. G. / A. G. / A. G.				2017/12/20		08:53	
MAXXAM JOB #				B755485			

Received in Sudbury

APPENDIX D

Non-Standard Special Provisions

DOWELS INTO ROCK - Item No.

Non-Standard Special Provision

Scope of Work

This special provision covers the requirements for the placement and field testing of dowels into rock.

Construction

Dowels into rock shall be constructed in accordance with OPSS.PROV 904 Concrete Structuresⁱ. All reinforcing steel supplied shall be in accordance with OPSS 1440 Steel Reinforcement for Concreteⁱⁱ (dowel bars conforming to CAN/CSA G30.18, Grade 400).

Where dowels are to be placed in rock, hole shall be drilled to the required depth and size. Hole diameter shall be two times the nominal diameter of the dowel. Each hole shall be cleaned out, grouted and the dowel set in place. Grout shall be of the same strength as the footing concrete or at least 30 MPa at 28 days.

If hole contains water, the Contractor shall remove the water, otherwise a tremie procedure shall be used to completely fill the hole with grout. The dowel shall be forced into the hole after the grout has been placed and while it is still fresh.

Rock Dowel Testing

All proposed testing procedures shall be in general conformance with ASTM D3689, ASTM D1143/D1143M and ASTM D4435. Field testing must be carried out in the presence of, and the results reviewed and approved by, the Contract Administrator.

Performance Tests

The following table summarizes the number of rock dowels where performance testing shall be carried out to confirm that the design load of the rock dowels can be achieved. The Contract Administrator will select the rock dowels to be tested.

Structure	Foundation	Number of Dowels for Performance Testing
Bear Creek Culvert or Wingwall Footings	Per footing	1

Performance test shall be by axial tensioning using a hydraulic jack with a capacity of at least 1.5 times the ultimate strength of the dowels.

Rock dowels shall be loaded and unloaded in 3 cycles and measurements of the displacement of the dowel shall be carried out at each load increment (step) in accordance with the following schedule:

Cycle-Step	1-1	1-2	1-3	2-1	2-2	2-3	2-4
% Design Load	50	75	25	50	75	100	25
Cycle-Step	3-1	3-2	3-3	3-4	3-5		
% Design Load	50	75	100	110	25		

The design load shall be taken as 360 kN for 35M dowels, 252 kN for 30M dowels, 180 kN, for 25M dowels, and 108 kN for 20M dowels.

Displacement measurements shall be carried out at each load increment using calibrated displacement gauges capable of measuring movements of 0.0025 cm. Measurements shall be referenced to an independent fixed referenced pint.

Rock dowels which fail to meet the acceptance criteria shall be replaced at the Contractor's expense and re-tested. If a rock dowel fails, three (3) additional rock dowels shall be tested at the same abutment and pier footing as directed by the Contract Administrator.

Acceptance criteria for the rock dowels will be in accordance with the Post-Tensioning Institute (1985) as follows:

- The dowels are acceptable if the total elastic movement is greater than 80 percent of the theoretical elastic elongation of the free stressing length and is less than the theoretical elongation of the free stressing length plus 50 percent of the bond length.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

ⁱ OPSS.PROV 904 Construction Specification for Concrete Structures

ⁱⁱ OPSS 1440 Material Specification for Steel Reinforcement for Concrete

Existing Subsurface Conditions

Notice to Contractor

The Contractor is alerted to the presence of cobbles and boulders within the embankment fill and native soils as encountered by casing/coring advancement in Boreholes BC-2 and BC-4, respectively. The extent and depth of cobbles and boulders may vary beyond and between the borehole locations.

The granular embankment fill and native soils present below the groundwater level will slough, run, boil or cave into the excavation unless appropriate controls are in place.

The native silty clay and silt deposits are potentially sensitive to disturbance and loosening from vibrations and/or sheet pile/pile driving operations.

The bedrock at this site is classified as strong (Grade R4) and pre-drilling and hoe ramming techniques alone may not be adequate to break-up the bedrock depending on the quantity of bedrock excavation that is required. As such, consideration may need to be given to controlled blasting / excavation techniques.

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Non-Standard Special Provision

Amendment to OPSS 902, November 2010

902.01 SCOPE

Section OPSS 902.01 of OPSS 902 is amended by the addition of the following:

As part of the work under this item, the Contractor shall:

- Carry out any additional field investigation the Contractor deems necessary in order to engineer the dewatering systems.
- Design and install dewatering systems the culvert replacement and wingwall construction (including placement and compaction of the granular levelling/bedding, backfill and cover, as appropriate) to be carried out in the dry.
- Carry out works necessary for the dewatering system which includes cofferdams, tremie concrete seal, and excavation for tremie concrete, etc., as may be required.
- Cut off the top of the dewatering systems 600 mm below grade or creek bed (as may be required).
- Supply, place and compact the granular levelling/bedding, backfill and cover (as appropriate) within the limits of the dewatering excavation for the replacement culvert and wingwalls.

All work as shown on the Contract Drawings.

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517 Dewatering
OPSS 805 Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517.

Dewatering System means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517.

Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517.

Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a 5 year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of n/a from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website <https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

The Quality Verification Engineer shall witness the following Interim Inspections of the work:

- a) Dewatering of excavation for structure.
- b) Completion of excavation for foundation.
- c) Excavation for backfill and frost tapers.
- d) Backfilling.

A copy of the written permission to proceed shall be submitted to the Contract Administrator prior to commencement of the successive operation.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.



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