



THURBER ENGINEERING LTD.

**DETAILED FOUNDATION INVESTIGATION AND DESIGN REPORT
DUNC LAKE CULVERT REPLACEMENT
HIGHWAY 17, UNSURVEYED TERRITORY
THUNDER BAY DISTRICT, ONTARIO
LATITUDE: 48.718928°, LONGITUDE: -85.689204°**

G.W.P. 6810-14-00, W.P. 6810-14-01, SITE No. 48E-047/C

GEOCRES Number: 42C-45

Report

to

HATCH

Date: December 18, 2018
File: 15595



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the detailed design of the proposed Dunc Lake Culvert replacement. The Dunc Lake Culvert is located on Highway 17, west of the town of White River, in the Unsurveyed District of Thunder Bay, Ontario. Thurber previously completed a preliminary foundation investigation at the culvert site in 2017.

The purpose of this investigation was to explore the subsurface conditions at the culvert location and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by Hatch to carry out this detailed foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0008.

The preliminary investigation previously conducted by Thurber is described in the following report:

- Preliminary Foundation Investigation and Design Report, Dunc Lake Culvert Replacement, Highway 17, Unsurveyed Territory, Thunder Bay District, Ontario, GEOCRES Number 42C-44, prepared by Thurber Engineering Ltd.

The borehole logs from the preliminary investigation are included in this report.

2. SITE DESCRIPTION

The site is located along Highway 17, approximately 38 km west of the town of White River, Ontario. Highway 17 generally runs in an east-west direction at the culvert site. The existing culvert allows water from Dunc Lake to flow from north to south under Highway 17.

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Based on the Ontario Structure Inspection Manual (OSIM) prepared by MTO on November 20, 2014 the existing culvert is a structural plate corrugated steel pipe arch that is 3.7 m wide, 2.4 m high and 29.1 m long. The culvert barrel is in fair condition with light rusting of the bottom 200 mm of the CSP and rusting bolts.

The estimated culvert invert is at approximate Elevation 324.1 m at the inlet (north) and 324.0 m at the outlet (south). The existing road grade at the culvert location is at approximate Elevation 327.7 m. The height of fill above the culvert is approximately 1.0 m. The water level within Dunc Lake to the north and south of the culvert on October 4, 2015 was reported at Elevation 325.1 m. Photographs in Appendix D show the culvert and the surrounding area.

The site lies within the physiographic region known as the Wawa Subprovince of the Superior Province of the Canadian Shield. Based on OGS Map MRD126-Revision 1, titled "1:250,000 Scale Bedrock Geology of Ontario", dated 2011, the bedrock is of the Neo- to Mesoarchean age and consists of metasedimentary rocks, including wacke, siltstone and arkose. Based on OGS Map 2681, titled "Quaternary Geology of the Cedar Lake Area, Northern Ontario", dated 2009, the subsoils on site generally consist of a bedrock-drift complex (thin stratified veneer with numerous outcrops).

3. INVESTIGATION PROCEDURES

The current investigation and field testing program was carried out between June 26 and 27, 2018, and consisted of drilling and sampling two (2) boreholes, designated as Boreholes 18-23 and 18-24, to depths of 8.1 m and 11.1 m, respectively. Both boreholes were drilled within the paved portion of Highway 17 at locations of proposed temporary modular bridge abutments.

The previous preliminary investigation was carried out between July 13, and September 10, 2017, during which time six boreholes denoted as Boreholes 17-01 to 17-06 were advanced to depths of between 1.7 and 9.9 m.

The Record of Borehole sheets for the boreholes from the current and previous preliminary investigations are included in Appendix A. The approximate locations of the boreholes from both investigations are shown on the Borehole Locations and Soil Strata Drawings included in Appendix C.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were estimated from topographic drawings provided to Thurber by Hatch. The



boreholes from the current investigation were drilling using a track-mounted CME 55 drill rig using wash boring techniques. In all boreholes, soil samples were obtained at selected intervals using a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT), or from auger cuttings for surficial material.

The field investigation was supervised on a full-time basis by a member of Thurber's technical staff who directed the drilling, sampling and in-situ testing operations, logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed in the open boreholes throughout the drilling operations. Boreholes were backfilled in general accordance with Ontario regulation 903, as amended by Regulation 128/03. A piezometer was installed as part of the preliminary investigation in Borehole 17-03.

Details of the piezometer installations and borehole completion are summarized as follows:

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
18-23	8.1 / 319.6	None Installed	Borehole backfilled with cuttings to 1.7 m, bentonite holeplug to 0.6 m, sand to 0.3 m, then asphalt cold patch to surface.
18-24	11.1 / 316.5	None Installed	Borehole backfilled with cuttings to 2.9 m, bentonite holeplug to 0.6 m, sand to 0.3 m, then asphalt cold patch to surface.
17-01	6.2 / 318.1	None Installed	Bentonite holeplug and caved material to surface
17-02	7.3 / 317.0	None Installed	Bentonite holeplug and caved material to surface

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
17-03	9.9 / 317.8	9.8/317.9	Sand from 9.9 to 7.7 m, bentonite holeplug to 0.1 m, then asphalt to surface
17-03 (DCPT)	1.4 / 326.3	None Installed	Cuttings to 0.1 m then asphalt to surface
17-04	1.8 / 325.8	None Installed	Cuttings to 0.3 m, dry cement to 0.1m then asphalt to surface
17-05	3.0 / 324.6	None Installed	Cuttings to 2.7 m, dry cement to 0.1m then asphalt to surface
17-06	1.7 / 325.9	None Installed	Cuttings to 1.0 m, bentonite holeplug to 0.3 m, concrete to 0.1m, then asphalt to surface

4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (hydrometer and/or sieve). Point load tests were conducted on bedrock cores. Laboratory testing results are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the fill, and a sample of the surface water from the lake upstream of the existing culvert were collected and submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters. The results of the analytical testing are summarized in this report and also presented in Appendix B.



5. DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

In general, the subsurface conditions encountered in these boreholes consisted of asphalt pavement underlain by sand and gravel fill and gravelly sand with rock fill, which were in turn underlain by a layer of native sand and silt, and metasedimentary bedrock. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes 18-23, 18-24, and 17-03 to 17-06 were drilled through the paved portions of Highway 17 and encountered a 75 mm to 125 mm thick layer of asphalt at the surface of each of these holes.

5.2 Sand and Gravel Fill

Sand and gravel fill with trace silt was encountered below the asphalt in Boreholes 18-23, 18-24, and 17-03 to 17-06. The thickness of the sand and gravel fill ranged from 0.6 to 1.7 m. Borehole 17-04 was terminated within this layer at a depth of 1.8 m (Elev. 325.8 m).

SPT 'N' values within the sand and gravel fill ranged from 29 to 102 blows per 0.3 m of penetration was recorded, indicating a compact to very dense relative density. Measured moisture contents between 3 percent and 68 percent were measured in the fill (typically 3 to 23 percent).

The results of grain size distribution analyses carried out on selected samples of the sand and gravel fill are presented on the Record of Borehole sheets included in Appendix A and on Figure B1 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	33 to 55
Sand	41 to 57
Silt and Clay	4 to 10

5.3 Gravelly Sand Fill with Rockfill

A layer of gravelly sand fill containing rock fill and trace silt was encountered below the sand and gravel fill in Boreholes 18-23, 18-24, 17-03, 17-05 and 17-06. The gravelly sand with rock fill layer extended to depths of 3.0 to 4.1 m (Elev. 324.7 to 323.6 m) and ranged from 2.3 to 2.7 m in thickness where fully penetrated. Boreholes 17-05 and 17-06 were terminated within this layer at depths of 3.0 and 1.7 m respectively (Elev. 324.6 and 325.9 m). A dynamic cone penetration test (17-03 DCPT) was terminated upon refusal at a depth of 1.4 m (Elev. 326.3 m), which is expected to have occurred on this rock fill layer.

SPT 'N' values recorded within the gravelly sand with rock fill ranged from 16 to greater than 50 blows per 0.3 m of penetration, indicating that the rock fill material is compact to very dense. Measured moisture contents between 5 percent and 18 percent were measured in this fill.

The results of grain size distribution analyses carried out on selected samples of the gravelly sand with rock fill are presented on the Record of Borehole sheets included in Appendix A and on Figure B2 of Appendix B. The results of the grain size distribution analysis are summarized below:

Soil Particle	Percentage (%)
Gravel	28 to 33
Sand	58 to 60
Silt and Clay	9 to 12

5.4 Sand to Sandy Silt

A deposit of sand to sandy silt, ranging in composition from trace silt to silty and trace gravel to gravelly, and containing trace clay, underlaid the fill in Boreholes 18-23, 18-24 and 17-03, at depths of between 3.0 m to 4.1 m (Elevations 324.7 m to 323.6 m), and was the surface soil layer below 0.3 m of lake water in Boreholes 17-01 and 17-02. Organic and wood debris were also encountered near the surface in Boreholes 17-01 and 17-02. This sand layer had a thickness ranging from 2.4 to 4.9 m and extended to depths ranging from 3.2 m to 7.9 m (Elev. 322.3 to 319.9 m).



SPT 'N' values within the sand to sandy silt deposit ranged from 3 to over 100 blows per 0.3 m of penetration, indicating a very loose to dense consistency (typically compact to dense). Measured moisture contents within the sand to sandy silt deposit varied between 7 percent and 28 percent.

The results of grain size distribution analyses carried out on selected samples of the sand to sandy silt layer are presented on the Record of Borehole sheets included in Appendix A and on Figure B3 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 14
Sand	28 to 86
Silt	19 to 63
Clay	4 to 9
Silt and Clay	13

5.5 Cobbles and Gravel

A layer of cobbles and gravel was encountered in Boreholes 17-02 and 17-03 below the sand deposit at depths of 3.9 and 6.6 m (Elevation 320.4 and 321.1 m respectively). The layer was 0.1 to 0.4 m in thickness.

5.6 Bedrock

Metasedimentary bedrock was encountered in Boreholes 18-23, 18-24 and 17-01 to 17-03 at depths ranging from 3.2 to 7.9 m (Elevations 319.7 to 322.3). The bedrock was confirmed by coring 2.7 to 3.2 m in each borehole. The bedrock was generally described as fresh to slightly weathered, with occasional quartz veins. Boreholes 18-23, 18-24, and 17-01 to 17-03 were terminated within the bedrock at depths ranging from 6.2 to 11.1 m (Elev. 316.5 to 319.6 m).

Total Core Recovery (TCR) in the bedrock was 100% with Solid Core Recovery (SCR) ranging from 49% to 100%. The Rock Quality Designation (RQD) determined from the recovered cores generally ranged from 19% to 100%, indicating very poor to excellent quality (typically fair to excellent). Average unconfined compressive strengths (UCS) of the rock ranged between 90 MPa to greater than 250 MPa based on correlations with the point load tests (PLT), indicating that the rock was strong to extremely strong.



5.7 Groundwater Conditions

Groundwater conditions were observed during drilling operations, and groundwater levels were measured in the open boreholes upon completion of drilling. A standpipe piezometer was installed at Borehole 17-03. The groundwater levels measured in the open boreholes and piezometer are summarized below:

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
18-23	June 26, 2018	Dry	-	Open borehole
18-24	June 27, 2018	2.8	324.8	Open borehole
17-03	July 14, 2017	2.8	324.9	Open borehole
	July 16, 2017	2.1	325.6	Standpipe piezometer
17-04	July 13, 2017	Dry	-	Open borehole
17-05	July 13, 2017	2.4	325.2	Open borehole
17-06	July 13, 2017	Dry	-	Open borehole

The water level of Dunc Lake on October 4, 2015 was reported to be Elev. 325.1 m and was measured at Boreholes 17-01 and 17-02 to be Elev. 324.3 m on September 9 and 10, 2017.

The groundwater and lake levels above are short-term readings, and seasonal fluctuations are to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the gravelly sand fill from Borehole 17-03 and a sample of the lake water were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

Table 6.1 – Analytical Test Results

Parameter	Units (Soil)	Units (Water)	Test Results	
			17-03, SS#3, 2.4 m – 3.0 m	Dunc Lake
			(Gravelly Sand Fill)	(Lake Water)
Sulphide	mg/L	mg/L	<0.02	<0.006



Parameter	Units (Soil)	Units (Water)	Test Results	
			17-03, SS#3, 2.4 m – 3.0 m	Dunc Lake
			(Gravelly Sand Fill)	(Lake Water)
Chloride	mg/L	mg/L	310	38
Sulphate	mg/L	mg/L	96	1.8
pH	No unit	No unit	8.83	7.84
Electrical Conductivity	µS/cm	µS/cm	680	210
Resistivity	Ohms.cm	Ohms.cm	1470	4760
Redox Potential	mV	mV	245	291

7. MISCELLANEOUS

Thurber marked the borehole locations in the field and obtained subsurface utility clearances prior to drilling.

Downing Drilling of Hawkesbury, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the current investigation. The field investigation was supervised on a full-time basis by Mr. Ryan McCourt of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. of Thurber.

Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field relative to the topographic plans provided by Hatch. The coordinate system MTM NAD83 Zone 14 was used for these boreholes.

Routine laboratory testing was carried out at Thurber's geotechnical laboratory. Interpretation of the field data and preparation of this report was carried out by Mr. Cory Zanatta, P.Eng. and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the factual report and presents detailed foundation design recommendations for the proposed Dunc Lake Culvert replacement on Highway 17, located in the Unsurveyed District of Thunder Bay, Ontario. This detailed foundation report should be read in conjunction with the Preliminary Foundation Report dated September 6, 2018.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractors must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the existing culvert site was obtained from the MTO Terms of Reference, and the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on November 20, 2014. The existing structure consists of a structural plate corrugated steel pipe arch structure. The culvert measures 3.7 m wide, 2.4 m high and is 29.1 m long. The estimated culvert invert is at approximate Elevation 324.1 m at the inlet (north) and 324.0 m at the outlet (south). The existing road grade at the culvert location is at approximate Elev. 327.7 m, and there is approximately 1.0 m of fill above the culvert.

The preliminary foundation report provided recommendations for both twin pipe culverts and

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concrete box culverts. General Arrangement Drawings and discussions with Hatch indicated that a 5 percent horizontally ellipsed Structural Plate Corrugated Steel Pipe (SPCSP) culvert is the preferred replacement option. The 5 percent ellipsed SPCSP will have a span of 3.56 m and a rise of 3.20 m. The invert of the new pipe culvert (underside of pipe) is at approximate Elevation 323.51 m and 323.38 m at the inlet and outlet, respectively.

The new pipe culvert replacement will be constructed along an alignment located approximately 8 m west of the existing culvert alignment. The existing culvert may be used to maintain lake flow under the highway during construction. No grade raise is proposed for the culvert replacement and no headwalls or wingwalls are proposed.

A temporary modular bridge is proposed to accommodate vehicular traffic during installation of the replacement culvert. Temporary roadway protection may also be used to support the existing culvert during excavation for the replacement culvert.

9. CULVERT FOUNDATION DESIGN

In general, the subsurface conditions encountered in the boreholes consisted of asphalt overlying up to 4.0 m of embankment fill consisting of sand and gravel and rock fill overlying native compact to dense sand to sandy silt and metasedimentary bedrock.

Water levels in the piezometer and open boreholes ranged from 324.8 to 325.6 m. The lake water level was reported to range between Elev. 324.3 and 325.1 m.

The invert level of the proposed SPCSP is at approximate Elevation 323.51 m to 323.38 m. The founding soils encountered at this level generally consist of compact sand. There will be approximately 1.6 m of fill above the proposed replacement culverts.

Foundation design aspects for the replacement culvert include subgrade conditions and preparation, settlement of the foundation soils under the imposed loads, lateral earth pressures, temporary modular bridge foundation design, groundwater control, cofferdams, staged construction, and restoration of the roadway embankment.

The preliminary investigation report provided foundation recommendations for different types of culverts and these recommendations are not repeated here but may be used for detailed design where applicable.



9.1 Foundations

Replacement of the culvert with an SPCSP on an alignment located approximately 8 m west of the existing culvert alignment is being considered for this site. There is no grade raise proposed, however there is minor amount of embankment widening along the south embankment. Due the compact to dense sand foundation soils in the area of the embankment widening and culvert re-alignment, and the removal of soil from the culvert barrel location which may result in net unloading, any settlement is expected to be less than 25 mm and will be mostly completed by the end of construction.

The SPCSP should be placed on a minimum 300 mm thick layer of bedding material conforming to Ontario Provincial Standard Specification (OPSS) OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.014 or 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation, placement and compaction of the bedding should be carried out in the dry. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212 μm .

The underside of the bedding material should be placed at or below Elevation 323.1 m to 323.2 m, which corresponds to compact to dense sand subgrade. Any loose soil, cobbles and boulders, and any organic or other deleterious material encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition.

9.2 Frost Cover

The depth of frost penetration at this site is approximately 2.4 m based on OPSD 3090.100. The SPCSP do not require frost cover / protection.

The General Arrangement drawing indicates that the replacement culvert will be shifted some 8 m to the west of the existing culvert location. As the existing embankment and underlying subgrade soil within this area predominantly comprise sand and gravel to gravelly sand fill material, and the foundation soils are sands, construction of a new frost taper does not appear to be warranted as part of the culvert replacement.



9.3 Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, organic lakebed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint must be removed and replaced with granular material compacted as per OPSS.PROV 501.

In the event that sub-excavation is required, the width of the sub-excavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The sub-excavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted as per OPSS.PROV 501.

The work should be carried out in accordance with OPSS 902 and culvert construction, and subgrade preparation must be carried out in the dry. Due to the anticipated difficulty in dewatering in a lake environment where the foundation soils are permeable, and where the water level is expected to be approximately 1 to 2 m above the proposed culvert invert level, consideration may be given to using rock fill to replace sub-excavated areas below the groundwater level. Section 10 provides recommendations for construction in the wet.

9.4 Settlement

It is anticipated that the replacement culvert will be constructed approximately 8 m west of the existing culvert alignment with no grade raise and minor embankment widening at the south embankment. Since the foundation soils consist of compact to dense sand overlying bedrock and construction of the culvert may result in net unloading, very little post-construction settlement is expected. The post-construction settlements after culvert construction and embankment reconstruction at this site are estimated to be less than 25 mm, provided all the surficial vegetation, peat, topsoil, organic lakebed deposits, disturbed material or otherwise loose/soft soils are stripped from the areas around the culvert inlet and outlet and within the widened embankment footprint. The post-construction settlements will essentially be complete by the end of construction.



10. EXCAVATION AND GROUNDWATER CONTROL

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native sand at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits that are anticipated in the inlet and outlet areas should be classified as Type 4 soils.

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS 902.

Excavations for culvert replacement will be carried out through the existing embankment fill and extended into the native sand. It must be noted that obstructions may be encountered within the fill, including the gravelly sand with rock fill layer.

Installation of the culvert should be carried out in the dry. It is anticipated that excavation for culvert replacement will be carried out below the lake water level, and diversion of the lake flow through the existing culvert will be required. Give the relatively high permeability of the embankment fill materials and native cohesionless soils, water inflow/seepage into the excavation should be anticipated. Cofferdam enclosures along with the use of sumps / pumps within the enclosures will be required to maintain dry excavations during the course of staged construction. Recommendations for cofferdam design are provided in Sections 14 and 15 below. The dewatering scheme should be effective to lower the groundwater level at least 0.5m below the final subgrade level to avoid base boiling in the native sandy soils.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP FOUN0003 which amends OPSS 902.

In accordance with SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517. A preconstruction survey is not required, thus Designer Fill-In ** in SP FOUN0003 should be "N/A". Considering the conditions on site and dewatering requirements, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing dewatering systems of similar nature and scope to the required work is required.

Suggested wording for an NSSP in this regard is included in Appendix E. Further assessment of dewatering requirements and the need for a Permit to Take Water (PTTW) should be carried out by specialists experienced in the field.



While all efforts must be made to construct a cofferdam at the inlet and outlet of the culvert to dewater the work area by pumping, it may not be possible to fully dewater the temporary excavation in the lake environment, particularly since the foundation soils consist of sand. Accordingly, placement of any backfill below the culvert bedding may have to be done in the wet. When backfilling is conducted in the wet, select rock fill should be used. The recommended gradation of the rock fill is as follows:

Sieve Size	Percent Passing (%)
150 mm	100
106 mm	50 – 100
75 mm	15 – 80
26.5 mm	0 – 15
0.075 mm	0 - 2

A separation layer consisting of a non-woven geotextile should be placed between the native soils and rock fill. The geotextile should meet the specifications for the OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212 micro millimetres. The rock fill should be completely wrapped with the geotextile to minimize migration of the fines into the rock fill.

Rock fill used to backfill sub excavated areas below the water table may be placed by end dumping. Granular fill must not be used to backfill excavations below the water table. The rock fill placement below the water level should follow OPSS.PROV 209 (Embankments over Swamps and Compressible Soils). The water level should be maintained at a minimum elevation below the base of the culvert bedding to allow for placement and compaction of the bedding to take place in the dry.

Rock fill placed above the water level should be placed in a controlled manner (not end dumping) including blading, dozing and chinking of the rock to minimize voids and bridging. Rock fill above the water level must be compacted as per OPSS.PROV 206. Where granular fill or bedding material is to be placed over rock fill, the rock fill subgrade must be blinded with spall material and rock fill chinking shall be in accordance with OPSS.PROV 206. All granular fill must be compacted as per OPSS 501.



Another option would be to use a coarse 53 mm clear stone wrapped in geotextile for backfilling in the wet below the culvert. Once the clear stone backfill is above the water level, granular bedding for the culvert may be placed in the dry.

11. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010 or 802.014, as appropriate. Backfilling for the culvert should be in accordance with OPSS PROV 401 for a CSP culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

Lateral earth pressures acting on the culvert walls may be assumed to be a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2014, but are generally given by the expression:

$$p_h = K (\gamma h + q)$$

where	p_h	=	horizontal pressure on the wall at depth h (kPa)
	K	=	earth pressure coefficient (see table below)
	γ	=	bulk unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended unfactored values are shown in Table 11.1 below.

Table 11.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) or Type III $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive	3.7	-	3.3	-

Note: Submerged unit weight should be used below the groundwater level/high creek level.

For rigid structures, at-rest horizontal earth pressures should be used for design. Active pressures should be used for any unrestrained wall.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude of the surcharge should be 12 kPa at the top of fill and decrease to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or B Type II.

12. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. In view of the relatively shallow bedrock at the site, the area corresponds to a Seismic Site Class C in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.034 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 12.1 may be used:



Table 12.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I (modified) or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE})*	0.28	0.32
Passive (K_{PE})	3.6	3.2
At Rest (K_{OE})**	0.47	0.52

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

** After Woods

The site is underlain by compact to dense sand. In view of the low potential for seismic activity in this area, liquefaction is not considered to be a concern at this site.

13. COFFERDAMS

Construction of cofferdams will be required to construct the culvert replacement in the dry. It is recommended that the temporary culvert excavations be carried out within an enclosure. Sand bag cofferdams are considered feasible at this site. Unbraced sheet pile cofferdams are not likely to be feasible at this site due to the presence of shallow bedrock and internally braced sheet pile cofferdam may be required. Sheet piles driven to bedrock may not be able to provide sufficient lateral resistance. If sheet pile cofferdams are considered for this site, the recommendations provided in Section 15 below for Temporary Protection Systems are also applicable to sheet pile cofferdams, however a Professional Engineer experienced in design must check that the appropriate lateral resistance can be achieved.

Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field. Design of a suitable and effective dewatering system is the responsibility of the Contractor as indicated in Section 10. The dewatering system must be effective to lower the water table a minimum of 0.5 m below the final culvert subgrade.

14. TEMPORARY PROTECTION SYSTEM

Temporary roadway protection may be used to support the existing culvert during excavation for the replacement culverts.

Temporary roadway protection system should be implemented in accordance with OPSS PROV 539 and designed for Performance Level 2.



Options for roadway protection are a soldier pile-lagging system or interlocking sheet piles, although it may be difficult to drive steel sheet piles due to the presence of rock fill and relatively shallow bedrock.

The soil parameters in Table 14.1 may apply for the design of the temporary roadway protection system with horizontal backfill.

Table 14.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Sand to Sandy Silt
Φ (angle of internal friction)	32°	30°
γ (total unit weight)	20 kN/m ³	20 kN/m ³
γ_w (submerged unit weight)	10 kN/m ³	10 kN/m ³
K_a	0.31	0.33
K_p	3.3	3.0

Full hydrostatic pressure should be considered assuming a water level at least equal to the design lake water level.

The temporary protection system may be removed or partially removed upon completion of the work. Care must be taken when removing the sheet piles or soldier piles as to not incur damage to the subgrade of the newly installed culvert.

The design of the temporary protection system is the responsibility of the Contractor. The actual pressure distribution acting on the protection/shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors have to be considered when designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

15. TEMPORARY MODULAR BRIDGE

It is understood that a Temporary Modular Bridge (TMB) is the preferred method to maintain a lane for traffic for staging purposes. The design of the abutment foundation for the TMB is the responsibility of the contractor. The contractor must retain a Professional Engineer, experienced in bridge design, to design the TMB.

Boreholes 18-23 and 18-24 were drilled near the potential abutments of the TMB.



The modular bridge may be supported on precast concrete bearing pads founded on engineered granular fill pads. The granular fill pads should be a minimum of 1 m thick and consist of OPSS Granular A or Granular B Type II, placed in 150 mm thick lifts and compacted to 100% of the SPMDD at $\pm 2\%$ of Optimum Moisture Content (OMC).

The minimum footing width should be 1.5 m and the footing should be embedded a minimum of 0.5 m below the finished grade in front of the footing. The front edge of the footing should be set back a minimum of 2 m for the west abutment and 2.5 m for the east abutment from the crest of the temporary excavation slope at the top of the footing level.

The recommended geotechnical resistance at the ULS and SLS for a minimum 1.5 m wide concrete pad footing founded on the engineered granular fill at or below Elev. 326.4 m for the east or west abutment, are given below:

- Factored Geotechnical Resistance at ULS of 150 kPa
- Factored Geotechnical Resistance at SLS (less than 25 mm settlement) of 100 kPa

Resistance to lateral forces/sliding resistance between the concrete pad and the underlying Granular A or B Type II engineered fill should be calculated assuming an ultimate coefficient of friction of 0.55. A resistance factor of 0.8 should be applied to this ultimate value.

In order to achieve a stability safety factor of 1.3, the temporary excavation slope in front of the TMB abutments should be no steeper than 1.5H:1V after dewatering (3H:1V below the groundwater level before dewatering) as shown in Figures 1 and 2 in Appendix F. The temporary excavation slope for the modular bridge must be protected from erosion by covering the slope with tarp. Dewatering will be required during excavation of the temporary slopes as described in Section 10.

It is recommended that the contractor retain a geotechnical consultant who is RAQS qualified at the medium complexity level (RAQs Category - Geotechnical Structures and Embankment – Medium Complexity) to design the TMB footings and stable temporary slopes in front of the footings for the temporary modular bridge. All final reports and drawings must be sealed and signed by a Professional Engineer, who shall also be a RAQs Designated Contact. An NSSP for this effect is attached in Appendix E.



16. EMBANKMENT RESTORATION

Provided that the embankment is reconstructed with side slopes inclined not steeper than 2H:1V, the restored embankment slope should remain stable.

The placement of additional fill to widen the embankment slopes will induce settlement. The foundation soils in the embankment widening footprint generally consist of compact to dense sand to silty sand underlain by bedrock. Provided all surficial vegetation, peat, topsoil, organic lakebed deposits, disturbed material or otherwise loose/soft soils are stripped from the areas around the culvert inlet and outlet and within the widened embankment footprint, then post-construction settlement due to embankment widening is expected to be less than 25 mm.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material. For embankment restoration below the lake water elevation, rock protection, as described below in Section 17, should be provided. The existing granular fill should not be reused to restore the embankment.

Inspection and approval of the foundation subgrade by qualified geotechnical personnel should be conducted.

17. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field in accordance with OPSS 810.010, OPSS 511 and OPSS PROV 1004.

Typically, rock protection should be provided over all surfaces with which lake water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS PROV 804.

A geosynthetic clay liner should be used to minimize the potential for erosion or piping around the culvert. The geosynthetic clay liner should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material. The material requirements should be in accordance with OPSS PROV 1205. A clay liner with a minimum 0.5 m thickness may be used in place of the geosynthetic clay liner.



18. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the fill soil and lake water indicate the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding native soil or surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested. The effect of road deicing salt should also be considered while selecting the class of concrete.
- The potential surface water corrosion on metal is considered to be mild. However, due to the low resistivity of the soil, the potential for corrosion on steel, cast iron and other metals is considered to be severe.
- Appropriate protection measures are recommended for metal structural elements. The effect of road deicing salt should be considered while selecting the corrosion protection measures.

19. CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- A suitable dewatering / unwatering system must be employed to enable culvert construction and subgrade preparation in the dry and prevent base boiling, sloughing and instability of the excavation walls. The contractor should be prepared to take appropriate measures to construct in the wet should the dewatering system prove to be ineffective at lowering the water table to the appropriate depth.
- The water level in the lake may fluctuate and be at a higher elevation at the time of construction than indicated in the report.
- Rockfill was encountered in the embankment fill; therefore rockfill should be anticipated and dealt with during construction. These materials may interfere with the installation of the temporary roadway protection system. Suggested wording for an NSSP on obstructions is included in Appendix E.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions



may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

20. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Cory Zanatta, P.Eng. and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$


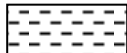



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W _L < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W _L < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W _L < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W _L > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				
<u>TERMS</u>		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.				
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

RECORD OF BOREHOLE No 18-23

1 OF 1

METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 663.0 E 401 280.2 ORIGINATED BY BRM
DIST Thunder Bay HWY 17 BOREHOLE TYPE NW Casing/HQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.06.26 - 2018.06.26 LATITUDE 48.733164 LONGITUDE -100.342550 CHECKED BY MEF

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
327.7	GROUND SURFACE															
0.0	ASPHALT (125mm)															
0.1	SAND and GRAVEL, trace silt Very Dense Brown Moist (FILL)		1	SS	102											40 52 8 (SI+CL)
327.0																
0.7	Gravelly SAND with ROCKFILL, trace silt Compact to Dense Brown Moist (FILL)		2	SS	23											
			3	SS	23											
			4	SS	39											
324.7																
3.0	Silty SAND, some gravel, trace clay Dense Dark Brown to Grey Moist to Wet		5	SS	33											
			6	SS	35											14 47 33 6
322.3																
5.4	BEDROCK: (Meta-Sedimentary), slightly weathered, bluish grey														FI	
	Sub vertical fracture 5.4m, 5.9m, 6.1m and 6.2m		1	RUN											2	RUN #1 TCR=100% SCR=49% RQD=36% UCS=>250MPa (Average)
	Sub horizontal fracture at 5.6m														1	
	Rubble zone from 5.6m to 7.1m														2	
															0	
	Mechanical fracture at 7.3m, 8.0m and 8.1m		2	RUN											0	RUN #2 TCR=100% SCR=97% RQD=87% UCS=>250MPa (Average)
	Sub horizontal fracture at 7.9m														1	
319.6															0	
8.1	END OF BOREHOLE AT 8.1m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 1.7m, BENTONITE HOLEPLUG TO 0.6m, SAND TO 0.3m, THEN COLD PATCH ASPHALT TO SURFACE.															

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-24

1 OF 2

METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 679.4 E 401 247.8 ORIGINATED BY BRM
DIST Thunder Bay HWY 17 BOREHOLE TYPE NW Casing/HQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.06.27 - 2018.06.27 LATITUDE 48.733306 LONGITUDE -100.342994 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
327.6	GROUND SURFACE							20	40	60	80	100				
0.0	ASPHALT (100mm)															
0.1	SAND and GRAVEL, trace silt Very Dense Brown Moist (FILL)		1	SS	76											
326.9							327									
0.7	Gravelly SAND with ROCK FILL, trace silt Compact to Very Dense Brown Moist (FILL)		2	SS	50/ 0.075											
			3	SS	16		326									33 58 9 (SI+CL)
			4	SS	50/ 0.050		325									
324.6																
3.0	SAND, trace gravel Compact Brown Wet		5	SS	22		324									
323.0							323									
4.6	Sandy SILT, trace clay Loose Grey Wet		6	SS	5											0 28 63 9
							322									
321.5																
6.1	SAND, trace silt, trace clay, no gravel to gravelly Compact Grey Wet		7	SS	25		321									
							320									
319.7			8	SS	50/ 0.100											
7.9	BEDROCK: (Meta-Sedimentary), fresh, very strong, bluish grey Mechanical fracture at 8.1m, 8.2m, 8.3m and 8.6m Sub horizontal fracture at 8.3m, 8.6m, 9.2m and 9.3m Sub vertical fracture at 8.5m and 9.2m Rubble zone (75mm) at 7.9m, 9.1m Horizontal fracture at 8.8m and 9.0m Sub horizontal fracture at 9.7m		1	RUN			319									RUN #1 TCR=100% SCR=70% RQD=52% UCS=184MPa (Average)
							318									RUN #2 TCR=100% SCR=100% RQD=86% UCS>=250MPa (Average)

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-01

1 OF 1

METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 684.6 E 401 271.0 ORIGINATED BY TY
HWY 17 BOREHOLE TYPE BW Coring COMPILED BY AN
DATUM Geodetic DATE 2017.09.10 - 2017.09.10 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
324.3	GROUND SURFACE													
0.0 324.0	WATER													
0.3 														

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 11/15/17

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-02

1 OF 1

METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 660.3 E 401 253.8 ORIGINATED BY TY
HWY 17 BOREHOLE TYPE BW Coring COMPILED BY AN
DATUM Geodetic DATE 2017.09.07 - 2017.09.09 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS ▽*	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							WATER CONTENT (%) w _P w w _L PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		
324.3	GROUND SURFACE							20	40	60	80	100					
0.0	WATER							20	40	60	80	100					
324.0																	
0.3	SAND , some silt, trace gravel, trace clay, organics and wood debris Compact Brown Wet		1	SS	13		324										
			2	SS	19		323										
	Becoming gravelly																
			3	SS	10		322										
	Trace gravel																
			4	SS	14		321										
	Becoming silty		5	SS	3												
320.4																	
3.9	COBBLES and GRAVEL																
320.0																	
4.3	BEDROCK : (metasedimentary), occasional quartz veins, fresh, extremely strong, grey		1	RUN			320										
			2	RUN													
			3	RUN			319										
			4	RUN													
							318										
			5	RUN													
317.0																	
7.3	END OF BOREHOLE AT 7.3m. WATER LEVEL AT SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CAVED TO SURFACE.						317										

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 11/15/17

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-03

1 OF 2

METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 674.3 E 401 263.8 ORIGINATED BY ES
HWY 17 BOREHOLE TYPE Solid Stem Augers/NW/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2017.07.14 - 2017.07.14 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
327.7	GROUND SURFACE							<div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div>						
0.0	ASPHALT: (100mm)							<div><div>204060</div><div>PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT</div><div>w_p w w_L</div></div>						
0.1	SAND and GRAVEL, trace silt Compact Brown Damp (FILL)		1	GS			327							
			1	SS	29									33 57 10 (SI+CL)
326.3														
1.4	Gravelly SAND with ROCKFILL, trace silt Very Dense to Dense Brown Damp to Wet (FILL)		2	SS	52/ 0.150		326							
			3	SS	48		325							
			4	SS	47									
							324							
323.6														
4.1	SAND, fine grained, some silt to silty, trace gravel, trace clay Compact Grey to Brown Wet		5	SS	25		323							0 76 20 4
			6	SS	12		322							
321.1														
319.0	COBBLES and GRAVEL		1	RUN			321							RUN #1 TCR=100% SCR=75% RQD=75% UCS=193MPa
6.7	BEDROCK: (metasedimentary), occasional quartz veins, fresh, very strong to strong, grey Sub-vertical fracture (100mm) at 6.9m and (175mm) at 8.1m Sub-horizontal fracture (25mm) at 7.0m, 7.5m, 7.9m and 8.3m Broken zone (50mm) at 8.0m Sub-horizontal fracture (25mm) at 8.4m and 9.5m Sub-vertical fracture (50mm) at 9.2m, 9.5m, 9.7m and (175mm) at 9.8m Broken zone (50mm) at 9.3m and 9.7m		2	RUN			320							RUN #2 TCR=100% SCR=97% RQD=77% UCS=153MPa
			3	RUN			319							RUN #3 TCR=100% SCR=97% RQD=82% UCS=90MPa
317.8							318							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity 20
15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-03

2 OF 2

METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 674.3 E 401 263.8 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE Solid Stem Augers/NW/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.14 - 2017.07.14 CHECKED BY NLB

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			20	40	60	80	100					
9.9	Continued From Previous Page END OF BOREHOLE AT 9.9m. WATER LEVEL AT 2.8m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.07.16 2.1 325.6 2017.07.16 Decommissioned -																

RECORD OF BOREHOLE No 17-03 DCPT 1 OF 1 METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 674.3 E 401 263.8 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2017.07.14 - 2017.07.14 CHECKED BY NLB

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	WATER CONTENT (%)					
327.7	GROUND SURFACE													
0.0	Auger to 0.4m and start DCPT													
327.3														
0.4	DCPT start at 0.4m													
							327							
326.3														
1.4	END OF DCPT AT 1.4m UPON REFUSAL. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.													

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RECORD OF BOREHOLE No 17-04

1 OF 1

METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 680.1 E 401 255.6 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.07.13 - 2017.07.13 CHECKED BY NLB

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
327.6	GROUND SURFACE																
0.0	ASPHALT: (100mm)																
0.1	SAND and GRAVEL, trace silt Brown Damp (FILL) Possible rockfill from 0.8 to 1.8m		1	GS												55 41 4 (SI+CL)	
325.8																	
1.8	END OF BOREHOLE AT 1.8m UPON AUGER REFUSAL ON PROBABLE ROCKFILL. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.3m, CEMENT TO 0.1m, THEN ASPHALT TO SURFACE.																

RECORD OF BOREHOLE No 17-05

1 OF 1

METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 685.3 E 401 247.0 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.07.13 - 2017.07.13 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							PLASTIC LIMIT W _P NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)		
327.6	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT: (100mm)																
0.1	SAND and GRAVEL, trace silt Brown Damp (FILL)		1	GS			327										
326.4																	
1.2	Gravelly SAND with ROCKFILL, some silt Brown Damp to Moist (FILL)		2	GS			326										
324.6							325										28 60 12 (SI+CL)
3.0	END OF BOREHOLE AT 3.0m. BOREHOLE OPEN TO 1.5m AND WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 2.7m, CEMENT TO 0.1m, THEN ASPHALT TO SURFACE.																

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 11/15/17

RECORD OF BOREHOLE No 17-06

1 OF 1

METRIC

W.P. 6810-14-01 LOCATION Dunc Lake Culvert, MTM NAD 83 Zone 14 N 5 398 691.1 E 401 238.9 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.07.13 - 2017.07.13 CHECKED BY NLB

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)
327.6	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT: (75mm)																
0.2	SAND and GRAVEL, trace silt Brown Damp (FILL)		1	GS			327									47	44 9 (SI+CL)
326.5																	
1.1	Gravelly SAND with ROCKFILL, trace silt Brown Moist (FILL)																
325.9							326										
1.7	END OF BOREHOLE AT 1.7m UPON AUGER REFUSAL ON PROBABLE ROCKFILL. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 1.0m, BENTONITE HOLEPLUG TO 0.3m, CONCRETE TO 0.1m, THEN ASPHALT TO SURFACE.																

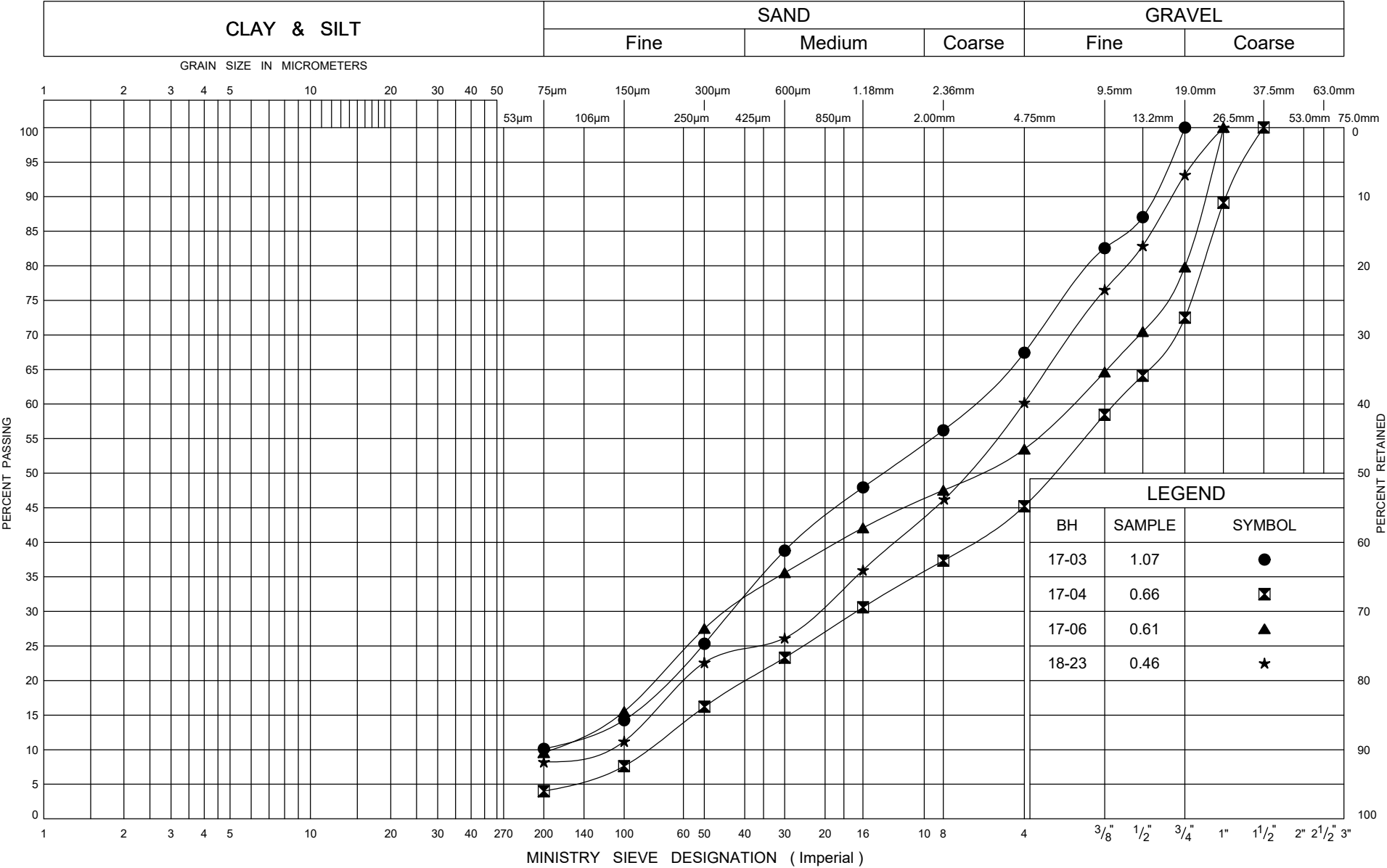
+³, ×³: Numbers refer to
Sensitivity

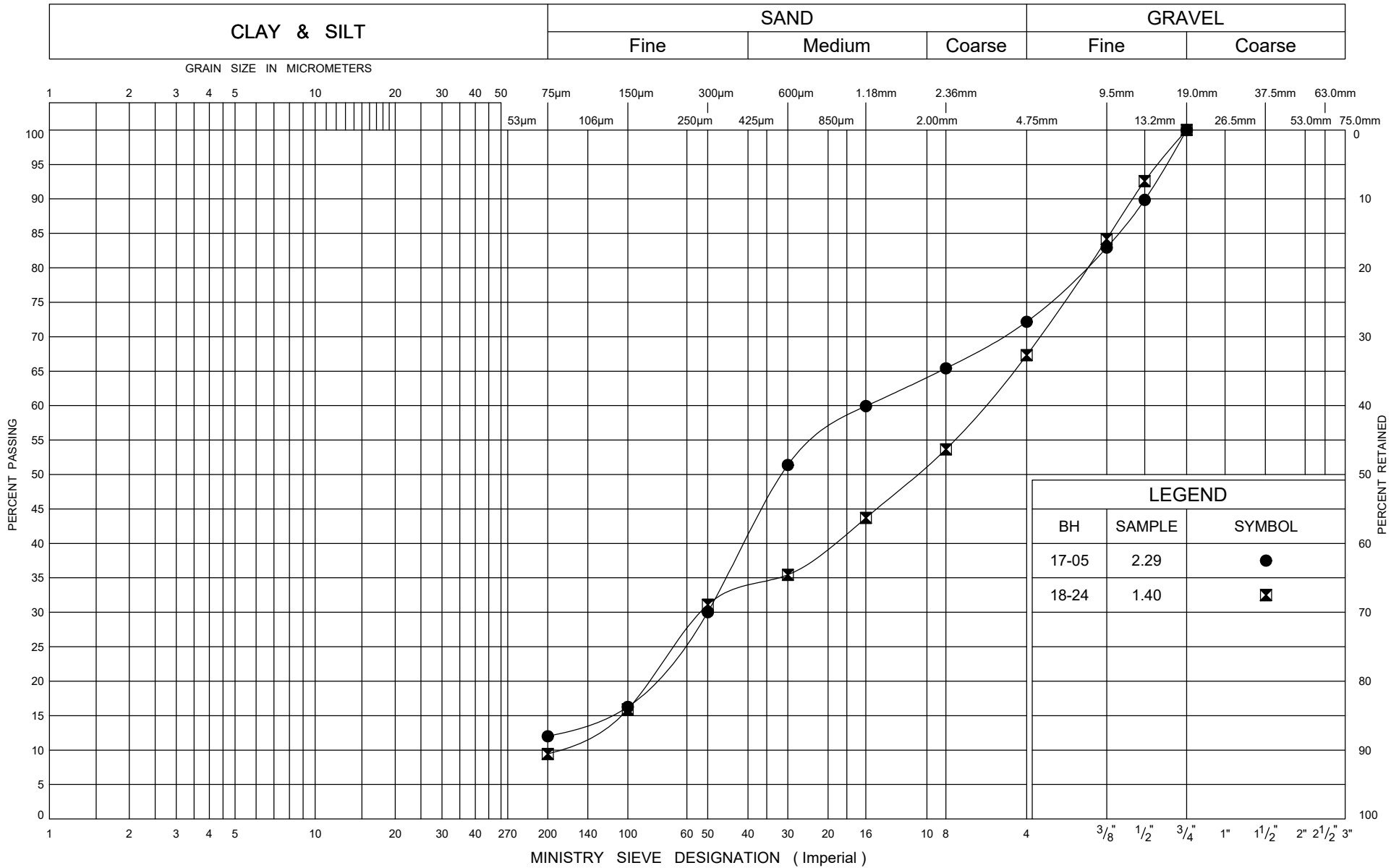
20
15
10
(%) STRAIN AT FAILURE

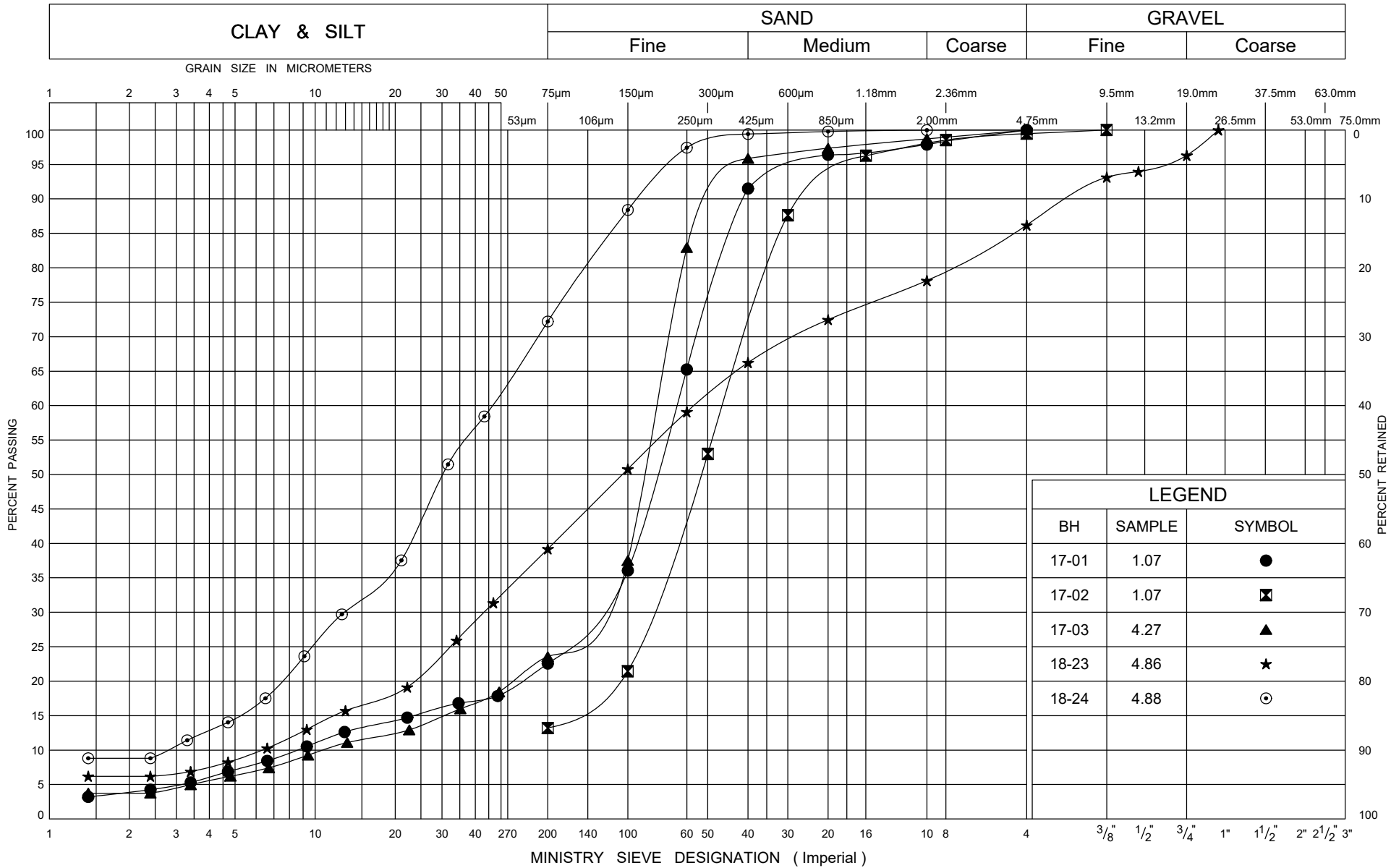


Appendix B

Laboratory Test Results









ASTM D5731-08

Date Drilled: June 27/18

Date Tested July 5/18

Tester: RT

Reviewed by MEF

[illegible]



ASTM D5731-08

Date Drilled:	June 27/18
Date Tested:	July 5/18
Tester:	RT
Reviewed by:	MEF

[illegible]



ASTM D5731-08

Date Drilled:	Sep 19/17
Date Tested:	Sep 25/17
Tester:	GA
Reviewed by:	WM

[illegible]



ASTM D5731-08

Date Drilled:	Sep 8/17
Date Tested:	Sep 25/17
Tester:	GA
Reviewed by:	WM

[illegible]

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 15595

Client: HATCH

Project Name: Dunc Lake Culvert Replacement

Core Size:	NQ	BH No :	17-03
-------------------	----	----------------	-------

Date Drilled: July 14/17

Date Tested: Sep 6/17

Tester: JZ

Reviewed by: WM

[illegible]

Certificate of Analysis

SGS Canada Inc.
185 Concession St. Box 4300
Lakefield, Ont., Canada, K0L 2H0



Client
SGS LIMS Number
Analysis Package:

Attention: Mark Farrant
Project#: 15595
Thurber Engineering Ltd.
CA14253-SEP17
Corrosivity (Soil)

Sample ID Unit BH-3, SS#3, 8'-10'

Sample Date/Time 14-Jul-17

Moisture	%	13.2
pH	no unit	8.83
Corrosivity Index	none	14.0
Soil Redox Potential	mV	245
Sulphide	mg/L	<0.02
Chloride	mg/L	310.0
Sulphate	mg/L	96
Conductivity	uS/cm	680
Resistivity (calculated)	ohms.cm	1470

Corrosivity Scale according to AWWA C-105.
An index greater than 10 indicates the
soil matrix may be corrosive to cast iron alloys.

Deanna Edwards B.Sc., C.Chem
Project Specialist
Environment, Health and Safety

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(Printed copies are available upon request.). Test Method information available upon request. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Certificate of Analysis

SGS Canada Inc.
185 Concession St. Box 4300
Lakefield, Ont., Canada, K0L 2H0



Client
SGS LIMS Number
Analysis Package:

Attention: Mark Farrant
Project#: 15595
Thurber Engineering Ltd
CA13437-JUL17
Corrosivity

Sample ID	Unit	Analysis Start Date	Analysis Approval Date	Dunc Lake Culvert
Sample Date/Time				
Temperature Upon Receipt	°C			21.0
Corrosivity Index	NA	01-Jun-17	01-Jun-17	
Redox Potential	mV	29-May-17	30-May-17	291
Sulphide	mg/L	01-Jun-17	01-Jun-17	<0.006
% Moisture (wet wt)	NA	30-May-17	01-Jun-17	
pH	units	30-May-17	31-May-17	7.84
Chloride	mg/L	31-May-17	01-Jun-17	38.0
Sulphate	mg/L	31-May-17	01-Jun-17	1.8
Conductivity	µS/cm	30-May-17	31-May-17	210
Resistivity (calculated)	ohms.cm	30-May-17	01-Jun-17	4760

Corrosivity Index is based on the AWWA
Corrosivity Scale according to AWWA C-105.
An index greater than 10 indicates the
soil matrix may be corrosive to cast iron alloys.

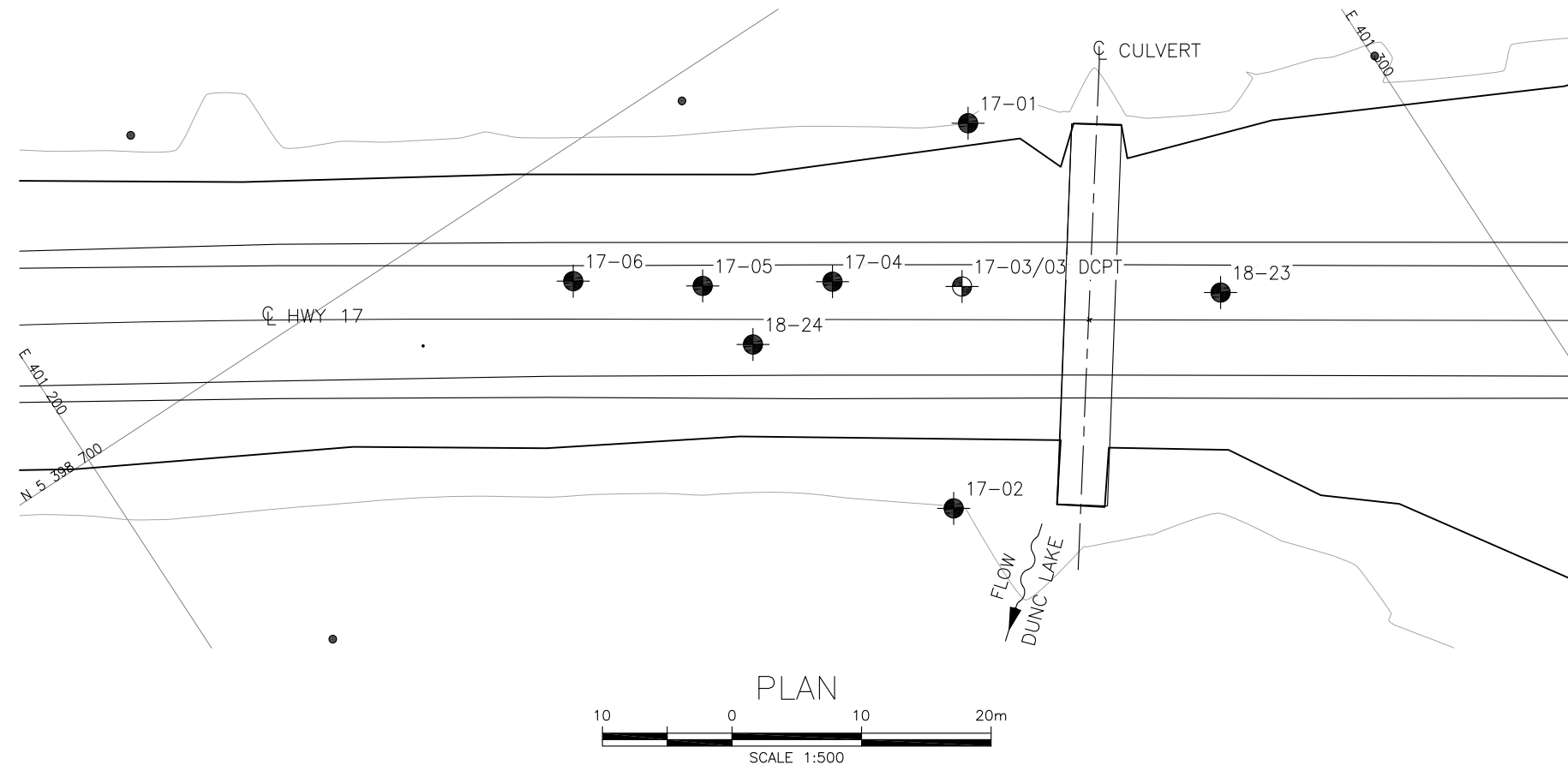
Deanna Edwards B.Sc., C.Chem
Project Specialist
Environment, Health and Safety

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(Printed copies are available upon request.). Test Method information available upon request. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.



Appendix C

Borehole Locations and Soil Strata Drawing



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



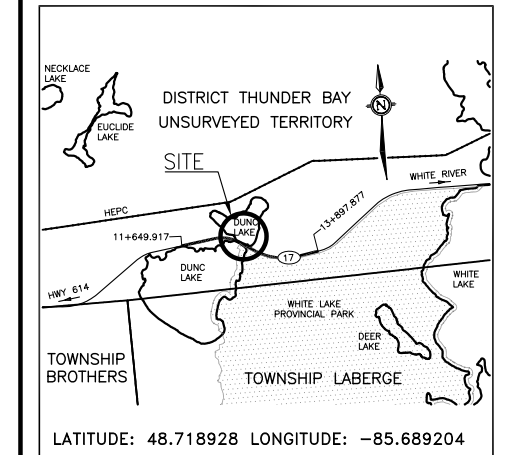
CONT No
WP No 6810-14-01

HIGHWAY 17
DUNC LAKE
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET

HATCH



KEYPLAN

LEGEND

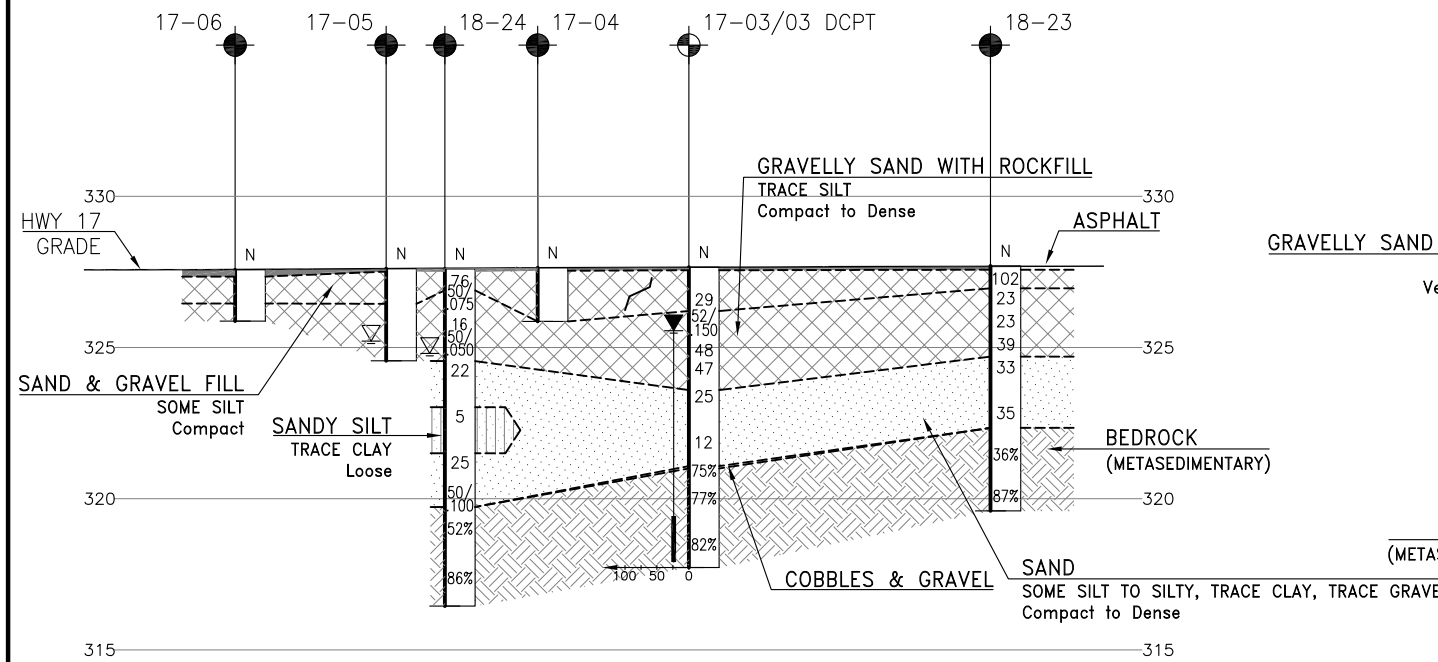
- Borehole
- Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- Water Level
- Head Artesian Water
- Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-01	324.3	5 398 684.6	401 271.0
17-02	324.3	5 398 660.3	401 253.8
17-03/03 DCPT	327.7	5 398 674.3	401 263.8
17-04	327.6	5 398 680.1	401 255.6
17-05	327.6	5 398 685.3	401 247.0
17-06	327.6	5 398 691.1	401 238.9
18-23	327.7	5 398 663.0	401 280.2
18-24	327.6	5 398 679.4	401 247.8

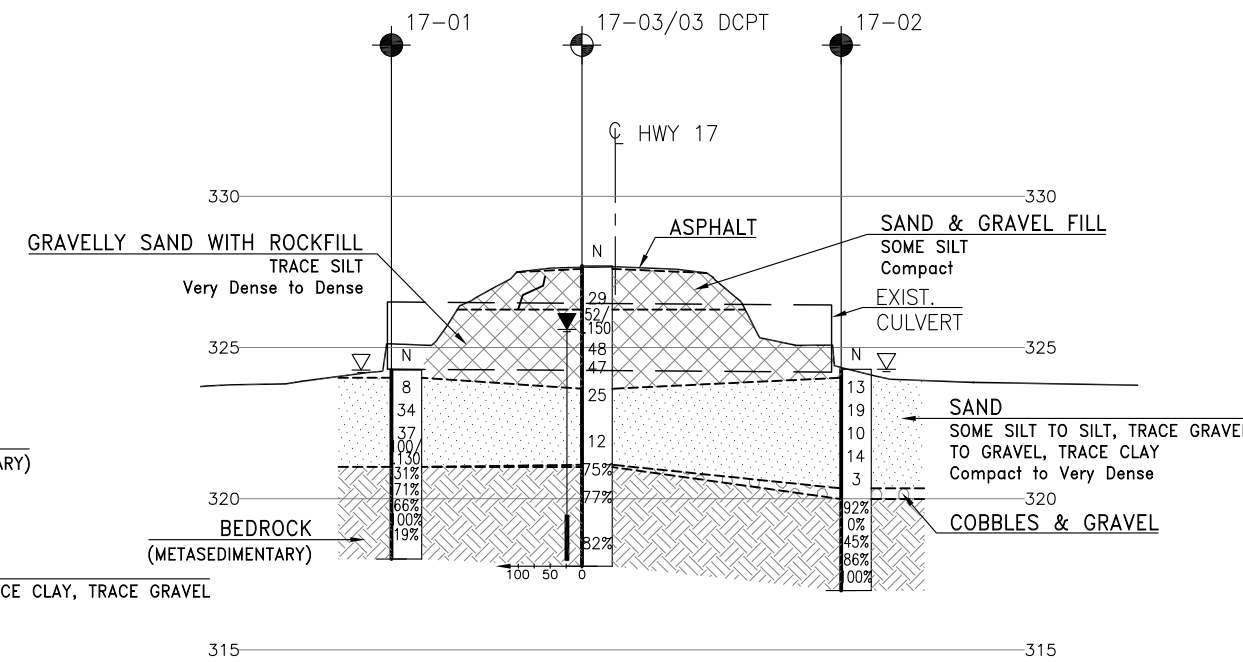
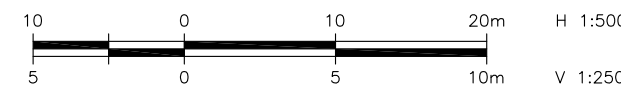
-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 14.

GEOCRES No.



PROFILE ALONG Q HWY 17



SECTION ALONG Q CULVERT

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	NLB	CHK MEF	CODE
DRAWN	AN	CHK PKC	SITE
LOAD	DATE	DEC 2018	
STRUCT	DWG	1	



Appendix D

Site Photographs



Photo 1: Culvert inlet looking west (May 17, 2017)



Photo 2: Culvert inlet looking east (May 17, 2017)



Photo 3: Culvert outlet looking west (May 17, 2017)



Photo 4: Culvert outlet looking east (May 17, 2017)



Photo 5: Culvert inlet looking north (May 17, 2017)



Photo 6: Road approach looking west (May 17, 2017)



Photo 7: Road approach looking east (May 17, 2017)



Appendix E

List of Specifications and Suggested Wording for NSSP



1. List of OPSS and OPSD Documents Relevant to this Project

- OPSS PROV 206 (Construction Specification for Grading)
- OPSS PROV 209 (Construction Specification for Embankments over Swamps and Compressible Soils)
- OPSS PROV 401 (Construction Specification for Trenching, Backfilling and Compacting)
- OPSS 421 (Pipe Culvert Installation in Open Cut)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS 511 (Construction Specification for Rip-Rap, Rock Protection, And Granular Sheeting)
- OPSS PROV 517 (Construction Specification for Dewatering)
- SP517F01 Amendment to OPSS 517 (Design Storm Return Period and Preconstruction Survey Distance)
- OPSS PROV 539 (Construction Specification for Temporary Protection Systems)
- OPSS PROV 804 (Construction Specification for Seed and Cover)
- OPSS 902 (Construction Specification for Excavating and Backfilling – Structures)
- OPSS PROV 1004 (Material Specification for Aggregates – Miscellaneous)
- OPSS PROV 1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material)
- OPSS PROV 1205 (Material Specification for Clay Seal)
- OPSS 1860 (Material Specification for Geotextiles)
- OPSD 208.010 (Benching of Earth Slopes)
- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- OPSD 802.014 (Flexible Pipe Embedment in Embankment)
- OPSD 810.010 (General Rip-Rap Layout for Sewer and Culvert Outlets)



- OPSD 3090.100 (Foundation Frost Depths for Northern Ontario)
- Special Provision No. FOUN0003 to OPSS 902 (Dewatering Structure Excavations)

2. Suggested Wording for NSSP

- **Suggested Text for NSSP on Obstructions**

“Excavations and installation of a replacement culvert could encounter obstructions such as rockfill and cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.”

- **Suggested Text for NSSP on Dewatering**

Dewatering will be required to install the new culvert and the diversion pipe in the dry. The design of an effective dewatering system is the responsibility of the contractor. The dewatering system must be effective to lower the groundwater table at a minimum of 0.5 m below the final subgrade level to avoid basal heave and base boiling. The dewatering system is to be designed in accordance with SP FOUN0003 and OPSS.PROV. 517. A preconstruction survey is not required. A dewatering engineer with a minimum of 5 years of experience in designing dewatering systems shall be retained by the contractor for design of an effective dewatering system.

The Contractor should be notified that if it is not feasible to completely dewater the excavation in the lake environment, that at a minimum, the water level should be maintained below the elevation of the base of the culvert bedding material, to allow the placement and compaction of the bedding to take place in the dry.

- **Suggested Text for NSSP on Temporary Modular Bridge**

The Contractor is responsible for the detailed design of the Temporary Modular Bridge (TMB) including, but not limited to, slope stability of the temporary excavation slope in front of the TMB abutment footings, determination of bearing capacity for the abutment footings and safe footing set back distance from the open excavation, as well as the performance of the



temporary footings throughout construction. As a minimum, modular bridge footings shall be set back a minimum two (2) metres from the top of the temporary excavation. The temporary excavation slope shall be no steeper than 1.5 horizontal to 1.0 vertical with full dewatering to 500 mm below the final base of the temporary excavation for the duration of time when the temporary modular bridge is in use. The contractor is responsible for retaining a RAQs approved Licensed Geotechnical Engineer with a medium-complexity rating (RAQs Category – Geotechnical Structures and Embankment – Medium Complexity) to confirm all aspects of the modular bridge slope stability and foundation design. All final reports and drawings must be sealed and signed by a Professional Engineer, who shall also be a RAQs Designated Contact.



Appendix F

Stability Analysis Figures

FIGURE 1 - DUNC LAKE CULVERT EXCAVATION - WEST ABUTMENT

File Name: Dunc Lake LT 1.5H to 1V temp slope- pipe removal- 2m top setback - west footing.gsz
Created By: Geoff Lay
Date: 11/02/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 0.1 m
Seismic: 0

Fill 21 kN/m³ 0 kPa 35 °
Sand - Compact 21 kN/m³ 0 kPa 32 °

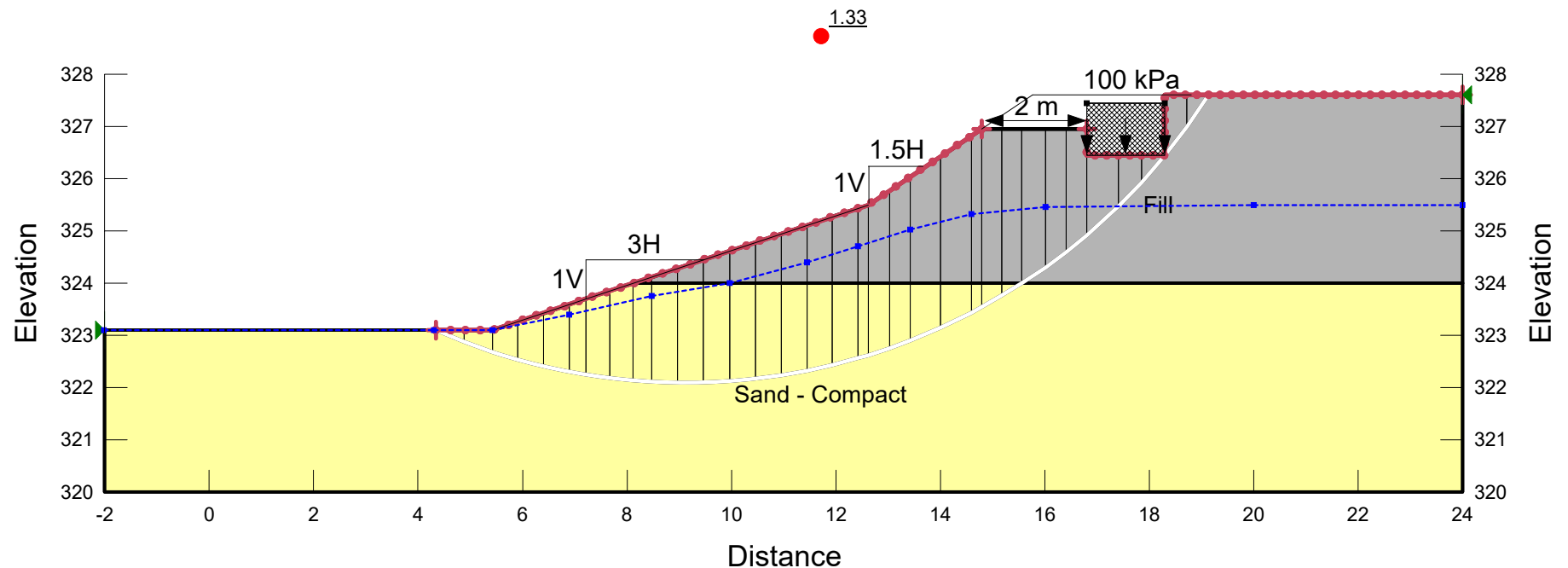


FIGURE 2 - DUNC LAKE CULVERT EXCAVATION - EAST ABUTMENT

File Name: Dunc Lake LT 1.5H to 1V temp slope- pipe removal- 2.5m top setback - east footing.gsz
Created By: Geoff Lay
Date: 11/02/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 0.1 m
Seismic: 0

Fill 21 kN/m³ 0 kPa 35 °
Sand - Compact 21 kN/m³ 0 kPa 32 °

