THURBER ENGINEERING LTD.

DETAILED FOUNDATION INVESTIGATION AND DESIGN REPORT
LOUISE LAKE CULVERT REPLACEMENT
HIGHWAY 641, TOWNSHIP OF PELLAT
DISTRICT OF KENORA, ONTARIO
LATITUDE: 49.774013º, LONGITUDE: -94.646125º

G.W.P. No. 6846-14-00, W.P. No. 6846-14-01, SITE No. 41S-097/C

GEOCRES Number: 52E-69

Report

to

WSP Canada Inc.

Date: December 14, 2018
File: 22155

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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 detailed design of the proposed Louise Lake Culvert replacement. The Louise Lake culvert is located on Highway 641, west of Kenora, in the Township of Pellat, District of Kenora, Ontario. Thurber previously conducted 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 WSP Canada Inc. (WSP) to carry out this detailed foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0035-016.

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

"Preliminary Foundation Investigation Report, Louise Lake Culvert Replacement, Highway 641, Township of Pellat, District of Kenora, Ontario", Geocres Number: 52E-65, Date: October 2, 2017, File: 15593".

The record of borehole sheets and laboratory test results from the preliminary investigation are included in this report.

2. SITE DESCRIPTION

The site is located on Highway 641, approximately 4.2 km north of Highway 17, in the Township of Pellat, Ontario. The existing culvert allows Louise Lake to flow in a south to north direction under Highway 641. At each end of the culvert is open water of Louise Lake. Highway 641 generally runs in an east-west direction at the culvert site.

The Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on December 15, 2015 indicates that the existing structure is a single span corrugated steel elliptical culvert, approximately 18 m long and 3.8 wide. The inspection report indicated that the structure was built in 1975. The estimated culvert invert is at approximate Elevation 317.6 m at the inlet (south) and 317.5 m at the outlet (north). The existing road grade at the culvert location is at approximate Elev. 321.1 m, which indicates approximately 0.8 m of fill above the culvert.

The lands surrounding the culvert site predominantly consist of rural forested areas. Louise Lake is located immediately to the north and south of the culvert. Several residential properties are located along Hwy 641 both to the east and west of the culvert. Local topography is generally of low relief with hummocky or knobby bedrock outcrops.

Photographs of the culvert and surrounding areas are presented in Appendix C.

Based on published geological information, the culvert lies within glaciolucstrine plains of clay and silt deposits with glaciofluvial deltas of sand and gravel located within the vicinity of the culvert. Bedrock at the site is identified as gneissic tonalite to granodiorite.

3. INVESTIGATION PROCEDURES

The current site investigation and field testing program for this project was carried out in two phases; between March 14 and 19, 2018, and between May 26 and June 4, 2018. The field program consisting of drilling and sampling ten (10) boreholes (18-15 to 18-24) to depths of between approximately 5.5 m and 10.2 m below the existing ground or lake surface. Boreholes 18-15 to 18-23 were drilled near the locations of the proposed replacement culvert inlet and outlet, cofferdams, and roadway protection system. Borehole 18-24 was drilled through the paved portion of Highway 641 for the proposed roadway protection system.

The previous preliminary site investigation and field testing program for this project was carried out between March 15 and 18, 2017, and consisted of drilling and sampling seven (7) boreholes (17-01 to 17-07) to depths of between approximately 3.7 m and 10.0 m below existing ground

surface. Boreholes 17-01 to 17-03, and 17-05 to 17-07 were drilled through the paved portion of Highway 641. Borehole 17-04 was drilled near the inlet of the existing culvert and Borehole 17-01 was drilled as close as possible to the outlet of the culvert from atop the road embankment. Boreholes 17-05 to 17-07 were drilled to assess the existence and extent of any frost taper near the culvert.

The Record of Borehole sheets for the boreholes from the current and previous 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 D.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were estimated from the cross sections and topographic drawings provided to Thurber by WSP. The lake water surface and ice level elevations were based on the most recently available surveyed water levels provided on the topographic drawings. The coordinate system MTM NAD 83, Zone 17 was used for these boreholes.

A truck-mounted drill rig was used to advance the Borehole 18-24 using hollow stem augers. A portable Hilti drill and tripod equipment and a raft were used to advance Boreholes 18-15 to 18-23 using wash boring techniques, which included drilling on ice or water at Boreholes 18-15 to 18-22. Soil samples were obtained in the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). All of the boreholes from the current investigation were advanced into bedrock using an NQ core barrel. A Dynamic Cone Penetration Test (DCPT) was driven to cone refusal adjacent to Borehole 18-24.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed throughout the drilling operations and in the open boreholes upon completion of drilling. The boreholes were backfilled upon completion in general accordance with Ontario Regulation 903.

Completion details of the boreholes are summarized in Table 3.1.

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Table 3.1 – Borehole Completion Details

Borehole Number	Borehole Depth / Base Elevation (m)	Completion Details
18-15	6.2 / 311.8	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
18-16	8.6 / 309.2	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
18-17	7.8 / 310.0	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
18-18	6.9 / 310.9	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
18-19	6.0 / 311.8	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
18-20	7.9 / 310.1	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
18-21	7.1 / 310.9	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
18-22	5.5 / 312.5	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
18-23	5.5 / 312.4	Borehole backfilled with bentonite holeplug and auger cuttings to 0.3 m, then sand to surface.
18-24	10.2 / 310.9	Borehole backfilled with bentonite holeplug to 6.7 m, auger cuttings to 0.6 m, concrete to 0.3 m, then asphalt to surface.
17-01	7.7 / 313.4	Borehole backfilled with bentonite holeplug and auger cuttings to 0.4 m, then concrete to surface.
17-02	9.7 / 311.4	Borehole backfilled with bentonite holeplug, auger cuttings, then concrete to surface.
17-03	10.0 / 311.1	Borehole backfilled with bentonite holeplug, auger cuttings, then concrete to surface.
17-04	0.0 / 318.2	Auger refusal at surface using tripod equipment.

Borehole Number	Borehole Depth / Base Elevation (m)	Completion Details
17-05	3.7 / 317.3	Borehole backfilled with bentonite holeplug, auger cuttings, then concrete to surface.
17-06	3.7 / 317.4	Borehole backfilled with bentonite holeplug, auger cuttings, then concrete to surface.
17-07	3.7 / 317.5	Borehole backfilled with bentonite holeplug, auger cuttings, then concrete to surface.

4. LABORATORY TESTING

All 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 (sieve and/or hydrometer) and point load testing on bedrock, where appropriate. The results of this laboratory testing program are shown on the Record of Borehole sheets included in Appendix A and 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 native soil, and a sample of the surface water from the lake upstream of the existing culvert were collected during the previous investigation 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

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the Borehole Locations and Soil Strata drawings included in Appendix D. 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 must be recognized and expected that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered below the existing embankment fill consisted

of mainly sand to silty sand, with discontinuous deposits of gravelly sand and silty clay overlying granodiorite bedrock. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes 17-01 to 17-03, 17-05 to 17-07, and 18-24 were drilled through the paved portion of Highway 641. The asphalt was approximately 50 mm thick in all boreholes drilled in the paved portion, except at Borehole 18-24, where it was 300 mm thick. The asphalt extended to Elevations from 320.8 to 321.1 m.

5.2 Embankment Fill

Embankment fill beneath the asphalt was encountered in Boreholes 17-01 to 17-03, 17-05 to 17-07, and 18-24. Where fully penetrated, the fill extended to depths ranging from 4.1 to 5.3 m (Elev. 315.8 to 317.0 m). The fill consisted of predominantly sand to gravelly sand, containing trace to some silt, and was brown in colour. Underlying the granular fill, silty clay fill was also encountered in Boreholes 17-03, 17-05 to 17-07, and 18-24, and generally contained some sand, trace gravel, occasional organic material, and was grey in colour. A layer of cobble and boulder fill (possibly rock fill) was also encountered in Boreholes 17-01 to 17-03 and 18-24.

5.2.1 Sand to Gravelly Sand Fill

Gravelly sand to sand fill was encountered in Boreholes 17-01 to 17-03, 17-05 to 17-07, and 18-24 beneath the asphalt. The gravelly sand to sand fill typically extended to depths of approximately 1.5 m to 4.1 m below existing road surface (Elev. 317.0 to 319.7).

The SPT ‘N’ values of the sand to gravelly sand fill ranged from 9 to 30 blows for 0.3 m penetration, indicating a loose to dense relative density. Higher ‘N’ values were observed which ranged from 68 blows for 300 mm penetration to 100 blows for 50 mm penetration, and were likely a result of upper frozen material and larger gravel or cobble material. A DCPT conducted in Borehole 18-24 reached refusal of 100 blows per 0.3 m penetration at a depth of 3.2 m (Elev. 317.9 m) on possible cobbles within the fill. The measured moisture content ranged from 2% to 9% in the sand to gravelly sand fill.

The results of grain size analyses conducted on samples of the sandy to gravelly sand fill are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B1 of Appendix B. The results are summarized as follows:

Gravel %	11 to 27
Sand %	63 to 77
Silt and Clay %	7 to 14

5.2.2 Silty Clay Fill

Silty clay fill was encountered below the sand to gravelly sand fill in Boreholes 17-03, 17-05 to 17-07, and 18-24 at depths of approximately 1.5 m to 3.4 m (Elev. 317.7 to Elev. 319.7). The silty clay fill ranged in thickness from 1.2 m up to 2.2 m and extended to depths of approximately 3.7 to 4.6 m where fully penetrated or to the maximum drilled depth of 3.7 m in Boreholes 17-05 to 17-07. Sand pockets or seams were encountered in the silty clay fill in Boreholes 17-06 and 17-07. Occasional organic material was encountered within the silty clay fill.

The SPT 'N' values in the silty clay fill were 5 to 6 blows for 0.3 m penetration, indicating a firm consistency. Measured moisture contents in the silty clay fill ranged from 20% to 31%.

The results of grain size analyses conducted on samples of the silty clay fill are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B2 of Appendix B. The results are summarized as follows:

Gravel %	0 to 5
Sand %	10 to 46
Silt %	23 to 40
Clay %	26 to 57

The results of Atterberg Limits tests conducted on samples of the silty clay fill are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B6 of Appendix B. The results are summarized as follows:

Liquid Limit	38 to 40
Plastic Limit	16
Plasticity Index	22 to 23

The results of the Atterberg Limits testing indicate that the silty clay has an intermediate plasticity with group symbol CI.

5.2.3 Cobbles and Boulders Fill (Possibly Rock Fill)

A layer of cobbles and boulders (possibly rock fill) was encountered at the base of the embankment fill in Borehole 18-24. High DCPT values adjacent to Boreholes 17-02 and 17-03 as well as grinding observed during drilling in Boreholes 17-01 to 17-03 are also indicators of the presence of cobbles and boulders or rock fill. The deposit was countered at depths of between 3.7 m and 4.6 m below the existing road surface. The thickness of this layer ranged from 0.4 to 0.7 m, with the base of the layer extending to depths of 4.1 to 5.3 m (Elev. 315.8 to 317.0 m). Cobbles and boulders were also observed at the surface of the inlet and outlet of the existing culvert and prevented auger advancement in Borehole 17-04.

5.3 Organic Material / Lakebed Deposits

Boreholes 18-15, 18-17 to 18-19, and 18-22 encountered a layer of organic lakebed material below the lake water. The organic material ranged in thickness from 0.7 to 0.8 m and extended to depths from 1.4 to 2.1 m (Elev. 315.7 to 316.4 m). Where measured, the organic material was loose, based on an SPT 'N' value of 4 blows per 0.3 m penetration in Borehole 18-15. Samples of the organic lakebed material were not successfully recovered during the drilling process, due to the loose, underwater nature of the material.

A layer of peat was also encountered at a depth of 1.4 m in Borehole 18-23, which was buried by possible fill or recent alluvial lakebed deposits. The peat was 1.5 m thick and underlain by bedrock at a depth of 2.9 m (Elev. 315.1 m). The peat was very soft, based on SPT 'N' values of 2 blows per 0.3 m penetration. Measured moisture contents in the pear ranged from 110 to 171%.

5.4 Silty Clay

A layer of sandy, silty clay with trace gravel was encountered below the water and a thin veneer of sand in Boreholes 18-20 and 18-21. The silty clay was 0.9 to 1.5 m thick and extended to depths from 2.6 to 2.9 m (Elev. 315.1 to 315.4 m).

The silty clay was very soft to stiff, based on SPT 'N' values from 1 to 9 blows per 0.3 m penetration. Measured moisture contents in the silty clay ranged from 34 to 60%.

The results of grain size analyses conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B3 of Appendix B. The results are summarized as follows:

Gravel %	2 to 5
Sand %	22 to 32
Silt %	29 to 39
Clay %	27 to 44

5.5 Sand to Silty Sand

A deposit of sand to silty sand containing some silt to silty, trace clay to clayey, and trace gravel to gravelly was encountered beneath the embankment fill in Boreholes 17-01 to 17-03 and 18-24, beneath the surficial and lakebed deposits in Boreholes 18-15 to 18-19, 18-22 and 18-23. Occasional boulders and sand and gravel layers were encountered within this deposit. The thickness of this deposit ranged from 0.6 m to 4.6 m and extended to depths from 1.4 m to 7.7 m (Elev. 312.2 to Elev. 316.6 m).

SPT 'N' values recorded in the sand to silty sand ranged between 1 to 42 blows for 0.3 m penetration, indicating a loose to dense relative density (typically compact to dense). Higher SPT 'N' values of greater than 100 blows per 0.3 m penetration were also encountered due to the presence of boulders and near the interface with the underlying bedrock. Measured moisture contents in the sand to silty sand ranged from 6% to 89%.

The results of grain size analyses conducted on samples of the sand to silty sand are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B4 of Appendix B. The results are summarized as follows:

Gravel %	0 to 21
Sand %	54 to 81
Silt %	15 to 24
Clay %	3 to 18
Silt and Clay %	12 to 21

5.6 Gravelly Sand

A 0.8 m thick layer of gravelly sand with some cobbles was encountered at the ground surface in Borehole 18-23, extending to Elev. 317.2 m. The layer may have been fill or recent alluvial material.

A 1.0 to 1.6 m thick layer of gravelly sand with trace to some silt was also encountered above the bedrock in Boreholes 18-15, 18-20 and 18-21, which extended to depths from 3.5 m to 4.5 (Elev. 313.5 to 314.5 to m). The gravelly sand was loose to very dense based on SPT 'N' values of 9 to

61 blows per 0.3 m penetration. Measured moisture contents in the gravelly sand ranged from 8% to 19%.

The results of grain size analyses conducted on samples of the gravelly sand are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B5 of Appendix B. The results are summarized as follows:

Gravel %	13 to 24
Sand %	61 to 75
Silt and Clay %	12 to 15

5.7 Bedrock

Granodiorite bedrock was encountered below the overburden deposits in Boreholes 17-02, 17-03 and 18-15 to 18-24. Auger refusal on probable bedrock also occurred in Borehole 17-01.

The depth to bedrock is summarized in Table 5.1 below:

Table 5.1 – Summary of Bedrock Surface Depths / Elevations

Location	Borehole	Bedrock Surface	
		Depth (m)	Elevation (m)
Below Highway Embankment	17-01*	7.7	313.4
	17-02	6.7	314.4
	17-03	7.0	314.1
	18-24	7.4	313.7
Culvert Inlet	18-15	3.5	314.5
	18-20	4.5	313.5
	18-21	3.6	314.4
	18-22	3.4	314.6
	18-23	2.9	312.4
Culvert Outlet	18-16	5.6	312.2
	18-17	5.5	312.3
	18-18	5.6	312.2
	18-19	4.5	313.3

* Bedrock depth estimated from drill refusal in Borehole 17-01

The bedrock was proven in Boreholes 17-02, 17-03 and 18-15 to 18-24 by coring approximately 3 m in the majority of the boreholes.

The bedrock is generally described as moderately to slightly weathered and grey. Total Core Recovery (TCR) in the bedrock ranged from 77% to 100% with Solid Core Recovery (SCR)

ranging from 63% to 100%. The Rock Quality Designation (RQD) determined from the recovered cores generally ranged from 26% to 100%, indicating a highly variable poor to excellent rock quality. RQD values under 25% (very poor quality) were also recorded at highly broken / rubble zones in the bedrock. Average unconfined compressive strengths (UCS) of the rock ranged between 32 MPa to 424 MPa based on correlations with the point load tests (PLT) on solid rock cores indicating the rock varies from medium strong to extremely strong. Photographs of the bedrock core samples are included in Appendix B.

5.8 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. The groundwater level should be assumed to reflect the local lake water level. Water level measurements in the lake were reported on the MTO Site Plan Drawing, E-505-641-1, which reported measurements of Elev. 317.99 at the inlet and 317.84 at the outlet in May 2016. These lake level elevations were also used to reflect the lake level at the boreholes drilled on water or ice near the culvert inlet (Boreholes 18-15, 18-20 to 18-22), and outlet (Boreholes 18-16 to 18-19).

The groundwater levels measured in the open boreholes drilled on land are summarized in Table 5.2 below.

Table 5.2 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
18-23	March 19, 2018	0.0	318.0	Open borehole
18-24	March 14, 2018	Not recorded due to addition of coring water		
17-01	March 16, 2017	4.7	316.4	Open borehole
17-02	March 18, 2017	Not recorded due to addition of coring water		
17-03	March 15, 2017	4.8	316.3	Open borehole (prior to rock coring water added)
17-04	March 18, 2017	Dry	-	Open borehole
17-05	March 16, 2017	Dry	-	Open borehole
17-06	March 15, 2017	Dry	-	Open borehole
17-07	March 15, 2017	Dry	-	Open borehole

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

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the gravelly sand fill and silty clay fill from Boreholes 17-01 and 17-03, respectively, and a sample of the surface water from the Lake 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		
			17-01 SS#3 2.4 m	17-03 SS#3 2.4 m	Louise Lake
			(Gravelly Sand FIll)	(Silty Clay Fill)	(Lake Water)
Sulphide	%	mg/L	<0.02	<0.02	0.007
Chloride	µg/g	mg/L	18	75	3.1
Sulphate	µg/g	mg/L	3.3	27	1.6
pH	-	-	9.41	8.56	7.46
Conductivity	µS/cm	µS/cm	96	235	56
Resistivity	Ohms.cm	Ohms.cm	10400	4260	17700
Redox Potential	mV	mV	249	237	239

7. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to drilling. The northing and easting coordinates and ground surface elevations were estimated based on field measurements relative to the topographic plans provided by WSP.

OGS Inc. of Almonte, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the current field investigation. The field investigation was supervised on a full time basis by Mr. Jilesh Patel of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. of Thurber.

Geotechnical laboratory testing was carried out in Thurber's geotechnical laboratory. Analytical laboratory testing was carried out by SGS Canada Inc.

Interpretation of the field data and preparation of this report was carried out by 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 design of the proposed Louise Lake Culvert replacement on Highway 641, located in the Township of Pellat, District of Kenora, Ontario. This detailed foundation report should be read in conjunction with the Preliminary Foundation Investigation and Design Report dated October 2, 2017.

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 contractor 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, the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on December 15, 2015, and drawings provided by WSP. The existing structure is a single span corrugated steel elliptical culvert. The culvert measures 3.8 m wide and is approximately 18 m long. The estimated culvert invert is at approximate Elevation 317.6 m at the inlet (south) and 317.5 m at the outlet (north). The existing road grade at the culvert location is at approximate Elev. 321.1 m, which indicates approximately 0.8 m of fill above the culvert.

The preliminary foundation investigation and design report provided geotechnical

recommendations for both pipe and box culvert options. General Arrangement drawings provided by WSP indicate that a single Structural Plate Corrugated Steel Pipe (SPCSP) elliptical culvert is the preferred replacement option. The new pipe will have a 5.283 m span and a 3.531 m rise, with invert levels (underside of the pipe) at approximate Elevations of 316.58 and 316.53 m at the inlet and outlet respectively. The new pipe will be installed 8.5 m to the east of the existing culvert, and the existing culvert will be used as temporary diversion pipe while the new pipe is being installed. A temporary roadway protection system is to be installed between the existing culvert and the replacement culvert to protect the existing pipe during excavation for the new pipe. A traffic detour route is planned in order to allow for the replacement culvert is to be constructed during a temporary full road closure of Highway 641. The new pipe will be 27.88 m long and will include a 250 mm grade raise and widening of the embankment at the new culvert alignment. No headwalls or wingwalls are proposed for the culvert replacement.

9. CULVERT FOUNDATION DESIGN

In general, the subsurface conditions encountered in the boreholes consisted of embankment fill comprising sand to silty sand and silty clay, overlying a fill layer of cobbles and boulders (possible rock fill), underlain by loose to compact sand to silty sand and bedrock. The water level in the lake was measured at approximately Elev. 318 m in May 2016.

The founding soils encountered at the proposed culvert invert level (approx. Elev. 316.5 m) consist of cobble and boulder fill (possible rock fill) underlain by loose to compact native sand to silty sand. The culvert subgrade will be below the lake level. Organic lakebed deposits are also expected near the culvert inlet and outlet, beyond the existing embankment footprint. Foundation design aspects for the replacement culvert include subgrade conditions and preparation, settlement of founding soils, lateral earth pressures, roadway protection system design, groundwater control, cofferdams, and restoration of the roadway embankment.

The preliminary foundation investigation and design report provided foundation recommendations for different types of culverts, which are not repeated herein, however these recommendations where relevant may be used for detailed design.

9.1 Foundations

Replacement of the culvert with an elliptical SPCSP on an off-set alignment to the east is being considered for this site. A 250 mm grade raise and widening of the embankment at the inlet and outlet of the culvert are proposed.

The elliptical 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 Ontario Provincial Standard Drawing (OPSD) OPSD 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation and placement and compaction of bedding must be carried out in the dry. It is anticipated, however, that dewatering in the lake environment may not be fully effective at this site. Accordingly, recommendations for construction in the wet are provided in Section 13.

The underside of the bedding layer should be placed at or below Elevation 316.2 m, which corresponds to loose to compact native sand to silty sand subgrade in the location of the existing culvert. Existing cobble and boulder embankment fill may also be encountered at this elevation. Any silty clay fill, excessively large cobbles and boulders (possibly rock fill), and any soft, very loose, organic, or other detritus material (including organic lakebed material) should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

9.2 Frost Cover

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

Boreholes 17-05 to 17-07 were drilled to investigate the presence of an existing frost taper. The boreholes found the presence of 1.5 to 1.8 m of granular fill overlying silty clay fill to at least 15 m west and 30 m east of the centreline of the existing culvert. It is not known whether the granular fill material was intentionally placed as a frost taper, or as road embankment and base material.

The silty clay fill and the native sand to silty sand underlying the granular fill have low to moderate frost susceptibility. As the frost penetration line is below the top of the replacement culvert, frost treatment/taper for the culvert should be provided as per OPSD 803.031.

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, peat, organic lakebed deposits, disturbed soils and any deleterious materials within the replacement

culvert footprint must be removed and replaced with OPSS.PROV 1010 Granular B, Type II 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, subgrade preparation and placement and compaction of granular material must be carried out in the dry.

Due to the anticipated difficulty in dewatering adjacent to the lake, where the water level is approximately 1 to 1.5 m above the proposed culvert invert level, consideration may be given to using rockfill to replace sub-excavated areas below the groundwater level. Section 13 provides recommendation for construction in the wet.

9.4 Settlement

As the replacement culvert will be located to the east of the existing culvert, the installation of a pipe through the embankment will result in net unloading of the foundation soils. Since the foundation soils consist of loose to compact sand and silty sand, with only a grade raise of 250 mm, very little post construction settlement is expected at this site. The placement of additional fill to widen the embankment and flatten the side slopes will induce additional settlement, as discussed in Section 16.

10. LATERAL EARTH PRESSURES

Lateral earth pressures acting on any culvert walls or retaining walls, if employed, may be assumed to be a triangular distribution for design. 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) (use submerged unit with below lake level)

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 coefficient values are shown in Table 10.1 below.

Table 10.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35°$; $\gamma = 22.8$ kN/m^3; $\gamma_{submerged} = 12.8$ kN/m^3		OPSS Granular B Type I $\phi = 32°$; $\gamma = 21.2$ kN/m^3; $\gamma_{submerged} = 11.2$ 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 lake level.

For rigid structures, at-rest horizontal earth pressures should be used for design. Active pressures should be used for any unrestrained wall. Full hydrostatic pressure should be used below the lake level.

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 decreasing 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.

11. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site class is based on the soil conditions encountered in the upper 30 m of the stratigraphy. In view of the presence of shallow granodiorite bedrock on site, the site can be classified as Site Class C in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2,475-year return period seismic event at this site is 0.037 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 11.1 may be used:

Table 11.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or Granular B Type II $\phi = 35°$, $\gamma = 22.8$ kN/m^3; $\gamma_{submerged} = 12.8$ kN/m^3	**OPSS Granular B Type I $\phi = 32°$, $\gamma = 21.2$ kN/m^3; $\gamma_{submerged} = 11.2$ kN/m^3**	**Existing Fill $\phi = 30°$; $\gamma = 20$ kN/m^3; $\gamma_{submerged} = 10$ kN/m^3**
Active (K_{AE})*	0.29	0.32	0.35
Passive (K_{PE})	3.6	3.2	3.0
At Rest (K_{OE})**	0.48	0.52	0.55

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

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

12. CULVERT BACKFILL

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, as appropriate. Backfilling for the culvert should be in accordance with OPSS.PROV 421 for a CSP. All fills should be placed and 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.

13. 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, native sand and silty 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 and any cohesionless soils 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. Excavation for culvert replacement will be carried out through the existing embankment fill and extended into the native sand to silty sand deposit. It must be noted that obstructions may be encountered within the fill, such as the cobble and boulder 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 seepage should also be anticipated from the embankment fill. The water level must be depressed below the base of the culvert excavation to permit construction in the dry and to facilitate compaction of the bedding and backfill materials.

It will be necessary to construct cofferdams and to employ active dewatering to depress the water level in the culvert footprint area. Driving of sheet piles for a cofferdam may be difficult due to the presence of the cobble and boulder layer (possible rock fill) in the fill, and the relatively shallow bedrock surface near the culvert inlet and outlet. Recommendations for cofferdams are provided in Section 14 below. The dewatering scheme must be effective to maintain the groundwater level at a depth of at least 0.5 m below the final subgrade level to avoid base boiling in the native soils.

The design of a dewatering system 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 and SP517F01. A preconstruction survey is not required, thus Designer Fill-In ****** in SP FOUN003 should be “N/A”. Considering the conditions on site, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing systems of similar nature and scope to the required work is required, and thus Designer Fill-In ***** in SP517F01 should be “Yes”.

Suggesting 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 are highly permeable and granular. 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).

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, fully 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.

14. COFFERDAMS

Construction of cofferdams will be required to construct the culvert replacement in the dry. Since the subsurface soil conditions consist of highly permeable granular soils, underlain by relatively shallow and strong to extremely strong bedrock, an interlocking sheet pile cofferdam system is not a feasible option. Therefore, it is anticipated that pumping from within sand bag cofferdams will be required.

If pumping within the sand bag cofferdams is not effective to lower the water table to the desired level, then consideration may be given to constructing in the wet, as described in Section 13 above.

15. TEMPORARY PROTECTION SYSTEM

A temporary protection system is proposed between the existing culvert and the replacement culvert to protect the existing pipe during excavation for the new pipe. The temporary roadway protection system should be implemented in accordance with OPSS PROV 539 and designed for Performance Level 2.

Based on Boreholes 17-01 and 18-24, which were drilled on the existing highway embankment along the approximate alignment of the protection system, the subsurface conditions anticipated during installation of the protection system include gravelly sand, silty clay, and cobble and boulder embankment fill, underlain by native sand to silty sand. Options for roadway protection include a drilled-in soldier pile-lagging system, interlocking sheet piles, a sand bag gravity wall, or an open cut excavation. Due to the presence of cobbles and boulders in the fill, and the presence of relatively shallow strong to extremely strong bedrock, it may be difficult to drive sheet piles at this site. The sheet pile penetration may also not be deep enough for roadway protection, and therefore is not considered to be a feasible option. An open cut excavation would require 3H:1V side slopes below the groundwater level. Since there is only approximately 3.5 m of separation between the closest outside edges of the existing culvert and the new culvert, there will likely not be sufficient space for an open cut excavation while installing the new pipe. Therefore, a drilled-in soldier pile-lagging system, or a sand bag gravity wall system are anticipated to be the most feasible temporary protection system options.

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

The soil parameters in Table 15.1 may apply for design of the temporary roadway protection system with horizontal backfill.

Table 15.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Sand Fill	Silty Clay Fill	Sand to Silty Sand	Cobbles / Boulders or Rock Fill
γ (total unit weight)	20 kN/m^3	19 kN/m^3	20 kN/m^3	19 kN/m^3
γ' (submerged unit weight)	10 kN/m^3	9 kN/m^3	10 kN/m^3	9 kN/m^3
K_a	0.33	0.4	0.33	0.24 kN/m^3
K_p	3.0	2.5	3.0	4.2 kN/m^3

16. EMBANKMENT RESTORATION

The existing Highway 641 embankment is approximately 3.0 to 4.0 m in height at the culvert location. The existing embankment slopes side slopes are steep (1H:1V) and are exhibiting signs of erosion. Therefore, widening of the embankment is proposed to flatten the side slopes to 2H:1V. Provided that the embankment is reconstructed not steeper than 2H:1V, the restored embankment slopes should remain stable.

The placement of additional fill to widen the embankment and flatten the side slopes will induce settlement. The foundations soils in the embankment widening footprint generally consist of loose to compact 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 and OPSS.PROV 209. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material. 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 and in accordance with OPSD 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 concrete cut-off wall or clay seal should be used to minimize the potential for erosion or piping around the culvert. The clay seal should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS.PROV 1205. A geo-synthetic clay liner may be used in place of a compacted clay seal.

18. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the gravelly sand fill, silty clay fill and lake water indicates the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding soil and surface water is considered to be negligible due to the low concentrations of sulphate and chloride in the samples tested. However, the impact of road salt should be considered when selecting the class of concrete.
- The potential for soil or surface water corrosion on metal is considered to be mild to moderate. However, the impact of road salt on corrosion should be considered.
- Appropriate protection measures are recommended if metal structural elements are used. Corrosive effectives of road salts should be considered.

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 in the dry and prevent sloughing and instability of the excavation walls.
- The water level in the lake may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- Cobbles and boulders were encountered in the embankment fill; therefore, cobbles and boulders should be anticipated and dealt with during construction. These materials may interfere with the excavation, sheet pile and cofferdam installation. The Contractor must be prepared to remove or otherwise penetrate these obstructions. 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. 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.

Mark Farrant, P.Eng.
Geotechnical Engineer

P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact

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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

C_{pen} 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

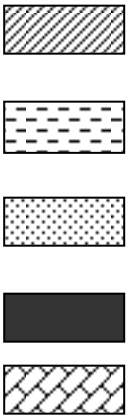
MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, 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

ROCK WEATHERING CLASSIFICATION

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

SYMBOLS



CLAYSTONE

SILTSTONE

SANDSTONE

COAL

Bedrock (general)

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
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.

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	(psi)	Field Estimation of Hardness*
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

THURBER

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RECORD OF BOREHOLE No 18-15 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 026.5 E 402 318.9 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.18 - 2018.03.18 LATITUDE 49.77389616 LONGITUDE -94.64600622 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
318.0	GROUND SURFACE							20 40 60 80 100	20 40 60		
0.0 317.5	**ICE**										
0.5 317.1	**WATER**										
0.9 316.4	**ORGANICS:** LAKEBED DEPOSITS Loose Wet (No recovery)		1	SS	4		317				
1.6 315.6	Silty **SAND**, some clay to clayey, trace gravel Loose Grey Wet		2	SS	5		316		○		4 54 24 18
2.4 314.5	Gravelly **SAND**, trace silt Compact to Very Dense Grey Wet		3	SS	22		315		○		
			4	SS	50/ 0.050				○	Fl	
3.5	**GRANODIORITE**, moderately to slightly weathered, grey, extremely strong sub horizontal fracture (75mm) at 3.5m, (100mm) at 3.7m and 3.8m		1	RUN			314			5 2	RUN #1 TCR=100% SCR=100% RQD=0% UCS=268MPa
	horizontal break at 4.0m, 4.1m, 4.2m, 4.3m, 4.5m, 4.6m, 4.8m and 5.0m		2	RUN						4 2	RUN #2 TCR=100% SCR=100% RQD=69% UCS=424MPa
	vertical break (75mm) at 5.0m						313			2	
	horizontal break at 5.0m, 5.5m, 5.6m, 5.7m, 5.8m, 5.9m, 6.0m and 6.1m		3	RUN						0 2 5	RUN #3 TCR=100% SCR=100% RQD=50% UCS=403MPa
311.8	sub horizontal break (150mm) at 6.1m						312			2	
6.2	END OF BOREHOLE AT 6.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20
15 5
10
(%) STRAIN AT FAILURE

ONTMT4S2 MTO-22155.GPJ 2017TEMPLATE(MTO).GDT 8/3/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-16 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 050.6 E 402 323.7 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.05.31 - 2018.05.31 LATITUDE 49.77411238 LONGITUDE -94.64593246 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
317.8	GROUND SURFACE										
0.0 / 317.1	**WATER**										
0.7 / 315.9	**SAND**, some silt, some gravel, trace clay Very Loose to Dense Grey Wet		1	SS	1		317		89		
			2	SS	35		316				10 66 15 9
1.9 / 315.3	**SAND** and **GRAVEL** Compact Grey Wet		3	SS	29						
2.5 / 312.5	Silty **SAND**, trace gravel, trace clay Loose to Compact Grey Wet		4	SS	8		315				
			5	SS	10						
			6	SS	24		314				6 70 20 4
							313				
5.3 / 312.2	Sandy **GRAVEL**, trace silt, some cobbles Very Dense Grey Wet		7	SS	100/ 0.025						
5.6			1	RUN			312			FI	RUN #1 TCR=94% SCR=94% RQD=69%
	GRANODIORITE, moderately to slightly weathered, grey, very strong horizontal fractures at 5.7m, 5.9m and 6.0m horizontal fractures at 6.1m, 6.3m, 6.4m, 6.5m and 6.6m sub horizontal fracture (50mm) at 6.3m, (25mm) at 6.4m and (50mm) at 6.6m horizontal fractures at 7.1m, 7.2m, 7.5m, 7.7m and 7.8m sub horizontal fracture (150mm) at 7.5m and (25mm) at 7.8m horizontal fractures at 7.9m, 8.1m, 8.2m, 8.3m and 8.4m sub horizontal fracture (25mm) at 8.3m		2	RUN						6 7 5	RUN #2 TCR=96% SCR=96% RQD=36%
			3	RUN			311			5 3	RUN #3 TCR=100% SCR=100% RQD=21%
			4	RUN						>10	RUN #4 TCR=94% SCR=94% RQD=26%
							310			>10	
			5	RUN						4 4	RUN #5 TCR=97% SCR=97% RQD=68%
309.2											
8.6	END OF BOREHOLE AT 8.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

+ ³, × ³: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

ONTMT4S2 MTO-22155.GPJ 2017TEMPLATE(MTO).GDT 8/3/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-17 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 055.5 E 402 324.7 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.06.02 - 2018.06.02 LATITUDE 49.77415625 LONGITUDE -94.64591731 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
317.8	GROUND SURFACE										
0.0 317.0	**WATER**						317				
0.8 316.2	**ORGANICS:** LAKEBED DEPOSITS Wet (No recovery)										
1.6	**SAND**, some silt to silty, some gravel, trace clay Compact to Dense Grey Wet		1	SS	18		316		○		17 71 12 (SI+CL)
			2	SS	14		315		○		
			3	SS	12				○		
			4	SS	36		314		○		
312.3			5	SS	100/		313			FI	
5.5	**GRANODIORITE**, moderately weathered, grey, very strong to strong vertical fracture (50mm) at 5.5m horizontal fractures from 5.6m to 6.0m sub horizontal fracture (125mm) at 5.7m horizontal fractures from 6.0m to 6.7m rubble zone (50mm) at 6.2m and (75mm) at 6.6m vertical fracture (50mm) at 6.5m sand seam (25mm) at 6.9m horizontal fractures from 7.1 and 7.4m rubble zone (100mm) at 7.3m vertical fracture at (50mm) at 7.4m		1	RUN	0.075		312			>10 >10	RUN #1 TCR=100% SCR=100% RQD=0%
			2	RUN						>10 >10 >10	RUN #2 TCR=82% SCR=82% RQD=12% UCS=178MPa (Average)
			3	RUN			311			>10 >10	RUN #3 TCR=92% SCR=92% RQD=0%
			4	RUN						>10	UCS=168MPa (Average)
310.0							310				RUN #4 TCR=88% SCR=88% RQD=0% UCS=99MPa (Average)
7.8	END OF BOREHOLE AT 7.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.									5	

+ ³, × ³: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

ONTMT4S2 MTO-22155.GPJ 2017TEMPLATE(MTO).GDT 8/3/18

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Ontario

THURBER

RECORD OF BOREHOLE No 18-18 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 053.8 E 402 328.4 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.06.04 - 2018.06.04 LATITUDE 49.77414015 LONGITUDE -94.64586656 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
317.8	GROUND SURFACE										
0.0 / 317.1	**WATER**										
0.7 / 316.4	**ORGANICS:** LAKEBED DEPOSITS Wet (No recovery)						317				
1.4	Silty **SAND**, some gravel to gravelly, trace clay, occasional cobbles Compact to Dense Grey Wet		1	SS	25		316		○		
			2	SS	19		315		○		
			3	SS	11		314				
313.5			4	SS	42				○		21 58 21 (SI+CL)
4.3 / 312.6	**BOULDER**						313				
5.2 / 312.2			5	SS	100/ 0.075					FI	RUN #1 TCR=100% SCR=100% RQD=100% UCS=104MPa (Average)
5.6	**GRANODIORITE**, moderately weathered, grey, medium to very strong horizontal fractures from 5.8m to 6.2m and 6.4m vertical fracture (25mm) at 6.0m sub horizontal fracture (25mm) at 6.3m sand seam (25mm) at 6.3m horizontal fractures at 6.4m, 6.6m and 6.7m		1	RUN			312			0	
			2	RUN						7	RUN #2 TCR=77% SCR=77% RQD=0% UCS=76MPa (Average)
			3	RUN						4	
310.9			4	RUN			311			4	RUN #3 ~~TCR=100%~~ SCR=100% RQD=37% UCS=38MPa (Average)
6.9	sub horizontal fracture (125mm) at 6.8m END OF BOREHOLE AT 6.9m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.									3	RUN #4 TCR=100% SCR=100% RQD=0% UCS=212MPa (Average)

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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THURBER

RECORD OF BOREHOLE No 18-19 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 055.5 E 402 319.5 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.06.01 - 2018.06.01 LATITUDE 49.77415694 LONGITUDE -94.64598981 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
317.8	GROUND SURFACE										
0.0	**WATER**										
316.5							317				
1.3	**ORGANICS:** LAKEBED DEPOSITS Wet										
315.7	(No recovery)						316				
2.1	Silty **SAND**, some gravel to gravelly, trace clay, occasional cobbles Dense Grey Wet		1	SS	36				○		
	Loose		2	SS	4		315		○		
	Compact		3	SS	20		314		○		17 63 20 (SI+CL)
313.3			4	SS	100/0.075						
4.5	**GRANODIORITE**, moderately to slightly weathered, grey, very strong horizontal fracture at 4.5m, 4.6m, 4.8m, 4.9m and 5.1m		1	RUN			313			FI 2 4	RUN #1 TCR=92% SCR=92% RQD=65% UCS=182MPa (Average)
	horizontal fracture at 5.2m, 5.7m and 5.8m sub horizontal fracture (100mm) at 5.7m and (125mm) at 5.9m rubble zone (75mm) at 5.8m		2	RUN						1 1 >10	RUN #2 TCR=94% SCR=94% RQD=61% UCS=104MPa (Average)
311.8							312				
6.0	END OF BOREHOLE AT 6.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE
10

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Ontario

THURBER

RECORD OF BOREHOLE No 18-20 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 020.7 E 402 322.8 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.17 - 2018.03.17 LATITUDE 49.77384398 LONGITUDE -94.645953 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
318.0	GROUND SURFACE										
0.0	**ICE**										
317.2							317				
0.8	**WATER**										
316.6							316				
1.4	Silty **CLAY**, sandy, trace gravel Soft to Stiff Grey Moist		1	SS	2				○		2 32 39 27
			2	SS	9				○		
315.1							315				
2.9	Gravelly **SAND**, trace silt Very Dense Grey Wet boulder at 3.2m		3	SS	61				○		13 75 12 (SI+CL)
	Compact		4	SS	13		314		○		
313.5			5	SS	100/				○	FI	RUN #1
4.5	**GRANODIORITE** moderately to slightly weathered, grey, very to extremely strong		1	RUN	0.050					0	TCR=100% SCR=100% RQD=0%
	vertical fracture (75mm) at 4.5m		2	RUN			313			6	
	horizontal break at 4.6m, 4.7m, 4.8m, 4.9m, 5.1m, 5.2m and 5.3m									4	RUN #2 TCR=100% SCR=100% RQD=29% UCS=225MPa (Average)
	vertical break (25mm) at 4.6m, (125mm) at 4.9m and 5.6m		3	RUN			312			3	
	horizontal break at 5.7m, 5.8m, 6.0m and 6.5m									1	
										2	RUN #3 TCR=88% SCR=79% RQD=43% UCS=298MPa (Average)
	sub horizontal fracture (50mm) at 7.2m		4	RUN			311			4	
	horizontal break at 7.4m and 7.5m									8	
310.1										4	
7.9	END OF BOREHOLE AT 7.9m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										RUN #4 TCR=100% SCR=100% RQD=88%

$+^3$, $\times^3$: Numbers refer to Sensitivity

20
15 5
10
(%) STRAIN AT FAILURE

ONTMT4S2 MTO-22155.GPJ 2017TEMPLATE(MTO).GDT 8/3/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-21 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 020.6 E 402 317.7 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.05.26 - 2018.05.26 LATITUDE 49.77384349 LONGITUDE -94.64602423 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
318.0	GROUND SURFACE							20 40 60 80 100	20 40 60		
0.0 316.5	**WATER**						317				
316.3 1.7 315.4	**SAND**, trace gravel Wet Silty **CLAY**, sandy, trace gravel Very Soft to Stiff Grey Wet		1 2	SS SS	1 9		316				5 22 29 44
2.6 314.4	Gravelly **SAND**, some silt Loose to Dense Grey Wet		3	SS	38		315			FI	24 61 15 (SI+CL)
3.6	**GRANODORITE** moderately to slightly weathered, grey, very strong horizontal fracture at 3.5m, 3.6m, 3.7m and 4.2m sub horizontal fracture (25mm) at 3.7m, (50mm) at 3.9m, 4.1m, (25mm) at 4.3m, 4.4m rubble zone (150mm) at 4.0m horizontal fracture at 4.4m horizontal break at 4.5m sub horizontal break (125mm) at 4.6m horizontal breaks at 5.5m and 5.9m horizontal break at 6.5m		1 2 3 4 5	RUN RUN RUN RUN RUN			314 313 312			4 >10 6 4 0 1 0	RUN #1 TCR=89% SCR=89% RQD=51% UCS=175MPa (Average) RUN #2 TCR=100% SCR=100% RQD=35% UCS=117MPa (Average) RUN #3 TCR=100% SCR=100% RQD=100% UCS=203MPa (Average) RUN #4 TCR=100% SCR=100% RQD=100% UCS=149MPa (Average) RUN #5 TCR=100% SCR=100% RQD=85%
310.9 7.1	END OF BOREHOLE AT 7.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.						311				UCS=165MPa (Average)

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

ONTMT4S2 MTO-22155.GPJ 2017TEMPLATE(MTO).GDT 8/3/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-22 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 022.6 E 402 313.0 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.16 - 2018.03.16 LATITUDE 49.77386197 LONGITUDE -94.6460888 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
318.0	GROUND SURFACE							20 40 60 80 100	20 40 60		
0.0	**WATER**										
316.6							317				
1.4	**ORGANICS:** LAKEBED DEPOSITS Wet										
315.9	(No recovery)						316				
2.1	Silty **SAND**, some gravel Compact Grey Wet		1	SS	21				○		
			2	SS	100/ 0.075		315		○		
314.6										FI	
3.4	**GRANODORITE** moderately to slightly weathered, grey, very strong horizontal fractures at 2.5m, 2.7m and 2.8m		1	RUN					○	0 2	RUN #1 TCR=100% SCR=100% RQD=59% UCS=119MPa (Average)
	sub horizontal fracture (125mm) at 2.5m, (50mm) at 2.7m		2	RUN			314			>10 0	RUN #2 TCR=100% SCR=100% RQD=100%
	horizontal breaks at 3.8m, 4.0m and 4.1m sub horizontal break (275mm) at 3.8m		3	RUN			313			0 2	RUN #3 TCR=100% SCR=100% RQD=66%
312.5										2	
5.5	END OF BOREHOLE AT 5.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

+ ³, × ³: Numbers refer to Sensitivity

20
15 5
10
(%) STRAIN AT FAILURE

ONTMT4S2 MTO-22155.GPJ 2017TEMPLATE(MTO).GDT 8/3/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-23 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 028.4 E 402 314.2 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Wash Boring/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.19 - 2018.03.19 LATITUDE 49.77391464 LONGITUDE -94.64607079 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
318.0	GROUND SURFACE										
0.0	Gravelly **SAND**, some cobbles Grey Wet (Possible FILL)										
317.2							317				
0.8	Silty **SAND**, some gravel Compact Grey Wet (Possible FILL)		1	SS	13						
316.6							316				
1.4	**PEAT**, trace sand Very Soft Brown Wet		2	SS	2				110		
			3	SS	2				171		
315.1							315				
2.9	**GRANODIORITE**, slightly weathered, grey, extremely weathered horizontal breaks at 3.1m, 3.5m, 3.8m, 3.9m and 4.1m		1	RUN							RUN #1 TCR=100% SCR=100% RQD=100% UCS=32MPa (Average)
			2	RUN			314				RUN #2 TCR=100% SCR=100% RQD=83% UCS=268MPa (Average)
			3	RUN							RUN #3 TCR=100% SCR=100% RQD=100% UCS=326MPa (Average)
			4	RUN			313				RUN #4 TCR=100% SCR=100% RQD=83% UCS=384MPa (Average)
312.4	horizontal breaks at 5.2m, 5.3m, 5.4m and 5.7m										
5.6	END OF BOREHOLE AT 5.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, CUTTINGS TO 0.3m THEN SAND TO SURFACE.										

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

ONTMT4S2 MTO-22155.GPJ 2017TEMPLATE(MTO).GDT 8/3/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-24 1 OF 2 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 037.4 E 402 316.0 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.14 - 2018.03.14 LATITUDE 49.77399481 LONGITUDE -94.64604336 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
321.1	GROUND SURFACE								
0.0 / 320.8	**ASPHALT**						321		
0.3	Gravelly **SAND**, trace silt Dense to Compact Brown Moist (FILL)		1	SS	38				20 73 7 (SI+CL)
	some cobbles		2	SS	38		320		
			3	SS	26		319		
317.7			4	SS	50/ 0.050		318		
3.4	Silty **CLAY** Grey Wet (FILL)						317		
316.5									
4.6	**COBBLES** and **BOULDERS**, some sand and gravel Very Dense Grey Wet (FILL)		5	SS	50/ 0.125		316		
315.8									
5.3	Silty **SAND**, trace gravel, trace clay Compact Grey Wet		6	SS	16		315		
313.7							314		
7.4	**GRANODIORITE**, moderately weathered, grey, extremely to very strong horizontal fractures at 7.5m, 7.9m, 8.2m, 8.3m, 8.4m and 8.6m sub horizontal fractures (25mm) at 7.6m, (75mm) at 7.6m, at 7.7m, (50mm) at 7.8m and (25mm) at 8.0m		1	RUN			313	FI 5 7 3	RUN #1 TCR=100% SCR=100% RQD=43% UCS=318MPa (Average)
	sub horizontal fractures at (175mm) at 8.6m, (75mm) at 9.4m, (50mm) at 9.0m, (25mm) at 9.1m, 9.2m rubble zone (50mm) at 9.3m		2	RUN			312	5 4 5 <10 4	RUN #2 TCR=100% SCR=84% RQD=82% UCS=136MPa (Average) RUN #3
	horizontal fractures at 9.0m, 9.4m,								

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

+ ³, × ³: Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

ONTMT4S2 MTO-22155.GPJ 2017TEMPLATE(MTO).GDT 8/3/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-24 2 OF 2 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83-17 N 5 516 037.4 E 402 316.0 ORIGINATED BY JP

DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.14 - 2018.03.14 LATITUDE 49.77399481 LONGITUDE -94.64604336 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	Continued From Previous Page										
310.9	9.5m, 9.6m and 9.8m		3	RUN			311			4	TCR=100%
10.2	horizontal fractures at 9.9m, 10.0m and 10.1m										SCR=100% RQD=0%
	END OF BOREHOLE AT 10.2m. BOREHOLE OPEN TO 10.2m AND BACKFILLED WITH BENTONITE HOLEPLUG TO 6.7m, CUTTINGS TO 0.6m, CONCRETE TO 0.3m THEN ASPHALT TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S2 MTO-22155.GPJ 2017TEMPLATE(MTO).GDT 8/3/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-01 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83 Zone 17 N 5 516 041.8 E 402 317.3 ORIGINATED BY AHF

HWY 641 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.03.16 - 2017.03.16 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
321.1	GROUND SURFACE										
0.0 / 0.0	**ASPHALT:** (50mm)						321				
	Gravelly **SAND**, trace silt Very Dense to Compact Brown Moist (FILL)		1	GS					○		
			1	SS	100/ 0.050				○		
							320				
			2	SS	68				○		25 67 8 (SI+CL)
							319				
			3	SS	11				○		
							318				
			4	SS	10				○		
317.0							317				
4.1 / 316.5	**COBBLES** and **BOULDERS** (FILL)										
4.6	**SAND**, some silt, trace to some gravel, trace to some clay Compact to Very Dense Grey Wet		5	SS	14	▽			○		13 59 16 12
							316				
			6	SS	5		315		○		
							314				
313.4			7	SS	100/ 0.125				○		0 81 16 3
7.7	END OF BOREHOLE AT 7.7m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT 4.7m IN OPEN BOREHOLEHOLE UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.4m, THEN CONCRETE TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \quad 5}$ (%) STRAIN AT FAILURE
$\frac{}{10}$

ONTMT4S MTO-15593.GPJ 2017TEMPLATE(MTO).GDT 10/2/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-02 1 OF 2 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83 Zone 17 N 5 516 042.0 E 402 309.2 ORIGINATED BY AHF

HWY 641 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2017.03.16 - 2017.03.18 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
321.1	GROUND SURFACE										
0.0	**ASPHALT:** (50mm)						321				
0.0	**SAND**, gravelly to some gravel, trace silt Compact to Very Dense Brown Moist (FILL)		1	GS							27 63 10 (SI+CL)
			2	GS			320				
			1	SS	27						17 76 7 (SI+CL)
			2	SS	30		319				
			3	SS	100/ 0.125		318				
317.2											
3.9	**COBBLES** and **BOULDERS** (FILL)						317				
316.5											
4.6	**SAND**, some silt, some gravel, roots and rootlets Loose to Very Dense Grey Wet		4	SS	6		316				
			5	SS	100/ 0.125		315				
314.4										FI	
6.7	**GRANODIORITE**, moderately weathered, grey						314			>10	
	125mm highly fracture zone at 6.7m									3	
	Sub-horizontal fracture at 7.0m and at 7.3m		1	RUN						1	RUN #1 TCR=83% SCR=63% RQD=57%
	Vertical fracture (50mm) at 6.9m									3	
	Horizontal fracture at 6.9m, 7.0m, 7.2m, 7.4m, 7.7m, 7.8m, 7.9m, 8.3m, 8.5m, 9.2m, 9.3m and 9.6m						313			3	
	Sub-horizontal fracture at 8.6m and 8.7m		2	RUN						3	RUN #2 TCR=100% SCR=77% RQD=79%
	Sub-vertical fracture from 9.1m to 9.7m						312			2	
311.4										3	
9.7	END OF BOREHOLE AT 9.7m. BOREHOLE BACKFILLED WITH										

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

ONTMT4S MTO-15593.GPJ 2017TEMPLATE(MTO).GDT 10/2/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-02 2 OF 2 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83 Zone 17 N 5 516 042.0 E 402 309.2 ORIGINATED BY AHF

HWY 641 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2017.03.16 - 2017.03.18 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	BENTONITE HOLEPLUG, CUTTINGS AND CONCRETE TO SURFACE. GROUND WATER LEVEL IN OPEN BOREHOLE NOT RECORDED DUE TO WATER ADDED FOR ROCK CORING. DYNAMIC CONE PENETRATION TEST CONDUCTED ADJACENT TO BOREHOLE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-15593.GPJ 2017TEMPLATE(MTO).GDT 10/2/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-03 1 OF 2 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83 Zone 17 N 5 516 035.9 E 402 322.3 ORIGINATED BY AHF

HWY 641 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2017.03.15 - 2017.03.15 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
321.1	GROUND SURFACE										
0.0	**ASPHALT:** (50mm)						321				
0.0	**SAND**, trace to some silt and gravel Very Dense to Loose Brown Moist (FILL)		1	GS					○		11 75 14 (SI+CL)
			1	SS	100/ 0.100				○		
			2	SS	9		320		○		13 77 10 (SI+CL)
318.8							319				
2.3	Silty **CLAY**, some sand, trace gravel, organics Firm Grey Moist (FILL)		3	SS	6				○		
			4	SS	6		318		○		0 10 33 57
317.4											
3.7	**COBBLES** and **BOULDERS** (FILL)										
317.0							317				
4.1	Silty **SAND**, some clay, some gravel Compact Grey Wet		5	SS	15	▽			○		
315.5							316				
5.6	**SAND**, some silt and gravel Compact Brown Wet		6	SS	20		315		○		
314.1											FI
7.0	**GRANODIORITE**, moderately weathered, grey Sub-horizontal fracture at 7.5m		1	RUN			314				0 1 RUN #1 TCR=100% SCR=95% RQD=82%
	Highly broken zone (200mm) at 7.9m Horizontal fracture at 8.5m, 8.6m, 9.0m and 9.1m Sub-vertical fracture at 9.0m		2	RUN			313				0 >10 RUN #2 TCR=100% SCR=83% RQD=83% 0 2 3
	Sub-horizontal fracture at 9.4m, 9.7m, 9.8m and 9.9m		3	RUN			312				0 2 RUN #3 TCR=100% SCR=81% RQD=62% 4
311.1											

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-03 2 OF 2 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83 Zone 17 N 5 516 035.9 E 402 322.3 ORIGINATED BY AHF

HWY 641 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2017.03.15 - 2017.03.15 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	Continued From Previous Page										
10.0	END OF BOREHOLE AT 10.0m. WATER LEVEL AT 4.8m IN OPEN BOREHOLE PRIOR TO ROCK CORING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, AUGER CUTTINGS, AND CONCRETE TO SURFACE. DYNAMIC CONE PENETRATION TEST CONDUCTED ADJACENT TO BOREHOLE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ontario

THURBER

RECORD OF BOREHOLE No 17-04 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83 Zone 17 N 5 516 032.1 E 402 316.0 ORIGINATED BY AHF

HWY 641 BOREHOLE TYPE Tripod COMPILED BY AN

DATUM Geodetic DATE 2017.03.18 - 2017.03.18 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
318.2	GROUND SURFACE										
0.0	TRIPOD REFUSAL DUE TO COBBLES AND BOULDERS AT SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-05 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83 Zone 17 N 5 516 044.2 E 402 299.5 ORIGINATED BY AHF

HWY 641 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.03.16 - 2017.03.16 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
321.0	GROUND SURFACE										
0.0	**ASPHALT:** (50mm)										
0.0	**SAND**, trace silt, some gravel, trace clay Brown Moist (FILL)		1	GS			320		○		16 71 10 3
319.2											
1.8	Silty **CLAY**, some sand, organics, roots and rootlets Grey Moist (FILL)		2	GS			319		○		
							318				
	Firm		1	SS	5				⊢○⊣		0 14 40 46
317.3											
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE OPEN AND DRY ON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS AND DRY CONCRETE TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE
10

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Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-06 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83 Zone 17 N 5 516 033.7 E 402 334.1 ORIGINATED BY AHF

HWY 641 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.03.15 - 2017.03.15 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
321.1	GROUND SURFACE										
0.0	**ASPHALT:** (50mm)						321				
0.0	**SAND**, some silt, trace gravel Brown Moist (FILL)		1	GS					○		
319.3							320				
1.8	Silty **CLAY**, trace gravel, with sand and gravel seams Grey Moist to Wet (FILL)		2	GS			319				5 46 23 26
	Firm		1	SS	6		318		85		
317.4											
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS AND DRY CONCRETE TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-15593.GPJ 2017TEMPLATE(MTO).GDT 10/2/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-07 1 OF 1 METRIC

W.P. 6846-14-01 LOCATION Louise Lake Culvert, MTM NAD 83 Zone 17 N 551 603.7 E 402 343.9 ORIGINATED BY AHF

HWY 641 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.03.15 - 2017.03.15 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
321.2	GROUND SURFACE										
0.0	**ASPHALT:** (50mm)										
0.0	**SAND**, some silt, trace gravel Brown Moist (FILL)		1	GS			321		○		
319.7							320				
1.5	Silty **CLAY**, some sand, trace gravel, with sand seams Brown Moist (FILL)		2	GS			319		○		
	Firm		1	SS	5		318		○		0 61 22 17
317.5											
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS AND DRY CONCRETE TO SURFACE.										

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-15593.GPJ 2017TEMPLATE(MTO).GDT 10/2/17

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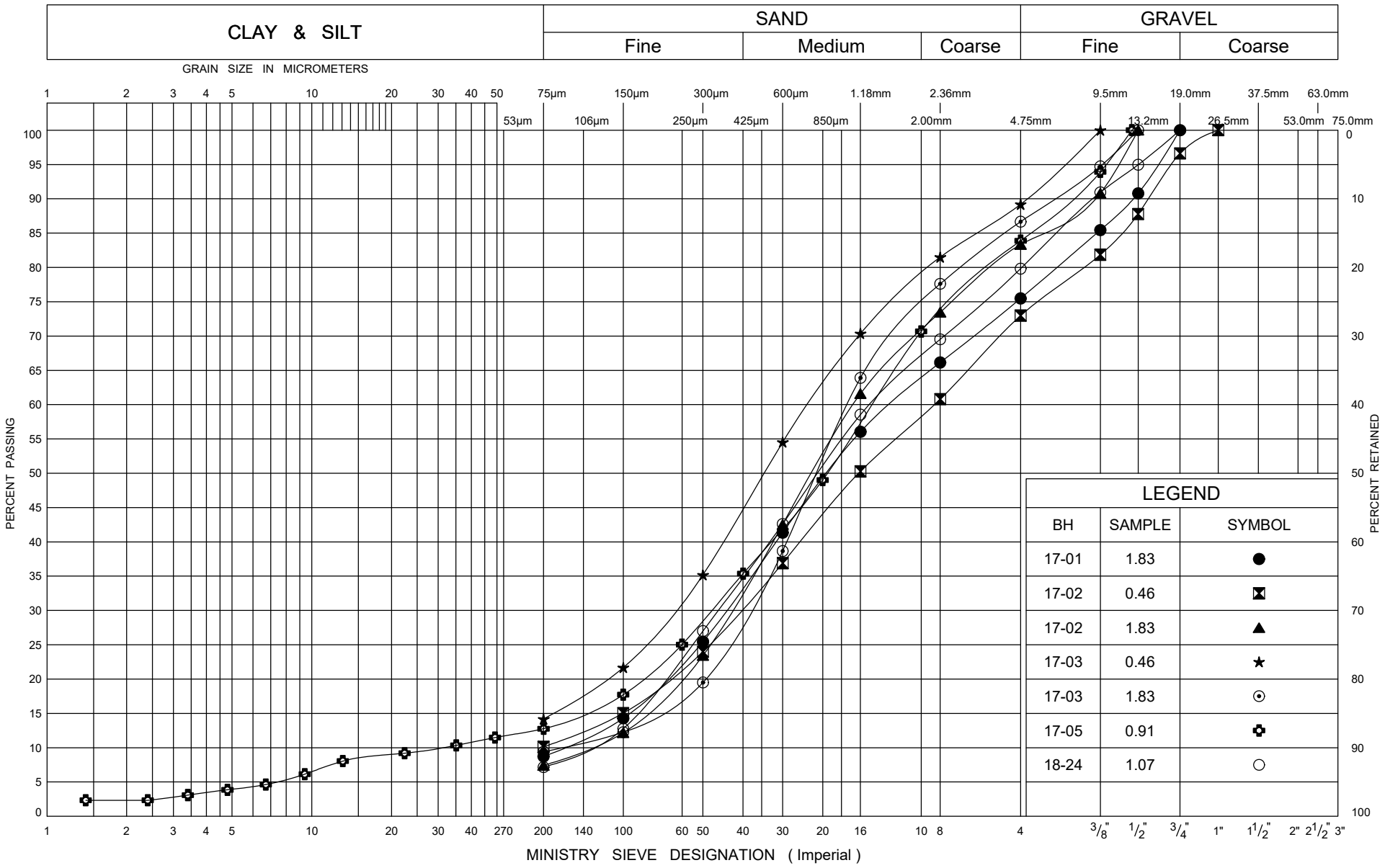
Appendix B

Geotechnical and Analytical Laboratory Test Results



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GRAIN SIZE DISTRIBUTION

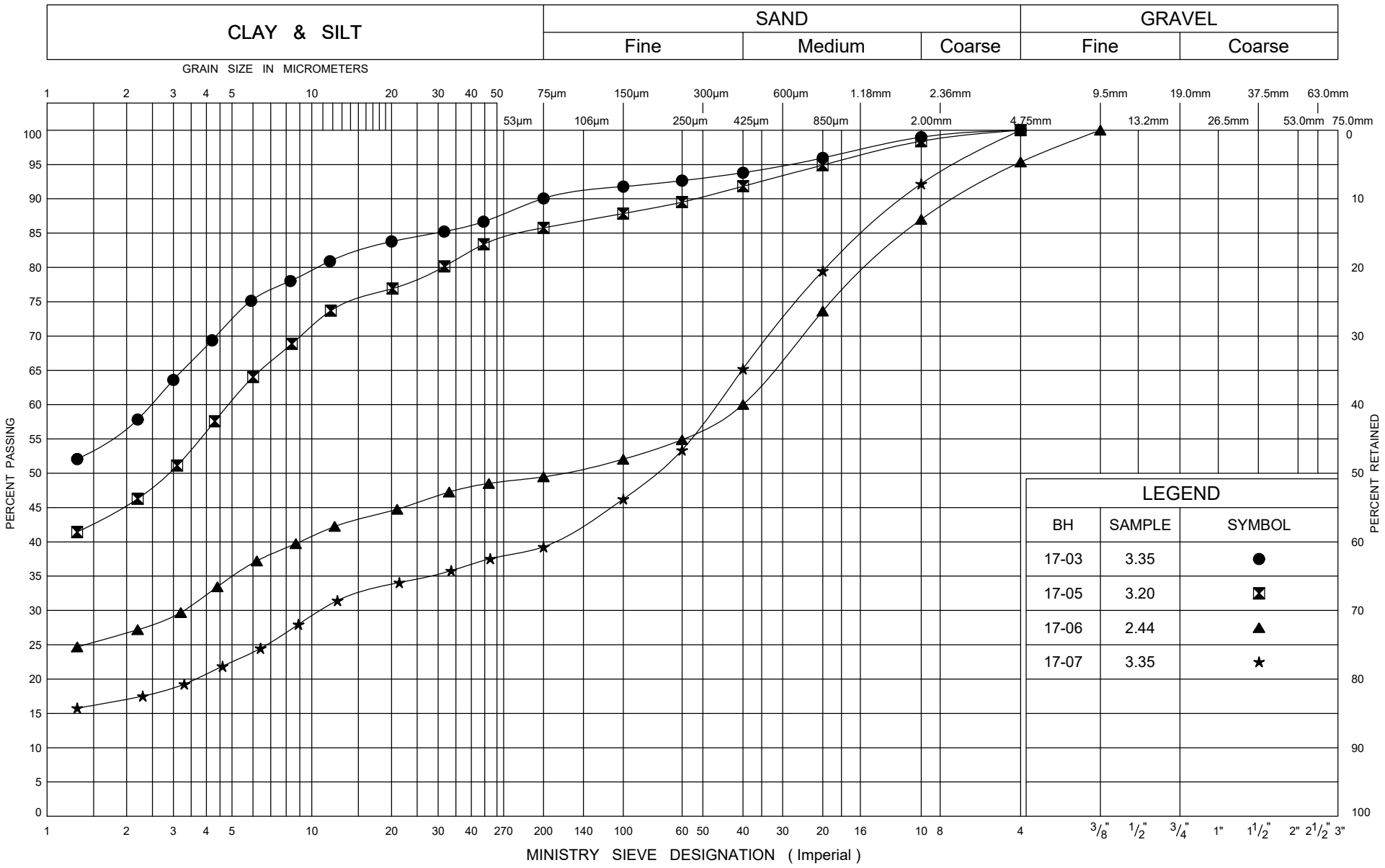
SAND to Gravelly SAND FILL

FIG No B1

W P 6846-14-01

Louise Lake Culvert Replacement

ONTARIO MOT GRAIN SIZE MTO-22155.GPJ ONTARIO MOT.GDT 8/3/18



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GRAIN SIZE DISTRIBUTION

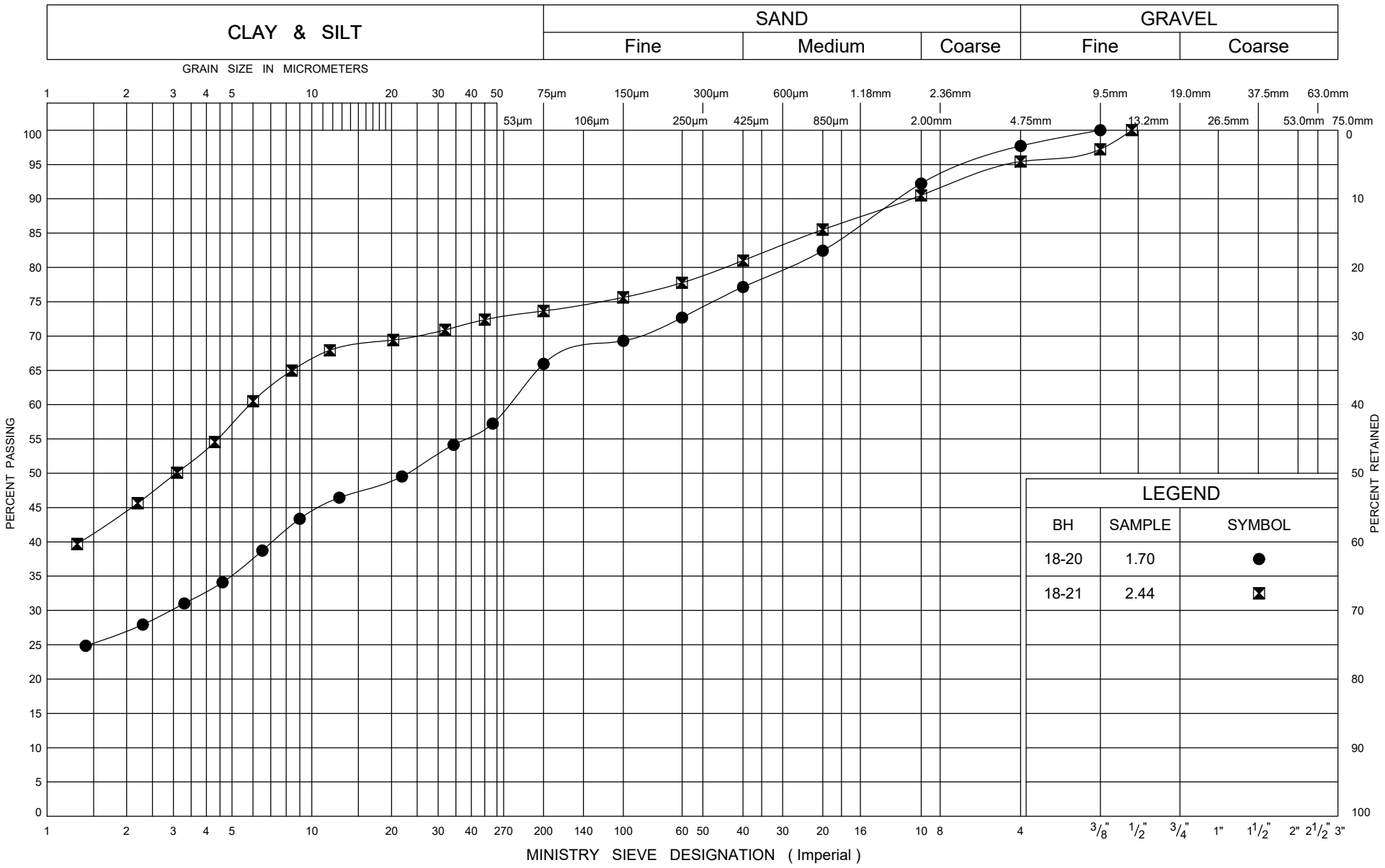
Silty CLAY FILL

FIG No B2

W P 6846-14-01

Louise Lake Culvert Replacement

ONTARIO MOT GRAIN SIZE MTO-22155.GPJ ONTARIO MOT.GDT 8/3/18



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GRAIN SIZE DISTRIBUTION

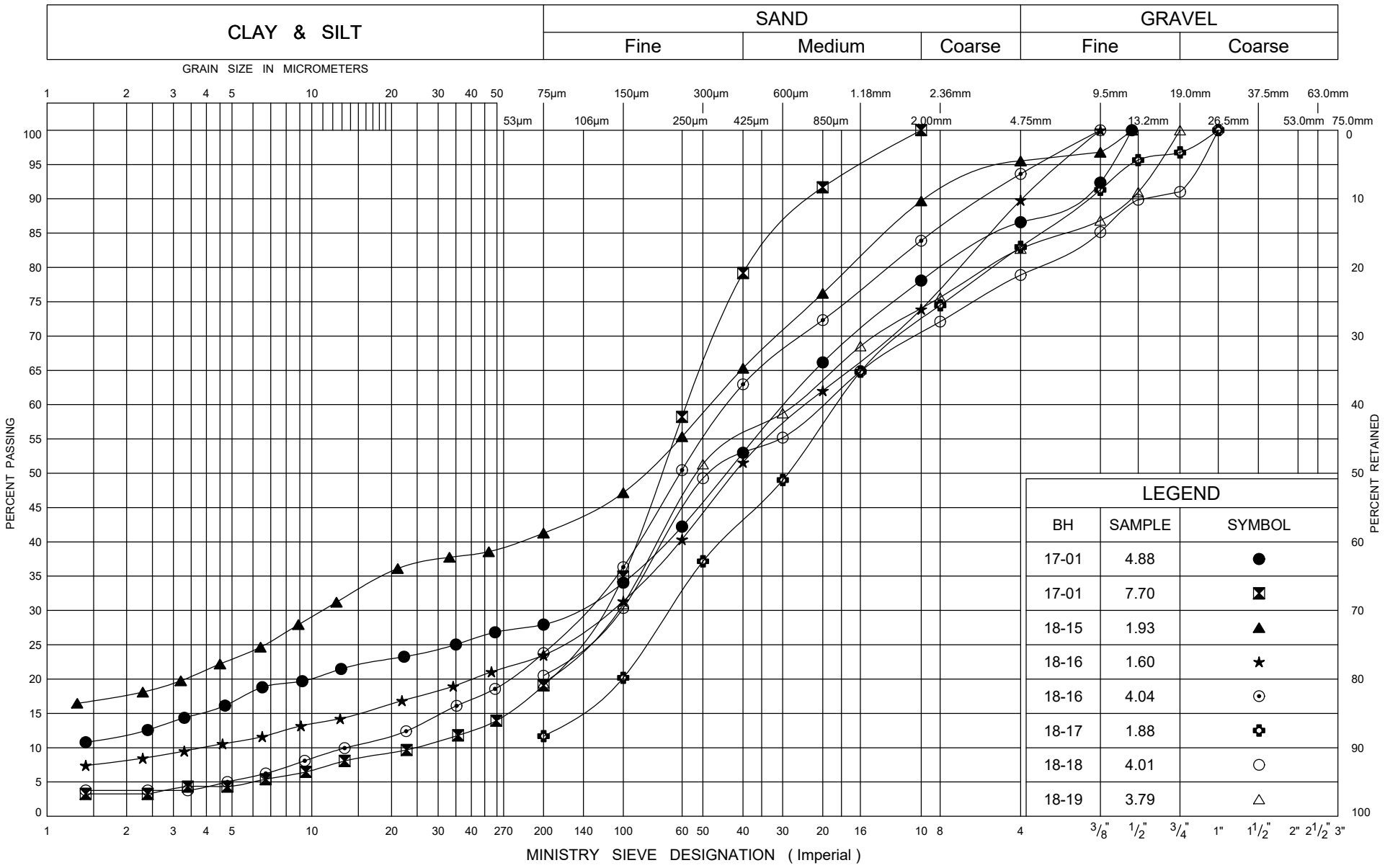
Silty CLAY

FIG No B3

W P 6846-14-01

Louise Lake Culvert Replacement

ONTARIO MOT GRAIN SIZE MTO-22155.GPJ ONTARIO MOT.GDT 8/3/18



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GRAIN SIZE DISTRIBUTION

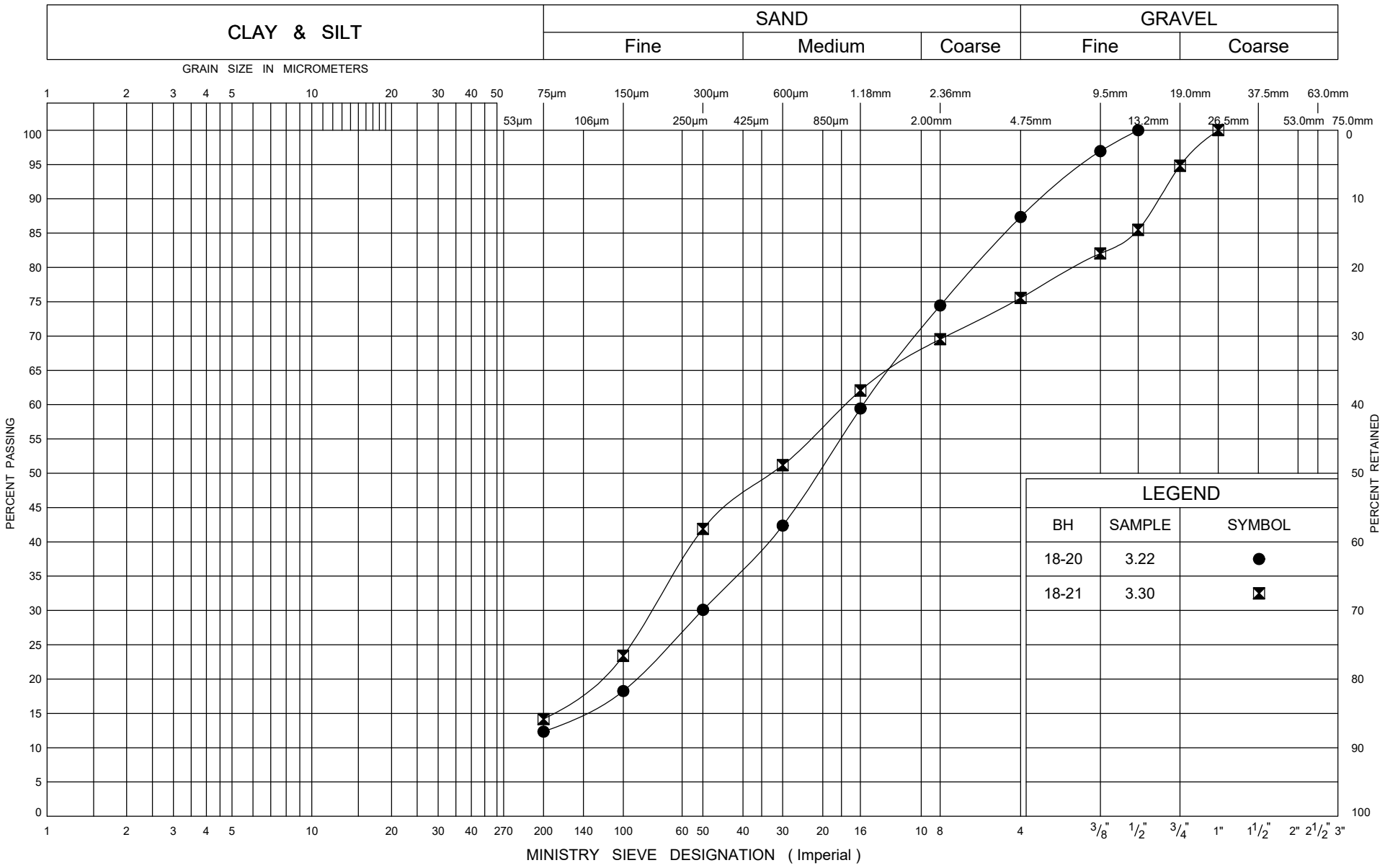
SAND to Silty SAND

FIG No B4

W P 6846-14-01

Louise Lake Culvert Replacement

ONTARIO MOT GRAIN SIZE MTO-22155.GPJ ONTARIO MOT.GDT 8/3/18



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GRAIN SIZE DISTRIBUTION

Gravelly SAND

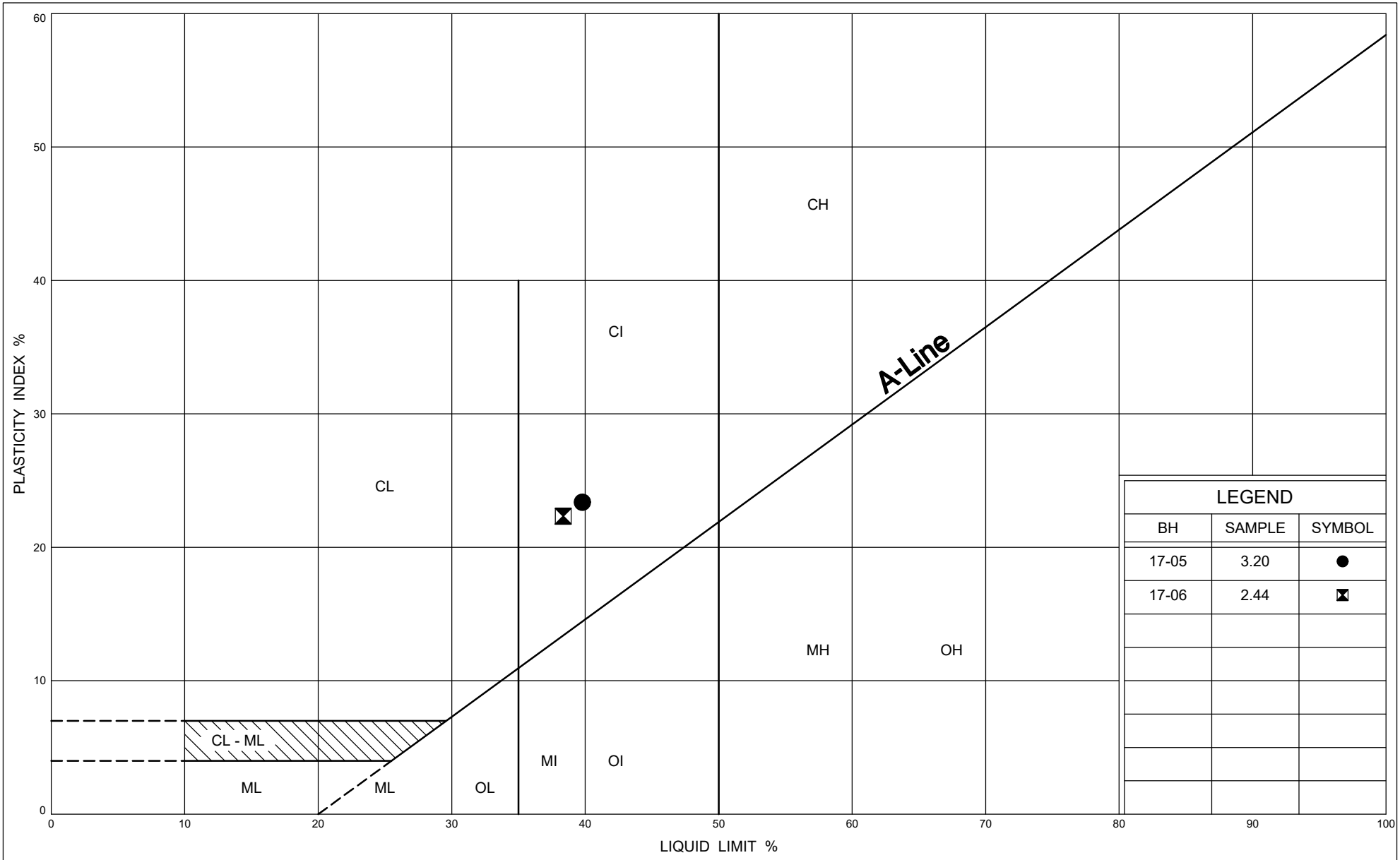
FIG No B5

W P 6846-14-01

Louise Lake Culvert Replacement

ONTARIO MOT GRAIN SIZE MTO-22155.GPJ ONTARIO MOT.GDT 8/3/18

Oct 75, FF - S - 21



ONTARIO MOT PLASTICITY CHART MTO-22155.GPJ ONTARIO MOT.GDT 8/3/18

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PLASTICITY CHART

Silty CLAY FILL

FIG No B6

W P 6846-14-01

Louise Lake Culvert Replacement

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	18-Mar-18
Client:	WSP	**Date Tested:**	26-Mar-18
Project Name:	Louise Lake Culvert	**Tester:**	KF
Core Size:	NQ **BH No :** 18-15	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	2.7	D	27.4	47.7	154.6	11.2	268.2	Granodiorite	Extremely Strong
2	2	3.6	D	45.0	48.9	140.7	17.6	423.5	Granodiorite	Extremely Strong
3	3	4.6	D	43.1	49.1	170.2	16.8	403.1	Granodiorite	Extremely Strong
4										
5										
6										
7										
8										
9										
10										
11										
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35										

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have 0.7 x D on either side of test point.

* Correlation factor to obtain UCS values is 24.

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	31-May-18
Client:	WSP	**Date Tested:**	07-Jun-18
Project Name:	Louise Lake Culvert	**Tester:**	BS
Core Size:	NQ **BH No :** 18-16	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	5.5	D	23.7	50.5	50.5	8.9	212.6	Granodiorite	Very Strong
2	1	5.8	D	25.7	50.8	51.4	9.5	227.9	Granodiorite	Very Strong
3	1	6.1	D	15.0	50.3	50.5	5.6	135.4	Granodiorite	Very Strong
4	1	6.6	D	4.4	50.0	48.9	1.7	40.2	Granodiorite	Medium Strong
5	1	7.1	D	17.6	50.2	50.2	6.6	159.0	Granodiorite	Very Strong
6	1	7.3	D	19.3	49.8	94.0	7.3	176.4	Granodiorite	Very Strong
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16						**RUN#1 AVG=**		**158.6**		Very Strong
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* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
  Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
* Diametral Test should have 0.7 x D on either side of test point.
* Correlation factor to obtain UCS values is 24.

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	02-Jun-18
Client:	WSP	**Date Tested:**	08-Jun-18
Project Name:	Louise Lake Culvert	**Tester:**	BS
Core Size:	NQ **BH No :** 18-17	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	2	5.3	D	21.8	49.3	50.0	8.4	202.6	Granodiorite	Very Strong
2	2	5.7	D	20.2	49.6	50.2	7.8	186.5	Granodiorite	Very Strong
3	2	6.0	D	15.7	49.8	49.1	6.0	144.1	Granodiorite	Very Strong
4	3	6.2	D	18.3	49.7	52.9	7.0	168.3	Granodiorite	Very Strong
5	4	6.4	D	0.9	36.5	36.8	0.5	12.7	Granodiorite	Weak
6	4	6.9	D	12.7	36.9	36.9	7.7	185.7	Granodiorite	Very Strong
7										
8										
9										
10						**RUN#2 AVG=**		**177.7**		Very Strong
11						**RUN#3 AVG=**		**168.3**		Very Strong
12						**RUN#4 AVG=**		**99.2**		Strong
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Last Modified: September 14, 2016

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	04-Jun-18
Client:	WSP	**Date Tested:**	11-Jun-18
Project Name:	Louise Lake Culvert	**Tester:**	BS
Core Size:	NQ **BH No :** 18-18	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	5.0	D	11.4	50.0	53.7	4.3	104.1	Granodiorite	Very Strong
2	2	5.2	D	10.0	49.8	54.4	3.8	91.4	Granodiorite	Strong
3	2	5.6	D	6.6	49.9	47.3	2.5	60.3	Granodiorite	Strong
4	3	5.8	D	5.0	49.8	50.8	1.9	46.2	Granodiorite	Medium Strong
5	3	6.1	D	3.4	50.5	45.5	1.3	30.5	Granodiorite	Medium Strong
6	4	6.2	D	14.6	37.0	37.3	8.8	211.6	Granodiorite	Very Strong
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16						**RUN#1 AVG=**		**104.1**		Very Strong
17						**RUN#2 AVG=**		**75.8**		Strong
18						**RUN#3 AVG=**		**38.3**		Medium Strong
19						**RUN#4 AVG=**		**211.6**		Very Strong
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THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	01-Jun-18
Client:	WSP	**Date Tested:**	08-Jun-18
Project Name:	Louise Lake Culvert	**Tester:**	BS
Core Size:	NQ **BH No :** 18-19	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	3.8	D	20.0	50.0	51.7	7.6	181.8	Granodiorite	Very Strong
2	2	4.0	D	11.3	49.7	50.8	4.3	104.0	Granodiorite	Very Strong
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THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	17-Mar-18
Client:	WSP	**Date Tested:**	26-Mar-18
Project Name:	Louise Lake Culvert	**Tester:**	KF
Core Size:	NQ **BH No :** 18-20	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	2	3.3	D	23.6	48.5	117.2	9.4	225.2	Granodiorite	Very Strong
2	3	4.5	D	26.9	48.8	154.6	10.6	253.8	Granodiorite	Extremely Strong
3	3	4.8	D	36.4	49.0	106.2	14.2	341.4	Granodiorite	Extremely Strong
4										
5										
6										
7						**RUN#2 AVG=**		**225.2**		Very Strong
8						**RUN#3 AVG=**		**297.6**		Extremely Strong
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THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	26-May-18
Client:	WSP	**Date Tested:**	08-Jun-18
Project Name:	Louise Lake Culvert	**Tester:**	BS
Core Size:	NQ **BH No :** 18-21	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	2.4	D	20.8	48.2	48.0	8.4	200.6	Granodiorite	Very Strong
2	1	2.8	D	16.2	49.3	48.2	6.3	150.3	Granodiorite	Very Strong
3	2	3.3	D	13.0	50.2	46.4	4.9	117.4	Granodiorite	Very Strong
4	3	3.7	D	22.1	49.8	50.6	8.4	202.6	Granodiorite	Very Strong
5	4	4.0	D	26.1	50.3	55.2	9.8	235.3	Granodiorite	Very Strong
6	4	4.4	D	14.7	50.1	50.6	5.6	133.5	Granodiorite	Very Strong
7	4	4.9	D	8.5	50.2	53.1	3.2	76.7	Granodiorite	Strong
8	5	5.0	D	16.0	50.1	52.3	6.1	145.3	Granodiorite	Very Strong
9	5	5.5	D	20.5	50.2	51.7	7.7	185.6	Granodiorite	Very Strong
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16						**RUN#1 AVG=**		**175.4**		Very Strong
17						**RUN#2 AVG=**		**117.4**		Very Strong
18						**RUN#3 AVG=**		**202.6**		Very Strong
19						**RUN#4 AVG=**		**148.5**		Very Strong
20						**RUN#5 AVG=**		**165.4**		Very Strong
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THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	28-May-18
Client:	WSP	**Date Tested:**	07-Jun-18
Project Name:	Louise Lake Culvert	**Tester:**	BS
Core Size:	NQ **BH No :** 18-22	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	2.8	D	13.2	50.3	52.6	4.9	118.7	Granodiorite	Very Strong
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Last Modified: September 14, 2016

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	19-Mar-18
Client:	WSP	**Date Tested:**	26-Mar-18
Project Name:	Louise Lake Culvert	**Tester:**	KF
Core Size:	NQ **BH No :** 18-23	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	3.0	D	33.4	47.7	154.7	13.6	326.8	Granodiorite	Extremely Strong
2	2	3.7	D	27.4	47.7	310.0	11.2	267.9	Granodiorite	Extremely Strong
3	3	4.3	D	38.8	49.2	147.1	15.1	361.9	Granodiorite	Extremely Strong
4	4	5.3	D	41.6	49.5	115.7	16.0	384.4	Granodiorite	Extremely Strong
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Last Modified: September 14, 2016

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	22155	**Date Drilled:**	14-Mar-18
Client:	WSP	**Date Tested:**	26-Mar-18
Project Name:	Louise Lake Culvert	**Tester:**	KF
Core Size:	NQ **BH No :** 18-24	**Reviewed by:**	MEF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	7.4	D	33.4	46.8	153.7	14.0	336.6	Granodiorite	Extremely Strong
2	1	8.2	D	29.8	46.8	154.6	12.5	300.3	Granodiorite	Extremely Strong
3	2	9.0	D	13.6	47.2	154.6	5.7	135.7	Granodiorite	Very Strong
4										
5										
6						**RUN#1 AVG=**		**318.4**		Extremely Strong
7						**RUN#2 AVG=**		**135.7**		Very Strong
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Last Modified: September 14, 2016

THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	15593	**Date Drilled:**	18-Mar-17
Client:	Hatch	**Date Tested:**	25-Apr-17
Project Name:	Louise Lake Culvert	**Tester:**	RT
Core Size:	NQ **BH No :** 17-02	**Reviewed by:**	CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	6.9	D	15.2	47.5	85.4	6.2	149.6	Granodiorite	Very Strong
2	1	7.2	D	23.4	47.5	140.4	9.6	230.2	Granodiorite	Very Strong
3	1	7.5	D	19.7	47.5	150.0	8.1	194.1	Granodiorite	Very Strong
4	1	7.6	D	4.6	47.5	150.0	1.9	45.1	Granodiorite	Medium Strong
5	1	7.9	D	21.4	47.5	90.0	8.8	211.0	Granodiorite	Very Strong
6	2	8.4	D	19.8	47.5	45.7	8.1	195.3	Granodiorite	Very Strong
7	2	8.7	D	22.1	47.5	117.0	9.1	217.6	Granodiorite	Very Strong
8	2	9.0	D	21.0	47.5	89.7	8.6	207.0	Granodiorite	Very Strong
9	2	9.5	D	24.6	47.5	68.2	10.1	242.5	Granodiorite	Very Strong
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THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No:	15593	**Date Drilled:**	15-Mar-17
Client:	Hatch	**Date Tested:**	21-Apr-17
Project Name:	Louise Lake Culvert	**Tester:**	WHW
Core Size:	NQ **BH No :** 17-03	**Reviewed by:**	CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	7.1	A	24.8	47.5	50.9	8.0	191.7	Granodiorite	Very Strong
2	1	7.8	D	30.0	47.5	60.4	12.3	295.6	Granodiorite	Extremely Strong
3	1	7.5	A	21.4	47.5	41.7	8.1	193.7	Granodiorite	Very Strong
4	1	7.3	D	23.5	47.5	44.5	9.6	231.2	Granodiorite	Very Strong
5	2	7.6	D	25.0	47.5	56.8	10.3	246.3	Granodiorite	Very Strong
6	2	7.8	A	25.0	47.5	47.0	8.6	206.0	Granodiorite	Very Strong
7	2	8.0	D	25.1	47.5	65.0	10.3	247.3	Granodiorite	Very Strong
8	2	8.4	D	23.7	47.5	70.0	9.7	233.3	Granodiorite	Very Strong
9	2	8.8	D	25.0	47.5	150.0	10.3	246.3	Granodiorite	Very Strong
10	3	9.1	D	23.8	47.5	150.0	9.8	234.3	Granodiorite	Very Strong
11	3	9.4	D	25.0	47.5	150.0	10.3	246.3	Granodiorite	Very Strong
12	3	9.9	D	14.9	47.5	111.0	6.1	147.0	Granodiorite	Very Strong
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Photo 1: Borehole 18-15 Bedrock Core Sample

Photo 2: Borehole 18-16 Bedrock Core Sample

Photo 3: Borehole 18-17 Bedrock Core Sample

Photo 4: Borehole 18-18 Bedrock Core Sample

Photo 5: Borehole 18-19 Bedrock Core Sample

Photo 6: Borehole 18-20 Bedrock Core Sample

Photo 7: Borehole 18-21 Bedrock Core Sample

Photo 8: Borehole 18-22 Bedrock Core Sample

Photo 9: Borehole 18-23 Bedrock Core Sample

Photo 10: Borehole 18-24 Bedrock Core Sample

Photo 11: Borehole 17-02 Bedrock Core Sample

Photo 12: Borehole 17-03 Bedrock Core Sample

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 15593

08-May-2017

Thurber Engineering Ltd
Attn : Cory Zanatta

2010 Winston Park Dr
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 240
Fax:

Date Rec. : 02 May 2017
LR Report: **CA14060-MAY17**
Reference: 15593 Cory Zanatta

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: 17-01 SS3	6: 17-03 SS3
Sample Date & Time					26-Mar-17	26-Mar-17
Temperature Upon Receipt [°C]	---	---	---	---	6.0	6.0
Corrosivity Index [none]	08-May-17	14:35	08-May-17	14:35	4.0	4.0
Soil Redox Potential [mV]	03-May-17	16:33	04-May-17	14:12	249	237
Sulphide [%]	05-May-17	13:47	05-May-17	15:54	< 0.02	< 0.02
% Moisture (wet wt) [%]	04-May-17	13:57	04-May-17	14:37	1.4	16.7
pH [no unit]	03-May-17	15:41	05-May-17	09:17	9.41	8.56
Chloride [µg/g]	05-May-17	17:42	08-May-17	14:40	18	75
Sulphate [µg/g]	05-May-17	17:42	08-May-17	14:40	3.3	27
Conductivity [uS/cm]	03-May-17	15:41	05-May-17	09:17	96	235
Resistivity (calculated) [Ohms.cm]	03-May-17	15:41	08-May-17	14:21	10400	4260

Temperature of Sample upon Receipt: 12 degrees C
Cooling Agent Present: Yes
Custody Seal Present: No

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

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 15593
LR Report : **CA14060-MAY17**

Method Descriptions

Parameter	SGS Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006
Metals Prep	ME-CA-[ENV]ARD-LAK-AN-013
pH	ME-CA-[ENV]EWL-LAK-AN-001

Deanna Edwards, B.Sc, C.Chem
Project Specialist
Environmental Services, Analytical

OnLine LIMS

00009152

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 15593
LR Report : **CA14060-MAY17**

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank		RPD	Acceptance Criteria	LCS / Spike Blank			Matrix Spike / Reference Material		
							Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0108-MAY17												
Chloride	0.4	µg/g	<0.4		3	20	101	80	120	105	75	125
Sulphate	0.4	µg/g	<0.4		2	20	97	80	120	87	75	125
Carbon/Sulphur - QCBatchID: ECS0006-MAY17												
Sulphide	0.02	%	<0.02		ND	20	113	80	120			
Conductivity - QCBatchID: EWL0047-MAY17												
Conductivity	2	uS/cm	< 2		2	10	93	90	110	NA		
pH - QCBatchID: EWL0047-MAY17												
pH	0.05	no unit	NA		0		100			NA		

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

19-April-2017

Thurber Engineering Ltd
Attn : Cory Zanatta

2010 Winston Park Dr
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 240
Fax:

Date Rec. : 11 April 2017
LR Report: **CA14206-APR17**
Reference: Cory Zanatta

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: MDL	6: Louise Lake
Sample Date & Time						18-Mar-17
Temperature Upon Receipt [°C]	---	---	--	--	---	7.0
pH [no unit]	12-Apr-17	15:59	17-Apr-17	11:28	0.05	7.46
Conductivity [µS/cm]	12-Apr-17	15:59	17-Apr-17	11:28	2	56
Resistivity (calculated) [Ohms.cm]	17-Apr-17	16:10			---	17700
Redox Potential [mV]	12-Apr-17	13:31	13-Apr-17	11:42	---	239
Chloride [mg/L]	12-Apr-17	15:47	17-Apr-17	14:55	0.04	3.1
Sulphate [mg/L]	12-Apr-17	15:47	17-Apr-17	14:55	0.04	1.6
Sulphide [mg/L]	12-Apr-17	10:31	12-Apr-17	13:44	0.006	0.007

Temperature of Sample upon Receipt: 7 degrees C
Cooling Agent Present: Yes
Custody Seal Present: No

Deanna Edwards

Deanna Edwards, B.Sc, C.Chem
Project Specialist
Environmental Services, Analytical

OnLine LIMS

0000870945

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

LR Report : **CA14206-APR17**

Method Descriptions

Parameter	Units	SGS Method Code	Reference Method Code
Anions by IC	mg/L	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Conductivity	uS/cm	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	no unit	ME-CA-[ENV]EWL-LAK-AN-006	SM 4500
Redox Potential	mV		SM 2580
Sulphide by SFA	mg/L	ME-CA-[ENV]SFA-LAK-AN-008	SM 4500

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P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

LR Report : **CA14206-APR17**

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank		RPD	Acceptance Criteria	LCS / Spike Blank			Matrix Spike / Reference Material		
							Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0135-APR17												
Chloride	0.04	mg/L	<0.04		3	20	99	80	120	103	75	125
Sulphate	0.04	mg/L	<0.04		1	20	96	80	120	101	75	125
Conductivity - QCBatchID: EWL0161-APR17												
Conductivity	2	µS/cm	< 2		0	10	100	90	110	NA		
pH - QCBatchID: EWL0161-APR17												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0152-APR17												
Redox Potential	no	mV	NA		4	20	104	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0090-APR17												
Sulphide	0.006	mg/L	<0.006		ND	20	87	80	120	NV	75	125

THURBER

Appendix C

Site Photographs

Photo 1: Highway 654 embankment over Louis Lake Culvert, looking west

Photo 2: Louis Lake Culvert, South Side

Photo 3: Louis Lake Culvert, north side

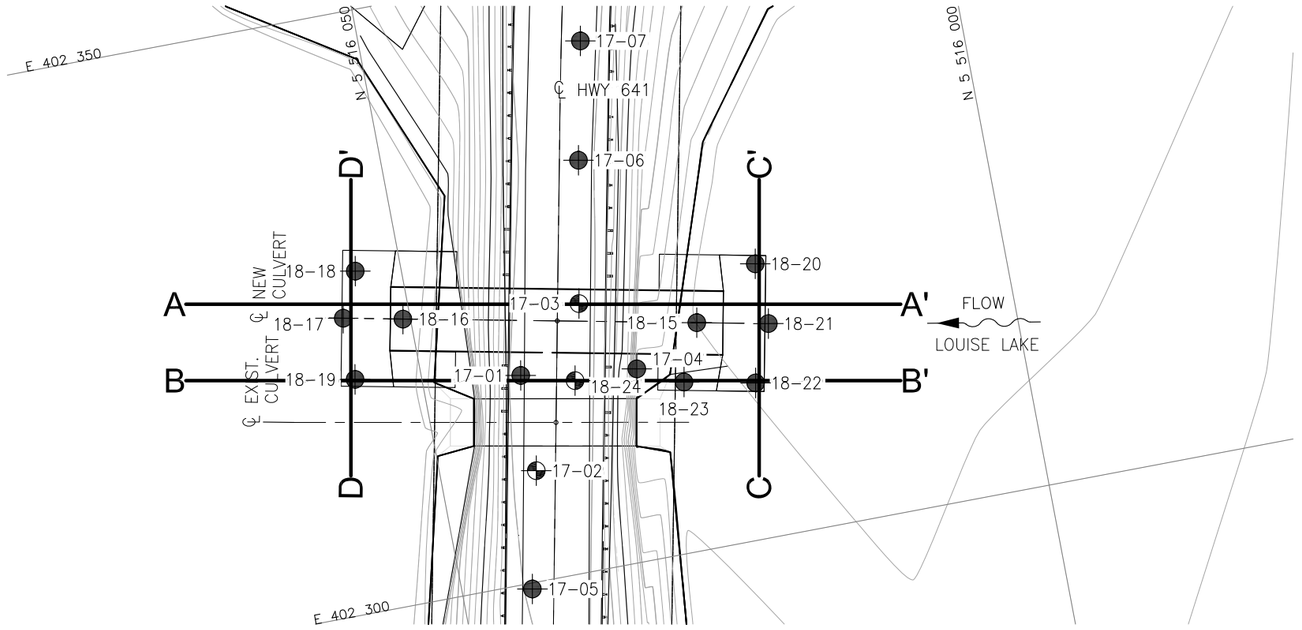
Photo 4: Louis Lake culvert, south side, location of Borehole 17-04

THURBER

Appendix D

Borehole Locations and Soil Strata Drawing

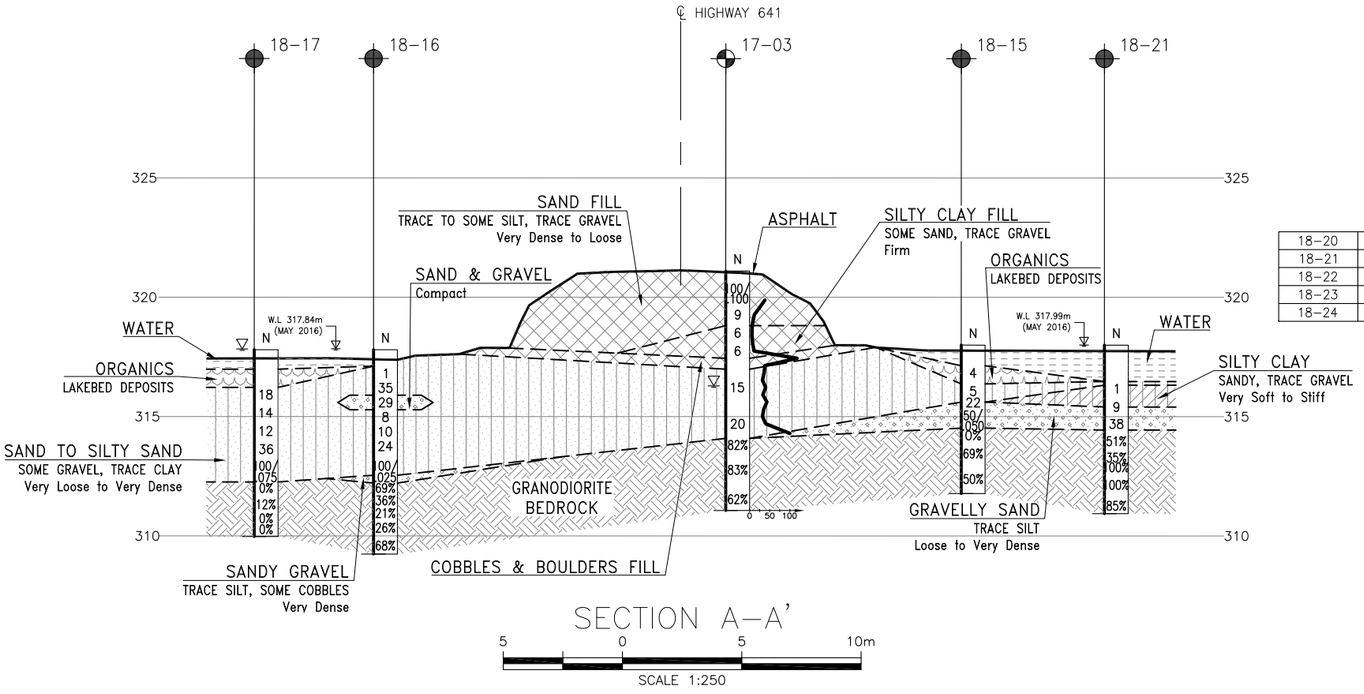
MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

10 0 10 20m

SCALE 1:500



SECTION A–A'

5 0 5 10m

SCALE 1:250

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No 6846-14-01

SHEET

HIGHWAY 641
LOUISE LAKE
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

wsp

THURBER ENGINEERING LTD.

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	321.1	5 516 041.8	402 317.3
17-02	321.1	5 516 042.0	402 309.2
17-03	321.1	5 516 035.9	402 322.3
17-04	318.2	5 516 032.1	402 316.0
17-05	321.0	5 516 044.2	402 299.5
17-06	321.1	5 516 033.7	402 334.1
17-07	321.2	5 516 031.7	402 343.9
18-15	318.0	5 516 026.5	402 318.9
18-16	317.8	5 516 050.6	402 323.7
18-17	317.8	5 516 055.5	402 324.7
18-18	317.8	5 516 053.8	402 328.4
18-19	317.8	5 516 055.5	402 319.5
18-20	318.0	5 516 020.7	402 322.8
18-21	318.0	5 516 020.6	402 317.7
18-22	318.0	5 516 022.6	402 313.0
18-23	318.0	5 516 028.4	402 314.2
18-24	321.1	5 516 037.4	402 316.0

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
3) Coordinate system is MTM NAD 83 Zone 17

GEOCRES No. 52E-69

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN	MEF	CHK PKC	CODE	LOAD	DATE DEC 2018
DRAWN	AN	CHK MEF	SITE	STRUCT	DWG 1

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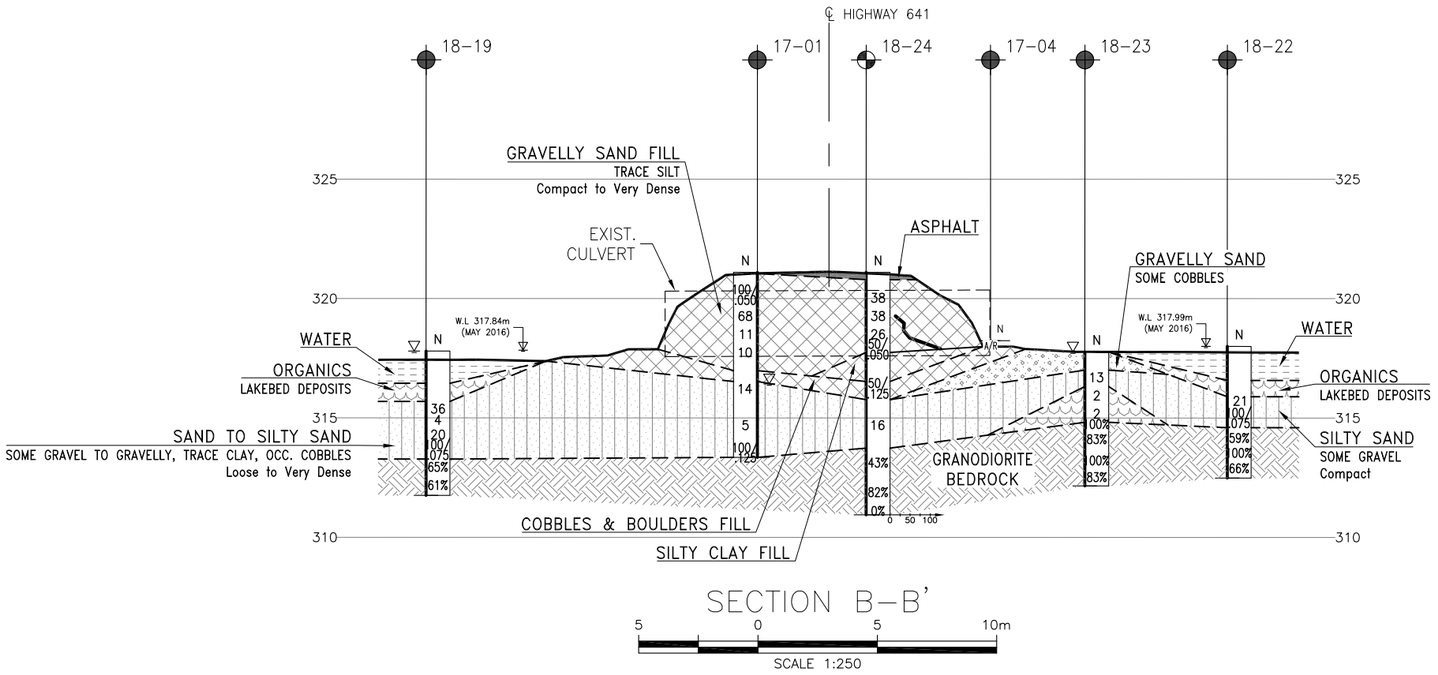
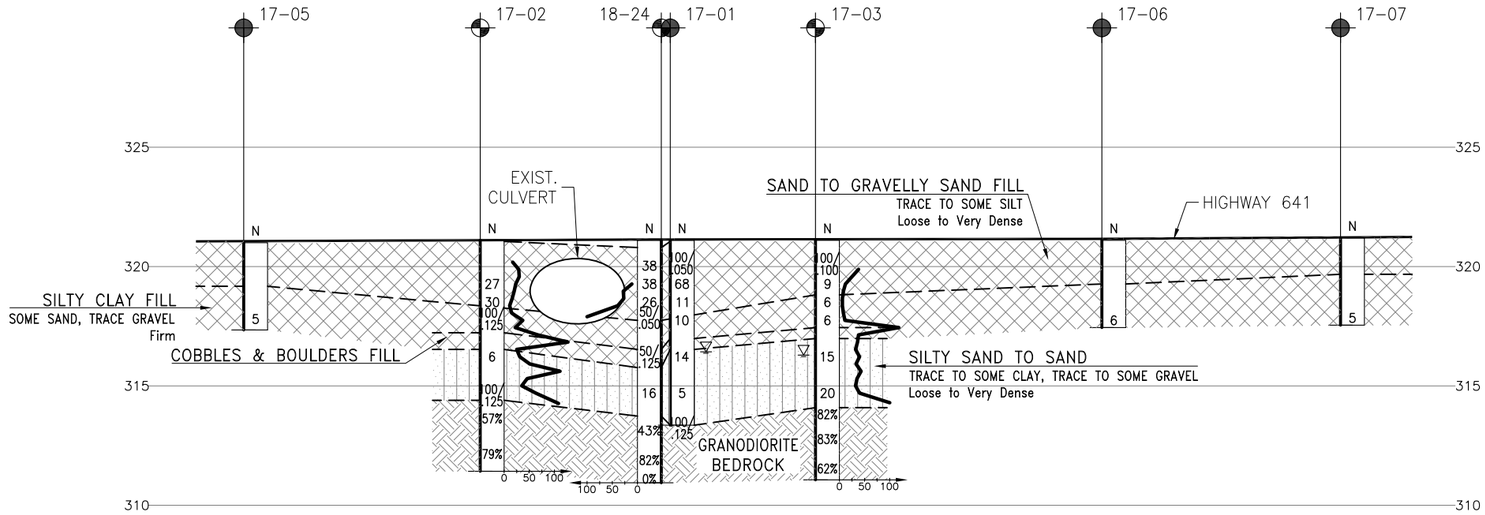


SECTION B–B'

5 0 5 10m

SCALE 1:250



PROFILE ALONG ℄ HWY 641

5 0 5 10m

SCALE 1:250

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No 6846-14-01

HIGHWAY 641
LOUISE LAKE
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

wsp

THURBER ENGINEERING LTD.

KEYPLAN

LICENSED PROFESSIONAL ENGINEER
P.K. CHATTERJI
Dec 14/18
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
M.E. FARRANT
100053767
Dec. 14, 2018
PROVINCE OF ONTARIO

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	321.1	5 516 041.8	402 317.3
17-02	321.1	5 516 042.0	402 309.2
17-03	321.1	5 516 035.9	402 322.3
17-04	318.2	5 516 032.1	402 316.0
17-05	321.0	5 516 044.2	402 299.5
17-06	321.1	5 516 033.7	402 334.1
17-07	321.2	5 516 031.7	402 343.9
18-15	318.0	5 516 026.5	402 318.9
18-16	317.8	5 516 050.6	402 323.7
18-17	317.8	5 516 055.5	402 324.7
18-18	317.8	5 516 053.8	402 328.4
18-19	317.8	5 516 055.5	402 319.5
18-20	318.0	5 516 020.7	402 322.8
18-21	318.0	5 516 020.6	402 317.7
18-22	318.0	5 516 022.6	402 313.0
18-23	318.0	5 516 028.4	402 314.2
18-24	321.1	5 516 037.4	402 316.0

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
3) Coordinate system is MTM NAD 83 Zone 17

GEOCRES No. 52E-69

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN	MEF	CHK	PKC	CODE	LOAD
DRAWN	AN	CHK	MEF	SITE	STRUCT

DATE DEC 2018
DWG 2

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METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

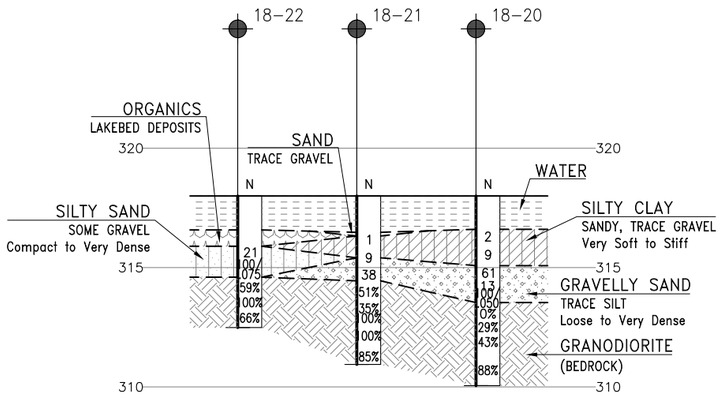
CONT No
WP No 6846-14-01

HIGHWAY 641
LOUISE LAKE
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

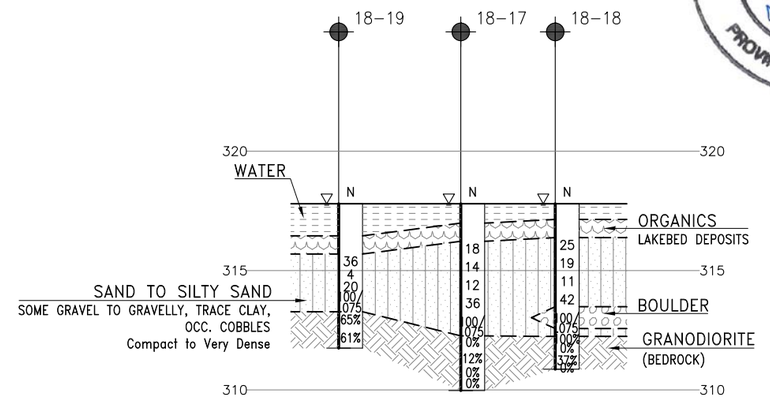
SHEET

wsp

THURBER ENGINEERING LTD.



SECTION C-C'



SECTION D-D'

18-20	318.0	5 516 020.7	402 322.8
18-21	318.0	5 516 020.6	402 317.7
18-22	318.0	5 516 022.6	402 313.0
18-23	318.0	5 516 028.4	402 314.2
18-24	321.1	5 516 037.4	402 316.0

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	321.1	5 516 041.8	402 317.3
17-02	321.1	5 516 042.0	402 309.2
17-03	321.1	5 516 035.9	402 322.3
17-04	318.2	5 516 032.1	402 316.0
17-05	321.0	5 516 044.2	402 299.5
17-06	321.1	5 516 033.7	402 334.1
17-07	321.2	5 516 031.7	402 343.9
18-15	318.0	5 516 026.5	402 318.9
18-16	317.8	5 516 050.6	402 323.7
18-17	317.8	5 516 055.5	402 324.7
18-18	317.8	5 516 053.8	402 328.4
18-19	317.8	5 516 055.5	402 319.5

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
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3) Coordinate system is MTM NAD 83 Zone 17

GEOCRES No. 52E-69

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN	MEF	CHK	PKC	CODE	LOAD
DRAWN	AN	CHK	MEF	SITE	STRUCT

DATE DEC 2018
DWG 3

THURBER

Appendix E

List of OPSSs and OPSDs 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 421 (Construction Specification for Pipe Culvert Installation in Open Cut)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS PROV 517 (Construction Specification for Dewatering)
- SP 517F01 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 511 (Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting)
- OPSS 1860 (Material Specification for Geotextiles)
- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- OPSD 803.031 (Frost Treatment – Pipe Culverts, Frost Penetration Line Between Top of Pipe and Bedding Grade)
- OPSD 810.010 (General Rip-Rap Layout for Sewer and Culvert Outlets)
- OPSD 3090.100 (Foundation Frost Penetration Depths for Northern Ontario)
- Special Provision No. FOUN0003 to OPSS 902 (Dewatering Structure Excavations)

2. Suggested Wording for NSSP on Dewatering

Dewatering will be required to install the new culvert 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, OPSS.PROV. 517 and SP517F01. 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.

3. Suggested Wording for NSSP on Obstructions

Excavations and installation of cofferdams and roadway protection systems will encounter obstructions such as a distinct layer of cobbles and boulders in the embankment fill (possibly rock fill), cobbles and boulders embedded in the fill and native soils, as well as shallow bedrock. 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. Vibrating equipment is not permitted for installation of sheet piles.