THURBER ENGINEERING LTD.

DETAILED FOUNDATION INVESTIGATION AND DESIGN REPORT
ALDER CREEK EAST CULVERT REPLACEMENT
HIGHWAY 17, UNSURVEYED TERRITORY
THUNDER BAY DISTRICT, ONTARIO
LATITUDE: 48.7199017º, LONGITUDE: -85.709616º

G.W.P. 6810-14-00, W.P. 6330-14-01, SITE No. 48E-075C

GEOCRES Number: 42C-46

Report

to

HATCH

Date: December 18, 2018
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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the detailed design of the proposed replacement of the Alder Creek East Culvert on Highway 17, located west of the town of White River, in the Unsurveyed District of Thunder Bay, Ontario. Thurber previously completed a preliminary foundation investigation at the culvert site in 2018.

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

Thurber was retained by Hatch to carry out this detailed foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0008.

The preliminary investigations were previously conducted by Thurber and Golder Associates and are described below:

- Preliminary Foundation Investigation and Design Report, Alder Creek East Culvert Replacement, Highway 17, Unsurveyed Territory, Thunder Bay District, Ontario, GEOCRES Number 42C-43, prepared by Thurber Engineering Ltd., dated September 11, 2018.
- Preliminary Foundation Investigation and Design Report, Alder Creek E. Culvert, Site No. 48E-75/C, Highway 17, District of Thunder Bay, Unsurveyed Territory, Ministry of Transportation, Ontario, G.W.P 6330-14-00” Geocres No. 42C-37, prepared by Golder Associates, dated October 30, 2015.

The borehole logs from Thurber's previously completed preliminary investigation are included in this report. The Record of Borehole sheets and Borehole Locations and Soil Strata drawing from the Golder report have been enclosed in Appendix E of this report for reference, and the subsurface information presented in that report was incorporated in the current report, as appropriate. It should be noted that Golder is solely responsible for the subsurface information provided in the Preliminary Foundation Investigation Report. The borehole logs from the Golder report should be included in the tender documents.

2. SITE DESCRIPTION

The site is located along Highway 17, approximately 39 km west of the town of White River, Ontario. Highway 17 generally runs in an east-west direction at the culvert site. Dunc Lake is located south of Highway 17 and Alder Creek East flows northerly from Dunc Lake.

Based on the Ontario Structure Inspection Manual (OSIM) prepared by MTO on November 20, 2014, the existing culvert is a corrugated steel pipe arch that is 3.9 m wide, 2.1 m high and 27.2 m long. The culvert barrel is in poor condition with medium corrosion on the bottom half of the culvert and rusted bolts. The culvert is sagging by approximately 0.2 m at the centre of the culvert and has excessive deformations at the outlet.

The estimated culvert invert is at approximate Elevation 324.1 m at the inlet (north) and 323.8 m at the outlet (south). The existing road grade at the culvert location is at approximate Elev. 327.4 m. The height of fill above the culvert is approximately 1.0 m to 1.5 m. The elevation of the water flowing through the culvert on May 20, 2014, was reported at approximately 325.1 m.

The area on either side of the creek near the inlet and outlet of the culvert is vegetated with tall grass, and shrubs. Photographs in Appendix D show the culvert and the surrounding area.

The site lies within the physiographic region known as the Wawa Subprovince of the Superior Province of the Canadian Shield. Based on OGS Map 2545, titled "Bedrock Geology of Ontario", dated 1991, the bedrock is of the Archean age and consists of intrusive rocks, mainly massive to foliated granodiorite and granite. The subsoils on site generally consist of an alluvial plain comprised mainly of sand and glacial till with a predominantly sand to silty sand matrix.

3. INVESTIGATION PROCEDURES

The current investigation and field testing program was carried out between July 23 and August 1, 2018, and consisted of drilling and sampling three (3) boreholes, designated as Boreholes

18-15 to 18-17, to depths of between 8.6 m and 10.5 m below existing ground surface. Borehole 18-15 was drilled at the inlet of the existing culvert near the locations of the proposed cofferdam. Boreholes 18-16 and 18-17 were drilled within the paved portion of the Highway, approximately 10 m east and 10 m west, respectively, of the existing culvert, for temporary roadway protection measures and for the proposed diversion pipe.

The previous preliminary investigation completed by Thurber was carried out between July 14 and September 14, 2017, during which time four boreholes denoted as Boreholes 17-07 to 17-10 were advanced to depths of 3.7 and 15.2 m at selected locations at the culvert site. In order to investigate the depth and extent of peat near the culvert, additional peat probes were also conducted near the inlet and outlet of the culvert during Thurber's preliminary investigation.

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

Four boreholes were previously drilled at this location and recorded within the October 30, 2015 report by Golder Associates. These boreholes (denoted as AL-1 to AL-4) were advanced to depths between 6.4 and 11.8 m. Based on a review of the Golder Borehole Locations and Soil Strata drawing, and topographic information provided by Hatch (Plan E-484854-17-1), the ground surface Elevations at Boreholes AL-1 and AL-4 have been re-interpreted as 325.1 m and 325.5 m respectively.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were estimated from topographic drawings provided to Thurber by Hatch. The boreholes from the current investigation were drilled using a truck-mounted drill rig for Boreholes 18-16 and 18-17, and a portable Hilti drill and tripod equipment for Borehole 18-15. The boreholes were advanced using wash boring techniques to depths between 8.6 m and 10.5 m. In all boreholes, soil samples were obtained at selected intervals using a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT), or from auger cuttings for surficial material.

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

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The groundwater level was measured within the open boreholes completed by Thurber upon completion of drilling. The boreholes were backfilled in general accordance with Ontario Regulation 903, as amended by Regulation 128/03.

Details of the borehole completion are summarized as follows:

Borehole Number	Borehole Depth / Base Elevation (m)	Completion Details
18-15	8.6/316.9	Borehole backfilled with filter sand and bentonite holeplug to surface.
18-16	10.5/316.8	Borehole caved to 3.4 m then backfilled with bentonite holeplug to 2.4 m, sand to 0.2 m, then asphalt to surface.
18-17	9.8/317.7	Borehole caved to 7.6 m then backfilled with bentonite holeplug to 3.0 m, sand to 0.2 m, then asphalt to surface.
17-07	15.2/310.1	Borehole backfilled with bentonite holeplug and cuttings to surface
17-08	3.7/323.8	Borehole backfilled with cuttings to 0.1 m, then cold patch asphalt to surface
17-09	3.7/323.9	Borehole backfilled with cuttings to 0.1 m, then cold patch asphalt to surface
17-10	3.7/323.9	Borehole backfilled with cuttings to 0.1 m, then cold patch asphalt to surface

4. LABORATORY TESTING

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

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the native silt, and a sample of the surface water from the lake upstream of the existing culvert were collected during Thurber's preliminary 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

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

In general, the subsurface conditions encountered in these boreholes beneath the asphalt and sand to silty sand embankment fill consisted of native sand to silt deposits overlying a sand and silt till. Peat was also encountered at the ground surface in the boreholes near the culvert inlet and outlet. Descriptions of the individual strata are presented below.

5.1 Asphalt

Asphalt was encountered at the surface in Boreholes AL-2, AL-3, 17-08, 17-09, 17-10, 18-16 and 18-17. The thickness of the asphalt ranged from 100 mm to 325 mm.

5.2 Silty Sand to Sand Fill

Silty sand to sand with some silt fill, containing trace gravel to becoming gravelly and trace clay, was encountered below the pavement structure in Boreholes AL-2, AL-3, 17-08 to 17-10, 18-16, and 18-17. The fill was approximately 2.2 m to 4.7 m thick and extended to Elevations 325.2 m to 322.7 m.

SPT 'N' values within the fill layer ranged from 9 to 93 blows per 0.3 m of penetration, indicating a loose to very dense relative density. Measured moisture contents within the fill varied between 4 percent and 16 percent.

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

Soil Particle	Percentage (%)
Gravel	8 to 28
Sand	43 to 74
Silt	28 to 33
Clay	5 to 6
Silt and Clay	11 to 28

5.3 Peat

A layer of black silty to sandy peat was encountered as the surface layer in Boreholes 18-15, 17-07, AL-1 and AL-4. The layer ranged in thickness from 0.3 m to 2.7 m and extended to Elevations 322.4 m to 325.2 m.

Additional peat probes were conducted up to 25 m to the east and west of the culvert inlet and outlet. The depth of the assumed base of the peat varied from approximately 0.5 m to 1.5 m at the inlet, and 0.4 m to 1.3 m at the outlet. At both the inlet and outlet, the thickness of the peat decreased with increased distance from the culvert. The approximate locations of the peat probes are shown on the Borehole Locations and Soil Strata drawing in Appendix C. The depths to the assumed base of the pear are summarized in the following table:

Peat Probe Number	Approximate Location	Depth to Assumed Base of Peat (m)
P1	25 m West of Culvert Outlet	0.4
P2	15 m West of Culvert Outlet	0.9
P3	5 m West of Culvert Outlet	1.0
P4	5 m East of Culvert Outlet	1.3
P5	15 m East of Culvert Outlet	1.1
P6	25 m East of Culvert Outlet	0.8
P7	25 m West of Culvert Inlet	0.6
P8	15 m West of Culvert Inlet	1.3
P9	5 m West of Culvert Inlet	1.5
P10	5 m East of Culvert Inlet	1.4
P11	15 m East of Culvert Inlet	1.2
P12	25 m East of Culvert Inlet	0.5

SPT ‘N’ values within the peat ranged from 1 to 10 blows per 0.3 m of penetration, indicating a very soft to firm/compact consistency. Higher SPT ‘N’ values of 15 and 25 were also recorded but were likely due to frozen ground at the time of the Golder investigation. Moisture contents between 48 percent and 58 percent were measured in the peat.

5.4 Sand to Silt

Sand with some silt ranging to silt with trace sand, containing trace gravel, trace clay, and occasional cobbles was encountered in all boreholes at depths of between 0.3 m to 4.9 m (Elevations 325.2 m to 322.4 m). Where fully penetrated the sand to silt layer was approximately 2.3 m to 7.9 m thick and extended to depths of between 4.5 m and 10.2 m (Elevations 321.0 m to 316.6 m). Boreholes 17-08 to 17-10 and AL-1 were terminated within the sand to silt layer at depths of between 3.7 m and 8.2 m (Elevations 323.9 m to 316.9 m).

Boulders were encountered in the sand to silt layers in Boreholes 17-07, 18-15 and 18-16 at depths of between 5.2 m and 6.9 m. Where measured, the boulder diameters ranged from 0.6 m to 0.9 m.

The SPT ‘N’ values for the silt to sand ranged from 2 to 98 blows per 0.3 m penetration with typical values between 4 to 30 blows indicating a loose to compact condition. The silt to sand had a measured moisture content ranging from 6 percent to 36 percent. A higher moisture content of 60 percent was recorded in Borehole 18-15 and is likely due to the presence of organics.

The results of grain size distribution analyses carried out on selected samples of the sand to silt are presented on the Record of Borehole sheets included in Appendices A and E and on Figure B2 and B3 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 12
Sand	2 to 82
Silt	38 to 95
Clay	0 to 8
Silt and Clay	17

5.5 Sand and Silt to Silty Sand Till

Sand and silt to silty sand till, containing trace clay to becoming clayey, trace to some gravel, and occasional cobbles, was encountered in Boreholes 18-15 to 18-17, 17-07, and AL-2 to AL-4 at depths of between 4.5 m to 10.2 m (Elevations 321.0 m to 316.6 m). These boreholes were terminated within the sand and silt to silty sand till at depths of between 6.4 m to 15.2 m (Elevations 319.1 m to 310.1 m).

The SPT 'N' values recorded in the sand and silt to silty sand till ranged from 8 to greater than 100 blows per 0.3 m penetration indicated a loose to very dense relative density. The sand and silt to silty sand till had a measured moisture content ranging from 8 percent to 16 percent.

The results of grain size distribution analyses and an Atterberg Limit carried out on selected samples of the sand and silt to silty sand till are presented on the Record of Borehole sheets included in Appendices A and E and on Figures B4 and B5 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 50
Sand	31 to 37
Silt	13 to 55
Clay	1 to 27

The results of Atterberg Limits testing are summarized below:

Index Property	Percentage (%)
Plastic Limit	11
Liquid Limit	21
Plasticity Index	10

The results of the Atterberg Limit test indicate the layer to be of low plasticity with group symbols CL.

5.6 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. The groundwater levels are summarized below:

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
18-15	August 1, 2018	0.7	324.8	Open borehole
18-16	July 24, 2018	2.0	325.3	Open borehole
18-17	July 23, 2018	2.4	325.1	Open borehole
17-07	September 12, 2017	0.3	325.0	Open borehole
17-08	June 14, 2017	2.1	325.4	Open borehole
17-09	June 14, 2017	2.4	325.2	Open borehole
17-10	June 14, 2017	Dry	Dry	Open borehole
AL-01	April 7, 2015	1.0	324.1	Open borehole
AL-02	March 17, 2015	2.9	324.7	Open borehole
AL-03	March 17, 2015	3.0	324.2	Open borehole
AL-04	April 7, 2015	0.8	324.7	Open borehole

The creek water level on May 20, 2014 was reported to be Elev. 325.1 m upstream and downstream of the outlet.

The groundwater levels above 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 after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native silt from Borehole 17-07 and a sample of the creek water were submitted for analytical testing of corrosivity parameters and sulphate during the preliminary investigation. 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	
			17-07, SS#6, 4.6 m – 5.2 m	Alder Creek East
			(Silt)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	mg/L	mg/L	1000	23
Sulphate	mg/L	mg/L	73	1.5
pH	No unit	No unit	8.60	7.90
Electrical Conductivity	µS/cm	µS/cm	1090	170
Resistivity	Ohms.cm	Ohms.cm	910	5880
Redox Potential	mV	mV	196	291

7. MISCELLANEOUS

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

Downing Drilling of Hawkesbury, Ontario and OGS 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. Liam Steers and Mr. Ryan McCourt of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. of Thurber.

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

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

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the factual report and presents detailed foundation design recommendations for the proposed Alder Creek East Culvert replacement on Highway 17, located in the Unsurveyed District of Thunder Bay, Ontario. This detailed foundation report should be read in conjunction with the Preliminary Foundation Report dated September 11, 2018.

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

Information on the existing culvert site was obtained from the MTO Terms of Reference, the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on November 20, 2014, and the report “Preliminary Foundation Investigation and Design Report, Alder Creek E. Culvert, Highway 17, District of Thunder Bay, Unsurveyed Territory, Ministry of Transportation, Ontario, G.W.P 6330-14-00” Geocres No. 42C-37, prepared by Golder Associates, dated October 30, 2015. The existing structure consists of a structural plate corrugated steel pipe arch structure. The culvert measures 3.9 m wide, 2.1 m high and 27.2 m long. The estimated culvert invert is at approximate Elevation 324.1 m at the inlet (north) and 323.8 m at the outlet (south). The existing road grade at the culvert location is at approximate Elev. 327.4 m, and there is approximately 0.8

m to 1.5 m of fill above the culvert.

The preliminary foundation report provided recommendations for both pipe culverts and box culverts. General Arrangement Drawings and discussions with Hatch indicate that a precast concrete box culvert is the preferred replacement option. The concrete box culvert is to have an interior width of 4.0 m and a interior height of 2.2 m. The invert level of the new box culvert (underside of box) will be at approximately 323.5 and 323.2 m at the inlet and outlet, respectively.

The new culvert replacement will be constructed generally along the same alignment as the existing culvert. No grade raise is proposed for the culvert replacement. No headwalls or wingwalls are proposed.

A temporary creek diversion pipe is to be located approximately 11 m west of the culvert centreline while the new culvert is being installed. The invert level of the diversion pipe is approximately at Elevation 324.0 m.

It is understood that temporary roadway protection will be used to construct the new box culvert in stages.

9. CULVERT FOUNDATION DESIGN

In general, the subsurface conditions encountered in the boreholes from the current and preliminary investigations consisted silty sand to sand embankment fill overlying native very loose to very dense silt to sand, which is further underlain by silt and sand till. Surficial silty to sandy peat was also encountered near the outlet and inlet of the existing culvert.

Water levels in the open boreholes ranged from Elevation 324.1 m to 325.4 m. The creek water level on May 20, 2014 was reported to be Elev. 325.1 m upstream and downstream of the culvert.

The founding soils encountered at the proposed invert levels generally consists of loose to compact silty sand to silt soils or compact sand fill. There is approximately 0.8 m to 1.6 m of fill about the proposed culvert replacement.

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

Foundation design aspects for the replacement culvert include subgrade conditions and preparation, geotechnical resistances, settlement of foundation soils, lateral earth pressures, roadway protection system design, groundwater control, cofferdams, staged construction, and restoration of the roadway embankment.

9.1 Foundations

Replacement of the culvert with a concrete box culvert on the same alignment is considered a viable alternative for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

In order to provide a uniform foundation subgrade, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert, similar to as shown on OPSD 803.010. The bedding material should be placed on the prepared subgrade as soon as practicable following its inspection and approval. The subgrade preparation and placement and compaction of the bedding material should be carried out in the dry. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212 µm. The subgrade surface prepared to support the box units should have a 75 mm minimum thick top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elevation 323.1 m, which corresponds to loose to compact native silty sand to silt or sand fill. Any excessively loose soil, large cobbles and boulders, and any organic or other deleterious material encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition. Sub-excavation of peat may be required at the ends of the culvert if the replacement culvert will extend beyond the footprint of the existing culvert.

The following geotechnical resistances are recommended for the design of a 5 m to 6 m wide box culvert founded at or below Elevation 323.5 m on the loose to compact native silt to silty sand or sand fill:

Geotechnical Resistance	5 m to 6 m wide Culvert
Factored Geotechnical Resistance at ULS	225 kPa
Geotechnical Resistance at SLS (for up to 25 mm settlement)	150 kPa

A consequence factor of 1.0 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per Canadian Highway Bridge Design Code (CHBDC) 2014, Section 6.9.

The factored ultimate resistance and settlement are dependent on the footing/culvert size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert width or founding/invert elevation differs significantly from that given above.

The above geotechnical resistances are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance values used in design must be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

Resistance to sliding between the concrete and the underlying Granular A or B Type II bedding material should be calculated assuming an ultimate coefficient of friction of 0.45.

The culvert should be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

9.2 Frost Cover

The depth of frost penetration at this site is approximately 2.4 m based on OPSD 3090.100. The frost cover requirement does not apply to the box culvert option.

Based on the results of the field investigation, the existing embankment and underlying subgrade soil at the culvert location comprise mainly sand fill material to below the frost penetration depth; therefore, construction of new frost tapers does not appear warranted as part of the culvert replacement.

9.3 Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining loose fill, topsoil, organic creek bed deposits, peat, disturbed soils and any deleterious materials within the replacement culvert footprint must be removed and replaced with granular material compacted as per OPSS.PROV 501. In particular, it is anticipated that peat will be encountered near the inlet and outlet of the culvert if the new culvert will extend beyond the footprint of the existing culvert.

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

The work should be carried out in accordance with OPSS 902 and culvert construction, and subgrade preparation must be carried out in the dry.

9.4 Settlement

The replacement culvert will be constructed approximately on the same alignment and with similar opening size as the existing culvert with no grade raise on the overlying embankment or embankment widening. Therefore, changes in the loading conditions on the foundation soils consisting of compact native sands and silts are not expected to be significant. The post-construction settlements after culvert construction and embankment reconstruction at this site are estimated to be less than 25 mm. The foundation settlements will essentially be complete at the end of construction.

If the final design involves embankment widening or grade raise, foundation soil settlement due to this addition of fill must be assessed to determine the impact of such settlement on the performance of the replacement culvert.

10. EXCAVATION AND GROUNDWATER CONTROL

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native sands and silts at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level.

Surficial alluvial deposits that are anticipated in the inlet and outlet areas should be classified as Type 4 soils.

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

Excavations for culvert replacement will be carried out through the existing embankment fill and extend into the native sands and silts.

Installation of the culvert must be carried out in the dry. It is anticipated that excavation for culvert replacement will be carried out at or below the creek water level, and diversion of the creek flow will be required. Seepage should be anticipated from the embankment fill and the silt to sand soils adjacent to the creek. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps within an enclosure will be required to maintain dry excavations during the course of staged construction. Recommendations for cofferdam design are provided in Sections 14 and 15 below. The dewatering scheme must be effective to lower the groundwater level at least 0.5 m below the final subgrade level to avoid base boiling in the native soils.

The invert level of the temporary diversion pipe will also be below the groundwater table. Dewatering will also be required for the construction and installation of the diversion pipe.

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

In accordance with SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517. A preconstruction survey is not required, thus Designer Fill-In ** in SP FOUN0003 should be “N/A”. Considering the conditions on site, 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.

Dewatering must remain operational and effective until the culvert is installed and backfilled. Suggesting wording for an NSSP in this regard is included in Appendix F.

11. STREAM DIVERSION PIPE

A temporary CSP stream diversion pipe is proposed to accommodate creek water flow during culvert replacement. Based on the general arrangement drawing, the invert of the diversion pipe is at approximate Elevation 324.0 m, which corresponds to loose silt and sand. Peat may also be encountered at the inlet and outlet.

The temporary diversion pipe should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per 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 should be carried out in the dry. The prepared subgrade should be protected from disturbance during construction.

The stream diversion pipe could be installed within the temporary open cut excavations, or within a shored excavation using a trench box.

12. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010 or 803.010, as appropriate. Backfilling for the culvert should be in accordance with OPSS 422 and OPSS 902. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

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

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

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

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended unfactored values are shown in Table 12.1 below.

Table 12.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II ϕ = 35°; γ = 22.8 kN/m³		OPSS Granular B Type I or Type III ϕ = 32°; γ = 21.2 kN/m³	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive	3.7	-	3.3	-

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

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

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

13. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site includes loose to compact sand and silt soils, underlain by very dense sand and silt till. This would correspond to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.034 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 13.1 may be used:

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Table 13.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II ϕ = 35°, γ = 22.8 kN/m^3	OPSS Granular B Type I or Type III ϕ = 32°, γ = 21.2 kN/m^3
Active (K_{AE})[1,2]	0.29	0.32
Passive (K_{PE})	3.6	3.2
At Rest (K_{OE})[3]	0.49	0.53

Note 1: Mononobe and Okabe, 1929, World Engineering Congress 9: 179-187

Note 2: Passive case assumes a horizontal surface in front of the wall.

Note 3: Wood, J. H. 1973, earthquake induced soil pressures on structures, PhD Thesis, California Institute of Technology, Pasadena, CA.

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

14. COFFERDAMS

Construction of cofferdams will be required to construct the culvert replacement in the dry. It is recommended that excavations be enclosed within a water tight enclosure. Both sand bag cofferdams and interlocking sheet piles are considered feasible for cofferdam construction at this site. Due to the highly permeable foundation soils, interlocking sheet pile cofferdams are expected to be more effective than sand bag cofferdams, however boulders were encountered in several boreholes which may impede the driving of sheet piles. The recommendations provided in Section 15 below for Temporary Protection Systems are also applicable to sheet piled cofferdams. Sheet pile cofferdams should extend deep enough to penetrate a sufficient distance in the native silt to sand and silt soils to reduce the upward seepage flow into the culvert excavation.

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

15. TEMPORARY PROTECTION SYSTEM

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

Options for roadway protection are a soldier pile-lagging system or interlocking sheet piles. The presence of occasional boulders may however impede the driving of sheet piles.

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

Table 15.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Sand Fill	Native Silt to Sand and Silt
Φ (angle of internal friction)	32˚	28˚
γ (total unit weight)	20 kN/m^3	20 kN/m^3
γ_w (submerged unit weight)	10 kN/m^3	10 kN/m^3
K_a	0.31	0.36
K_p	3.3	2.8

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

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

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

16. EMBANKMENT RESTORATION

Provided that the embankment is reconstructed with side slopes inclined not steeper than 2H:1V, the restored embankment slope should remain stable. As discussed in Section 9.4, and if there is no grade raise or embankment widening, settlement under the restored embankment will be less than 25 mm.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206. The embankment reconstruction material may consist of imported Granular A, Granular B Type II, or Granular B Type III material.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces 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 creek 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 and a clay seal (only at the inlet) 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 geosynthetic 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 native silt and creek water indicate the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surface water is considered to be negligible due to the low concentration of sulphate and chloride in the sample tested. However, the silt sample had a high chloride content, indicating that the surrounding soil may be corrosive to steel reinforcement in concrete structures. The effect of road deicing salt should also be considering while selecting the class of concrete.
- The potential for surface water corrosion on metal is considered to be negligible. However, the corrosion potential from the soil on steel, cast iron, and other metals is very severe based on the low resistivity value and high pH of the soil sample tested.

- Appropriate protection measures are recommended for concrete and metal structural elements. The effect of road deicing salt should be considered while selecting the corrosion protection measures.

19. CONSTRUCTION CONCERNS

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

- A suitable dewatering / unwatering system must be employed to enable culvert construction and subgrade preparation in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at a higher elevation at the time of construction than indicated in the report.
- Cobbles, boulders or other buried obstructions may be encountered during excavation in the existing embankment fill and native soils and may interfere with the installation of the temporary roadway protection system. Suggested wording for an NSSP on obstructions is included in Appendix F.
- The Contractor’s selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

20. CLOSURE

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

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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			

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 18-15

METRIC

W.P. 6330-14-01 LOCATION Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 625.4 E 399 727.7 ORIGINATED BY LS

DIST Thunder Bay HWY 17 BOREHOLE TYPE Wash Boring COMPILED BY MP

DATUM Geodetic DATE 2018.07.31 - 2018.08.01 LATITUDE LONGITUDE CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
325.5	GROUND SURFACE								
0.0	**PEAT**, silty to sandy, trace gravel, trace organics, trace rootlets, Soft, Brown, Moist	1	SS	3					
325.2 / 0.3	**SILT** and **SAND**, trace gravel, trace organics, trace clay, Loose to Compact, Brown, Moist to Wet	2	SS	9	Water level ▽ (approx. 324.8)	4	53	39	4
		3	SS	24					
323.7 / 1.8	**SAND**, some silt, trace gravel, Very Loose, Brown to Grey, Wet	4	SS	4					
	Some organics at 2.9m to 3.0m	5	SS	3		1	82	17 (SI+CL)	
		5B	SS						
322.5 / 3.0	**SILT**, trace to some sand, trace clay, Compact, Brown to Grey, Wet	6	SS	18		0	8	85	7
		7	SS	19					
	Boulder at 6.1m								
319.3 / 6.2	**SILT** and **SAND**, clayey, trace gravel, Very Stiff to Hard, Grey, Wet, (TILL)	8	SS	20					
	Boulder at 7.6m								
316.9 / 8.6		9	SS	180		0	37	36	27

8.6 END OF BOREHOLE AT 8.6m ON CASING REFUSAL. WATER LEVEL AT 0.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH FILTER SAND AND BENTONITE HOLEPLUG TO SURFACE.

Elevation scale: 325, 324, 323, 322, 321, 320, 319, 318, 317

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 (%)

+ 3, × 3: Numbers refer to Sensitivity; (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-16

METRIC

W.P. 6330-14-01 | LOCATION Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 639.5 E 399 742.6 | ORIGINATED BY BRM

DIST Thunder Bay HWY 17 | BOREHOLE TYPE NW Casing | COMPILED BY MP

DATUM Geodetic | DATE 2018.07.24 - 2018.07.24 | LATITUDE | LONGITUDE | CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
327.3	GROUND SURFACE								
0.0	**ASPHALT** (100mm)								
327.0 / 0.3 (0.1)	Gravelly **SAND**, some silt Very Dense Brown Moist (FILL)	1	SS	77		28	61	11 (SI+CL)	
	Silty **SAND**, wth gravel to some gravel, trace clay Very Dense Brown Moist (FILL)	2	SS	60					
		3	SS	60	∇	24	43	28	5
324.9 / 2.4	**SILT**, some peat, some sand, trace gravel Compact to Dense Black to Brown Wet	4	SS	29					
		5	SS	16					
		6	SS	34					
322.1 / 5.2	**BOULDER**								
321.2 / 6.1	**SAND** and **SILT**, some gravel, trace clay Compact to Very Dense Grey Wet	7	SS	24					
		8	SS	98		12	41	39	8
319.1 / 8.2	**SAND** and **SILT**, some clay to clayey, trace gravel, occasional cobbles and boulders Very Dense Dark Grey Moist (TILL)	9	G						

Plot headings: 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. Elevation scale: 327, 326, 325, 324, 323, 322, 321, 320, 319, 318.

Continued Next Page

+ ³, × ³ : Numbers refer to Sensitivity

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

Ministry of Transportation
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THURBER

RECORD OF BOREHOLE No 18-16

METRIC

W.P. 6330-14-01	LOCATION Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 639.5 E 399 742.6		ORIGINATED BY BRM
DIST Thunder Bay HWY 17	BOREHOLE TYPE NW Casing		COMPILED BY MP
DATUM Geodetic	DATE 2018.07.24 - 2018.07.24	LATITUDE LONGITUDE	CHECKED BY MEF

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
	Continued From Previous Page													
316.8			10	SS	50/ 0.100		317		o		4	34	37	25
10.5	END OF BOREHOLE AT 10.5m. WATER LEVEL AT 2.0m UPON COMPLETION. BOREHOLE CAVED TO 3.4m, THEN BACKFILLED WITH BENTONITE HOLEPLUG TO 2.4m, SAND TO 0.2m, THEN COLD PATCH ASPHALT TO SURFACE.													

Legend: SHEAR STRENGTH kPa — ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE. Plastic limit w_P, natural moisture content w, liquid limit w_L.

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-17

METRIC

W.P.	6330-14-01	LOCATION	Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 640.0 E 399 719.5	ORIGINATED BY	BRM
DIST	Thunder Bay HWY 17	BOREHOLE TYPE	NW Casing	COMPILED BY	MP
DATUM	Geodetic	DATE	2018.07.23 - 2018.07.23 LATITUDE LONGITUDE	CHECKED BY	MEF

SOIL PROFILE / SAMPLES

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
327.5	GROUND SURFACE					
0.0	**ASPHALT** (100mm)					
0.1	Silty **SAND**, some gravel, trace clay Very Dense to Compact Light Brown to Grey Moist (FILL)	1	SS			
		2	SS	80		17 55 28 (SI+CL)
		3	SS	20		
325.2 / 2.3	**SILT** and **SAND**, trace gravel, trace clay Compact to Loose Brown to Grey Wet	4	SS	19	∇	6 47 39 8
		5	SS	4		
		6	SS	5		
321.4 / 6.1	**SILT**, trace sand, trace clay Loose Grey Wet	7	SS	9		0 2 91 7
319.9 / 7.6	Silty **SAND**, some gravel, trace clay Compact Grey Moist (TILL)	8	SS	19		
		9	SS	17		
317.7 / 9.8	END OF BOREHOLE AT 9.8m.					

ELEVATION SCALE: 327, 326, 325, 324, 323, 322, 321, 320, 319, 318

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

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 18-17

METRIC

W.P. 6330-14-01 LOCATION Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 640.0 E 399 719.5 ORIGINATED BY BRM

DIST Thunder Bay HWY 17 BOREHOLE TYPE NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.23 - 2018.07.23 LATITUDE LONGITUDE CHECKED BY MEF

SOIL PROFILE			SAMPLES					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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	Continued From Previous Page										
	WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE CAVED TO 7.6m, THEN BACKFILLED WITH BENTONITE HOLEPLUG TO 3.0m, SAND TO 0.2m, THEN COLD PATCH ASPHALT TO SURFACE.										

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-07

METRIC

W.P.	6330-14-01	LOCATION	Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 650.8 E 399 721.8	ORIGINATED BY	TTB
HWY	17	BOREHOLE TYPE	Hilti Portable/Wash Boring/Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.09.12 - 2017.09.14	CHECKED BY	NLB

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
325.3	GROUND SURFACE
0.0	**PEAT**, silty, trace sand, trace clay Compact Brown Wet
324.5 / 0.8	Silty **SAND**, trace gravel Compact Grey Wet
323.1 / 2.2	**SILT**, trace to some sand, trace clay, trace gravel, occasional cobbles Compact Grey Wet Trace clay (at approx. elev. 319.1)
318.4 / 6.9	**BOULDER**
317.8 / 7.5	**SILT**, some sand, trace gravel Compact Grey Wet
316.6 / 8.7	**SILT** and **SAND**, trace to some clay, trace gravel, occasional cobbles and boulders Very Dense (TILL)

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	10	
2	SS	10	
3	SS	13	
4	SS	25	
5	SS	22	0 2 91 7
6	SS	14	
7	SS	19	0 17 75 8
1	GS		
8	SS	14	
2	GS		
9	SS	100/ 0.100	

Ground water level (∇) at approx. elev. 325.

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (325, 324, 323, 322, 321, 320, 319, 318, 317, 316); 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

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 1/26/18

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-07

METRIC

W.P.	6330-14-01	LOCATION	Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 650.8 E 399 721.8	ORIGINATED BY	TTB
HWY	17	BOREHOLE TYPE	Hilti Portable/Wash Boring/Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.09.12 - 2017.09.14	CHECKED BY	NLB

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SILT and **SAND**, trace to some clay, trace gravel, occasional cobbles and boulders Very Dense Grey Moist (TILL)				315					
		10	SS	100/ 0.125						
					314					
		3	GS							
		11	SS	50/ 0.025		o	6	34	38	22
					313					
		4	GS		312					
		12	SS	100/ 0.050		o				
					311					
310.1 / 15.2	END OF BOREHOLE AT 15.2m. BOREHOLE OPEN AND WATER LEVEL AT 0.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.	13	SS	50/ 0.0						

Column headings also include: STRAT PLOT; GROUND WATER CONDITIONS; 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 (20 40 60); UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%).

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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-08

METRIC

W.P. 6330-14-01
LOCATION Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 638.7 E 399 742.7
ORIGINATED BY ES

HWY 17
BOREHOLE TYPE Solid Stem Augers
COMPILED BY AN

DATUM Geodetic
DATE 2017.07.14 - 2017.07.14
CHECKED BY NLB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
327.5	GROUND SURFACE						
327.2 / 0.0	**ASPHALT:** (300mm)						
324.7 / 0.3	**SAND**, some silt, trace gravel; Brown; Moist; (FILL)	1	GS		Water level at approx. elev. 325.4		
323.8 / 2.8	**SAND** and **SILT**, trace clay, trace peat; Compact; Dark Brown; Wet	2	GS				0 56 38 6
		1	SS	12			
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE OPEN AND WATER LEVEL AT 2.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.						

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; ELEVATION SCALE (327, 326, 325, 324); 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.

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-09

METRIC

W.P.	6330-14-01	LOCATION	Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 640.6 E 399 752.6	ORIGINATED BY	ES
HWY	17	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.07.14 - 2017.07.14	CHECKED BY	NLB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
327.6	GROUND SURFACE											
0.0 / 327.3	**ASPHALT:** (325mm)											
0.3	Silty **SAND**, trace gravel, trace clay Brown Moist to Wet (FILL)		1	GS			327	~3	8	53	33	6
			2	GS		▽ (≈325.2)	326	~8				
324.6 / 3.0	**SAND** and **SILT**, trace gravel Dense Grey Wet		1	SS	31		325	~7				
323.9 / 3.7	END OF BOREHOLE AT 3.7m. BOREHOLE OPEN AND WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.						324					

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 (%)

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-10

METRIC

W.P.	6330-14-01	LOCATION	Alder Creek East Culvert, MTM NAD 83 Zone 14 N 5 398 642.3 E 399 762.4	ORIGINATED BY	ES
HWY	17	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AB
DATUM	Geodetic	DATE	2017.07.14 - 2017.07.14	CHECKED BY	NLB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
327.6	GROUND SURFACE												
0.0 / 327.3	**ASPHALT:** (300mm)												
0.3	**SAND**, some silt, trace gravel Brown Moist (FILL)		1	GS			327, 326	o					
324.9 / 2.7	**SAND** and **SILT**, trace clay, occasional cobbles Dense Grey to Brown Wet		2	GS			325	o					
			1	SS	42			o		0	55	38	7
323.9 / 3.7	END OF BOREHOLE AT 3.7m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.						324						

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

REMARKS & GRAIN SIZE DISTRIBUTION (%)

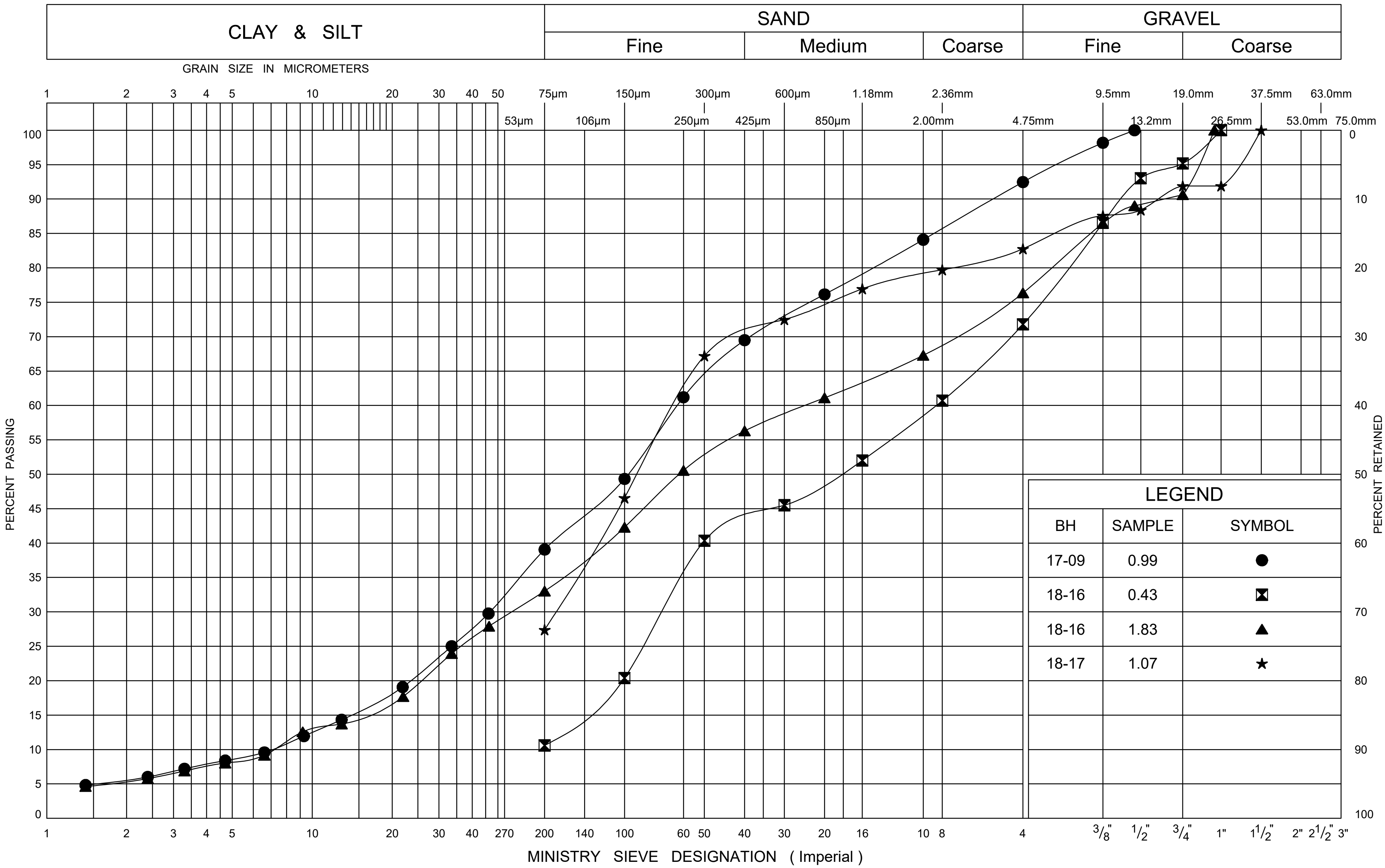
+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 1/11/18

Appendix B

Laboratory Test Results



LEGEND

BH	SAMPLE	SYMBOL
17-09	0.99	●
18-16	0.43	⊠
18-16	1.83	▲
18-17	1.07	★

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GRAIN SIZE DISTRIBUTION

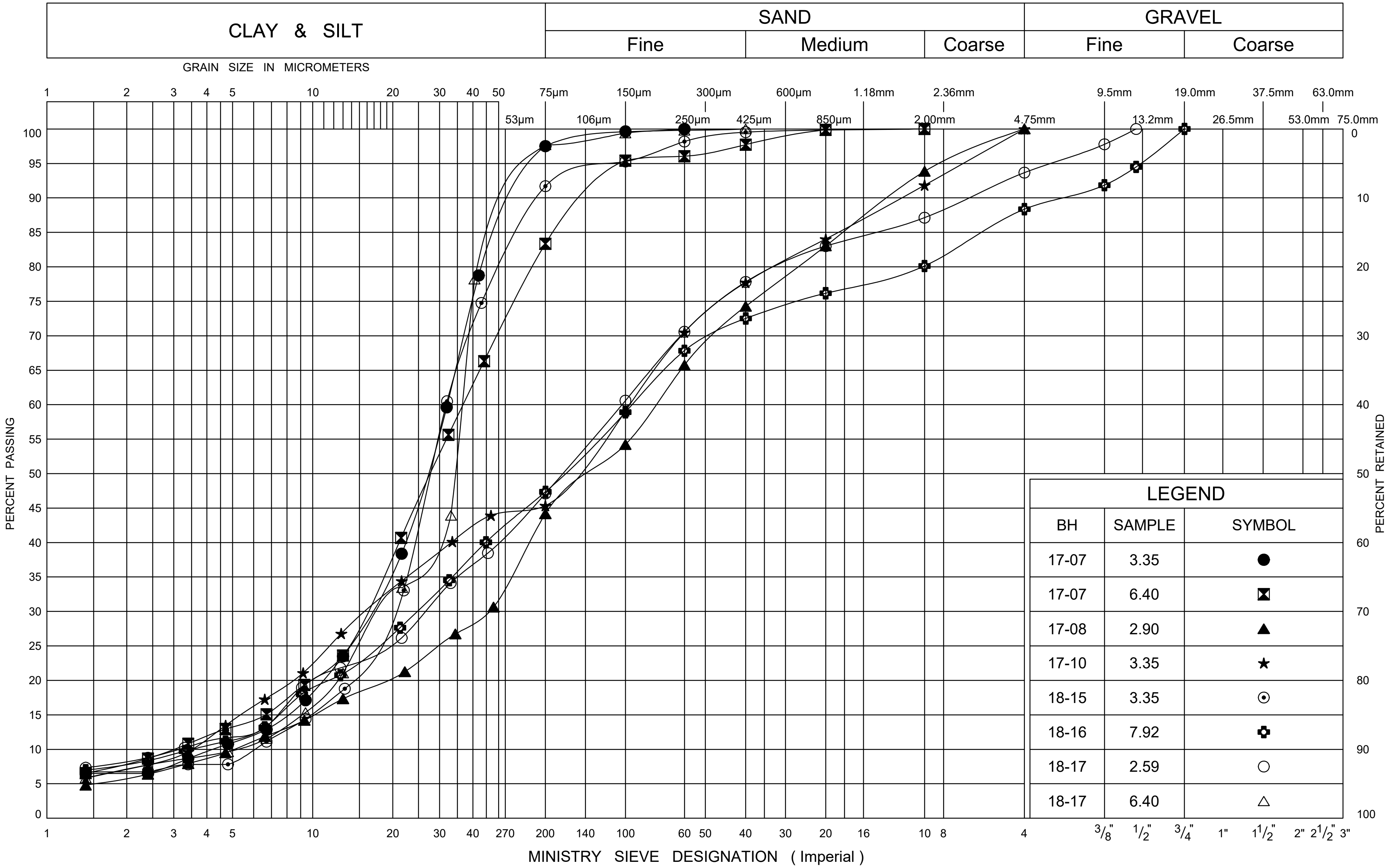
Silty SAND to Silty SAND FILL

FIG No B1

W P 6330-14-01

Alder Creek East Culvert

78 12 M



LEGEND

BH	SAMPLE	SYMBOL
17-07	3.35	●
17-07	6.40	⧗
17-08	2.90	▲
17-10	3.35	★
18-15	3.35	⊙
18-16	7.92	✤
18-17	2.59	○
18-17	6.40	△

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Ontario

GRAIN SIZE DISTRIBUTION

SAND to SILT

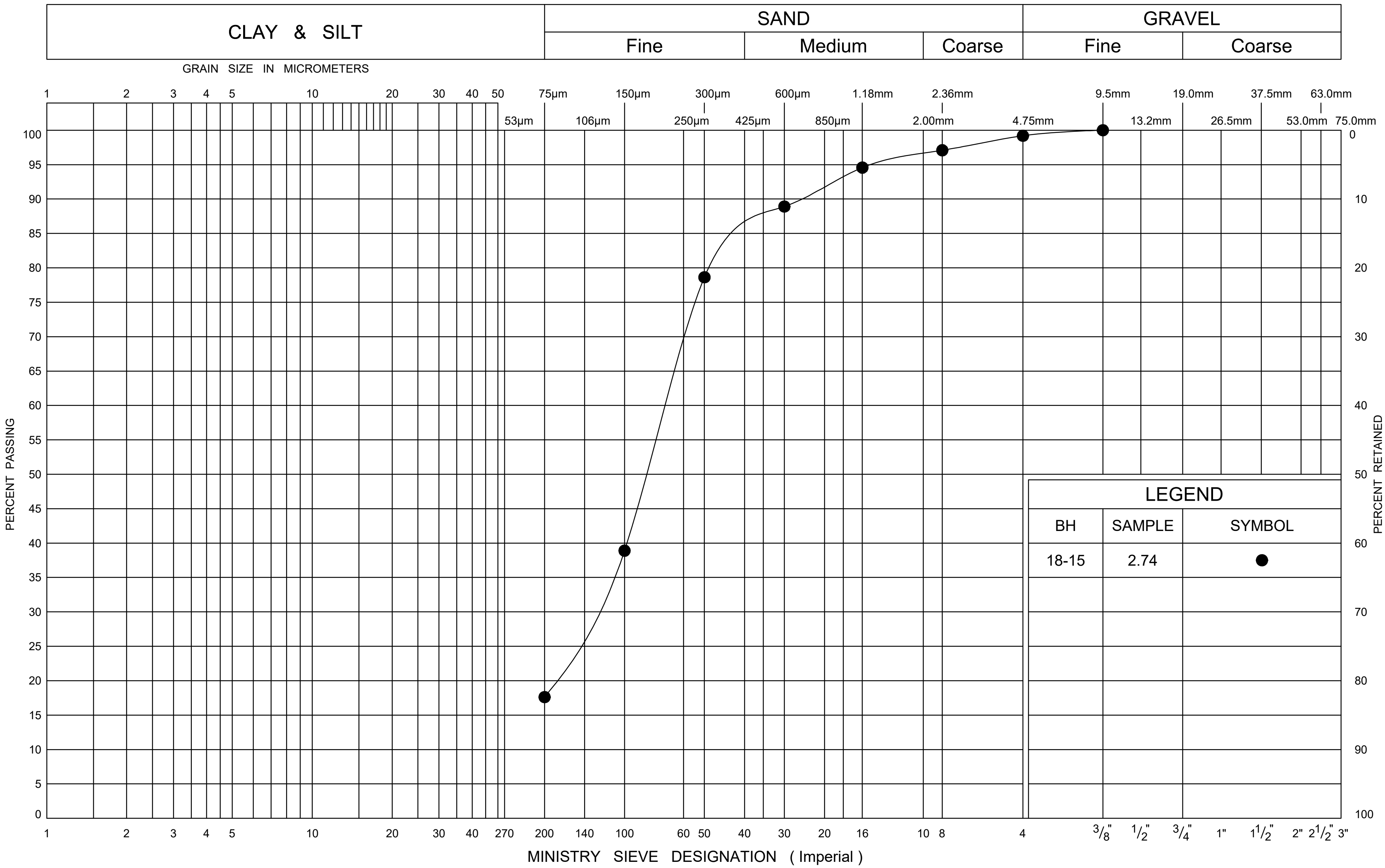
FIG No B2

W P 6330-14-01

Alder Creek East Culvert

ONTARIO MOT GRAIN SIZE 2 MTO-15595.GPJ ONTARIO MOT.GDT 11/1/18

78 12 M



ONTARIO MOT GRAIN SIZE 2 MTO-15595.GPJ ONTARIO MOT.GDT 11/1/18

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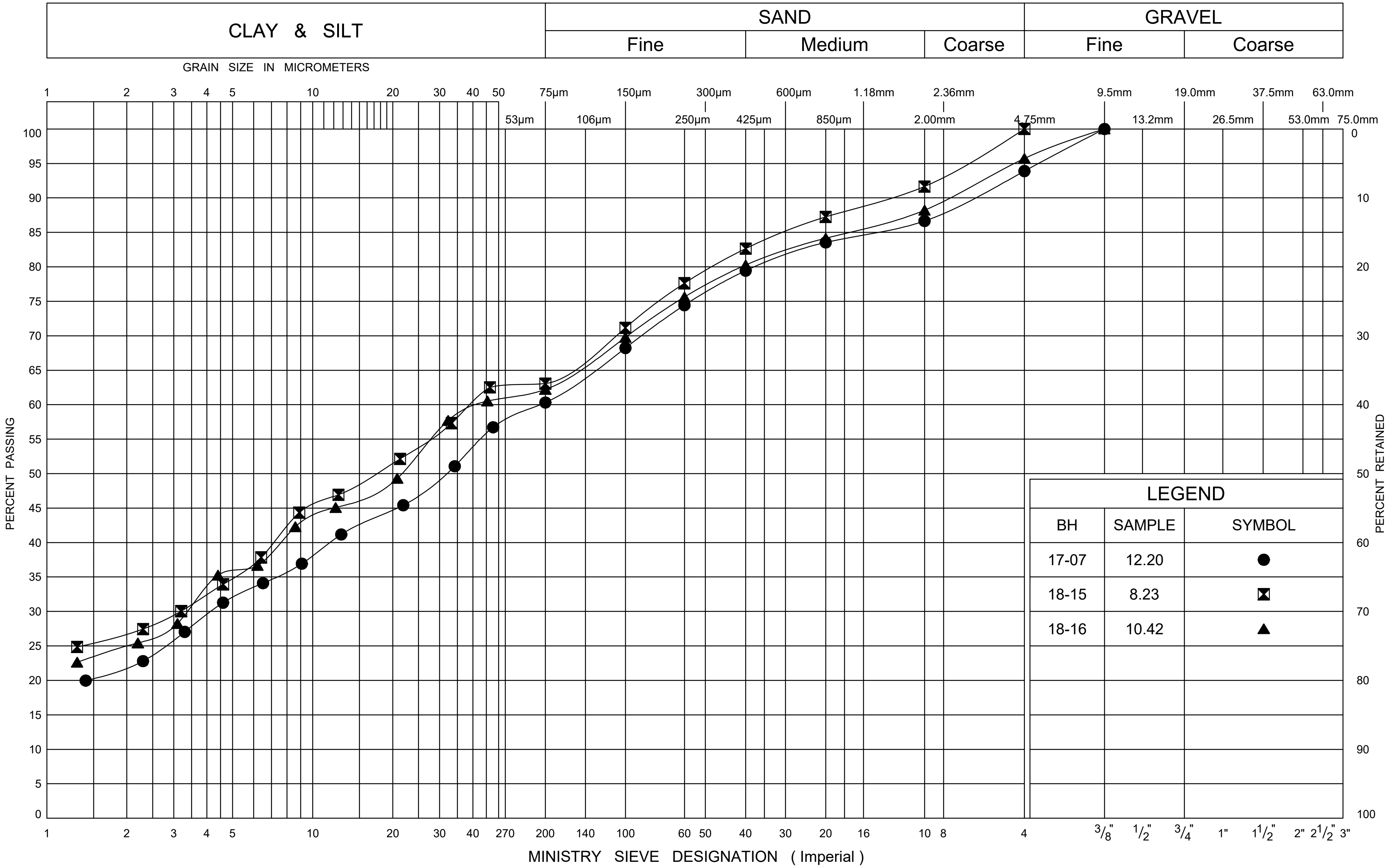
GRAIN SIZE DISTRIBUTION
SAND

FIG No B3

W P 6330-14-01

Alder Creek East Culvert

78 12 M



LEGEND		
BH	SAMPLE	SYMBOL
17-07	12.20	●
18-15	8.23	⊠
18-16	10.42	▲

ONTARIO MOT GRAIN SIZE 2 MTO-15595.GPJ ONTARIO MOT.GDT 11/1/18

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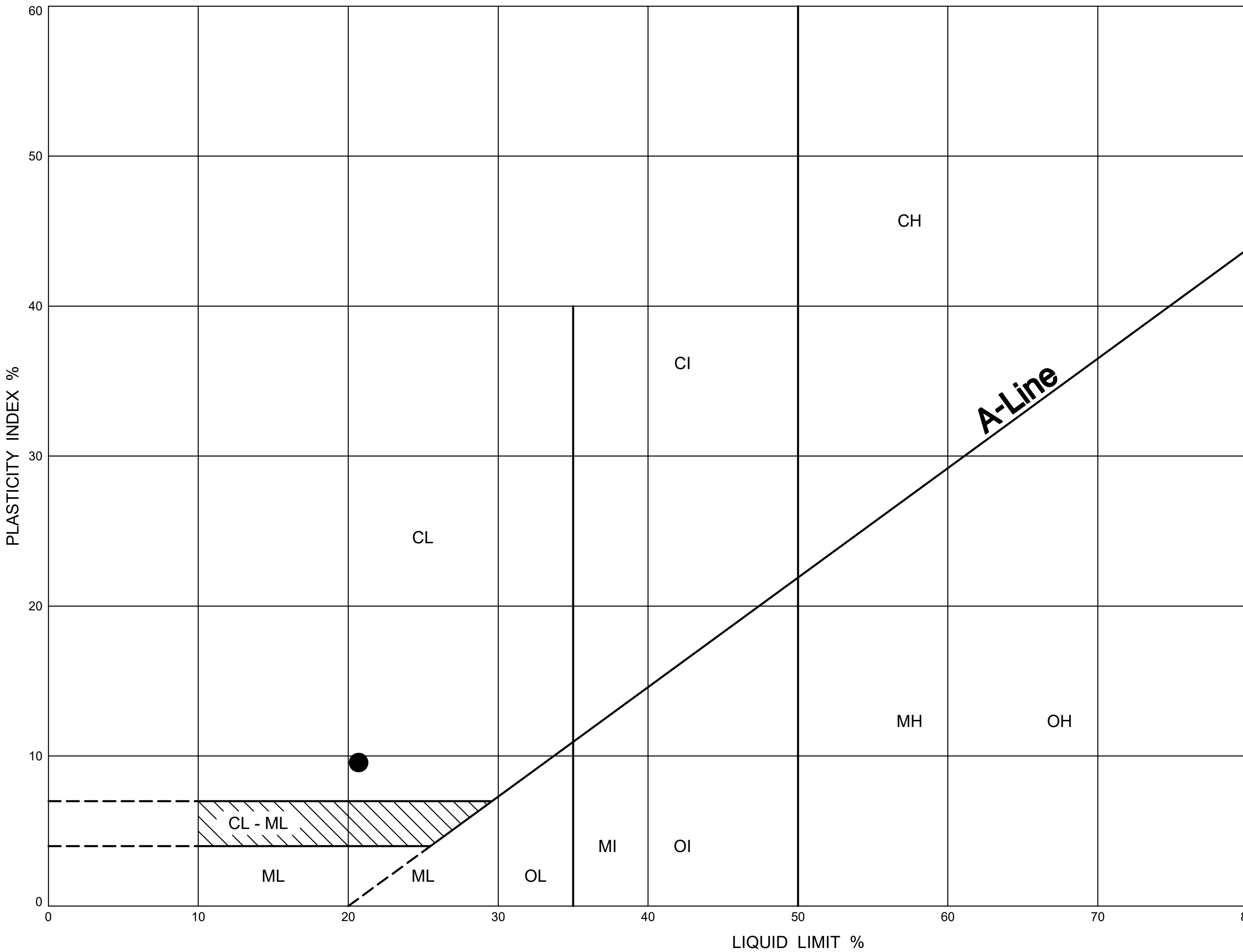
GRAIN SIZE DISTRIBUTION

SILT and SAND TILL

FIG No B4

W P 6330-14-01

Alder Creek East Culvert



LEGEND		
BH	SAMPLE	SYMBOL
18-15	8.23	●

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PLASTICITY CHART
SILT and SAND TILL

FIG No B5

W P 6330-14-01

Alder Creek East Culvert

FINAL REPORT

CA14723-OCT17 R1

15595

Prepared for

Thurber Engineering Ltd.

FINAL REPORT

First Page

CLIENT DETAILS		LABORATORY DETAILS	
Client	Thurber Engineering Ltd.	Project Specialist	Deanna Edwards, B.Sc, C.Chem
		Laboratory	SGS Canada Inc.
Address	103, 2010 Winston Park Drive Oakville, ON L6H 5R7.	Address	185 Concession St., Lakefield ON, K0L 2H0
Contact	Mark Farrant	Telephone	705-652-2000
Telephone	905-829-8666 x 228	Facsimile	705-652-6365
Facsimile		Email	deanna.edwards@sgs.com
Email	mfarrant@thurber.ca	SGS Reference	CA14723-OCT17
Project	15595	Received	10/25/2017
Order Number		Approved	11/02/2017
Samples	Soil (1)	Report Number	CA14723-OCT17 R1
		Date Reported	11/02/2017

COMMENTS

Temperature of Sample upon Receipt: 6 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.

SIGNATORIES

Deanna Edwards, B.Sc, C.Chem

Deanna Edwards

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Holding Time Summary........ 4

QC Summary........ 5-6

Legend........ 7

Annexes........ 8-9

RESULTS

		Sample Number	5
		Sample Name	BH-7, SS#6, 15'-17'
		Sample Matrix	Soil
		Sampled By	Mark Farrant
		Sample Date	24/10/2017
Parameter	**Units**	**RL**	**Result**

| Internal ref.: ME-CA-{ENV}EWL-LAK-AN-27

Parameter	Units	RL	Result
Corrosivity Index	none	1	14
Soil Redox Potential	mV	-	196
Resistivity (calculated)	ohms.cm	-9999	910

Anions by IC

Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-[ENV]IC-LAK-AN-001

Parameter	Units	RL	Result
Chloride	µg/g	0.4	1000
Sulphate	µg/g	0.4	73

Carbon/Sulphur

Method: ASTM E1915-07A | Internal ref.: ME-CA-[ENV]ARD-LAK-AN-020

Parameter	Units	RL	Result
Sulphide	%	0.02	< 0.02

Conductivity

Method: SM 2510 | Internal ref.: ME-CA-[ENV]EWL-LAK-AN-006

Parameter	Units	RL	Result
Conductivity	uS/cm	2	1090

Moisture

Method: CCME Tier 1 | Internal ref.: ME-CA-[ENV]GC-LAK-AN-010

Parameter	Units	RL	Result
Moisture Content	%	0.1	15.0

pH

Method: SM 4500 | Internal ref.: ME-CA-[ENV]EWL-LAK-AN-001

Parameter	Units	RL	Result
pH	no unit	0.05	8.60

HOLDING TIME SUMMARY

Sample Name	QC Batch Reference	Sample Number	Sampled	Received	Extracted/ Prepared	Analysed	Holding Time	Approved

|

BH-7, SS#6, 15'-17'	NA	5	10/24/2017	10/25/2017	10/31/2017	10/31/2017		10/31/2017

Anions by IC
Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-[ENV]IC-LAK-AN-001

BH-7, SS#6, 15'-17'	DIO0421-OCT17	5	10/24/2017	10/25/2017	10/27/2017	10/27/2017	11/21/2017	10/31/2017

Carbon/Sulphur
Method: ASTM E1915-07A | Internal ref.: ME-CA-[ENV]ARD-LAK-AN-020

BH-7, SS#6, 15'-17'	ECS0041-OCT17	5	10/24/2017	10/25/2017	10/27/2017	10/27/2017	11/07/2017	10/30/2017

Conductivity
Method: SM 2510 | Internal ref.: ME-CA-[ENV]EWL-LAK-AN-006

BH-7, SS#6, 15'-17'	EWL0401-OCT17	5	10/24/2017	10/25/2017	10/26/2017	10/26/2017	11/21/2017	10/30/2017

Moisture
Method: CCME Tier 1 | Internal ref.: ME-CA-[ENV]GC-LAK-AN-010

BH-7, SS#6, 15'-17'	GCM0415-OCT17	5	10/24/2017	10/25/2017	10/26/2017	10/26/2017	12/23/2017	10/31/2017

pH
Method: SM 4500 | Internal ref.: ME-CA-[ENV]EWL-LAK-AN-001

BH-7, SS#6, 15'-17'	EWL0401-OCT17	5	10/24/2017	10/25/2017	10/26/2017	10/26/2017	10/31/2017	10/30/2017

QC SUMMARY

Anions by IC

Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-[ENV]IC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0421-OCT17	µg/g	0.4	<0.4	1	20	100	80	120	95	75	125
Sulphate	DIO0421-OCT17	µg/g	0.4	<0.4	5	20	96	80	120	94	75	125

Carbon/Sulphur

Method: ASTM E1915-07A | Internal ref.: ME-CA-[ENV]ARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide	ECS0041-OCT17	%	0.02	<0.02	ND	20	109	80	120			

Conductivity

Method: SM 2510 | Internal ref.: ME-CA-[ENV]EWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0401-OCT17	uS/cm	2	< 2	0	10	99	90	110	NA		

QC SUMMARY

pH

Method: SM 4500 l Internal ref.: ME-CA-[ENV]EWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0401-OCT17	no unit	0.05	NA	1		100			NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

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

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

Multielement Scan Qualifier: as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

Duplicate Qualifier: for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Matrix Spike Qualifier: for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

LEGEND

FOOTNOTES

NSS Insufficient sample for analysis.
RL Reporting Limit.
↑ Reporting limit raised.
↓ Reporting limit lowered.
NA The sample was not analysed for this analyte
ND Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. “Temperature Upon Receipt” is representative of the whole shipment and may not reflect the temperature of individual samples.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/terms_and_conditions.htm. The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

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-- End of Analytical Report --

Certificate of Analysis

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

Attention: Mark Farrant
Project#: 15595

Client Thurber Engineering Ltd
SGS LIMS Number CA13437-JUL17
Analysis Package: Corrosivity

Sample ID Sample Date/Time	Unit	Analysis Start Date	Analysis Approval Date	Alder Creek East
Temperature Upon Receipt	°C			21.0
Corrosivity Index	NA	01-Jun-17	01-Jun-17	
Redox Potential	mV	29-May-17	30-May-17	291
Sulphide	mg/L	01-Jun-17	01-Jun-17	<0.006
% Moisture (wet wt)	NA	30-May-17	01-Jun-17	
pH	units	30-May-17	31-May-17	7.90
Chloride	mg/L	31-May-17	01-Jun-17	23
Sulphate	mg/L	31-May-17	01-Jun-17	1.5
Conductivity	µS/cm	30-May-17	31-May-17	170
Resistivity (calculated)	ohms.cm	30-May-17	01-Jun-17	5880

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

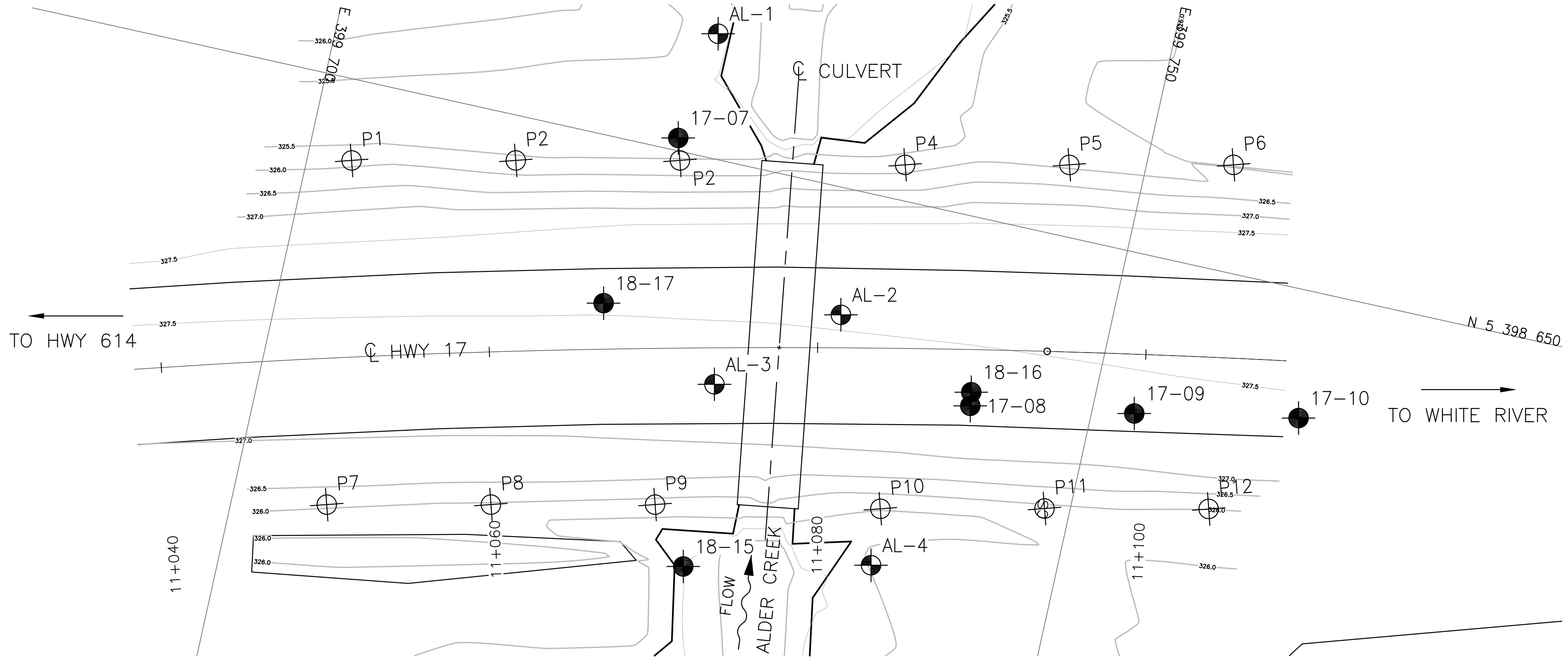
Deanna Edwards

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

THURBER

Appendix C

Borehole Locations and Soil Strata Drawing



METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No 6330-14-01

HIGHWAY 17
ALDER CREEK EAST
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

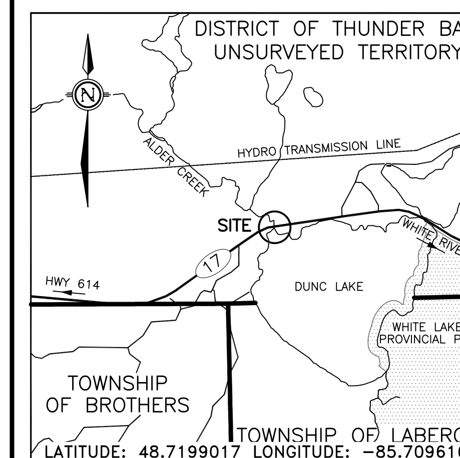
SHEET

HATCH

THURBER ENGINEERING LTD.

LICENSED PROFESSIONAL ENGINEER
M.E. FARRANT
100053767
Dec. 18/18
PROVINCE OF ONTARIO

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



KEYPLAN

LEGEND

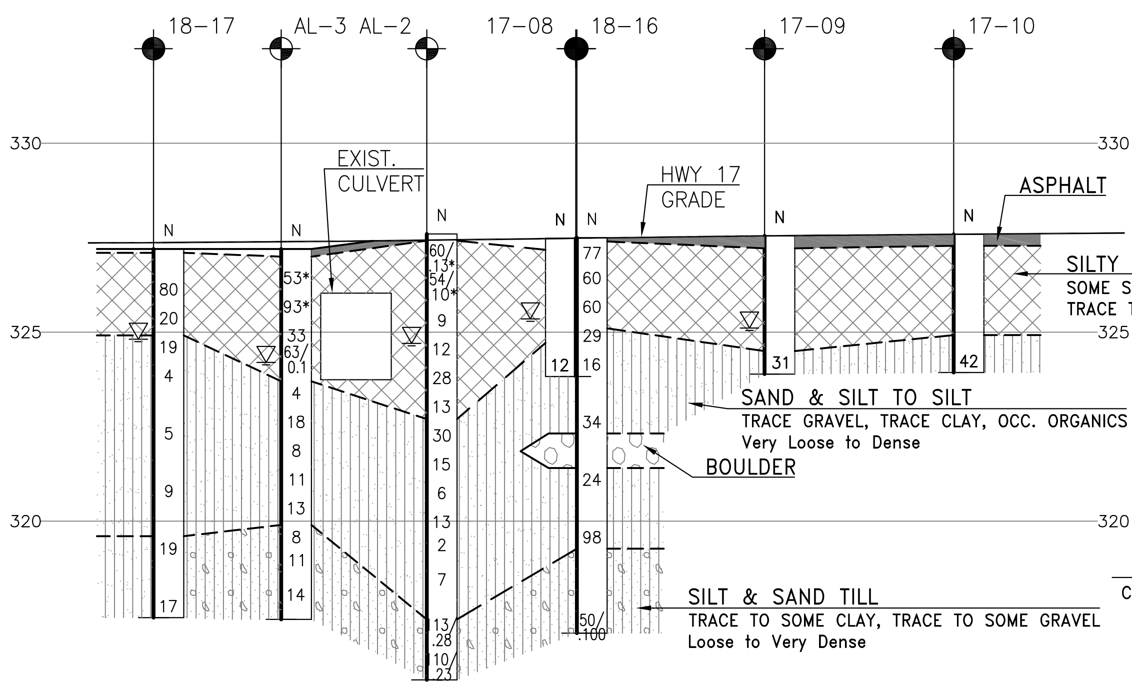
⊕ (solid)	Borehole
⊕ (half)	Borehole (Previous Investigation)
⊕	Peat Probe
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
∇	Water Level
	Head Artesian Water
	Piezometer
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-07	325.3	5 398 650.8	399 721.8
17-08	327.5	5 398 638.7	399 742.7
17-09	327.6	5 398 640.4	399 752.6
17-10	327.6	5 398 642.3	399 762.4
18-15	325.5	5 398 625.4	399 727.7
18-16	327.3	5 398 639.5	399 742.6
18-17	327.5	5 398 640.0	399 719.5
AL-1	325.1	5 398 657.5	399 722.8
AL-2	327.6	5 398 642.4	399 733.8
AL-3	327.2	5 398 636.6	399 727.2
AL-4	325.5	5 398 627.9	399 738.9

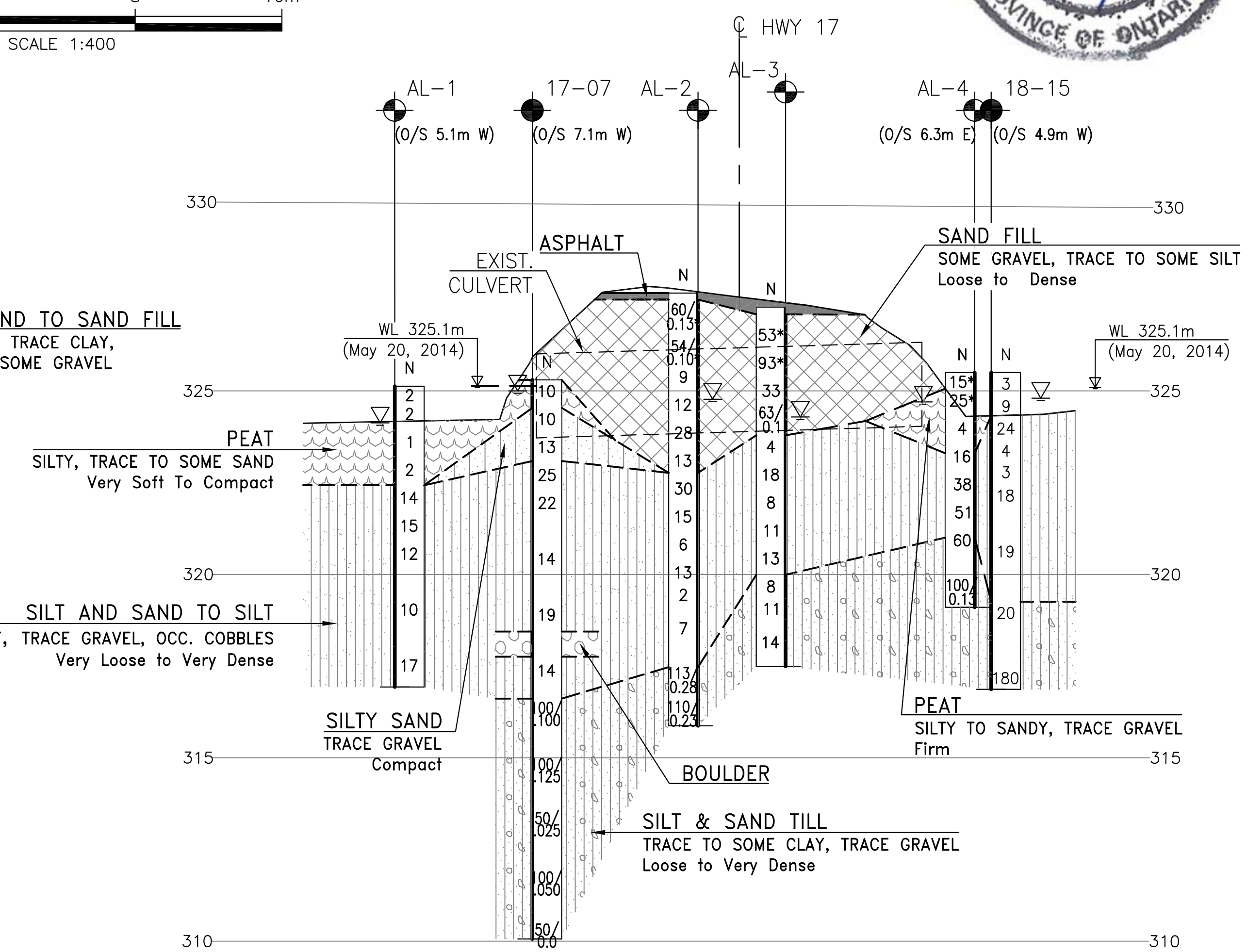
-NOTES-

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 14.
4) * Re-intepreted from original borehole logs.

GEOCRES No.



PROFILE ALONG ℄ HWY 17



SECTION ALONG ℄ CULVERT

8 0 8 16m H 1:400
4 0 4 8m V 1:200

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

THURBER

Appendix D

Site Photographs

THURBER

Photo 1: Culvert outlet looking south (May 17, 2017)

THURBER

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

THURBER

Photo 3: Road approach looking west (May 17, 2017)

THURBER

Photo 4: Road approach looking east (May 17, 2017)

Photo 5: Looking west on north side of road (outlet) (June 26, 2017)

Photo 6: Looking east on north side of road (outlet) (June 26, 2017)

THURBER

Photo 7: Looking east on south side of road (inlet) (June 26, 2017)

Photo 8: Looking west on south side of road (inlet) (June 26, 2017)

THURBER

Appendix E

Factual Data from 2015 Golder Foundation Investigation Report

Golder Associates

RECORD OF BOREHOLE No AL-1

 METRIC

PROJECT 1411523
G.W.P. 6330-14-00
LOCATION N 5398657.5; E 399722.8
ORIGINATED BY MR
DIST ___ HWY 17
BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers
COMPILED BY MT
DATUM GEODETIC
DATE April 7, 2015
CHECKED BY SEMP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
325.9	GROUND SURFACE					
0.0	Silty PEAT, trace to some sand Very soft Black Wet	1	SS	2		
		2	SS	2	∇ (Elev. 325)	
		3	SS	1		
323.2		4 A / B	SS	2		
2.7	SILT to Sandy SILT Compact Grey Wet	5	SS	14		0 26 74 0
		6	SS	15		
		7	SS	12		
		8	SS	10		0 5 95 0
317.7	Some gravel encountered below 7.6 m depth.	9	SS	17		
8.2	END OF BOREHOLE					

Note:

1. Water level at a depth of 1.0 m below ground surface (Elev. 324.9 m) upon completion of drilling.

Chart columns: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (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. Elevation scale 325 to 318.

Water content plotted: sample 4 ≈ 57%; sample 5 ≈ 22%; sample 8 ≈ 23%.

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

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 26/10/15 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No AL-2

 METRIC

PROJECT 1411523
G.W.P. 6330-14-00
DIST ___ HWY 17
DATUM GEODETIC

LOCATION N 5398642.4; E 399733.8
BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers
DATE March 17, 2015

ORIGINATED BY RI
COMPILED BY MT
CHECKED BY SEMP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
327.6	GROUND SURFACE
0.0	ASPHALT (180 mm)
0.2	Sand, some gravel, trace to some silt (FILL) Loose to compact Brown to grey Frozen* to wet Augers grinding on inferred cobbles below 3.8 m depth.
322.7 / 4.9	Sandy SILT to SILT and SAND, trace gravel, trace clay Very loose to compact Grey Wet Trace organics in Sample 6B.
317.4 / 10.2	SILT and SAND, some gravel, some clay (TILL) Very dense Grey Wet
315.8 / 11.8	END OF BOREHOLE Note: 1. Water level at a depth of 2.9 m below ground surface (Elev. 324.7 m) upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	60/ 0.13*	14 74 (12)
2	SS	54/ 0.10*	
3	SS	9	
4	SS	12	
5	SS	28	
6A / 6B	SS	13	0 55 44 1
7	SS	30	
8	SS	15	
9	SS	6	2 28 68 2
10	SS	13	
11	SS	2	
12	SS	7	
13	SS	113/ 0.28	
14	SS	110/ 0.23	12 31 41 16

Elevation scale: 327, 326, 325, 324, 323, 322, 321, 320, 319, 318, 317, 316

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED: 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

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

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 26/10/15 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No AL-3

 METRIC

PROJECT 1411523

G.W.P. 6330-14-00 LOCATION N 5398636.6; E 399727.2 ORIGINATED BY RI

DIST HWY 17 BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers COMPILED BY MT

DATUM GEODETIC DATE March 17, 2015 CHECKED BY SEMP

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
327.2	GROUND SURFACE							
0.0	ASPHALT (190 mm)					327		
0.2	Sand, some gravel, some silt (FILL) Dense Brown Frozen* to wet Augers grinding on inferred cobbles below 1.5 m depth.	1	SS	53*		326		
		2	SS	93*			○	12 74 (14)
		3	SS	33		325		
		4	SS	63/0.1	▽	324		
323.7 3.5	SILT to SILT and SAND, trace gravel, trace clay Loose to compact Grey Wet	5	SS	4		323		
		6	SS	18		322		
		7	SS	8			○	0 8 90 2
		8	SS	11		321		
319.9 7.3	SILT and SAND, trace to some gravel, trace clay (TILL) Loose to compact Grey Wet	9 A/B	SS	13		320		
		10	SS	8		319		
		11	SS	11			○	7 36 55 2
		12	SS	14		318		
317.4 9.8	END OF BOREHOLE Note: 1. Water level at a depth of 3.0 m below ground surface (Elev. 324.2 m) upon completion of drilling.							

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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

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

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 26/10/15 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No AL-4

 METRIC

PROJECT 1411523
G.W.P. 6330-14-00
LOCATION N 5398627.9; E 399738.9
ORIGINATED BY MR
DIST HWY 17
BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers
COMPILED BY MT
DATUM GEODETIC
DATE April 7, 2015
CHECKED BY SEMP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	NATURAL MOISTURE CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
325.7	GROUND SURFACE						
0.0	Silty to Sandy PEAT, trace gravel, trace wood Firm Black to dark brown Frozen* to wet	1	SS	15*		~44	
		2	SS	25*	▽ (Elev. 324.9 m)		
		3	SS	5			
323.5 2.2	SILT and SAND Compact to very dense Grey Wet Trace to some gravel below 3.0 m depth. Augers grinding on inferred cobbles below 3.8 m depth.	4	SS	16		~20	0 56 44 0
		5	SS	38			
		6	SS	51			
321.2 4.5	Gravelly SILTY SAND, trace clay (TILL) Very dense Grey Wet One large piece of gravel on 19 mm sieve in Sample 7.	7	SS	60		~5	50 36 13 1
		8	SS	100/0.13			
319.3 6.4	END OF BOREHOLE Note: 1. Water level at a depth of 0.8 m below ground surface (Elev. 324.9 m) upon completion of drilling.						

Elevation scale: 325, 324, 323, 322, 321, 320

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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

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

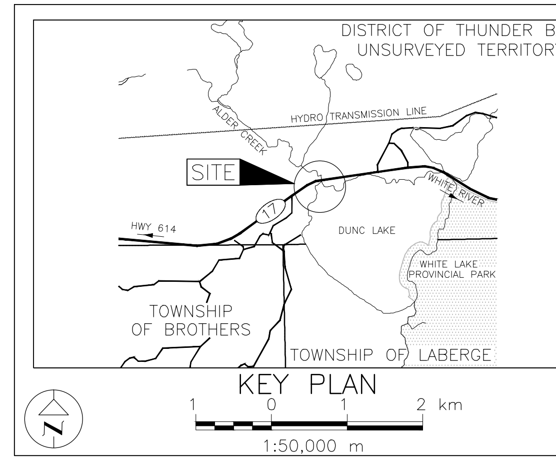
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 6330–14–00

SHEET

HIGHWAY 17
ALDER CREEK CULVERT STA 11+078
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates



LEGEND

- ● Borehole
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ▽ WL upon completion of drilling

BOREHOLE CO–ORDINATES			
No.	ELEVATION	NORTHING	EASTING
AL–1	325.9	5398657.5	399722.8
AL–2	327.6	5398642.4	399733.8
AL–3	327.2	5398636.6	399727.2
AL–4	325.7	5398627.9	399738.9

NOTES

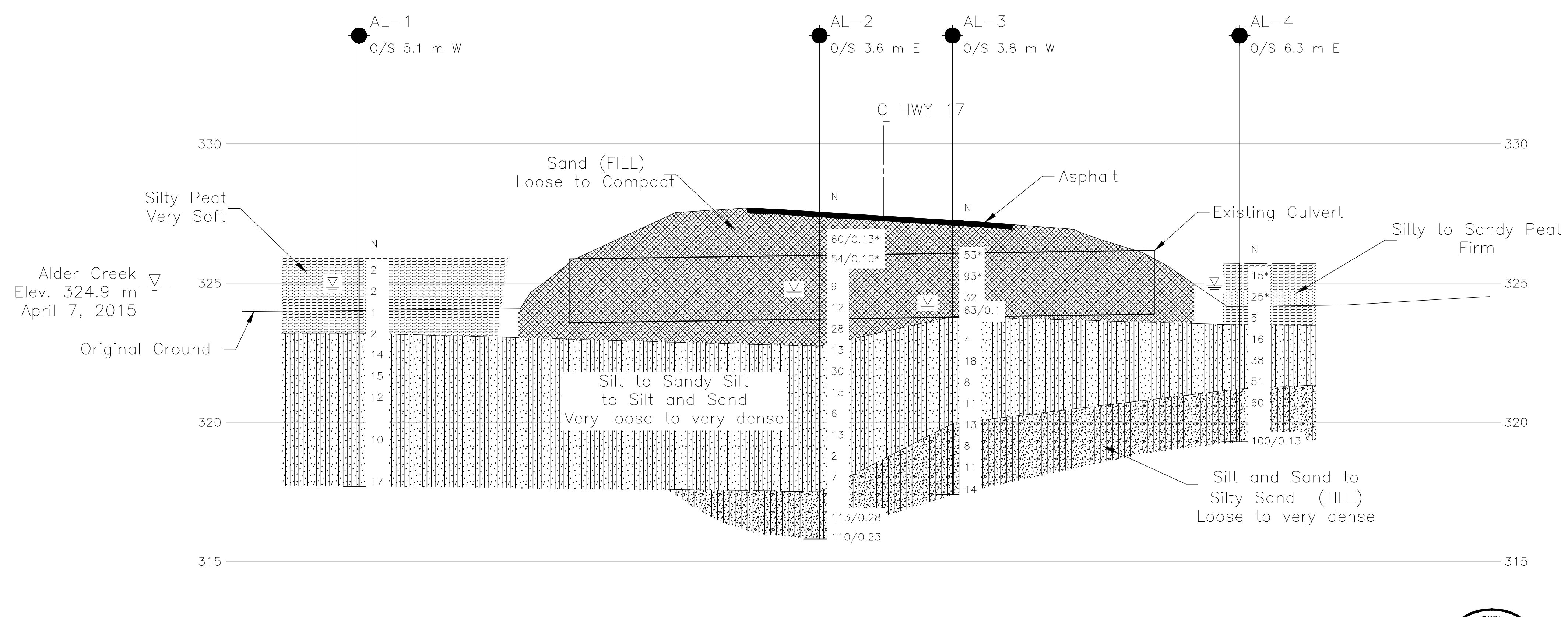
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MTO, drawing file no. E484854171, received FEB 20, 2015.



A–A' / 1
PROFILE
HORIZONTAL SCALE
2 0 2 4 m
2 0 2 4 m
VERTICAL SCALE

LICENSED PROFESSIONAL ENGINEER S.E.M. POOT 90471921 OCT 28, 2015 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA OCT 28, 2015 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 42C–37

HWY. 17	PROJECT NO. 1411523		DIST.
SUBM'D. AC	CHKD.	DATE: 10/22/2015	SITE: 48E–75/C
DRAWN: JJL/TB	CHKD. SEMP	APPD. JMAC	DWG. 1

THURBER

Appendix F

List of Specifications and Suggested Wording for NSSP

THURBER

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

- OPSS PROV 206 (Construction Specification for Grading)
- OPSS PROV 313 (Construction Specification for Hot Mix Asphalt - End Result)
- OPSS PROV 401 (Construction Specification for Trenching, Backfilling and Compacting)
- OPSS 421 (Pipe Culvert Installation in Open Cut)
- OPSS 422 (Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS 511 (Construction Specification for Rip-Rap, Rock Protection, And Granular Sheeting)
- OPSS 517 (Construction Specification for Dewatering)
- SP 517F01 (Temporary Flow Passage System)
- 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 1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material)
- OPSS PROV 1205 (Material Specification for Clay Seal)
- OPSS 1860 (Material Specification for Geotextiles)
- OPSD 208.010 (Benching of Earth Slopes)
- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- OPSD 802.014 (Flexible Pipe Embedment in Embankment)
- OPSD 802.034 (Rigid Pipe Bedding and Cover in Embankment, Original Ground: Earth or Rock)

- OPSD 803.010 (Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m)
- OPSD 803.031 (Frost Treatment – Pipe Culverts, Frost Penetration Line Between Top of Pipe and Bedding Grade)
- OPSD 810.010 (General Rip-Rap Layout for Sewer and Culvert Outlets)
- OPSD 3090.100 (Foundation Frost Depths for Northern Ontario)

2. Suggested Wording for NSSP

- **Suggested Text for NSSP on "Obstructions"**

Excavations and installation of cofferdams and roadway protection systems could encounter obstructions such as cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths. Due to the presence of sands and silts in the foundation soils, which may be subject to disturbance from vibration, vibrating equipment is not permitted for installation of sheet piles.

- **Suggested Text for Notice to Contractor on "Dewatering**"

"The Contractor is alerted that water levels may be higher than the water levels shown in the Foundation Investigation Report prepared for this site. While reference should be made to that report for a description of the encountered conditions, the Contractor must satisfy themselves regarding the groundwater levels likely to prevail at the time of construction and be prepared to implement dewatering procedures.

The Contractor is further notified that failure to implement dewatering in advance of excavating below the groundwater table may result in sloughing and boiling of the soil in the excavation and a loss in stability and bearing resistance.

THURBER

Design and provision of an effective dewatering system is the responsibility of the Contractor. The dewatering system must be effective to lower the groundwater table at a minimum of 0.5 m below the final subgrade level to avoid basal heave and base boiling. The dewatering system is to be designed in accordance with SP FOUN0003 and OPSS.PROV. 517. A preconstruction survey is not required, thus Designer Fill-In ** in SP FOUN0003 should be “N/A”. 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.