



THURBER ENGINEERING LTD.

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

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

GEOCRES Number: 42C-43

Report

to

HATCH

Date: September 11, 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 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 carried out the investigation as a sub-consultant to Hatch under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0008.

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.

A previous foundation investigation carried out at this site was documented in the report titled "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. Reference should be made to that report for a written description of the subsurface conditions, borehole location plan, stratigraphic profile, record of borehole sheets and laboratory test results obtained during the preliminary stage of the design. It should be noted that Golder is solely responsible for the subsurface information provided in the Preliminary Foundation Investigation 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. 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 field investigation for this project 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 at selected locations at the culvert site. Borehole 17-07 was drilled near the inlet of the existing culvert and Boreholes 17-08 to 17-10 were advanced at selected locations within the eastbound lane of Highway 17 to assess the existence and extent of any frost taper near the culvert. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing provided in Appendix C.

A track-mounted CME 55 drill rig was used to drill Boreholes 17-08 to 17-10 and a Hilti DD 250 E portable drill rig was used to drill Borehole 17-07. The boreholes were advanced using solid stem



augers and diamond drilling to depths between 3.7 and 15.2 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 results of the boreholes are presented on the Record of Borehole sheet in Appendix A.

In order to investigate the depth and extent of peat near the culvert, additional peat probes were conducted near the inlet and outlet of the culvert.

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.

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.

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
17-07	15.2/310.1	Bentonite holeplug and cuttings to surface
17-08	3.7/323.8	Cuttings to 0.1 m below surface then cold patch asphalt to surface
17-09	3.7/323.9	Cuttings to 0.1 m below surface then cold patch asphalt to surface



Borehole Number	Borehole Depth / Base Elevation (m)	Completion Details
17-10	3.7/323.9	Cuttings to 0.1 m below surface 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 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 consisted of asphalt and sand fill where the boreholes were advanced through the embankment and silty to sandy peat where the boreholes were advanced through the native soil near the inlet and outlet. The sand fill or peat layer was underlain by silt to silt and sand, which was underlain by silt and sand till. 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 and 17-10. The thickness of the asphalt ranged from 180 mm to 325 mm.

5.2 Peat

A layer of black silty to sandy peat was encountered as the surface layer in Boreholes 17-07, AL-1 and AL-4. The layer ranged in thickness from 0.8 m to 2.7 m and extended to elevations ranging from 322.4 m to 324.5 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.

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.

5.3 Silty Sand to Sand Fill

A layer of brown to grey sand to silty sand fill was encountered below the asphalt in Boreholes AL-2, AL-3, 17-08, 17-09 and 17-10. This layer ranged from silty sand with trace gravel and trace clay to sand with some gravel and some silt. The fill layer ranged in thickness from 2.4 to 4.7 m and extended to Elevations of 324.9 m to 322.7 m.

Boreholes 17-08 to 17-10 and Boreholes AL-2 and AL-3 were drilled to assess the existence and extent of any frost taper near the culvert. Based on the information obtained from the borehole investigation, the granular base/subbase material extended below the frost penetration depth estimated in this area, and a defined frost taper was not observed at the culvert location.

SPT 'N' values within the fill layer ranged from 9 to 33 blows per 0.3 m of penetration, indicating a loose to dense relative density. Higher SPT 'N' values up to 93 were also recorded but were likely due to frozen ground at the time of the Golder investigation. 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 14
Sand	53 to 74
Silt	33
Clay	6
Silt and Clay	12 to 14

5.4 Silty Sand

A layer of native silty sand with trace gravel was encountered below the peat in Borehole 17-07 at a depth of 0.8 m. The silty sand layer was 1.4 m thick and extended to a depth of 2.2 m (Elevation 323.1 m). The silty sand deposit was compact, based on SPT 'N' values of 10 and 13 blows per 0.3 m of penetration. The measured moisture content of the silty sand was 11 percent.

5.5 Silt to Sand and Silt

A layer of dark brown to grey silt to sand and silt with trace clay, trace gravel, and occasional cobbles, was encountered below the peat, sand fill, and silty sand layers at depths ranging from 2.2 m to 4.9 m (Elevation 324.9 m to 322.4 m). Boreholes AL-1, 17-08, 17-09 and 17-10 were terminated in the silt to sand and silt layer at depths ranging from 3.7 m to 8.2 m (Elevation 323.9 m to 316.9 m). The thickness of the silt to sand and silt layer ranged from 2.3 to 6.5 m in Boreholes AL-2, AL-3, AL-4 and 17-07 and extended to depths ranging from 4.5 m to 10.2 m (Elevation 321.0 m to 316.6 m). A 0.6 m diameter boulder was encountered within the silt layer in Borehole 17-07 at a depth of 6.9 m (Elevation 318.4 m).

The SPT 'N' values for the silt to sand and silt ranged from 2 to 51 blows per 0.3 m penetration indicated a very loose to very dense relative density. The silt to sand and silt had a measured moisture content ranging from 6 percent to 26 percent.

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



Soil Particle	Percentage (%)
Gravel	0 to 2
Sand	2 to 56
Silt	38 to 95
Clay	0 to 8

5.6 Silt and Sand Till

A layer of grey silt and sand till ranging from silt and sand with trace to some gravel and trace to some clay to gravelly silty sand with trace clay was encountered in Boreholes AL-2, AL-3, AL-4 and 17-07 at depths ranging from 4.5 m to 10.2 m (Elevation 321.0 m to 316.6 m). All four of these boreholes were terminated within the silt and sand till at depths ranging from 6.4 m to 15.2 m (Elevation 319.1 m to 310.1 m).

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

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

Soil Particle	Percentage (%)
Gravel	6 to 50
Sand	31 to 36
Silt	13 to 55
Clay	1 to 22

5.7 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	
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
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

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. 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.

RPM Drilling Ltd. of Thunder Bay, Ontario and OGS of Almonte, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full-time basis by Mr. Ty Tonus-Burman and Ms. Eckie Siu. Overall supervision of the field program was provided by Mr. Cory Zanatta, EIT 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 Dr. Nancy Berg, EIT and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.


Sept. 11/18

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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 foundation design recommendations for the preliminary design of the proposed Alder Creek East Culvert replacement on Highway 17, located in the Unsurveyed District of Thunder Bay, Ontario.

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 1.0 m to 1.5 m of fill above the culvert.



Preliminary General Arrangement Drawings and discussions with Hatch indicate that three replacement options being considered at this site are a precast concrete box culvert, one large corrugated steel pipe culvert or twin corrugated steel pipe culverts. The precast concrete box culvert consists of a 4.5 m wide, 2.25 m high, 28.2 m long culvert with the proposed underside of box at an approximate Elevation of 323.3 m at the inlet and 323.0 m at the outlet. The corrugated steel pipe (CSP) options would consist of either two parallel 28.2 m long, 2.4 m diameter CSP culverts with a proposed invert level at an approximate Elevation of 323.6 m at the inlet and 323.3 m at the outlet, or a single 28.2 m long, 4.0 m diameter CSP culvert with a proposed invert level at an approximate Elevation of 322.4 m at the inlet and 322.1 m at the outlet. The concrete box and single CSP options are proposed to be installed perpendicular to the highway alignment and the twin CSP option will follow the same alignment as the existing culvert. 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. No grade raise or embankment widening are proposed.

9. CULVERT DESIGN

9.1 Culvert Alternatives

This section presents discussions on available types of replacement culverts and foundation alternatives and provides recommendations on preferred foundation options.

Several common culvert types that may be considered for the culvert replacement at this site are listed below:

- Concrete Pipe or Corrugated steel pipe (CSP)
- Concrete box (closed) culvert composed of pre-cast segments
- Concrete box or metal box, open footing culvert

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix F. From a foundations and constructability perspective, use of the CSP or pre-cast concrete box culverts are preferred over the open footing option, based on the following considerations:

- Pre-cast box or pipe culverts would require shallower depth of excavation compared with the open footing culvert;



- Pre-cast concrete box or pipe segments can often be installed more expeditiously than cast in place open footing culverts, resulting in shorter durations for dewatering and construction;
- A segmental box or pipe structure can accommodate some potential differential settlement along the culvert axis.

The open footing culvert is not recommended at this site due to the need for deeper excavation and additional dewatering effort in cohesionless soils below the water table to provide adequate frost protection.

Recommendations for the design and installation of CSP and concrete box culverts are presented below.

9.2 Summary of Subsurface Conditions

In general, the subsurface conditions encountered in the boreholes from the current and preliminary investigations consisted of approximately 200 mm to 300 mm of asphalt overlaying 2.5 m to 4.7 m of silty sand to sand embankment fill overlying native very loose to very dense silt to sand and silt, and silt and sand till. Surficial silty to sandy peat was also found in Boreholes 17-07, AL-1 and AL-4, which were drilled beyond 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.

9.3 Foundation Design for Culverts

The invert level of the proposed culvert ranges from Elevation 322.1 m to 323.6 m depending on the selected culvert type. The founding soils encountered at this level typically consist of loose to compact native silt to silty sand or compact sand fill. Peat was also encountered at this level beyond the inlet and outlet. There will be approximately 1.2 to 1.6 m of fill cover above the proposed replacement culvert.

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, staged construction, and restoration of the roadway embankment.



9.3.1 Concrete Pipe or Corrugated Steel Pipe Culvert

Replacement of the culvert with one or multiple concrete pipes or CSPs on the same alignment may be considered 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.

If this alternative is selected, the concrete pipes or CSPs 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 802.034 or 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212 μm .

The underside of the bedding layer should be placed at or below Elevation 323.3 m, which corresponds to loose to compact native silt to sandy 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.

9.3.2 Concrete Box Culvert

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 322.9 m, which corresponds to loose to compact native silt to sandy 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 preliminary design of a 5 m or 6 m wide box culvert founded at or below Elevation 322.9 m on the loose to compact native silt to sandy silt 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.

9.3.3 Culvert Headwalls / Wingwalls

If headwalls or wingwalls are proposed for the replacement culvert, consideration may be given to using Retained Soil Systems (RSS) walls or concrete walls. RSS walls are generally more tolerant to differential settlement.

The borehole information indicates that the founding conditions at the inlet and outlet generally consist of peat underlain by compact native sands and silts.

9.3.3.1 RSS Walls

RSS walls, if used, would be constructed in a watercourse at this site. It should be noted that RSS wall types listed on the MTO DSM are not pre-approved for use within or adjacent to watercourses or floodplains. If consideration is given to the use of an RSS wall at this site then the Contractor will be required to submit a project/site-specific design submission to the MTO RSS Committee for approval. Suggested wording for an NSSP in regard to this has been included in Appendix F.

For RSS walls, the contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS mass and, in severe cases, failure of the system. The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

The RSS mass should be founded on a minimum 0.5 m thick engineered fill layer resting on the compact to dense native sand and silt subgrade at or below an approximate elevation of 322.7 m. An RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 135 kPa (for up to 25 mm of settlement). Engineered fill layer placed under the RSS mass should consist of OPSS.PROV Granular A or Granular B Type II compacted to 100 percent of its Standard Proctor Maximum Dry



Density (SPMDD) at a moisture content within 2 percent of optimum. The engineered layer should extend at least 300 mm beyond the limits of the RSS mass and levelling strip.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.45 for an engineered granular fill subgrade.

Topsoil, organics, loose fill, and any soft/wet material must be stripped from the footprint of the RSS. The subgrade under the RSS foundation should be inspected, and any soft spots sub-excavated and replaced with compacted granular materials prior to placing fill. The subgrade preparation for the RSS wall and placement and compaction of the granular fill must be carried out in the dry.

A geotextile filter fabric should be incorporated in the RSS design to prevent loss of fines from the granular material behind the RSS wall subject to fluctuating water levels. Since the RSS wall will be constructed adjacent to a creek, the wall may be subjected to flooding. The RSS supplier should be made aware that the RSS strips may need to be longer in flooding conditions and the strips must be corrosion resistant.

The RSS walls may be founded on native sands and silts, which are erodible. Adequate scour and erosion protection must be provided in front of the base of the RSS walls to prevent any foundation soil erosion undermining the walls.

The proprietary RSS system must meet MTO's specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The internal stability of the RSS wall must be analyzed by the supplier/designer of the proprietary product selected for this site.

Lateral earth pressures acting on the RSS wingwalls should be computed as described in Section 12. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

Global stability of the RSS walls should be assessed once the detailed configurations of the walls are known.



9.3.3.2 Foundation for Concrete Retaining Walls

Any concrete retaining walls, if required, may be supported on spread footings founded on the loose to compact native silt to sand and silt subgrade. Any organic or soft soil should be removed from the wall subgrade and replaced with granular fill compacted as per OPSS.PROV 501. The walls should be provided with sufficient frost cover and founded at Elevation 321.8 m at the inlet and 321.5 m at the outlet or lower. A factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 135 kPa (up to 25 mm of settlement) may be used for design. A minimum 300 mm thick granular levelling pad should be provided below the footing. Load inclination and eccentricity should also be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

The concrete retaining wall should be designed against various modes of failure including translation and overturning. Resistance to sliding between the granular pad (below the precast concrete footing) and the underlying native soil should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35 for compact silt to sand and silt.

Lateral earth pressures acting on the concrete wingwalls should be computed as described in Section 12. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

9.4 Frost Cover

The depth of frost penetration at this site is approximately 2.4 m based on OPSD 3090.100. The base of concrete retaining wall footings, if employed, should be provided with a minimum of 2.4 m of earth cover as protection against frost action. The frost cover requirement does not apply to the pipe and box culvert options.

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.

9.4.1 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.

9.4.2 Settlement

It is anticipated that 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.

If the new culvert will extend beyond the footprint of the existing culvert, post-construction settlement of the foundation soil is estimated to be less than 25 mm, provided that all peat is removed, as described in Sections 9.3.1, 9.3.2 and 9.4.1.

9.5 Construction Considerations

Construction staging will be required to maintain one lane of traffic.

Staged construction sequencing will likely require the following:



- Diversion of the creek will be required for construction. In addition, an effective dewatering plan will be required to construct the culvert in the dry.
- Temporary roadway protection may be required during all stages of construction, including excavation and removal of the existing culvert, installation of the new culvert and backfilling.
- All culvert subgrade preparation and foundation construction must be carried out in the dry.

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 and silt 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.

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 and SP517F01. 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 not required, and thus Designer Fill-In ***** in SP517F01 should be "No".



The groundwater level should be maintained at a depth of at least 0.5 m below the final subgrade level. 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 preliminary general arrangement drawing, the invert of the diversion pipe is at approximate Elevation 324.0 m, which corresponds to sand fill and native sands and silts. Peat may also be encountered at the inlet and outlet.

The temporary CSP 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 PROV 401 for a CSP and OPSS 902 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

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

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

where

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

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

Table 12.1 – Lateral Earth Pressure Coefficients (K)

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

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

For rigid structures 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. Based on the harmonic mean of the N_{60} values for the site the area corresponds 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:

Table 13.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE})*	0.29	0.32
Passive (K_{PE})	3.6	3.2
At Rest (K_{OE})**	0.49	0.53

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

** After Woods

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



Table 14.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing 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.

15. 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 9.3, 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 and OPSS PROV 209. 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.

16. PAVEMENT REINSTATEMENT RECOMMENDATIONS

Pavement reinstatement designs were developed using the MTO Northwestern Region Pavement Design Chart. It is understood that the 20-year Design ESALs are estimated at 4.5 million, with culvert backfill materials assumed to be granular material meeting OPSS Granular B (Type II or III) subbase requirements. The required pavement reinstatement that is to support these conditions should comprise:

50 mm	Superpave 12.5 Surface Course
40 mm	Superpave 12.5 Upper Binder Course
40 mm	Superpave 12.5 Lower Binder Course
150 mm	Granular A Base
300 mm	Granular B, Type II or III Subbase

The asphalt mix shall be designed in accordance with OPSS.PROV 313 and OPSS.PROV 1151. It is understood that pavement reinstatement should be designed to support 20-year ESALs of 4.5 million ESALs, designating a Traffic Category C for the Superpave 12.5 asphalt mix.

The performance grade (PG) asphalt cement for the asphalt mix shall be PG 58-34, in accordance with OPSS.PROV 1101.

All granular base material shall consist of new OPSS Granular A, while the new granular subbase material shall consist of new OPSS Granular B, Type II or III. All granular material shall meet the requirements of OPSS 1010. All granular material should be compacted in accordance with the requirements of OPSS 501, and should be carried the entire width of the roadway platform. During reinstatement of the pavement, drainage must be maintained within the existing and new granular base and subbase layers.

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 considered 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 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 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 Dr. Nancy Berg, EIT and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Nancy Berg
Sept. 11/18

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Geotechnical Engineer



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



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION






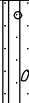
MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels,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

RECORD OF BOREHOLE No 17-07

1 OF 2

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			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
325.3	GROUND SURFACE					▽									
0.0	PEAT , silty, trace sand, trace clay Compact Brown Wet		1	SS	10		325								
324.5															
0.8	Silty SAND , trace gravel Compact Grey Wet		2	SS	10		324								
			3	SS	13										
323.1															
2.2	SILT , trace to some sand, trace clay, trace gravel, occasional cobbles Compact Grey Wet		4	SS	25		323								
			5	SS	22		322								
							321								
			6	SS	14										
							320								
	Trace clay														
			7	SS	19		319								
318.4															
6.9	BOULDER		1	GS			318								
317.8															
7.5	SILT , some sand, trace gravel Compact Grey Wet		8	SS	14		317								
316.6			2	GS											
8.7	SILT and SAND , trace to some clay, trace gravel, occasional cobbles and boulders Very Dense (TILL)						316								
			9	SS	100/ 0.100										

Continued Next Page

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

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		NATURAL MOISTURE CONTENT	Liquid Limit	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		PLASTIC LIMIT	w _p		w	w _L
	Continued From Previous Page													
	SILT and SAND , trace to some clay, trace gravel, occasional cobbles and boulders Very Dense Grey Moist (TILL)													
			10	SS	100/ 0.125									
			3	GS										
			11	SS	50/ 0.025									
			4	GS										
			12	SS	100/ 0.050									
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									

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-08

1 OF 1

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

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L				GR	SA	SI	CL	
327.5	GROUND SURFACE						327									0	56	38	6	
0.0	ASPHALT: (300mm)																			
327.2	SAND, some silt, trace gravel Brown Moist (FILL)		1	GS																
0.3																				
324.7	SAND and SILT, trace clay, trace peat Compact Dark Brown Wet		2	GS		324														
2.8			1	SS	12															
323.8																				
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.																			

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-09

1 OF 1

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

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
327.6	GROUND SURFACE															
0.0	ASPHALT: (325mm)															
327.3																
0.3	Silty SAND, trace gravel, trace clay Brown Moist to Wet (FILL)		1	GS			327									8 53 33 6
			2	GS			326									
							325									
324.6																
3.0	SAND and SILT, trace gravel Dense Grey Wet		1	SS	31		324									
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.															

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-10

1 OF 1

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

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
327.6	GROUND SURFACE														
0.0	ASPHALT: (300mm)														
327.3															
0.3	SAND, some silt, trace gravel Brown Moist (FILL)		1	GS			327								
							326								
324.9							325								
2.7	SAND and SILT, trace clay, occasional cobbles Dense Grey to Brown Wet		2	GS											
			1	SS	42									0 55 38 7	
323.9							324								
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.														

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



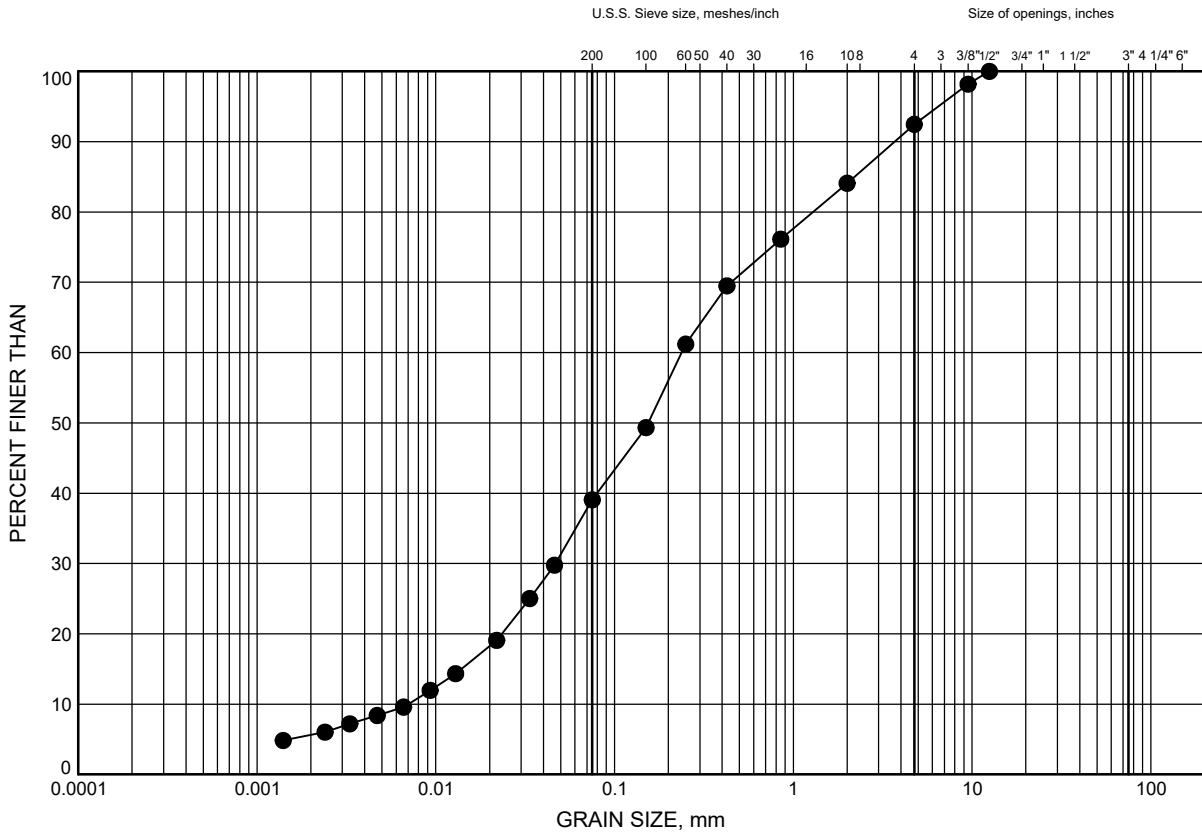
Appendix B

Laboratory Test Results

Alder Creek East Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-09	1.0	326.6

Date January 2018
W.P. 6330-14-01

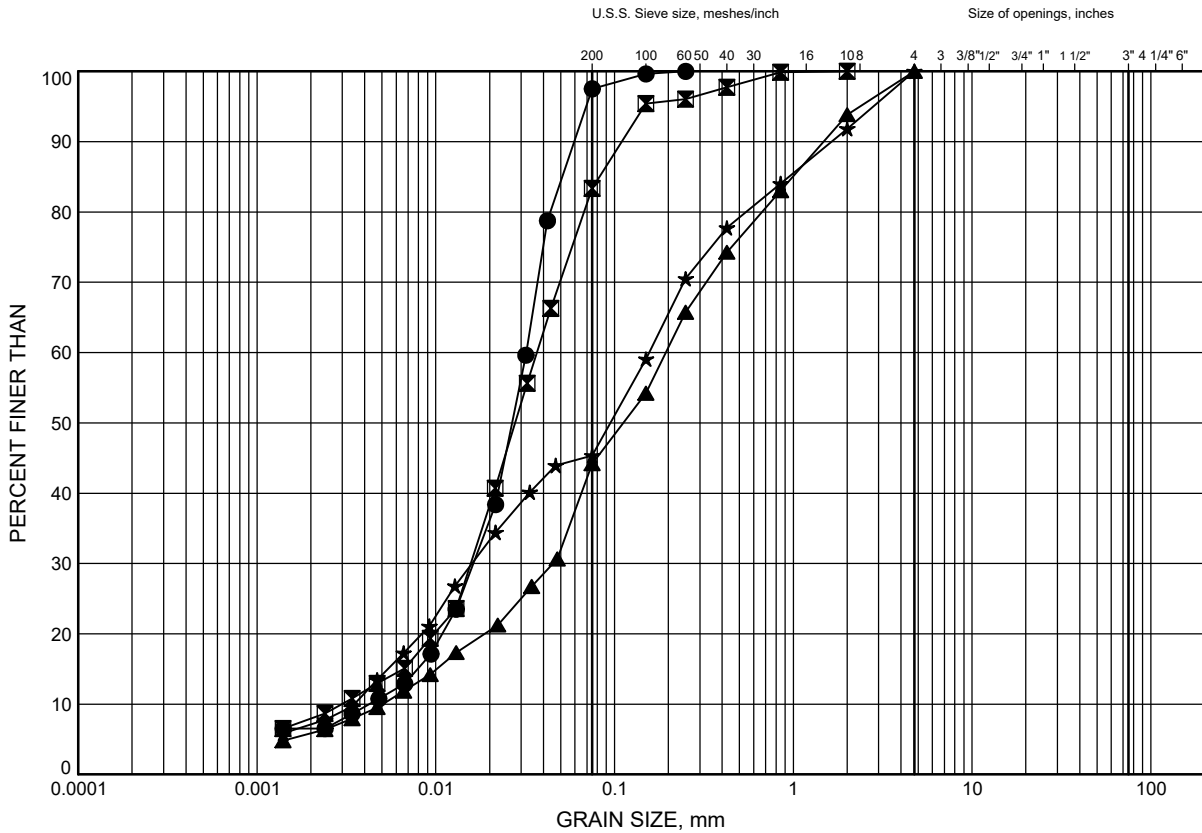


Prep'd AN
Chkd. NLB

Alder Creek East Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2

SILT to SAND and SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-07	3.4	321.9
⊠	17-07	6.4	318.9
▲	17-08	2.9	324.6
★	17-10	3.4	324.2

Date January 2018
W.P. 6330-14-01

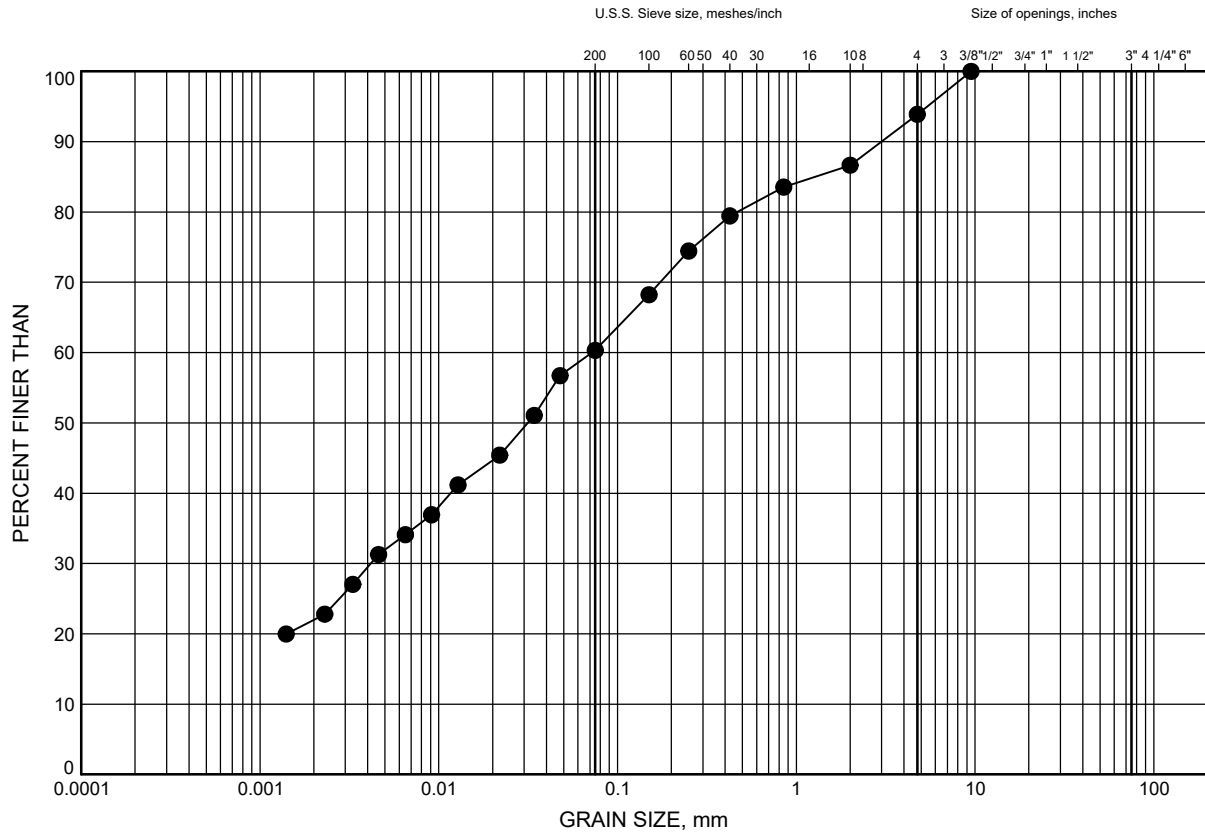


Prep'd AN
Chkd. NLB

Alder Creek East Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

SILT and SAND TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-07	12.2	313.1

Date January 2018
W.P. 6330-14-01



Prep'd AN
Chkd. NLB



FINAL REPORT

CA14723-OCT17 R1

15595

Prepared for

Thurber Engineering Ltd.

First Page

CLIENT DETAILS

Client Thurber Engineering Ltd.

Address 103, 2010 Winston Park Drive
Oakville, ON
L6H 5R7.

Contact Mark Farrant

Telephone 905-829-8666 x 228

Facsimile

Email mfarrant@thurber.ca

Project 15595

Order Number

Samples Soil (1)

LABORATORY DETAILS

Project Specialist Deanna Edwards, B.Sc, C.Chem

Laboratory SGS Canada Inc.

Address 185 Concession St., Lakefield ON, K0L 2H0

Telephone 705-652-2000

Facsimile 705-652-6365

Email deanna.edwards@sgs.com

SGS Reference CA14723-OCT17

Received 10/25/2017

Approved 11/02/2017

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





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QC Summary..... 5-6

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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

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

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

Sulphide	%	0.02	< 0.02	
----------	---	------	--------	--

Conductivity

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

Conductivity	uS/cm	2	1090	
--------------	-------	---	------	--

Moisture

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

Moisture Content	%	0.1	15.0	
------------------	---	-----	------	--

pH

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

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
---------------------	---------------	---	------------	------------	------------	------------	------------	------------



FINAL REPORT

CA14723-OCT17 R1

QC SUMMARY

Anions by IC
Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-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-IENVIARD-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-IENVIEWL-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 | Internal ref.: ME-CA-IENVIEWL-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



Client
SGS LIMS Number
Analysis Package:

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

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

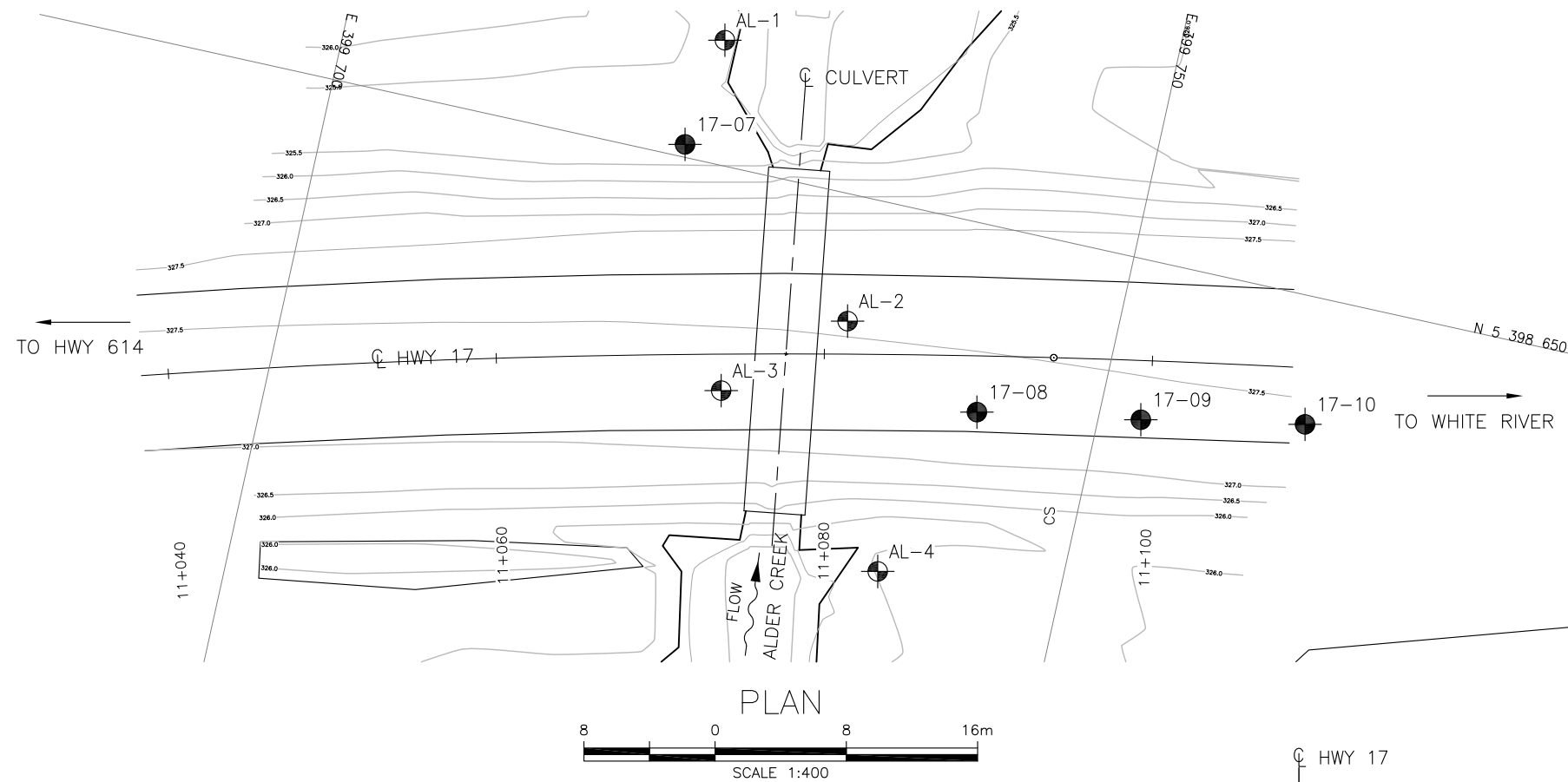
Deanna Edwards B.Sc., C.Chem
Project Specialist
Environment, Health and Safety

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



Appendix C

Borehole Locations and Soil Strata Drawing



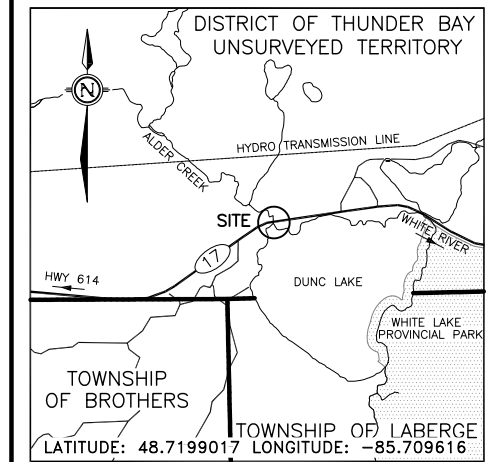
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No
WP No 6330-14-01






HIGHWAY 17
ALDER CREEK EAST
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

HATCH



KEYPLAN

LEGEND

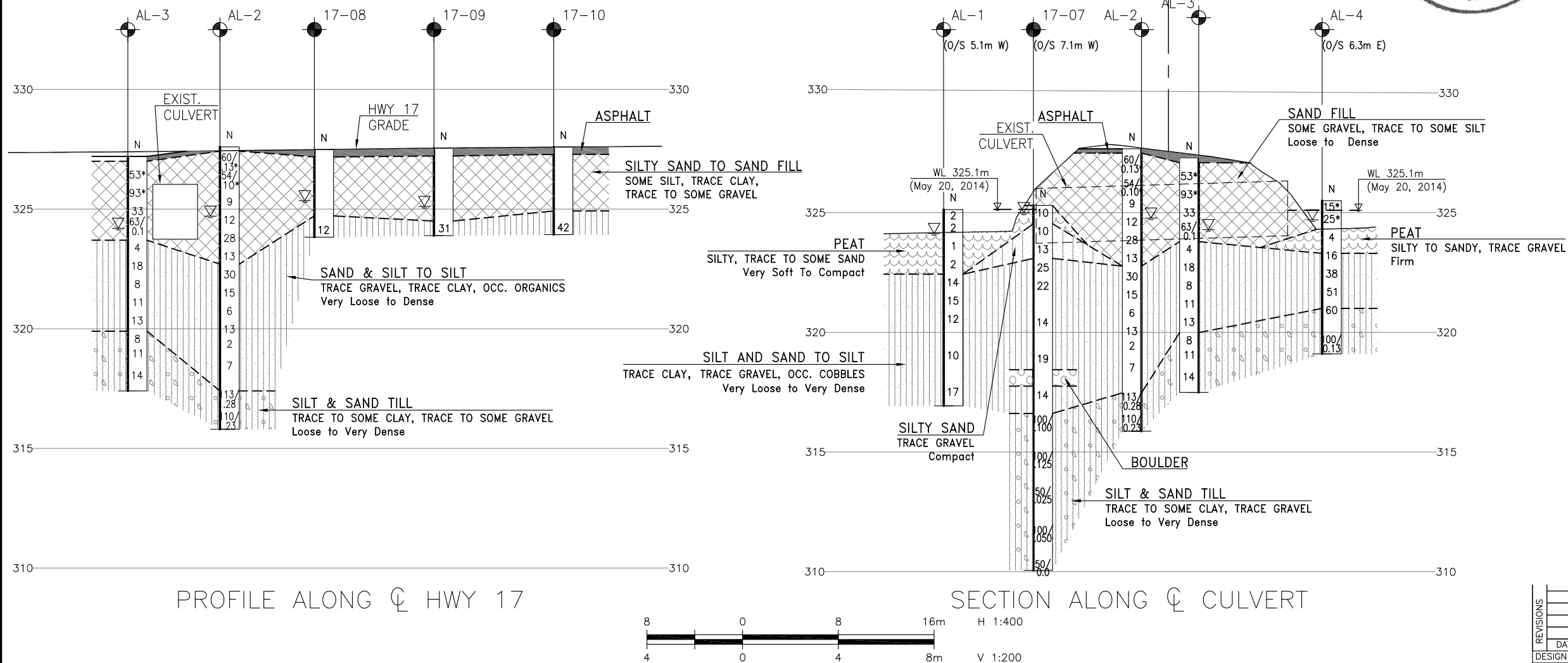
	Borehole
	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-07	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
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-interpreted from original borehole logs.

GEOCRES No. 42C-43

[illegible]



Appendix D

Site Photographs



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



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



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



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)



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)



Appendix E

Factual Data from 2015 Golder Foundation Investigation Report

PROJECT		1411523		RECORD OF BOREHOLE		No AL-1		1 OF 1		METRIC													
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													
SOIL PROFILE				SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH		DESCRIPTION		STRAT PLOT		NUMBER		TYPE		"N" VALUES		GROUND WATER CONDITIONS		ELEVATION SCALE		SHEAR STRENGTH kPa		WATER CONTENT (%)		γ		GR SA SI CL	
325.9		GROUND SURFACE				1		SS		2				325				20		40		60	
0.0		Silty PEAT, trace to some sand Very soft Black Wet				2		SS		2				324				20		40		60	
						3		SS		1								20		40		60	
323.2						A												20		40		60	
2.7		SILT to Sandy SILT Compact Grey Wet				4		SS		2				323				20		40		60	
						5		SS		14				322				20		40		60	
						6		SS		15								20		40		60	
						7		SS		12				321				20		40		60	
						8		SS		10				320				20		40		60	
						9		SS		17				319				20		40		60	
317.7		Some gravel encountered below 7.6 m depth.												318				20		40		60	
8.2		END OF BOREHOLE																20		40		60	
		Note: 1. Water level at a depth of 1.0 m below ground surface (Elev. 324.9 m) upon completion of drilling.																20		40		60	

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

PROJECT 1411523		RECORD OF BOREHOLE No AL-2		1 OF 1 METRIC	
G.W.P. 6330-14-00		LOCATION N 5398642.4; E 399733.8		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	
SOIL PROFILE		SAMPLES		DYNAMIC CONE PENETRATION RESISTANCE PLOT	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES
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		1	SS	60/ 0.13*
			2	SS	54/ 0.10*
			3	SS	9
			4	SS	12
	Augers grinding on inferred cobbles below 3.8 m depth.		5	SS	28
322.7			6A	SS	13
4.9	Sandy SILT to SILT and SAND, trace gravel, trace clay Very loose to compact Grey Wet Trace organics in Sample 6B.		6B	SS	
			7	SS	30
			8	SS	15
			9	SS	6
			10	SS	13
			11	SS	2
			12	SS	7
317.4					
10.2	SILT and SAND, some gravel, some clay (TILL) Very dense Grey Wet		13	SS	113/ 0.28
			14	SS	110/ 0.23
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.				

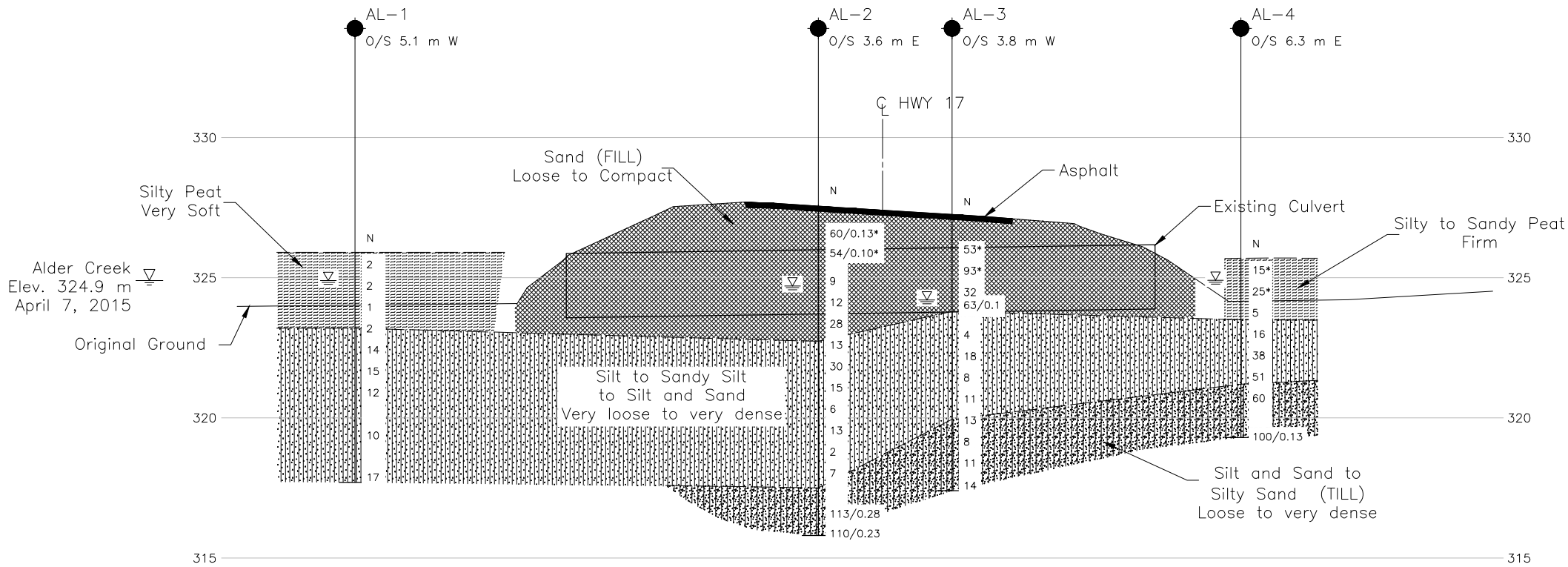
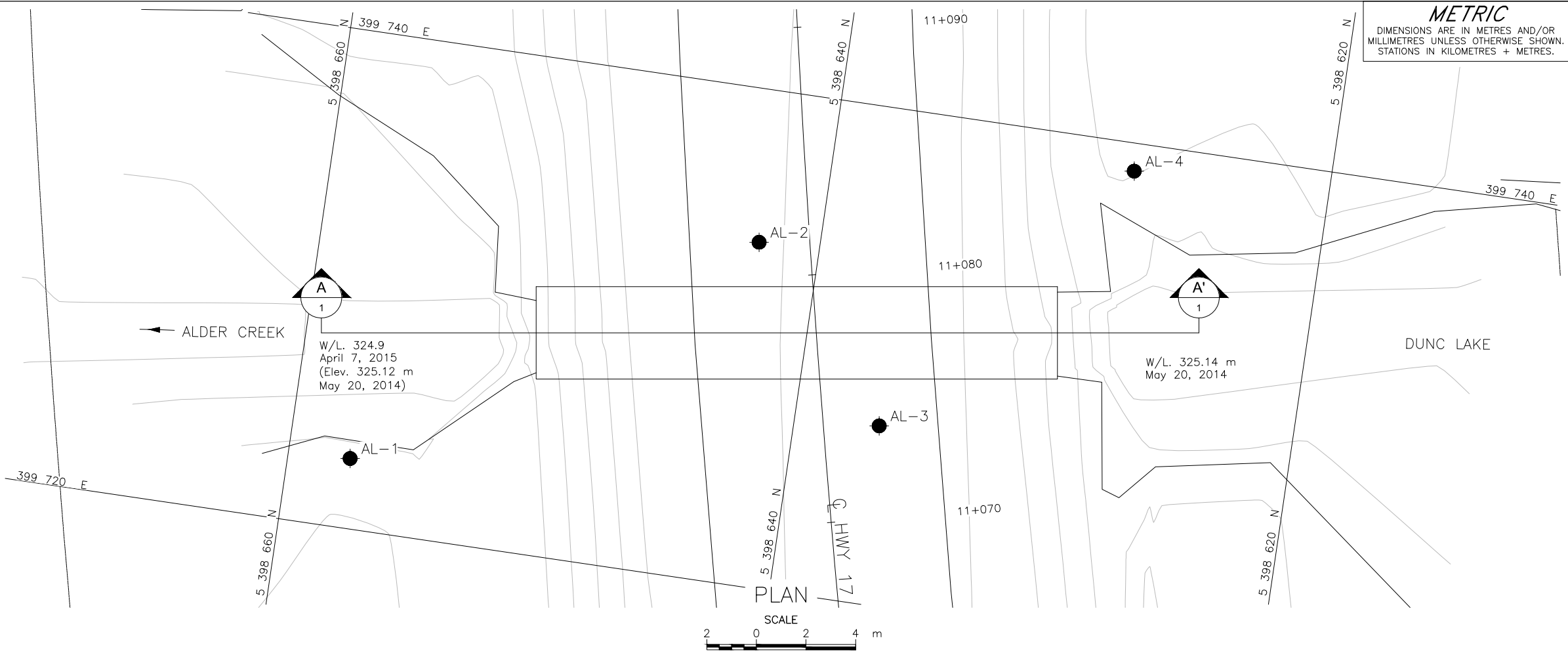
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT		1411523		RECORD OF BOREHOLE No AL-3		1 OF 1 METRIC																			
G.W.P.		6330-14-00		LOCATION		N 5398636.6; E 399727.2																			
DIST		HWY 17		BOREHOLE TYPE		108 mm I. D. Hollow Stem Augers																			
DATUM		GEODETIC		DATE		March 17, 2015																			
				ORIGINATED BY		RI																			
				COMPILED BY		MT																			
				CHECKED BY		SEMP																			
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					W _p W W _L			WATER CONTENT (%)			γ			GR SA SI CL			
327.2	GROUND SURFACE							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					20 40 60			20 40 60			kN/m ³						
0.0	ASPHALT (190 mm)						327																		
0.2	Sand, some gravel, some silt (FILL) Dense Brown Frozen* to wet		1	SS	53*		326																		
	Augers grinding on inferred cobbles below 1.5 m depth.		2	SS	93*		325																		
			3	SS	33		324																		
			4	SS	63/0 1		323																		
323.7	SILT to SILT and SAND, trace gravel, trace clay Loose to compact Grey Wet		5	SS	4		322																		
3.5			6	SS	18		321																		
			7	SS	8		320																		
			8	SS	11		319																		
319.9	SILT and SAND, trace to some gravel, trace clay (TILL) Loose to compact Grey Wet		9	SS	13		318																		
7.3			10	SS	8																				
			11	SS	11																				
			12	SS	14																				
317.4	END OF BOREHOLE																								
9.8	Note: 1. Water level at a depth of 3.0 m below ground surface (Elev. 324.2 m) upon completion of drilling.																								

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

PROJECT 1411523		RECORD OF BOREHOLE No AL-4				1 OF 1 METRIC								
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								
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa		WATER CONTENT (%)			γ	GR SA SI CL
							20 40 60 80 100	20 40 60 80 100	W _p	W	W _L			
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*		325							
			2	SS	25*									
			3	SS	5		324							
323.5	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		323							0 56 44 0
2.2			5	SS	38		322							
			6	SS	51									
321.2	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		321							50 36 13 1
4.5							320							
319.3	END OF BOREHOLE		8	SS	100/0.13									
6.4	Note: 1. Water level at a depth of 0.8 m below ground surface (Elev. 324.9 m) upon completion of drilling.													

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

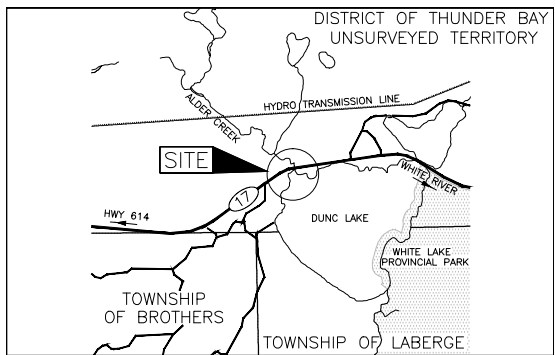


CONT No. .
GWP No. 6330-14-00



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

SHEET



KEY PLAN
1 0 1 2 km
1:50,000 m

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.

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: JLL/TB	CHKD. SEMP	APPD. JMAC	DWG. 1



Appendix F

List of Specifications and Suggested Wording for NSSP



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

- OPSS PROV 206 (Construction Specification for Grading)
- OPSS PROV 209 (Construction Specification for Embankments over Swamps and Compressible Soils)
- OPSS PROV 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 1004 (Material Specification for Aggregates – Miscellaneous)
- OPSS PROV 1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material)
- OPSS PROV 1101 (Material Specification for Performance Graded Asphalt Cement)
- OPSS PROV 1151 (Material Specification for Superpave And Stone Mastic Asphalt Mixtures)
- 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. Vibrating equipment is not permitted for installation of sheet piles.

- **Suggested Text for Notice to Contractor on “Dewatering”**

Dewatering will be required to install the new culvert and the diversion pipe in the dry. The design of an effective dewatering system is the responsibility of the contractor. The dewatering system must be effective to lower the groundwater table at a minimum of 0.5 m below the final subgrade level to avoid basal heave and base boiling. The dewatering system is to be designed in accordance with SP FOUN0003, 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.

- **Suggested Wording for NSSP on “Approval Process for RSS Walls”**

The RSS wall types listed on the MTO DSM are not pre-approved for use within or adjacent to watercourses or floodplains. If consideration is given to the use of an RSS wall at this site then the Contractor will be required to submit a project/site specific design submission to the MTO RSS Committee for approval. The Contractor will need to assume a minimum of 8-weeks of review time by the MTO RSS Committee. The submission shall include working drawings, supporting design documentations and commentary which will specifically address the proposed RSS design with respect to the following:

- RSS embedment depth and scour protection;
- Backfill material and the control of migration of fines;
- Performance in differential hydrostatic pressures;
- Pullout capacity and frictional resistance between reinforcements and select backfill under fully saturated conditions; and,
- CHBDC structure design requirement for a 75-year service life – stability, durability, long-term performance.



Appendix G

Comparison of Alternative Culvert Types



COMPARISON OF ALTERNATIVE CULVERT TYPES

Concrete Pipe or Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
<p><u>Advantages:</u></p> <ul style="list-style-type: none"> i. Ease of construction. ii. Foundation design not governed by foundation bearing capacity iii. Segmented pipes can accommodate some potential differential settlement along culvert axis iv. Steel pipes may be more cost effective than concrete box or open footing culverts. 	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. ii. Less stringent requirement for soil geotechnical resistances as loading is spread over a larger area. iii. Segmental option can accommodate some potential differential settlement along culvert axis. 	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> i. Conventional construction. ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.
<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> i. Steel pipes may have shorter design life than concrete culverts. ii. Multiple pipes maybe needed to meet hydraulic requirements. 	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> i. More expensive than a Concrete pipe or CSP culvert. 	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> i. Greater potential for differential settlement. ii. Deeper excavation and potentially longer dewatering requirements.
FEASIBLE	FEASIBLE	NOT RECOMMENDED