



October 30, 2015

## 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**

**Submitted to:**

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**GEOCRES No.: 42C-37**

**Report Number: 1411523-R19**

**Distribution:**

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REPORT





## Table of Contents

### **PART A – PRELIMINARY FOUNDATION INVESTIGATION REPORT**

<b>1.0 INTRODUCTION.....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION.....</b>	<b>1</b>
<b>3.0 INVESTIGATION PROCEDURES .....</b>	<b>1</b>
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS .....</b>	<b>2</b>
4.1 Regional Geology .....	2
4.2 Subsurface Conditions.....	2
<b>5.0 CLOSURE.....</b>	<b>4</b>

### **PART B - PRELIMINARY FOUNDATION DESIGN REPORT**

<b>6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS.....</b>	<b>6</b>
6.1 General.....	6
6.2 Foundations .....	6
6.2.1 Foundation Options.....	6
6.2.2 Foundation Elevations and Frost Protection .....	7
6.2.2.1 Box Culvert .....	7
6.2.2.2 Open Footing Culvert.....	7
6.2.2.3 Pipe Culvert .....	7
6.2.3 Geotechnical Resistances.....	8
6.2.3.1 Box Culvert .....	8
6.2.3.2 Open Footing Culvert.....	8
6.2.4 Resistance to Lateral Loads/Sliding Resistance .....	9
6.2.5 Stability and Settlement .....	9
6.3 Lateral Earth Pressures .....	9
6.4 Construction Considerations.....	10
6.4.1 Temporary Roadway Protection.....	10
6.4.2 Excavation and Replacement Below Culvert .....	11
6.4.3 Culvert Bedding and Backfill .....	11
6.4.3.1 Box Culvert .....	11



## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

6.4.3.2	Open Footing Culvert.....	12
6.4.3.3	Pipe Culvert.....	12
6.4.3.4	Backfill .....	12
6.4.4	Subgrade Protection .....	13
6.4.5	Erosion Protection.....	13
6.4.6	Control of Groundwater and Surface Water .....	14
6.4.7	Obstructions.....	14
6.4.8	Analytical Testing for Construction Materials .....	15
6.5	Recommendations for Further Work During Detail Design .....	15
<b>7.0</b>	<b>CLOSURE.....</b>	<b>15</b>

### REFERENCES

#### TABLES

Table 1	Summary of Culvert Details
Table 2	Comparison of Foundation Alternatives
Table 3	Geotechnical Axial Resistance and Reaction for Pre-Cast Box and Open Footing Replacement Culverts
Table 4	Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Open Footing Replacement Culverts

#### DRAWING

Drawing 1	Borehole Locations and Soil Strata
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#### PHOTOGRAPHS

#### APPENDIX A RECORD OF BOREHOLES

Lists of Abbreviations and Symbols
Record of Boreholes AL-1 to AL-4

#### APPENDIX B LABORATORY TEST RESULTS

Table B1	Summary of Analytical Testing of Alder Creek Water Sample
Figure B1	Grain Size Distribution – Sand (Fill)
Figure B2	Grain Size Distribution – Silt to Silt and Sand
Figure B3	Grain Size Distribution – Silt and Sand to Silty Sand (TILL)



# **PART A**

**PRELIMINARY FOUNDATION INVESTIGATION REPORT  
ALDER CREEK E. CULVERT – SITE NO. 48E-75/C  
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## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by Hatch Mott MacDonald (HMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the replacement of the Alder Creek E. culvert (Site No. 48E-75/C). The Alder Creek culvert is located in the District of Thunder Bay in Unsurveyed Territory on Highway 17 at STA 11+078, approximately 11.5 km east of the Highway 17 and Highway 614 junction. The key plan showing the general location of this section of Highway 17 and the location of the investigated area are shown on Drawing 1.

## **2.0 SITE DESCRIPTION**

The Alder Creek culvert consists of a Structural Plate Corrugated Steel Pipe (SP CSP) arch structure, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

For the purposes of this report Highway 17 runs in a west-east direction with the culvert perpendicular to the highway in a north-south orientation on a slight skew. In general, the topography in the area of the culvert is relatively flat with low-lying terrain in close proximity to the culvert. Dunc Lake, located immediately south of the highway, drains northerly via Alder Creek. At the culvert location, the highway grade is at about Elevation 327.4 m and the culvert invert is at approximately Elevation 323.9 m at the south end (inlet) and at Elevation 323.5 m at the north end (outlet). The creek water level was at Elevation 325.1 m, as measured by others on May 20, 2014. The creek water level was at Elevation 324.9 m, as measured by Golder on April 7, 2015. Surface conditions in the culvert inlet and outlet areas are shown on Photographs 1 to 4, attached.

## **3.0 INVESTIGATION PROCEDURES**

The field work for this subsurface investigation was carried out on March 17 and April 7, 2015, during which time four boreholes (Boreholes AL-1 to AL-4) were advanced at approximately the locations shown on Drawing 1. Boreholes AL-1 and AL-4 were advanced at the toe of slope near the culvert outlet and inlet, respectively, and Boreholes AL-2 and AL-3 were advanced from the existing highway platform. The boreholes were advanced using a track-mounted CME 55 drill rig supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec.

The boreholes were advanced using 108 mm inside diameter hollow stem augers. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The field work was supervised on a full-time basis by members of Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations and grain size distributions were carried out on selected soil samples. The geotechnical laboratory testing was completed according to MTO LS standards.



## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

A sample of the creek water was obtained at the culvert site on March 25, 2015) using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters, including pH, resistivity, conductivity, sulphates and chlorides.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to the highway centerline and existing culvert and converted into northing/easting on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile provided by MTO (Drawing E484854171.dwg). The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and summarized below.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
AL-1	5398657.5	399722.8	325.9	8.2
AL-2	5398642.4	399733.8	327.6	11.8
AL-3	5398636.6	399727.2	327.2	9.8
AL-4	5398627.9	399738.9	325.7	6.4

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)<sup>1</sup> mapping, the subsoils in the vicinity of the Alder Creek E. culvert site generally consist of an alluvial plain comprised mainly of sand bordered by areas of bedrock knobs.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)<sup>2</sup>, the site is underlain by granodiorite to granite bedrock of the Archean Era bordering with areas of metasedimentary bedrock consisting of wacke, arkose, argillite, slate, marble, chert and iron formations.

### 4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ field tests (i.e., SPT 'N'-values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

<sup>1</sup> Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42CNW

<sup>2</sup> Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2543.



## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

### Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and, sand fill (for boreholes advanced through the embankment) and silty to sandy peat (for boreholes advanced from the toe of slope), underlain by deposits of silt to silt and sand and silt and sand to silty sand till. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows)	Laboratory Testing
				Relative Density/ Consistency	
<b>Asphalt</b>	AL-2, AL-3	0.180 – 0.190	327.6 – 327.2	n/a	n/a
<b>(FILL)</b> <sup>1</sup> Sand, some gravel, trace to some silt; brown to grey; frozen / wet	AL-2, AL-3	3.3 – 4.7	327.4 -327.0	N = 9 – 33 <sup>2</sup>	w = 4% – 14% 2 – M (Fig. B1)
				<b>Loose to dense</b>	
Silty to Sandy <b>Peat</b> , trace gravel, trace wood; black; frozen/wet	AL-1, AL-4	2.2 – 2.7	325.9 – 325.7	N = 1 – 5 <sup>3</sup>	w = 47% – 57%
				<b>Very soft to firm</b>	
<b>Silt to Silt and Sand</b> , trace to some gravel, trace clay; grey; wet	AL-1 to AL-4	2.3 – >5.5 m (AL-1 terminated in this deposit)	323.7 – 322.7	N = 2 – 51	w = 20% – 26% 6 – MH (Fig. B2)
				<b>Very Loose to Very Dense</b>	
<b>Silt and Sand to Silty Sand (TILL)</b> <sup>4</sup> , trace to some gravel to gravelly, trace to some clay; grey; wet	AL-2 to AL-4	1.6 – 2.5 (not fully penetrated)	321.2 – 317.4	N = 8 – >100	w = 8% – 16% 3 – MH (Fig. B3)
				<b>Loose to Very Dense</b>	

#### Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration

w = Natural Moisture Content (%)

M = Sieve analysis

MH = Combined Sieve and Hydrometer analysis

#### Notes:

<sup>1</sup> At two sampling depths within the upper 2 m of granular fill, the split spoon samples did not penetrate the entire SPT depth, due to the frozen state of the material. In addition, one split spoon sample below the frost depth did not penetrate the entire SPT depth, inferred due to the presence cobbles as evidenced by auger grinding.

<sup>2</sup> SPT 'N'-values of 53 and 93 blows per 0.3 m of penetration were measured in the upper 2 m of granular fill in one borehole, however, these values are considered indicative of the frozen state of the material and not representative of the relative density of the fill deposit.

<sup>3</sup> SPT 'N'-values of 15 and 25 blows per 0.3 m of penetration was measured in the upper 1.5 m layer of the peat deposit; however, the values are inferred indicative of the frozen state of the material and not representative of the consistency of the peat deposit.





## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

<sup>4</sup> The tested sample of silty sand till from Borehole AL-4 (sample 7) contained one piece of coarse gravel, which was approximately 35 per cent of the sample weight.

### Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The creek water level was measured at Elevation 324.9 m on April 7, 2015. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
AL-1	1.0	324.9
AL-2	2.9	324.7
AL-3	3.0	324.2
AL-4	0.8	324.9

## 5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Rob Ireland and Mr. Mathew Riopelle under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Adam Core, P.Eng. and Mr. David Muldowney, P.Eng., carried out a technical review of the report. Mr. Jorge M. A. Costa, P.Eng., the Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.





**PRELIMINARY FOUNDATION REPORT  
ALDER CREEK E. CULVERT - SITE NO. 48E-75/C**

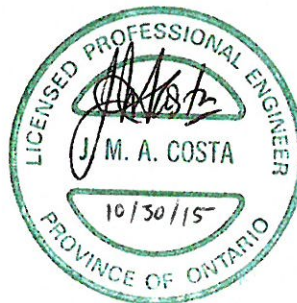
## Report Signature Page

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AC/DAM/JMAC/kp

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**PRELIMINARY FOUNDATION REPORT  
ALDER CREEK E. CULVERT - SITE NO. 48E-75/C**

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# **PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT  
ALDER CREEK E. CULVERT – SITE NO. 48E-75/C  
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## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides preliminary foundation design recommendations for the proposed replacement of the Alder Creek E. culvert. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation.

The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the culvert replacement. Further investigation and analysis may be required during detail design, once the configuration of the proposed culvert and replacement strategy is finalized, to confirm and expand on the preliminary foundation recommendations provided in this report.

Where comments are made on construction, they are provided to highlight those aspects that could affect the future detail design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

It is assumed that the existing SP CSP arch culvert is to be replaced with a culvert of similar dimensions or slightly larger, on the same alignment, as well as at invert elevations similar to those of the existing culvert. In addition, it is assumed that there will be no embankment grade raise or widening in the area of the culvert as part of the Highway 17 reinstatement.

### **6.2 Foundations**

#### **6.2.1 Foundation Options**

The Alder Creek E. culvert is located in the District of Thunder Bay in Unsurveyed Territory on Highway 17 at STA 11+078, approximately 11.5 km east of the Highway 17 and Highway 614 junction. The highway embankment is constructed of granular fill material and is approximately 3.7 m high relative to the culvert invert with approximately 1 m of soil cover over the culvert. The existing culvert consists of a Steel Plate Corrugated Steel Pipe (SP CSP) arch, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

Based on discussions with HMM and a review of the preliminary General Arrangement (GA) drawings, we understand that a slight realignment of the culvert may be necessary and the following replacement culvert types are being considered at this location:

- A pre-cast concrete box; and
- A pre-cast open footing structure with either a pre-cast concrete arch or metal box.

In this report we have considered the following culvert options:

- A pre-cast concrete box;
- An open footing structure supported on either cast-in-place or pre-cast footings; and



- A pipe culvert.

We understand that a sheet-pile abutment and concrete cap option is not being considered for culvert replacements on the Highway 17 corridor based on discussions with HMM and MTO. A corrugated steel pipe (CSP) culvert similar to the existing culvert configuration could be considered but would provide less flow-through capacity compared to a box culvert or open footing culvert with a similar span and would likely require multiple, parallel pipes if additional flow-through capacity is required. If a pipe culvert is selected, a concrete pipe would be preferred as CSP culverts generally have a shorter design life. Open footing arch culverts could be considered but the flow-through capacity for certain types and sizes, or arches, could be limited or restricted due to the need to provide adequate soil cover (including the roadway pavement structure) and the overall performance of such structures over the longer term is not known. From a foundation perspective, a concrete box culvert sufficiently wide to handle the creek flow is preferred at this site. A pre-cast concrete box is recommended, rather than an open footing culvert, as the subsurface conditions at the foundation level are suitable for the support of a box foundation; it can accommodate an accelerated construction schedule; and there are reduced excavation, dewatering and shoring requirements. Other culvert types may be preferred due to construction staging or other considerations such as fisheries requirements related to natural channel substrate. A comparison of culvert types based on advantages, disadvantages and risks/consequences is presented in Table 2.

## **6.2.2 Foundation Elevations and Frost Protection**

### **6.2.2.1 Box Culvert**

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as a box structure is tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the replacement box culvert be founded on a granular bedding/levelling pad placed on the generally compact silt to silt and sand deposit. In this regard, the culvert may have to be constructed on a pad of granular replacement fill following sub-excavation of the existing embankment fill and/or organics (where encountered) as detailed in Section 6.4.2. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3.

### **6.2.2.2 Open Footing Culvert**

Strip footings for an open footing culvert should be founded on the compact silt to sand and silt stratum at a minimum depth of 2.4 m below the lowest surrounding grade (i.e., invert) to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation Frost Penetration Depths for Northern Ontario). The footings must be founded below any existing fill and/or organics (where encountered). Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

### **6.2.2.3 Pipe Culvert**

It is not necessary to found a pipe culvert at the standard depth for frost protection purposes, as such a culvert is tolerant to small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend



that the replacement pipe culvert, if adopted, be founded on a granular bedding layer placed over the generally compact silt to silt and sand deposit. In this regard, the culvert will have to be constructed on granular replacement fill following sub-excavation of the existing embankment fill and/or peat (where encountered) as detailed in Section 6.4.2. Recommended foundation elevation and foundation conditions for a replacement pipe culvert are provided in Table 3.

## **6.2.3 Geotechnical Resistances**

### **6.2.3.1 Box Culvert**

A box culvert, placed on the properly prepared subgrade and bedding/levelling pad at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement, as provided in Table 3. These recommendations are based on an assumed 6.5 m wide box culvert as noted in Table 3.

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS are dependent on the foundation size, configuration and applied loads; the geotechnical resistance/reaction should, therefore, be reviewed if the culvert width or founding elevation differs from those given in Table 3.

The geotechnical resistance/reaction provided in Table 3 are based on loading applied perpendicular to the base of the culvert; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the Canadian Highway Bridge Design Code (CHBDC 2006) and its Commentary.

The loading on the foundation soils below the culvert and the associated settlements at the culvert location will be governed by the design height of the overlying and adjacent embankment fill, however it is assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is to take place as the magnitude of settlement that will occur under the culvert will be impacted by any additional soil loading both on and adjacent to the culvert.

### **6.2.3.2 Open Footing Culvert**

Strip footings placed on the properly prepared subgrade, at or below the founding elevation recommended in Table 3, should be designed based on the factored geotechnical axial resistance at ULS and geotechnical reaction at SLS, for 25 mm of settlement, as provided in Table 3. These recommendations are based on an assumed footing width of 0.6 m and 1.2 m as noted in Table 3.

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS are dependent on the foundation size, configuration and applied loads; the geotechnical axial resistance/reaction should, therefore, be reviewed if the culvert footing width or founding elevation differs from those given in Table 3.



The geotechnical resistance/reaction provided in Table 3 are based on loading applied perpendicular to the base of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section 6.7.4 of the CHBDC and its Commentary.

The loading on the foundation soils below the culvert footing and the associated settlements at the culvert location will be governed by the design height of the overlying and adjacent embankment fill, however it is assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is to take place as the magnitude of settlement that will occur under the culvert footing will be impacted by any additional soil loading both on and adjacent to the culvert.

#### **6.2.4 Resistance to Lateral Loads/Sliding Resistance**

Resistance to lateral forces/sliding resistance between the base of the box culvert and granular bedding material or between the base of the strip footing and subgrade soil should be calculated in accordance with Section 6.7.5 of the CHBDC. Table 4 provides the coefficients of friction between the base of the culvert/footing and potential interface materials.

#### **6.2.5 Stability and Settlement**

Given that an embankment grade raise or widening is not proposed as part of the culvert replacement and highway embankment reconstruction, the existing native soils will not experience additional load, and therefore, settlement of the culvert after embankment reconstruction is estimated to be less than 25 mm.

For the subsurface conditions and the proposed embankments height up to about 3.7 m above the existing ground surface relative to the culvert invert, granular fill embankments at this site will be stable at side slopes inclined at 2 Horizontal to 1 Vertical (2H:1V) or flatter.

### **6.3 Lateral Earth Pressures**

The lateral earth pressures acting on the side walls (or head/wing walls if required) of the culvert will depend on the type and method of placement of backfill materials, the nature of soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

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

- Select, free draining granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of up to 300 mm. Backfill



## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

should be placed in a maximum of 200 mm loose lift thickness. Weep holes should be installed to allow for positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).

- The granular fill may be placed either in a zone with the width equal to at least 2.4 m behind the back of the walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5 H:1V extending up and back from the rear face of the base of the walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC). The pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	Internal Angle of Friction ( $\phi$ )	Unit Weight	Coefficients of Static Lateral Earth Pressure	
			At-Rest, $K_o$	Active, $K_a$
Granular 'A'	35°	22 kN/m <sup>3</sup>	0.43	0.27
Granular 'B' Type II	35°	21 kN/m <sup>3</sup>	0.43	0.27
Granular 'B' Type I or III	32°	21 kN/m <sup>3</sup>	0.47	0.30

If the structure allows for lateral yielding, active earth pressures may be used in the design of the structure. If the structure does not allow for lateral yielding, at-rest earth pressures should be assumed for design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the Commentary to the CHBDC.

## 6.4 Construction Considerations

### 6.4.1 Temporary Roadway Protection

The temporary excavation for the culvert replacement will be made through the existing embankment granular fill comprised of loose to dense sand and into the native soils, which are comprised of generally loose to compact silt to silt and sand. All excavations must be carried out in accordance with Ontario Regulation 213, Ontario Occupational Health and Safety Act for Construction Projects (as amended). The granular fill and native soil are considered to be Type 3 soil above the groundwater table and Type 4 soil below the groundwater table. Temporary open-cut excavations in Type 3 soils should remain stable if side slopes are formed no steeper than 1H:1V. In Type 4 soils, the side slopes should be formed no steeper than 3H:1V.

Temporary protection support systems may be required along the highway to facilitate construction staging and maintain traffic during culvert replacement work. The temporary support systems could consist of driven sheet-piling extended to a suitable depth, or may also consist of soldier piles and lagging where H-piles are driven to a suitable depth and horizontal lagging is installed as the excavation proceeds. Support to the system could be in the form of struts and walers and rakers or anchors. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways.





The installation of the sheet-piles for temporary shoring may be impeded by the presence of cobbles inferred to be present within the embankment fill in Boreholes AL-2 and AL-3 and within the silt and sand deposit in Borehole AL--4. It may be necessary to excavated and replace the existing fill material (and native silt and sand, where practical) in the areas of sheet-pile installation in a series of limited length and narrow trenches. In general, the narrowest suitable excavator bucket should be used. The replacement fill could consist of excavated fill material or imported granular material such as OPSS.PROV 1010 Granular 'A' or Granular 'B' Type I, II or III provided that 100 per cent of the material passes the 75 mm size and less than 5 per cent passes the 75 µm size. The excavated fill material may be re-used to backfill the excavation after removing any cobbles/boulders that would otherwise impede the sheet-pile installation. Excavation and replacement should be carried out in the same day to avoid leaving any trench open overnight. Consideration should be given to including an NSSP in the contract documents to address obstructions. A sample NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

#### **6.4.2 Excavation and Replacement Below Culvert**

Prior to placement of any replacement fill, bedding material or concrete, all existing fill, organics (including silty peat to sandy peat or mixed organic materials) and any disturbed soils, should be sub-excavated from below the plan limits of the proposed works to the founding levels provided in Table 3.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organics and other unsuitable materials have been removed as noted above, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for an open footing culvert. Following inspection, if required the sub-excavated area should be backfilled with granular material meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II or III that is placed and compacted to 100 per cent of the materials Standard Proctor Maximum Dry Density (SPMDD) in accordance with OPSS.PROV 501 (Compacting). Side slopes for granular fill should be no steeper than 2H:1V.

The use of Granular 'B' Type II is recommended in wet ground conditions or below water and placement should be in accordance with OPSS.PROV 209 (Embankments over Swamps). It is recommended that the fines content of the Granular 'B' Type II fill placed below the water be restricted to a maximum of 5 per cent passing the No. 200 sieve, to reduce the potential for segregation of fines during placement and to reduce the potential post-construction settlement and associated maintenance needs.

#### **6.4.3 Culvert Bedding and Backfill**

##### **6.4.3.1 Box Culvert**

The bedding and levelling pad requirements for a pre-cast box culvert should be accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and groundwater seepage through the adjacent embankment fill and native granular soil deposits during excavation to the invert and bedding level and hence the potential for subgrade disturbance, it is recommended that a 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material be used for bedding purposes. As the native soil below the bedding is generally fine grained, it is recommended that a non-woven geotextile be placed



between the native soil and the bottom of the bedding. The geotextile should meet the specifications for OPSS 1860 (Geotextiles) Class II, and have a fabric opening size (FOS) not greater than 212  $\mu\text{m}$ . The bedding should be placed in maximum 200 mm thick loose lifts and compacted to not less than 95 per cent of the SPMD of the materials as specified in OPSS.PROV 501 (Compacting). In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or concrete fine aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete), similar to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

A frost taper should be constructed in a similar configuration as that shown in OPSD 803.010. Although OPSD 803.010 relates to box culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 6.5 m wide box culvert replacement option.

#### **6.4.3.2 Open Footing Culvert**

The excavation and backfilling requirements for the open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures). The open footing culvert should be provided with at least 2.4 m of soil cover for frost protection.

Should a pre-cast open footing culvert be the selected replacement option, a bedding layer and levelling pad will be required above the native soil. The bedding layer and levelling pad for the pre-cast open footings should follow the recommendations as discussed above in Section 6.4.3.1 for the box culvert replacement option.

A frost taper should be constructed in a similar configuration as that shown in OPSD 803.010 (Backfill and Cover for Concrete Culverts). Although OPSD 803.010 also relates to an open footing culvert with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the 0.6 m or 1.2 m wide strip footing for the open footing culvert replacement option.

#### **6.4.3.3 Pipe Culvert**

The bedding, levelling and backfill for a concrete pipe, CSP or SP CSPA culvert should be in accordance with OPSD 802.034 (Rigid Pipe Bedding and Cover in Embankment), OPSD 802.014 (Flexible Pipe Embedment in Embankment) or OPSD 802.024 (Flexible Pipe Arch, Embedment in Embankment), respectively, and culvert construction should be in accordance with OPSS 421 (Pipe Culvert Installation in Open Cut). It is important that the backfill at the haunches be well compacted. The pipe culvert should be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II material for bedding purposes, however this layer thickness should be confirmed at the detail design stage for the actual culvert type and size selected.

A frost taper should be constructed in accordance with OPSD 803.031 (Frost Treatment).

#### **6.4.3.4 Backfill**

Backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the No. 200 (0.075 mm) sieve. The backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at



least 98 per cent of the SPMDD of the materials in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm.

Backfill placement for reconstruction of the roadway embankments adjacent to and over the culvert should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the existing embankment fill and new fill along the cut faces.

Inspection and field density testing should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

#### **6.4.4 Subgrade Protection**

The native silt to silt and sand subgrade will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance, a 300 mm thick compacted bedding layer should be placed directly between the subgrade soils and the footings similar to the bedding for the box and pipe replacement culvert options. Alternatively a concrete working slab could be placed on the subgrade if the concrete footings are not placed within four hours after preparation, inspection, and approval of the foundation subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28 day compressive strength of 20 MPa. Consideration should be given to include an NSSP in the contract to address subgrade protection at this site. An NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

#### **6.4.5 Erosion Protection**

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a concrete cut-off wall or clay seal should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum thickness of 1 m, if constructed of natural clay or soil bentonite mix. The clay seal should extend from a depth of 1 m below the scour level to a minimum vertical height equivalent to the high water level. The seal should also extend a minimum horizontal distance of 2 m on either side of the culvert inlet. Alternatively, a 0.6 m thick clay blanket may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height of two times the culvert height or the high water level, whichever is greater, provided it can be constructed given the close proximity of Dunc Lake relative to the culvert inlet.

The requirements for and design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. As a minimum, rip rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip Rap Treatment). Erosion protection for the inlet of the culvert should also follow the standard presented in OPSD 810.010 (Rip Rap Treatment) similar to the outlet but with the rip rap placed up to the toe of slope level, in combination with the cut off measures noted



above. Similarly, rip rap should be provided over the full extent of the clay seal/blanket, including the creek side slopes and fill slope over the culvert, if a clay seal/blanket is adopted.

#### **6.4.6 Control of Groundwater and Surface Water**

Excavation along the culvert alignment will be required to remove fill, organic and overburden soils prior to placement of replaced fill (if required), bedding material, the actual culvert, backfill and the roadway pavement structure. Groundwater flow into the excavation can be expected due to the depth of the excavations and the presence of relatively permeable granular fill and native granular soils. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

Depending on the creek flow, local surface water flow conditions and groundwater level at the time of construction, water flow could be passed through the area by means of a temporary culvert, the existing culvert or diverted by pumping from behind temporary cofferdams.

Excavations for box, open footing and pipe culvert options will extend below the creek water level, and the groundwater level, and will require temporary shoring with dewatering to allow for construction/placement of the footings/culvert in dry conditions, where required. Temporary shoring and dewatering could be in the form of a cut-off wall or cofferdam advanced to an appropriate depth to control groundwater inflow from the creek and to prevent base heaving of the foundation subgrade. As discussed in Section 6.4.2, sub-excavation replacement fill, if required, can be placed sub-aqueously if comprised of Granular 'B' Type II, however, dewatering may still be required for footing/box culvert placement as the culvert invert is below the creek water level.

Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering). Consideration should be given to include an NSSP in the contract to address unwatering at this site. An NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

At this preliminary stage, an accurate prediction of the groundwater pumping volumes cannot be made, as the flow rate would be dependent on construction methods adopted by the contractor. However, given the granular nature of the fill adjacent to the culvert and the native materials below the culvert, it is considered that groundwater pumping volumes could exceed 50 m<sup>3</sup>/day during initial drawdown stages and/or during periods of heavy precipitation. For this pumping volume, a Permit to Take Water (PTTW) would be required.

#### **6.4.7 Obstructions**

The Contractor should be alerted to the presence of inferred cobbles within the embankment fill and native silt and sand deposit as noted in Boreholes AL-2, AL-3 and AL-4. An NSSP should be developed at the detail design stage for inclusion into the Contract Documents to alert the contractor to the presence of such obstructions.



#### **6.4.8 Analytical Testing for Construction Materials**

The results of an analytical test on a sample of creek water taken at the culvert site are presented in Table B1 in Appendix B. The suite of parameters tested is intended to allow the design engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection of steel reinforcing elements.

### **6.5 Recommendations for Further Work During Detail Design**

During the detail design phase, additional field investigation and testing should be carried out, based on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., staging). In particular, consideration should be given to drilling additional boreholes advanced to a suitable depth for design of temporary protection works if the culvert is to be constructed in stages while maintaining one open lane of traffic during construction and for the groundwater control (cut-off) system. The scope and results of this investigation must be reviewed at the time of the detail design to determine if they meet the then-current MTO requirements for the culvert type, groundwater cut-off system or staging strategy under consideration, and if additional investigation and analysis is necessary. If a grade raise or widening of the roadway is required at this site, additional settlement and stability analysis may be required. Further, the assessment of and need for an application for a PTTW should be defined early in the detail design phase of the project as not to delay the start of construction.

## **7.0 CLOSURE**

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



**PRELIMINARY FOUNDATION REPORT  
ALDER CREEK E. CULVERT - SITE NO. 48E-75/C**

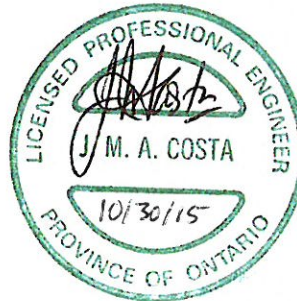
## Report Signature Page

**GOLDER ASSOCIATES LTD.**

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AC/DAM/JMAC/kp

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## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

### REFERENCES

Canadian Standards Association (CSA), 2006. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6 06. CSA Special Publication, S6.1 06.

Occupational Health and Safety Act and Regulation for Construction Projects(as amended).

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2543.

Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42CNW.

ASTM International:

ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

Ontario Provincial Standard Specifications (OPSS)

OPSS 421	Construction Specification for Pipe Sewer Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 902	Construction Specification for Excavating and Backfilling – Structures
OPSS 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 209	Construction Specification for Embankments over Swamps and Compressible Soils
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1002	Material Specification for Aggregates - Concrete
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
OPSD 802.014	Flexible Pipe, Embedment in Embankment, Original Ground: Earth or Rock
OPSD 802.024	Flexible Pipe Arch, Embedment in Embankment, Original Ground: Earth or Rock
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





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## **PRELIMINARY FOUNDATION REPORT**

### **ALDER CREEK E. CULVERT - SITE NO. 48E-75/C**

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OPSD 803.031 Frost Treatment – Pipe Culverts, Frost Penetration Line between Top of Pipe and Bedding Grade

OPSD 810.010 General Rip-Rap Layout for Sewer and Culvert Outlets

OPSD 3090.100 Foundation, Frost Penetration Depths for Northern Ontario

Ontario Water Resource Act:

Regulation 903 Wells (as amended)



## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

Table 1: Summary of Culvert Details

Culvert Location	Site #	Approximate Height of Embankment <sup>1</sup> (m)	Existing Culvert			Approximate Invert Elevation <sup>2</sup>	
			Type	Approximate Dimension <sup>2</sup>	Approximate Length (m)	North End of Culvert (m)	South End of Culvert (m)
Hwy 17 STA 11+078	48E-75/C	3.7	SP CSP arch	3.9 m wide x 2.1 m high	27	323.5	323.9

- Notes:
1. Embankment height is relative to existing ground surface at the centreline of the roadway and the invert elevation of the culvert.
  2. Culvert dimensions are based on the Sept. 2010 MTO NW Region OSIM Inspection report and the invert elevations are based on the plan and profile drawings provided by MTO (Drawing E484854171.dwg).

Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC



## PRELIMINARY FOUNDATION REPORT

### ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

**Table 2: Comparison of Foundation Alternatives**

Option	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	<ul style="list-style-type: none"> <li>Minimizes depth of excavation, protection system (if required) and dewatering requirements compared to open footing option. Minor excavation required for sub-excavation of existing fill/organics and for the bedding/levelling course.</li> <li>Allows faster construction resulting in shorter duration for dewatering and surface water pumping.</li> <li>More tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site or if heave/settlement occurs resulting from freeze/thaw of the subgrade.</li> <li>Backfill/bedding under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements.</li> </ul>	<ul style="list-style-type: none"> <li>May not satisfy fisheries requirements related to natural channel substrate, if applicable.</li> <li>Cut-off wall (or clay seal/blanket) likely required at inlet to mitigate potential scour under culvert.</li> <li>Transportation to and on-site lifting of large pre-cast sections will be required.</li> <li>May require water diversion of a relatively wide creek channel.</li> </ul>	<ul style="list-style-type: none"> <li>Some risk of disturbance of the native silt to silt and sand deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad.</li> <li>Low risk related to settlement performance</li> </ul>
Open Footing Culvert	<ul style="list-style-type: none"> <li>May be feasible to construct the culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering/unwatering (pumping) of surface water.</li> <li>Existing culvert can likely be used for water diversion while new footings are being constructed adjacent to the culvert depending on the width of the new culvert.</li> <li>Readily suitable for construction using concrete or metal sections.</li> <li>Would likely satisfy fisheries requirements related to natural channel substrate, if applicable.</li> </ul>	<ul style="list-style-type: none"> <li>Excavation depths are greater than for a concrete box or pipe culvert option, resulting in increased excavation support and dewatering/unwatering requirements and additional spoil material to be disposed off-site whether the footings are pre-cast or cast-in-place.</li> <li>Constructing footings in the dry will take longer due to requirements for installation of a groundwater and surface water control system, dewatering and surface water pumping, and excavation in a confined space, and would require a tremie concrete plug to allow for subsequent unwatering and footing construction.</li> <li>Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site.</li> <li>Concrete or metal arch sections supported on concrete open (strip) footings may not allow for adequate soil cover to be placed including the roadway pavement structure and the long-term performance of such structures is not known.</li> </ul>	<ul style="list-style-type: none"> <li>High risk of disturbance of the native silt to silt and sand deposit during construction; can be mitigated with use of a concrete working slab or Granular 'B' Type II pad.</li> <li>May require greater depth of dewatering/unwatering for footing construction.</li> <li>Culvert joints may be required to accommodate total and differential settlement (if required).</li> </ul>



## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

Option	Advantages	Disadvantages	Risks/Consequences
Pipe Culvert(s)	<ul style="list-style-type: none"><li>■ Allows for faster construction resulting in shorter duration for dewatering and surface water pumping compared to an open footing culvert.</li><li>■ More tolerant of total and differential settlement if the highway embankment is raised or widened.</li><li>■ Backfill under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements.</li></ul>	<ul style="list-style-type: none"><li>■ Reduced flow-through capacity compared to box culvert options with a similar span - additional flow capacity may have to be provided by multiple pipes.</li><li>■ Cut-off wall (or clay seal/blanket) may be required at inlet to mitigate potential scour under culvert(s).</li><li>■ Difficult to compact backfill materials to level of culvert springline.</li><li>■ CSP does not have as long of design life compared to concrete options.</li></ul>	<ul style="list-style-type: none"><li>■ Some risk of disturbance of the native silt to silt and sand deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad.</li><li>■ Limited risk related to settlement performance.</li></ul>



**PRELIMINARY FOUNDATION REPORT**  
**ALDER CREEK E. CULVERT - SITE NO. 48E-75/C**

**Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box and Open Footing Replacement Culverts**

<b>Culvert Location</b>	<b>Approximate Invert Elevation <sup>1</sup> (North End / South End)</b>	<b>Culvert Type</b>	<b>Approximate Backfill/Bedding/Footing Founding Elevation (North End / South End)</b>	<b>Founding Condition</b>	<b>Factored Geotechnical Axial Resistance at ULS <sup>2</sup></b>	<b>Geotechnical Reaction at SLS for 25 mm of Settlement <sup>2</sup></b>
Hwy 17 STA 11+078	323.5 m / 323.9 m	Pre-Cast Box	323.1 m / 323.5 m	Bedding/Levelling Pad over Compact Silt to Silt and Sand	225 kPa	75 kPa
		Open Footing (0.6 m wide)	321.1 m / 321.5 m	Compact Silt to Silt and Sand	180 kPa	170 kPa
		Open Footing (1.2 m wide)			195 kPa	160 kPa
		Pipe Culvert <sup>3</sup>	323.2 m / 323.6 m	Bedding over Compact Silt to Silt and Sand	N/A	N/A

- Notes:
1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing E484854171.dwg).
  2. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an assumed 6.5 m wide box culvert and a 0.6 m and 1.2 m wide open footing. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the foundation widths differ from those given above.
  3. The founding elevation may need to be adjusted based on the type and size of the pipe culvert and required bedding thickness.

Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC



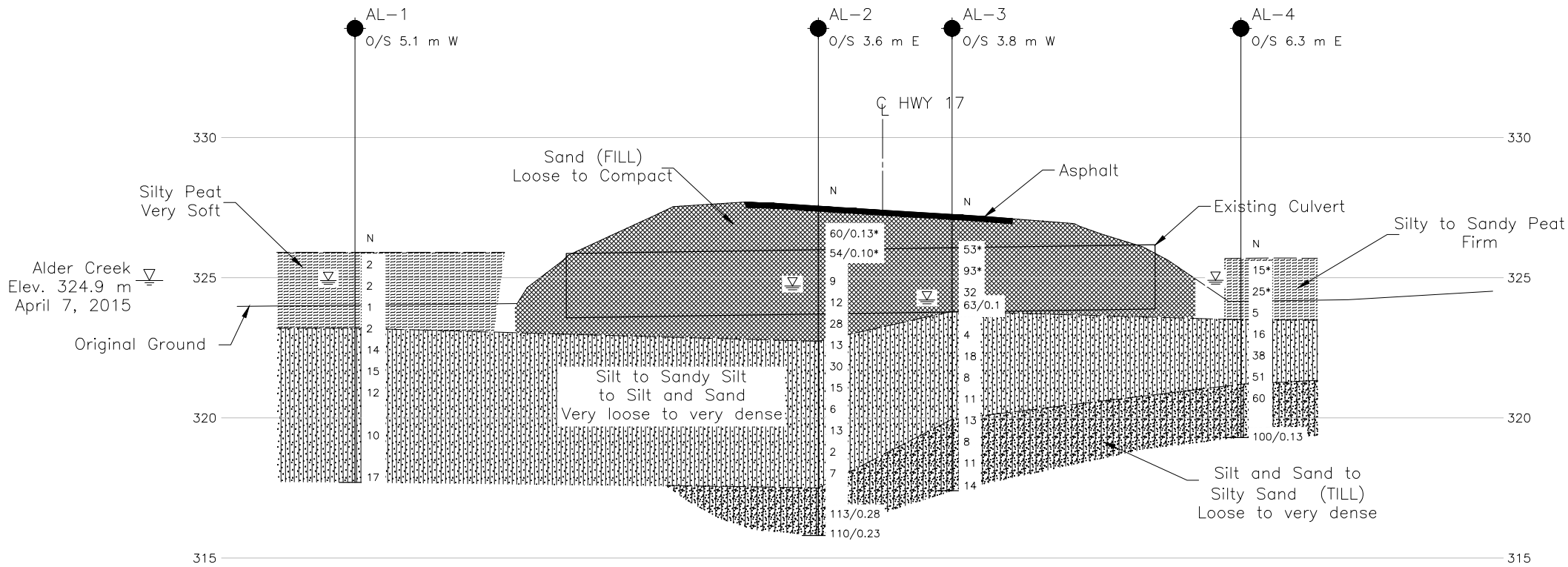
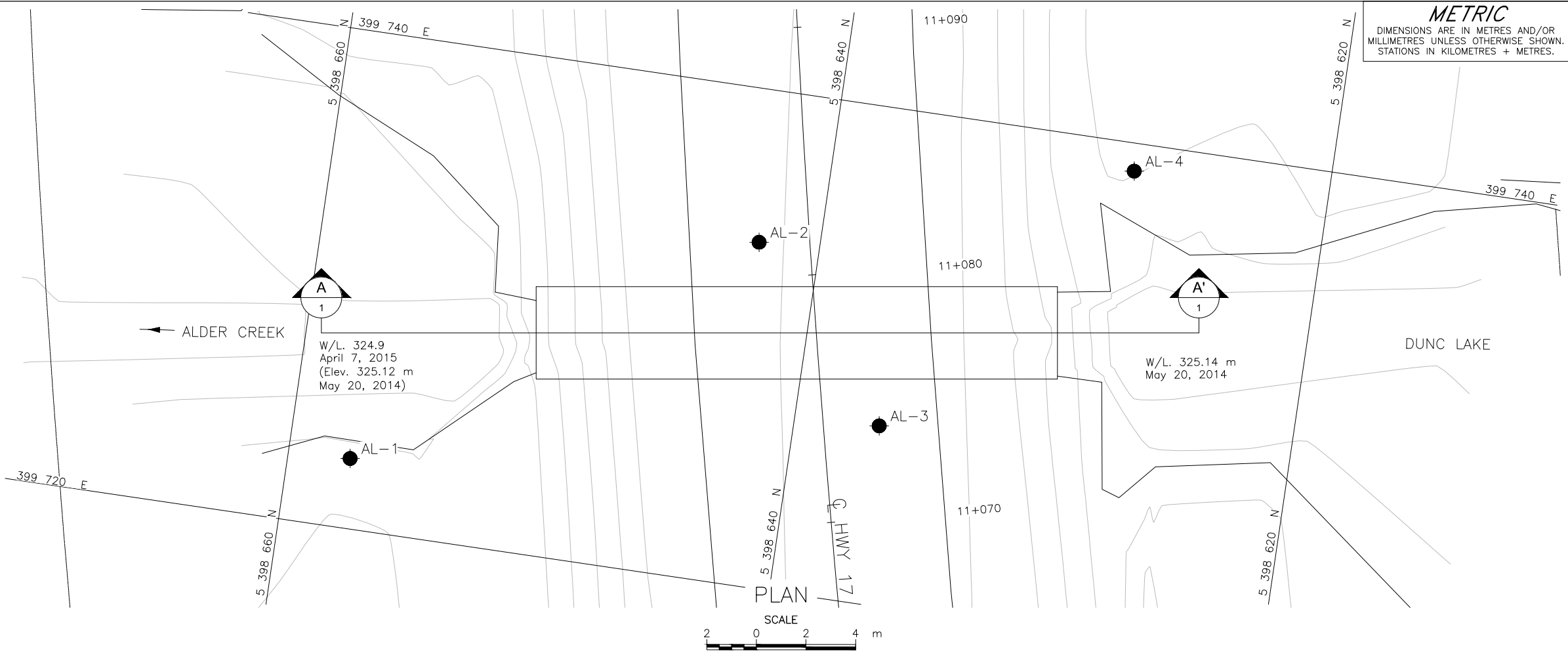
## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

**Table 4: Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Open Footing Replacement Culverts**

Culvert Location	Pre-Cast Box Culvert or Open Footing		Cast-in-place Open Footing	
	Interface Material	Coefficient of Friction <sup>1</sup> (tan $\delta$ )	Interface Material	Coefficient of Friction <sup>1</sup> (tan $\delta$ )
Hwy 17 STA 11+078	Compacted Granular Fill (Levelling Pad)	0.45	Compact Silt to Silt and Sand	0.35

Notes: 1. These values are unfactored.

Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC

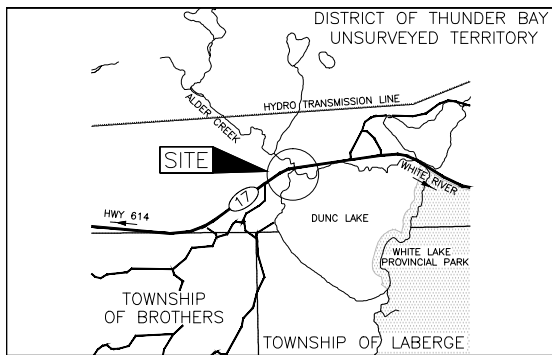


CONT No. .  
GWP No. 6330-14-00



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





## PHOTOGRAPHS

**Photograph 1: Alder Creek Culvert  
South Side - Inlet (Golder – April 7, 2015)**



**Photograph 2: Alder Creek Culvert  
North Side - Outlet (Golder – April 7, 2015)**





## PHOTOGRAPHS

**Photograph 3: Alder Creek Culvert  
South Side - Inlet (Taken from MTO, OSIM 48E-75/C)**



**Photograph 4: Alder Creek Culvert  
North Side - Outlet (Taken from MTO, OSIM 48E-75/C)**





# **APPENDIX A**

## **Record of Boreholes**





## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I. GENERAL

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

<b>(a)</b>	<b>Index Properties</b>
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	plasticity index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_\alpha$	secondary compression index
$m_v$	coefficient of volume change
$C_v$	coefficient of consolidation (vertical direction)
$C_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction = $\tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
$S_t$	sensitivity

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

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



## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

#### Dynamic Cone Penetration Resistance; $N_d$ :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

	$c_u, s_u$	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

### IV. SOIL TESTS

w	water content
w <sub>p</sub>	plastic limit
w <sub>l</sub>	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
D <sub>R</sub>	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	unit weight

**Note:** 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

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 kN/m <sup>3</sup>	GR SA SI CL
								20 40 60 80 100	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60				
325.9	GROUND SURFACE																
0.0	Silty PEAT, trace to some sand Very soft Black Wet		1	SS	2		325										
			2	SS	2		324										
			3	SS	1		323										
323.2			A	SS	2		322										
2.7	SILT to Sandy SILT Compact Grey Wet		4	SS	2		321										
			5	SS	14		320										
			6	SS	15		319										
			7	SS	12		318										
			8	SS	10												
			9	SS	17												
317.7	Some gravel encountered below 7.6 m depth.																
8.2	END OF BOREHOLE																
	Note: 1. Water level at a depth of 1.0 m below ground surface (Elev. 324.9 m) upon completion of drilling.																

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

<b>PROJECT</b> 1411523		<b>RECORD OF BOREHOLE No AL-2</b>		1 OF 1 <b>METRIC</b>	
<b>G.W.P.</b> 6330-14-00		<b>LOCATION</b> N 5398642.4; E 399733.8		<b>ORIGINATED BY</b> RI	
<b>DIST</b> _____ <b>HWY</b> 17		<b>BOREHOLE TYPE</b> 108 mm I. D. Hollow Stem Augers		<b>COMPILED BY</b> MT	
<b>DATUM</b> GEODETIC		<b>DATE</b> March 17, 2015		<b>CHECKED BY</b> SEMP	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			LIQUID LIMIT	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)					GR	SA	SI	CL
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>						
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*													14	74 (12)		
			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															0	55 44 1		
			7	SS	30																
			8	SS	15																
			9	SS	6													2	28 68 2		
			10	SS	13																
			11	SS	2																
			12	SS	7																
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													12	31 41 16		
315.8	END OF BOREHOLE																				
11.8	Note:  1. Water level at a depth of 2.9 m below ground surface (Elev. 324.7 m) upon completion of drilling.																				

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



PROJECT		1411523		<b>RECORD OF BOREHOLE No AL-3</b>		1 OF 1 <b>METRIC</b>										
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			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
327.2	GROUND SURFACE															
0.0	ASPHALT (190 mm)															
0.2	Sand, some gravel, some silt (FILL) Dense Brown Frozen* to wet		1	SS	53*											
	Augers grinding on inferred cobbles below 1.5 m depth.		2	SS	93*											12 74 (14)
			3	SS	33											
			4	SS	63/0 1											
323.7	SILT to SILT and SAND, trace gravel, trace clay Loose to compact Grey Wet		5	SS	4											
3.5			6	SS	18											
			7	SS	8											0 8 90 2
			8	SS	11											
319.9	SILT and SAND, trace to some gravel, trace clay (TILL) Loose to compact Grey Wet		9	SS	13											
7.3			10	SS	8											
			11	SS	11											7 36 55 2
			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		<b>RECORD OF BOREHOLE No AL-4</b>				1 OF 1 <b>METRIC</b>											
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			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
325.7	GROUND SURFACE							20	40	60	80	100					
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*		324										
			3	SS	5												
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
			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	
							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:



# **APPENDIX B**

## **Laboratory Test Results**



## PRELIMINARY FOUNDATION REPORT ALDER CREEK E. CULVERT - SITE NO. 48E-75/C

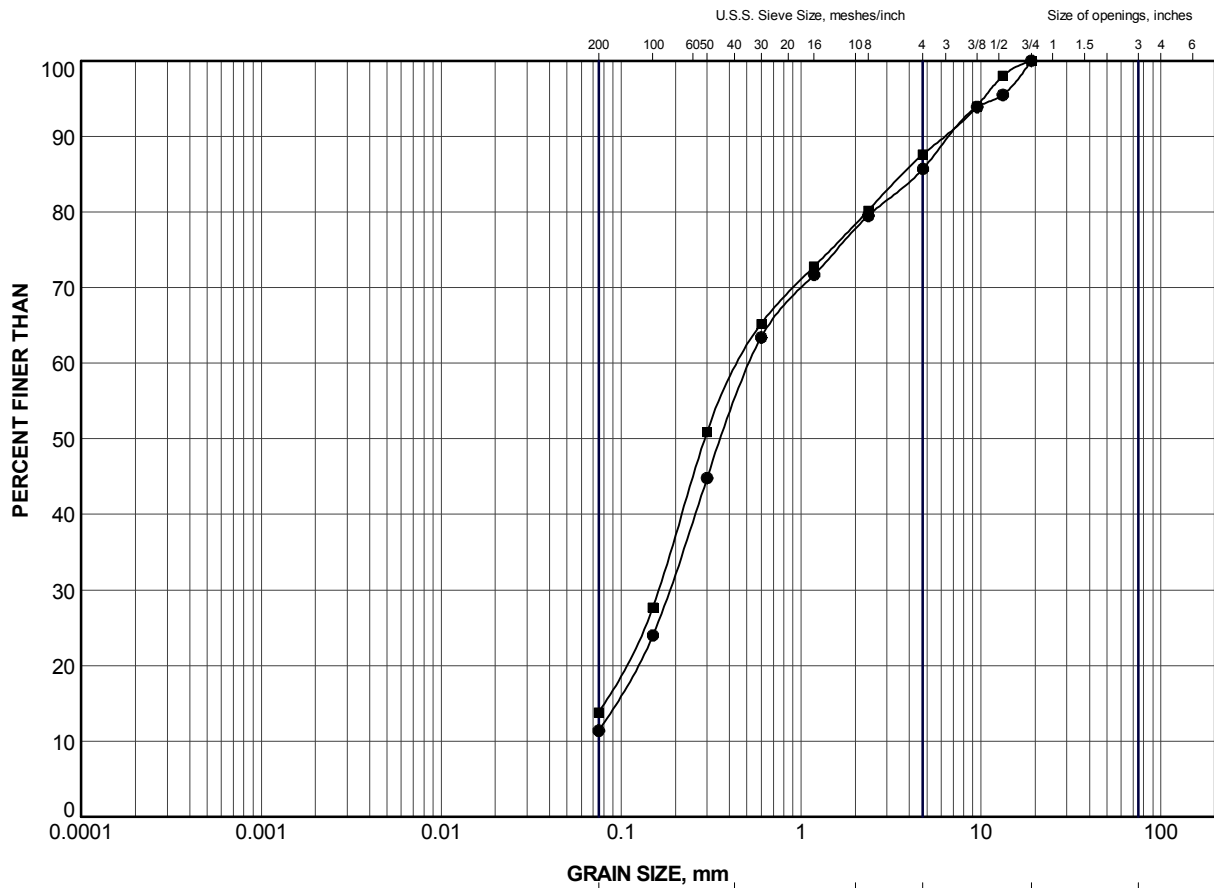
**Table B1: Summary of Analytical Testing of Alder Creek Water Sample**

Parameter	Units	Result
Chloride (CL)	mg/L	21.6
Sulphate (SO4)	mg/L	2.02
Conductivity (EC)	µS/cm	174
Resistivity	µohm-cm	<0.33
pH	n/a	7.55

Notes:

1. Sample obtained on March 25, 2015.
2. Analytical testing carried out by ALS Canada Ltd.


Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC

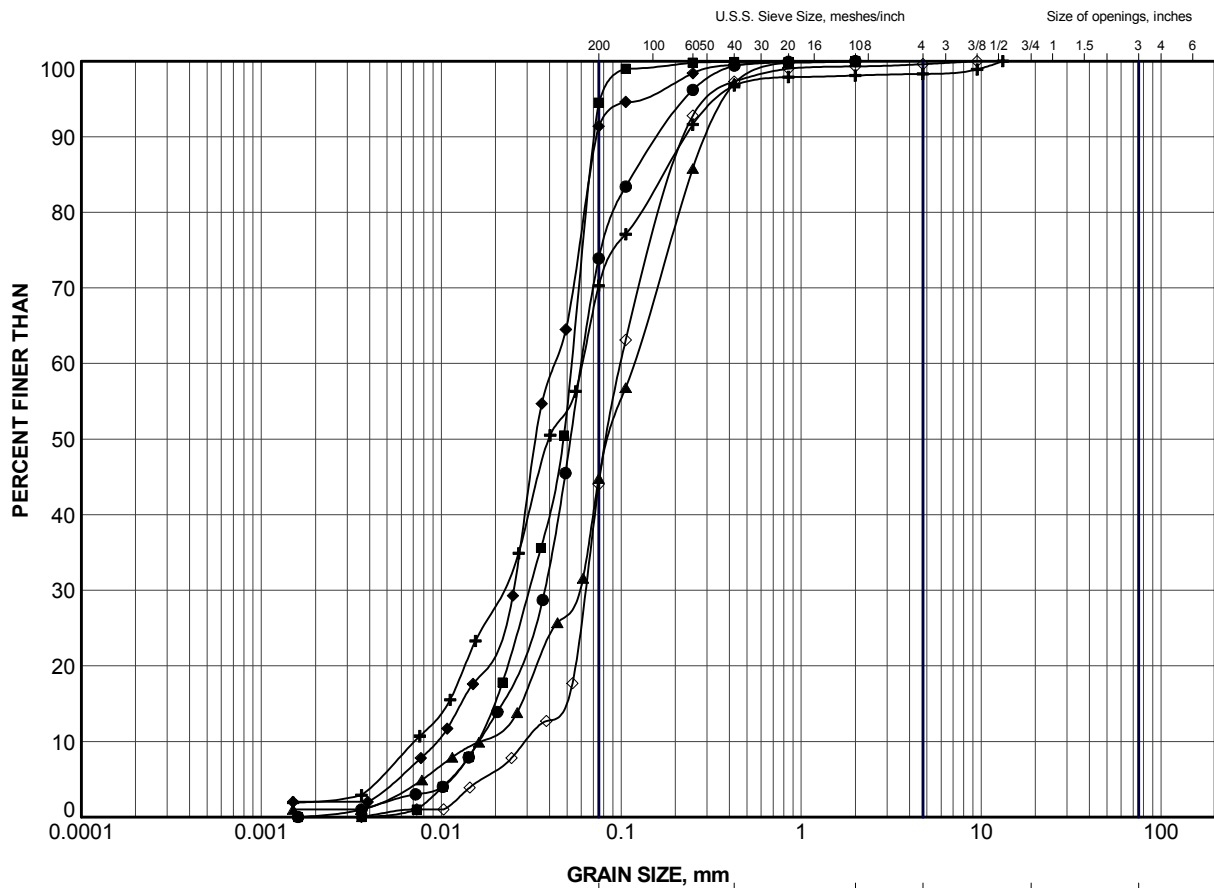


GRAVEL SIZE, mm							Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	AL-2	1	326.7
■	AL-3	2	325.4

PROJECT						HIGHWAY 17 ALDER CREEK CULVERT STA 11+078					
TITLE						GRAIN SIZE DISTRIBUTION SAND (FILL)					
PROJECT No.			1411523			FILE No.			1411523.GPJ		
DRAWN	TB	July 2015	SCALE	N/A	REV.						
CHECK	SEMP	July 2015									
APPR	JMAC	July 2015									
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B1</b>								



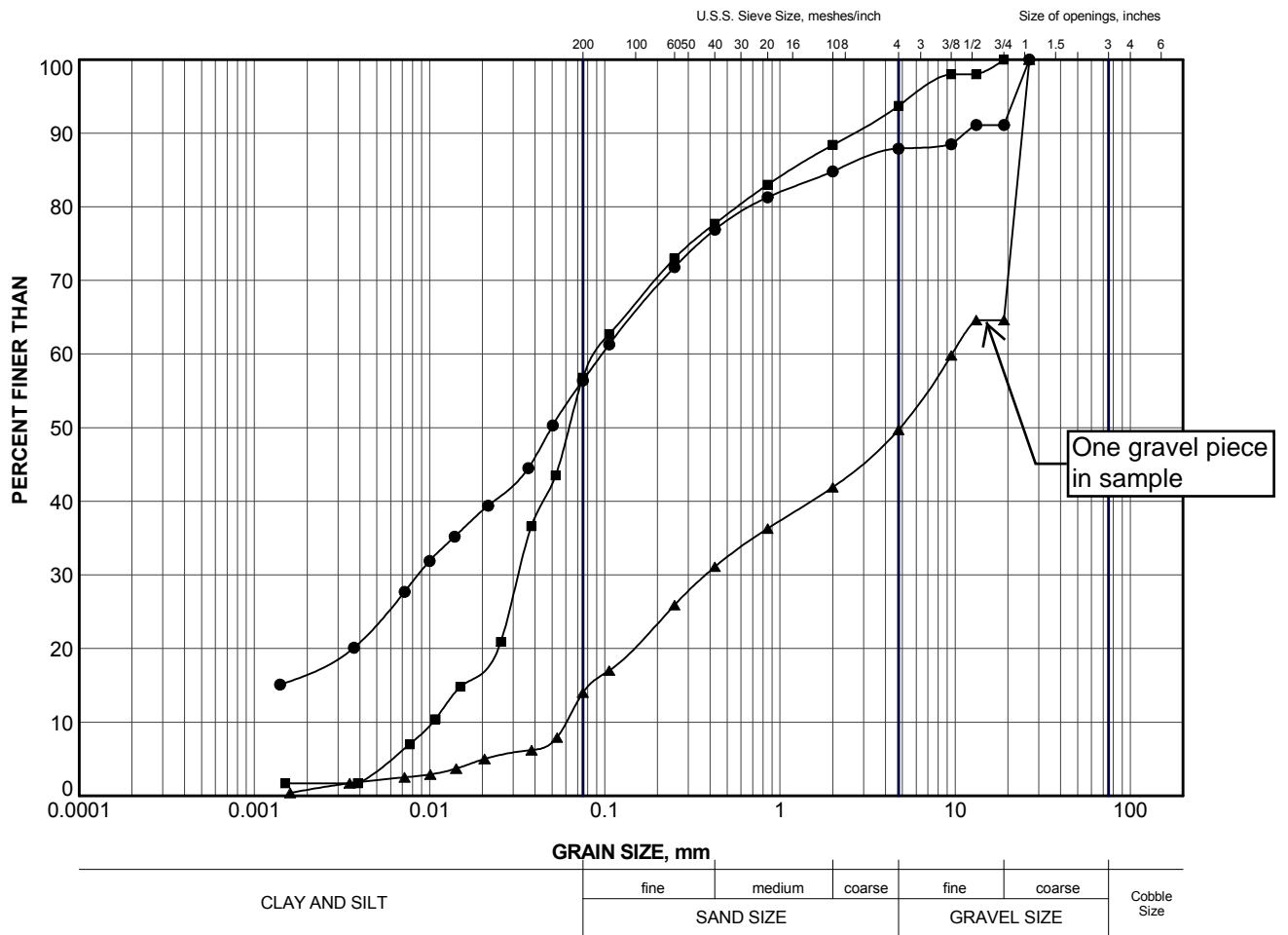
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	AL-1	5	322.5
■	AL-1	8	319.5
▲	AL-2	6B	322.7
+	AL-2	9	320.4
◆	AL-3	7	321.6
◇	AL-4	4	323.1

PROJECT					
HIGHWAY 17 ALDER CREEK CULVERT STA 11+078					
TITLE					
GRAIN SIZE DISTRIBUTION SILT to SILT and SAND					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	TB	Jul 2015	SCALE	N/A	REV.
CHECK	SEMP	Jul 2015	FIGURE B2		
APPR	JMAC	Jul 2015			





### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	AL-2	14	316.0
■	AL-3	11	318.5
▲	AL-4	7	320.8

PROJECT					
HIGHWAY 17 ALDER CREEK CULVERT STA 11+078					
TITLE					
GRAIN SIZE DISTRIBUTION SILT and SAND to SILTY SAND (TILL)					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	TB	Jul 2015	SCALE	N/A	REV.
CHECK	SEMP	Jul 2015	FIGURE B3		
APPR	JMAC	Jul 2015			





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