



September 8, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

**CHOWDER CREEK CULVERT - SITE NO. 48E-84/C
HIGHWAY 11, DISTRICT OF THUNDER BAY
UNSURVEYED TERRITORY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 6312-14-00**

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REPORT





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PART A

**PRELIMINARY FOUNDATION INVESTIGATION REPORT
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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 Chowder Creek culvert (Site No. 48E-84/C). The Chowder Creek culvert is located in the District of Thunder Bay in Unsurveyed Territory on Highway 11 at STA 15+113, approximately 40 km east of the junction of Highway 11 and Highway 625 near Longlac, Ontario. The key plan showing the general location of this section of Highway 11 and the location of the investigated area are shown on Drawing 1.

2.0 SITE DESCRIPTION

The Chowder Creek culvert consists of a twin cell, open bottom timber structure, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

In general, the topography in the area is relatively flat with low-lying swampy terrain in the vicinity of the existing twin cell timber culvert. Highway 11 runs in a west-east direction with the culvert perpendicular to the highway in a north-south orientation. The Chowder Creek flows southerly and drains into Inman Lake, which subsequently drains into Chowder Lake. At the culvert location, the highway grade is at Elevation 280.7 m and the culvert invert is at approximately Elevations 277.4 m and 277.1 m at the inlet (north end) and outlet (south end), respectively. The Inman Lake water level was at Elevation 278.6 m as measured by others on November 4, 2008. The Chowder Creek water level was at Elevation 278.0 m as measured by Golder on March 24, 2015. Surface conditions in the culvert inlet and outlet area are shown on Photographs 1 to 4, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between March 23 and 27, 2015, during which time four boreholes (Boreholes CH-1 to CH-4) were advanced at approximately the locations shown on Drawing 1. Boreholes CH-1 and CH-4 were advanced at the toe of slope near the culvert inlet/outlet and Boreholes CH-2 and CH-3 were advanced from the existing highway platform. The boreholes were advanced using a CME 850 track-mounted drill rig supplied and operated by Cartwright Drilling Inc. of Thunder Bay, Ontario.

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 a member 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



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Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions and Atterberg limits were carried out on selected soil samples. The geotechnical laboratory testing was completed according to MTO LS standards.

A sample of the creek water was obtained during the field investigation (on March 26, 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 drawing provided by MTO on drawing BC494854113.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)
CH-1	5518887.7	393801.5	279.2	5.9
CH-2	5518876.8	393809.3	280.7	11.0
CH-3	5518872.8	393804.9	280.7	10.0
CH-4	5518862.3	393812.2	278.7	9.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)¹ mapping, the subsoils in the vicinity of the Chowder Creek culvert site generally consist of organic terrain deposits comprised mainly of peat/muck bordering with areas of undulating to rolling bedrock knobs and ground moraines comprised of till deposits.

Based on geological mapping by the Ontario Ministry of Northern Development and Mines (MNDM)², the site is underlain by bedrock from the Archean Era, comprised of mafic to intermediate metavolcanic rock consisting of basaltic and andesitic flows, tuffs and breccias, chert and iron formations bordering with massive granodiorite to granite 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'

¹ Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42FNW

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



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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.

In summary, the subsoil conditions encountered at the site consist of asphalt and sand fill underlain by deposits of peat, silty sand, silt to silt and sand, and silty sand to gravelly sand. 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	
Asphalt	CH-2, CH-3	0.14 – 0.15	280.7	n/a	n/a
(FILL) Sand , trace to some gravel, trace to some silt, trace organics; brown to black; moist to wet / frozen	CH-2 to CH-4	2.2 – 4.0	280.6 – 278.7	N = 1 – 9 ¹	w = 5% – 20% ² 2 - MH (Fig. B1)
				Very Loose to Loose	
Peat , some sand; black; moist to wet	CH-1 to CH-4	0.7 – 2.1	279.2 – 276.5	N = WH – 3	w = 39% – 131%
				Very Soft to Soft	
Silty Sand , trace organics; grey, moist to wet	CH-1, CH-2	0.6 – 0.7	278.5 – 275.7	N = 15	n/a
				Compact	
Silt , trace sand to Silt and Sand , trace to some clay, trace gravel; grey; wet ³	CH-1 to CH-4	3.1 – 4.4	277.8 – 274.4	N = WH – 30	w = 18% – 26% 4 – MH (Fig. B2) 6 – AL = NP
				Very loose to Compact	
Silty Sand to Gravelly Sand , trace clay ; grey; wet ³	CH-1 to CH-4	1.1 – 2.3	274.7 – 270.0	N = 14 – 58	w = 15% – 17% 3 – MH (Fig. B3)
				Compact to Very Dense	

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
AL = Atterberg Limits Test
NP = Non-Plastic Test Result

Notes:

¹ In the granular fill, SPT 'N'-values ranging from 32 blows to 64 blows per 0.3 m of penetration were measured, however, these are likely indicative of the frozen state of the material and are not representative of the relative density of the fill.



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² A natural moisture content of 49 per cent was measured on one sample of the granular fill near the ground surface of Borehole CH-4, however, this is likely due to the presence of organics within the fill and is likely not representative of the moisture content of the fill.

³ Auger grinding due to inferred cobbles was noted within the silt deposit in Borehole CH-1 and sand deposit in Borehole CH-3.

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 278.0 m on March 24, 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)
CH-1	Not Obtained	-
CH-2	4.0	276.7
CH-3	2.6	278.1
CH-4	1.7	277.0

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Nicholas Jamin under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Tibor Berecz, and Mr. David Muldowney, P.Eng. provided 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.



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Report Signature Page

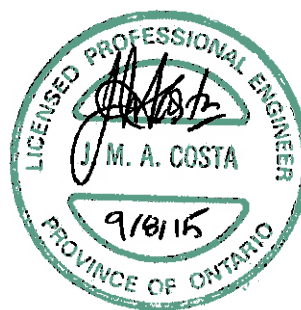
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PART B

**PRELIMINARY FOUNDATION DESIGN REPORT
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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 Chowder Creek 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 twin cell, open bottom, timber culvert will be replaced with a culvert of similar height and length dimensions, along the same alignment and at similar invert elevations to those of the existing culvert but likely the new culvert will be wider than the existing timber culvert. In addition, it is assumed that there will be no embankment grade raises or widening in the area of the culvert as part of the Highway 11 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The Chowder Creek culvert is located in the District of Thunder Bay in Unsurveyed Territory on Highway 11 at STA 15+113, approximately 40 km east of the junction of Highway 11 and Highway 625 near Longlac, Ontario. The highway embankment is constructed of granular fill material and is approximately 3.6 m high relative to the existing culvert invert with approximately 1.5 m of cover over the existing culvert. The existing culvert consists of a two-cell timber structure, 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 culvert types are being considered at this location:

- an approximately 4.5 m wide pre-cast concrete box with a slight realignment;
- twin pre-cast concrete boxes (approximately 5.5 m wide overall); and
- an approximately 7.3 m wide open footing structure with either pre-cast concrete arch or metal box segments.

In this report we have considered the following options:



- an open footing structure supported on either cast-in-place or pre-cast footings;
- a pre-cast concrete box culvert(s); and
- a pipe culvert(s).

Based on discussions with MTO and HMM, we understand that a pre-cast concrete slab supported on sheet-pile abutment is not being considered for culvert replacements on the Highway 11 corridor. A pipe culvert, including an elliptical culvert and/or flexible arch culvert, is considered feasible at this site but would provide less flow-through capacity compared to a box culvert or open footing culvert with a similar span. Further, it is likely that multiple parallel pipe culverts would be required to meet flow requirements. Open footing arch culverts are also feasible at this site but consideration would need to be given to the type (concrete or metal) and size of the structure to ensure that adequate flow-through capacity and soil cover (including the roadway pavement structure) above the culvert can be provided. From a foundation perspective, a pre-cast concrete box culvert sufficiently wide to handle the creek flow would be suitable for this site. An open footing culvert is recommended over a box culvert as the footings for the open footing culvert could be constructed beyond the existing culvert limits allowing the existing culvert to be used as diversion channel whereas a box culvert replacement would require creek realignment or staged construction (for twin boxes). In addition, the open footing culvert replacement would provide a natural channel substrate and would likely satisfy fisheries requirements. Further, due to the presence of the peat deposit, which extends below the depth of the existing (and assumed) culvert invert, the excavation, dewatering and temporary support requirements would be similar for both open footing and pre-cast box culvert replacements. Other culvert types may be preferred due to construction staging or other considerations. 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 Open Footing Culvert

Strip footings for an open footing culvert should be founded at a minimum depth of 2.6 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation, Frost Penetration Depths for Northern Ontario). In addition, the footings should extend below any existing fill and/or peat deposits, where present. In this regard, the central and southern portion of the culvert may have to be constructed on a thin granular mat/pad replacing the peat layer present along this section of the culvert, which extends to about Elevation 274.4 m. Details regarding the peat sub-excavation and replacement fill are discussed in Section 6.4.2. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

6.2.2.2 Box Culvert

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as box structure segments are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. However, the peat deposit as encountered in the boreholes would have to be removed and the excavation backfilled with granular fill or select rock fill placed on the very loose to compact sand and silt deposits. Similar to the open footing culvert option, the northern portion of the box culvert could be founded on a bedding layer and



levelling course overlying the native soils but the central and southern portion of the culvert would have to be constructed on a thicker granular mat/pad replacing the peat layer present along this section of the culvert. Recommended foundation elevation and foundation conditions for a replacement box 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 the very loose to compact sand and silt deposits or a bedding layer overlying the native soils at the northern portion of the alignment, whereas the central and southern portion of the culvert will to be constructed on a granular mat/pad replacing the peat layer present along this section of the culvert, 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 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 Serviceability Limit State (SLS), for 25 mm of settlement, as provided in Table 3. These recommendations are based on an assumed footing width of 0.6 m or 1.2 m as provided 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 C6.7.4 of the CHBDC 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 applicable as the settlement under the culvert as a result of soil loading (not culvert loading) may govern.

6.2.3.2 Box Culvert

A box culvert, placed on the properly prepared levelling course on a subgrade comprised of replacement granular fill or select rock fill at or below the founding elevation identified in Table 3, should be based on the



recommended factored geotechnical axial resistance at ULS and geotechnical reaction at SLS, for 25 mm of settlement, as provided in Table 3. Should higher geotechnical axial resistances be required, consideration could be given to sub-excavating the peat deposit and the loose to compact silt to silt and sand deposit to Elevation 274.4 m along the entire culvert alignment and replacing with engineered fill as described further in Section 6.4.2. These recommendations are based on a box culvert width of 5 m as provided 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 applicable as the settlement under the culvert will occur as a result of soil loading (not culvert loading).

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, provided any organic deposits are removed below the plan limits of the proposed works.

For the subsurface conditions and the proposed embankments height up to about 3.6 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 should be placed in maximum 200 mm thick loose lifts. 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 2.6 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 following parameters (unfactored) may be used to calculate the lateral earth pressures acting on the culvert:

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

If the structure allows for lateral yielding, active earth pressures may be used in the design of the structure(s). 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 fill comprised of sand and into native soils, which are comprised of peat, compact silty sand and very 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 soils are considered to be Type 3 soil above the groundwater table and Type 4 soil below. 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. The installation of the sheet-piles for temporary shoring may be impeded by the presence of inferred cobbles within the native soils, as encountered in Boreholes CH-1 and CH-3. 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.

6.4.2 Excavation and Replacement Below Culvert

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

The excavation subgrade and subsequently the culvert founding surface 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, 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 in accordance with OPSS.PROV 501 (Compacting) or select rock fill (depending on the depth of the sub-excavation) that is placed in accordance with OPSS.PROV 206 (Grading). The use of Granular 'B' Type II or select rock fill is recommended in wet ground conditions or below water. Where an engineered fill pad is required to replace the removed peat/organic deposit, the fill pad should extend at least 1 m beyond the plan limits of the footings, unless shoring is utilized and left in place.

Granular 'B' Type II fill placed above the water table should be compacted to 100 per cent of the Standard Proctor Maximum Dry Density (SPMDD) and the compaction should be carried out in accordance with OPSS.PROV 501 (Compacting). If the Granular B Type II fill is placed below the water level, the fill should be placed in accordance with OPSS.PROV 209 (Embankments over Swamps and Compressible Soils). 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. Side slopes for granular fill should be no steeper than 2H:1V.

If rock fill is used, the rock fill should be well graded and should consist of fragments of sound rock, free of organic matter or any deleterious material and should have a maximum particle size of 300 mm similar to the requirements outlined in MTO Northern Region Directive (2002) titled *Backfill to Structures Adjacent to Rock Embankment Approaches*. Placement of rock fill above the water level should be carried out in accordance with the requirements as outlined in OPSS.PROV 206 (Grading). Rock fill placed below the water level should be in accordance with OPSS.PROV 209 (Embankments over Swamps and Compressible Soils). Side slopes for rock fill should be no steeper than 1.25H:1V.

An NSSP should be provided at the detail design stage for fill restrictions, if required depending on final culvert design and construction staging.

6.4.3 Culvert Bedding and Backfill

6.4.3.1 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 2.6 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 or engineered fill pad. The bedding layer and levelling pad for the pre-cast open footings should follow the recommendations as discussed below in Section 6.4.3.2 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 relates to an open footing box culvert with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the approximately 7 m wide (span) open footing culvert shown on the preliminary GA. If raised footings are selected as the preferred culvert replacement option, a longer frost taper (i.e., 20H:1V) should be considered due to the potential for additional heave/settlement associated with freeze-thaw cycles.

6.4.3.2 Box Culvert

The bedding and levelling pad requirements for a pre-cast box culvert should be in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and groundwater seepage through the adjacent granular fill the sub-excavation replacement fill and the native soils, it is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material be used for bedding purposes. If the sub-excavation replacement fill below the bedding is comprised of rock fill, it is recommended that a non-woven geotextile be placed between the rock fill 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 µm. The bedding should be placed in maximum 200 mm thick loose lifts and compacted to at least 98 per cent of the standard Proctor maximum dry density (SPMDD) 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 fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided with a geometry similar to that presented in 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 (Backfill and Cover for Concrete Culverts). 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 5m wide (overall) box culvert replacement option, shown on the Preliminary General Arrangement.

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, placed on a geotextile separating the bedding from the underlying sub-excavation replacement fill if rock fill is used as noted in Section 6.4.3.2, 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 granular backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD 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 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 subgrade will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance the sub-excavation backfill (Granular 'B' Type II or select rockfill) should be placed as noted in Section 6.4.2. In the case of an open footing culvert founded on native subgrade, a concrete working slab should be placed on the subgrade if the concrete footings, is 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 the case of a box or pipe culvert, if selected, to prevent surface water from flowing either beneath the box 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. If the clay seal (cut-off) extends into the rock fill sub-excavation backfill, a separation layer of Granular 'B' Type II should be placed against the rock fill, followed by a separate geotextile, as described in Section 6.4.3.2, between the Granular 'B' Type II and the clay seal. The seal should also extend a minimum horizontal distance of 2 m on either side of 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 the existing embankment fill, peat and potentially a portion of the native soils to achieve the required strip footing founding level or an adequate subgrade level for the sub-excavation backfill prior to placement of bedding, the actual culvert, culvert backfill and roadway pavement structure. Groundwater flow into the excavation can be expected due to the depth of the excavations and the presence of relatively permeable embankment fill, new backfill and native 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, using the existing culvert or diverted by pumping from behind a temporary cofferdam.

Excavations for box, open footing and pipe culvert options will extend below the creek water level and groundwater level and will therefore require temporary shoring with dewatering to allow for construction/placement of the footings and/or placement of bedding material in dry conditions, where required. Temporary shoring and dewatering could be in the form of a sheet-pile cut off wall or cofferdam advanced to an appropriate depth to control groundwater inflow including infiltration water from the creek and to prevent base heaving of the foundation subgrade. As discussed in Section 6.4.2, engineered fill or sub-excavation replacement backfill can be placed subaqueously, 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, it is considered that groundwater pumping volumes could exceed 50 m³/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 native soils as noted in Boreholes CH-1 and CH-3. An NSSP should be developed at the detail design stage for inclusion into the Contract Documents to alert the contractor to the potential 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 may be required, 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 for design of temporary protection works if the culvert is to be constructed in stages while maintaining one open lane of traffic during construction. 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 or staging strategy under consideration, and if additional



investigation and analysis is necessary. Further, the 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., Designated MTO Foundations Contact and Principal, conducted an independent quality control review of this report.



**PRELIMINARY FOUNDATION REPORT
CHOWDER CREEK CULVERT - SITE NO. 48E-84/C**

Report Signature Page

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TB/AC/DAM/JMAC/kp

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PRELIMINARY FOUNDATION REPORT CHOWDER CREEK CULVERT - SITE NO. 48E-84/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 – West Central Sheet, Ontario Geological Survey – Map 2543.

Ministry of Transportation, Ontario. Northern Region Directive. “Backfill to Structures Adjacent to Rock Embankment Approaches” dated November 2002.

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

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 206	Construction Specification for Grading
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



PRELIMINARY FOUNDATION REPORT CHOWDER CREEK CULVERT - SITE NO. 48E-84/C

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 Penetration Depths for Northern Ontario

Ontario Water Resource Act:

Regulation 903	Wells (as amended)
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PRELIMINARY FOUNDATION REPORT CHOWDER CREEK CULVERT - SITE NO. 48E-84/C

Table 1: Summary of Culvert Details

Culvert Location	Site #	Approximate Height of Embankment ¹ (m)	Existing Culvert			Approximate Invert Elevation ²	
			Type	Approximate Dimension ²	Approximate Length (m)	North End of Culvert (m)	South End of Culvert (m)
Hwy 11 STA 15+113	48E-84/C	3.6	Two Cell Timber Box	2.1 m wide x 1.8 m high (each cell)	26	277.4	277.1

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 and invert elevations are based on the plan and profile drawings provided by MTO (Drawing BC494854113.dwg).

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Checked by: DAM
Reviewed by: JMAC



PRELIMINARY FOUNDATION REPORT CHOWDER CREEK CULVERT - SITE NO. 48E-84/C

Table 2: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Risks/Consequences
Open Footing Culvert	<ul style="list-style-type: none"> ■ Footings could be founded at a higher elevation on engineered fill below the frost penetration depth after removal of organic material and backfilling with granular fill. ■ Existing culvert can likely be used for water diversion while new footings are being constructed adjacent to the culvert. ■ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable. 	<ul style="list-style-type: none"> ■ Excavation depths at the north end of the culvert are greater than for a concrete box culvert option, resulting in increased excavation support and dewatering/unwatering requirements and additional spoil material to be disposed off-site. ■ Requires parallel sheet pile cut-off walls for each strip footing to allow for excavation of unsuitable material, tremie placement of a concrete plug at base of footing and unwatering for construction of footings in dry conditions. ■ Placement of granular fill and constructing footings in the dry will take longer due to requirements for installation of groundwater control system, dewatering and surface water pumping and excavating in a constrained space. ■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site. ■ Relatively low bearing resistance at footing founding level requires larger footing. 	<ul style="list-style-type: none"> ■ High risk of disturbance of the native sand and silt deposits during construction; can be somewhat mitigated with use of a tremie concrete plug but would require greater depth of dewatering for footing construction. ■ Higher risk of additional settlement for footings due to the smaller foundation footprint.
Pre-Cast Box Culvert	<ul style="list-style-type: none"> ■ Allows for faster construction resulting in shorter duration for dewatering and surface water pumping. ■ More tolerant of total and differential settlement due to frost penetration into the subgrade soils, if the highway embankment is raised or widened at the culvert site or if remnants of the peat deposit are not fully removed. ■ Backfill/bedding under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements. 	<ul style="list-style-type: none"> ■ Would not satisfy fisheries requirements related to natural channel substrate. ■ Cut-off wall (or clay seal/blanket) typically required at inlet to mitigate potential scour under culvert. ■ Transportation to and on-site lifting of large pre-cast sections will be required. ■ Will likely require water diversion of the creek channel to accommodate construction using a full width culvert section, unless the culvert is comprised of multiple parallel box sections. ■ Requires a deep and large excavation footprint to remove organic materials and hence large quantity of material to be disposed off-site. ■ Requires large volume of granular fill or select rockfill to raise excavation bottom to desired level of bedding/levelling course. 	<ul style="list-style-type: none"> ■ High risk of disturbance of the native sand and silt deposits during construction; can be mitigated with use of a tremie concrete slab or Granular 'B' Type II pad to allow for placement of bedding/levelling course. ■ Lower risk related to settlement performance as box segments are more tolerant of differential settlement.



PRELIMINARY FOUNDATION REPORT CHOWDER CREEK CULVERT - SITE NO. 48E-84/C

Option	Advantages	Disadvantages	Risks/Consequences
Circular Pipe	<ul style="list-style-type: none">■ Allows for faster construction resulting in shorter duration for dewatering and surface water pumping.■ More tolerant of total and differential settlement if the highway embankment is raised or widened or if remnants of the peat deposit are not fully removed.■ Backfill under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements.	<ul style="list-style-type: none">■ Reduced flow through capacity - additional flow capacity would have to be provided by multiple pipes.■ Cut-off wall (or clay seal/blanket) may be required at inlet to mitigate potential scour under culvert.■ CSP does not have as long of design life compared to concrete options.■ Would still require a deep and large excavation to allow for removal of organic materials and hence large quantity of material to be disposed off-site.■ Would require large volume of granular fill to raise excavation bottom to desired invert level.	<ul style="list-style-type: none">■ Some risk of disturbance of the native sand and silt deposits during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad.■ Limited risk related to settlement performance.



**PRELIMINARY FOUNDATION REPORT
CHOWDER CREEK CULVERT - SITE NO. 48E-84/C**

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

Culvert Location	Approximate Invert Elevation ¹ (North End/ South End)	Culvert Type	Approximate Backfill/Bedding/Footing Founding Elevation ² (North End / South End)	Founding Condition	Factored Geotechnical Axial Resistance at ULS ³	Geotechnical Reaction at SLS for 25 mm of Settlement ³
Hwy 11 STA 15+113	277.4 m/277.1 m	Pre-Cast Box	277.0 m/276.7 m (Remove organic materials as required, likely as deep as Elev. 274.4 m)	Levelling Course/Bedding on Replacement Fill over Very Loose to Compact Silt and Sand Deposits	100 kPa	50 kPa
			277.0 m/276.7 m (Remove organic materials and loose to compact Silt to Silt and Sand to Elev. 274.4 m along entire culvert footprint)	Replacement Fill over Very Loose to Compact Silt and Sand Deposits	150 kPa	100 kPa
		Open Footing (0.6 m and 1.2 m wide)	274.8 m/274.4 m	Very Loose to Compact Silt and Sand Deposits	100 kPa	100 kPa
		Pipe Culvert ⁴	277.4 m/274.4 m (Remove organic materials as required, likely as deep as Elev. 274.4 m)	Bedding on Replacement Engineered Fill over Very Loose to Compact Silt and Sand Deposits	N/A	N/A

- Notes:
1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing BC494854113.dwg).
 2. Backfill/bedding/footing founding elevation at the central and south end of the proposed replacement culverts are based on the elevation required to sub-excavate the peat deposit as encountered in Boreholes CH-3 and CH-4.
 3. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an approximately 5 m wide box or twin-cell box culvert and an 0.6 m or 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.
 4. The foundation elevation may need to be adjusted based on the type and size of the pipe culvert and the required bedding thickness.

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



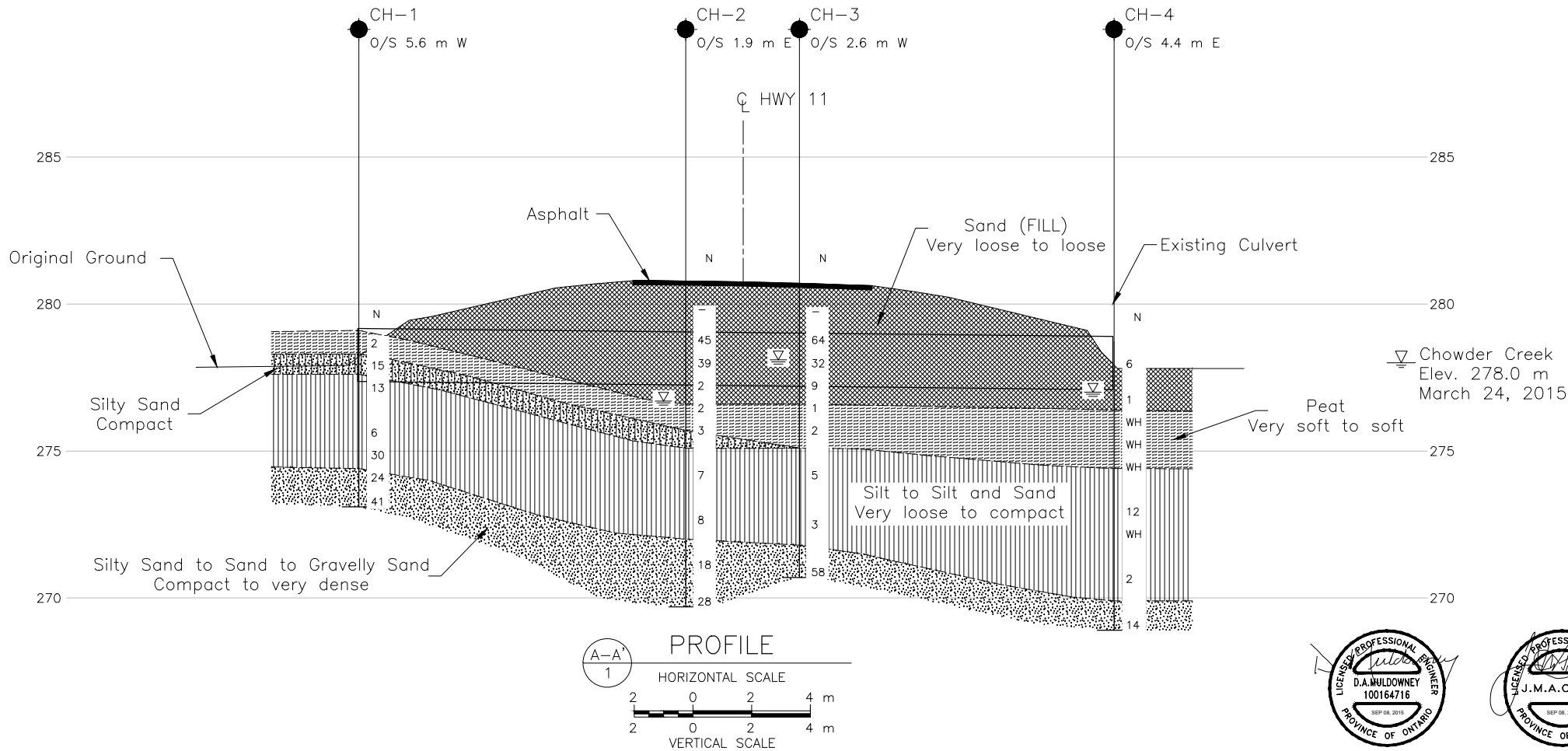
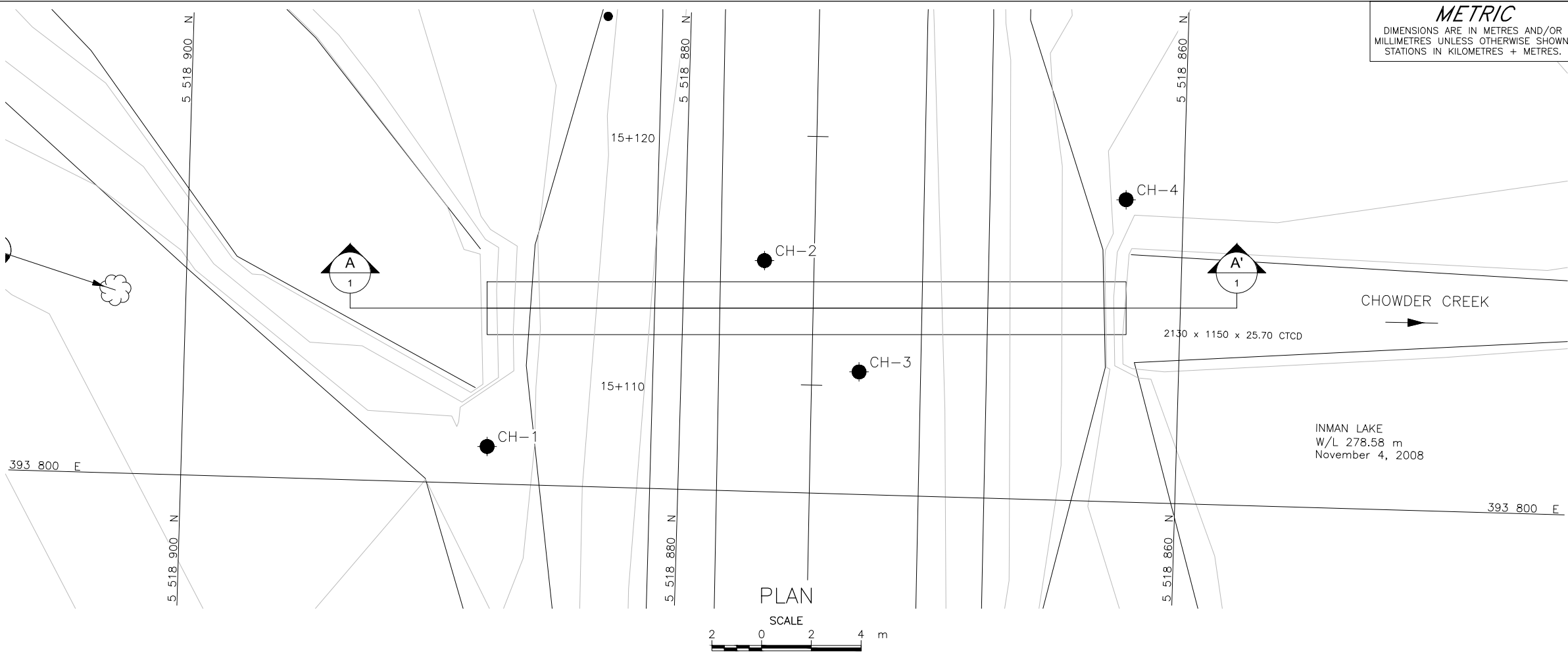
PRELIMINARY FOUNDATION REPORT CHOWDER CREEK CULVERT - SITE NO. 48E-84/C

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

Culvert Location	Pre-Cast Box Culvert		Cast-in-place Open Footing	
	Interface Material	Coefficient of Friction ¹ (tan δ)	Interface Material	Coefficient of Friction ¹ (tan δ)
Hwy 11 STA 15+113	Compacted Granular Fill (Levelling Pad)	0.45	Very Loose to Compact Silt and Sand Deposits	0.30

Note: 1. These values are unfactored. In accordance with CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistances.

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Checked by: DAM
Reviewed by: JMAC

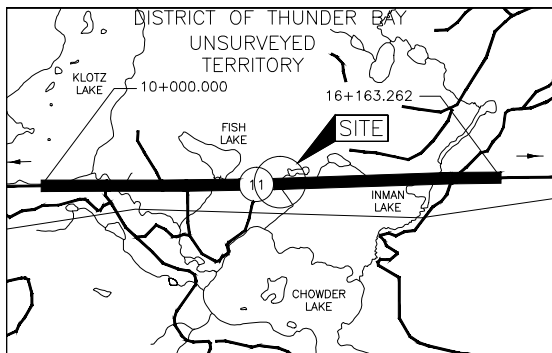


CONT No. .
GWP No. 6312-14-00



HIGHWAY 11
CHOWDER CREEK CULVERT STA 15+113
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



LEGEND

- Borehole - Current Investigation
- 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
CH-1	279.2	5518887.7	393801.5
CH-2	280.7	5518876.8	393809.3
CH-3	280.7	5518872.8	393804.9
CH-4	278.7	5518862.3	393812.2

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. BC494854113, received FEB 20, 2015.



NO.	DATE	BY	REVISION
Geocres No. 42F-35			
HWY. 11	PROJECT NO. 1411523		DIST. .
SUBM'D. AC	CHKD. .	DATE: 8/26/2015	SITE: 48E-84/C
DRAWN: JJL	CHKD. DAM	APPD. JMAC	DWG. 1



PHOTOGRAPHS

**Photograph 1: Chowder Creek Culvert
North Side - Inlet (Taken from MTO, OSIM_08-22-2012)**



**Photograph 2: Chowder Creek Culvert
South Side - Outlet (Taken from MTO, OSIM_08-22-2012)**





PHOTOGRAPHS

**Photograph 3: Chowder Creek Culvert
North Side - Inlet (Taken from MTO, OSIM_08-22-2012)**



**Photograph 4: Chowder Creek Culvert
South Side – Outlet (Golder – March 23, 2015)**





APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

I. GENERAL

π	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

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a)	Index Properties
$\rho(\gamma)$	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
γ'	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_α	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
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	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 ρ . Unit weight symbol is γ 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 cm² 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

	kPa	C_u, S_u	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_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	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_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	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 CH-1			1 OF 1 METRIC											
G.W.P. 6312-14-00			LOCATION N 5518887.7; E 393801.5			ORIGINATED BY NJ											
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY AC											
DATUM GEODETIC			DATE March 27, 2015			CHECKED BY DAM											
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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p W W _L WATER CONTENT (%)			γ	GR SA SI CL
279.2	GROUND SURFACE							20 40 60 80 100									
0.0	PEAT, some sand Very soft Black Moist		1	SS	2		279										
278.5																	
0.7	Silty SAND Compact Grey Moist to wet		2	SS	15		278										
277.8																	
1.4	SILT, trace to some clay, trace sand Loose to compact Grey Wet		3	SS	13		277										
	Augers grinding from 3.0 m to 3.8 m depth on inferred cobbles.		4	SS	6		276										
			5	SS	30		275										
274.7																	
4.5	SAND, some silt, some gravel, trace clay Compact to dense Grey Wet		6	SS	24		274										
			7	SS	41												
273.3																	
5.9	END OF BOREHOLE Note: 1. Water level not obtained.																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 03/09/15 DATA INPUT:

PROJECT 1411523			RECORD OF BOREHOLE No CH-2			1 OF 1 METRIC											
G.W.P. 6312-14-00			LOCATION N 5518876.8; E 393809.3			ORIGINATED BY NJ											
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY AC											
DATUM GEODETIC			DATE March 23, 2015			CHECKED BY DAM											
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	20 40 60	W _p W W _L	20 40 60	20 40 60	20 40 60				
280.7	GROUND SURFACE																
0.0	ASPHALT (140 mm)																
0.1	Sand, trace to some gravel, trace to some silt (FILL) Very loose Brown Frozen* to wet		1	AS	-		280										
			2	SS	45*		279										
			3	SS	39*		278										9 78 (13)
			4	SS	2		277										
276.6	PEAT Very soft to soft Black Wet		A 5 B	SS	2		276										
275.7	Silty SAND, trace organics Grey Wet		A 6 B	SS	3		275										
275.1	SILT, some sand, trace to some clay Loose Grey Wet						274										
272.0	Silty SAND, trace gravel Compact Grey Wet		8	SS	8		273										0 16 72 12
			9	SS	18		272										
			10	SS	28		271										
269.7	END OF BOREHOLE						270										4 68 (28)
11.0	Note: 1. Water level at a depth of 4.0 m below ground surface (Elev. 276.7 m) upon completion of drilling.																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 03/09/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No CH-3				1 OF 1 METRIC											
G.W.P. 6312-14-00		LOCATION N 5518872.8; E 393804.9				ORIGINATED BY NJ											
DIST _____ HWY 11		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC											
DATUM GEODETIC		DATE March 24, 2015				CHECKED BY DAM											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
280.7	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT (150 mm)																
0.2	Sand, trace to some gravel, trace to some silt (FILL) Loose Brown Frozen* to wet		1	AS	-		280										
			2	SS	64*		279										
			3	SS	32*		278										5 83 (12)
			4	SS	9		277										
276.6	PEAT Very soft Black Wet		A 5 B	SS	1		276										
			6	SS	2												
275.1	SILT, trace sand, trace clay Very loose to loose Grey Wet						275										
			7	SS	5		274										NP 0 4 90 6
							273										
			8	SS	3		272										
271.9	SAND, some silt, trace to some gravel, trace clay Very dense Grey Wet		A 9 B	SS	58		271										11 70 15 4
270.7	Augers grinding from 8.8 m to 9.1 m depth on inferred cobbles. END OF BOREHOLE																
10.0	Note: 1. Water level at a depth of 2.6 m below ground surface (Elev. 278.1 m) upon completion of drilling.																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 03/09/15 DATA INPUT:

PROJECT 1411523			RECORD OF BOREHOLE No CH-4			1 OF 1 METRIC															
G.W.P. 6312-14-00			LOCATION N 5518862.3; E 393812.2			ORIGINATED BY NJ															
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY AC															
DATUM GEODETIC			DATE March 25, 2015			CHECKED BY DAM															
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		
278.7	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60	W _p W W _L										
0.0	Sand, some gravel (FILL) Very loose to loose Brown to black Moist to wet Trace organics in the upper 0.8 m.		1	SS	6		278														
			2	SS	1		277														
276.5	PEAT Very soft Black Moist to wet		3	SS	WH		276														
			4	SS	WH		275														
274.4			A 5 B	SS	WH		274														
4.3	SILT and SAND, trace to some clay, trace gravel Very loose to compact Grey Wet		6	SS	12		273														
			7	SS	WH		272														
			8	SS	2		271														
270.0							270														
8.7	Gravelly SAND, trace to some silt Compact Grey Wet		9	SS	14		269														
268.9	END OF BOREHOLE																				
9.8	Note: 1. Water level at a depth of 1.7 m below ground surface (Elev. 277.0 m) upon completion of drilling.																				

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 03/09/15 DATA INPUT:



APPENDIX B

Laboratory Test Results



PRELIMINARY FOUNDATION REPORT CHOWDER CREEK CULVERT - SITE NO. 48E-84/C

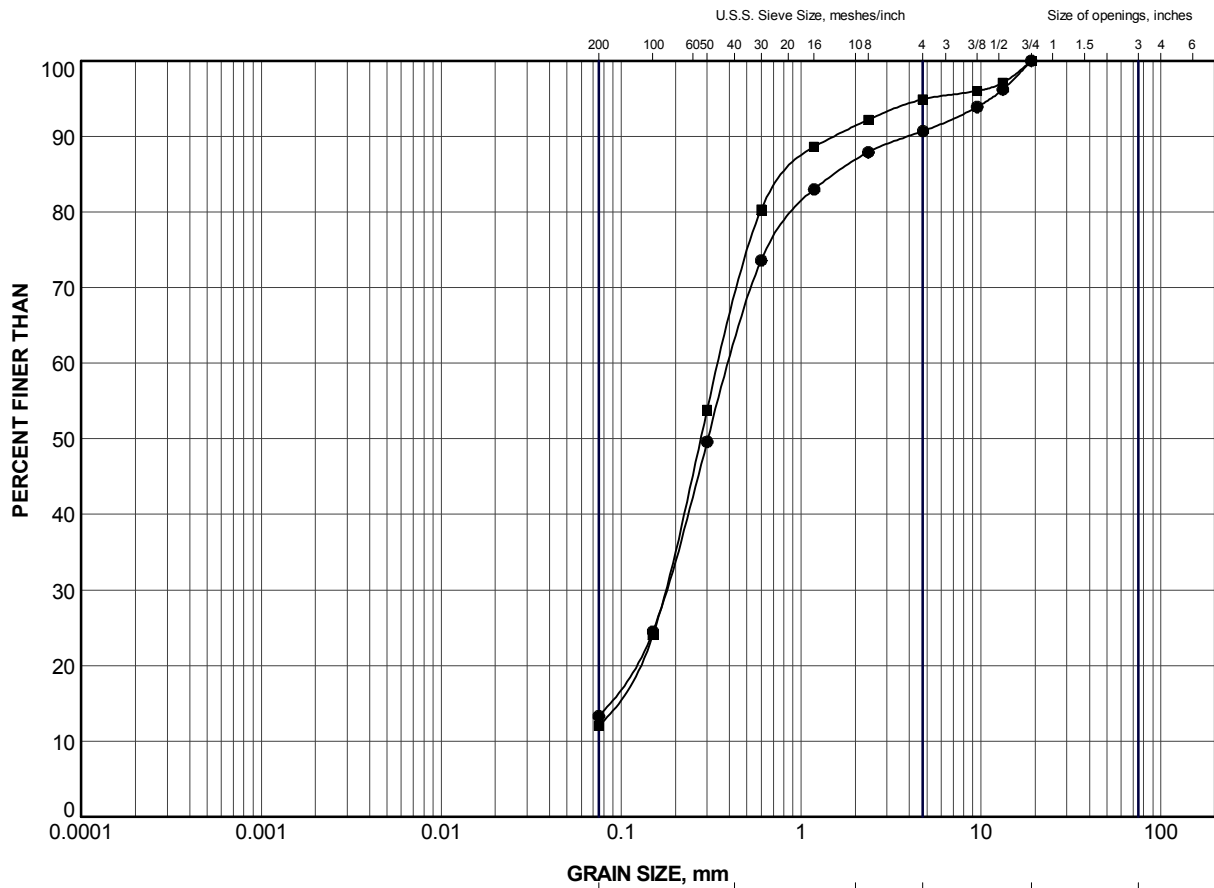
Table B1: Summary of Analytical Testing of Chowder Creek Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	14.0
Sulphate (SO4)	mg/L	0.61
Conductivity (EC)	µS/cm	342
Resistivity	µohm-cm	<0.33
pH	n/a	7.49

Notes:

1. Sample obtained on March 26, 2015.
2. Analytical testing carried out by ALS Canada Ltd.


Prepared by: TB
Checked by: DAM
Reviewed by: JMAC

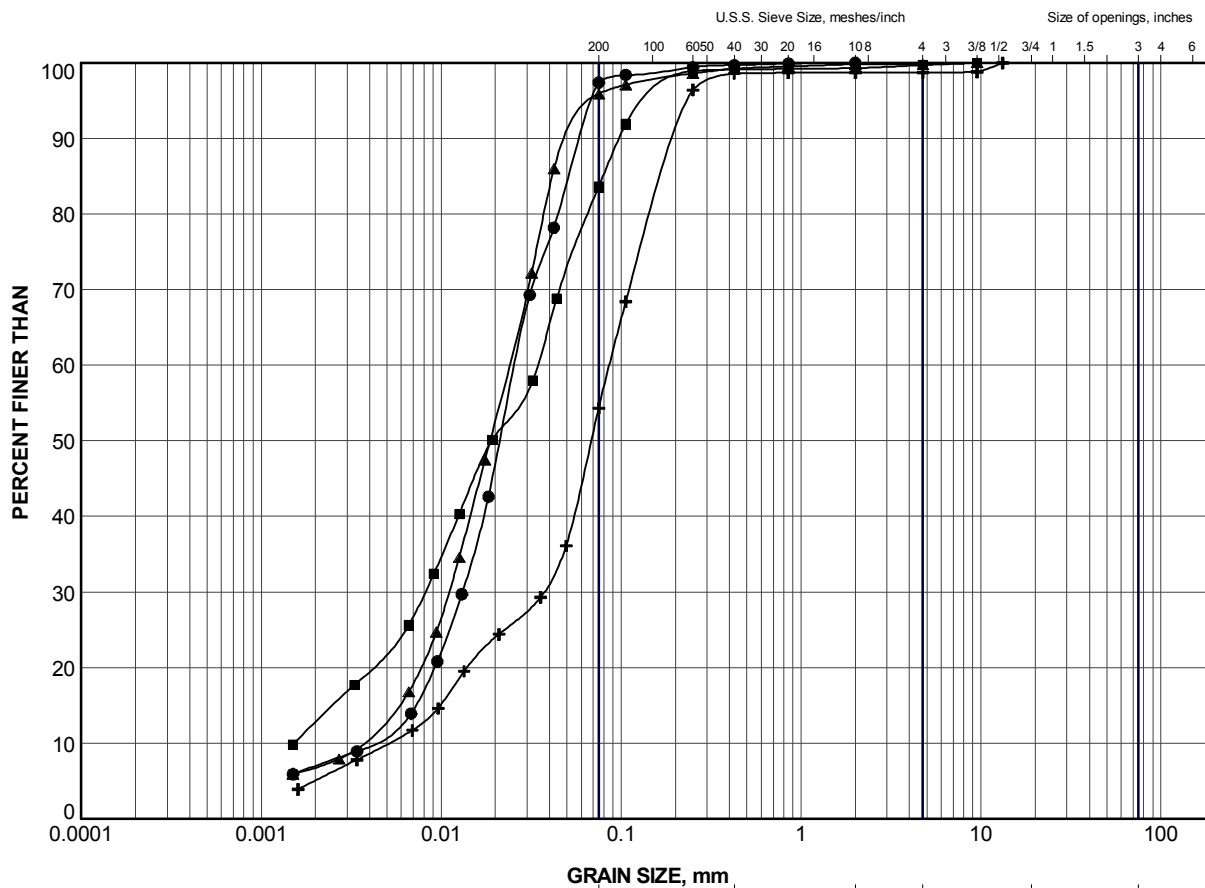


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CH-2	3	278.1
■	CH-3	3	278.4


PROJECT					
HIGHWAY 11 CHOWDER CREEK CULVERT STA 15+113					
TITLE					
GRAIN SIZE DISTRIBUTION SAND (FILL)					
		PROJECT No.		1411523	
		FILE No.		1411523.GPJ	
		DRAWN	TB	May 2015	SCALE N/A
		CHECK	DAM	May 2015	REV.
		APPR	JMAC	May 2015	
					FIGURE B1

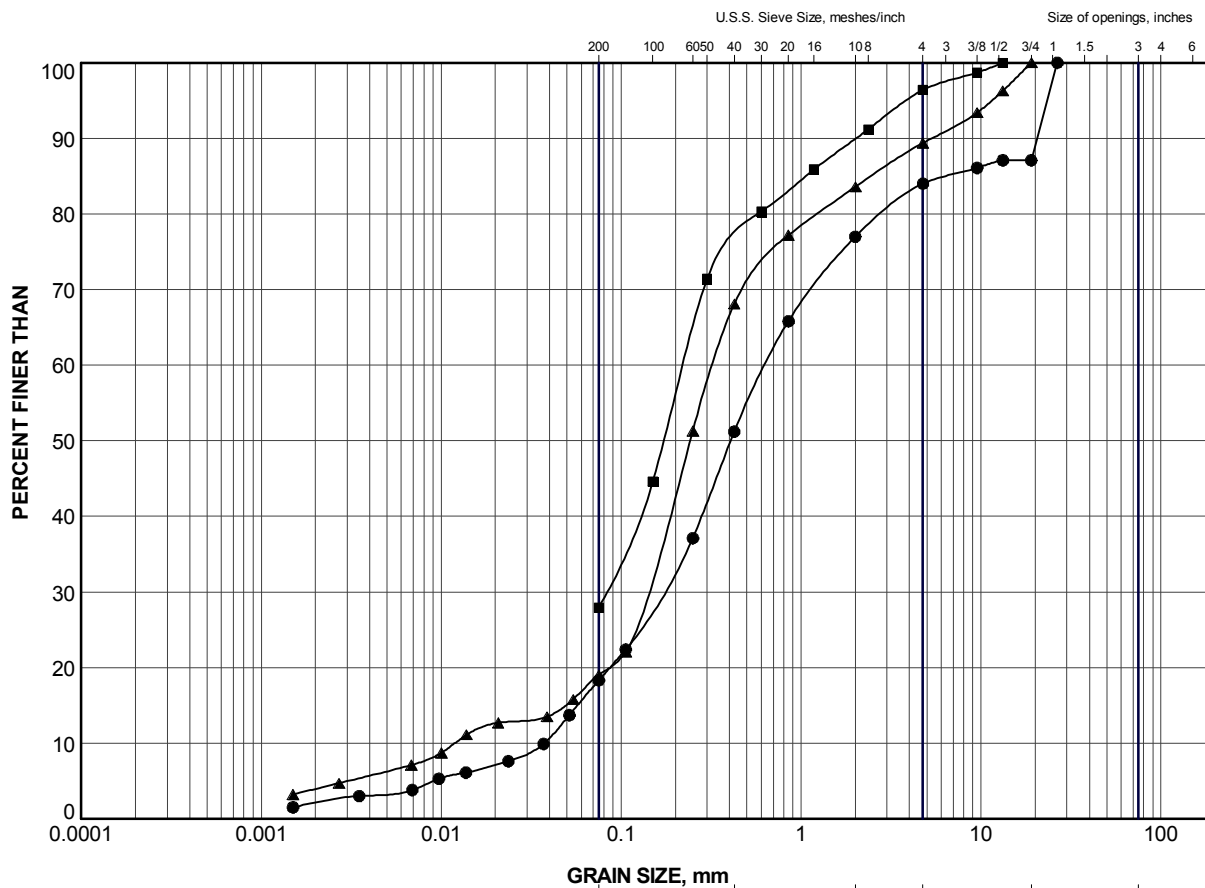


CLAY AND SILT		GRAVEL SIZE, mm					Cobble Size
		fine	medium	coarse	fine	coarse	
		SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CH-1	3	277.4
■	CH-2	8	272.8
▲	CH-3	7	274.3
+	CH-4	7	272.3


PROJECT						HIGHWAY 11 CHOWDER CREEK CULVERT STA 15+113					
TITLE						GRAIN SIZE DISTRIBUTION SILT to SILT and SAND					
PROJECT No.				1411523		FILE No.				1411523.GPJ	
DRAWN	TB	May 2015		SCALE	N/A	REV.					
CHECK	DAM	May 2015									
APPR	JMAC	May 2015									
 Golder Associates SUDBURY, ONTARIO				FIGURE B2							



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CH-1	6	274.3
■	CH-2	10	270.0
▲	CH-3	9A	271.2

PROJECT					
HIGHWAY 11 CHOWDER CREEK CULVERT STA 15+113					
TITLE					
GRAIN SIZE DISTRIBUTION SILTY SAND to SAND					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	TB	May 2015	SCALE	N/A	REV.
CHECK	DAM	May 2015			
APPR	JMAC	May 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE B3		

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