



May 14, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

FISH CREEK CULVERT, SITE NO. 48E-70/C
HIGHWAY 11, DISTRICT OF THUNDER BAY
UNSURVEYED TERRITORY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6306-14-00

Submitted to:

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GEOCRES No.: 42F-32

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 Fish Creek culvert (Site No. 48E-70/C). The Fish Creek culvert is located in the District of Thunder Bay on Highway 11 at STA 10+868, approximately 26 km west of the Northeast/Northwest Region Boundary. 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 Fish Creek culvert consists of a three-cell, timber box culvert, 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 this area is relatively flat with moderate to dense tree cover. Fish creek drains northerly into nearby Klotz Lake, which is located to the north of the culvert site and Highway 11 alignment. At the culvert location, the highway grade is at Elevation 275.3 m and the culvert invert is at approximately Elevation 271.0 m. Surface conditions in the culvert inlet and outlet are as shown on Photographs 1 and 2, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out on December 10 and 11, 2014, during which time four boreholes (Boreholes FS-1 to FS-4) were advanced. Boreholes FS-1 to FS-4 were advanced using truck or track-mounted CME-55 drill rig. Both drill rigs were supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec.

Boreholes FS-1 and FS-4 were advanced at the toe of slope near the culvert inlet/outlet using 108 mm inside diameter hollow stem augers. Boreholes FS-2 and FS-3 were advanced from the existing highway platform using NW casing and wash boring techniques. 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 levels in the open boreholes were 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 Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions, and Atterberg limits tests were carried out on selected soil samples.



A sample of the creek water was obtained during the field investigation 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 member 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 in January 2015 (Drawing BC494854113.dwg). The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole locations 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)
FS-1	5518791.8	389568.2	272.4	6.2
FS-2	5518777.6	389557.4	275.3	9.3
FS-3	5518772.3	389569.8	275.2	10.9
FS-4	5518759.0	389559.0	272.2	8.5

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 Fish Creek culvert site generally consist of ground moraine deposits comprised primarily of tills. Bordering the Fish Creek site closely to the west the subsoils consist of alluvial plain and organic terrain deposits comprised of primarily peat/muck.

Based on geological mapping by the Ministry of Northern Development and Mines (Map 2542)², the site is underlain by bedrocks of the Archean Era, comprised of mafic to intermediate metavolcanic rocks consisting of basaltic and andersitic flows, tuffs and breccias, chert and iron formations with minor metasedimentary and intrusive rocks.

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 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 section 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.

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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Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and granular fill (for boreholes advanced through the embankment) and/or sandy peat/organic silt at the toe of slope overlying in places cohesionless deposits of sand to silt to silty sand, which are underlain by a till deposit comprised of silt and sand to clayey silt. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided in the following table and sections.

Deposit/Layer Description	Boreholes	Thickness (m)	Elevation (m)	N Values (blows)	Laboratory Testing
				Consistency or Relative Density	
Asphalt	FS-2, FS-3	0.140	275.3 – 275.2	n/a	n/a
(FILL) Sand and Gravel to sand, trace to some silt, trace clay, brown, frozen to wet	FS-2, FS-3	4.4	275.2 – 275.1	N = 8 – 29 ¹	w = 13% – 26 % 2 - MH (Fig. B1)
				Loose to Compact	
Organic Silt, Sandy Peat, trace sand, trace gravel, trace wood, dark brown to brown, wet	FS-1, FS-2, FS-4	0.1 – 2.2	272.4 – 270.9	N = 2 to 9	w = 53%
				Soft to Stiff	
Sand to Silt, trace to some gravel, trace clay, trace to some organics, brown to grey, wet	FS-4	3.8	271.4	N = 2 – 8	w = 10% – 22% 1 – MH (Fig. B2)
				Very Loose to Loose	
Silt and Sand to Clayey Silt (TILL), trace to some gravel, grey, wet Slight to no plasticity	FS-1 to FS-4	Boreholes terminated in this deposit	270.8 – 268.3	N = 8 – 108 ²	w = 7% – 12% 8 – MH (Fig. B3) 4 – AL (Fig. B4) w _l = 16% – 18% w _p = 12% – 13% I _p = 3% – 6% 4 – AL – NP
				Loose to Very Dense	

Where:

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

w = Natural Moisture Content (%)

MH = Combined Sieve and Hydrometer analysis

M = Sieve analysis for particle size

AL = Atterberg Limits Test

w_p = Plastic Limit (%)

w_l = Liquid Limit (%)

I_p = Plasticity Index (%)

NP = Non-plastic test result



Notes:

¹In the fill, three SPT 'N'-values did not fully penetrate the full 0.3 m of the split-spoon sample, however these are likely indicative of the frozen state of the material and are not representative.

²In the till deposit, several of the SPT 'N'-values did not fully penetrate the full 0.3 m of the split-spoon sample, as a result of the very dense nature of the deposit.

Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The creek ice level was measured at Elevation 271.6 m on December 10, 2014. 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)
FS-1	0.8	271.6
FS -2	3.4	271.9 ¹
FS -3	2.7	272.5 ¹
FS -4	0.8	271.4

Notes: 1. Boreholes FS-2 and FS-3 were advanced using NW casing and wash boring. As such, water levels may not be representative of in situ groundwater conditions.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Cody Walter 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, E.I.T., and Ms. Sarah E.M. Poot, P.Eng., an Associate of Golder provided a technical review of the report. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Foundations Contact for Golder, conducted an independent quality control review audit of this report.



Report Signature Page

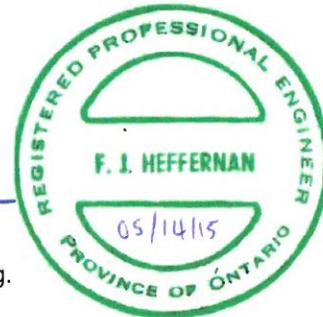
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PART B

**PRELIMINARY FOUNDATION DESIGN REPORT
FISH CREEK CULVERT – SITE NO. 48E-70/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 Fish 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.

A preliminary General Arrangement (GA) drawing was not available during preparation of this report, however it is assumed that the replacement culvert dimensions, alignment and invert elevation of will be similar to that of the existing culvert. In addition, it is assumed that there will be no embankment grade raises or widening as part of the Hwy 11 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The existing Fish Creek Culvert is located on Highway 11 at STA 10+868 approximately 26 km west of the Northeast/Northwest Region Boundary. The highway embankment is constructed of granular fill material and is approximately 4.3 m high. The existing culvert consists of a three-cell timber box culvert, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

Pre-cast concrete box and open-footing concrete culverts are both considered feasible alternatives for the replacement culvert. For the open footing option, consideration may be given to both cast-in-place or pre-cast footing options. Open footing pre-cast concrete arch and structural plate corrugated steel pipe (SPCSP) arch culverts could be considered but given the limited soil cover, arch culverts would likely decrease the flow through capacity and the limited cover may not allow for proper backfilling for an arch culvert. Similarly CSPs would likely decrease the flow through capacity and generally have a shorter design life than concrete culverts. We also understand based on conversations with HMM and MTO that a sheet-pile abutment and concrete cap option is not being considered for culvert locations on the Highway 11 or 17 corridors. The advantages and disadvantages associated with both the pre-cast box culvert and open footing culvert options are summarized in Table 2. From a foundation perspective, a concrete box culvert sufficiently wide to handle the flow is preferred. Other culvert types may be preferred over box culverts due to construction staging or other concerns. Recommendations for a pre-cast box culvert and an open-footing culvert are provided in the following sections.



6.2.2 Foundation Elevations and Frost Protection

6.2.2.1 Box Culvert Replacement

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3. We recommend that the replacement culvert be founded on the compact to very dense deposit of silt and sand to clayey silt till as encountered in the boreholes.

6.2.2.2 Open Footing Culvert Replacement

Strip footings for 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 Depths for Northern Ontario). In addition, the footings should extend below any existing fill and organic silt/sandy peat material, where present. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

6.2.3 Geotechnical Resistances

6.2.3.1 Box Culvert Replacement

Box culverts, placed on the properly prepared subgrade at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement, provided in Table 3. These recommendations are based on the box culvert width 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 that 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 is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical axial resistance at SLS (as provided in Table 3) in the design of the culverts 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 Open Footing Culvert Replacement

Strip footings for open footing culverts or wing walls placed on the properly prepared subgrade, at or below the founding elevation recommended in Table 3, should be designed based on the factored geotechnical resistance at ULS and geotechnical reaction at SLS, for 25 mm of settlement, provided in Table 3. These recommendations are based on the assumed footing width of 0.6 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 footing width or founding elevation differs from that 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 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 is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical axial resistance at SLS (as provided in Table 3) in the design of the culverts 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.

6.2.4 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces / sliding resistance between the base of the box culvert and granular bedding material or 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 embankment grade raise or widening is not proposed as part of the culvert replacement and highway embankment, the existing native soils will not experience additional load, and therefore, settlement of the culvert is estimated to be less than 25 mm.

For the subsurface conditions and the proposed embankments height up to about 4.3 m relative to the culvert invert, granular fill embankments at this site will be stable at side slopes of 2 Horizontal to 1 Vertical (2H:1V) or flatter. This assumes that there is no grade raise or platform widening at the culvert site.

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 a maximum of 200 mm loose lift thickness. Weep holes should be installed to provide 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).
- For restrained walls, 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 horizontal to 1 vertical (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 (ϕ)	Unit Weight	Coefficients of Static Lateral Earth Pressure	
			At-Rest, K_0	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 structures allow for lateral yielding, active earth pressures may be used in the design of the structure(s). If the structures do not allow 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 and into native soils, which are comprised of loose to very dense silt and sand to clayey silt till. 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 fills 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 1 Horizontal to 1 Vertical (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 either driven sheet-piling or soldier piles and lagging where H-piles would be driven to a suitable depth and horizontal lagging 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.

Alternatively, a temporary Bailey bridge could be considered provided to bypass traffic during culvert installation. The Bailey bridge could be founded on spread footings on the glacial till at this site.

6.4.2 Excavation and Replacement Below Culvert

Prior to placement of any bedding material, granular fill or concrete, all organics (including peat, organic silt, topsoil and mixed organic soil materials) and any softened or disturbed soils, should be sub-excavated from below the plan limits of the proposed works.

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, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for a cast-in-place open footing culvert. Following inspection, the sub-excavated area should be backfilled with granular material meeting the requirements of an OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III that is placed and compacted in accordance with OPSS.PROV 501 (Compacting). For backfilling below the water level, we recommend that only Granular B Type II be utilized.

6.4.3 Culvert Bedding and Backfill

6.4.3.1 Box Culvert Replacement

The bedding, levelling pad and granular backfill 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 some groundwater seepage through the native soils during excavation to the invert and bedding level, 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. Given the potential presence of groundwater/surface water, we do not recommend that Granular B Type I or III 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 be 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) 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 fine concrete aggregate meeting the grading



requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided similar to that presented on OPSD 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction in dry conditions.

A frost taper should be constructed with a similar geometry to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

6.4.3.2 Open Footing Culvert Replacement

The backfill requirements for the cast-in-place 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 soil cover for frost protection. 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 as specified in OPSS.PROV 501 (Compacting).

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

A frost taper should be constructed with a similar geometry to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

6.4.3.3 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 and compacted 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.

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 soils (silt and sand to clayey silt) will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance and as an alternative to the 300 mm compacted bedding layer, a mass concrete working slab could be placed on the subgrade if the concrete footings, or the box culvert, 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. A sample NSSP can 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 clay seal or concrete cut-off wall 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 opening. 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.

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 blanket, including the creek side slopes and fill slope over the culvert if this clay seal is adopted.

6.4.6 Control of Groundwater and Surface Water

Excavation along the culvert alignment will be required to remove organic and overburden soils prior to placement of backfill, bedding material and the culvert structure. As a result of the excavation, some groundwater flow into the excavation can be expected due to the relatively impermeable nature of the 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, 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, or diverted by pumping from behind temporary sheet-pile cofferdams.

Groundwater control may be required for the box culvert or open footing culvert as the foundation excavation to the culvert invert or footing level is expected to extend below the groundwater level. Excavations will be advanced through the native soils, however, seepage into the excavation may be adequately controlled by pumping from properly filtered sumps. Based on the gradation of the deposit, this material will require extensive pumping. 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. A sample NSSP can 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 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 location of the culvert and the replacement strategy (i.e. staging). The scope and results of this investigation must be reviewed at that time 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. If a grade raise or widening of the roadway is required at this site, additional settlement and stability analysis will be required. 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. If a Bailey Bridge is considered Boreholes should be advanced at or near the proposed abutment locations.

7.0 CLOSURE

This Preliminary Foundation Design Report was prepared by Mr. Adam Core, E.I.T. and the technical aspects were reviewed by Ms. Sarah E.M. Poot, P.Eng., an Associate of Golder. Mr. Fintan J. Heffernan, P.Eng., Designated MTO Foundations Contact, conducted an independent quality control review of this report.



Report Signature Page

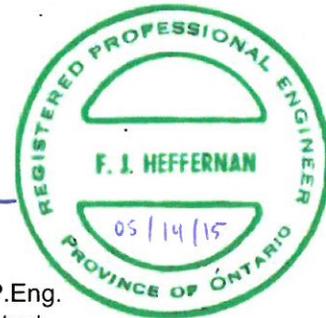
GOLDER ASSOCIATES LTD.

Adam Core
Geotechnical Engineering Intern



Sarah E.M. Poot, P.Eng.
Geotechnical Engineer, Associate

Fintan J. Heffernan, P.Eng.
Designated MTO Contact



AC/SEMP/FJH/kp

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n:\active\2014\1190 sudbury\1191\1411523 - hmm 26 culverts thunder bay\reporting\preliminary design\r01 - fish creek\final\1411523 dft rpt r01 15may14 fish creek.docx



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, January 2006.

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542.

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

ASTM International:

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

ASTM D2573 Standard Test Method for Field Vane Shear Test in Cohesive Soil

Ontario Provincial Standard Specifications (OPSS)

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 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 803.010 Backfill and Cover for Concrete Culverts

OPSD 810.010 Rip-Rap Treatments for Sewer and Culvert Outlets

OPSD 3090.100 Foundation Frost Depths for Northern Ontario

Ontario Water Resource Act:

Regulation 903 Wells (as amended)



**PRELIMINARY FOUNDATION REPORT
FISH CREEK CULVERT, SITE NO. 48E-70/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 10+868	48E-70/C	4.3	Three Cell Timber Box	2.1, 2.1, 1.7 m X 1.8 m	27	271.0	271.0

- 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 (BC494854113.dwg).

Prepared by: AC
Checked by: SEMP
Reviewed by: FJH



**PRELIMINARY FOUNDATION REPORT
FISH CREEK CULVERT, SITE NO. 48E-70/C**

Table 2: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	<ul style="list-style-type: none"> ■ Minimizes depth of excavation, protection system (if required) and dewatering requirements compared to open footing option. ■ Allows 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 at the culvert site. ■ 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"> ■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Cut-off wall or clay seal may be required at inlet to mitigate potential scour under culvert. ■ May require realignment or a staged construction approach to use one of the existing culvert cells as a diversion pipe. ■ Large disturbance to creek bed during construction. 	<ul style="list-style-type: none"> ■ Some risk of disturbance of the very loose to compact native silt and sand deposits during construction; can be mitigated with use of a mass concrete working slab or granular pad but would require dewatering. ■ Limited risk related to settlement performance.
Open Footing Culvert	<ul style="list-style-type: none"> ■ Would satisfy any fisheries requirements related to natural channel substrate, if applicable. ■ May be feasible to build culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering and surface water pumping. ■ If a large span is required, it may be possible to construct the open footings beyond the existing culvert limits, reducing impact to creek bed and allowing for the use of the existing culvert(s) as the creek diversion pipe. 	<ul style="list-style-type: none"> ■ Excavation depths are greater than for box culvert option, resulting in increased excavation support and dewatering requirements and additional spoil material to be disposed of off-site. ■ Constructing footings in the dry will take longer due to requirements for dewatering and surface water pumping. ■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site. 	<ul style="list-style-type: none"> ■ High risk of disturbance of the very loose to compact native silt and sand deposits during construction; can be somewhat mitigated with use of a mass concrete working slab or granular pad but would require dewatering. ■ Culvert joints may be required to accommodate total and differential settlement (if applicable).

Prepared by: AC
Checked by: SEMP
Reviewed by: FJH



**PRELIMINARY FOUNDATION REPORT
FISH CREEK CULVERT, SITE NO. 48E-70/C**

Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box and Cast-In-Place Open Footing Culvert Replacements

Culvert Location	Approximate Invert Elevation ¹	Culvert Type	Approximate Founding Elevation	Founding Condition	Factored Geotechnical Axial Resistance at ULS ²	Geotechnical Reaction at SLS for 25 mm of Settlement ²
Hwy 11 STA 10+868	271.0 m	Pre-Cast Box	270.2	Loose Silt to Silty Sand or Loose to Very Dense Silt and Sand to Clayey Silt (TILL)	400 kPa	200 kPa
		Open Footing	268.4 m	Compact to Very Dense Silt and Sand to Clayey Silt (TILL)	400 kPa	250 kPa

- Notes:
1. Culvert invert elevations are based on the profile drawings provided by MTO (BC494854113.dwg).
 2. The factored geotechnical resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an assumed 7.2 m wide box culvert and a 0.6 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.

Prepared by: AC
Checked by: SEMP
Reviewed by: FJH



**PRELIMINARY FOUNDATION REPORT
FISH CREEK CULVERT, SITE NO. 48E-70/C**

Table 4: Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Cast-In-Place Open Footing Culvert Replacements

Culvert Location	Pre-Cast Box or Open Footing Culvert		Cast-In-Place Open Footing Culvert	
	Interface Material	Coefficient of Friction ¹ (tan δ)	Interface Material	Coefficient of Friction ¹ (tan δ)
Hwy 625 STA 10+041	Compacted Granular Fill (Bedding/Levelling)	0.45	Compacted Granular Fill (Bedding/Levelling)	0.55
			Compact to Very Dense Silt and Sand to Clayey Silt (TILL)	0.40

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

Prepared by: AC
Checked by: SEMP
Reviewed by: FJH

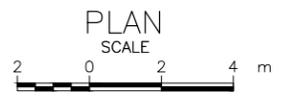
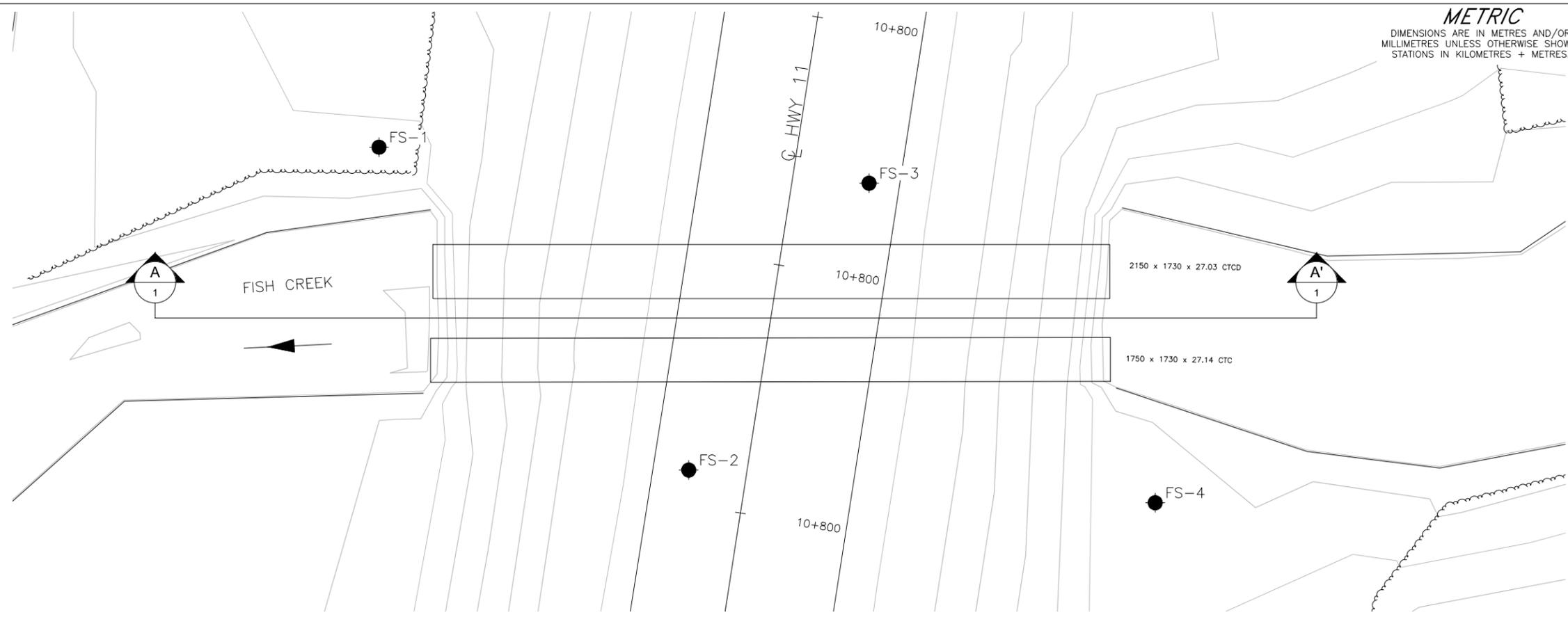
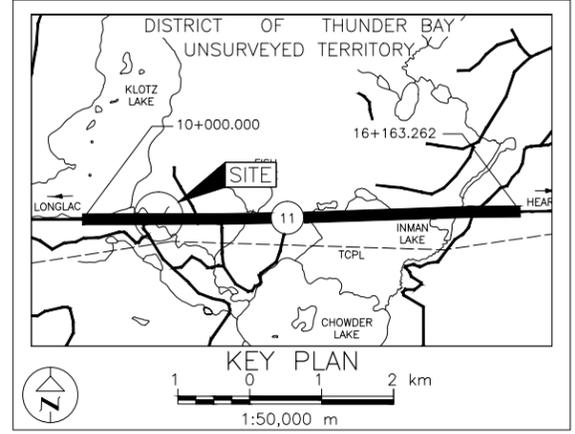
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. GWP No. 6306-14-00



HIGHWAY 11
FISH CREEK CULVERT STA 10+868
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



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
FS-1	272.4	5518791.8	389568.2
FS-2	275.3	5518777.6	389557.4
FS-3	275.2	5518772.3	389569.8
FS-4	272.2	5518759.0	389559.0

NOTES

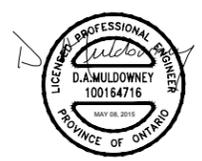
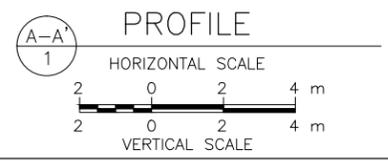
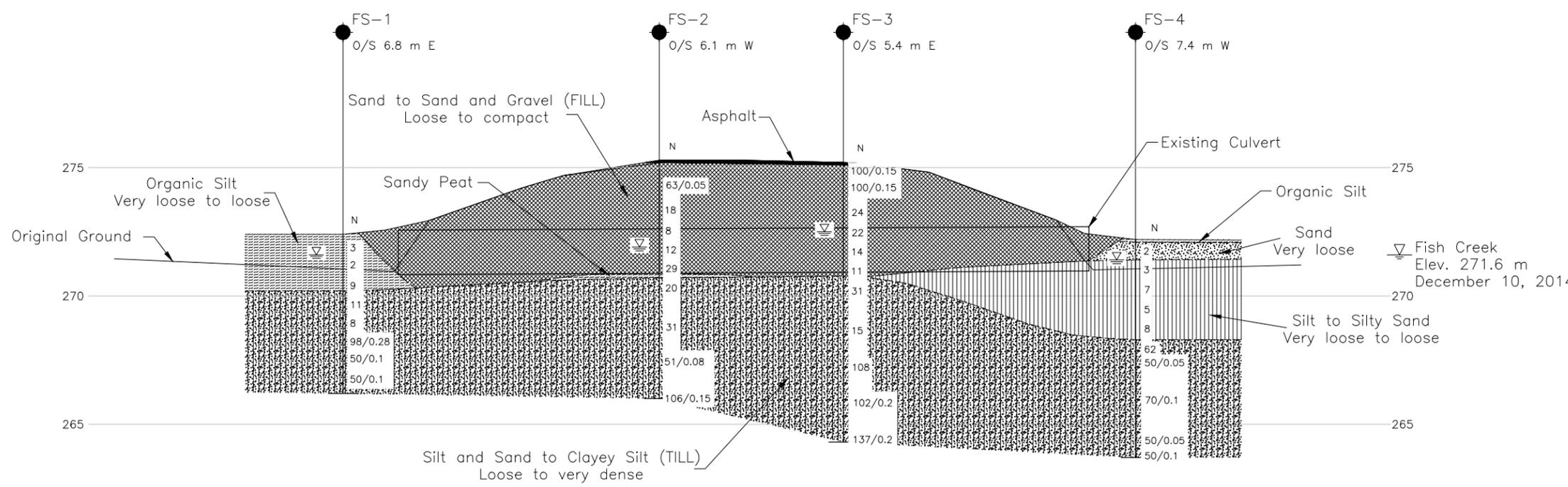
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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, dated NOV 2008, received JAN 27, 2015.



NO.	DATE	BY	REVISION

Geocres No. 42F-32

HWY. 11	PROJECT NO. 1411523	DIST. .
SUBM'D. AC	CHKD. .	DATE: 5/8/2015
DRAWN: TB	CHKD. DAM	APPD. FJH
		SITE: 48E-70/C
		DWG. 1



PHOTOGRAPHS

**Photograph 1: Fish Creek Culvert
North Elevation (Taken from MTO, OSIM_08-22-2012)**



**Photograph 2: Fish Creek Culvert
North Elevation (Taken from MTO, OSIM_08-22-2012)**





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.

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

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

	<u>kPa</u>	<u>C_u, S_u</u>	<u>psf</u>
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.

PROJECT <u>1411523</u>	RECORD OF BOREHOLE No FS-1	1 OF 1 METRIC
G.W.P. <u>6306-14-00</u>	LOCATION <u>N 5518791.8; E 389568.2</u>	ORIGINATED BY <u>CW</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>108 mm I. D. Hollow Stem Augers</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>December 11, 2014</u>	CHECKED BY <u>SEMP</u>

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									WATER CONTENT (%)		
						20	40	60	80	100	20	40	60		GR	SA	SI	CL	
272.4	GROUND SURFACE																		
0.0	ORGANIC SILT, trace sand, trace gravel, trace wood Soft to stiff Dark Brown Wet Augers grinding from 2.0 m to 2.2 m depth.		1	SS	3														
			2	SS	2														
			3	SS	9														
270.2	SILT and SAND, trace to some clay, trace to some gravel (TILL) Loose to very dense Grey Moist to wet		4	SS	11														
			5	SS	8														
			6	SS	98/0.28														
			7	SS	50/0.1														
266.2	END OF BOREHOLE		8	SS	50/0.1														
6.2	Note: 1. Water level at a depth of 0.8 m below ground surface (Elev. 271.6 m) upon completion of drilling.																		

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 12/03/15 DATA INPUT:

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

PROJECT 1411523	RECORD OF BOREHOLE No FS-2	1 OF 1 METRIC
G.W.P. 6306-14-00	LOCATION N 5518777.6; E 389557.4	ORIGINATED BY MR
DIST _____ HWY 11	BOREHOLE TYPE NW Casing, Wash Boring	COMPILED BY AC
DATUM GEODETIC	DATE December 11, 2014	CHECKED BY SEMP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
			NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
275.3	GROUND SURFACE																
0.0	ASPHALT (140 mm)																
	Sand and gravel, trace asphalt (FILL) Brown Frozen		1	SS	63/0.05												
274.0																	
1.3	Sand, trace to some gravel, trace to some silt, trace clay (FILL) Loose to compact Brown Wet		2	SS	18												11 81 5 3
	A 0.3 m thick sandy silt, trace clay seam encountered at 2.8 m depth.		3	SS	8												
			4	SS	12												
			5	SS	29												
270.9																	
4.6	Sandy PEAT, trace wood Dark brown Wet		6	SS	20												
	SILT and SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Grey Wet		7	SS	31												
			8	SS	51/0.08												NP 9 36 47 8
			9	SS	106/0.15												
266.0	END OF BOREHOLE																
9.3	Note: 1. Water level at a depth of 3.4 m below ground surface (Elev. 271.9 m) upon completion of drilling.																

SUD-MTO 001 1411523.GPJ GAL=MISS.GDT 12/03/15 DATA INPUT:

PROJECT 1411523	RECORD OF BOREHOLE No FS-3	1 OF 1 METRIC
G.W.P. 6306-14-00	LOCATION N 5518772.3; E 389569.8	ORIGINATED BY MR
DIST _____ HWY 11	BOREHOLE TYPE NW Casing, Wash Boring	COMPILED BY AC
DATUM GEODETIC	DATE December 10, 2014	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									WATER CONTENT (%)		
						20	40	60	80	100	20	40	60		GR	SA	SI	CL	
275.2	GROUND SURFACE																		
0.0	ASPHALT (140 mm)		1	SS	100/0.15														
	Sand and gravel, trace asphalt (FILL) Black Frozen		2	SS	100/0.15														
273.8																			
1.4	Sand to gravelly sand, trace silt, trace clay (FILL) Compact Brown Wet		3	SS	24						○								
			4	SS	22														
			5	SS	14						○								21 71 6 2
			6	SS	11						○								
270.8																			
4.4	SILT and SAND to CLAYEY SILT, trace to some gravel (TILL) Compact to very dense Grey Wet		7	SS	31						○				NP				19 63 35 3
			8	SS	15														
			9	SS	108						○								
			10	SS	102/0.2														
			11	SS	137/0.2							○H							11 33 44 12
264.3	END OF BOREHOLE																		
10.9	Note: 1. Water level at a depth of 2.7 m below ground surface (Elev. 272.5 m) upon completion of drilling.																		

SUD-MTO 001 1411523.GPJ GAL=MISS.GDT 12/03/15 DATA INPUT:

PROJECT <u>1411523</u>	RECORD OF BOREHOLE No FS-4	1 OF 1 METRIC
G.W.P. <u>6306-14-00</u>	LOCATION <u>N 5518759.0; E 389559.0</u>	ORIGINATED BY <u>MR</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>108 mm I. D. Hollow Stem Augers</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>December 10, 2014</u>	CHECKED BY <u>DAM</u>

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	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
272.2	GROUND SURFACE															
0.0	ORGANIC SILT Brown Moist	A	SS	2												
271.4	SAND, some gravel Very loose Brown Wet	B	SS	3												
0.8	SILT to Silty SAND, trace to some organics, trace gravel, trace clay Very loose to loose Brown to grey Wet	2	SS	3												
		3	SS	7											2	17 76 5
		4	SS	5												
		5	SS	8												
268.3	SILT and SAND to CLAYEY SILT, trace to some clay, trace to some gravel (TILL) Very dense Grey Wet	A	SS	62												
3.9		B	SS	62											NP	10 38 42 10
		7	SS	50/0.05												
		8	SS	70/0.1											3	23 57 17
		9	SS	50/0.05												
263.7	END OF BOREHOLE	10	SS	50/0.1											5	30 47 18
8.5	Note: 1. Water level at a depth of 0.8 m below ground surface (Elev. 271.4 m) upon completion of drilling.															

SUD-MTO 001 1411523.GPJ GAL=MISS.GDT 12/03/15 DATA INPUT:



APPENDIX B

Laboratory Test Results



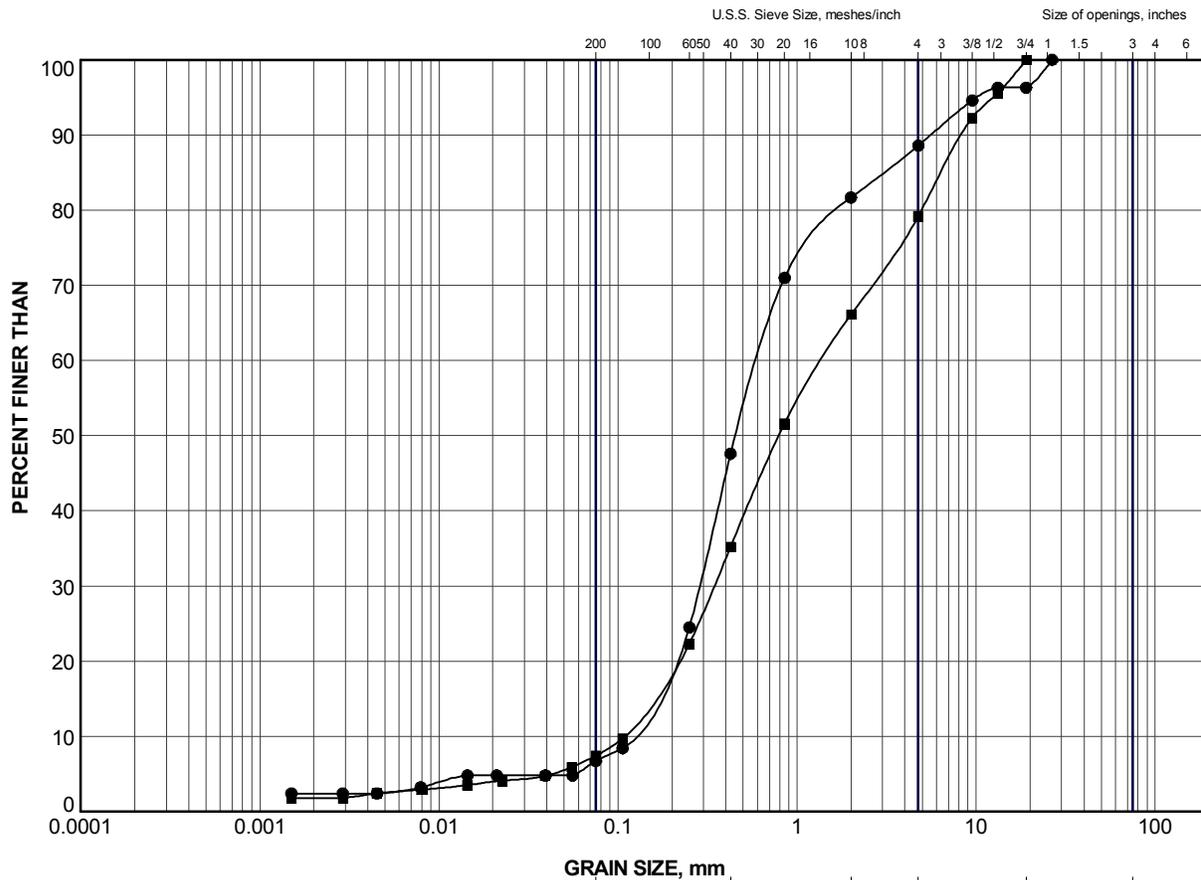
**PRELIMINARY FOUNDATION REPORT
FISH CREEK CULVERT, SITE NO. 48E-70/C**

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

Parameter	Units	Result
Chloride (CL)	mg/L	3.60
Sulphate (SO4)	mg/L	0.80
Conductivity (EC)	μ S/cm	147
Resistivity	μ ohm-cm	<0.33
pH	n/a	7.74

- Notes:
1. Sample obtained on December 9, 2014.
 2. Analytical testing carried out by ALS Canada Ltd.

Prepared by: AC
Checked by: SEMP
Reviewed by: FJH



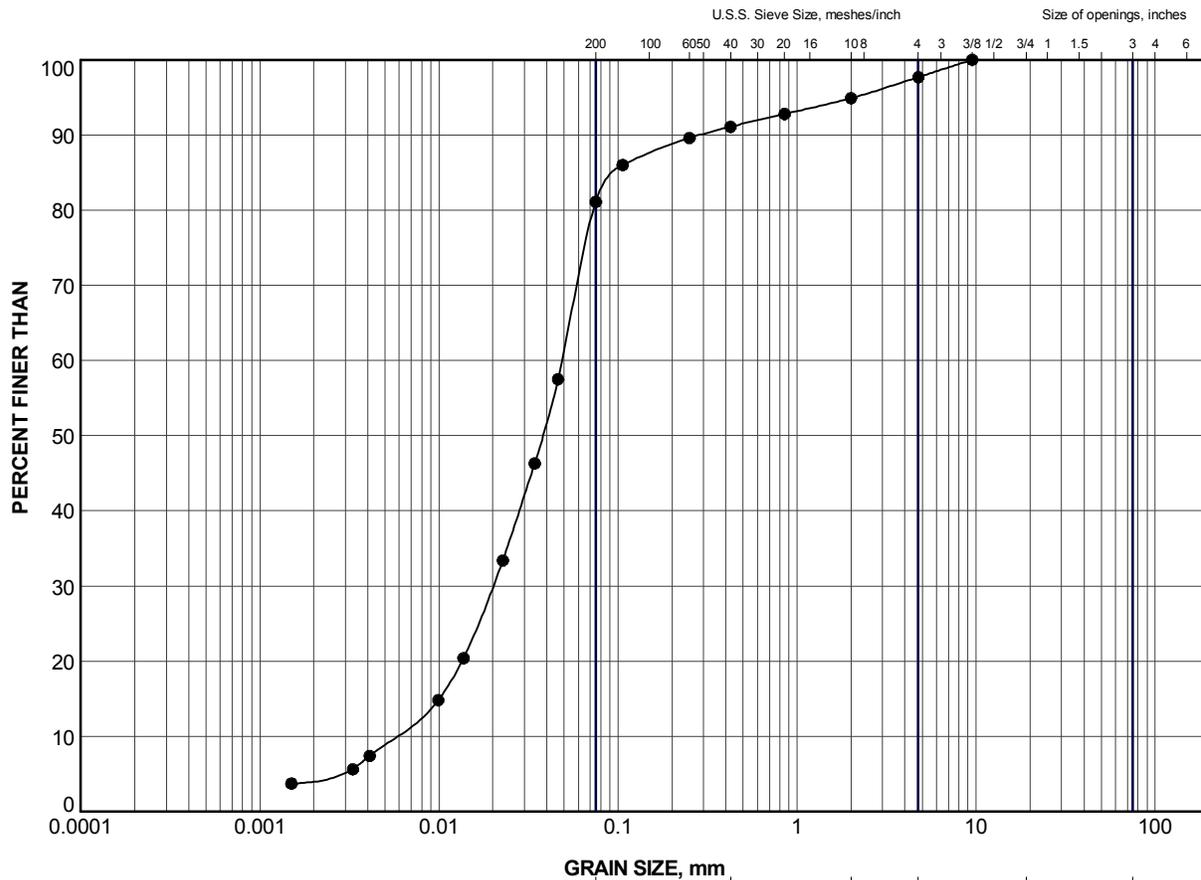
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FS-2	2	273.5
■	FS-3	5	271.9

PROJECT						HIGHWAY 11 FISH CREEK CULVERT STA 10+868					
TITLE						GRAIN SIZE DISTRIBUTION SAND to GRAVELLY SAND (FILL)					
PROJECT No.			1411523			FILE No.			1411523.GPJ		
DRAWN	TB	Mar 2015	SCALE	N/A	REV.						
CHECK	DAM	Mar 2015									
APPR	FJH	Mar 2015	FIGURE B1								





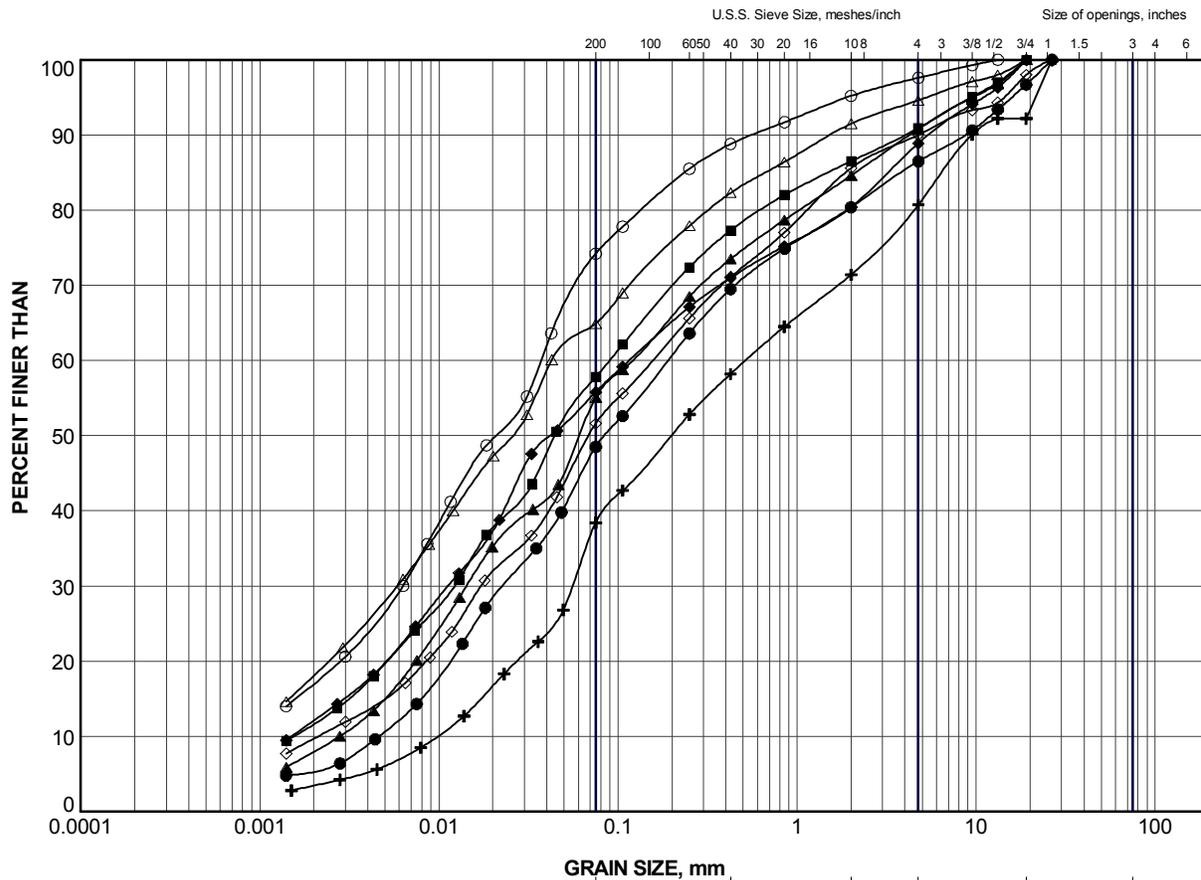
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FS-4	3	270.4

PROJECT						HIGHWAY 11 FISH CREEK CULVERT STA 10+868					
TITLE						GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.			1411523			FILE No.			1411523.GPJ		
DRAWN	TB	Mar 2015	SCALE	N/A	REV.	FIGURE B2					
CHECK	DAM	Mar 2015									
APPR	FJH	Mar 2015									





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

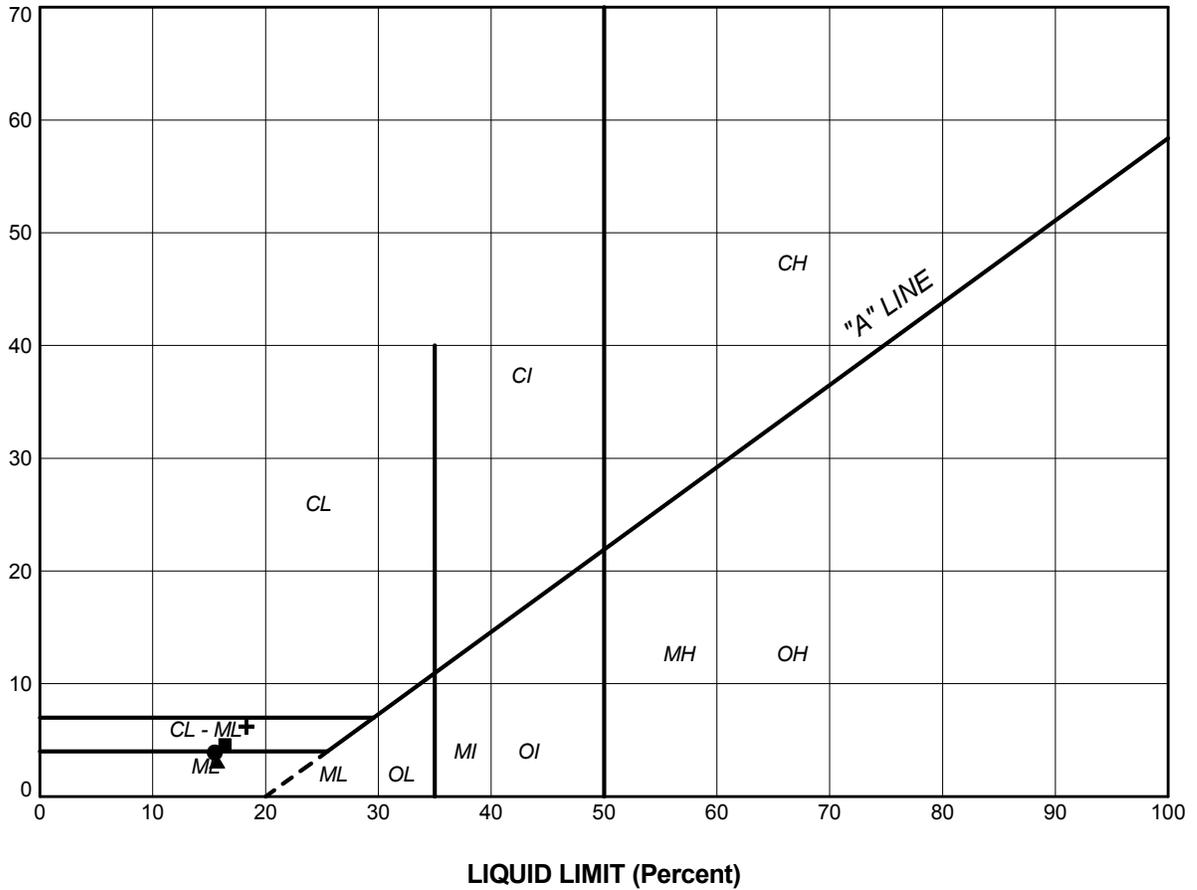
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FS-1	6	268.4
■	FS-1	8	266.3
▲	FS-2	8	267.6
+	FS-3	7	270.3
◆	FS-3	11	264.4
◇	FS-4	6B	268.0
○	FS-4	8	266.1
△	FS-4	10	263.8

PROJECT						HIGHWAY 11 FISH CREEK CULVERT STA 10+868					
TITLE						GRAIN SIZE DISTRIBUTION SILT and SAND to CLAYEY SILT (TILL)					
PROJECT No.			1411523			FILE No.			1411523.GPJ		
DRAWN	TB	Mar 2015	SCALE	N/A	REV.						
CHECK	DAM	Mar 2015									
APPR	FJH	Mar 2015	FIGURE B3								



PLASTICITY INDEX (Percent)



SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	FS-1	8	15.5	11.6	3.9
■	FS-3	11	16.4	11.8	4.6
▲	FS-4	8	15.7	12.6	3.1
+	FS-4	10	18.3	12.1	6.2

PROJECT					HIGHWAY 11 FISH CREEK CULVERT STA 10+868				
TITLE					PLASTICITY CHART SILT and SAND to CLAYEY SILT (TILL)				
PROJECT No.			1411523		FILE No.			1411523.GPJ	
DRAWN		TB	Mar 2015		SCALE		N/A	REV.	
CHECK		DAM	Mar 2015		FIGURE B4				
APPR		FJH	Mar 2015						
 Golder Associates SUDBURY, ONTARIO									

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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