



September 8, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

**FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/C
HIGHWAY 11, DISTRICT OF THUNDER BAY
UNSURVEYED TERRITORY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6310-14-00**

Submitted to:

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GEOCRES No.: 42F-34

REPORT

Report Number: 1411523-R23

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PART A

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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 Flynne Creek East culvert (Site No. 48E-125/C). The Flynne Creek East culvert is located in the District of Thunder Bay Unsurveyed Territory on Highway 11 at STA 18+316, approximately 59 km east of 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 Flynne Creek East culvert consists of a two-cell, timber box 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 of the culvert is relatively flat with moderate to dense tree cover beyond the highway right-of-way on the north side of Highway 11 and bordered by Flynne Lake on the south side of Highway 11 beyond the Highway right-of-way. For the purposes of this report Highway 11 runs in a west-east direction with the culvert perpendicular to the highway in a north-south orientation. At the culvert location, the highway grade is at Elevation 271.5 m and the culvert invert is at approximately Elevations 268.4 m and 268.3 m, at the inlet (north end) and outlet (south end), respectively. Based on drawings from MTO, the creek flows in a southerly direction via a drainage ditch into Flynne Lake. The creek ice level was measured by Golder on March 17, 2015 at Elevation 269.9 m. Surface conditions in the culvert inlet and outlet areas are shown on Photographs 1 to 4, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between February 21 and 23 and on March 17, 2015, during which time four boreholes (Boreholes FE-1 to FE-4) and two Dynamic Cone Penetration Tests (DCPTs) were advanced at approximately the locations shown on Drawing 1. Boreholes FE-1 and FE-4 were advanced at the toe of slope near the culvert outlet/inlet and Boreholes FE-2 and FE-3 were advanced from the existing highway platform using 108 mm inside diameter hollow stem augers. The drilling equipment was supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec.

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

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



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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 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 (Drawing BC494854114.dwg). The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depth 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 / DCPT Depth (m)
FE-1	5518599.7	396979.9	270.4	5.3 / 5.8
FE-2	5518591.1	396989.5	271.5	9.8 / 11.0
FE-3	5518586.9	396984.7	271.5	10.7
FE-4	5518576.3	396997.0	270.4	5.9

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 Flynn Creek East culvert site generally consist of organic terrain deposits comprised of mainly peat/muck bordering with areas of undulating to rolling bedrock knobs.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)², the site is underlain by mafic to intermediate metavolcanic bedrock of Archean Era, comprised of massive granodiorite to granite 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 detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ field tests (i.e., SPT 'N' values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1

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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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.

Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and sand to gravelly sand fill or peat underlain by non-cohesive deposits of silt, silt and sand to sand and sandy silt to the borehole termination depths. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows)	Laboratory Testing
				Relative Density/ Consistency	
Asphalt	FE-2, FE-3	0.13 – 0.14	271.5	n/a	n/a
(FILL) Sand to gravelly sand, trace to some silt; brown to grey; frozen to moist ¹	FE-2, FE-3	2.4 – 3.3	271.4	n/a ²	w = 5% – 50% 1 – MH (Fig. B1)
				n/a ²	
Peat to Silty Peat , amorphous, some rootlets, trace gravel; black to brown; frozen to moist	FE-1, FE-4	0.6 – 1.4	270.4	N = 4 ³	w = 108%–250%
				Soft	
Silt , trace to some clay, trace to some sand, trace gravel; grey, moist to wet ⁴	FE-1 to FE-4	1.2 – 2.9	269.8 – 268.1	N = 3 – 24	w = 19% – 25% 5 – MH (Fig. B2) 3 – AL (NP)
				Very loose to compact	
Silt and Sand to Sand , trace gravel; grey; wet ⁵	FE-1 to FE-4	1.6 up to 5.2 m (boreholes terminated in this deposit)	267.6 – 266.1	N = 0 (weight of rods) – 11	w = 20% – 25% 4 – MH (Fig. B3)
				Very loose to Compact	
Sandy Silt ; grey; wet	FE-3	2.0 (borehole terminated in this deposit)	262.8	N = 0 (weight of hammer)	w = 23% 1 – AL(NP)
				Very loose	

Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration
w = Natural Moisture Content (%)
MH = Combined Sieve and Hydrometer analysis
AL = Atterberg Limits
NP = Non-plastic

Notes:

¹ Wood fragments encountered within the fill between 2.9 m and 3.4 m depth.



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² In the granular fill, SPT 'N'-values of 17 blows and greater than 50 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.

³ In the peat, SPT 'N'-values of 2 blows and 4 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.

⁴ A 75 mm thick layer of black organics was noted at the top of the silt deposit in Borehole FE-3

⁵ A DCPT was advanced adjacent to Boreholes FE-1 and FE-2 to below the sand 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 269.9 m on March 17, 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)
FE-1	1.2	269.2
FE-2	1.4	270.1
FE-3	1.8	269.7
FE-4	1.5	268.9

5.0 CLOSURE

The field drilling program was carried out under the supervision of Ms. Selena Contardo and 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 Ms. Sarah E. M. Poot, P.Eng., Associate of Golder, 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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**PRELIMINARY FOUNDATION REPORT
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PART B

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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 Flynne Creek East 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 timber culvert is to be replaced with a culvert of similar height and length dimensions, on the same alignment as well as at invert elevations similar to those of the existing culvert but likely the new culvert will be much wider than the existing timber culvert. In addition, it is assumed that there will be no embankment grade raise or widening in the area of the culvert as part of the Hwy 11 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The existing Flynne Creek East culvert is located in the District of Thunder Bay Unsurveyed Territory on Highway 11 at STA 18+316, approximately 59 km east of Longlac, Ontario. The highway embankment is constructed of granular fill material and is approximately 3.3 m high relative to the culvert invert, with approximately 1.6 m of cover over the existing culvert. The existing culvert consists of a two cell timber open footing "box", the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

Based on discussions with HMM and as indicated on the preliminary General Arrangement (GA) drawings, we understand that the following culvert types are being considered at this location:

- Twin 2.4 m wide pre-cast concrete boxes (approximately 5.5 m wide overall); and
- An approximately 7.3 m wide pre-cast open footing culvert.

In this report we have considered the following culvert options:

- A pre-cast concrete box;
- An open footing structure supported on either cast-in-place or pre-cast footings; and
- Circular pipe(s).



We understand that a sheet-pile abutment and concrete cap option is not being considered for culvert replacements on the Highway 11 or 17 corridors based on discussions with HMM and MTO. A corrugated steel pipe (CSP) culvert would likely decrease the flow-through capacity and generally has a shorter design life than a concrete culvert and, at this culvert location, the use of multiple CSP culverts would likely be required to meet the flow capacity. From a foundation perspective, a box culvert sufficiently wide to handle the creek flow is preferred. A pre-cast concrete box culvert is recommended over an open footing culvert as it can accommodate an accelerated construction schedule and there are reduced excavation, dewatering and shoring requirements. Further, if twin boxes are considered, one of the existing cells of the timber culvert can likely be used as the diversion channel during construction. Other culvert types may be preferred due to construction staging or other considerations such as fisheries requirements related to natural channel substrate. A comparison of culvert types based on advantages, disadvantages and risks/consequences is presented in Table 2.

6.2.2 Foundation Elevations and Frost Protection

6.2.2.1 Box Culvert

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as a box structure is tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3. We recommend that the replacement box culvert be founded on the zone of loose to compact silt deposit as encountered in the boreholes, at a depth that would provide for essentially the same invert elevation(s) as the base channel of the existing culvert. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3.

6.2.2.2 Open Footing Culvert

Strip footings for an open footing culvert should be founded 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). The footings will be founded on the very loose silt and sand to sand deposit, which will have relatively low bearing resistance. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

6.2.2.3 Pipe Culvert

It is not necessary to found a pipe culvert at the standard depth for frost protection purposes, as such a culvert is tolerant to small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the replacement pipe culvert, if adopted, be founded on the zone of loose to compact silt stratum, which is considered to provide a higher bearing resistance than deeper zones within the silt stratum. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3.



6.2.3 Geotechnical Resistances

6.2.3.1 Box Culvert

A box culvert, placed on the properly prepared subgrade and/or properly placed granular pad/backfill at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement, as provided in Table 3. These recommendations are based on the box culvert width of 5.5 m as noted in Table 3.

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS are dependent on the foundation size, configuration and applied loads; the geotechnical 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 proposed as the bearing resistance of the underlying strata decreases with depth and settlement under the culvert could occur as a result of any additional soil loading.

6.2.3.2 Open Footing Culvert

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

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

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

The loading on the foundation soils below the culvert 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 width of the footing if different than given in Table 3, and 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 and may be affected by the loading on a wider culvert strip footing.

6.2.4 Resistance to Lateral Loads/Sliding Resistance

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

6.2.5 Stability and Settlement

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

For the subsurface conditions and the proposed embankments height up to about 3.3 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.

Should a grade raise or widening be required, given the presence of the very loose to compact silt to silt and sand to sand deposits, it is anticipated that while there would likely not be any stability issues provided that any organics are removed if present, settlement of the subsoils should be expected.

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 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).



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

Temporary protection support systems may be required along the highway to facilitate construction staging and maintain traffic during culvert replacement work. The temporary support systems could consist of driven sheet-piling extended to a suitable depth, or may also consist of soldier piles and lagging where H-piles are driven to a suitable depth and horizontal lagging is installed as the excavation proceeds. Support to the system could be in the form of struts and walers and rakers or anchors. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways. In this context, a soldier pile and lagging system may not adequately prevent loss of wet fine grained materials (silt; silt and sand to sand) into the excavation and proper construction procedures must be adopted to mitigate for the potential for loss of soil from behind the protection system.



The installation of the sheet-piles for temporary shoring may be impeded by the presence of buried wood within the fill, as encountered in Borehole FE-2. It may be necessary to excavate and replace the existing fill material in the areas of sheet-pile installation in a series of limited length and narrow trenches. In general, the narrowest suitable excavator bucket should be used. The replacement fill could consist of excavated fill material or imported granular material such as Granular 'A' or Granular 'B' Type I, II or III provided that 100 per cent of the material passes the 75 mm size and less than 5 per cent passes the 75 µm size. The excavated spoil pile may be re-used to backfill the excavation after removing the wood and/or any cobbles and boulders if encountered that may impede the sheet-pile installation. Excavation and replacement should be carried out on the same day to avoid leaving any trench open overnight. Consideration should be given to include an NSSP in the contract to address obstructions; a sample NSSP should be provided at the detail design stage.

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 disturbed soils, should be sub-excavated from below the plan limits of the proposed works to the founding levels provided in Table 3.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organics and other unsuitable materials have been removed as noted above, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for an open footing culvert. Following inspection, 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). The use of Granular 'B' Type II is recommended in wet ground conditions or below water and placement should be in accordance with OPSS.PROV 209 (Embankments over Swamps).

6.4.3 Culvert Bedding and Backfill

6.4.3.1 Box Culvert

The bedding and levelling pad requirements for a pre-cast box culvert should be accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and groundwater seepage through the native soils during excavation to the invert and bedding level, it is recommended that a 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material be used for bedding purposes. As the native soil below the bedding is generally fine grained, it is recommended that a non-woven geotextile be placed between the native soil and the bottom of the bedding. The geotextile should meet the specifications for OPSS 1860 (Geotextiles) Class II, and have a fabric opening size (FOS) not greater than 212 µm. The bedding should be placed in maximum 200 mm thick loose lifts and compacted to not less than 95 per cent of the 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 concrete fine aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) similar to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts) is required for culvert construction in dry conditions.



A frost taper should be constructed in a similar configuration as that shown in OPSD 803.010. Although OPSD 803.010 relates to box culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 5.5 m wide box culvert replacement option.

6.4.3.2 *Open Footing Culvert*

The excavation and backfilling requirements for the open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures). The open footing culvert should be provided with at least 2.6 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. The bedding layer and levelling pad for the pre-cast open footings should follow the recommendations as discussed above in Section 6.4.3.1 for the box culvert replacement option.

A frost taper should be constructed in a similar configuration as that shown in OPSD 803.010 (Backfill and Cover for Concrete Culverts). Although OPSD 803.010 also relates to an open footing culvert with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 7.3 m (overall) wide open footing culvert replacement option.

6.4.3.3 *Pipe Culvert*

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

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

6.4.3.4 *Backfill*

Backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the No. 200 (0.075 mm) sieve. The backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD of the materials in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm.

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



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

6.4.4 Subgrade Protection

The native silt subgrade (for the box culvert option) and the silt and sand to sand subgrade (for the open footing culvert option) 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 for the box culvert option, a concrete working slab should be placed on the subgrade if the box culvert or the concrete footings are not placed within four hours after preparation, inspection, and approval of the foundation subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28 day compressive strength of 20 MPa. Consideration should be given to include an NSSP in the contract to address subgrade protection at this site. An NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

6.4.5 Erosion Protection

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

The requirements for and design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. As a minimum, rip rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip Rap Treatment). Erosion protection for the inlet of the culvert should also follow the standard presented in OPSD 810.010 (Rip Rap Treatment) similar to the outlet but with the rip rap placed up to the toe of slope level, in combination with the cut off measures noted above. Similarly, rip rap should be provided over the full extent of the clay seal/blanket, including the creek side slopes and fill slope over the culvert, if a clay seal/blanket is adopted.

6.4.6 Control of Groundwater and Surface Water

Excavation along the culvert alignment will be required to remove fill, organic and overburden soils prior to placement of engineered backfill if required, bedding material and the culvert structure. Groundwater flow into the excavation can be expected due to the depth of the excavations and the presence of relatively permeable fill and native soils. Therefore, control of groundwater will be necessary to allow for construction to be carried out in



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/C

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 a portion of the existing two cell culvert or diverted by pumping from behind temporary cofferdams.

Excavations for box, open footing and pipe culvert options will extend below the creek water level, and the groundwater level, and will require temporary shoring with dewatering to allow for construction/placement of the footings in dry conditions. Temporary shoring and dewatering could be in the form of a cut-off wall or cofferdam advanced to an appropriate depth to control groundwater inflow from the creek. As discussed in Section 6.4.2, sub-excavation replacement backfill if required can be placed sub-aqueously, 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

Based on anecdotal evidence, we understand that corduroy roads were commonly used during culvert construction in the Northwest Region. The Contractor should be alerted to the potential for buried wood within the fill, as encountered in Borehole FE-2. 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 should be carried out, based on the final configuration and/or alignment of the culvert and the replacement strategy (i.e., staging). In particular, consideration should be given to drilling additional boreholes advanced to a suitable depth for design of temporary protection works if the culvert is to be constructed in stages while maintaining one open lane of traffic during construction for the open footing culvert option if selected, and for the groundwater control (cut-off)



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system. The scope and results of this investigation must be reviewed at the time of the detail design to determine if they meet the then-current MTO requirements for the culvert type, groundwater cut-off system or staging strategy under consideration, and if additional investigation and analysis is necessary. It is recommended that a supplemental investigation be carried out at the detail design stage, comprised of three boreholes: one borehole through the roadway further away from the culvert to provide data for roadway protection design; and two boreholes at the culvert inlet and outlet ends to greater depth for the groundwater control system design (by the contractor). If a grade raise or widening of the roadway is required at this site, additional settlement and stability analysis may be required. Further, the assessment of and need for an application for a PTTW should be defined early in the detail design phase of the project as not to delay the start of construction.

7.0 CLOSURE

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



**PRELIMINARY FOUNDATION REPORT
FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/C**

Report Signature Page

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PRELIMINARY FOUNDATION REPORT FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/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.

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

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
OPSD 802.014	Flexible Pipe, Embedment in Embankment, Original Ground: Earth or Rock
OPSD 802.024	Flexible Pipe Arch, Embedment in Embankment, Original Ground: Earth or Rock
OPSD 802.034	Rigid Pipe Bedding and Cover in Embankment, Original Ground: Earth or Rock
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/C

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 FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/C

Table 1: Summary of Culvert Details

Culvert Location	Site #	Approximate Height of Embankment ¹	Existing Culvert			Approximate Invert Elevation ²	
			Type	Approximate Dimension ²	Approximate Length	North End of Culvert	South End of Culvert
Hwy 11 STA 18+316	48E-125/C	3.3 m	Two Cell Timber Box	1.4 m wide x 1.6 m high each cell	27 m	268.4 m	268.3 m

- 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 BC494854114.dwg).

Prepared by: TB
Checked by: SEMP
Reviewed by: JMAC



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/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 blanket likely required at inlet to mitigate potential scour under the culvert. Transportation to and on-site lifting of large pre-cast sections will be required. May require water diversion of a relatively wide creek channel. 	<ul style="list-style-type: none"> Some risk of disturbance of the native silt deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad. Lower risk related to settlement performance as box segments are more tolerant of differential settlement.
Open Footing Culvert	<ul style="list-style-type: none"> May be feasible to build culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering/unwatering (pumping) of surface water, but would still need to found footings below the depth of frost penetration. Would likely satisfy fisheries requirements related to natural channel substrate, if applicable. Suitable footing founding condition likely at similar depth to those of existing timber culvert. Existing culvert can be used for water diversion while new footings are being constructed adjacent to the culvert. Readily suitable for construction using concrete of metal arch sections 	<ul style="list-style-type: none"> Excavation depths to found the footings at frost depth 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. Constructing footings in the dry will take longer due to requirements for groundwater control system, dewatering and surface water pumping. Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site. Footings founded on very loose relative density zone of the silt stratum resulting in low available bearing resistances and greater potential for settlement of the structure. 	<ul style="list-style-type: none"> High risk of disturbance of the silt deposit during construction; can be somewhat mitigated with use of a concrete working slab or granular working pad but would require greater depth of dewatering for footing construction.



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/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.■ 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 blanket may be required at inlet to mitigate potential scour under culvert.■ CSP does not have as long a design life compared to concrete options.■ Difficult to compact backfill materials to springline level of the culvert.	<ul style="list-style-type: none">■ Some risk of disturbance of the native silt to sand deposit 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.



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FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/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 (North End / South End)	Founding Condition	Factored Geotechnical Axial Resistance at ULS ²	Geotechnical Reaction at SLS for 25 mm of Settlement ²
Hwy 11 STA 18+316	268.4 m / 268.3 m	Pre-Cast Box	268.0 m/267.9 m	Granular Backfill and/ Bedding over Loose to Compact Silt Deposit	150 kPa	100 kPa
		Open Footing (0.6 m)	265.8 m/265.7 m	Very Loose Silt and Sand to Sand	150 kPa	100 kPa
		Open Footing (1.2 m)			150 kPa	70 kPa
		Pipe Culvert	268.1 m/268.0 m ³	Bedding over Very to Compact Silt	N/A	N/A

- Notes:
1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing BC494854114.dwg).
 2. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on a proposed 5.5 m wide box culvert and an assumed 0.6 m or 1.2 m wide footing for an open footing culvert. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the foundation widths differ from those given above.
 3. The foundation elevation may need to be adjusted based on the size of the pipe culvert and required bedding thickness.

Prepared by: AC
Checked by: SEMP
Reviewed by: JMAC



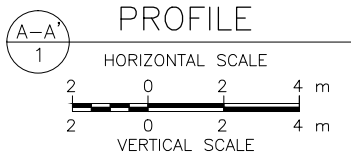
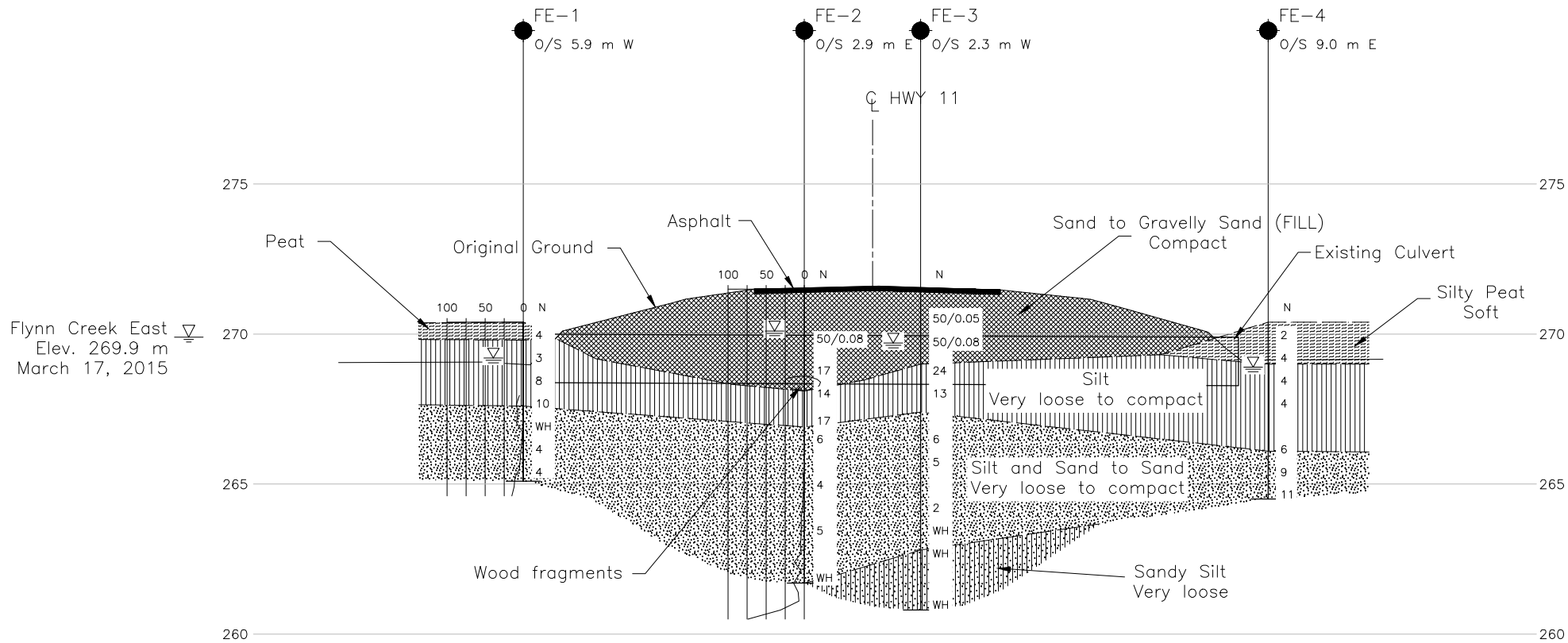
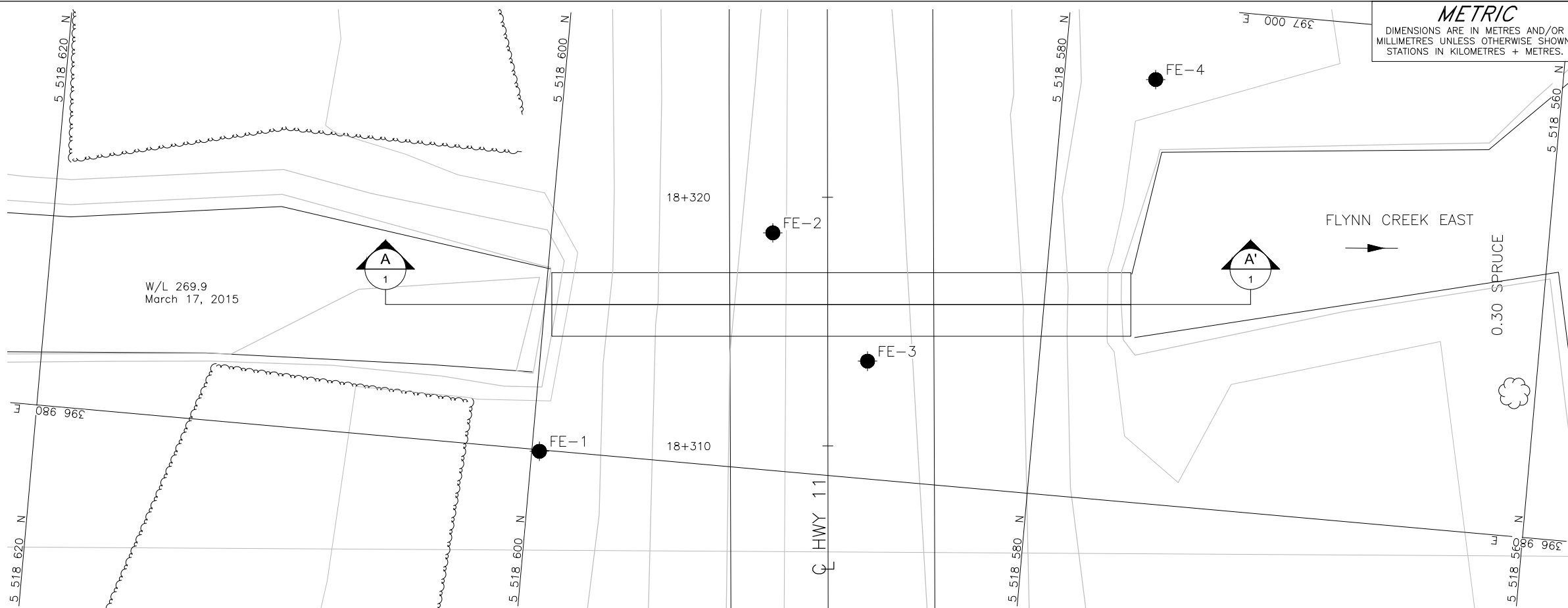
PRELIMINARY FOUNDATION REPORT FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/C

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

Culvert Location	Pre-Cast Box or Open Footing		Cast-in-place Open Footing	
	Interface Material	Coefficient of Friction ¹ (tan δ)	Interface Material	Coefficient of Friction ¹ (tan δ)
Hwy 11 STA 18+316	Compacted Granular Fill (Bedding/Levelling Pad)	0.45	Very Loose Silt and Sand to Sand	0.35

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

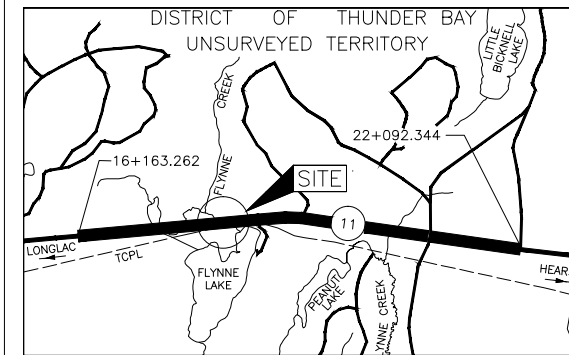
Prepared by: AC
Checked by: SEMP
Reviewed by: JMAC



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

CONT No. GWP No. 6310-14-00

HIGHWAY 11
FLYNN CREEK EAST CULVERT STA 18+316
BOREHOLE LOCATION PLAN AND
SOIL STRATA



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
FE-1	270.4	5518599.7	396979.9
FE-2	271.5	5518591.1	396989.5
FE-3	271.5	5518586.9	396984.7
FE-4	270.4	5518576.3	396997.0

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. BC494854114, dated NOV 2008, received FEB 20 2015.



NO.	DATE	BY	REVISION
Geocres No. 42F-34			
HWY. 11	PROJECT NO. 1411523		DIST. .
SUBM'D. AC	CHKD. .	DATE: 9/3/2015	SITE: 48E-125/C
DRAWN: TB	CHKD. SEMP	APPD. JMAC	DWG. 1



PHOTOGRAPHS

**Photograph 1: Flynne Creek East Culvert
North Side - Inlet (Taken from MTO, OSIM_09-21-2010)**



**Photograph 2: Flynne Creek East Culvert
South Side - Outlet (Taken from MTO, OSIM_09-21-2010)**





PHOTOGRAPHS

**Photograph 3: Flynne Creek East Culvert
North Side - Inlet (Taken from MTO, OSIM_09-21-2010)**



**Photograph 4: Flynne Creek East Culvert
South Side - Outlet (Golder – February 20, 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

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

IV. SOIL TESTS

w	water content
w_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 FE-1			1 OF 1 METRIC			
G.W.P. 6310-14-00			LOCATION N 5518599.7; E 396979.9			ORIGINATED BY SC			
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY TB			
DATUM GEODETIC			DATE February 23, 2015			CHECKED BY SEMP			
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100 PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%) 20 40 60 UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
270.4	GROUND SURFACE								
0.0	PEAT (Amorphous), some rootlets, trace gravel		1	SS	4		270		
269.8	Black Frozen								
0.6	SILT, trace to some clay, trace sand, trace gravel		2	SS	3		269		
	Very loose to compact								
	Grey Moist		3	SS	8		268		1 4 90 5
267.6	SAND, trace to some silt, trace gravel		4	SS	10		267		
2.8	Very loose								
	Grey Wet		5	SS	WR		266		1 89 (10)
			6	SS	4				
	Approximately 0.7 m of heave encountered at 5.3 m depth.		7	SS	4		265		
265.1	END OF BOREHOLE								
5.3									
264.6	END OF DCPT								
5.8	Note: 1. Water level at a depth of 1.2 m below ground surface (Elev. 269.2 m) upon completion of drilling. 2. Advanced DCPT 0.5 m west of Borehole FE-1. Advanced hollow stem augers to 2.3 m depth and started DCPT.								

PROJECT 1411523			RECORD OF BOREHOLE No FE-2			1 OF 1 METRIC											
G.W.P. 6310-14-00			LOCATION N 5518591.1; E 396989.5			ORIGINATED BY NJ											
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY TB											
DATUM GEODETIC			DATE March 17, 2015			CHECKED BY SEMP											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ kN/m ³	GR SA SI CL
							20 40 60 80 100	20 40 60 80 100	20 40 60	W _p W W _L							
271.5	GROUND SURFACE																
0.0	ASPHALT (130 mm)																
0.1	Sand, some gravel (FILL) Compact Grey to brown Frozen* to moist		1	AS	-		271										
	Trace wood encountered in Samples 3 and 4A.		2	SS	50/0.08		270										
			3	SS	17*		269										
268.1			A														
3.4	SILT, trace to some clay, trace sand Compact Grey Wet		4	SS	14		268										
			B														
			5	SS	17		267										
266.9																	
4.6	SAND, trace to some silt, trace gravel Very loose to loose Grey Wet		6	SS	6		266										
	Approximately 0.3 m of heave encountered in augers at 4.6 m depth.																
			7	SS	4		265										
			8	SS	5		264										
							263										
	Approximately 0.9 m of heave encountered in augers at 9.1 m depth.		9	SS	WH		262										
261.7																	
9.8	END OF BOREHOLE						261										
260.5																	
11.0	END OF DCPT																
	Note: 1. Water level at a depth of 1.4 m below ground surface (Elev. 270.1 m) upon completion of drilling. 2. Advanced DCPT 1.0 m north of Borehole FE-2. Advanced hollow stem augers to 4.6 m depth and started DCPT.																

PROJECT 1411523			RECORD OF BOREHOLE No FE-3			1 OF 1 METRIC											
G.W.P. 6310-14-00			LOCATION N 5518586.9; E 396984.7			ORIGINATED BY NJ											
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY TB											
DATUM GEODETIC			DATE March 17, 2015			CHECKED BY SEMP											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ kN/m³	GR SA SI CL
							20 40 60 80 100	20 40 60 80 100	20 40 60	W _p W W _L							
271.5	GROUND SURFACE																
0.0	ASPHALT (140 mm)																
0.1	Sand to gravelly sand, trace to some silt (FILL) Brown Frozen* to wet		1	AS	-		271										
			2	SS	50/ 0.05*												
			3	SS	50/ 0.08*		270										
269.0	SILT, trace to some clay, trace sand Compact Grey Wet		A 4	SS	24		269										21 70 (9)
2.5	A 75 mm thick layer of black organics encountered at 2.5 m depth.		B														
			5	SS	13		268										0 4 89 7
267.4	SILT and SAND to SAND Very loose to loose Grey Wet																
4.1			6	SS	6		267										
			7	SS	5		266										
			8	SS	WR		265										
			9	SS	2		264										
			10	SS	WH												0 52 41 7
262.8	Sandy SILT, trace clay Very loose Grey Wet		A 11	SS	WH		263										
8.7			B				262										
			12	SS	WH		261										NP
260.8	END OF BOREHOLE																
10.7	Note: 1. Water level at a depth of 1.8 m below ground surface (Elev. 269.7 m) upon completion of drilling.																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/05/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No FE-4				1 OF 1 METRIC											
G.W.P. 6310-14-00		LOCATION N 5518576.3; E 396997.0				ORIGINATED BY SC											
DIST _____ HWY 11		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY TB											
DATUM GEODETIC		DATE February 21, 2015				CHECKED BY SEMP											
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									
270.4	GROUND SURFACE							20	40	60	80	100					
0.0	Silty PEAT (Amorphous) Soft Black to brown Frozen* to moist		1	SS	2*	▽	270										
			2	SS	4		269										
269.0	SILT, trace to some sand, trace clay Loose Grey Wet		3	SS	4		268										
1.4			4	SS	4		267										
			A														
			5	SS	6		266										
			B														
266.1	SAND, trace to some silt Loose to compact Grey Wet		6	SS	9	265											
4.3			7	SS	11												
264.5	END OF BOREHOLE																
5.9	Note: 1. Water level at a depth of 1.5 m below ground surface (Elev. 268.9 m) upon completion of drilling.																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/05/15 DATA INPUT:



APPENDIX B

Laboratory Test Results



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK EAST CULVERT - SITE NO. 48E-125/C

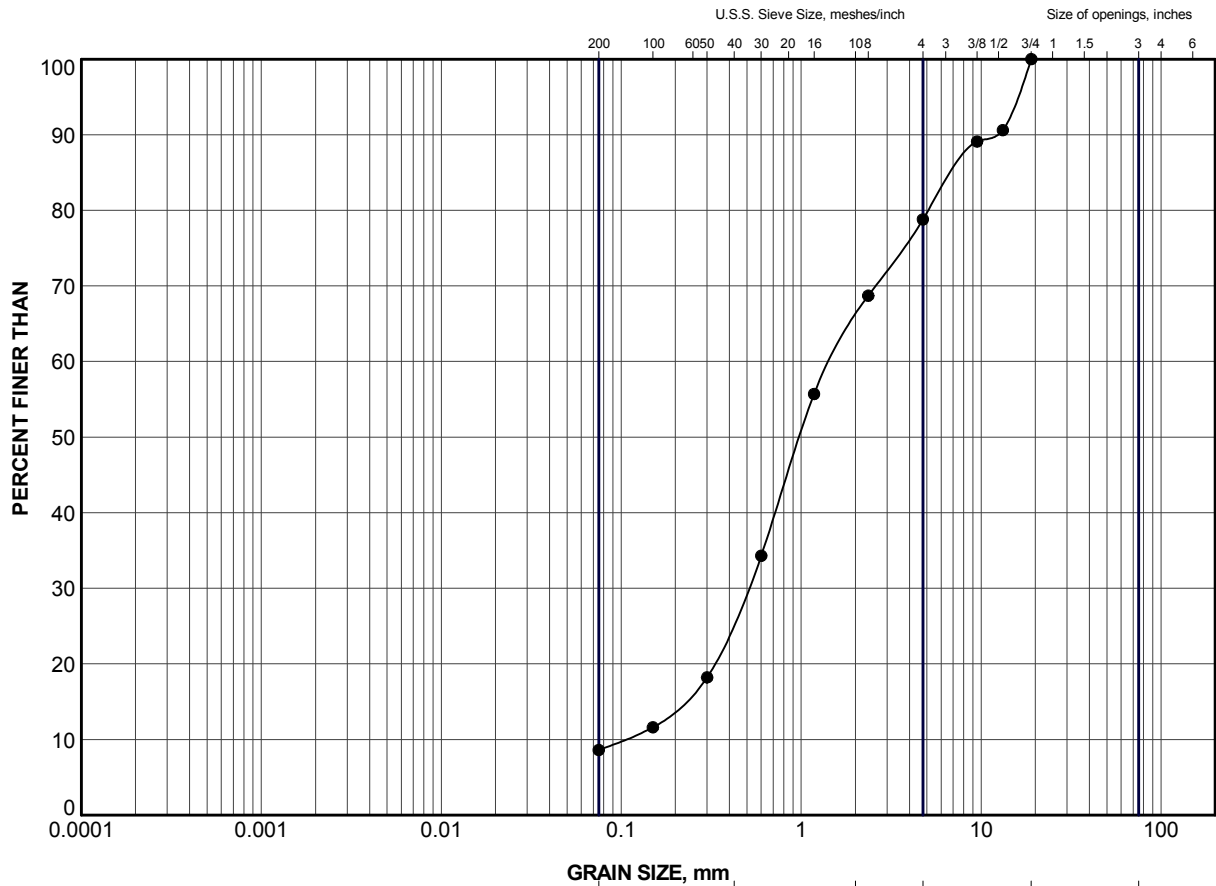
Table B1: Summary of Analytical Testing of Flynne Creek East Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	8.86
Sulphate (SO4)	mg/L	<0.30
Conductivity (EC)	µS/cm	219
Resistivity	µohm-cm	<0.33
pH	n/a	7.53

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	GRAIN SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
SAND SIZE				GRAVEL SIZE		

LEGEND

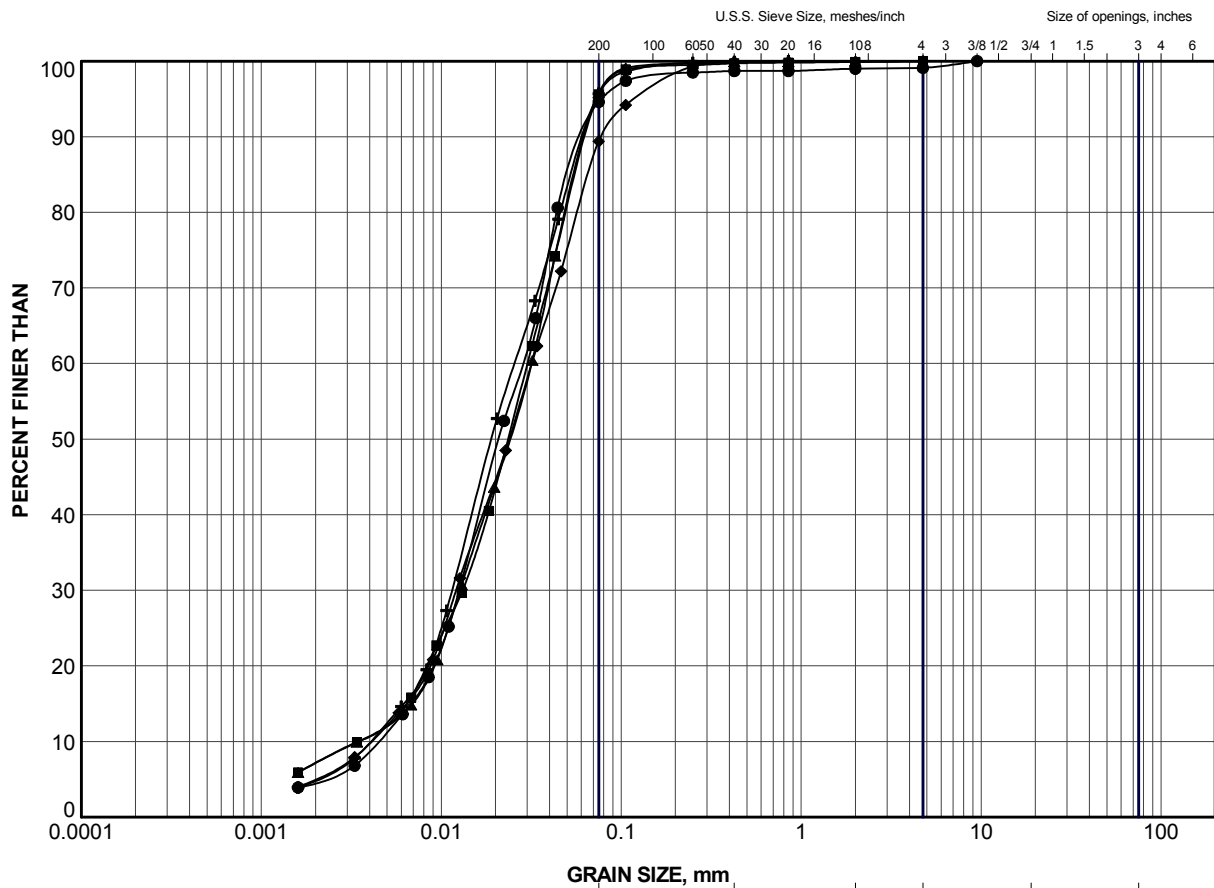
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FE-3	4A	269.1

PROJECT						HIGHWAY 11 FLYNNE CREEK EAST CULVERT STA 18+316					
TITLE						GRAIN SIZE DISTRIBUTION GRAVELLY SAND (FILL)					
PROJECT No.			1411523			FILE No.			1411523.GPJ		
DRAWN	TB	May 2015	SCALE	N/A	REV.	FIGURE B1					
CHECK	SEMP	May 2015									
APPR	JMAC	May 2015									

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SUD-MTO GSD (NEW) GLDR_LDN.GDT

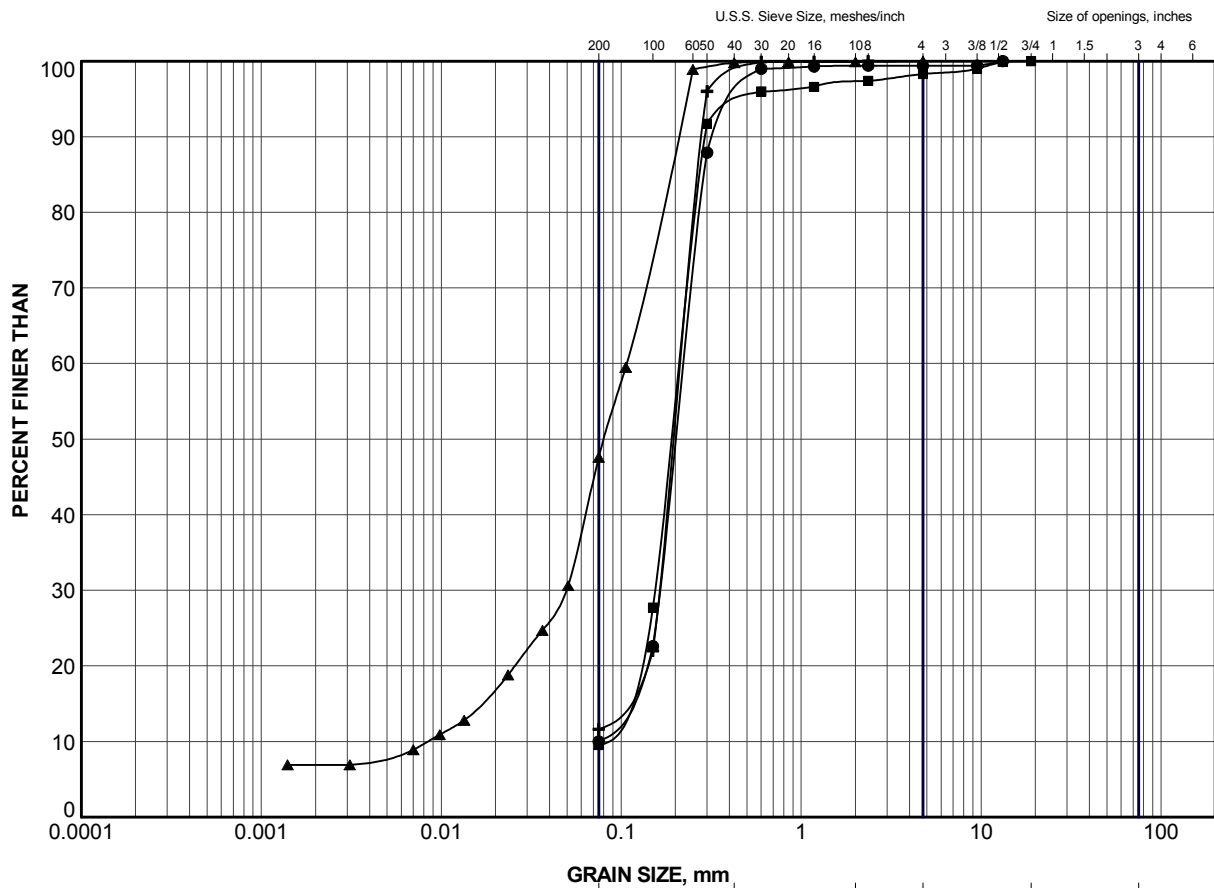


LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FE-1	3	268.6
■	FE-2	4B	267.9
▲	FE-3	5	268.2
+	FE-4	3	268.6
◆	FE-4	4	267.8


PROJECT					
HIGHWAY 11 FLYNN CREEK EAST CULVERT STA 18+316					
TITLE					
GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	TB	May 2015	SCALE	N/A	REV.
CHECK	SEMP	May 2015			
APPR	JMAC	May 2015			
			FIGURE B2		





LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FE-1	6	266.3
■	FE-2	7	265.1
▲	FE-3	10	263.6
+	FE-4	7	264.8

PROJECT						HIGHWAY 11 FLYNN CREEK EAST CULVERT STA 18+316					
TITLE						GRAIN SIZE DISTRIBUTION SILT and SAND to SAND					
PROJECT No.			1411523			FILE No.			1411523.GPJ		
DRAWN	TB	May 2015	SCALE	N/A	REV.						
CHECK	SEMP	May 2015									
APPR	JMAC	May 2015									
 Golder Associates SUDBURY, ONTARIO						FIGURE B3					

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