



September 8, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

**MCINTYRE CREEK CULVERT - SITE NO. 48C-341/C
HIGHWAY 102, DISTRICT OF THUNDER BAY
TOWNSHIP OF MCINTYRE
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6822-14-00**

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REPORT





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PART A

**PRELIMINARY FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Hatch Mott MacDonald (HMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the replacement of the McIntyre Creek culvert (Site No. 48C-341/C). The McIntyre Creek culvert is located in the District of Thunder Bay in the Township of McIntyre on Highway 102 at STA 17+768, approximately 0.5 km west of the junction of Highway 102 and Highway 589. The key plan showing the general location of this section of Highway 102 and the location of the investigated area are shown on Drawing 1.

2.0 SITE DESCRIPTION

The McIntyre Creek culvert consists of a three-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 this area is relatively flat with moderate to dense tree cover beyond the highway right-of-way to the south and the McIntyre River running parallel to the Highway to the north. It should be noted that the orientation (i.e. north, south, east, west) stated in the text of the report is typically reference to project north and therefore may differ from Magnetic North shown on the drawing. For the purposes of this report Highway 102 runs in a west-east direction with the culvert perpendicular in a north-south orientation. At the culvert location, McIntyre Creek flows northerly and drains to the McIntyre River. At the culvert location, the highway grade is at Elevation 312.2 m and the culvert invert is at approximately Elevation 308.8 m at the inlet (south) end and Elevation 308.5 m at the outlet (north) end. The creek water level was at Elevation 309.0 m and 308.7 m at the inlet and outlet ends, respectively, as measured by others on November 14, 2014. The creek water level was measured at Elevation 308.9 m at the outlet (north) end as measured by Golder on March 11, 2015. Surface conditions at the culvert inlet and outlet areas are shown on Photographs 1 to 3, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out from January 13 to 16, 2015, during which time four (4) boreholes (Boreholes MC-1 to MC-4) were advanced at approximately the locations shown on Drawing 1. Boreholes MC-1 and MC-4 were advanced at the toe of slope near the culvert outlet/inlet and Boreholes MC-2 and MC-3 were advanced from the existing highway platform. All boreholes were advanced using 108 mm inside diameter hollow stem augers. All drilling equipment was supplied and operated by Cartwright Drilling Inc. of Thunder Bay.

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

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



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content and organic 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 subsequent to the field investigation (in July 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 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 on drawing E-287-102-1.dwg. The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and summarized below.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
MC-1	5371981.2	354345.0	309.3	6.1
MC-2	5371966.1	354334.3	312.1	9.8
MC-3	5371963.9	354341.7	312.2	9.8
MC-4	5371951.6	354336.6	309.6	6.1

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 McIntyre Creek culvert site generally consist of outwash plain deposits of sand bordering with ground moraine deposits of silt.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)², the site is underlain by bedrock of the Proterozoic Era, comprised of sedimentary rocks consisting of wacke, shale, iron formation, limestone and minor volcanic rocks bordering with mafic to intermediate volcanic rocks and rock from the diorite-monzonite-granodiorite suite.

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 tests (i.e., SPT 'N' values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred

¹ Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52ASW.

² Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542.



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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 granular fill (for boreholes advanced through the embankment) and organics comprised of topsoil to sandy topsoil and organic silt (for boreholes advanced at the toe of slope) overlying a deposit of silt and sand, underlain by a deposit of silt. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows)	Laboratory Testing
				Relative Density	
Asphalt	MC-2, MC-3	0.100 – 0.125	312.2 – 312.1	n/a	n/a
(FILL) ¹ Sand to gravelly Silty Sand, trace clay; brown; frozen to wet	MC-2, MC-3	4.0 – 4.5	312.1 – 312.0	N = 5 – 20 ²	w = 7% – 17% 1 - M (Fig. B1)
				Loose to Compact	
Topsoil/Sandy Topsoil/Organic Silt , dark brown/black to grey; frozen to wet	MC-1, MC-4	0.9 – 2.2	309.6 – 309.3	N = 3 – 4	w = 44% - 110% 1 – AL = NP OC = 10%
				Very Loose	
Silt and Sand , some gravel, trace clay; grey; moist to wet	MC-2 to MC-4	1.2 – 2.6	308.0 – 307.4	N = 8 – 15	w = 10% - 24% 3 – MH (Fig. B2) 4 – AL = NP
				Loose to Compact	
Silt , ³ trace to some sand, trace clay; grey; wet	MC-1 to MC-4	Boreholes terminated in this deposit (2.6 – 5.2)	308.4 – 305.0	N = 6 – 104	w = 11% – 22% 3 – MH (Fig. B3) 1 – MH (Fig. B4) ³
				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
AL = Atterberg Limits Test
OC = Organic Content (%)
NP = Non-Plastic test result

Notes:

¹ Wood was encountered within the granular fill in Borehole MC-3. Additional boreholes were drilled to the east of the original borehole location (and culvert) to sample beyond 3.2 m depth.



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² In the granular fill, two SPT 'N'-values of 26 blows and 51 blows per 0.3 m of penetration were noted, however, these are likely indicative of the frozen state of the material and are not representative.

³ A sand and gravel seam was encountered in Borehole MC-1 at 4.6 m depth.

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 308.9 m on March 11, 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)
MC-1	3.7	305.6
MC-2	6.6	305.5
MC-3	9.1	303.1
MC-4	4.0	305.6

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Jim Mucklow and Ms. Selena Contardo, under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Adam Core, P.Eng., and Mr. David Muldowney, P.Eng. 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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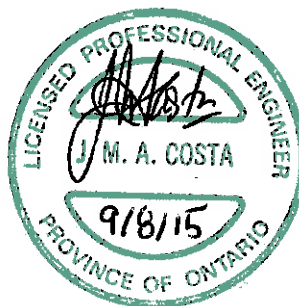
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PART B

**PRELIMINARY FOUNDATION DESIGN REPORT
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

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

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

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

It is assumed that the culvert will be replaced with a culvert of similar dimensions, alignment as well as invert elevation to that of the existing culvert. In addition, it is assumed that there will be no embankment grade raises or widening in the area of the culvert as part of the Hwy 102 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The existing McIntyre Creek culvert is located in the District of Thunder Bay in the Township of McIntyre on Highway 102 at STA 17+768, approximately 0.5 km west of the junction of Highway 102 and Highway 589. The highway embankment is constructed of granular fill material and is approximately 3.5 m high relative to the culvert invert with approximately 2.5 m of cover over the existing culvert. The existing culvert consists of a three cell timber box, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

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

- Pre-cast open footing with either pre-cast concrete arch or metal box;
- Pre-cast concrete box;
- Pre-cast concrete slab on sheet-pile abutments; and
- Pipe culvert(s).

In this report we have considered the following options:

- Open footing concrete culvert (cast-in-place or pre-cast footing);



- Pre-cast concrete box culvert; and
- Pre-cast concrete slab supported on sheet-pile abutment type culvert; and
- Pipe culvert(s).

A pipe culvert would likely decrease the flow through capacity, however multiple pipe culverts would likely be required to meet the flow capacity and could be comprised of multiple parallel corrugated steel pipes (CSP) and pre-cast concrete pipe culverts (circular or arched). From a foundation perspective, a concrete box culvert sufficiently wide to handle the flow is preferred at this site to reduce the need for excavation and groundwater management and surface water diversion, and tolerance to settlement/heave due to freezing of subgrade. Other culvert types may be preferred due to construction staging or other considerations such as substrate requirements but construction may likely be more difficult. 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 Replacement

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, as these are expected to occur given that the creek water column was frozen full depth and into the creek bed at the time of the subsurface investigation (January 2015). 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 a Granular 'B' Type II bedding/levelling layer constructed as replacement backfill to the excavation of organic/loose soils overlying the compact silt and sand and/or the compact silt deposits as encountered in the boreholes. Details for the construction of the granular backfill (bedding) replacing the organic silt and existing fill layers present along the culvert, are presented in Section 6.4.2.

6.2.2.2 Open Footing Culvert Replacement

Strip footings for the alternative open footing culvert should be founded at a minimum depth of 2.4 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), any existing fill and/or organic deposits, where present. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

6.2.2.3 Pre-Cast Concrete Slab on Sheet-Pile Abutments

Sheet-pile abutments supporting a concrete slab, if utilized at this site as the culvert construction option will penetrate well below the frost depth to bear within the dense to very dense silt deposit. Therefore, such a foundation should not be subject to frost induced heave per se, but, adhesion of the subsoils to the sheet-pile walls along the depth of the frost penetration zone would have to be considered in the overall assessment of the



sheet-pile depths in order to resist uplift (heave). An estimate of the additional depth required to resist uplift can be provided at the detail design stage if this is culvert replacement option is selected.

6.2.2.4 Pipe Culverts

It is not necessary to found pipe culverts at the standard depth for frost protection purposes, as such culverts are tolerant to small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the pipe culverts be founded on a Granular 'B' Type II bedding/levelling layer constructed as replacement backfill to the excavation of organic/loose soils overlying the compact silt and sand and/or the compact silt deposits as encountered in the boreholes. Recommended foundation elevation and foundation conditions for circular pipe culverts are provided in Table 3.

6.2.3 Geotechnical Resistances

6.2.3.1 Box Culvert Replacement

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

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

The loading on the foundation soils below the culvert and the associated settlements at the culvert location will be governed by the design height of the overlying and adjacent embankment fill, however it is assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is applicable as the settlement under the culvert as a result of soil loading (not culvert loading) may govern.

6.2.3.2 Open Footing Culvert Replacement

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 the assumed footing 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 axial resistance/reaction should, therefore, be reviewed if the culvert footing width or founding elevation differs from those given in Table 3.

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

The loading on the foundation soils below the culvert footings and the associated settlements at the culvert location will be governed by the design height of the overlying and adjacent embankment fill, however it is assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is applicable as the settlement under the culvert as a result of soil loading (not culvert loading) may govern.

6.2.3.3 *Pre-Cast Slab and Sheet-Pile Abutments*

The sheet-piles should be driven to/into the generally dense to very dense silt at or below the founding elevation recommended in Table 3, and should be designed based on the factored geotechnical resistances at ULS and unit geotechnical reaction at SLS (for 25 mm of settlement), provided in Table 3. The unit factored geotechnical axial resistance and reaction provided in Table 3 are primarily a function of the toe resistance developed within the dense to very dense silt deposit. These values do not include downdrag forces, which may need to be considered if the grade is raised or the embankments are widened, nor do the estimated depths of sheet-pile embedment account for uplift stresses due to adhesion to frozen ground.

If a higher geotechnical resistance/reaction is required for design, the sheet-piles may need to be driven to a greater depth to increase the frictional resistance and potentially toe resistance; however, additional drilling would be required to confirm the subgrade soil conditions at depth.

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 3.5 m above the existing ground surface adjacent to the culvert, granular fill embankments at this site will be stable at side slopes inclined at 2 Horizontal to 1 Vertical (2H:1V) or flatter.

It is anticipated that there would not be any settlement or stability issues should a nominal grade raise or widening be required at this site, provided that any organics or loose materials is removed, should these be encountered in the widening footprint area.

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

The following parameters (unfactored) may be used to calculate the lateral earth pressures acting on the culvert or sheet-piles:

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
Silt and Sand	28°	18 kN/m ³	0.53	0.36
Silt	27°	18 kN/m ³	0.55	0.38



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 loose to compact sand to gravelly silty sand and into native soils which are comprised of very loose organic silt, loose to compact silt and sand and generally compact to very dense silt. 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 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 extended to suitable depth, or soldier piles and lagging where H-piles are driven to a suitable depth and horizontal lagging is installed as the excavation proceeds. Support to the system could be in the form of struts and walers and rakers or anchors. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways.

The installation of the sheet-piles for culvert construction and/or temporary shoring may be impeded by the presence of wood, such as was encountered within the fill material in Borehole MC-3. 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 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 that may impede the sheet-pile installation. Alternatively, imported Granular 'A' or Granular 'B' Type I, II or III may be used as backfill for the excavated trench. 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 can be provided at the detail design stage, if required depending on final culvert design and construction staging.

6.4.2 Excavation and Replacement Below Culvert

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



The 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 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. 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 at least 98 per cent of the SPMDD as specified in OPSS.PROV 501 (Compacting). In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided with a geometry similar to that presented 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 presented on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

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).

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 with geometry similar to that presented on OPSD 803.010 (Backfill and Cover for Concrete Culverts).



6.4.3.3 *Pipe Culverts*

The bedding, levelling and backfill for concrete pipe, CSP or CSP arch culverts 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 culverts 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 (including the sheet-pile abutments, if selected as the preferred option) should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the No. 200 (0.075 mm) sieve. The granular backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD 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 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 and sand and the silt subgrades 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 concrete working slab should 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 a 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 very loose to loose overburden soils prior to placement of backfill, bedding material, engineered fill and the actual culvert structure. Groundwater flow into the excavation can be expected due to the depth of the excavations and the presence of relatively permeable fill. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

Depending on the creek flow, local surface water flow conditions and groundwater level at the time of construction, water flow could be passed through the area by means of a temporary culvert, using a portion of (or all) the existing three-cell culvert or diverted by pumping from behind a temporary cofferdam.

For both the box and open footing culvert options, excavations will extend below the creek water level and will therefore require temporary shoring with dewatering to allow for construction/placement of the footings and/or placement of engineered fill in dry conditions. Temporary shoring and dewatering could be in the form of a sheet-pile cut off wall or cofferdam advanced to an appropriate depth to control groundwater inflow from the creek. As discussed in Section 6.4.2, engineered fill or organic sub-excavation replacement backfill can be placed subaqueously, however, dewatering may still be required for footing/box culvert placement as the culvert invert is at or 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. 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 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 presence of buried wood within the fill and upper portion of the native silt and sand, as encountered in Borehole MC-3. An NSSP should be developed at the detail design stage for inclusion into the Contract Documents to alert the contractor to the potential presence of such obstructions.

6.4.8 Analytical Testing for Construction Materials

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

6.5 Recommendations for Further Work During Detail Design

During the detail design phase, additional field investigation and testing may be required, based on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., staging). In particular, consideration should be given to drilling additional boreholes advanced to a suitable penetration depth within the silt deposit if the pre-cast slab supported on sheet-pile abutments culvert option is selected or for design of temporary protection works if the culvert is to be constructed in stages while maintaining one lane of traffic open. The scope and results of this investigation must be reviewed at the time of the detail design to determine if they meet the then-current MTO requirements for the culvert type or staging strategy under consideration, and if additional investigation and analysis is necessary. 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.

7.0 CLOSURE

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



**PRELIMINARY FOUNDATION REPORT
MCINTYRE CREEK CULVERT - SITE NO. 48C-341/C**

Report Signature Page

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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 2542.

Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52ASW.

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



PRELIMINARY FOUNDATION REPORT MCINTYRE CREEK CULVERT - SITE NO. 48C-341/C

OPSD 803.010 Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m

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

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

OPSD 3090.100 Foundation, Frost Penetration Depths for Northern Ontario

Ontario Water Resource Act:

Regulation 903 Wells (as amended)



PRELIMINARY FOUNDATION REPORT MCINTYRE CREEK CULVERT - SITE NO. 48C-341/C

Table 1: Summary of Culvert Details

Culvert Location (Township)	Site #	Approximate Height of Embankment ¹ (m)	Existing Culvert			Approximate Invert Elevation ²	
			Type	Approximate Dimension ²	Approximate Length (m)	South End of Culvert (m)	North End of Culvert (m)
Hwy 102 STA 17+768 (Township of McIntyre)	48C-341/C	3.5	Three Cell Timber Box	1.5 m wide x 1.0 m high each of 3 cells	18	308.8	308.5

- 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 E-287-102-1.dwg).

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



PRELIMINARY FOUNDATION REPORT

MCINTYRE CREEK CULVERT - SITE NO. 48C-341/C

Table 2: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Risks/Consequences
Open Footing Culvert	<ul style="list-style-type: none"> ■ May be feasible to construct culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering/unwatering (pumping) of surface water. ■ 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. ■ 	<ul style="list-style-type: none"> ■ Excavation depths are greater than for box culvert option, resulting in increased excavation support requirements and additional spoil material to be disposed off-site. ■ Constructing footings in the dry will take longer due to requirements for installation of groundwater control system, dewatering and surface water pumping, and excavating in a constrained space. ■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site. ■ Concrete or metal arch sections supported on concrete open (strip) footings may not allow for adequate soil cover to be placed, including roadway fill. 	<ul style="list-style-type: none"> ■ High risk of disturbance of the native 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. ■ Culvert joints may be required to accommodate total and differential settlement (if applicable). ■ Will likely have to employ a groundwater cut-off system in combination with constructing footings on a tremie concrete plug – high risk that inappropriate construction procedures will result in loosening of silt and sand (and silt) deposits at excavation base due to upward groundwater pressures.
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. Minor excavation required for removal of organic/unsuitable materials to the base of the bedding/levelling course. ■ 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, or remnants of the peat deposit are not fully removed. ■ Backfill/bedding under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements. 	<ul style="list-style-type: none"> ■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Cut-off wall (or clay blanket) required at inlet to mitigate potential scour under culvert. ■ Transportation to and on-site lifting of large pre-cast sections will be required. ■ May require water diversion of the creek channel to accommodate construction using a full width culvert section unless the culvert is comprised of multiple parallel box sections. 	<ul style="list-style-type: none"> ■ Some risk of disturbance of the native silt and sand and deposits during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad or bedding layer. ■ Low risk related to settlement performance.



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Option	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Slab and Sheet-Pile Abutment	<ul style="list-style-type: none"> ■ May not require temporary diversion of the creek, depending on the required width of the culvert in comparison to the existing culvert as the sheet-piles can be installed around the existing culvert, which acts as the channel diversion and the new culvert can be constructed in sections. ■ Minimizes excavation depths and does not require dewatering. ■ Would satisfy fisheries requirements related to natural channel substrate, if applicable. 	<ul style="list-style-type: none"> ■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site (i.e. potential for downdrag and/or heave due to adhesion during frozen ground conditions on the sheet-piles). ■ Steel sheet-piles may not have as long of a design life compared to concrete options. ■ May require additional deeper boreholes to assess adequacy of subsurface soils for potentially higher bearing capacities, if required. ■ Potential difficulties in driving/vibrating sheet-piles to required depth due to presence of very dense zone in the silt stratum. 	<ul style="list-style-type: none"> ■ Some risk related to obstructions within the fill; if not completely removed can be mitigated by sub-excavation and replacing material prior to installation of the sheet-piles. ■ Joints may need to be incorporated into the slab to accommodate total and differential settlement. ■ Varying sheet-pile lengths depending on presence of very dense zone in silt stratum and ability to achieving pile capacities uniformly along the sheet-pile walls.
Pipe Culvert(s)	<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, unless multiple pipe culverts considered. ■ Cut-off wall or clay blanket may be required at inlet to mitigate potential scour under culvert. ■ CSP does not have as long of design life compared to concrete options. 	<ul style="list-style-type: none"> ■ Some risk of disturbance of the native silt and sand subgrade 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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Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box, Open Footing and Pre-Cast Concrete Slab on Sheet-Pile Abutments
Replacement Culverts

Culvert Location (Township)	Approximate Invert Elevation ¹ (South End / North End)	Culvert Type	Approximate Backfill/Bedding or Footing Founding Elevation (South End / North End)	Founding Condition	Factored Geotechnical Axial Resistance at ULS ²	Geotechnical Reaction at SLS for 25 mm of Settlement ²
Hwy 102 STA 17+768 (Township of McIntyre)	308.8 m / 308.5 m	Pre-Cast Box	308.4 m / 308.1 m (Organic removal potentially to Elev. 307.4 m at south end)	Granular 'B' Type II Replacement Fill/Bedding over Loose to Compact Silt and Sand and/or Loose to Compact Silt	150 kPa	100 kPa
		Open Footing	306.4 m / 306.1 m	Compact Silt and Sand and/or Compact to Very Dense Silt	175 kPa	175 kPa
		Pipe Culvert ³	308.5 m / 308.2 m (Organic removal potentially to Elev. 307.4 m at south end)	Granular 'B' Type II Replacement Fill/Bedding over Loose to Compact Silt and Sand and/or Loose to Compact Silt	N/A	N/A
	N/A	Pre-Cast Slab on Sheet-Pile Abutments ⁴	~ 303.0 m	Dense to Very Dense Silt	200kN/m	150 kN/m

- Notes:
1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing BC5019311053.dwg).
 2. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an assumed 3.6 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.
 3. The founding elevation may need to be adjusted based on the type and size of pipe culvert and the required bedding thickness.
 4. The factored geotechnical resistance at ULS and geotechnical reaction at SLS (for 25 mm of settlement) are provided per horizontal metre of EZ88 series sheet-piling. These values assume the sheeting is driven into the dense to very dense silt deposit as encountered in Boreholes MC-2 and MC-3. The recommended geotechnical resistance/reaction should be reviewed once the culvert alignment (sheet-piling alignment) is finalized.

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



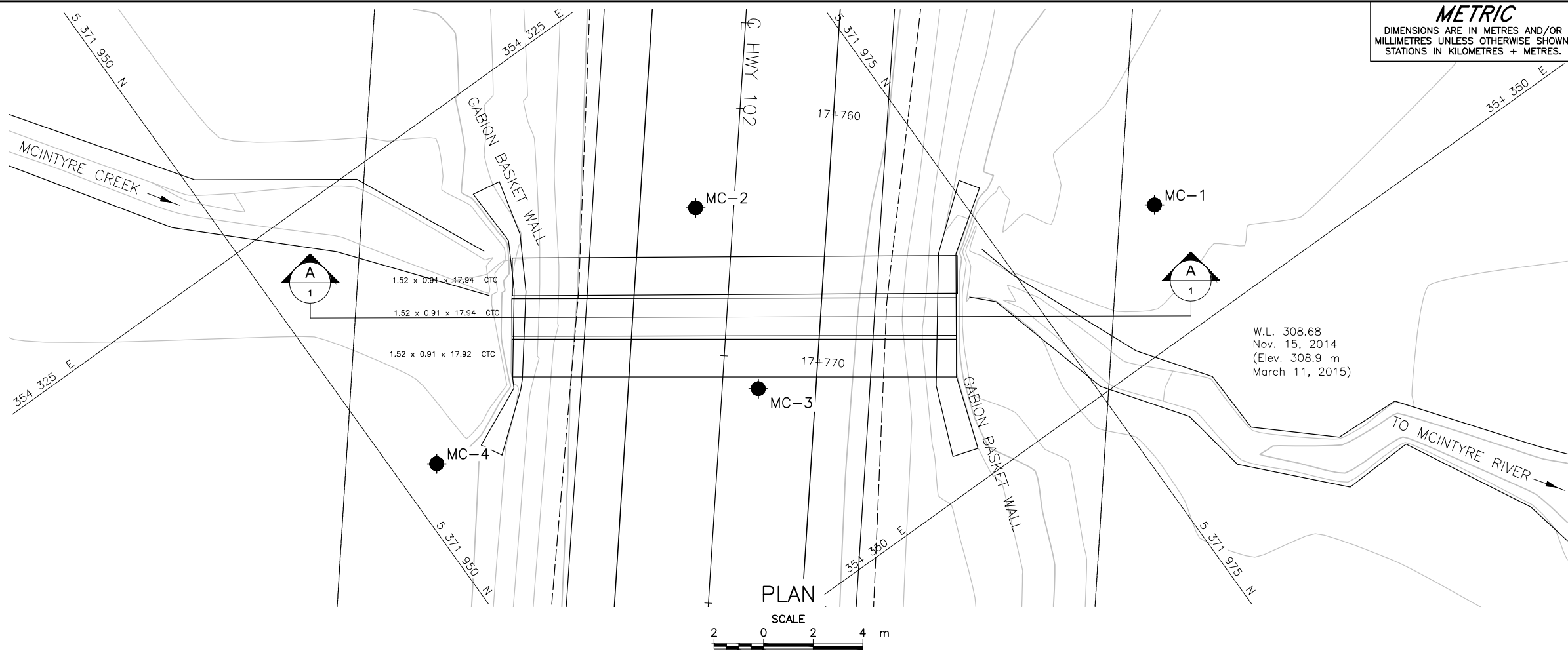
PRELIMINARY FOUNDATION REPORT MCINTYRE CREEK CULVERT - SITE NO. 48C-341/C

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

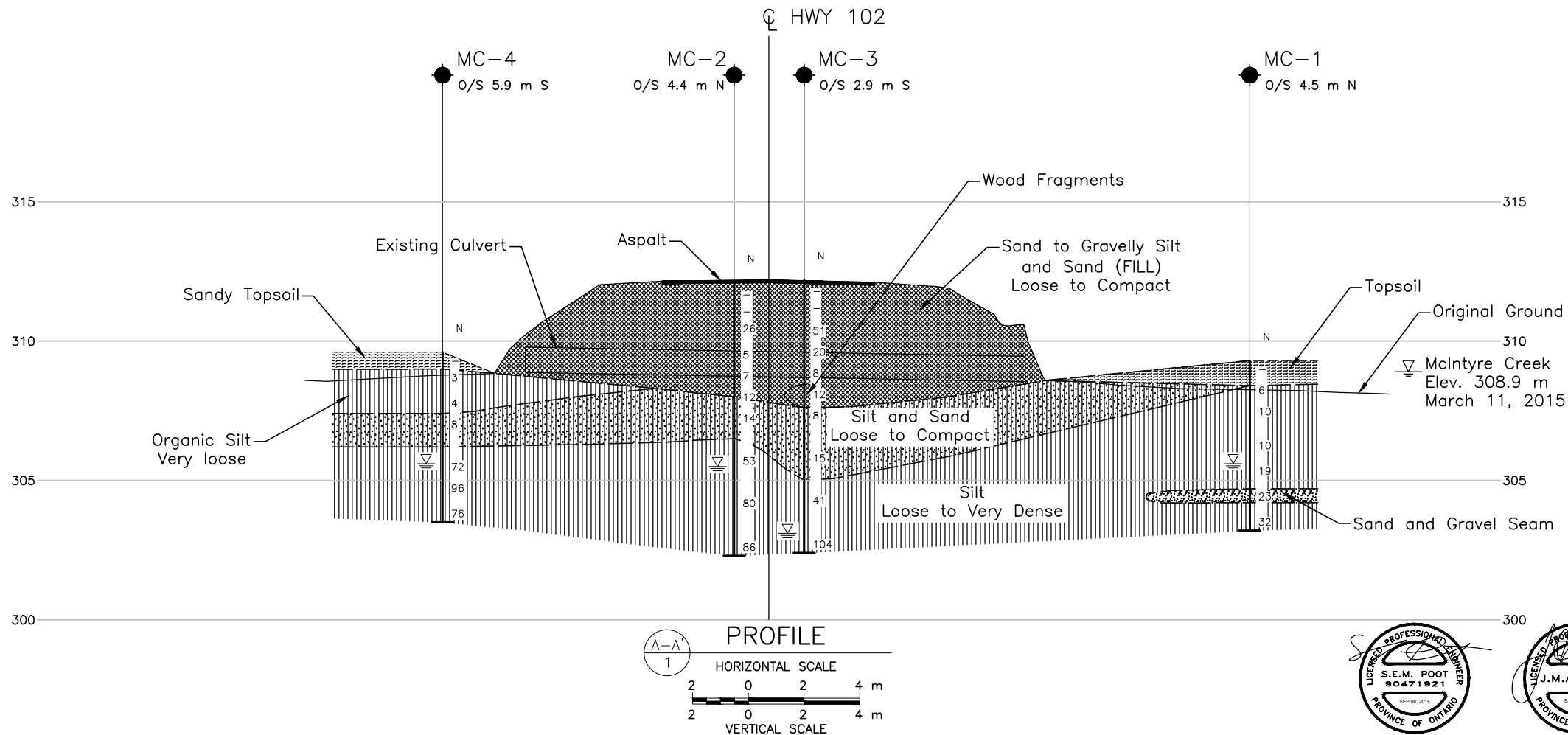
Culvert Location (Township)	Pre-Cast Box Culvert or Open Footing		Cast-in-place Open Footing	
	Interface Material	Coefficient of Friction ¹ (tan δ)	Interface Material	Coefficient of Friction ¹ (tan δ)
Hwy 102 STA 17+768 (Township of Gorham)	Compacted Granular Fill (Bedding Backfill or Levelling Pad)	0.45	Loose to Compact Silt and Sand and/or Compact to Very Dense Silt	0.30

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: DAM
Reviewed by: JMAC



W.L. 308.68
Nov. 15, 2014
(Elev. 308.9 m
March 11, 2015)

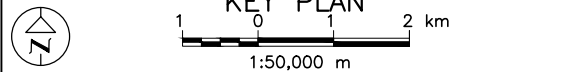
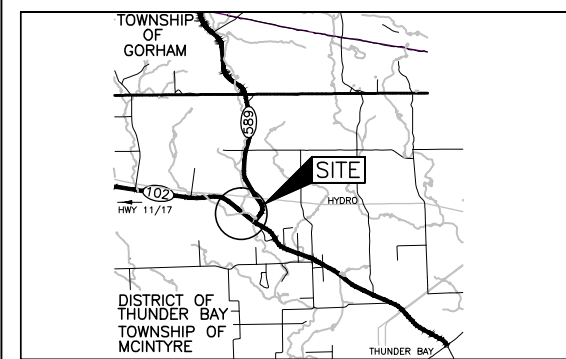


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 6822-14-00

HIGHWAY 102
MCINTYRE CREEK CULVERT STA 17+768
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



LEGEND

Borehole

Standard Penetration Test Value

Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)

WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
MC-1	309.3	5371981.2	354345.0
MC-2	312.1	5371966.1	354334.3
MC-3	312.2	5371963.9	354341.7
MC-4	309.6	5371951.6	354336.6

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. E-287-102-1, received FEB 15, 2015.



NO.	DATE	BY	REVISION
Geocres No. 52A-200			
HWY. 102	PROJECT NO. 1411523		DIST. .
SUBM'D. AC	CHKD. .	DATE: 4/24/2015	SITE: 48C-341/C
DRAWN: JJL	CHKD. SEMP	APPD. JMAC	DWG. 1



PHOTOGRAPHS

**Photograph 1: McIntyre Creek Culvert
North Elevation – Outlet (HMM – November 13, 2014)**



**Photograph 2: McIntyre Creek Culvert
South Elevation – Inlet (HMM – November 13, 2014)**





PHOTOGRAPHS

**Photograph 3: McIntyre Creek Culvert
Looking West at North End of Culvert (Golder – January 14, 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 MC-1				1 OF 1 METRIC								
G.W.P. 6822-14-00		LOCATION N 5371981.2; E 354345.0				ORIGINATED BY JM								
DIST _____ HWY 102		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC								
DATUM GEODETIC		DATE January 16, 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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
309.3	GROUND SURFACE							20 40 60 80 100						
0.0	TOPSOIL Dark brown Frozen		1	AS	-		309							
308.4														
0.9	SILT, some sand, trace to some gravel, trace clay Loose to dense Grey Wet		2	SS	6		308							
			3	SS	10		307							
			4	SS	10		306							
			5	SS	19		305							
	Sand and gravel seam at 4.6 m depth.		6	SS	23		304							
			7	SS	32									
303.2														
6.1	END OF BOREHOLE Note: 1. Water level at a depth of 3.7 m below ground surface (Elev. 305.6 m) upon completion of drilling.													





SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 27/04/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No MC-2				1 OF 1 METRIC										
G.W.P. 6822-14-00		LOCATION N 5371966.1; E 354334.3				ORIGINATED BY SC										
DIST _____ HWY 102		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC										
DATUM GEODETIC		DATE January 15, 2015				CHECKED BY SEMP										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
312.1	GROUND SURFACE															
0.0	ASPHALT (125 mm)															
0.1	Sand to gravelly silt and sand, trace clay (FILL) Loose to compact Brown Frozen* to wet		1	AS	-											
			2	AS	-											
			3	SS	26*											
	Augers grinding at 2.7 m depth to 3.2 m depth.		4	SS	5											
			5	SS	7											
308.0			6A	SS	12											
4.1	SILT and SAND, some gravel Compact Grey Wet		6B													
			7	SS	14											
306.5																
5.6	SILT, trace to some sand, trace clay Very dense Grey Wet															
			8	SS	53											
			9	SS	80											
			10	SS	86											
302.3																
9.8	END OF BOREHOLE															
	Note: 1. Water level at a depth of 6.6 m below ground surface (Elev. 305.5 m) upon completion of drilling.															

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 27/04/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No MC-3				1 OF 1 METRIC											
G.W.P. 6822-14-00		LOCATION N 5371963.9; E 354341.7				ORIGINATED BY SC											
DIST _____ HWY 102		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC											
DATUM GEODETIC		DATE January 13, 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									
312.2	GROUND SURFACE							20	40	60	80	100					
0.1	ASPHALT (100 mm)																
	Sand to gravelly silty sand, trace clay (FILL)		1	AS	-												
	Loose to very dense		2	AS	-												
	Brown																
	Frozen* to wet																
			3	SS	51*												
			4	SS	20												
	Trace wood in samples 5 and 6.		5	SS	8												
			6	SS	12												
307.6																	
4.6	SILT and SAND, some gravel, trace clay		7	SS	8												
	Loose to compact																
	Grey																
	Wet																
	Trace wood in sample 7.		8	SS	15												
305.0																	
7.2	SILT, trace sand, trace clay		9	SS	41												
	Dense to very dense																
	Grey																
	Wet																
			10	SS	104												
302.4																	
9.8	END OF BOREHOLE																
	Notes:																
	1. Water level at a depth of 9.1 m below ground surface (Elev. 303.1 m) upon completion of drilling.																
	2. Auger refusal was encountered at 3.7 m depth on a 75 mm thick piece of wood as encountered in Sample 5. Advanced additional borehole to 1.4 m east of Borehole MC-3 to auger refusal at 3.2 m depth. Advanced additional borehole 2.9 m east of Borehole MC-3 to obtain Samples 6 to 10.																

SUD-MTO 001 1411523.GPJ GAL-MISS GDT 27/04/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No MC-4				1 OF 1 METRIC												
G.W.P. 6822-14-00		LOCATION N 5371951.6; E 354336.6				ORIGINATED BY SC												
DIST _____ HWY 102		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC												
DATUM GEODETIC		DATE January 15, 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										WATER CONTENT (%)
309.6	GROUND SURFACE							20	40	60	80	100						
0.0	Sandy TOPSOIL Black to grey Moist		1	AS	-													
309.0	ORGANIC SILT Very loose Black to grey Moist		2	SS	3													
0.6																		
			3	SS	4													
307.4	SILT and SAND, some gravel, trace clay Loose Grey Moist		4	SS	8													
2.2																		
306.2	SILT, trace clay Very dense Grey Wet		5	SS	72													
3.4																		
			6	SS	96													
			7	SS	76													
303.5	END OF BOREHOLE																	
6.1	Note: 1. Water level at a depth of 4.0 m below ground surface (Elev. 305.6 m) upon completion of drilling.																	

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 27/04/15 DATA INPUT:



APPENDIX B

Laboratory Test Results



PRELIMINARY FOUNDATION REPORT MCINTYRE CREEK CULVERT - SITE NO. 48C-341/C

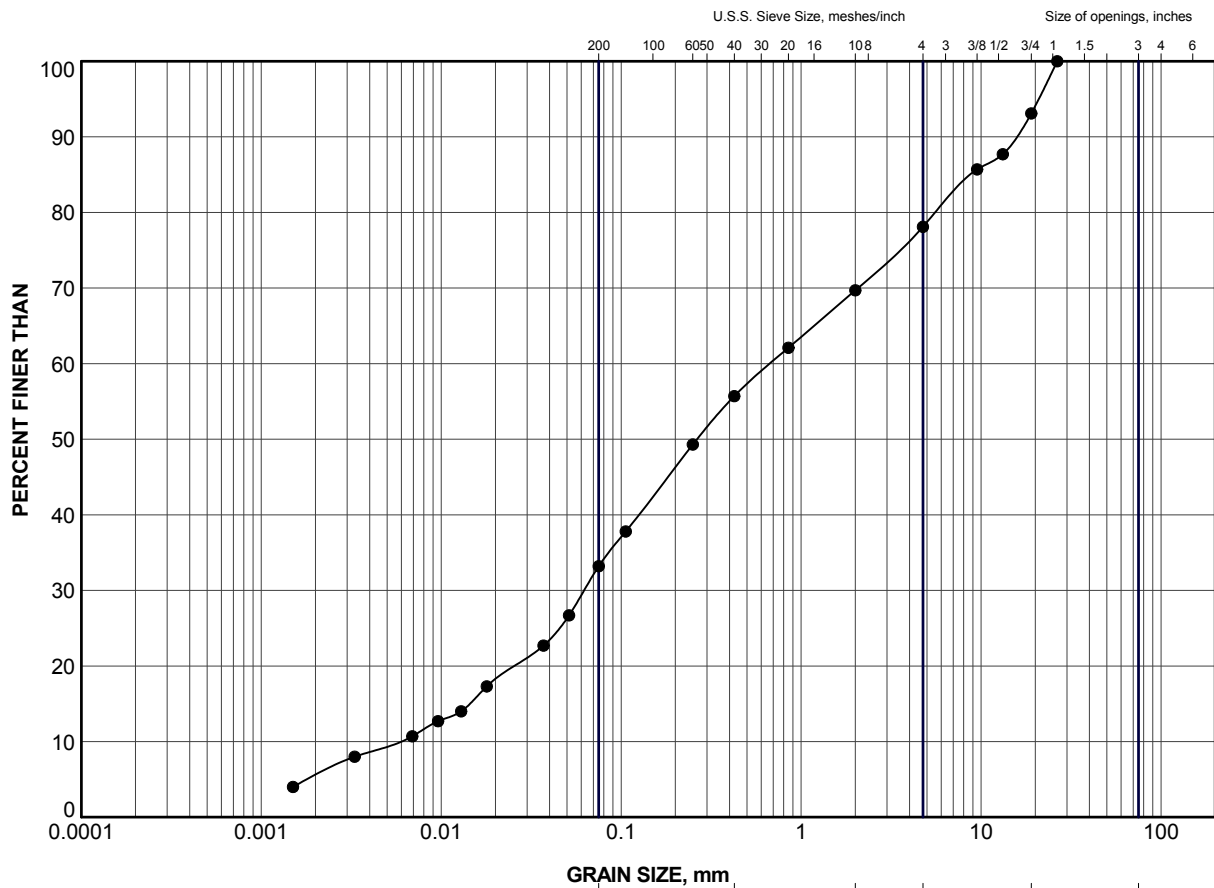
Table B1: Summary of Analytical Testing of McIntyre Creek Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	54.5
Sulphate (SO4)	mg/L	0.39
Conductivity (EC)	µS/cm	453
Resistivity	µohm-cm	<0.33
pH	n/a	7.61

Notes:

1. Sample obtained on July 22, 2015.
2. Analytical testing carried out by ALS Canada Ltd.


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

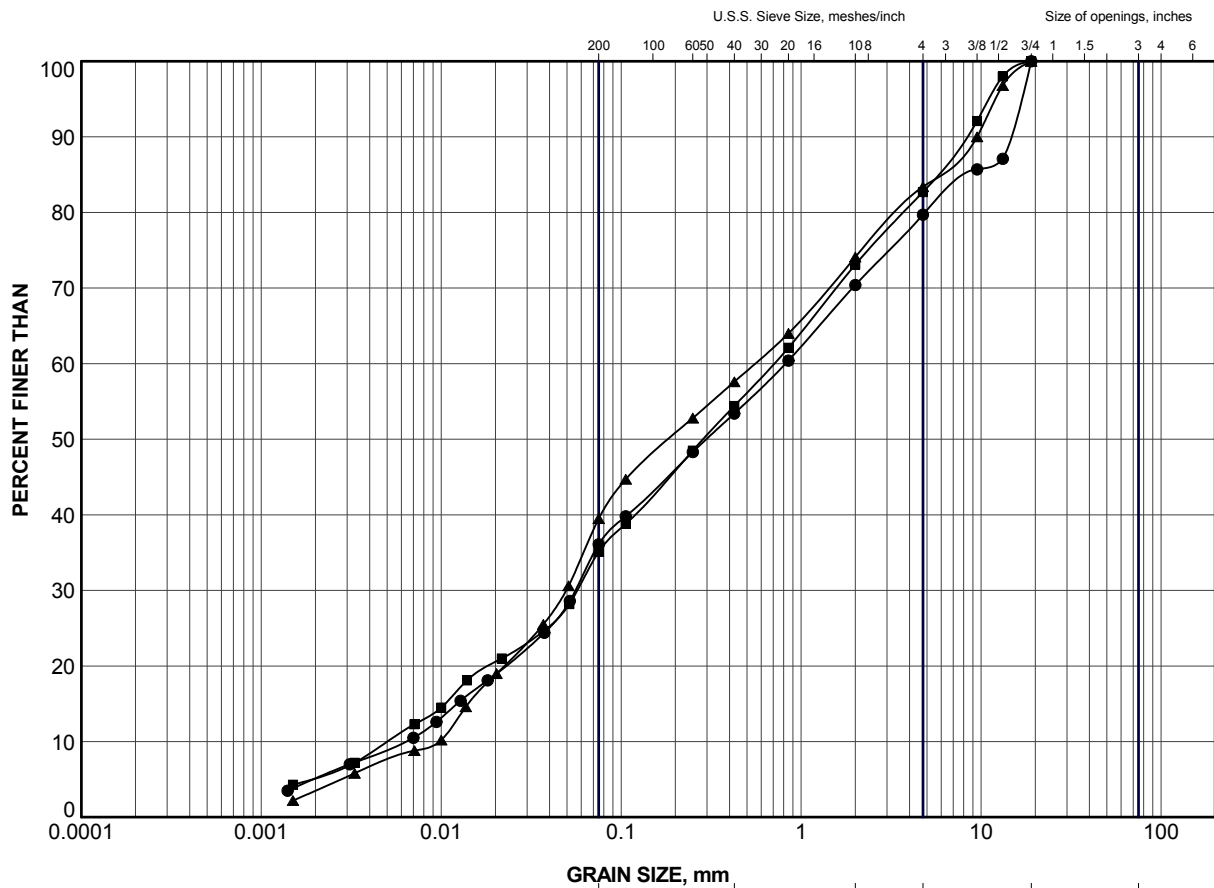


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	MC-3	2	311.2


PROJECT					
HIGHWAY 102 MCINTYRE CREEK CULVERT STA 17+768					
TITLE					
GRAIN SIZE DISTRIBUTION GRAVELLY SILTY SAND (FILL)					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	DAM	Apr 2015			
APPR	JMAC	Apr 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE B1		

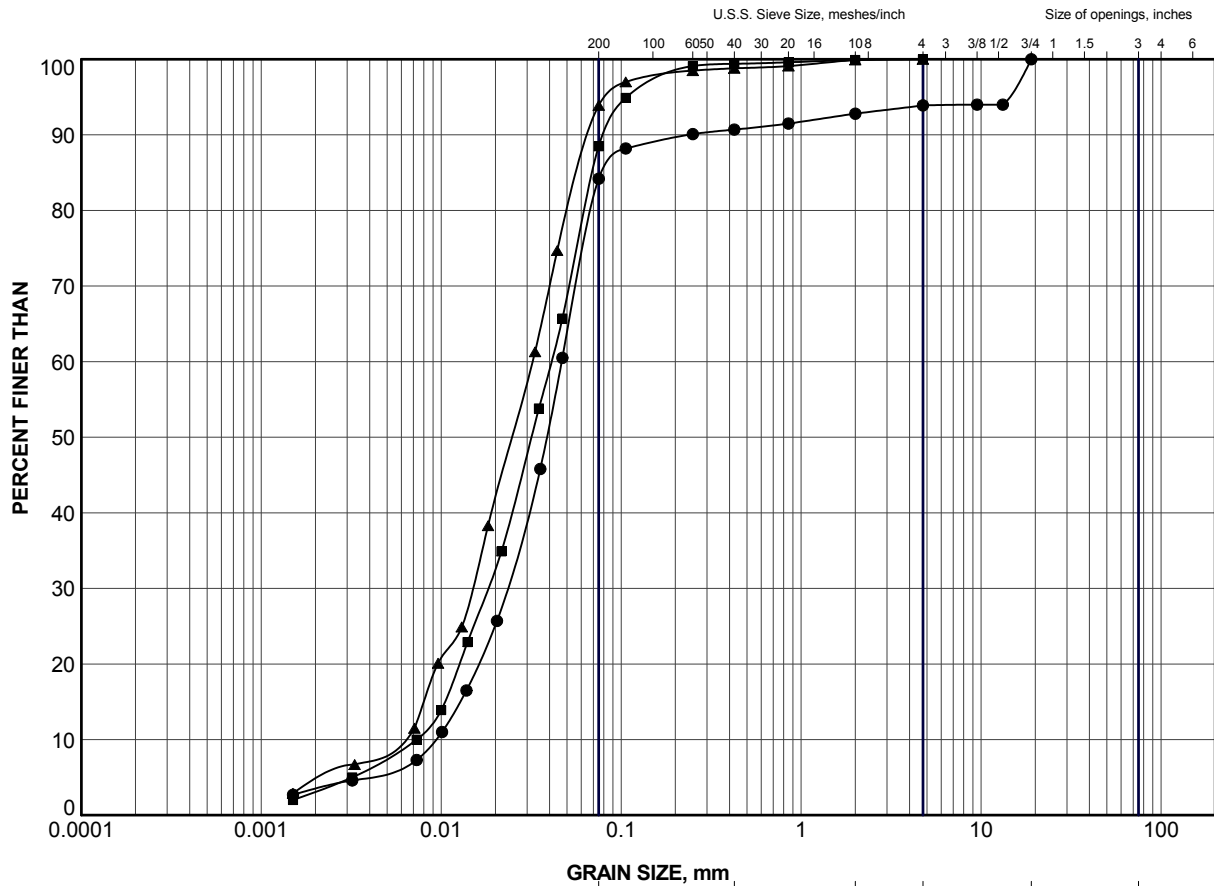


CLAY AND SILT	SAND SIZE			GRAVEL SIZE		Cobble Size
	fine	medium	coarse	fine	coarse	

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	MC-2	7	307.2
■	MC-3	7	307.3
▲	MC-4	4	307.0


PROJECT					
HIGHWAY 102 MCINTYRE CREEK CULVERT STA 17+768					
TITLE					
GRAIN SIZE DISTRIBUTION SILT and SAND					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	DAM	Apr 2015			
APPR	JMAC	Apr 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE B2		

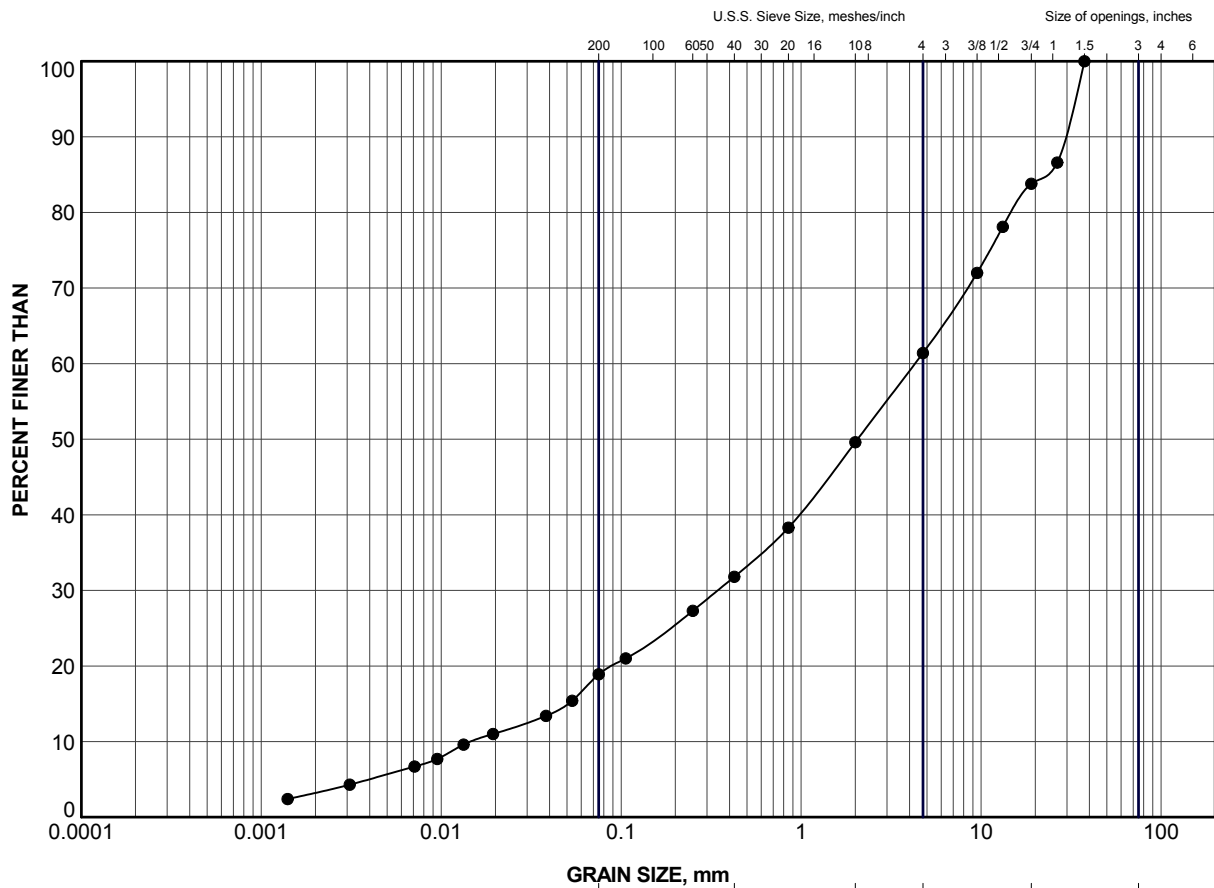


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	MC-1	3	307.5
■	MC-2	9	304.2
▲	MC-3	9	304.3


PROJECT					
HIGHWAY 102 MCINTYRE CREEK CULVERT STA 17+768					
TITLE					
GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	DAM	Apr 2015			
APPR	JMAC	Apr 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE B3		



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	MC-1	6	304.4

PROJECT					
HIGHWAY 102 MCINTYRE CREEK CULVERT STA 17+768					
TITLE					
GRAIN SIZE DISTRIBUTION SAND and GRAVEL (SEAM)					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	DAM	Apr 2015			
APPR	JMAC	Apr 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE B4		

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