



September 8, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

BRUNSVINE CREEK CULVERT - SITE NO. 45-5/C
HIGHWAY 621, DISTRICT OF RAINY RIVER
TOWNSHIP OF McCROSSON
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6329-14-00

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REPORT





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PART A

**PRELIMINARY FOUNDATION INVESTIGATION REPORT
BRUNSVINE CREEK CULVERT – SITE NO. 45-5/C
HIGHWAY 621, DISTRICT OF RAINY RIVER
TOWNSHIP OF McCROSSON
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 6329-14-00**



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 Brunsvine Creek culvert (Site No. 45-5/C). The Brunsvine Creek culvert is located in the District of Rainy River in the Township of McCrosson on Highway 621 at STA 40+216, approximately 3.0 km north of the junction of Highway 600 and Highway 621. The key plan showing the general location of this section of Highway 621 and the location of the investigated area are shown on Drawing 1.

2.0 SITE DESCRIPTION

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

In general, the topography in the culvert area is relatively flat with swampy terrain consisting of open water and tall grass/shrubs and sparse to moderate tree cover beyond the highway right-of-way. It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on the drawing. For the purposes of this report Highway 621 runs in a north-south direction with the culvert in a west-east orientation on a slight skew. At the culvert location, Brunsvine Creek flows westerly. The highway grade is at Elevation 327.4 m and the culvert invert is at approximately Elevation 322.3 m at both the inlet and outlet ends. The creek water level was at Elevation 324.0 m and 323.9 m at the inlet and outlet ends, respectively as measured by others on June 19, 2014. The creek ice level was at Elevation 323.7 m as measured by Golder on February 23, 2015. Surface conditions at the culvert inlet and outlet are shown on Photographs 1 to 3, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out on February 23, February 25 and March 19, 2015, during which time four boreholes (Boreholes BV-1 to BV-4) were advanced at approximately the locations shown on Drawing 1. Boreholes BV-1 and BV-4 were advanced at the toe of slope near the culvert outlet/inlet and Boreholes BV-2 and BV-3 were advanced from the existing highway platform. All boreholes were advanced using a track-mounted CME 55 drilling rig supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec.

The boreholes were advanced using 108 mm inside diameter hollow stem augers. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). Samples of the cohesive soils were obtained using 76 mm O.D. thin walled Shelby Tubes (ASTM D1587) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using MTO Standard 'N' size vanes. 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).



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

A sample of the creek water was obtained during the field investigation (on February 24, 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 a 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 E6496211.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)
BV-1	5426692.3	203197.8	324.7	9.8
BV-2	5426694.9	203211.8	327.5	9.8
BV-3	5426708.1	203216.5	327.4	11.3
BV-4	5426708.9	203231.8	324.5	10.5

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)¹ mapping, the subsoils in the vicinity of the Brunsvine Creek culvert site generally consist of glaciolacustrine plain deposits of clays and silts.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)², the site is underlain by bedrock of the Archean Era, comprised of bedrock from the foliated tonalite suite consisting of tonalite to granodiorite.

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

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



4.2 Subsurface Conditions

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

Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and granular fill (for boreholes advanced through the embankment), underlain by a deposit of clay. 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) / Shear Strength (kPa)	Laboratory Testing
				Relative Density or Consistency	
Asphalt	BV-2, BV-3	0.100	327.5 – 327.4	N/A	N/A
(FILL) ¹ Sand to Sand and Gravel, trace to some silt; brown; frozen	BV-1 to BV-3	0.7 – 2.0	327.4 – 324.7	N/A ²	w = 3% – 4% 2 – M (Fig. B1)
Clay ³ , trace sand, trace gravel; brown to grey; wet	BV-1 to BV-4	7.7 – 10.5 (Boreholes terminated in this deposit)	325.4 – 324.0	N = 0 (weight of hammer) – 13 s _u = 33 – > 100 S = 1 – 2	w = 22% – 50% w _l = 52% – 71% w _p = 20% – 28% I _p = 32% – 46% 6 – MH (Fig. B2) 8 – AL (Fig. B3)
				Firm to Very Stiff	

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

s_u = Undrained Shear Strength (kPa)

S = Sensitivity

w_p = Plastic Limit (%)

w_l = Liquid Limit (%)

I_p = Plasticity Index (%)



Notes:

¹ Some organics were noted within the sand fill at the toe of slope in Borehole BV-1.

² In the fill deposit, SPT 'N'-values ranging from 12 blows to 119 blows per 0.3 m of penetration were measured, however, these are likely indicative of the frozen state of the material and are not representative of the relative density of the fill. Further, two split spoons did not penetrate the entire SPT depth, inferred to be due to the frozen state of the material.

³ Sandy silt laminations were noted within the clay deposit at various depths as indicated on the Record of Boreholes sheets.

Groundwater Conditions

All boreholes were noted to be dry upon completion of drilling. The creek ice level was measured at Elevation 323.7 m on February 23, 2015. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle, under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Adam Core, P.Eng., and Mr. David Muldowney, P.Eng., 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
BRUNSVINE CREEK CULVERT - SITE NO. 45-5/C**

PART B

**PRELIMINARY FOUNDATION DESIGN REPORT
BRUNSVINE CREEK CULVERT – SITE NO. 45-5/C
HIGHWAY 619, DISTRICT OF RAINY RIVER
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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 Brunsvine Creek culvert. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation.

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

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

It is assumed that the existing Steel Plate Corrugated Steel Pipe Arch (SP CSPA) culvert will be replaced with a culvert of similar length and height dimensions, along the same alignment and at a similar invert elevation to that of the existing culvert but likely the new culvert will be much wider than the existing arch 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 621 reinstatement. We understand from the inspection reports that there is a sag in the culvert and that the top of the culvert is barely exposed above the water level, which indicates that the culvert may have experienced settlement under the embankment loading, likely due to the presence of the firm to very stiff clay deposit. In this regard, the designer may want to consider a higher invert elevation.

6.2 Foundations

6.2.1 Foundation Options

The Brunsvine Creek culvert is located in the District of Rainy River in the Township of McCrosson on Highway 621 at STA 40+216, approximately 3.0 km north of the junction of Highway 600 and Highway 621. The highway embankment is constructed of granular fill material and is approximately 5.1 m high relative to the culvert invert with approximately 2 m of cover over the existing culvert. The existing culvert consists of an SP CSPA, 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, we understand that a slight realignment of the culvert may be necessary and the following culvert types are being considered at this location:

- Twin 3.6 m wide pre-cast concrete boxes (about 7.8 m wide overall) on a new alignment;
- A 6.5 m wide open footing structure with either pre-cast concrete rectangular or arch segments; and
- A 7.7 m wide pre-cast concrete slab supported on sheet-pile abutments.



In this report we have considered the following options:

- A pre-cast concrete box culvert(s);
- An open footing rectangular or arch structure support with either cast-in-place or pre-cast footings;
- A pre-cast concrete slab supported on sheet-pile abutments; and
- A pipe culvert(s).

A pipe culvert, including an elliptical culvert and/or flexible arch culvert similar to the existing culvert configuration, is considered feasible at this site but would provide less flow-through capacity compared to box a culvert or open footing culvert with a similar span. If a pipe culvert is selected, a concrete pipe would be preferred as a structural plate of corrugated steel pipe typically has a shorter design life. A pre-cast concrete slab supported on sheet-pile abutments is also considered feasible at this site but the sheet-piles may need to be advanced to a significant depth to develop sufficient frictional forces or to penetrate into a competent stratum to develop sufficient toe resistance to meet the geotechnical axial design requirements. From a foundation perspective, a box-type culvert sufficiently wide to handle the creek flow is preferred. Although an open footing culvert is also suitable for this site, a pre-cast concrete box culvert is recommended as it can accommodate an accelerated construction schedule and there are reduced excavation, dewatering and shoring requirements. Other culvert types may be preferred due to construction staging or other considerations such as fisheries requirements related to natural channel substrate. A comparison of culvert types based on advantages, disadvantages and risks/consequences is presented in Table 2.

6.2.2 Foundation Elevations and Frost Protection

6.2.2.1 Box Culvert Replacement

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as box structure segments are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the replacement box culvert be founded on the firm to very stiff clay stratum. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3.

6.2.2.2 Open Footing Culvert Replacement

Strip footings for an open footing culvert should be founded on the firm to very stiff clay stratum at a minimum depth of 2.3 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation, Frost Penetration Depths for Northern Ontario). In addition, the footings should extend below any existing fill and/or organics, 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 generally stiff to very stiff clay deposit, as noted in Table 3.



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 stresses due to adhesion to frozen ground (as well as potential downdrag forces) can be provided at the detail design stage if this is culvert replacement option is selected.

6.2.2.4 *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 firm to very stiff clay stratum. Recommended foundation elevation and foundation conditions for a pipe culvert 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 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 a box culvert width of 8 m as provided in Table 3.

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

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

The loading on the foundation soils below the culvert and the associated settlements at the culvert location will be governed by the design height of the overlying and adjacent embankment fill, however it is assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is applicable as the settlement under the culvert 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 an assumed footing width of 0.6 m and 1.2 m as provided in Table 3.

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

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

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

6.2.3.3 Pre-Cast Concrete Slab and Sheet-Pile Abutments

The sheet-piles should be driven to/into the stiff to very stiff portion of the clay stratum at or below the founding elevation recommended in Table 3, and should be designed based on the factored unit 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/reaction provided in Table 3 are primarily based on frictional forces. 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.

The unit factored geotechnical axial resistance/reaction provided in Table 3 are primarily based on frictional forces between the sheet-pile and the subgrade soil interface material. 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/or to penetrate into a competent soils stratum to develop higher toe resistances; however, additional drilling would be required to confirm the subgrade soil conditions at greater 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 reconstructed embankment height to about 5.1 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.

Given the presence the firm to very stiff clay deposit at this site, additional long term settlement and stability analysis will be required if a grade raise and/or widening is proposed. Further, depending on the magnitude of the grade raise and/or widening, additional field work and specialized laboratory testing may be required. Given that the existing culvert and embankment appear to have settled over time, it is important that there be no additional loading on the subsoils. Even small grade raises/widening could result in time-dependent settlement as well as differential settlement.

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 2.3 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:



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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
Clay	27°	17 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 fill comprised of sand to sand and gravel and into native soils which are comprised of firm to very stiff clay. 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. 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.

6.4.2 Excavation and Replacement Below Culvert

Prior to placement of any bedding material, engineered fill or concrete, any organics (including topsoil, peat or mixed organic materials), if encountered, and any softened 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 (Pre-cast 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 I, 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 in accordance with OPSS 422 (Pre-cast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the adjacent granular fill 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 standard Proctor maximum dry density (SPMDD) as specified in OPSS.PROV 501 (Compacting). In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided with a geometry similar to that presented in OPSS 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction in dry conditions.

Given the height of the existing embankment (i.e., 5.1 m relative to the culvert invert) and the relatively low frost susceptibility of the granular fill, a frost taper may not be required provided the top of the culvert is established below the 2.3 m frost penetration depth. Where the top of culvert extends above the 2.3 m frost penetration depth, a frost taper should be constructed in a similar configuration as that shown in OPSS 803.010 (Backfill and Cover for Concrete Culverts). Although OPSS 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 8 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 2.3 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.

Given the height of the existing embankment (i.e., 5.1 m relative to the culvert invert) and the relatively low frost susceptibility of the granular fill, a frost taper may not be required provided the top of the culvert is below the



2.3 m frost penetration depth. Where the top of the culvert extends above the 2.3 m frost penetration depth, 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 9 m 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.

Given the height of the existing embankment (i.e., 5.1 m relative to the culvert invert) and the relatively low frost susceptibility of the granular fill, a frost taper may not be required provided the top of the culvert is below the 2.3 m frost penetration depth. Where the top of the culvert extends above the 2.3 m frost penetration depth, a frost taper should be constructed in accordance with OPSD 803.031 (Frost Treatment)

6.4.3.4 Backfill

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

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

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

6.4.4 Subgrade Protection

The native clay subgrade 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 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. 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 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. Given the relatively wide configuration of the creek stream at the culvert inlet, a clay blanket will likely not be practical at this culvert site.

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

6.4.6 Control of Groundwater and Surface Water

Excavation along the culvert alignment will be required to remove the existing fill, organic materials where present and some of the native clay stratum to achieve the required invert/bedding level prior to placement of bedding, the actual culvert, backfill and roadway pavement structure. Groundwater flow into the excavation can be expected due to the depth of the excavations and the presence of relatively permeable embankment fill. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

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



Excavations for box, open footing and pipe culvert options will extend below the creek water level and may therefore require temporary shoring with unwatering to allow for construction/placement of the footings and/or placement of bedding material in dry conditions, where required. Although the open boreholes were noted to be dry upon completion of drilling, it is likely that the groundwater level is near ground surface, but discharge of groundwater into open excavations will be slow and of limited volume, and the need for dewatering will be limited. Temporary shoring and groundwater control 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 and to prevent base heaving of the foundation subgrade.

Dewatering of all excavations, if required, 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 groundwater and surface flow rate into the excavation would be dependent on construction methods adopted by the contractor. However, it is considered that groundwater pumping volumes would not exceed 50 m³/day either during initial drawdown stages nor during periods of precipitation provided that surface water flows are directed away from the open excavations. At this time it is considered that a Permit to Take Water (PTTW) would be not be required, but such a requirement should be confirmed at the detail design stage of the project.

6.4.7 Analytical Testing for Construction Materials

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

6.5 Recommendations for Further Work During Detail Design

During the detail design phase, additional field investigation and testing may be required, based on the final configuration and/ 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 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 open lane of traffic during construction. The scope and results of this investigation must be reviewed at the time of the detail design to determine if they meet the then-current MTO requirements for the culvert type or staging strategy under consideration, and if additional investigation and analysis is necessary. 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. Mr. Jorge M. A. Costa, P.Eng., the Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.

**PRELIMINARY FOUNDATION REPORT
BRUNSVINE CREEK CULVERT - SITE NO. 45-5/C**

Report Signature Page

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PRELIMINARY FOUNDATION REPORT BRUNSVINE CREEK CULVERT - SITE NO. 45-5/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 2542.

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

ASTM International:

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

ASTM D1587 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

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

Ontario Provincial Standard Specifications (OPSS)

OPSS 421 Construction Specification for Pipe Sewer Installation in Open Cut

OPSS 422 Construction Specification for Pre-cast 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

BRUNSVINE CREEK CULVERT - SITE NO. 45-5/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 BRUNSVINE CREEK CULVERT - SITE NO. 45-5/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)	West End of Culvert (m)	East End of Culvert (m)
Hwy 621 STA 40+216 (Township of McCrosson)	45-5/C	5.1	SP CSPA	3.1 m wide x 2.1 m high	35	322.3	322.3

- 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 E6496211.dwg).

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



**PRELIMINARY FOUNDATION REPORT
BRUNSVINE CREEK CULVERT - SITE NO. 45-5/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 for faster construction resulting in shorter duration for dewatering and surface water pumping. ■ More tolerant of total and differential settlement due to frost penetration into the subgrade soils and if the highway embankment is raised or widened at the culvert site ■ Backfill/bedding under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements. 	<ul style="list-style-type: none"> ■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Cut-off wall (or clay seal) typically 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 creek channel. 	<ul style="list-style-type: none"> ■ Some risk of disturbance of the native clay 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. ■ Existing culvert can be used for water diversion while new footings are being constructed adjacent to the culvert. ■ Would likely satisfy fisheries requirements related to natural channel substrate, but will require regrading of channel bottom under existing arch culvert and excavation of embankment/subgrade for widening. ■ Readily suitable for construction using concrete or metal sections. 	<ul style="list-style-type: none"> ■ Excavation depths 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 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. 	<ul style="list-style-type: none"> ■ High risk of disturbance of the native clay 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. ■ Risk of additional settlement for footings due to the smaller foundation footprint. ■ Culvert joints may be required to accommodate total and differential settlement. ■ Will likely require excavation/regarding into channel bottom.



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BRUNSVINE CREEK CULVERT - SITE NO. 45-5/C**

Option	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Slab and Sheet-pile Abutments	<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 along 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 on the sheet-piles and/or heave due to adhesion during frozen ground conditions). ■ Potential difficulties in driving/vibrating sheet-piles due to disturbance of the native clay deposit. ■ May require additional deeper boreholes to assess adequacy of subsurface soils for potentially higher bearing capacities, if required. ■ Steel sheet-piles may not have as long of a design life compared to concrete options. 	<ul style="list-style-type: none"> ■ High risk that additional sheet-pile lengths will be required to achieve sufficient geotechnical axial resistance/reaction. ■ Some risk that additional sheet-pile lengths may be required due to disturbance of the subsurface soils during sheet-pile installation. ■ Joints may need to be incorporated into the slab to accommodate total and differential settlement.
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 seal) may be required at inlet to mitigate potential scour under culvert. ■ CSP does not have as long of design life compared to concrete options. ■ Difficult to compact backfill materials to level of culvert springline. 	<ul style="list-style-type: none"> ■ Some risk of disturbance of the native clay 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.



PRELIMINARY FOUNDATION REPORT BRUNSVINE CREEK CULVERT - SITE NO. 45-5/C

**Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box, Open Footing Culverts and Pre-Cast Concrete Slab on Sheet-pile
Abutments Replacement Culverts**

Culvert Location (Township)	Approximate Invert Elevation ¹	Culvert Type	Approximate Backfill/Bedding or Footing Founding Elevation	Founding Condition	Factored Geotechnical Axial Resistance at ULS	Geotechnical Reaction at SLS for 25 mm of Settlement
Hwy 621 STA 40+216 (Township of McCrosen)	322.3 m	Pre-Cast Box ²	321.9 m	Bedding on Firm to Very Stiff Clay Stratum	100 kPa	75 kPa
		Open Footing ²	320.0 m	Firm to Very Stiff Clay Stratum	100 kPa	75 kPa
		Pipe Culvert	322.0 m	Bedding on Firm to Very Stiff Clay Stratum	N/A	N/A
	N/A	Pre-Cast Slab on Sheet-pile Abutments ³	~ 315.0 m	Firm to Very Stiff Clay Stratum	45 kPa ³	35 kPa ³

- Notes:
1. Culvert invert elevation is based on the profile drawings provided by MTO (Drawing E12736191.dwg).
 2. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS (for 25 mm of settlement) are estimated based on an approximately 8 m wide box culvert (as proposed by HMM) and an assumed 0.6 m or 1.2 m wide open footing. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the foundation widths differ from those given above.
 3. 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. The recommended unit geotechnical resistance/reaction do not account for adhesion (due to frost heave) or downdrag (due to settlement associated with grade raises or embankment widening). The unit geotechnical axial resistance/reaction should be reviewed once the culvert alignment (sheet-piling alignment) is finalized.

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



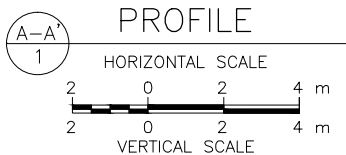
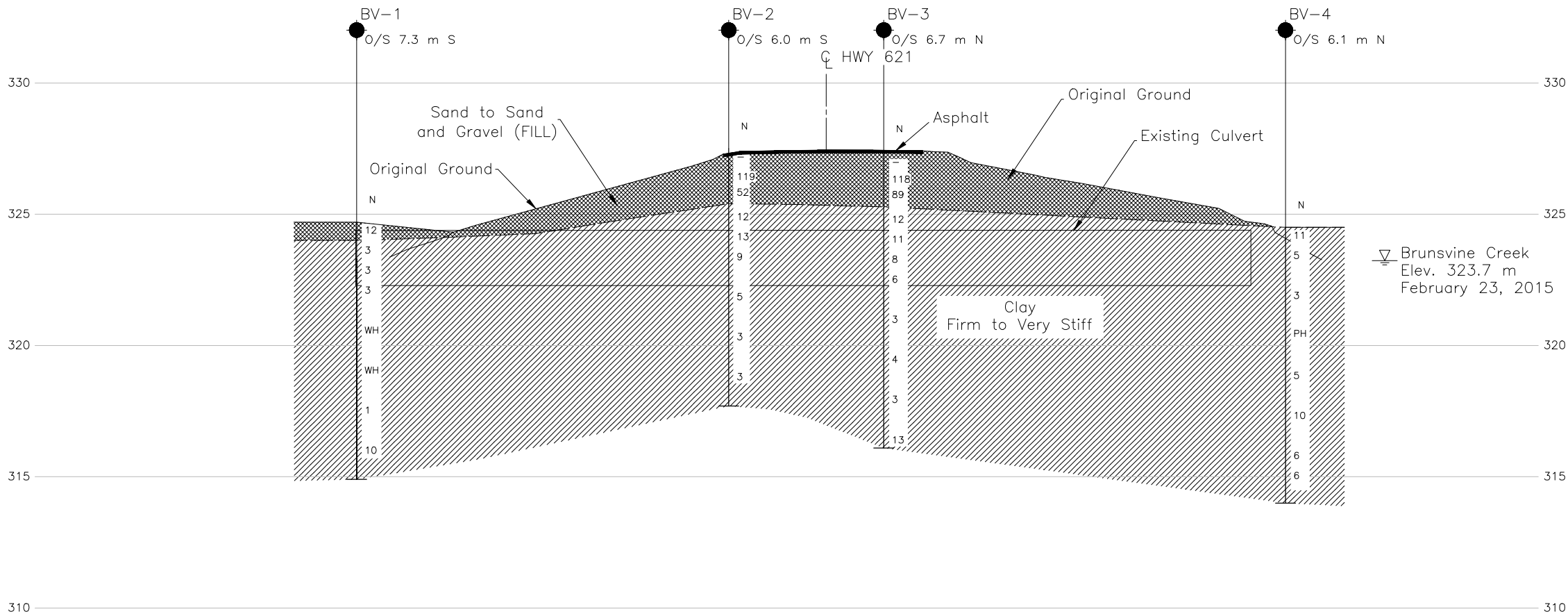
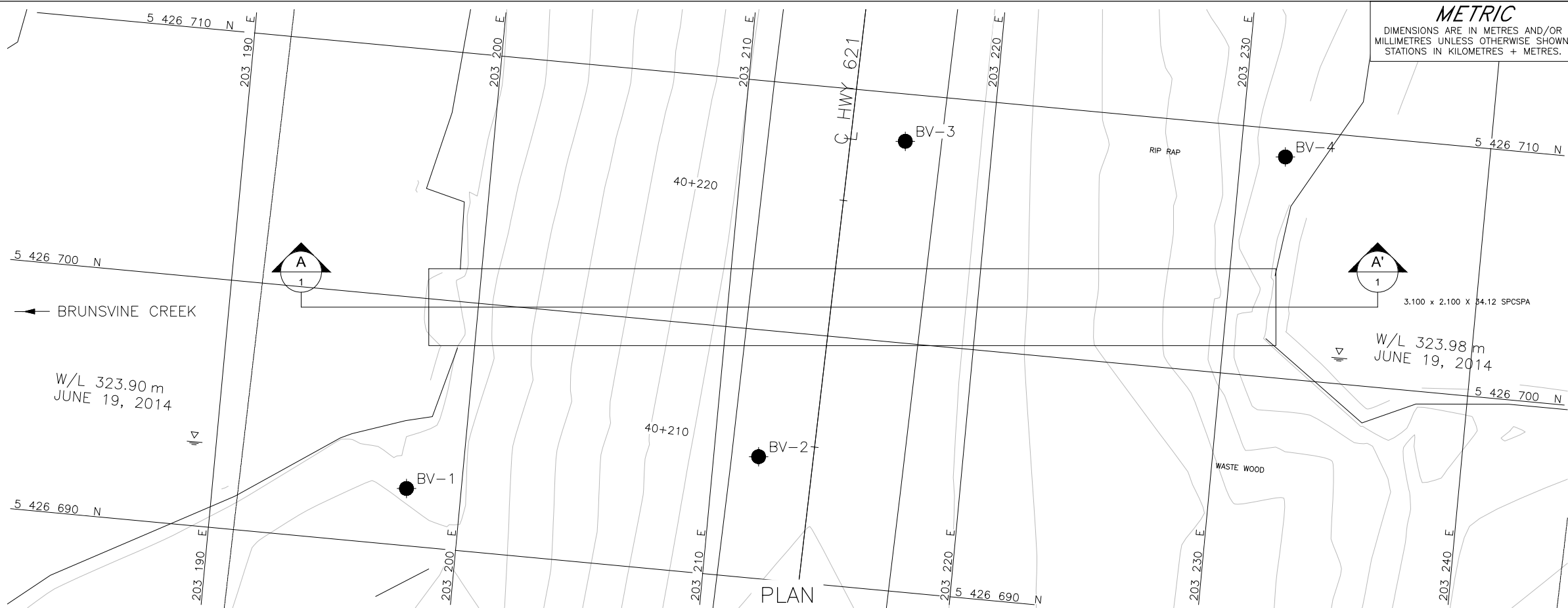
PRELIMINARY FOUNDATION REPORT BRUNSVINE CREEK CULVERT - SITE NO. 45-5/C

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

Culvert Location (Township)	Pre-Cast Box or Open Footings		Cast-in-place Open Footing	
	Interface Material	Coefficient of Friction ¹ (tan δ)	Interface Material	Coefficient of Friction ¹ (tan δ)
Hwy 621 STA 40+216 (Township of McCrosson)	Compacted Granular Fill (Backfill or Levelling Pad)	0.45	Firm to Very Stiff Clay	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



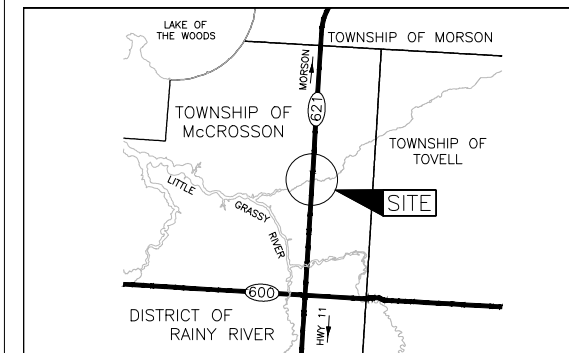
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. .
GWP No. 6329-14-00



HIGHWAY 621
BRUNSVINE CREEK CULVERT STA 40+216
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



LEGEND

- Borehole
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)
- ▽ WL upon completion of drilling - Dry

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
BV-1	324.7	5426692.3	203197.8
BV-2	327.5	5426694.9	203211.8
BV-3	327.4	5426708.1	203216.5
BV-4	324.5	5426708.9	203231.8

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. E6496211, received FEB 20, 2015.

NO.	DATE	BY	REVISION
Geocres No. 52E-58			
HWY. 621	PROJECT NO. 1411523		DIST. .
SUBM'D. AC	CHKD. DAM	DATE: 8/26/2015	SITE: 45-5/C
DRAWN: JJL	CHKD. .	APPD. JMAC	DWG. 1





PHOTOGRAPHS

**Photograph 1: Brunsvine Creek Culvert
East End – Inlet (HMM taken November 2014)**



**Photograph 2: Brunsvine Creek Culvert
West End – Outlet (HMM taken November 2014)**





PHOTOGRAPHS

**Photograph 3: Brunsvine Creek Culvert
Looking at East End - Inlet (Golder – March 18, 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

[illegible]

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

[illegible]

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

PROJECT 1411523			RECORD OF BOREHOLE No BV-3			1 OF 1 METRIC																				
G.W.P. 6329-14-00			LOCATION N 5426708.1; E 203216.5			ORIGINATED BY MR																				
DIST _____ HWY 621			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY AC																				
DATUM GEODETIC			DATE February 23, 2015			CHECKED BY DAM																				
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)											
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					W _p W W _L			WATER CONTENT (%)			γ			GR SA SI CL				
327.4	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60																
0.0	ASPHALT (100 mm)		1	AS	-		327																			
0.1	Sand, trace to some gravel to sand and gravel, trace to some silt (FILL) Brown Frozen		2	SS	118																					
			3	SS	89/0.15		326																			
325.3	CLAY Firm to very stiff Brown to grey Wet		4	SS	12		325																			
2.1	Sandy silt laminations between 2.1 m and 5.6 m depth.		5	SS	11		324																			
			6	SS	8		323																			
			7	SS	6		322																			
			8	SS	3		321																			
			9	SS	4		320																			
			10	SS	3		319																			
			11	SS	13		318																			
316.1	END OF BOREHOLE						317																			
11.3	Note: 1. Borehole dry upon completion of drilling.																									

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 06/05/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No BV-4				1 OF 1 METRIC								
G.W.P. 6329-14-00		LOCATION N 5426708.9; E 203231.8				ORIGINATED BY MR								
DIST HWY 621		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC								
DATUM GEODETIC		DATE March 19, 2015				CHECKED BY DAM								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
324.5 0.0	GROUND SURFACE CLAY Firm to very stiff Brown to grey Frozen* to wet Trace to some organics in the upper 1.5 m.		1	SS	11*		324							
			2	SS	5		323							
							322							
			3	SS	3		321							
							320							
			4	TO	PH		319							
							318							
			5	SS	5		317							
							316							
			6	SS	10		315							
		7	SS	6										
		8	SS	6										
314.0 10.5	END OF BOREHOLE Notes: 1. Borehole dry upon completion of drilling. 2. Advanced additional borehole 0.2 m north of Borehole BV-4 to obtain Shelby Tube sample at 2.3 m depth and additional field vanes at 3.4 m and 3.7 m depths (Italics).						314							

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 06/05/15 DATA INPUT:



APPENDIX B

Laboratory Test Results



PRELIMINARY FOUNDATION REPORT BRUNSVINE CREEK CULVERT - SITE NO. 45-5/C

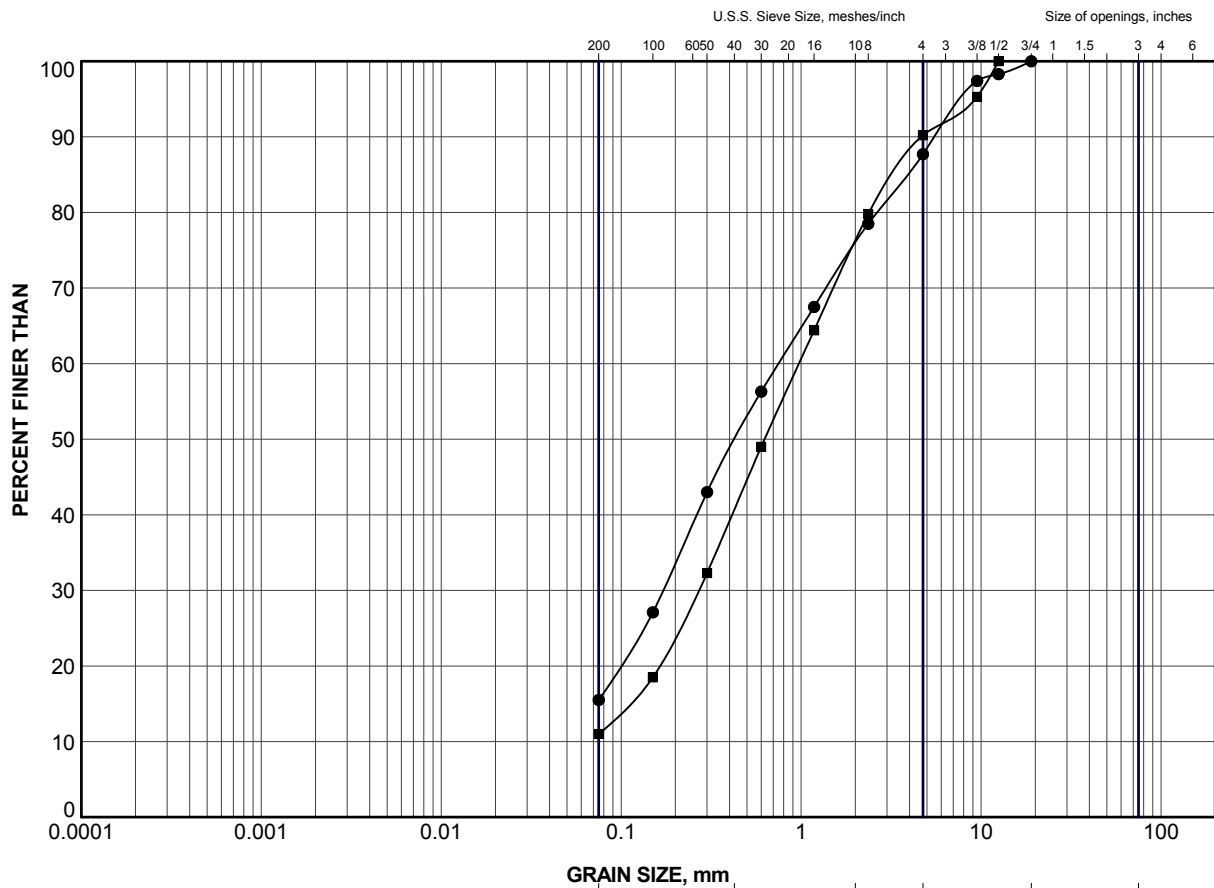
Table B1: Summary of Analytical Testing of Brunsvine Creek Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	30.3
Sulphate (SO4)	mg/L	0.71
Conductivity (EC)	µS/cm	817
Resistivity	µohm-cm	<0.33
pH	n/a	7.29

Notes:

1. Sample obtained on February 24, 2015.
2. Analytical testing carried out by ALS Canada Ltd.


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

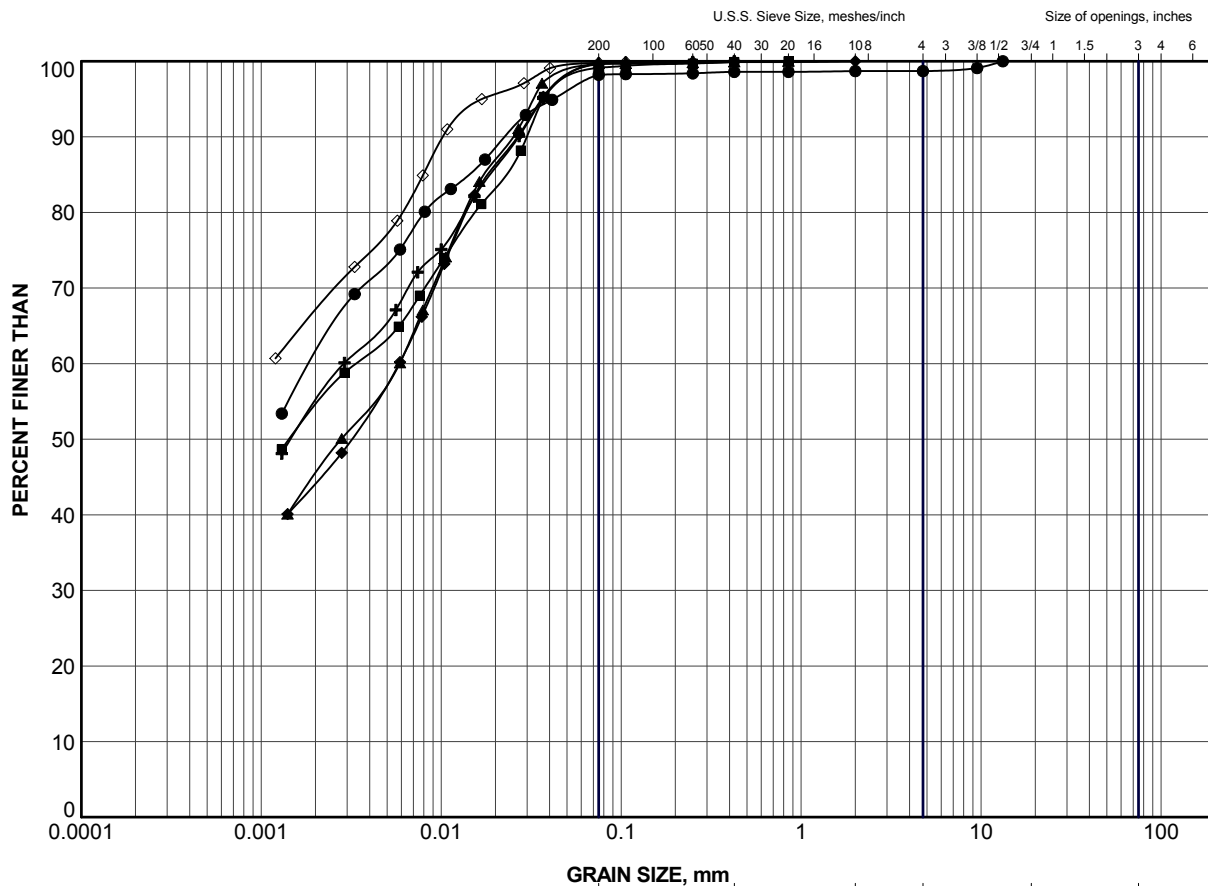


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BV-2	2	326.4
■	BV-3	3	325.8

PROJECT					
HIGHWAY 621 BRUNSVINE CREEK CULVERT STA 40+216					
TITLE					
GRAIN SIZE DISTRIBUTION 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		



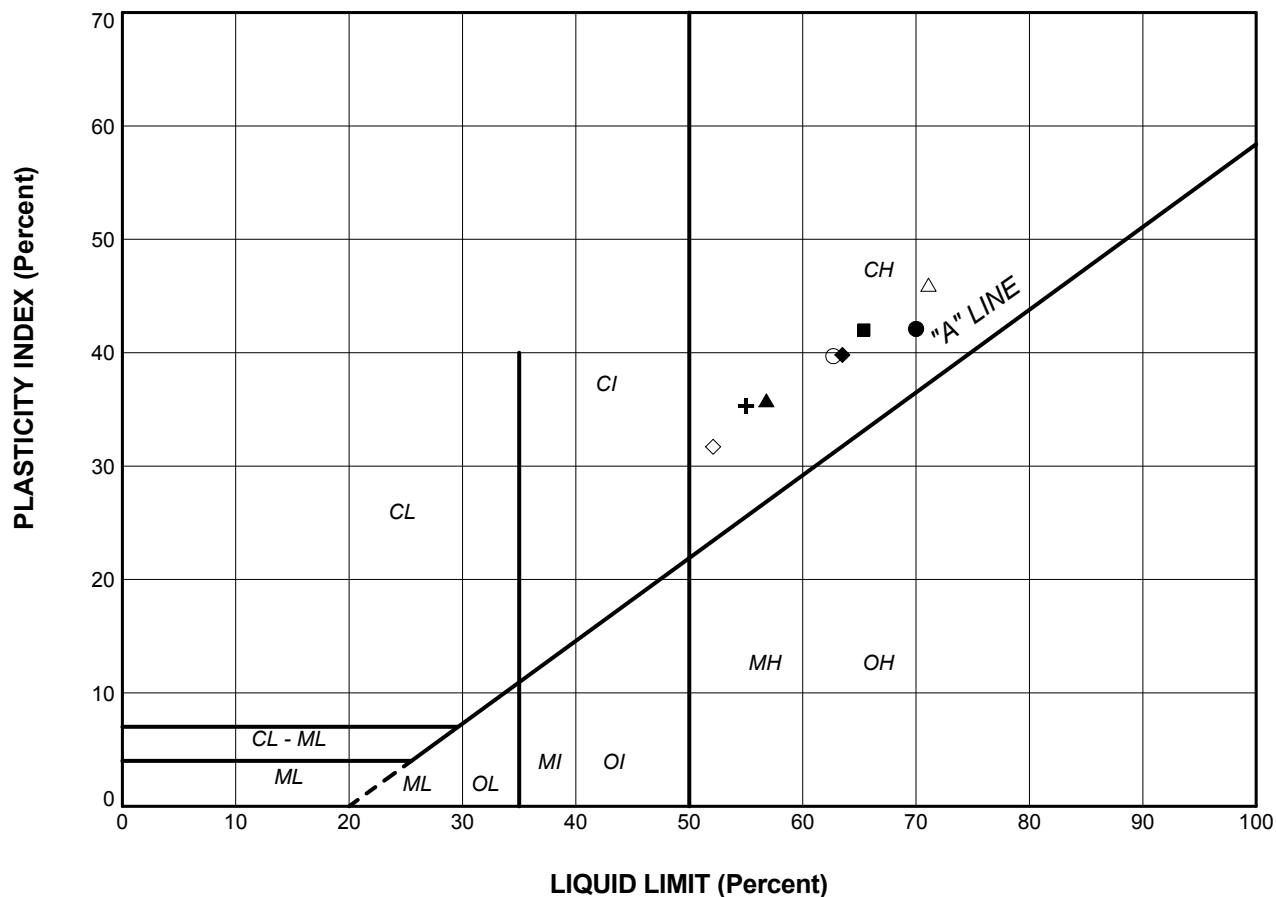
CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BV-1	4	322.1
■	BV-2	6	323.4
▲	BV-2	9	318.8
+	BV-3	6	323.3
◆	BV-3	9	319.5
◇	BV-4	6	317.3

PROJECT					
HIGHWAY 621 BRUNSVINE CREEK CULVERT STA 40+216					
TITLE					
GRAIN SIZE DISTRIBUTION CLAY					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	DAM	Apr 2015			
APPR	JMAC	Apr 2015			
			FIGURE B2		





LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BV-1	4	70.0	27.9	42.1
■	BV-1	7	65.4	23.4	42.0
▲	BV-2	6	56.8	21.0	35.8
+	BV-2	9	55.0	19.7	35.3
◆	BV-3	6	63.5	23.7	39.8
◇	BV-3	9	52.1	20.4	31.7
○	BV-4	3	62.7	23.0	39.7
△	BV-4	6	71.1	25.1	46.0

PROJECT					
HIGHWAY 621 BRUNSVINE CREEK CULVERT STA 40+216					
TITLE					
PLASTICITY CHART CLAY					
PROJECT No.		1411523		FILE No.	
DRAWN		J.J.L.		Apr 2015	
CHECK		DAM		Apr 2015	
APPR		JMAC		Apr 2015	
SCALE		N/A		REV.	
Golder Associates SUDBURY, ONTARIO		FIGURE B3			

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

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