

Foundation Investigation and Design Report, (GWP 6327-14-00) Replacement of Brusvine Creek Culvert, Highway 621 Near Rainy River, Northwest Region, Site No. 45-005C

Agreement 3014-E-0025
Geocres No. 52-E-63

Prepared for:
Ministry of Transportation
West Region
659 Exeter Road
London ON N6E 1L3

Reviewed by:
Stantec Consulting Ltd.
200 – 835 Paramount Drive
Stoney Creek ON L8J 0B4

Prepared by:
Amec Foster Wheeler Americas Ltd.
3215 North Service Road
Burlington ON L7N 3G2



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BRUSVINE CREEK CULVERT, HIGHWAY 621 NEAR RAINY RIVER, NORTHWEST REGION, SITE
NO. 45-005C

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DRAWINGS

DRAWING 1 Borehole Locations and Soil Strata

LIST OF APPENDICES

Appendix A:	Record of Boreholes from Previous Investigations
Appendix B:	Laboratory Test Results from Previous Investigation
Appendix C:	Non-Standard Special Provisions (NSSPs)

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PART A

DETAIL FOUNDATION INVESTIGATION REPORT REPLACEMENT OF BRUSVINE CREEK CULVERT HIGHWAY 621 NEAR RAINY RIVER NORTHWEST REGION

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1.0 Introduction

The Ontario Ministry of Transportation (MTO) retained Stantec Consulting Ltd. (Stantec) to complete the Detail Design and Class Environmental Assessment (Class EA) for the rehabilitation or reconstruction of 17 structures on Highway 11, 17, 61, 599, 619 and 621 in Northwestern Ontario, under a number of separate group work projects (GWPs) and contracts. The Stantec team is supplemented by Amec Foster Wheeler Americas Limited, operating as Amec Foster Wheeler Environment & Infrastructure (Amec Foster Wheeler).

This report addresses the results of the geotechnical analyses carried out by Amec Foster Wheeler on behalf of Stantec for the proposed replacement of the existing Brusvine Creek Culvert, Site Number 45-005C on Highway 621.

The terms of reference and scope of work for the foundation engineering services are outlined in MTO's Request for Proposal (RFP) and associated Addendum and clarification responses for Assignment No. 3014-E-0025 and in Section 17.8 of the *Technical and Financial Proposal* for this assignment.

2.0 Site Description

The existing culvert is located on Highway 621 approximately 3 km north of the intersection of Highway 600 and Highway 621 within the township of McCrosson in the Old County of Kerona, Ontario.

The existing Steel Plate Corrugated Steel Pipe Arch (SP CSPA) culvert which was constructed in 1978 is about 35 m long with a diameter of about 3.0 m.

In general, the terrain in this area is relatively flat, with swampy areas consisting of open water and tall shrubs, and sparsely to moderately treed areas outside of the highway right-of-way.

Highway 621 in the vicinity of the project site runs in the north-south direction and the existing culvert runs in the west-east direction on a slight skew. The highway grade in the area is at about Elevation 327.4 m and the invert of the existing culvert is at about Elevation 322.3 m which infers an embankment height of about 5.1 m at the site.

The creek water elevation was at about 324.0 m and 323.9 m at the inlet and outlet ends of the culvert in June 2014, as reported by others.

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3.0 Investigation Procedure

3.1 PREVIOUS INVESTIGATIONS

A borehole investigation was completed at this structure site in February and March 2015 by Golder Associates Ltd. (Golder), as presented in a report titled "Preliminary Foundation Investigation and Design Report, Brusvine 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" and dated September 8, 2015. The final report was provided to Amec Foster Wheeler by MTO to assist with the preparation of this detail design report.

Four boreholes (Boreholes BV-1 to BV-4) were drilled at the site as part of the 2015 investigation as shown on Drawing 1. Boreholes BV-1 and BV-4 were advanced at the toe of the slope near the culvert outlet and inlet and Boreholes BV-2 and BV-3 were advanced from the existing highway platform. All boreholes were advanced using a CME drilling rig.

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).

Index and classification testing consisting of moisture 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 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:

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Borehole Designation	Location (MTM NAD83 Zone 15)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
BV-1	5,426,692.3	203,197.8	324.7	9.8
BV-2	5,426,694.9	203,211.8	327.5	9.8
BV-3	5,426,708.1	203,216.5	327.4	11.3
BV-4	5,426,708.9	203,231.8	324.5	10.5

4.0 Geological and Subsurface Conditions

4.1 SITE GEOLOGY

The Northern Ontario Engineering Geology Terrain Study (NOEGTS) Map 52ESE indicates that the surficial soil in the vicinity of the culvert consists of glaciolacustrine deposits of silt and clay. The geological mapping by the Ministry of Northern Development and Mines (MNDM) Map 2542 indicates that the surficial soil is underlain by bedrock of Archean Era, comprised of foliated tonalite suite consisting of tonalite to granodiorite.

4.2 SUBSURFACE CONDITIONS

Four (4) boreholes (referenced as Boreholes BV-1 to BV-4, herein) were advanced in the vicinity of the existing culvert as part of the 2015 investigation. Amec Foster Wheeler discussed the locations, depths and soils strata for the 2015 boreholes with MTO Foundations and it was mutually agreed that the existing borehole information satisfied the requirements of the Terms of Reference, and that no additional boreholes were needed to supplement the existing subsurface information for this culvert replacement.

The approximate borehole locations, ground surface elevations and interpreted stratigraphic conditions based on the investigation at the site are presented on Drawing 1 and are included in Appendix A. The results of geotechnical laboratory testing from the investigation are presented in Appendix B.

The surficial soil at the site consisted of sand fill at the location of Borehole BV-1, asphalt and granular fill at the locations of Boreholes BV-2 and BV-3 which were advanced through the highway embankment, and clay at the location of Borehole BV-1. In all of the boreholes the surficial soil is underlain by a firm to very stiff clay of high plasticity which extended to the borehole termination depths.



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4.2.1 Asphalt

An approximately 100 mm thick layer of asphalt was encountered at the surface in Boreholes BV-2 and BV-3, which were advanced through the existing Highway 621 pavement structure.

4.2.2 Fill

Sand fill consisting of trace to some silt and gravel was encountered below the asphalt in Boreholes BV-2 and BV-3 and at the surface in Borehole BV-1 and extended to a depth of 2.1 m (Elevations 325.4 m and 325.3 m, respectively) in Boreholes BV-2 and BV-3 and to a depth of 0.7 m (Elevation 324.0 m) in Borehole BV-1.

The Standard Penetration Test (SPT) 'N' values within the sand fill ranged from 12 blows per 0.3 m of penetration to 89 per 0.15 m of penetration, indicating that the sand fill is compact to very dense. The presence of frozen ground may have contributed to the high SPT 'N' values for some of the SPTs.

Moisture contents measured for two recovered fill samples ranged from approximately 3% to 5%. The results of the grain size distribution tests conducted on selected samples of the sand fill are presented on the borehole records in Appendix A, and in Appendix B and are summarized herein:

Gravel	10 % to 12 %
Sand	72 % to 79 %
Silt and Clay	11 % to 16 %

4.2.3 Clay

A deposit of brown to grey clay containing laminations of sandy silt was encountered below the fill in all boreholes and extended to the borehole termination depths of 7.7 m to 10.5 m (Elevations 325.4 m to 325.0 m).

The SPT 'N' values within the deposit range from 0 (i.e., weight of hammer) to 13 blows per 0.3 m of penetration. In situ vane testing was conducted in this deposit and the measured undrained shear strengths ranged from 33 kPa to greater than 100 kPa indicating that the clay has a firm to very stiff consistency. The in-situ sensitivity values based on the ratio of undisturbed and remolded shear vane strengths range between 1 and 2.

Moisture contents measured for the recovered samples of clay ranged from approximately 30% to 50%. The results of the grain size distribution tests conducted on selected samples of the clay are presented on the borehole records in Appendix A, in Appendix B, and are summarized as follows:



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Gravel	0 % to 1 %
Sand	0 % to 1 %
Silt	33 % to 56 %
Clay size fines	44 % to 67 %

Atterberg limits testing carried out on selected samples of the clay measured plastic limits of 20 % to 28 % and liquid limits of 52 % to 71 % suggesting that the clay is highly plastic (CH). The test results are plotted on a plasticity chart on Figure B3 in Appendix B.

4.3 GROUNDWATER CONDITIONS

All boreholes were reported dry upon completion of drilling. The creek ice level was reported to be at about Elevation 323.7 m on February 23, 2015.

The groundwater, and creek water and creek ice levels should also be expected to fluctuate seasonally and should be expected to rise during wet periods of the year.

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5.0 Closure

This Foundation Investigation Report was prepared by Mr. Mehdi Mostakhdemi, M.Sc., P.Eng., a geotechnical engineer at Amec Foster Wheeler. Mr. Ty Garde, M.Eng., P.Eng., a Designated Foundation Contact for Amec Foster Wheeler, conducted an independent review of the report.

Sincerely,

Amec Foster Wheeler Environment & Infrastructure
a Division of Amec Foster Wheeler Americas Limited

Amec Foster Wheeler Americas Ltd.

Report prepared by:



Mehdi Mostakhdemi, M.Sc., P.Eng.
Geotechnical Engineer

Amec Foster Wheeler Americas Ltd.

Report reviewed by:



Ty Garde, M.Eng., P.Eng.
Designated MTO Foundations Contact

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PART B

FOUNDATION DESIGN REPORT REPLACEMENT OF BRUSVINE CREEK CULVERT HIGHWAY 621 NEAR RAINY RIVER NORTHWEST REGION

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6.0 Discussion and Engineering Recommendations

6.1 GENERAL

This section of the report provides foundation design recommendations for the proposed replacement of the Brusvine Creek culvert located on Highway 621 within the township of McCrosson in the Old County of Kenora, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the preliminary subsurface investigation at this site. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess foundation alternatives and to carry out the design of the structure foundations. Where comments are made on construction, they are provided to highlight those aspects that could affect the 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 understood that the existing CSP culvert will be replaced with a similar culvert to be located about 9 m north of the existing culvert. It is also understood that an embankment grade raise and/or a widening are not proposed at the location of the culvert as part of the improvements on Highway 621.

6.2 FOUNDATIONS FOR CULVERT REPLACEMENT

The existing Brusvine Creek culvert is a Steel Plate Corrugated Steel Pipe Arch (SP CSPA) culvert, about 35 m long with a diameter of about 3.0 m. The highway grade in the area is at about Elevation 327.4 m and the invert of the existing culvert is at about Elevation 322.3 m.

Based on the subsurface conditions at this site, pipe culvert, open footing culvert and box culvert options have been considered for the proposed replacement of the existing culverts at the site. A summary of the advantages and disadvantages associated with each option is provided below, and a comparison of the alternative foundation options based on advantages, disadvantages, risks and relative costs is provided in Table 1 following the text of this report.

- **Pipe Culvert:** A pipe culvert is feasible for the replacement culvert but would provide less flow through capacity compared to other alternatives. A SP CSPA culvert similar to the existing culvert at the site also provides a shorter design life compared to a concrete pipe.
- **Open Footing Culvert:** An open footing culverts is feasible for the replacement culvert but would provide less flow through capacity compared to a box culvert. Therefore, deeper excavation would be required for this option compared to a box culvert, which

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would result in increased excavation support requirements as well as increased volumes of soil for disposal.

- **Box Culvert:** A Precast Concrete Box culvert would be the most feasible option due to its relatively high flow-through capacity, reduced depth of excavation and reduced spoil disposal volumes, as well as a lower volume of dewatering (groundwater control) during construction. Precast box culvert segments are more tolerant of differential settlement if the highway embankment is widened in the future.

Based on the above considerations, the preferred option from a geotechnical/foundations perspective is to replace the existing culvert with a precast concrete box culvert.

The applicability and final selection of the replacement culvert type will be the responsibility of the drainage, highway and structural engineers. Based on the information provided to us at the time of preparation of this report, it is understood that the culvert will be replaced by a round Corrugated Steel Pipe (CSP). In this case, reference should be made to the foundation engineering recommendations provided in the following sections of this report regarding settlement performance, bedding, backfill, and construction considerations.

Based on the General Arrangement drawing for the replacement culvert, the new culvert will be constructed approximately 9 m north of the existing creek. The new bed will be at about Elevation 322.1 m across the length of the culvert. The diameter of the proposed CSP culvert will be about 3.6 m and the culvert will about 35.8 m long. It is also understood that the Highway grades in the vicinity of the culvert will not change.

The General Arrangement drawing indicates that the preferred option is to replace the existing culvert with a round CSP culvert. However, an open footing concrete culvert or a box culvert structure are also considered feasible for the replacement of the existing culvert and recommendations for the three options are provided in the following sections.

6.2.1 Round CSP Culvert Replacement

It is understood that a round CSP will likely be selected for the proposed culvert replacement. In this case, reference should be made to the discussion regarding the pipe manufacturer's requirements regarding bedding and backfill (Section 6.3), and construction considerations (Section 6.7).

6.2.2 Open Footing Culvert and Wingwalls

Strip footings for an open footing culvert replacement, and for any associated concrete wing walls/retaining walls, should be founded at a minimum depth of 2.3 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per Ontario



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Provincial Standard Drawing (OPSD) 3090.100 (Foundation Frost Depths for Northern Ontario). In addition, the footings should extend below any existing fill and surficial organic materials, where present, as these materials are not considered to be competent to support the foundations. Assuming the creek bed has a minimum elevation of 322.4 m, strip footings would be required to be founded at a maximum elevation of 320.1 m. The clay subgrade material will be susceptible to both frost action (freeze, thaw) and heave/settlement. To protect the founding subgrade from frost penetration, a suitable amount of insulation would be required, extending out laterally from the footing. Even if partial or full sub-excavation of the clay deposit to the frost depth is carried out, the footings may still be subject to frost heave if the material becomes saturated (depending on creek water levels), which may occur differentially along the footings or across the culvert (i.e., between the footings on the north and south sides). Further, if the fill material is placed subaqueously (i.e., below the water level), the footings/culvert may be subject to additional settlement if adequate compaction of the engineered fill is not achieved.

Based on the borehole information, strip footings at this elevation will be founded in the firm to stiff clay. For 0.6 m wide and 1.2 m wide strip footings placed on properly prepared subgrade, at the approximate founding elevation of 320.1 m, a factored geotechnical resistance (assuming an ultimate geotechnical resistance factor of 0.5 for a typical degree of understanding) at Ultimate Limit States (ULS) of 150 kPa may be used in the design. As no substantial additional loads are anticipated at the proposed culvert replacement, the settlement of the foundation soils is estimated to be less than 25 mm. A factored geotechnical resistance (assuming a serviceability geotechnical resistance factor of 0.8 for a typical degree of understanding) at Serviceability Limit States (SLS) of 120 kPa may be used in the design.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances/reactions should, therefore, be reviewed if the selected footing width or founding elevation differs significantly from those given above. The geotechnical resistances/reactions provided above are given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.10.4 of the Canadian Highway Bridge Design Code (CHBDC) 2014.

The footing subgrade should be cleaned of any loosened / softened material and inspected by qualified geotechnical personnel, to check that all existing fill and surficial organic soils or other unsuitable materials have been removed and to confirm the adequacy of the foundation conditions for the design geotechnical resistance.

The footing subgrade will be susceptible to loosening and degradation on exposure to water and construction traffic. It is recommended that a concrete working slab (mudslab) be placed on the inspected and approved footing subgrade within four hours of inspection, to protect the subgrade from degradation and to form a working mat for construction of the foundations. The subgrade should also be protected from freezing.



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6.2.3 Box Culvert

Rigid box structures can tolerate small magnitudes of movements (settlement and heave) related to the freeze-thaw actions and therefore, box culverts could be founded above the standard depth for frost penetration depth. However, box culverts should be founded below any existing fill and surficial organic materials as they typically undergo larger amounts of settlements. In addition, box culverts should be provided with at least 300 mm of OPSS.PROV 1010 Granular A material for bedding purposes, as discussed in Section 6.2.4 of this report.

The factored geotechnical resistance at Ultimate Limit States (ULS) for the culverts will be controlled by both the combined shear strength of the granular bedding, where present, and the native clay, which is generally stiffer at the subgrade level but firm at a relatively shallow depth below that level; therefore, the failure mechanism would be one of potential 'punching' failure through the shallower materials into the firm clay. Based on the borehole data, and assuming a bearing width of 3 m, the factored ULS geotechnical resistance (assuming an ultimate geotechnical resistance factor of 0.5 for a typical degree of understanding) may be taken as 160 kPa. As no substantial additional loads are anticipated at the proposed culvert replacement, the settlement of the foundation soils is estimated to be less than 25 mm. A factored geotechnical resistance (assuming a serviceability geotechnical resistance factor of 0.8 for a typical degree of understanding) at Serviceability Limit States (SLS) of 125 kPa may be used in the design. The ULS resistance and SLS settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the founding elevation differs significantly from that given above. The geotechnical resistance/reaction provided above are based on loading applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.10.4 of the CHBDC 2014.

The subgrade should be cleaned of loose / softened material and inspected by qualified geotechnical personnel, to check that all existing fill or other unsuitable materials have been removed and to confirm the adequacy of the foundation conditions for the design geotechnical resistance.

The subgrade will be susceptible to loosening and degradation on exposure to water and construction traffic. It is recommended that a concrete working slab (mudslab) be placed on the inspected and approved footing subgrade within four hours of inspection, to protect the subgrade from degradation and to form a working mat for construction of the foundations. As an alternative to the placement of 300 mm of granular bedding material on the native soil below the base slab, a 100 mm thick mass concrete slab could be placed on the subgrade to protect it from degradation. In this case, a 75 mm thick layer of OPSS.PROV 1010 Granular A or concrete fine aggregate meeting the gradation requirements set out in OPSS.PROV



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1002 (Material Specification for Aggregates - Concrete) should be placed on top of the mass concrete slab to provide a "levelling pad" for the box culvert replacement. The subgrade should also be protected from freezing.

6.2.4 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces / sliding resistance between the base slab or concrete footings for the proposed culvert and the subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC 2014. A coefficient of friction ($\tan \delta$) of 0.45 may be used in the sliding assessment between pre-cast concrete box culverts founded on compacted granular fill (bedding). For cast-in-place concrete footings on the residual soil (clay) a coefficient of friction ($\tan \phi'$) of 0.3 may be used in the sliding assessment. The above coefficient of frictions are un-factored and a resistance factor of 0.8 should be applied in accordance with Table 6.2 of CHBDC 2014 based on the available subsurface conditions.

6.3 CULVERT BEDDING AND BACKFILL

The bedding, leveling and backfill for the proposed CSP culvert should be designed and constructed in accordance with OPSD 802.014 Flexible Pipe Embedment in Embankment and OPSS 421 Pipe Culvert Installation in Open Cut. The CSP culvert should be constructed on a minimum of 150 mm thick layer of bedding materials selected and compacted as per the manufacturer's specifications. Where the earth cover above the top of culvert is less than the frost penetration depth of 2.3 m, a frost taper should be constructed in accordance with OPSD 803.031 Frost Treatment.

If the creek flow velocities are sufficiently high, provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet and outlet, including in front of any wing walls/retaining walls adjacent to the creek channel. The requirements for and design of erosion protection measures for the culvert inlet should be assessed by the hydraulic design engineer. As a minimum, rip-rap treatment for the culvert outlet should be consistent with the standard Treatment Type A presented in OPSD 810.010 (*Rip-Rap Treatment for Sewer and Culvert Outlets*), 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 if adopted, including the creek side slopes and embankment fill slope adjacent to the culverts.

For the box culvert option, the bedding levelling pad and backfill requirements should be in accordance with OPSS 422 (Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut) for pre-cast rigid frame culverts. Box culverts should be provided with at least 300 mm of OPSS.PROV 1010 Granular A material for bedding purposes, or alternatively a 100 mm thick concrete working slab with 75 mm of bedding material.

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Backfill and cover for concrete box culverts should be completed in accordance with the manufacturer's recommendations or in general accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts), provided the box culverts are designed to meet these conditions. Backfill to culvert walls should consist of granular fill meeting the requirements of OPSS.PROV 1010 Granular A or Granular B Type II, but with less than 5 per cent passing the No. 200 sieve. The backfill and bedding should be placed and compacted in accordance with OPSS 501 (Compacting).

The fill depth during placement should be maintained equal on both sides of the culvert walls for the open footing culvert, with one side not exceeding the other by more than 500 mm. The box culvert should be designed for the full overburden and hydrostatic pressures, and live load, assuming that the embankment fill has a unit weight of 22 kN/m³ for Granular A, and 21 kN/m³ for Granular B Type II or select earth fill above and/or surrounding the culvert.

To compensate for the fine grained nature of the subsurface soil below the bedding, a nonwoven geotextile should be placed between the native soil and the bedding to control fines migration from the fine grained native soil into the granular fill. 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 501 (Compacting).

Where the top of culvert extends above the frost penetration depth, a frost taper should be constructed similar to the configuration presented in OPSD 803.010 (Backfill and Cover for Concrete Culverts).

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 EROSION PROTECTION

Provision should be made for scour and erosion protection. 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 and downstream 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 extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including along the embankment slope.



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If the creek flow velocities are sufficiently high, provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet and outlet adjacent to the creek channel and to prevent undermining of the shallow foundations. The requirements for and design of erosion protection measures for the culvert should be provided by the hydraulic design engineer. As a minimum, rip-rap at the inlet, outlet and along the length of the culvert (for open footing culvert) should be provided. Erosion protection at the areas where the existing storm pipe(s) enter the culvert should also be provided.

Above the high water level placement of topsoil and seeding or pegged sod is recommended as soon as practicable after construction of the embankments in order to reduce the potential for erosion of the side slopes, due to surface water runoff. The erosion protection should be in accordance with OPSS 804 (Seed and Cover). Below the high water level rip-rap should be provided to control surface erosion.

6.5 SEISMIC CONSIDERATIONS

The CHBDC 2014 contains updated seismic analysis and design methodology. The CHBDC 2014 method uses a site classification system defined by the average soil/bedrock properties (e.g. shear wave velocity, Standard Penetration Test (SPT) resistance, undrained soil shear strength etc.) in the top 30 metres below the foundation level. There are 6 site classes from A to F, decreasing in ground stiffness from A, hard rock, to E, soft soil; with site class F used to denote other soils (e.g., sites underlain by thick peat deposits, high plastic clays, liquefiable soils, etc.). The site class is then used to obtain acceleration and velocity-based site coefficients $F(PGA)$ and $F(PGV)$, respectively, for the effects of site-specific soil conditions in design.

Based on the results of the previous investigation, a Site Class of E for "Soft Soil" is recommended for seismic design purposes at this site as determined based on Section 4.4.3.2 of CHBDC 2014.

6.5.1 Seismic Analysis Coefficient

The Peak Ground Acceleration Ratio (PGA), Peak Ground Velocity (PGV), and the 5% damped spectral response acceleration values shall be determined for the 475-year, 975-year, and 2475-year return periods in accordance with Section 4.4.3.1 of the CHBDC 2014.

The corresponding acceleration coefficients associated with return periods of 475 years, 975 years and 2475 years of ground motion for Site Class C at the project site are estimated and summarized in the following table:

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Return Period (Years)	Probability of Exceedance	Coefficient of PGA	Coefficient of PGV	5% Damped Spectral Response Acceleration for a Period of 0.2 s, $S_a(0.2)$
475	10% in 50 years	0.0097	0.0064	0.018
975	5% in 50 years	0.019	0.012	0.033
2475	2% in 50 years	0.037	0.024	0.063

Note: Values obtained from the Site Class C of Earthquakes Canada web-site.

Based on Section 4.4.4 of the CHBDC 2014, the new culvert structure is assigned Seismic performance category 1. Therefore, a seismic analysis is not required for this structure in accordance with Section 4.4.5.1 of the CHBDC 2014. This requirement has been reviewed and confirmed by the structural engineer.

6.6 LATERAL EARTH PRESSURES FOR ABUTMENTS AND WING WALLS

The lateral earth pressures acting on the culvert walls, culvert retaining walls (if any), as well as on any road protection system will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culvert walls. It should be noted that these design recommendations and parameters assume 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 specifications of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II should be used as backfill behind the walls. The Granular 'A' or Granular 'B' Type II fill should be compacted in loose lifts not greater than 200 mm thick in accordance with OPSS.PROV 501. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper should be in accordance with OPSD 3101.150 and 3121.150. A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall stem. Compaction equipment should be used in accordance with OPSS 501.06. Other surcharge loadings should be accounted for in the design, as required. The granular fill may be placed either in a zone with width equal to at least 1.2 m behind the back of the wall stem (Case I) in or within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (Case II).

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- For Case I, the pressures are based on the existing overburden soil materials and the following parameters (unfactored) may be used:

Soil Unit Weight:	21 kN/m³
Coefficients of static lateral earth pressure:	
Active, K_a	0.38
At rest, K_o	0.55

- For Case II, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	Granular 'A'	Granular 'B' Type II
Soil Unit Weight:	22 kN/m³	21 kN/m³
Coefficients of static lateral earth pressure:		
Active, K_a	0.27	0.27
At rest, K_o	0.43	0.43

If the wall support and superstructure allow lateral movements of the stem (unrestrained stem), active earth pressure may be used in the design of the structures. If the wall support does not allow lateral movement (restrained stem) such as in box culvert configuration, at rest earth pressures should be assumed for geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as follows:

- rotation (i.e., ratio of wall movement to wall height) of approximately 0.002 about the base of a vertical wall;
- horizontal translation of 0.001 times the height of the wall; or
- a combination of both

6.7 CONSTRUCTION CONSIDERATIONS

6.7.1 Open Cut Excavations

It is understood that excavation will for the removal of the existing culvert and placement of the replacement culvert structure. Where space and construction activities permit the construction

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of unsupported open-cut excavations, these excavations should be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) for Construction Activities. Based on the OHSA classification system, the soils to be excavated on site would be classified as follow:

Fill Materials Type 3
Firm to very stiff clay Type 3

Temporary unsupported excavations (i.e. those that are open for a relatively short time period) should be made with side slopes no steeper than 1H:1V. Stockpile of excavated materials and heavy construction equipment should be kept at least the same horizontal distance from the edge of excavation as the depth of the excavation to prevent local instabilities.

6.7.2 Groundwater Control

Control of the surface water and groundwater will be necessary for the construction of the culvert replacement and any associated wing walls, to allow excavation and foundation construction to be carried out in dry conditions.

Depending on the creek flow at the time of construction, the surface water flow could be passed through the culvert area by means of a temporary pipe, using the existing CSPA culvert or diverted by pumping from behind a temporary cofferdam. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the sensitive subgrade soils. Any necessary permits should be obtained prior to construction.

Groundwater seepage into the excavations is anticipated at the site. The estimated hydraulic conductivity of the native clay on site is expected to be in the order of 10^{-5} cm/s to 10^{-3} cm/s and therefore, dewatering of temporary excavations by pumping from filtered sumps should be adequate at the site. It is expected that groundwater pumping volumes from the sumps be less than 50 m³ per day and that a Permit to Take Water (PTTW) would not be required for the temporary groundwater control system at this site. The dewatering system on site should conform to OPSS 518 (Construction Specifications for Control of Water from Dewatering Operation). Care should be taken to direct the surface water away from the open excavation.

Notwithstanding, a dewatering NSSP should be included in the contract to cover the possibility that the groundwater level increases during construction to the point where some dewatering effort is required to provide a stable platform for construction purposes. A sample NSSP addressing the dewatering is provided in Appendix C. Removal of the existing culvert and construction of the replacement culvert will require control of the stream flow to prevent the stream from flowing into the construction zone.

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6.7.3 Temporary Protection System

Excavations for box or open footing culvert options will extend below the creek water level and may therefore require temporary shoring with unwatering along the culvert walls and perpendicular to Highway 621 to allow for construction/placement of the footings and/or placement of bedding material in dry conditions, where required. 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.

Temporary excavations for the culvert replacement are anticipated through the existing fill and into the firm to very stiff native clay. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects. Stockpiles of excavated material should be set back from the edge of the excavation by a distance at least equal to the excavation depth.

If the site conditions are such that open cut excavations are not feasible then the removal of the existing culvert and construction of the proposed culvert may be carried out within temporary protection systems. These protection systems should be designed and constructed in accordance with OPSS 539 (Construction Specification for Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539, provided that any adjacent utilities/structures can tolerate this magnitude of deformation.

The designer of the temporary work supports must consider the temporary works design as part of the assessment of ground movements and their impact on existing structures and underground utilities at the site. The criteria for the design and performance of the temporary works must also consider such analysis. Sufficient design and analysis will have to be carried out in order to conduct cost estimates of the temporary works, to determine the feasibility of the design criteria, to assess construction feasibility of temporary works alternatives, and to indicate to the contractor the temporary ground support system(s) which are to form the basis of the bid.

6.7.4 Subgrade Protection

Where clayey soils are exposed at the footing subgrade level, they will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that a working mat of lean concrete or mass concrete be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade. Where a box culvert extension or replacement is adopted, a 75 mm thick levelling pad of Granular "A" or fine aggregate (meeting the gradation requirements set out in OPSS 1002) should be provided on top of the concrete mat. Alternatively, for a box culvert

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extension/replacement, the subgrade can be protected with a Granular "A" pad in lieu of the lean mix concrete/mass concrete working mat.

This requirement can be addressed either with a note on the General Arrangement drawing, or with a Non-Standard Special Provision (NSSP). A sample NSSP to address this requirement is included in Appendix C.

6.7.5 Corrosion Protection

Analytical laboratory tests to assess corrosion potential of the creek water were completed as part of the previous investigation. The test results may be used in the consideration of potential corrosion of the pipe in contact with the creek water. The analytical laboratory test results are outlined below:

Chloride, CL (mg/L)	Sulphate, SO ₄ (mg/L)	Electrical Conductivity, EC (mS/cm)	Resistivity (mΩ·cm)	pH
30.3	0.71	817	<0.33	7.29

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7.0 Closure

This Foundation Design Report was prepared by Mr. Mehdi Mostakhdemi, M.Sc., P.Eng. Mr. Ty Garde, M.Eng, P.Eng., a Designated MTO Foundations Contact for Amec Foster Wheeler, conducted an independent review of this report.

Sincerely,

Amec Foster Wheeler Environment & Infrastructure
a Division of Amec Foster Wheeler Americas Limited

Amec Foster Wheeler Americas Ltd.

Report prepared by:



Mehdi Mostakhdemi, M.Sc., P.Eng.
Geotechnical Engineer

Amec Foster Wheeler Americas Ltd.

Report reviewed by:



Ty Garde, M.Eng., P.Eng.
Designated MTO Foundations Contact

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8.0 References

Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual*, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.

Canadian Standards Association (CSA), 2014. *Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6 14*. CSA Special Publication, S6.1 14.

Kulhawy, F.H. and Mayne, P.W., 1990. *Manual on Estimating Soil Properties for Foundation Design*. EL 6800, Research Project 1493 6. Prepared for Electric Power Research Institute, Palo Alto, California.

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 421	Materials Specification for Aggregate – Base, Subbase, Select Subgrade, and Backfill Material
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut
OPSS.PROV.501	Construction Specification for Compacting
OPSS 518	Construction Specifications for Control of Water from Dewatering Operations
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 1002	Materials Specification for Aggregate
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
OPSD 802.014	Flexible Pipe Embedment in Embankment
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
OPSD 810.010	General Rip-Rap Layout
OPSD 3101.150	Walls Abutment, Backfill, Minimum Granular Requirement
OPSD 3121.150	Walls Retaining, Backfill, Minimum Granular Requirement

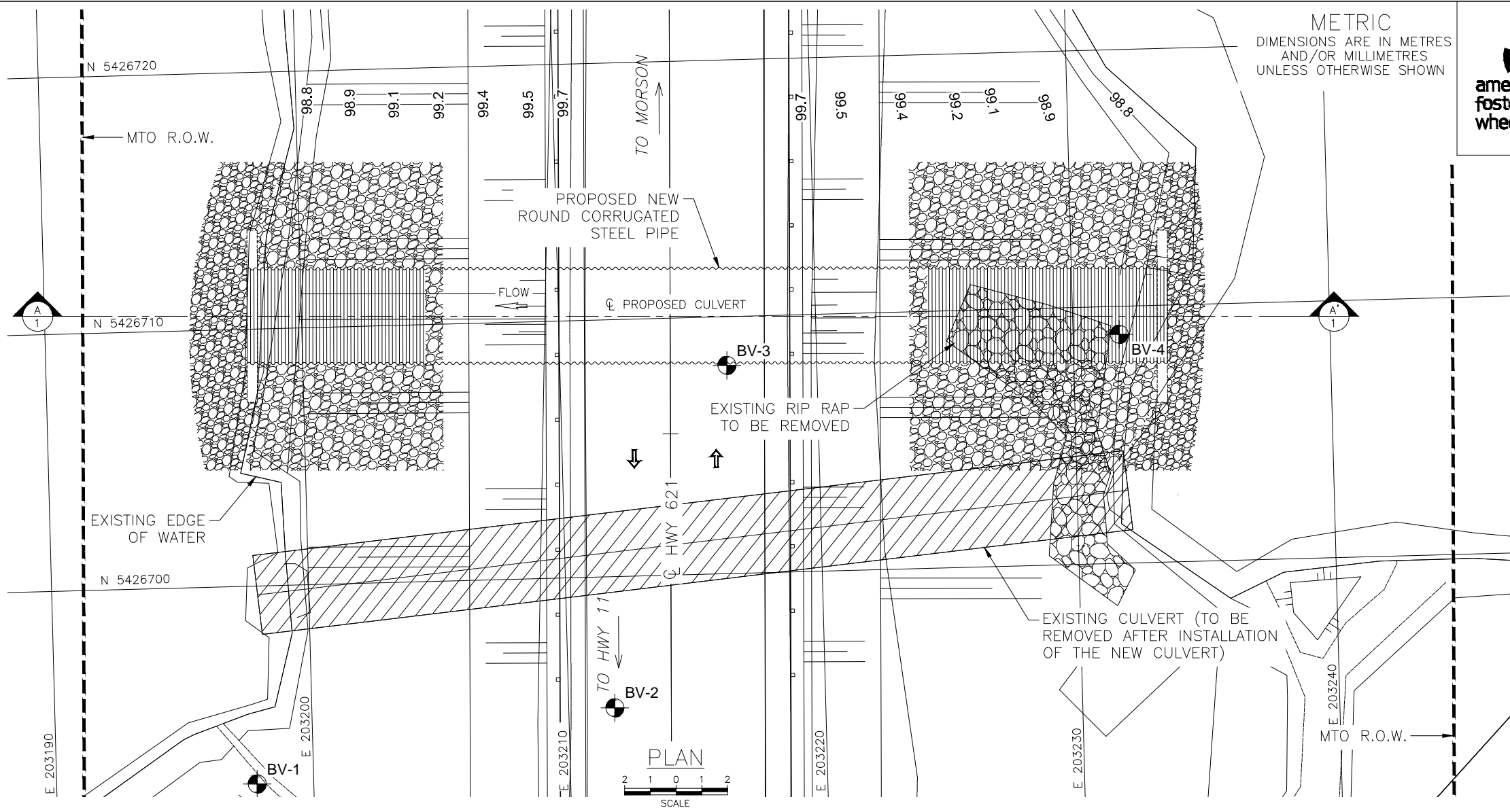
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Table 1: Comparison of Foundation Alternatives


Option	Advantages	Disadvantages	Feasibility
Pipe Culvert	<ul style="list-style-type: none"> Relatively simple installation Lower cost compared to open footing and precast box culverts Limited risk related to settlement performance Bedding under the culvert could be placed under water 	<ul style="list-style-type: none"> Feasibility depends of flow through capacity May require deeper excavation Cut-off wall or clay blanket would be required for scour protection Less durable compare to open footing culvert and precast box culvert 	Feasible
Open Footing Culvert	<ul style="list-style-type: none"> Relatively rapid installation if precast units are used Likely better satisfies fisheries requirements, if applicable 	<ul style="list-style-type: none"> High risk of disturbance of founding soil Longer construction period Would require more groundwater control efforts Less tolerant of differential settlement if the highway is widened or its grade is raised in future Deeper excavation and thicker soil cover would be required for frost protection 	Feasible
Pre-Cast Box Culvert	<ul style="list-style-type: none"> Relatively rapid installation if precast units are used Tolerates larger differential settlements compare to pipe culvert and open footing culvert Excavations would be shallower compare to open footing culvert Bedding under the culvert could be placed under water 	<ul style="list-style-type: none"> High risk of disturbance of founding soil 	Preferred

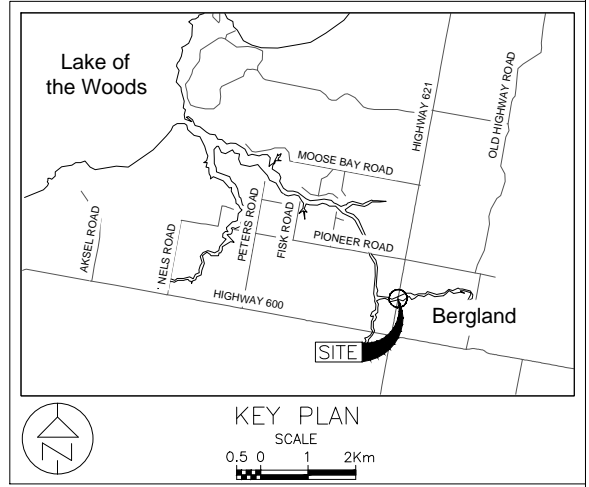
AutoCAD drawing: c:\Project\p115089\p115089-800.810-R02001\p115089-Brusvine-BH-1.dwg
Dec 15/16 2:35pm brian.mcmaster



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

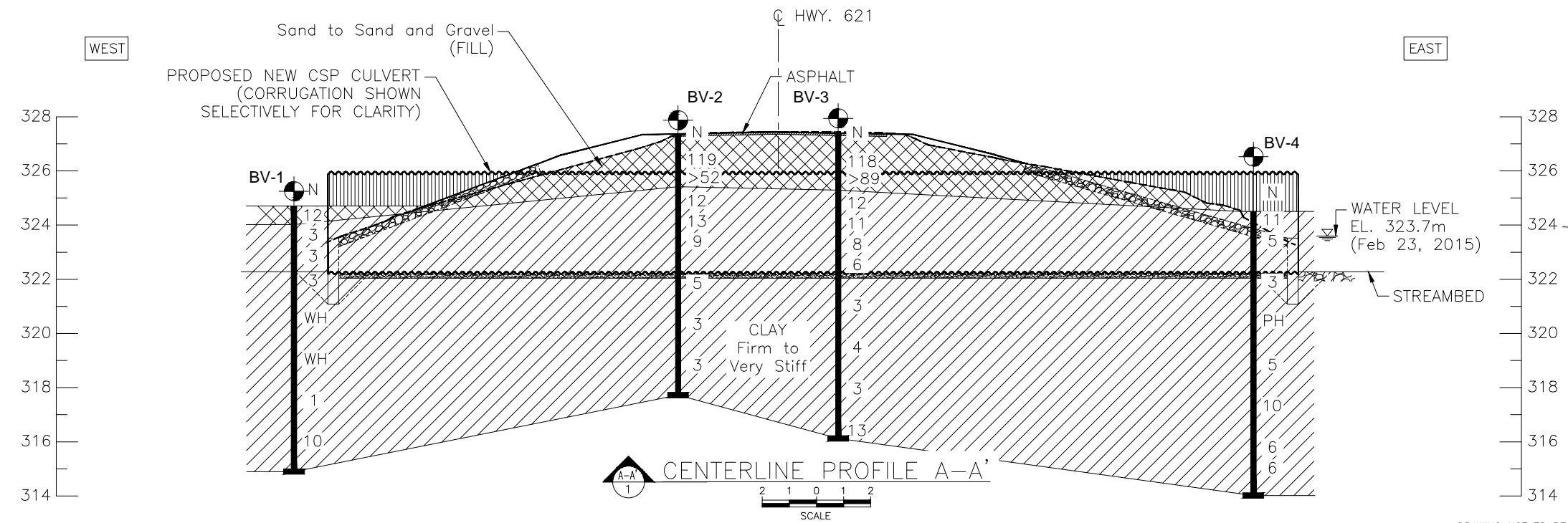


DIST CONT No - GWP No - 6329-14-00	
BRUSVINE CREEK CULVERT FOUNDATION INVESTIGATION & DESIGN BOREHOLE LOCATIONS & SOIL STRATA	SHEET 1



LEGEND	
	BOREHOLE LOCATION (PREVIOUS INVESTIGATION BY OTHERS)
N	STANDARD PENETRATION TEST VALUE
11	BLOWS/0.3m UNLESS OTHERWISE STATED (STD. PEN. TEST, 475 J/BLOW)
	WATER LEVEL UPON COMPLETION OF DRILLING
DRY	BOREHOLE DRY UPON COMPLETION OF DRILLING

- NOTES
- THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING FOUNDATION INVESTIGATION AND DESIGN REPORT.
 - THE INTERPRETED STRATIGRAPHY REPRESENTS SIMPLIFIED SUBSURFACE CONDITIONS. THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN DEFINED AT BOREHOLE LOCATIONS ONLY. CONDITIONS BETWEEN BOREHOLE LOCATIONS COULD DIFFER FROM ILLUSTRATED CONDITIONS.
 - THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. THE PROPOSED STRUCTURE DETAILS/WORKS ARE SHOWN FOR ILLUSTRATION PURPOSE ONLY AND MAY NOT BE CONSISTENT WITH THE DESIGN CONFIGURATION AS SHOWN ELSEWHERE ON THE DESIGN REPORT.
 - ELEVATIONS ARE REFERENCED TO GEODETIC DATUM.



No.	ELEVATION (m)	CO-ORDINATES (MTM, NAD 83 ZONE 15)	
		NORTHING (m)	EASTING (m)
BOREHOLES BY OTHERS			
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

DESIGN: MM	CHK: MM	CODE CAN/CSA S6-14	LOAD CL-625-ON	DATE: DEC 2016
DRAWN: SL	CHK: TG	SITE GROOMS No: 52-E-63	SCHEME	DWG:

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Appendix A: Record of Boreholes from Previous Investigations



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 BV-1				1 OF 1 METRIC							
G.W.P. 6329-14-00		LOCATION N 5426692.3; E 203197.8				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			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa		WATER CONTENT (%)		γ	GR SA SI CL
324.7	GROUND SURFACE							20 40 60 80 100	W _p W W _L	20 40 60	kN/m ³		
0.0	Sand, trace to some gravel, some organics (FILL) Brown Frozen		1	SS	12		324						
324.0													
0.7	CLAY, trace gravel, trace sand Firm to very stiff Brown to grey Wet		2	SS	3		323						
	Some organics in the upper 0.6 m.		3	SS	3		322						
	Sandy silt laminations between 4.2 m and 5.9 m depth.		4	SS	3		321						
			5	SS	WH		320						
			6	SS	WH		319						
			7	SS	1		318						
			8	SS	10		317						
							316						
							315						
314.9	END OF BOREHOLE												
9.8	Notes: 1. Borehole dry upon completion of drilling. 2. Advanced additional borehole 0.6 m south of Borehole BV-1 to obtain Shelby Tube samples at 3.8 m depth and 5.3 m depth and additional field vanes at 4.9 m, 5.2 m, 6.4 m and 6.7 m depths (Italics).												

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

PROJECT 1411523			RECORD OF BOREHOLE No BV-2			1 OF 1 METRIC																				
G.W.P. 6329-14-00			LOCATION N 5426694.9; E 203211.8			ORIGINATED BY MR																				
DIST _____ HWY 621			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY AC																				
DATUM GEODETIC			DATE February 25, 2015			CHECKED BY DAM																				
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)											
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					W _p W W _L			WATER CONTENT (%)			γ			GR SA SI CL				
327.5	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60																
0.0	ASPHALT (100 mm)		1	AS	-		327																			
	Sand, some gravel to sand and gravel, some silt (FILL)		2	SS	119																					
	Brown Frozen		3	SS	52/0.15		326																			
325.4	CLAY		4	SS	12		325																			
2.1	Firm to very stiff		5	SS	13		324																			
	Brown to grey		6	SS	9		323																			
	Wet		7	SS	5		322																			
	Sandy silt laminations between 2.1 m and 7.9 m depth.		8	SS	3		321																			
			9	SS	3		320																			
							319																			
							318																			
317.7	END OF BOREHOLE																									
9.8	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-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:

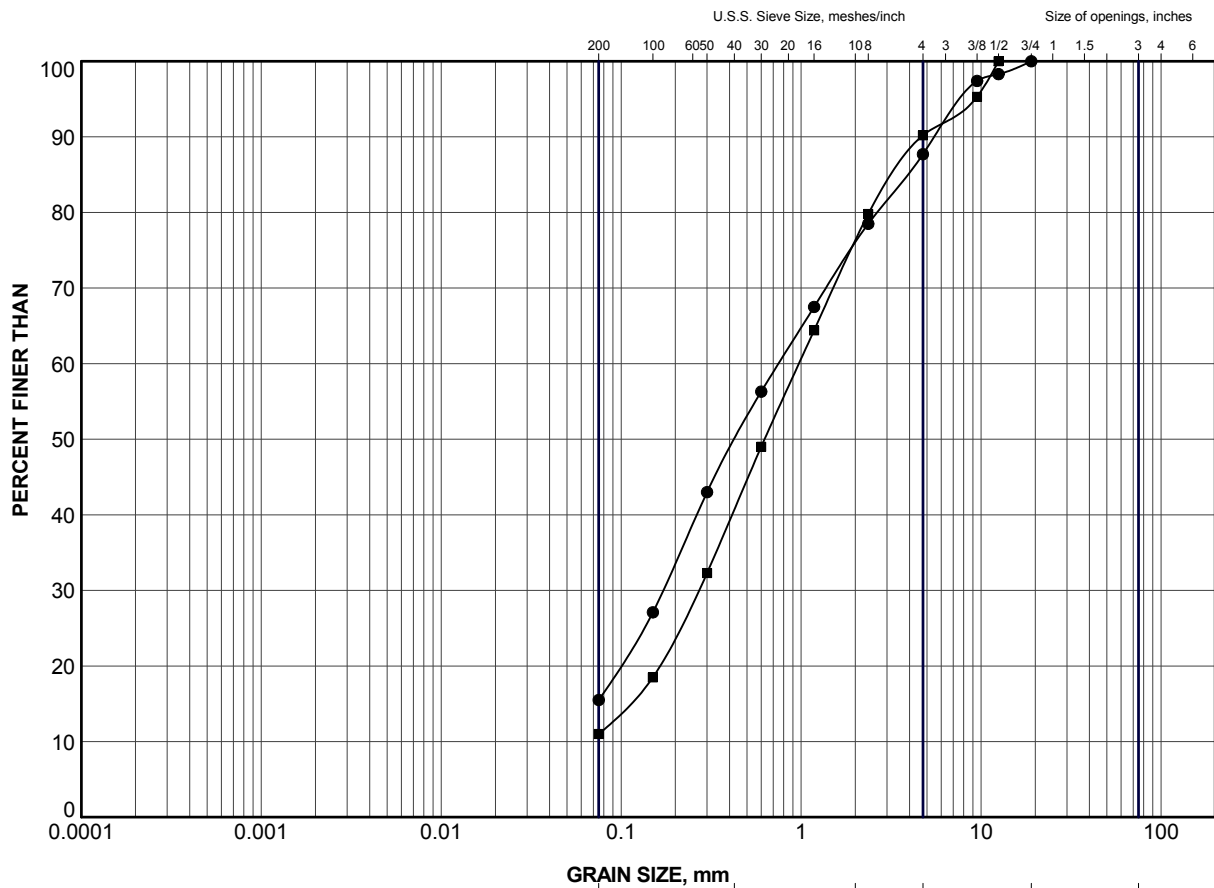
PROJECT 1411523		RECORD OF BOREHOLE No BV-4		1 OF 1 METRIC	
G.W.P. 6329-14-00		LOCATION N 5426708.9; E 203231.8		ORIGINATED BY MR	
DIST HWY 621		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers		COMPILED BY AC	
DATUM GEODETIC		DATE March 19, 2015		CHECKED BY DAM	
SOIL PROFILE		SAMPLES		DYNAMIC CONE PENETRATION RESISTANCE PLOT	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER TYPE "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
324.5	GROUND SURFACE				
0.0	CLAY Firm to very stiff Brown to grey Frozen* to wet Trace to some organics in the upper 1.5 m.		1 SS 11* 2 SS 5 3 SS 3 4 TO PH 5 SS 5 6 SS 10 7 SS 6 8 SS 6		
314.0	END OF BOREHOLE				
10.5	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).				

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

**FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF
BRUSVINE CREEK CULVERT, HIGHWAY 621 NEAR RAINY RIVER, NORTHWEST REGION, SITE
NO. 45-005C**

December 2016

Appendix B: Laboratory Test Results from Previous Investigation



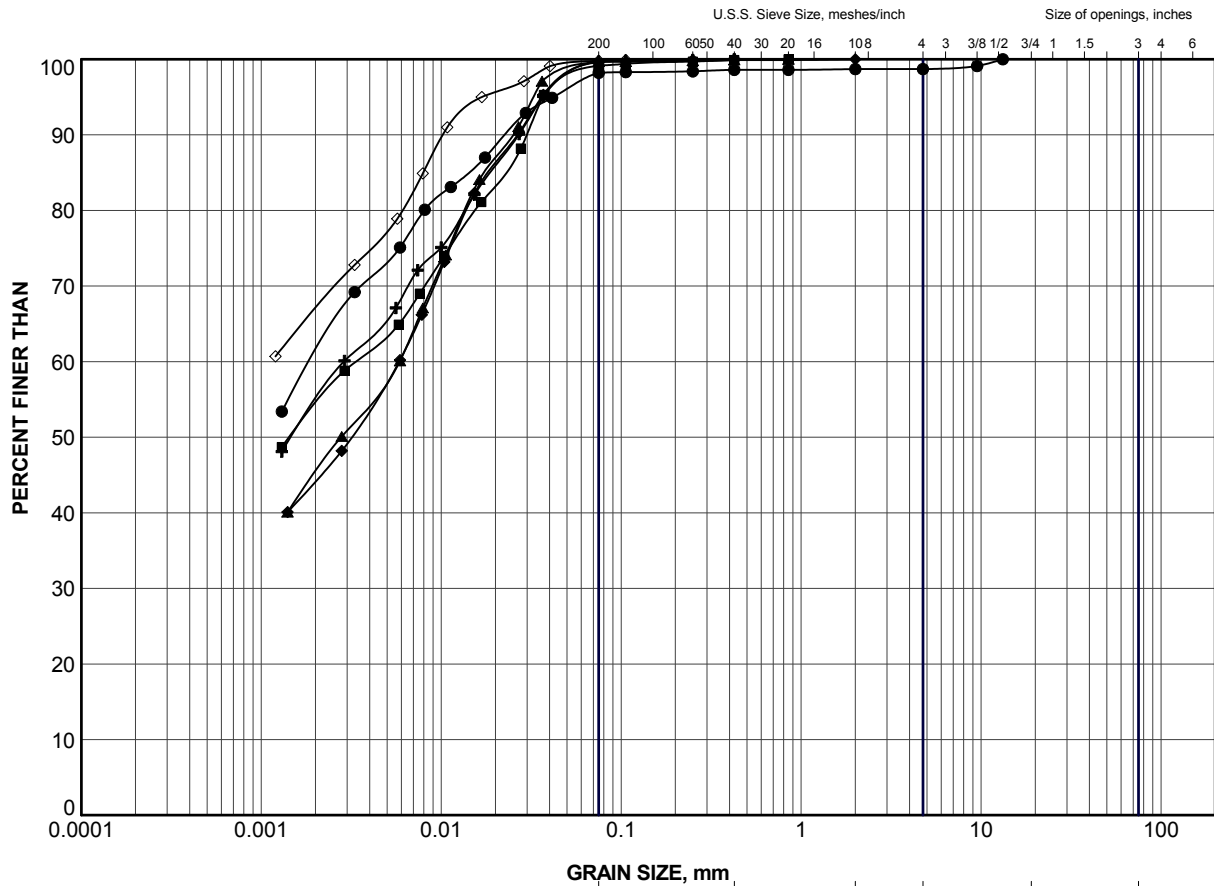
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

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			
			FIGURE B1		



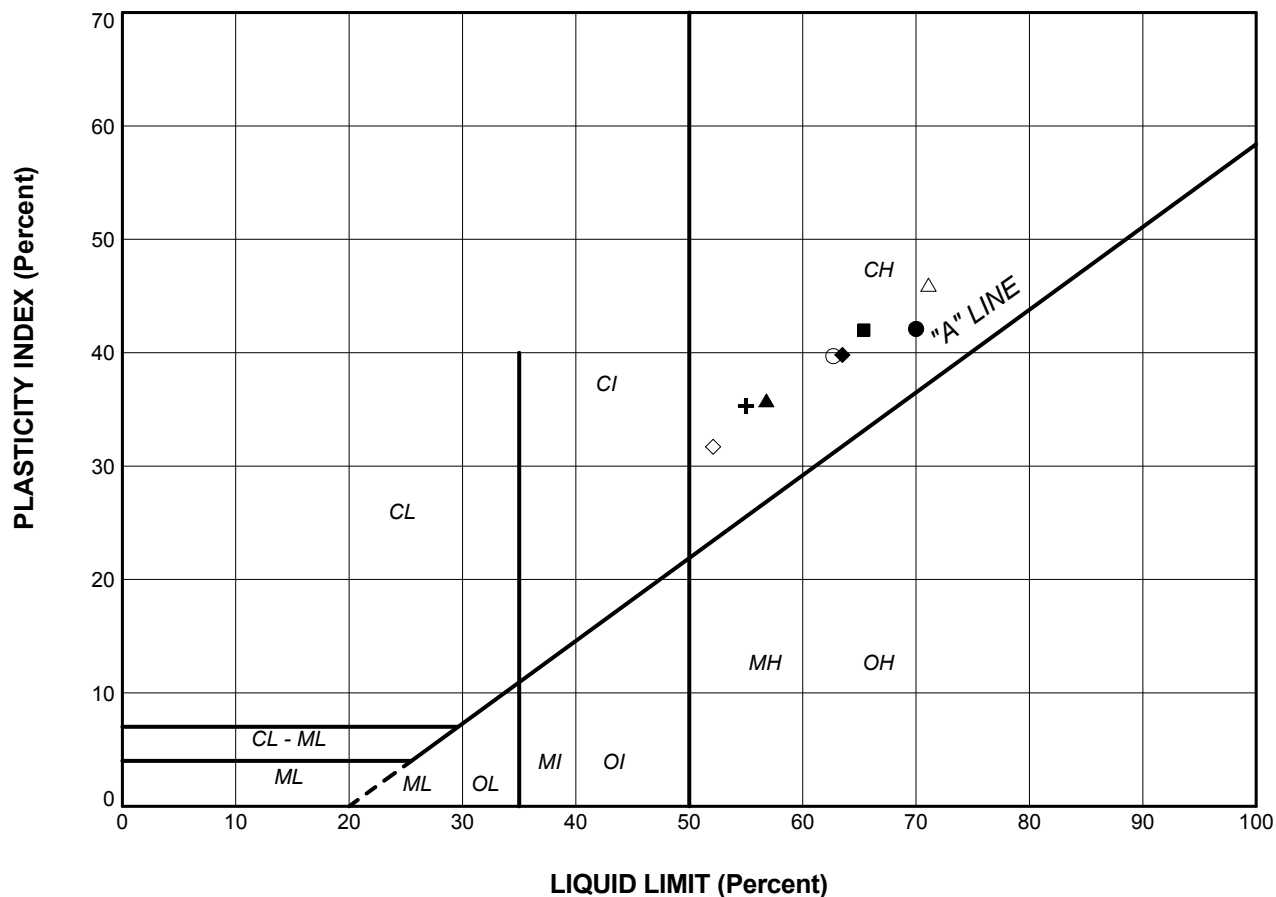


LEGEND

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		JJL	Apr 2015	SCALE N/A
CHECK		DAM	Apr 2015	REV.
APPR		JMAC	Apr 2015	
 Golder Associates SUDBURY, ONTARIO		FIGURE B3		

**FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF
BRUSVINE CREEK CULVERT, HIGHWAY 621 NEAR RAINY RIVER, NORTHWEST REGION, SITE
NO. 45-005C**

December 2016

Appendix C: Non-Standard Special Provisions (NSSPs)

FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF BRUSVINE CREEK CULVERT, HIGHWAY 621 NEAR RAINY RIVER, NORTHWEST REGION, SITE NO. 45-005C

December 2016

Dewatering

Non-Standard Special Provision (NSSP)

December 2016

CONSTRUCTION SPECIFICATION FOR DEWATERING

SCOPE

The work under this item includes the design, installation, operation, maintenance and removal of temporary dewatering systems to facilitate the culvert extensions at the Brusvine Culvert site. Foundations for the culvert extension may require excavation below the groundwater level.

REFERENCES

- OPSS 517 Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
- OPSS 518 Construction Specification for Control of Water from Dewatering Operations

SUBMISSION AND DESIGN REQUIREMENTS

Written details for the proposed dewatering system shall be submitted to the Contract Administrator for information purposes a minimum of ten business days prior to commencing dewatering operations. The Contractor shall reference borehole logs included in the Contract Documents as a guide in determining requirements.

CONSTRUCTION

Dewatering System

The Contractor is responsible for the design, installation, operation and maintenance of an adequate dewatering system to lower the groundwater level to at least 0.3 m below the founding level for the proposed culvert replacement, to allow excavation, subgrade preparation and construction in dry conditions.

Operation

A continuous dewatering operation shall be provided to facilitate the installation of the culvert extensions at all times during the work. All components of the dewatering system shall be maintained in an effective, functioning and stable condition at all times during the work. Notwithstanding the above, the work shall be completed in accordance with the environmental and operational constraints specified elsewhere in the contract.

FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF BRUSVINE CREEK CULVERT, HIGHWAY 621 NEAR RAINY RIVER, NORTHWEST REGION, SITE NO. 45-005C

December 2016

Restoration

All equipment and materials placed shall be removed from the right-of-way upon the completion of the work and all areas disturbed as part of this work shall be restored to their preconstruction conditions, unless specified otherwise.

BASIS OF PAYMENT

Payment at the contract price for the above tender item shall be full compensation for all labour, equipment and material to do the work.

FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF
BRUSVINE CREEK CULVERT, HIGHWAY 621 NEAR RAINY RIVER, NORTHWEST REGION, SITE
NO. 45-005C

December 2016

Subgrade Protection

Non-Standard Special Provision (NSSP)

December 2016

CONSTRUCTION SPECIFICATION FOR SUBGRADE PROTECTION

The subgrade soils for the culvert foundations or box culverts may be susceptible to disturbance and loosening from construction traffic and ponded water.

SCOPE

Where pre-cast box culverts are used, if all the box segments are not placed on the prepared subgrade within four hours of its inspection and approval, a working mat of lean concrete or mass concrete, with minimum thickness of 100 mm, should be placed on the foundation subgrade. A minimum 75 mm thick uncompacted levelling pad consisting of Granular 'A' material or fine aggregates (meeting the grading requirements specified in OPSS.PROV 1002) should be provided on top of the lean concrete mat.

As an alternative to a concrete working mat, the subgrade protection could be provided by placing at least 150 mm of OPSS 1010.PROV Granular A or fine aggregates (meeting the grading requirements specified in OPSS.PROV 1002).

BASIS OF PAYMENT

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.