



October 7, 2016

FOUNDATION INVESTIGATION AND DESIGN REPORT

**NORAMI CREEK CULVERT - SITE NO. 48E-62
HIGHWAY 11, DISTRICT OF THUNDER BAY
McCOMBER TOWNSHIP
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6166-04-00 W.P. 6166-04-01**

Submitted to:

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GEOCREs No.: 42E-26

Report Number: 1533879-R08

Distribution:

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REPORT





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PART A

**DETAIL FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Hatch Ltd. (Hatch), on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation engineering services for the replacement of the Norami Creek culvert (Site No. 48E-62). The Norami Creek culvert is located in the District of Thunder Bay in the Township of McComber on Highway 11 at STA 20+212, approximately 7.7 km west of the Highway 801 in Nezhah, Ontario. The key plan showing the general location of this section of Highway 11 and the location of the investigated area are shown on Drawing 1.

2.0 SITE DESCRIPTION

The Norami Creek culvert consists of a twin cell timber box, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is referenced to project north and therefore may differ from magnetic north shown on the drawing. For the purpose of this report, Highway 11 is oriented in a west-east direction (for this section of roadway) with the culvert perpendicular to the highway in a north-south orientation.

In general, the topography in the area of the culvert consists of low-lying swampy terrain on both sides of Highway 11. At the culvert location, the highway grade is at Elevation 318.8 m and the existing culvert invert, as provided by MTO, is at Elevation 315.7 m at the inlet (north end) and at Elevation 315.6 m at the outlet (south end). The creek ice/water level was measured by Golder on January 22, 2016, at Elevations 316.8 m and 316.2 m at the inlet and outlet ends, respectively. Surface conditions in the culvert inlet and outlet areas are shown on Photographs 1 to 4.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between January 22 and February 14, 2016, during which time six boreholes (Boreholes NR-1 to NR-6) were advanced at approximately the locations shown on Drawings 1 and 2. Boreholes NR-1, NR-2, NR-5 and NR-6 were advanced at the toe of slope near the culvert inlet/outlet and Boreholes NR-3 and NR-4 were advanced from the existing highway platform. Boreholes NR-1, NR-2 and NR-6 were advanced with a portable tripod using NW casing and wash boring techniques. The portable tripod was supplied and operated by Landcore Drilling of Chelmsford, Ontario. Borehole NR-3 was advanced using a truck mounted CME-55 drill rig and Boreholes NR-4 and NR-5 were advanced using a track mounted CME 850 drill rig. The CME-55 and CME-850 drill rigs, which were both equipped with 108 mm inside diameter hollow stem augers, were supplied and operated by Cartwright Drilling Ltd. of Thunder Bay, Ontario.

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 or a cathead hammer (for boreholes advanced using the portable tripod), in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).



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

A sample of the creek water was obtained on January 27, 2016, 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 results of the analytical testing are presented in Table B1 in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to the highway centerline and existing culvert and converted into northing/easting coordinates on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile drawing provided by MTO (drawing bc04113.dwg). The MTM NAD83 Zone 14 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)
NR-1	5503037.6	249433.2	316.7	9.8
NR-2	5503039.3	249442.4	316.8	9.8
NR-3	5503029.2	249444.7	318.8	12.8
NR-4	5503021.1	249430.4	318.8	12.8
NR-5	5503013.4	249445.6	316.7	9.8
NR-6	5503013.2	249437.6	316.8	9.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)¹ mapping, the Norami Creek culvert site is located within an outwash plain deposit consisting primarily of sand.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)², the site is underlain by metasedimentary rocks comprised of wacke, arkose, argillite, slate, marble, chert and iron formations.

¹ Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42ENW

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 detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ field tests (i.e., SPT 'N' values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawings 1 and 2 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.

In summary, the subsoil conditions encountered at the site consist of asphalt and granular fill (for boreholes advanced through the embankment) or ice/water and/or sandy peat to peat (for boreholes advanced beyond the embankment toe of slope) underlain by a deposit of sand to silt and sand further underlain by a deposit of silt. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Surface Elevation (m)	Deposit Thickness (m)	N Values (blows)	Laboratory Testing
				Relative Density	
Ice/Water	NR-1, NR-2 and NR-6	316.8 – 316.7	0.1 – 0.8	n/a	n/a
Asphalt	NR-3, NR-4	318.8	0.100 – 0.125	n/a	n/a
(FILL) Gravelly sand and sand, trace to some silt, trace to some organics, brown; frozen/moist	NR-3, NR-4	318.7	2.9	N = 5 - 10 ¹ Loose to Compact	w = 2% – 16% ² 3 – M (Fig. B1)
Sandy Peat to Peat (Fibrous), some silt, trace gravel; brown to black, frozen/wet	NR1, NR-2, NR-4, NR-5 and NR-6	316.7 – 315.8	0.1 – 1.5	N = 2 – 4 Very Loose	w = 60% & 88%
Sand to Silt and Sand³, trace to some organics; brown to grey; wet	NR-2, NR-3, NR-5 and NR-6	316.1 – 315.4	0.7 – 2.3	N = 3 – 13 Very Loose to Compact	w = 20% – 31% 2 – M/MH (Fig. B2)
Silt, trace to some clay, trace to some sand; brown to grey; wet	NR-1 to NR-6	315.8 - 313.8	6.8 – 8.9 (boreholes terminated in this deposit)	N = 7 – 24 Loose to compact	w = 18% - 29% ⁴ 13 – MH (Fig. B3) 1 – AL (NP)

Where:

- N = SPT 'N' values; number of blows for 0.3 m of penetration
- M = Sieve analysis
- MH = Combined sieve and hydrometer analysis
- w = Natural moisture content (%)
- AL = Atterberg limits test
- NP = Non Plastic Atterberg limit test result



Notes:

- ¹ An SPT 'N' value of 44 blows per 0.3 m of penetration was measured in the sand fill deposit, however this value is likely due to the frozen state of the material and is not considered to be representative of the relative density of the granular fill.
- ² A moisture content of the 33 per cent was measured in one sample of the sand fill; however, this is likely due to the presence of organics within the sample.
- ³ An approximately 100 mm thick piece of wood was encountered within the silty sand deposit in Borehole NR-3.
- ⁴ A moisture content of the 34 per cent was measured in one sample of the silt deposit; however, this is likely due to the presence of a clay seam within the sample.

Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The creek ice/water level was surveyed at Elevation 316.8 m and 316.2 m at the inlet and outlet ends, respectively, on January 22, 2016. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
NR-1	0.0	316.4
NR-2	0.0	316.6
NR-3	2.5	316.3
NR-4	5.3	313.5
NR-5	0.9	315.8
NR-6	0.5	316.3*

*Borehole NR-6 were advanced using NW casing and wash boring techniques and as such, the measured groundwater level may not be representative of the in-situ groundwater condition.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mike Arthur, Mr. Shane Albert and Mr. Mathew Riopelle, under the overall direction of Mr. Adam Core, P.Eng. This Detail 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., a Senior Consultant with and Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.



Report Signature Page

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PART B

**DETAIL FOUNDATION DESIGN REPORT
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed replacement of the Norami Creek culvert. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible foundation alternatives and carry out the design of the structure foundations, as may be required. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The design-build contractor must make their own interpretation based on the factual data in Part A of the report. Where comments are made on construction, they are provided only to highlight those aspects that could affect the 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 must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

The Norami Creek Culvert is located in the District of Thunder Bay in the Township of McComber on Highway 11 at about STA 20+212, approximately 7.7 km west of the Highway 801 in Nezhah, Ontario. The highway embankment is constructed of granular fill material and is about 2.9 m high relative to the existing culvert invert, with approximately 1.3 m of soil cover over the existing culvert. The details (i.e., width, height, length, etc.) of the existing twin cell timber box culvert are summarized in Table 1.

A box culvert, open footing culvert or pipe culvert(s) are all considered feasible alternatives for replacement of the existing culvert at this site. Although feasible, an open footing culvert presents additional challenges as it will extend the construction schedule and increase the excavation, dewatering and shoring requirements compared a box culvert. Given the relatively low embankment height and limited soil cover multiple pipe culverts would likely be required to provide a similar flow-through capacity compared to a box or open footing culvert, and if constructed from steel, a pipe culvert will likely have a shorter design life. From a foundation perspective, a closed-bottom box culvert sufficiently wide to handle the creek flow is preferred. A different culvert type may be preferred due to 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.

As outlined in the Request For Proposal (RFP), and as shown on the General Arrangement (GA) drawing provided by Hatch on June 3, 2016, we understand that the proposed replacement culvert consists of a pre-cast, single-cell, concrete box approximately 4.0 m wide by 2.3 m high (exterior dimensions) with the invert at about Elevation 315.50 m at the inlet end and Elevation 315.45 m at the outlet end. The proposed culvert is to be constructed along a new alignment with the centerline of the replacement culvert located about 4.3 m west of the existing culvert centreline. We understand that there is no proposed embankment grade raise or widening in the area of the culvert as part of the Highway 11 reinstatement.



6.2 Consequence and Site Understanding Classification

As the proposed replacement culvert crosses Highway 11 and will carry large volumes of traffic with the potential to impact alternative transportation corridors, a “typical consequence level” is considered appropriate as outlined in Section 6.5 of the Canadian Highway Bridge Design Code (CHBDC 2014) and its Commentary. Further, given the scope of work of the foundation field investigation and laboratory testing program as outlined in Sections 3.0 and 4.0, a “typical degree of site and prediction model understanding” has been utilized. Accordingly, the appropriate corresponding ULS and SLS consequence factor, Ψ , and geotechnical resistance factors, Φ_{gu} and Φ_{gs} , from Tables 6.1 and 6.2 of the CHBDC have been used for design.

6.3 Geotechnical Resistances

Prior to placing the granular/levelling pad and/or replacement culvert, it is recommended that any organic material (i.e., sandy peat to peat, topsoil or mixed organic soil) encountered below the culvert footprint be sub-excavated and replaced with Ontario Provincial Standard Specification, Provincial Oriented 1010 (OPSS.PROV) Granular ‘B’ Type II engineered fill, which is more suitable for use in wet ground conditions.

For a proposed 4.0 m wide box culvert founded on a properly prepared granular levelling/bedding pad overlying the native subgrade soils at approximately Elevation 314.8 m (taking into account the culvert invert elevations, a 300 mm thick concrete box bottom slab, a 75 mm levelling course and a 300 mm thick bedding layer), a factored ultimate geotechnical resistance at Ultimate Limit States (ULS) of 350 kPa and a factored serviceability geotechnical resistance at Serviceability Limit States (SLS) of 70 kPa (based on 25 mm of settlement) may be used for design.

Based on discussions with Hatch, we understand that a factored geotechnical resistance of 80 kPa at SLS is required for design of the proposed replacement box culvert. Provided that settlements of about 30 mm can be tolerated by the culvert structure and are acceptable from a roadway design and traffic performance perspective, a factored geotechnical resistance of 80 kPa may be used for design. Given that the existing embankment geometry is being maintained, actual settlements will likely be less than the calculated settlements, which have been factored in accordance with the CHBDC 2014.

In the event that an open footing culvert is chosen as the replacement option, factored geotechnical resistances of 220 kPa at ULS and 130 kPa at SLS may be used for an assumed 1.2 m wide footing founded at/or below Elev. 312.9 m to provide for a minimum 2.6 m of soil cover for protection against frost penetration, as interpreted from OPSD 3090.100.

The factored geotechnical resistances provided above are based on the loading applied perpendicular to the base of the culvert/footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC and its Commentary.

The loading on the foundation soils below the culvert and the associated settlement at the culvert location will be governed by the thickness/height of the overlying and adjacent embankment fill. As such, it is recommended that the structural engineer exercise caution when utilizing the values for the factored serviceability geotechnical resistance at SLS in the design of the culvert and that consideration be given to the sequence and staging of the construction. The factored serviceability geotechnical resistance at SLS provided above, assumes there will no temporary and/or permanent grade raise at the culvert location (including during the course of construction).



6.4 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces / sliding resistance should be calculated in accordance with Section 6.10.5 of the CHBDC (2014) applying the appropriate consequence and degree of site understanding factors as noted in Section 6.2. A coefficient of friction, $\tan \delta_i'$, of 0.45 may be used at the interface between the base of the box culvert and the granular bedding material or between the base of the strip footing and the subgrade soil.

6.5 Stability, Settlement and Horizontal Strain

For the subsurface conditions and the proposed reconstructed embankment height up to about 2 m above the existing ground surface along the embankment toe of slope (i.e., about 2.9 m high relative to the invert of the replacement culvert), granular fill embankments at this site will be stable at side slopes inclined at 2 horizontal to 1 vertical (2H:1V) or flatter

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 the embankment reconstruction is expected to be less than 25 mm.

Horizontal strain is not expected to occur as the permanent embankment geometry is not changing from the current (existing) geometry. As a result, culvert construction concurrent with the embankment construction can be carried out without the need for any foundation mitigation measures or provisions for a culvert camber.

6.6 Lateral Earth Pressures

The lateral earth pressures acting on the side walls of the culvert will depend on the type and method of placement of backfill materials, the nature of the 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 replacement culvert. 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 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 maximum 200 mm loose lift thickness. Weep holes should be installed to provide positive drainage of the granular backfill.
- For restrained culvert walls, granular fill may be placed in a zone with the width equal or greater than the equivalent depth of frost penetration which at this site is 2.6 m (OPSD 3090.100 – Foundation Frost Penetration Depth), behind the back of the walls (see Figure C6.20(a) of the Commentary to the CHBDC). The lateral earth pressures acting against the culvert walls are based on the proposed backfill material against the walls and the following parameters (unfactored) may be used:



Fill Type	Internal Angle of Friction (ϕ)	Unit Weight	Coefficients of Static Lateral Earth Pressure		
			Active, K_a	At-Rest, K_o	Passive, K_p
Granular 'A'	35°	22 kN/m ³	0.27	0.43	3.69
Granular 'B' Type II	35°	21 kN/m ³	0.27	0.43	3.69
Granular 'B' Type I or III	32°	21 kN/m ³	0.31	0.47	3.25

6.7 Culvert Construction Considerations

6.7.1 Temporary Roadway Protection

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

It is anticipated that temporary support systems will be required along the highway to facilitate staging during construction of the replacement culvert. The temporary support systems could consist of either driven sheet-piling or soldier piles and lagging where H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds. Support to the system could be in the form of struts and wales 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 roadway.

The design of the temporary support systems, as may be required for the temporary widening for staging, may be designed using the following parameters:

Soil Type	Unit Weight	Undrained Shear Strength	Internal Angle of Friction	Coefficient of Earth Pressure		
	(γ , kN/m ³)	(S_u , kPa)	(ϕ , degrees)	Active, K_a	At Rest, K_o	Passive, K_p
Existing Granular FILL (Loose to Compact)	20	-	30	0.33	0.50	3.00
Silty Peat to Peat (Very Loose)	12	1	27	0.38	0.55	2.66
Sand to Silt and Sand (Very Loose to Compact)	19	-	29	0.35	0.52	2.88
Silt (Loose to Compact)	18	-	28	0.36	0.53	2.77



The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.

Design of the temporary support system should include an evaluation of base stability, soil squeezing stability and hydraulic uplift stability as defined in the Canadian Foundation Engineering Manual (CFEM 2006). The subsurface soils (silt, silt and sand) at this site are sensitive to disturbance from vibration and/or driving operations for sheet pile installation, which should be considered in the design and installation of the temporary protection systems. The installation of sheet-piles for temporary shoring could potentially be impeded by the presence of wood within the sand to silt and sand deposit, as encountered in Boreholes NR-3. It is recommended that an NSSP be included in the contract documents to address obstructions; a sample NSSP is included in Appendix C.

6.7.2 Excavation and Replacement Fill Below Culvert

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

The subgrade for the box culvert should be inspected following sub-excavation to ensure that all organics and other unsuitable materials have been removed, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Following inspection, the sub-excavated area should be backfilled in a timely manner with granular material meeting the specification 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). For backfilling below the water level, if required, we recommend that only Granular B Type II be utilized.

6.7.3 Control of Groundwater and Surface Water

Temporary excavations along the culvert alignment will be required to remove the existing embankment fill, organic materials (where present) and a portion of the native soils to achieve the required excavation depth prior to placement of bedding/level pad, the actual culvert, backfill and roadway pavement structure.

Creek flows through the existing culvert will need to be diverted/pumped away from the excavation areas during the construction period. As a result of the excavation, groundwater flow into the excavation can be expected due to the relatively permeable nature of the adjacent granular embankment fill and non-cohesive native soils. 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.

Based on the GA drawing provided by Hatch, we understand that the proposed box culvert is to be placed approximately 4.3 m west of the existing culvert such that the creek flows can be diverted through the east cell of the existing timber box culvert during construction.

Excavations for the box culvert will extend below the creek water level and will therefore require temporary shoring with unwatering to allow for placement of the bedding material. 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 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 is included in Appendix C.

Provided that the creek flow is diverted away from the proposed excavation and the unwatering system is installed to a suitable depth to mitigate groundwater inflows, construction site dewatering pumping volumes are not anticipated to exceed 50 m³/day. As such, it is anticipated that, under recently introduced changes to the Environmental Protection Act by the Ontario Ministry of the Environment and Climate Change, an Environmental Activity Section Registry (EASR) would not be required.

6.7.4 Culvert Bedding

The bedding, levelling pad and granular backfill requirements for a pre-cast box culvert should be accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the embankment fill and native soils during excavation to the invert and bedding level, it is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material be used for bedding and sub-excavation backfilling purposes. Given the potential presence of groundwater/surface water, we do not recommend that Granular B Type I or III, nor any materials from the Group II list in OPSS 422, be used for bedding purposes. As the native soil below the bedding is generally fine grained, it is also recommended that a non-woven geotextile be placed between the native soil and the bottom of the granular 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) of the materials, consistent with OPSS.PROV 501 (Compacting). In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or concrete fine aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided similar to that presented on 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.

6.7.5 Backfill

Backfill above/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. The granular backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD of the materials in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm as per OPSS 422 (Precast Reinforced Concrete Box Culverts).

As existing granular embankment fill material, which is considered to have a relatively low susceptibility to frost heaving (based on MTO Pavement Design and Rehabilitation Manual, 2013), extends below the estimated 2.6 m depth of frost penetration, a frost taper as per OPSD 803.010 is not necessarily required at this site. However,



based on the design shown on the available Contract Drawings from 1973 (Contact No. 73-163), we understand that a Styrofoam frost heave treatment was incorporated into the embankment fill mass on both sides of the existing Norami Creek culvert. Given that there may have been a history of frost heave issues at this site, it would be prudent and is recommended that a frost taper be similarly incorporated into the embankment as part of the culvert replacement.

Backfill placement for reconstruction of the roadway embankments along 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.

6.7.6 Subgrade Protection

The native silt/silt and sand subgrade will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance, a 300 mm thick granular bedding layer should be placed in a timely manner, once the foundation subgrade has been inspected and approved. It is recommended that an NSSP be included in the contract to address subgrade protection at this site; a sample NSSP is included in Appendix C.

6.7.7 Erosion Protection

Provision should be made for scour and erosion protection at the box culvert location. To prevent surface water from flowing either beneath the box 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 and/or clay seal should be provided at the upstream end of the box culvert. Clay material should meet the requirements of OPSS 1205 (Clay Seal) and the seal should be a minimum thickness of 1 m, whether constructed of natural clay or soil-bentonite mix. The clay seal should extend from a depth of 1 m below the scour level to a minimum vertical height equivalent to the high water level. The seal should also extend a minimum horizontal distance of 2 m on either side of the culvert inlet opening. If a geosynthetic clay liner (GCL) is utilized in lieu of the clay seal, the GCL should be constructed within the embankment slope to allow for a minimum 0.3 m thick granular (embankment) fill cover to be placed over the GCL to provide for protection from the requisite overlying erosion protection material.

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 or GCL.



6.7.8 Obstructions

The contractor should be alerted to the presence of wood encountered within the silty sand deposit in Borehole NR-3. A sample NSSP is included in Appendix C.

6.7.9 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.

For potential sulphate attack on concrete, the results of the water analysis were compared to Table 3 in CSA A23-1-09, and indicate that the relative degree of sulphate attack is low (less than the moderate range). However, given that the culvert is located on Highway 11 and will be exposed to de-icing salts it is recommended that C-1 class exposure concrete be considered for the pre-cast culvert units. Further, the resistivity results indicate that the creek water has a moderate corrosiveness potential based on the Transportation Research Board Guidelines (Transportation Research Board, National Research Council, 1998 as referenced in the MTO Gravity Pipe Design Guidelines, 2014).

It should be noted that the creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events and the water chemistry could also be variable. These recommendations are provided as guidance only; the structural designer should take the results of the laboratory testing and the potential for corrosion into consideration when selecting materials for culvert construction.

7.0 CLOSURE

This Detail 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., a Senior Consultant with and Designated MTO Foundations Contact of Golder, conducted an independent quality control review of this report.



Report Signature Page

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AC/DAM/JMAC/kp

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REFERENCES

Canadian Foundation Engineering Manual 2006, 4th Edition, Canadian Geotechnical Society.

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

Canadian Standards Association (CSA), 2014. CSA A23.1-09 Concrete Materials and Methods of Construction (R2014)

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.

Ministry of Transportation, MTO Gravity Pipe Design Guidelines, MTO Drainage and Hydrology Design and Contract Standards Office, May 2014

Ministry of Transportation, “MTO Pavement Design and Rehabilitation Manual”, MTO Materials Engineering and Research Office, Second Edition 2013.

Transportation Research Board, National Research Council, 1998. Service Life Drainage Pipe, National Cooperative Highway Research Program (NCHRP) Synthesis 254.

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

ASTM International:

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

Ontario Provincial Standard Specifications (OPSS)

OPSS 422 Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut

OPSS 517 Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation

OPSS 1205 Material Specification for Clay Seal

OPSS 1860 Material Specification for Geotextiles

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS.PROV 1002 Material Specification for Aggregates - Concrete

OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010 Benching of Earth Slopes

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



DETAIL FOUNDATION REPORT NORAMI CREEK CULVERT - SITE NO. 48E-62

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)



DETAIL FOUNDATION REPORT NORAMI CREEK CULVERT - SITE NO. 48E-62

Table 1: Summary Details of Existing Culvert

Culvert Location	Site #	Approximate Height of Embankment ¹ (m)	Existing Culvert			Approximate Invert Elevation ²	
			Type	Approximate Dimension ²	Approximate Length (m)	North End of Culvert (m)	South End of Culvert (m)
Hwy 11 STA 20+212	48E-62	2.9	Twin Cell Timber Box	2.1 m wide x 1.6 m high (each cell)	19	315.7	315.6

- Notes:
1. Embankment height is relative to existing ground surface at the centreline of the roadway and the culvert invert.
 2. Culvert dimensions and invert elevations are based on the plan and profile drawings provided by MTO (Drawing bc904113.dwg).

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



**DETAIL FOUNDATION REPORT
NORAMI CREEK CULVERT - SITE NO. 48E-62**

Table 2: Comparison of Alternative Culvert Types

Option	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	<ul style="list-style-type: none"> ■ Minimizes depth of excavation, protection system (if required) and dewatering requirements compared to open footing option. ■ Allows faster construction resulting in shorter duration for dewatering and surface water pumping. ■ More tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site or if heave/settlement occurs resulting from freeze/thaw of the subgrade. ■ 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) likely 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 a relatively wide creek channel. 	<ul style="list-style-type: none"> ■ Some risk of disturbance of the native silt deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular 'B' Type II working pad/bedding. ■ Low risk related to settlement performance as box segments can accommodate some total and differential settlement.
Open Footing Culvert	<ul style="list-style-type: none"> ■ May be feasible to construct the culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering/unwatering (pumping) of surface water. ■ Readily suitable for construction using concrete or metal sections. ■ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable. 	<ul style="list-style-type: none"> ■ Excavation depths are greater than for a box culvert option, resulting in increased excavation support and dewatering requirements and additional spoil material to be disposed off-site. ■ Constructing footings in the dry will take longer due to requirements for installation of a groundwater and surface water control system, dewatering and surface water pumping and excavation in a confined space. ■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site. ■ Concrete or metal arch sections supported on concrete open (strip) footings may not allow for adequate soil cover to be placed including roadway pavement structure. 	<ul style="list-style-type: none"> ■ High risk of disturbance of the native silt deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad. ■ May require greater depth of dewatering for footing construction. ■ Culvert joints may be required to accommodate total and differential settlement.



**DETAIL FOUNDATION REPORT
NORAMI CREEK CULVERT - SITE NO. 48E-62**

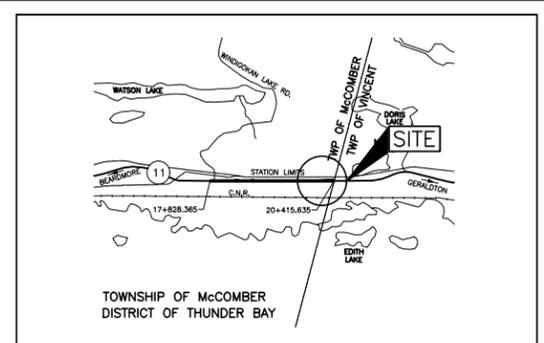
Option	Advantages	Disadvantages	Risks/Consequences
Pipe Culvert(s)	<ul style="list-style-type: none">■ Allows for faster construction resulting in shorter duration for dewatering and surface pumping compared to an open footing culvert.■ More tolerant of total and differential settlement if the highway 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 compared to box culvert and open footing options with a similar span – additional flow through capacity may have to be provided by multiple pipes.■ Cut-off wall or clay seal may be required at inlet to mitigate potential scour under culvert(s).■ Difficult to compact backfill materials to level of culvert springline.■ CSP does not have as long of design life compared to concrete options.	<ul style="list-style-type: none">■ Some risk of disturbance of the native silt deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad.■ Moderate risk related to anticipated differential settlement; but lower risk compared to open footing option.

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

CONT No. GWP No. 6166-04-00
HIGHWAY 11
NORAMI CREEK CULVERT STA 20+212
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



KEY PLAN
SCALE
1.5 0 1.5 3 km

LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
NR-1	316.7	5503037.6	249433.2
NR-2	316.8	5503039.3	249442.4
NR-3	318.8	5503029.2	249444.7
NR-4	318.8	5503021.1	249430.4
NR-5	316.7	5503013.4	249445.6
NR-6	316.8	5503013.2	249437.6

NOTES

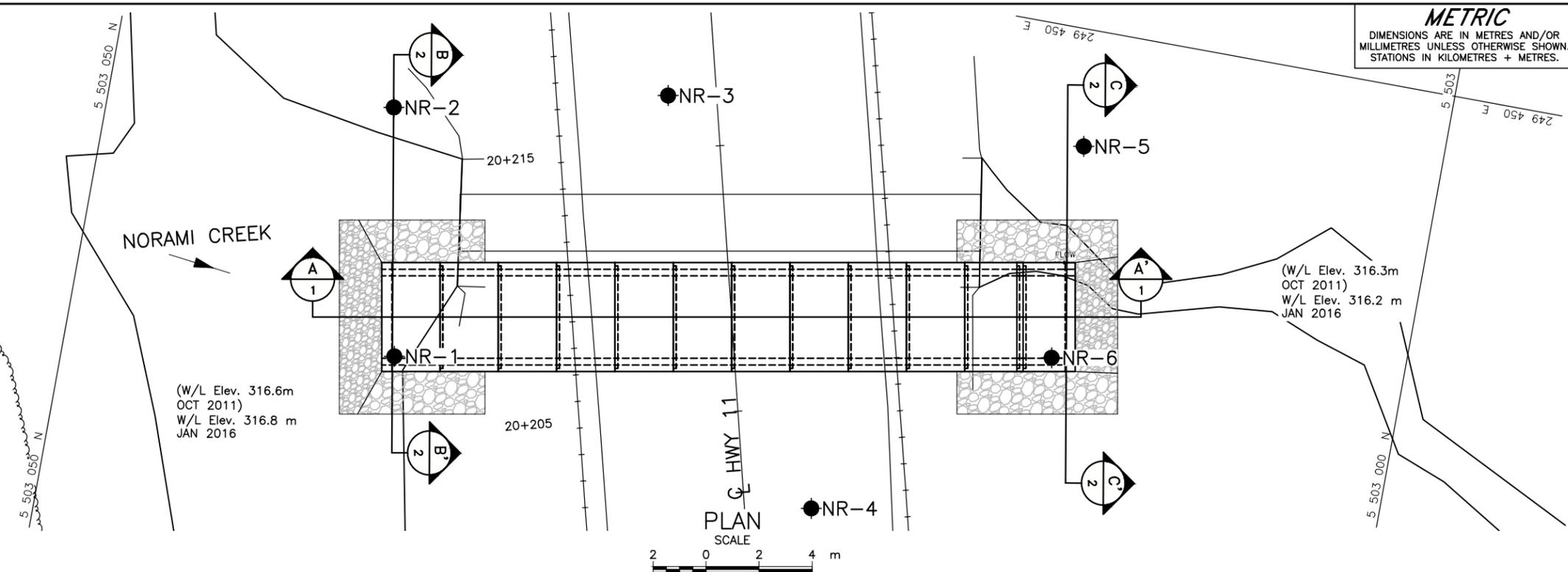
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

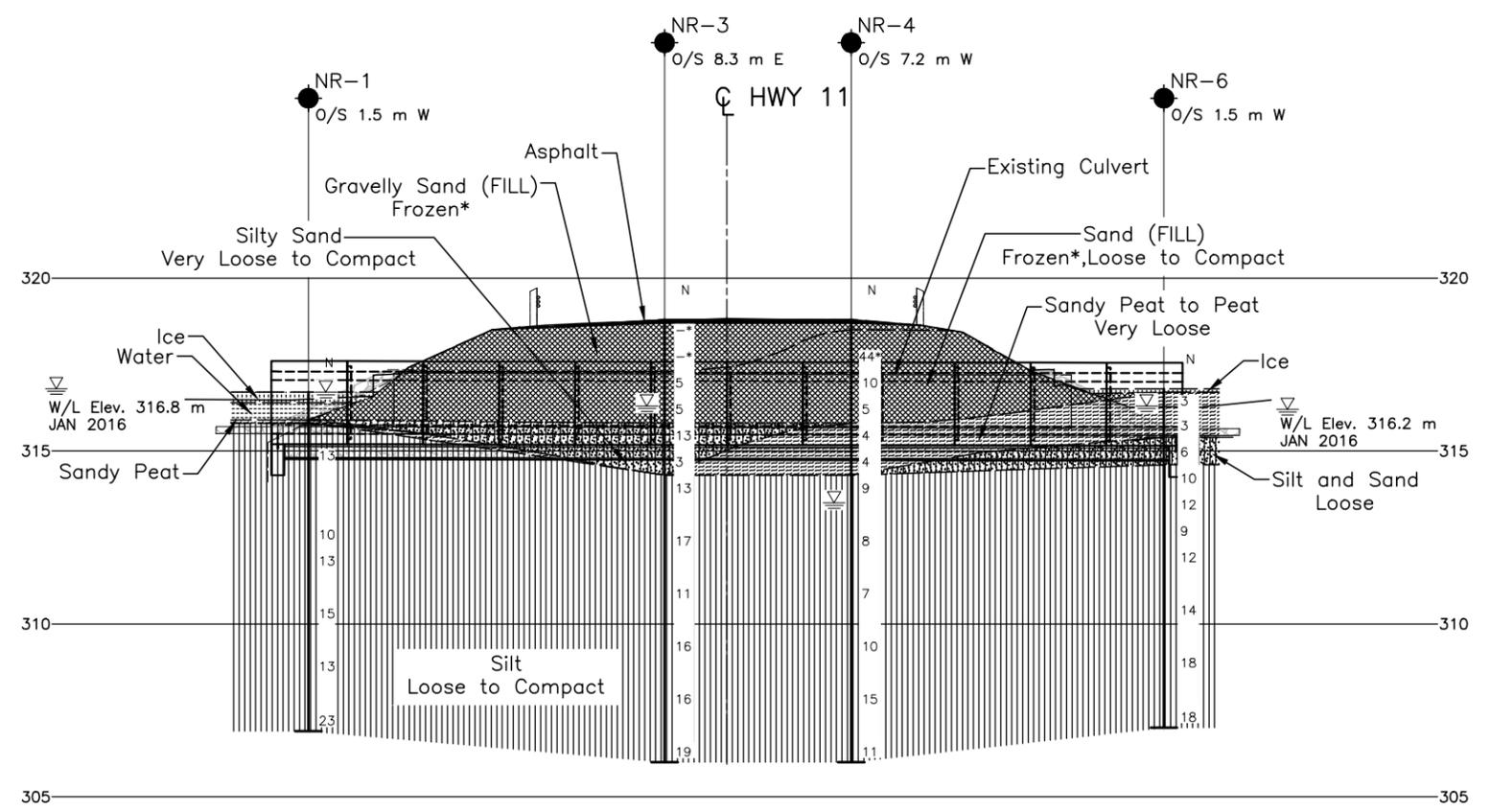
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MTO, drawing file nos. BC904113.dwg received Dec. 11, 2015. GA received in digital format by MTO, drawing file nos. ST-358767-NORAMI CREEK CULVERT-01-GENERAL ARRANGEMENT.dwg received June 27, 2016.



PLAN
SCALE
2 0 2 4 m



HORIZ. SCALE 1:200
VERT. SCALE 1:200
SCALE
2 0 2 4 m

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 PLOT DATE: 2016-10-27 10:54:15 AM
 PLOT BY: J.M.A. COSTA



NO.	DATE	BY	REVISION

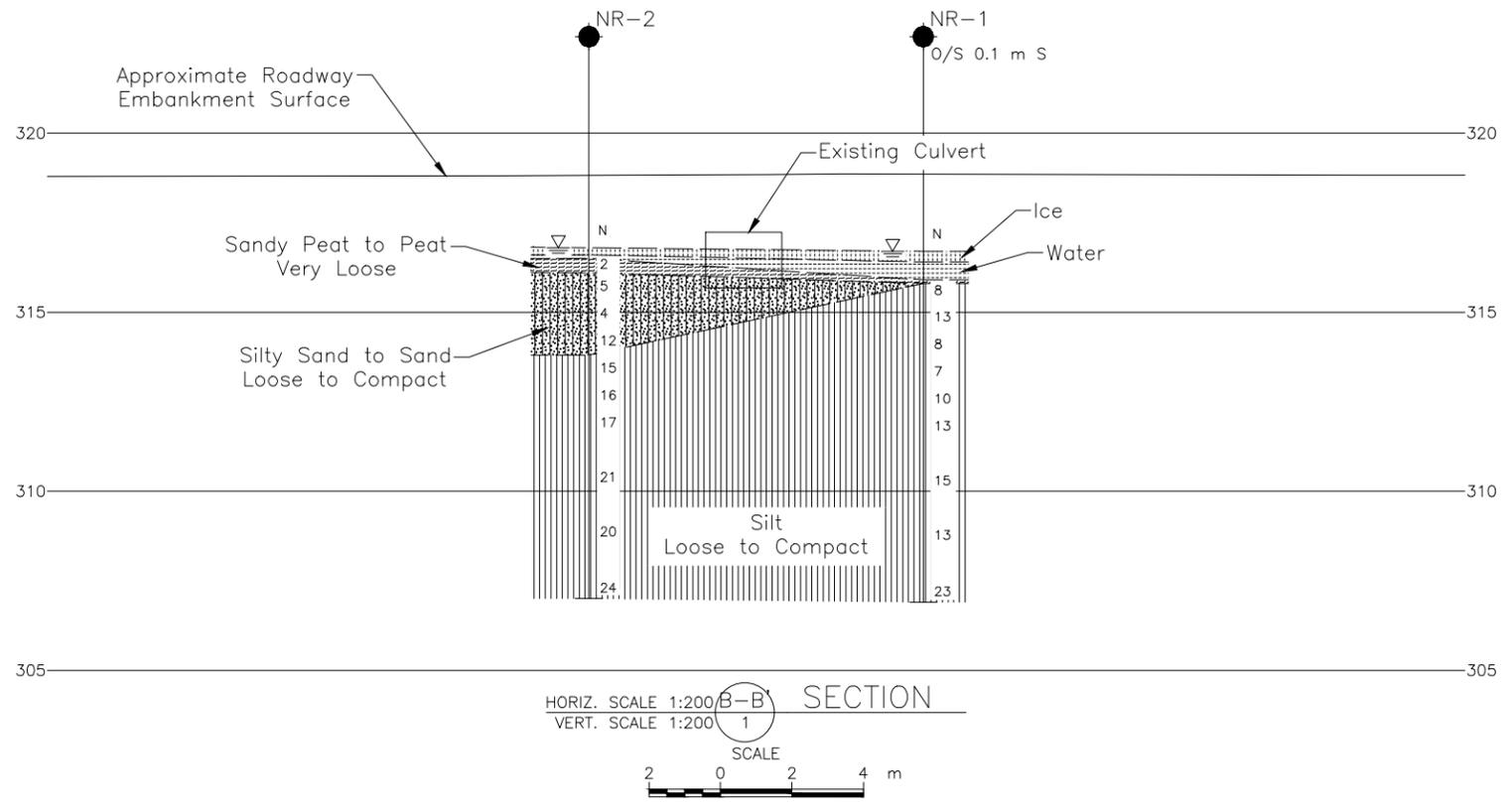
Geocres No. 42E-26

HWY. 11	PROJECT NO. 1533879	DIST. .
SUBM'D. AC	CHKD. .	DATE: 10/7/2016
DRAWN: JJJ	CHKD. DAM	APPD. JMAC
		SITE: 48E-62
		DWG. 1

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

CONT No. GWP No. 6166-04-00
 HIGHWAY 11
 NORAMI CREEK CULVERT STA 20+212
 SOIL STRATA

SHEET



LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
NR-1	316.7	5503037.6	249433.2
NR-2	316.8	5503039.3	249442.4
NR-5	316.7	5503013.4	249445.6
NR-6	316.8	5503013.2	249437.6

NOTES

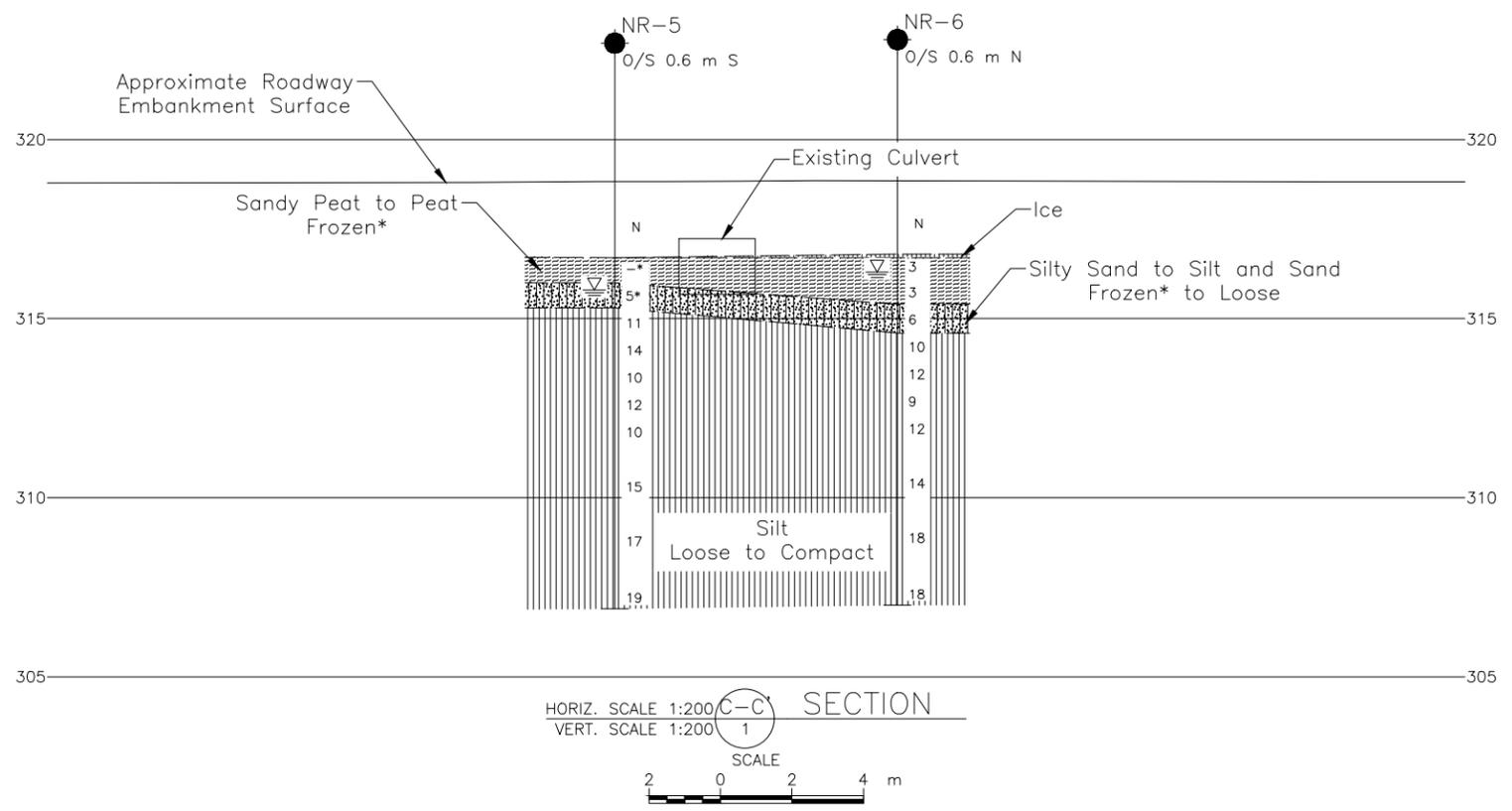
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NO.	DATE	BY	REVISION

Geocres No. 42E-26

HWY. 11	PROJECT NO. 1533879	DIST. .
SUBM'D. AC	CHKD. .	DATE: 10/7/2016
DRAWN: JJJ	CHKD. DAM	APPD. JMAC
		SITE: 48E-62
		DWG: 2



PHOTOGRAPHS

**Photograph 1: Norami Creek Culvert
Looking West at Inlet (December 2015)**



**Photograph 2: Norami Creek Culvert
Looking East at Outlet (December 2015)**





PHOTOGRAPHS

**Photograph 3: Norami Creek Culvert
Looking West at Inlet (February 2016)**



**Photograph 4: Norami Creek Culvert
Looking West at Outlet (February 2016)**





APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I.	GENERAL	(a)	Index Properties (continued)
π	3.1416	w	water content
$\ln x$,	natural logarithm of x	w_l or LL	liquid limit
\log_{10}	x or log x, logarithm of x to base 10	w_p or PL	plastic limit
g	acceleration due to gravity	I_p or PI	plasticity index = $(w_l - w_p)$
t	time	w_s	shrinkage limit
FoS	factor of safety	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)
II.	STRESS AND STRAIN	(b)	Hydraulic Properties
γ	shear strain	h	hydraulic head or potential
Δ	change in, e.g. in stress: $\Delta \sigma$	q	rate of flow
ε	linear strain	v	velocity of flow
ε_v	volumetric strain	i	hydraulic gradient
η	coefficient of viscosity	k	hydraulic conductivity (coefficient of permeability)
ν	Poisson's ratio	j	seepage force per unit volume
σ	total stress	(c)	Consolidation (one-dimensional)
σ'	effective stress ($\sigma' = \sigma - u$)	C_c	compression index (normally consolidated range)
σ'_{vo}	initial effective overburden stress	C_r	recompression index (over-consolidated range)
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)	C_s	swelling index
σ_{oct}	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3)/3$	C_α	secondary compression index
τ	shear stress	m_v	coefficient of volume change
u	porewater pressure	C_v	coefficient of consolidation (vertical direction)
E	modulus of deformation	C_h	coefficient of consolidation (horizontal direction)
G	shear modulus of deformation	T_v	time factor (vertical direction)
K	bulk modulus of compressibility	U	degree of consolidation
		σ'_p	pre-consolidation stress
III.	SOIL PROPERTIES	OCR	over-consolidation ratio = σ'_p / σ'_{vo}
(a)	Index Properties	(d)	Shear Strength
$\rho(\gamma)$	bulk density (bulk unit weight)*	τ_p, τ_r	peak and residual shear strength
$\rho_d(\gamma_d)$	dry density (dry unit weight)	ϕ'	effective angle of internal friction
$\rho_w(\gamma_w)$	density (unit weight) of water	δ	angle of interface friction
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	μ	coefficient of friction = $\tan \delta$
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)	c'	effective cohesion
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)	C_u, S_u	undrained shear strength ($\phi = 0$ analysis)
e	void ratio	p	mean total stress $(\sigma_1 + \sigma_3)/2$
n	porosity	p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
S	degree of saturation	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

$\tau = c' + \sigma' \tan \phi'$
shear strength = (compressive strength)/2



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w _p	plastic limit
w _l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-1	1 OF 1 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503037.6; E 249433.2</u>	ORIGINATED BY <u>SA</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>NW Casing and Wash Boring</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>February 1 and 2, 2016</u>	CHECKED BY <u>DAM</u>

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			20	40	60	80	100						20
316.7	GROUND SURFACE																
0.0	ICE (300 mm)				∇												
316.4																	
0.3	WATER (500 mm)																
315.9																	
0.9	Sandy PEAT (fibrous) (100 mm) Black Wet SILT, trace to some clay, trace to some sand, trace to some gravel Loose to compact Brown to grey Wet	1	SS	8													
		2	SS	13													0 3 95 2
		3	SS	8													
		4	SS	7													
		5	SS	10													
		6	SS	13													NP 0 4 93 3
		7	SS	15													
	Approximately 100 mm to 150 mm of heave encountered between 6.1 m and 9.1 m depth.	8	SS	13													13 8 73 6
		9	SS	23													
306.9	END OF BOREHOLE																
9.8																	

SUD-MTO 001 1533879.GPJ GAL=MISS.GDT 12/07/16 DATA INPUT:

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

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-2	1 OF 1 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503039.3; E 249442.4</u>	ORIGINATED BY <u>SA</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>NW Casing and Wash Boring</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>February 1, 2016</u>	CHECKED BY <u>DAM</u>

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80						100	20
316.8	GROUND SURFACE																	
0.0	ICE (200 mm)																	
0.3	WATER (100 mm)																	
316.1	PEAT (Fibrous), trace sand Very loose Black Wet		1	SS	2													
0.7	SILTY SAND to SAND, trace to some gravel, trace organics Loose to compact Brown to grey Wet		2	SS	5							○				8	82	(10)
			3	SS	4													
			4	SS	12													
313.8	SILT, trace to some clay, trace to some sand Compact Grey Wet		5	SS	15													
3.0			6	SS	16							○				0	8	88 4
			7	SS	17													
			8	SS	21													
			9	SS	20							○				0	3	90 7
	A 25 mm clay seam was noted at 8.1 m depth.																	
			10	SS	24													
307.0	END OF BOREHOLE																	
9.8																		

SUD-MTO 001 1533879.GPJ GAL=MISS.GDT 12/07/16 DATA INPUT:

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

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-3	2 OF 2 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503029.2; E 249444.7</u>	ORIGINATED BY <u>MR</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>February 14, 2016</u>	CHECKED BY <u>DAM</u>

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W		
306.0	--- CONTINUED FROM PREVIOUS PAGE --- SILT, trace to some clay, trace to some sand Compact Grey Wet		12	SS	19											
12.8	END OF BOREHOLE Note: 1. Water level at a depth of 2.5 m below ground surface (Elev. 316.3 m) upon completion of drilling.					306										

SUD-MTO 001 1533879.GPJ GAL-MISS.GDT 12/07/16 DATA INPUT:

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

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-4	1 OF 2 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503021.1; E 249430.4</u>	ORIGINATED BY <u>MA</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>January 22, 2016</u>	CHECKED BY <u>DAM</u>

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
			NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)			
								20	40	60	80	100						GR	SA	SI	CL
318.8	GROUND SURFACE																				
0.0	ASPHALT (100 mm)																				
0.3	Gravelly sand, some silt (FILL) Brown Frozen Sand, some silt, trace organics (FILL) Loose to compact Brown Frozen* to Moist		1	SS	44*		318														
			2	SS	10		317											0	86		(14)
			3	SS	5		316														
315.8	Sandy PEAT (Fibrous), some silt Very loose Brown Wet		4	SS	4		315														
			5	SS	4		314														
314.3	SILT, trace clay, trace sand Loose to compact Grey Wet		6	SS	9		313														
			7	SS	8		312														
			8	SS	7		311														
			9	SS	10		310														
			10	SS	15		309														
							308														
							307														

SUD-MTO 001 1533879.GPJ GAL=MISS.GDT 12/07/16 DATA INPUT:

Continued Next Page

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



PROJECT 1533879 **RECORD OF BOREHOLE No NR-4** 2 OF 2 **METRIC**

G.W.P. 6166-14-00 LOCATION N 5503021.1; E 249430.4 ORIGINATED BY MA

DIST HWY 11 BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers COMPILED BY AC

DATUM GEODETIC DATE January 22, 2016 CHECKED BY DAM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W			W _L	GR
306.0	--- CONTINUED FROM PREVIOUS PAGE --- SILT, trace clay, trace sand Loose to compact Grey Wet		11	SS	11													
12.8	END OF BOREHOLE Note: 1. Water level at a depth of 5.3 m below ground surface (Elev. 313.5 m) upon completion of drilling.																	

SUD-MTO 001 1533879.GPJ GAL-MISS.GDT 12/07/16 DATA INPUT:

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

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-5	1 OF 1 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503013.4; E 249445.6</u>	ORIGINATED BY <u>MR</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>February 13, 2016</u>	CHECKED BY <u>DAM</u>

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80					
316.7	GROUND SURFACE															
0.0	Sandy PEAT (Fibrous) Brown Frozen*		1	AS	-*											
316.0																
0.7	SILTY SAND, trace organics Grey Frozen*		2	SS	5*											
315.3																
1.4	SILT, trace to some clay, trace sand Compact Grey Wet		3	SS	11											
			4	SS	14											0 4 90 6
			5	SS	10											
			6	SS	12											
			7	SS	10											
			8	SS	15											0 4 88 8
			9	SS	17											
			10	SS	19											
306.9	END OF BOREHOLE															
9.8	Note: 1. Water level at a depth of 0.9 m below ground surface (Elev. 315.8 m) upon completion of drilling.															

SUD-MTO 001 1533879.GPJ GAL=MISS.GDT 12/07/16 DATA INPUT:

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-6	1 OF 1 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503013.2; E 249437.6</u>	ORIGINATED BY <u>SA</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>NW Casing and Wash Boring</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>January 31, 2016</u>	CHECKED BY <u>DAM</u>

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)		
						20	40	60	80	100	20	40	60		GR	SA	SI	CL	
316.8	GROUND SURFACE																		
0.0	ICE (100 mm)																		
0.1	PEAT (Fibrous), some sand, trace gravel Very loose Dark brown to black Wet		1	SS	3														
			2	SS	3														
315.4																			
1.4	SILT and SAND, trace clay, trace organics Loose Grey Wet		3	SS	6											0	40	58	2
314.6																			
2.2	SILT, trace to some clay, trace sand Loose to compact Grey Wet		4	SS	10														
			5	SS	12														
			6	SS	9											0	3	95	2
			7	SS	12														
			8	SS	14														
			9	SS	18											0	3	91	6
			10	SS	18														
307.0	END OF BOREHOLE																		
9.8	Note: 1. Water level at a depth of 0.5 m below ground surface (Elev. 316.3 m) upon completion of drilling.																		

SUD-MTO 001 1533879.GPJ GAL=MISS.GDT 12/07/16 DATA INPUT:



APPENDIX B

Laboratory Test Results



**DETAIL FOUNDATION REPORT
NORAMI CREEK CULVERT - SITE NO. 48E-62**

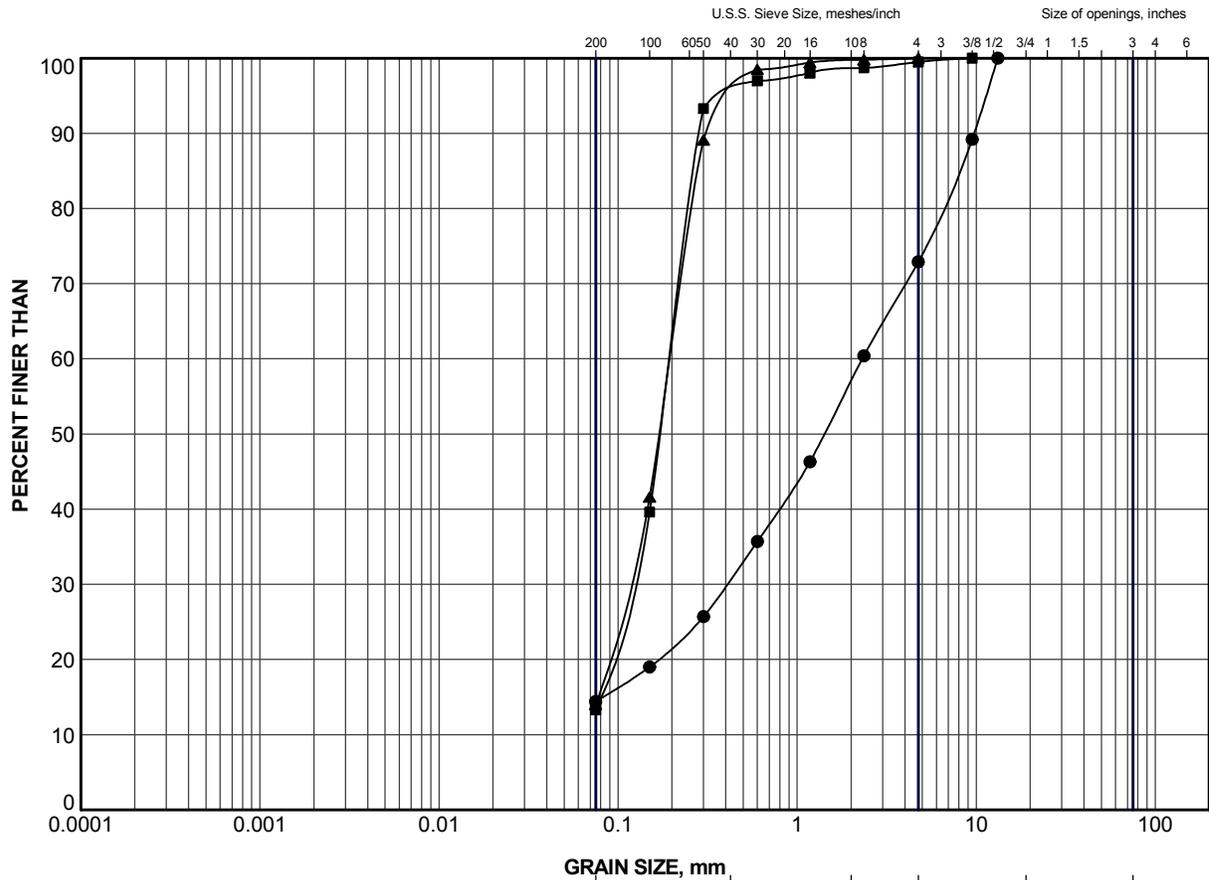
Table B1: Summary of Analytical Testing of Norami Creek Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	21.4
Sulphate (SO4)	mg/L	0.82
Conductivity (EC)	μ S/cm	230
Resistivity	ohm-cm	4350
pH	n/a	7.22

Notes:

1. Sample obtained on January 27, 2016.
2. Analytical testing carried out by ALS Canada Ltd.

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



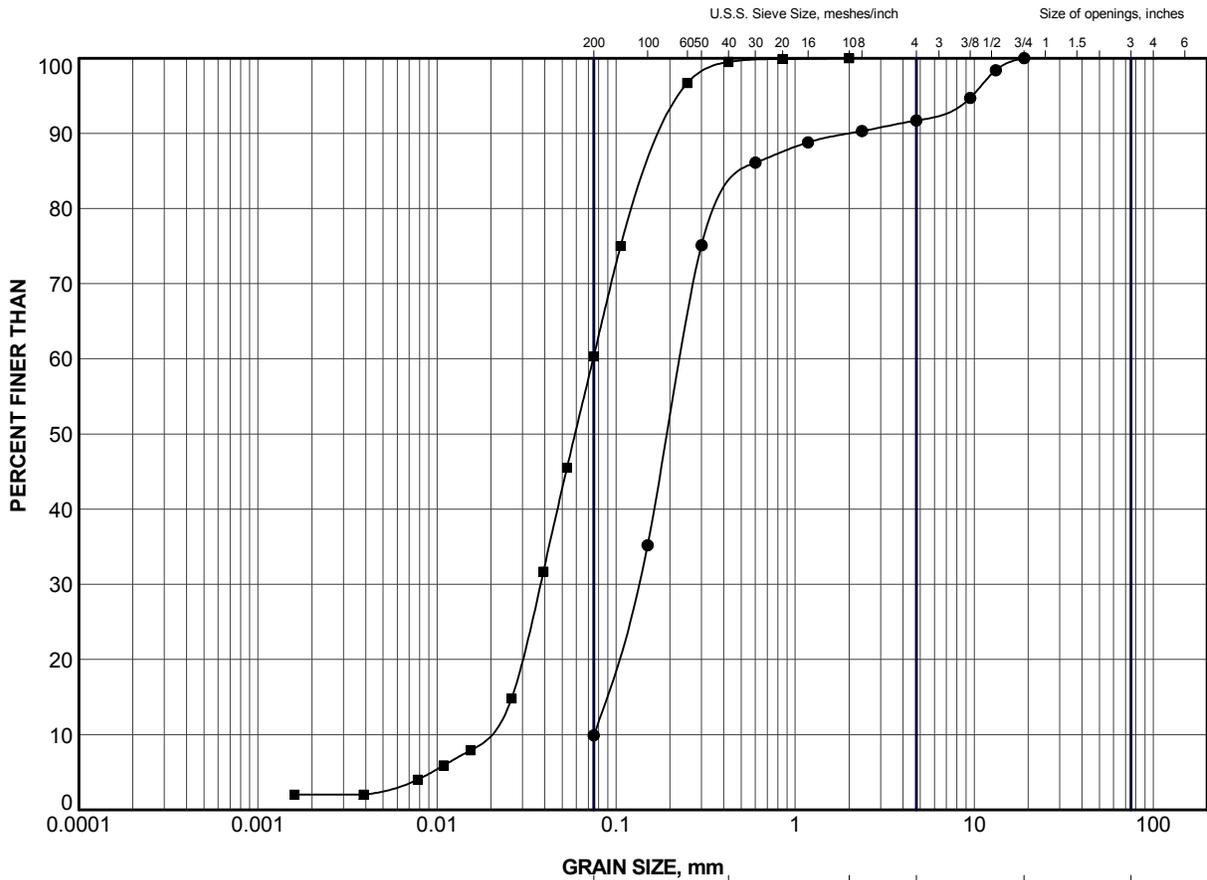
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	NR-3	2	317.7
■	NR-3	4	316.2
▲	NR-4	2	317.0

PROJECT HIGHWAY 11 NORAMI CREEK CULVERT STA 20+212					
TITLE GRAIN SIZE DISTRIBUTION SAND to GRAVELLY SAND (FILL)					
PROJECT No.		1533879		FILE No.	1533879.GPJ
DRAWN	JJL	Jun 2016	SCALE	N/A	REV.
CHECK	DAM	Jun 2016	FIGURE B1		
APPR	JMAC	Jun 2016			



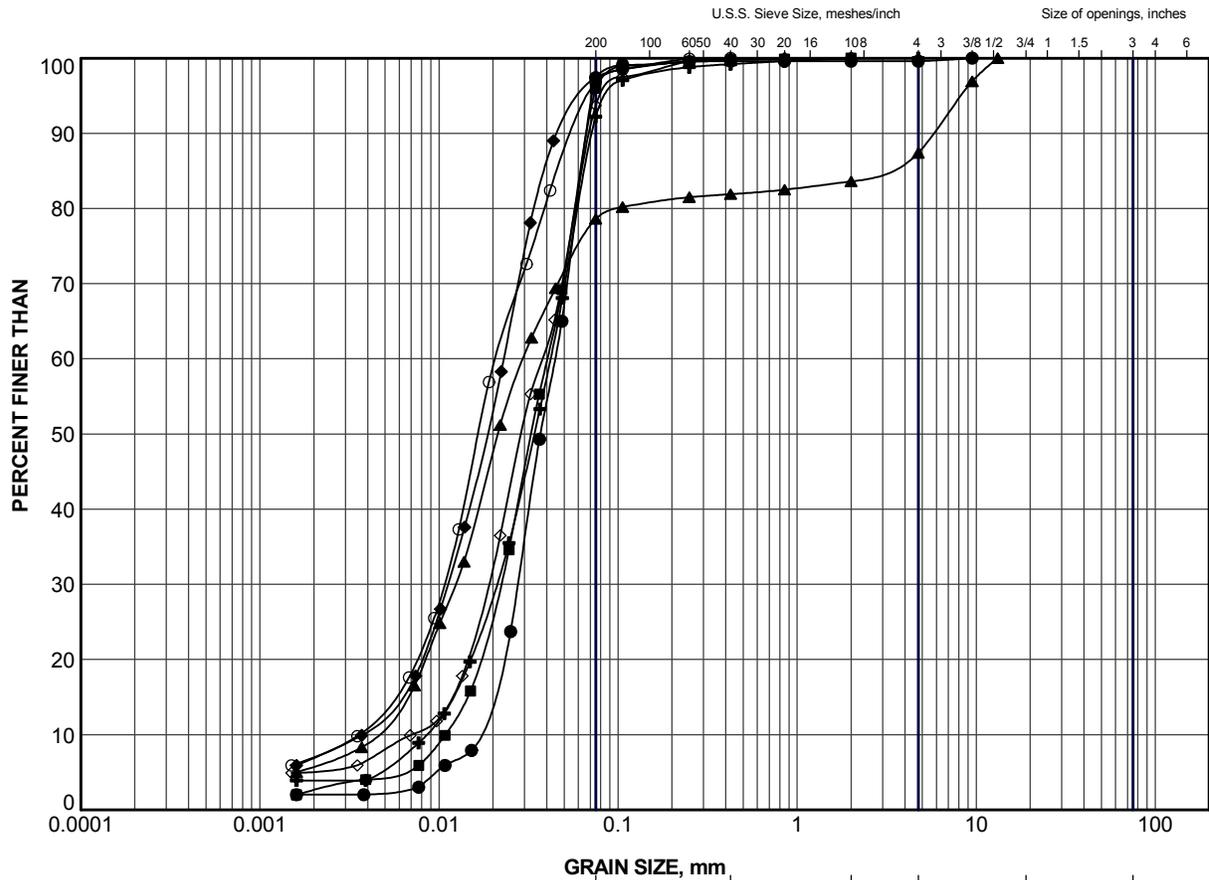


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	NR-2	2	315.7
■	NR-6	3	315.0

PROJECT HIGHWAY 11 NORAMI CREEK CULVERT STA 20+212					
TITLE GRAIN SIZE DISTRIBUTION SAND to SILT and SAND					
PROJECT No.		1533879		FILE No.	1533879.GPJ
DRAWN	JJL	Jul 2016	SCALE	N/A	REV.
CHECK	DAM	Jul 2016	FIGURE B2		
APPR	JMAC	Jul 2016			
 Golder Associates SUDBURY, ONTARIO					



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

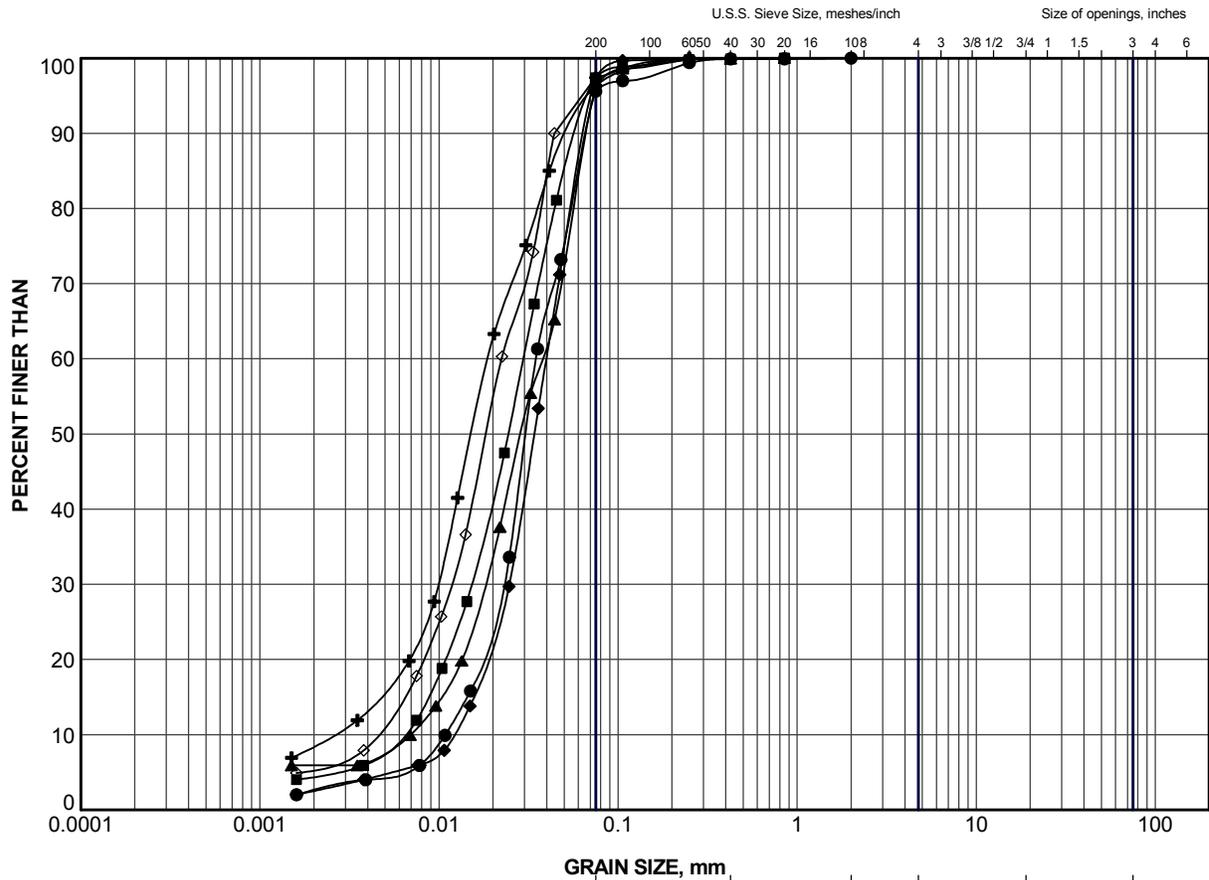
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	NR-1	2	314.9
■	NR-1	6	311.8
▲	NR-1	8	308.8
+	NR-2	6	312.7
◆	NR-2	9	308.9
◇	NR-3	7	313.9
○	NR-3	10	309.4

PROJECT HIGHWAY 11 NORAMI CREEK CULVERT STA 20+212					
TITLE GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.		1533879		FILE No.	1533879.GPJ
DRAWN	JJL	Jun 2016	SCALE	N/A	REV.
CHECK	DAM	Jun 2016	FIGURE B3.1		
APPR	JMAC	Jun 2016			



SUD-MTO GSD (2016) GLDR_LDN.GDT



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	NR-4	6	313.9
■	NR-4	9	309.4
▲	NR-5	4	314.1
+	NR-5	8	310.3
◆	NR-6	6	312.7
◇	NR-6	9	308.9

PROJECT HIGHWAY 11 NORAMI CREEK CULVERT STA 20+212					
TITLE GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.		1533879		FILE No. 1533879.GPJ	
DRAWN	JJL	Jun 2016	SCALE	N/A	REV.
CHECK	DAM	Jun 2016	FIGURE B3.2		
APPR	JMAC	Jun 2016			



SUD-MTO GSD (2016) GLDR_LDN.GDT



APPENDIX C

Non Standard Special Provisions

OBSTRUCTIONS

Non-Standard Special Provision

As part of the work for the culvert installation at the Norami Creek culvert, the Contactor shall be alerted to the presence of wood within the silty sand deposit as encountered in Borehole NR-3.

DEWATERING OF STRUCTURE EXCAVATION - Item No.

Non-Standard Special Provision

Construction of the Norami Creek culvert will require excavations to extend below the groundwater level. The silt stratum that is present below the groundwater level at about the culvert founding level will slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate excavation protection and dewatering system to enable construction and to prevent disturbance to the founding soils.

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.

SUBGRADE PROTECTION – Item No.

Non-Standard Special Provision

Scope of Work

The native subgrade soils at and immediately underlying the culvert founding grade at this site are susceptible to disturbance and loosening from construction traffic and ponded water. A 300 mm thick protection layer, or bedding layer, comprised of Granular A or Granular B Type II material should be placed on the prepared subgrade in a timely manner. The subgrade should be inspected and approved immediately before placing the bedding layer to confirm the subgrade conditions. Any loosened or disturbed soils below the plan limits of the proposed works should be sub-excavated and replaced with compacted engineered fill.

Basis of Payment

Payment at the lump sum contract price for the above tender item includes full compensation for all labour, equipment and material for completion of the work.

END OF SECTION

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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