



April 2, 2015

**DRAFT PRELIMINARY FOUNDATION INVESTIGATION AND
DESIGN REPORT**

**KABITOTIKWIA RIVER CULVERT SITE NO. 48W-196/C
HIGHWAY 811, DISTRICT OF THUNDER BAY
UNSURVEYED TERRITORY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6302-14-00**

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PART A

**PRELIMINARY FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Hatch Mott MacDonald (HMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the replacement of the Kabitotikwia River culvert (Site No. 48W-196/C). The Kabitotikwia River culvert is located in the District of Thunder Bay on Highway 811 at STA 10+040, approximately 9.8 km west of Highway 527. The key plan showing the general location of this section of Highway 811 and the location of the investigated area are shown on Drawing 1.

2.0 SITE DESCRIPTION

The Kabitotikwia River culverts, located on Highway 811 at STA 10+040 approximately 9.8 km west of the junction of Highway 527, consist of three Structural Plate Corrugated Steel Pipe (SP CSP) structures, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

In general, the topography in this area is relatively flat with moderate to dense tree cover along the highway right-of-way. At the culvert location, the Kabitotikwia River flows in a northerly direction, the highway grade is at Elevation 432.8 m and the culvert invert is at Elevations 429.7 m and 429.5 m at the inlet (south) and outlet (north) ends, respectively. The water level measured by others on October 29, 2013, was Elevation 428.8 m and the river ice 429.8 m measured by Golder on December 7, 2014, was Elevation 429.8 m. Surface conditions in the culvert area in October 2013 and December 2015 are shown on photographs 1 to 3.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between December 6 and 8, 2014, during which time four (4) boreholes (Boreholes KB-1 to KB-4) were advanced at approximately the locations shown on Drawing 1. Boreholes KB-1 and KB-4 were advanced using a track-mounted CME-55 drill rig and Boreholes KB-2 and KB-3 were advanced using a truck-mounted CME-55 drill rig. Both drill rigs were supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec.

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

The field work was supervised on a full-time basis by members of Golder's technical staff who, located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined and cared for the soil samples. The soil and rock 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, Atterberg limits and grain size distributions were carried out on selected soil samples. In addition, unconfined compressive strength tests were carried out on selected specimens of the bedrock core



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recovered from the boreholes. The geotechnical laboratory testing was completed according to MTO LS standards.

A sample of the river water was obtained during the field investigation using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters, including pH, resistivity, conductivity, sulphates and chlorides.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by member of our technical staff, referenced to the highway centerline and existing culvert and converted into Northing/Easting on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile drawing, provided by MTO in January 2015. The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole locations 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)
KB-1	5472758.2	341068.7	430.4	3.0
KB-2	5472742.2	341082.4	432.7	5.2
KB-3	5472745.2	341067.1	432.8	5.3
KB-4	5472731.7	341080.7	432.4	5.0

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)¹ mapping, the subsoils in the vicinity of the Kabitotikwia River culvert site generally consist of esker complex deposits comprised of primarily of gravel and sand, bordered closely to the west by a ground moraine deposit comprised mainly of till.

Based on geological mapping by the Ministry of Northern Development and Mines (Map 2542)², the site is underlain by bedrocks of the Archean era, comprised of foliated tonalite suite rocks consisting of foliated to massive tonalite to granodiorite rocks.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole and Record of Drillhole sheets contained in Appendix A. The results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ field tests (i.e., SPT 'N'-values) 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

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

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



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on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoil conditions encountered at the site consist of embankment granular fill underlain by thin, non-cohesive deposits of silty sand, silt, gravel and cobbles in places, which are underlain by diorite bedrock. A more detailed description of the soil deposits, bedrock and groundwater conditions encountered in the boreholes is below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Elevation (m)	N Values (blows)	Laboratory Testing
				Consistency or Relative Density	
(FILL) ¹ Sand to Sandy Gravel, trace to some silt, trace clay, trace organics, trace wood, brown, moist to wet	KB-1 to KB-4	0.2 – 3.6	432.8 – 430.4	N = 15 – 40 ^{1,2}	w = 4% – 25 % 2 – MH, 1 – M (Fig. B1) 2 – AL N.P.
				Compact to Dense	
Silt , some sand some gravel, trace clay, trace organics, brown, wet	KB-4	0.7	430.2	N = 13	-
				Compact	
Gravel and Cobbles	KB-4	0.7	429.5	-	-
Silty Sand (TILL) , trace gravel, grey, wet	KB-3	0.1	429.2	-	-

Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration

w = Natural Moisture Content (%)

MH = Combined Sieve and Hydrometer analysis

M = Sieve analysis for particle size

AL = Atterberg limits test

NP = Non=Plastic test results

Note:

¹ Within the fill, in Borehole KB-3 a 230 mm cobble was encountered at a depth of 0.5 m below ground surface, requiring NW casing and NQ coring techniques to advance the borehole through that portion of the deposit. In Borehole KB-4 the augers were noted to be grinding from ground surface to a depth of 1.5 m below ground surface.

² In the fill, in Boreholes KB-2 and KB-3, two 'N'-values of 100 blows for 0.15 m of penetration were recorded, inferred indicative of the presence of cobbles within the fill deposit.



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Bedrock

Bedrock was cored in Boreholes KB-1 to KB-4 and the depth to the bedrock surface and bedrock surface elevations are presented below.

Borehole No.	Depth to Bedrock (below ground surface) (m)	Bedrock Surface Elevation (m)	Core Thickness (m)
KB-1	0.2	430.2	2.8
KB-2	3.6	429.1	1.6
KB-3	3.7	429.1	1.6
KB-4	3.6	428.8	1.4

The retrieved bedrock core is described as black-white, medium to coarse grained, fresh, diorite, as presented on the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B2. A more detailed description of the bedrock properties encountered in the boreholes is provided in the following table.

Borehole No.	Total Core Recovery	Rock Quality Designation	Quality Classification Table 3.10 of CFEM 2006 ³	Uniaxial Compressive Strength (MPa)	Strength Classification Table 3.5 of CFEM 2006 ³
KB-1	100%	93% - 100%	Excellent	235	(R5) Very Strong
KB-2	100%	85% - 87%	Good	-	-
KB-3	100%	75% - 100%	Good to Excellent	176	(R5) Very Strong
KB-4	100%	100%	Excellent	-	-

Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The river ice level was measured at Elevation 429.8 m on December 7, 2014. Groundwater and river water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

³ Canadian Geological Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.



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Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
KB-1	1.6	428.8
KB-2	Dry to 1.4 m ¹	-
KB-3	Dry to 1.6 m ¹	-
KB-4	Dry to 0.6 m ¹	-

Note:

¹ Boreholes KB-2 to KB-4 caved at depths ranging from 0.6 m to 1.6 m (inferred depths to water level) upon completion of drilling and boreholes were noted to be dry to the caved depth.

5.0 CLOSURE

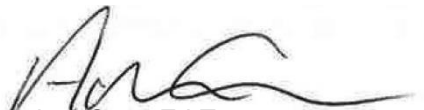
The field drilling program was carried out under the supervision of Mr. Cody Walter and Mr. Mathew Riopelle, under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Adam Core, E.I.T., and Ms. Sarah E. M. Poot, P.Eng. an Associate with Golder, provided a technical review of the report. Mr. Jorge M.A. Costa P.Eng., the Designated MTO Foundations Contact and Principal with Golder, conducted an independent quality control review of this report.




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Report Signature Page

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PART B

**PRELIMINARY FOUNDATION DESIGN REPORT
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

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

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

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

A preliminary General Arrangement drawing was not available during preparation of this report, however it is assumed that if the culverts are to be replaced, the overall opening (cross-sectional area) dimensions, alignment as well as the invert elevation of the replacement culvert will be similar to those of the existing culverts. In addition, it is assumed that there will be no embankment grade raises or widening in the area of the culvert as part of the Hwy 811 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The existing Kabitotikwia River culverts are located on Highway 811 at STA 10+040, approximately 9.8 km west of the Highway 527 junction. The highway embankment is construction of granular fill material and is approximately 3.2 m high. The existing culverts consists of three SP CSP structures, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

Pre-cast concrete box and open-footing concrete culverts (cast-in-place or pre-cast footing) are both considered feasible alternatives for the replacement culvert. Given that the existing structure consists of three SP CSP culverts, multiple circular or arch culverts consisting of concrete pipe or Corrugated Steel Pipe (CSP) could also be considered a feasible option at this culvert site. We also understand that given the shallow depth to bedrock and the obstructions (i.e., cobbles) encountered in the boreholes, a sheet pile abutment and concrete cap culvert type option is not being considered at this location.

The advantages and disadvantages associated with both the pre-cast box culvert, open footing culvert and circular pipe culvert options are summarized in Table 2. From a foundations perspective, an open footing culvert is preferred over a pre-cast box culvert based on the following:



- The proposed culvert invert will be at/close to the existing bedrock surface such that strip footings could be founded on bedrock;
- Open footing construction can easily accommodate differences in bedrock surface elevation;
- Open footing construction compared to pre-cast box culverts essentially require the same the depth of excavation and groundwater control;
- While pre-cast box culvert segments can often be installed more expeditiously than open footing culverts, on-site construction of an open footing culvert will be easier than transporting large size box-culvert sections; and
- An open footing culvert can readily accommodate anticipated minimal total and differential settlements if the highway embankment is raised or widened at the culvert site.

Other culvert types may be preferred over open footing culverts due to construction staging or other considerations such as cost of construction associated with pre-cast or prefabricated sections. Recommendations for a pre-cast box culvert, an open-footing culvert and circular pipe culvert are provided in the following sections, however, given that the bedrock surface was encountered at approximately the existing (and likely proposed) invert level, both the box culvert and strip footings for open culverts will be founded at approximately the same level with the same excavation and dewatering/unwatering requirements and similar geotechnical resistances are available at the founding level.

6.2.2 Foundation Elevations and Frost Protection

6.2.2.1 Box Culvert Replacement

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3. We recommend that the replacement box culvert be placed on a 300 mm thick granular bedding layer overlying bedrock. Depending on the bedrock surface elevation along the culvert alignment relative to the culvert invert elevation, levelling/lowering of the bedrock may be required over the entire base area to accommodate bedding placement as discussed further in Section 6.4.2, especially if it is required to lower the culvert invert to accommodate flow considerations (see Section 6.2.2.2). If it is not required to lower the culvert invert, then mass concrete may be required in places to raise the foundation level to the level of underside of the granular bedding layer, depending on the elevation of the bedrock surface.

6.2.2.2 Open Footing Culvert Replacement

Strip footings for open footing culvert should be founded at a minimum depth of 2.6 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation Frost Penetration Depths for Northern Ontario); however at this site the footings will be founded on bedrock such that cover for protection from frost penetration is not considered necessary. The footings should extend below



any existing fill and surficial organic materials, where present. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

6.2.2.3 Circular Pipe Culvert

It is not necessary to found a pipe culvert at the standard depth for frost protection purposes, as these are tolerant to small magnitudes of movement related to freeze-thaw cycles, should these occur. Recommended foundation elevation and foundation conditions for a circular pipe culvert are provided in Table 3. We recommend that the replacement pipe culvert if adopted be placed on a minimum 150 mm thick granular bedding layer overlying bedrock, but consistent with the requirements in OPSD 802.034 (Rigid Pipe Bedding and Cover). Depending on the bedrock surface Elevation along the culvert alignment relative to the culvert invert elevation, levelling/lowering of the bedrock may be required to accommodate bedding placement. Mass concrete or additional granular bedding may be required to level the subgrade to the invert elevation prior to placing the final granular bedding layer.

6.2.3 Geotechnical Resistance

6.2.3.1 Box Culvert Replacement

Box culverts, placed on the properly prepared bedrock surface (i.e., granular bedding layer over bedrock) at or below the founding elevation identified above, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement, provided in Table 3. These recommendations are based on the box culvert width provided in Table 1.

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

While loadings on the foundation below the culvert and the associated settlements at the culvert location will be governed by the design height of the overlying and adjacent embankment fill, the culvert would be founded on bedrock at this site, settlement is not an issue. Further, a grade raise is not proposed at the site such that no additional loads will be applied to the foundation.

6.2.3.2 Open Footing Culvert Replacement

Strip footings placed on the properly prepared bedrock surface, at or below the founding elevation recommended in Table 3, should be designed based on the factored geotechnical resistance at ULS and geotechnical reaction at SLS, for 25 mm of settlement, provided in Table 3. These recommendations are based on the assumed footing width of 0.6 m but will apply equally to other footing widths given that the founding stratum is bedrock.

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



6.2.4 Resistance to Lateral Loads / Sliding Resistance

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

6.2.5 Stability and Settlement

Given that an embankment grade raise or widening is not proposed as part of the culvert replacement and highway embankment reconstruction, the existing native soils immediately adjacent to the culvert foundation will not experience additional load, and the bedrock is considered an unyielding foundation, such that settlement of the culvert is estimated to be negligible.

For the subsurface conditions, proposed embankments height up to about 3.0 m above the existing ground surface no grade raise or platform widening at the culvert site, the granular fill embankment at this site will be stable at side slopes inclined at 2 Horizontal to 1 Vertical (2H:1V) or flatter.

Further, given the shallow depth to bedrock at this site, it is not expected that there will be any settlement or stability issues should a grade raise or widening be required in the immediate vicinity of the culvert.

6.3 Lateral Earth Pressures

The lateral earth pressures acting on the side walls (or head/wing walls if required) of the culvert will depend on the type and method of placement of backfill materials, the nature of soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culverts and any wing or head walls. It should be noted that these design recommendations and parameters are applicable to level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the 200 sieve (0.075 mm), should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of up to 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness. Weep holes should be installed to allow for positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).

The granular fill may be placed either in a zone with the width equal to at least 2.6 m behind the back of the walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5 H:1V extending up and back from the rear face of the base of the walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC). The pressures



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are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	Internal Angle of Friction (ϕ , degrees)	Unit Weight	Coefficients of Static Lateral Earth Pressure	
			At-Rest, K_o	Active, K_a
Granular 'A'	35	22 kN/m ³	0.43	0.27
Granular 'B' Type II	35	21 kN/m ³	0.43	0.27
Granular 'B' Type I or III	32	21 kN/m ³	0.47	0.30

If the structures allow for lateral yielding, active earth pressures may be used in the design of the structure(s). If the structures do not allow lateral yielding, at-rest earth pressures should be assumed for design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the Commentary to the CHBDC.

6.4 Construction Considerations

6.4.1 Temporary Roadway Protection

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

Temporary protection support systems may be required along the highway to facilitate construction staging and maintain traffic during culvert replacement work. At this site due to the relatively shallow depth to bedrock, a temporary support system comprised of sheet piling will not be feasible. Soldier piles and lagging (with the piles socketted into bedrock or supported by tiebacks or rakers) may be used for support of the excavation along the structure, as well as along the roadway. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways.

6.4.2 Excavation and Replacement Below Culvert

Although not anticipated to be present, all organics, where encountered, and any softened soils, should be sub-excavated from below the plan limits of the proposed works prior to placement of any bedding material, fill or concrete.



Although the bedrock surface elevation is relatively consistent between boreholes, localized areas of bedrock excavation may be required to found the culvert at the required depths. As it is understood that it may be necessary to lower the culvert invert by about 0.5 m to accommodate flow considerations, it may be necessary to excavate bedrock full width/length of the open portion of the culvert (i.e., base) although not necessary along the footprint of the strip footings. As the bedrock is classified as very strong, bedrock excavation would require pre-drilling and/or hoe ramming to allow it to be excavated. Depending on the final invert elevation, should lowering of the bedrock be required over a large extent of the open base area, pre-drilling and hoe ramming alone may not be feasible nor practical. Consideration should be given to controlled blasting excavation techniques as per OPSS.PROV 120 (Explosives) and OPSS.PROV 202 (Rock Removal - Manual or Blasting) in order to preserve the integrity of the rock mass in the area of the rock excavation. Pre-shearing, line-drilling or other specialized techniques may be required to maintain the excavation lines and preserve the integrity of the rock mass along the footprint of the footings that are to be constructed on top of the adjacent rock excavation area.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organics and other unsuitable materials have been removed, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for an open footing culvert. Following inspection and given the shallow depth to bedrock at this site, the sub-excavated areas of uneven bedrock surface, should be backfilled with mass concrete. A sample NSSP can be provided at the detail design stage, if required depending on final culvert design requirements. The bedrock surface should be cleaned, scaled, loosened debris removed and inspected before placing concrete.

6.4.3 Culvert Bedding and Backfill

6.4.3.1 Box Culvert Replacement

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). A 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided over the bedrock/mass concrete in a similar configuration to that shown on OPSS 803.010 (Backfill and Cover for Concrete Culverts) whether the replacement consists of 3 separate units or one larger unit, for culvert construction in dry conditions.

A frost taper should be constructed in accordance with OPSS 803.010 (Backfill and Cover for Concrete Culverts).

6.4.3.2 Open Footing Culvert Replacement

The backfill requirements for the cast-in-place open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures) and also in a similar configuration to that shown on OPSS 803.010, as noted in Section 6.4.3.1. The backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD of the materials as specified in OPSS.PROV 501 (Compacting).



Should a pre-cast open footing culvert be the selected replacement option, a levelling pad will be required over the bedrock/mass concrete along the footprint of the footings as discussed above in Section 6.4.3.1 for the box culvert replacement.

A frost taper should be constructed in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts).

6.4.3.3 Circular Pipe Culvert

The bedding, levelling and backfill for a circular concrete pipe, CSP culvert or SPCSP arch should be in accordance with OPSD 802.034 (Rigid Pipe Bedding and Cover in Embankment), OPSD 802.010 (Flexible Pipe Embedment and Backfill – Earth Excavation) or OPSD 802.024 (Flexible Pipe Arch, Embedment in Embankment Original Ground: Earth or Rock), respectively, and culvert construction should be in accordance with OPSS 421 (Pipe Culvert Installation in Open Cut). It is important that the backfill at the haunches be well compacted. The circular culvert should be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II material for bedding purposes, however this layer thickness should be confirmed at the detail design stage for the actual culvert type selected and to verify whether bedrock excavation is required to accommodate such a bedding layer.

A frost taper should be constructed in accordance with OPSD 803.030 or OPSD 803.031 (Frost Treatment) depending on the final invert elevation to mitigate potential for differential heave between the embankment fill and the pipe trench granular backfill due to frost penetration.

6.4.3.4 Backfill

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

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

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

6.4.4 Erosion Protection

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring of the bedding or any native soil remaining in place) or around the culvert (creating seepage through the embankment fill, and



potentially causing erosion and loss of fine soil particles), a concrete cut-off wall or a clay seal should be provided at the upstream end of the culvert. A concrete cut-off wall should be considered at this culvert site, preventing 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). Alternatively, if a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum thickness of 1 m, if constructed of natural clay or soil bentonite mix. The clay seal should extend from a depth of 1 m below the scour level to a minimum vertical height equivalent to the high water level. The seal should also extend a minimum horizontal distance of 2 m on either side of the culvert inlet opening. Alternatively, a 0.6 m thick clay blanket may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height of two times the culvert height or the high water level, whichever is greater.

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

6.4.5 Control of Groundwater and Surface Water

Excavation along the culvert alignment will be required to remove embankment fill and overburden soils, if encountered, prior to placement of backfill, bedding material and the culvert structure. As a result of the excavation, groundwater flow into the excavation can be expected due to the relatively permeable nature of the fill and native soils. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

Depending on the river flow, surface water flow conditions and groundwater level at the time of construction, water flow could be passed through the area by means of a temporary culvert, or diverted by pumping from behind temporary sand bag cofferdams (as a sheet-pile cofferdam is not feasible at this location).

Groundwater control may be required, for the all culvert options as the foundation excavation to the culvert invert or footing level is expected to extend below the groundwater and/or river level. Excavations will be advanced through the fill and native soils and for into the bedrock, however, seepage into the excavation will occur through the soils and along the soil/bedrock interface. It is likely that standard pumping from sumps will not be adequate at this site and careful consideration should be given to the dewatering and channel diversion site to allow for the bedrock/footing level to be exposed in-the-dry. Unwatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering). Consideration should be given to including an NSSP in the contract to address unwatering at this site. A sample NSSP can be provided at the detail design stage, if required depending on final culvert design and construction staging.

At this preliminary stage, an accurate prediction of the groundwater pumping volumes cannot be made, as the flow rate would be dependent on construction methods adopted by the contractor. However, it is considered that



groundwater pumping volumes could exceed 50 m³/day during initial drawdown stages and/or during periods of heavy precipitation. For this pumping volume, a Permit to Take Water (PTTW) would be required.

6.4.6 Analytical Testing for Construction Materials

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

6.5 Recommendations for Further Work During Detail Design

During the detail design phase, additional field investigation and testing may be required, based on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., staging). Due to the shallow depth to bedrock and the size(s) of the existing and thus proposed culvert, consideration should be given to advancing additional boreholes or probeholes across the proposed footprint to further delineate the bedrock surface during the detail design phase. The scope and results of this investigation must be reviewed at that time to determine if they meet the then-current MTO requirements for the culvert type or staging strategy under consideration, and if additional investigation and analysis is necessary. If a grade raise or widening of the roadway is required at this site, additional settlement and stability analysis may be required depending on the quality of the subsurface soils under the widened area. Further, the need for an application for a PTTW should be defined early in the detail design phase of the project as not to delay the start of construction.

7.0 CLOSURE

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



Report Signature Page

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AC/SEMP/JMAC/kp

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n:\active\2014\1190 sudbury\1191\1411523 - hmm 26 culverts thunder bay\reporting\preliminary design\r12 - kabitotikwia river\draft\1411523 dft rpt r12 15april2 kabitotikwia river.docx



DRAFT PRELIMINARY FOUNDATION REPORT KABITOTIKWIA RIVER CULVERT, SITE NO. 48W-196/C

Table 1: Summary of Culvert Details

Culvert Location	Site #	Approximate Height of Embankment ¹	Existing Culvert			Approximate Invert Elevation ²	
			Type	Approximate Dimension ²	Approximate Length	North End of Culvert	South End of Culvert
Hwy 811 STA 10+040	48W-196/C	3.2 m	3 – SP CSPs	3 – 3.05 m x 2.13 m	20	429.5	429.7

- Notes:
1. Embankment height is relative to existing ground surface at the centreline of the roadway and the invert elevation of the culvert.
 2. Culvert dimensions and invert elevations are based on the plan and profile drawings provided by MTO (Drawing E4928298111.dwg).

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



DRAFT PRELIMINARY FOUNDATION REPORT KABITOTIKWIA RIVER CULVERT, SITE NO. 48W-196/C

Table 2: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	<ul style="list-style-type: none"> ■ Allows faster construction compared to cast-in-place options resulting in shorter duration for dewatering and surface water pumping. ■ More tolerant of total and differential settlement if the highway embankment is widened at the culvert site depending on soil conditions under the widening footprint. ■ Minor variations in bedrock elevation can be accounted for with mass concrete or by a granular bedding layer. 	<ul style="list-style-type: none"> ■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Concrete cut-off wall (or clay blanket) may be required at inlet to mitigate potential scour under culvert. ■ Bedrock is likely at a higher elevation at the culvert outlet than the desired invert; bedrock excavation may be required or mass concrete/ thicker bedding at the inlet and provided the required invert level can be achieved. ■ Transportation and on-site lifting of large pre-cast sections will be required. 	<ul style="list-style-type: none"> ■ Limited risk related to settlement performance. ■ Potential for bedrock surface to be encountered higher than anticipated, requiring bedrock excavation to achieve the desired invert elevation.
Open Footing Culvert	<ul style="list-style-type: none"> ■ May be feasible to build culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering and surface water pumping. ■ Would satisfy any fisheries requirements related to natural channel substrate, if applicable. ■ Minor variations in bedrock elevation can be easily accommodated for with cast-in-place open footing option or mass concrete. ■ No settlement expected as footings are founded on bedrock or mass concrete on bedrock. 	<ul style="list-style-type: none"> ■ Will take longer to construct for cast-in-place culverts. ■ Require unwatering and surface water pumping for construction of footing in dry conditions. ■ Less tolerant of total and differential settlement if the highway embankment is widened at the culvert site, depending on subsoil conditions under undrained footprint. ■ For a pre-cast footing option, if bedrock is encountered higher elevation than the desired invert, bedrock excavation may be required. 	<ul style="list-style-type: none"> ■ For pre-cast footing option, if bedrock is encountered higher than anticipated, bedrock excavation may be required to reach desired invert elevation.



DRAFT PRELIMINARY FOUNDATION REPORT KABITOTIKWIA RIVER CULVERT, SITE NO. 48W-196/C

Table 2: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Risks/Consequences
Circular Pipe Culvert	<ul style="list-style-type: none">■ Allows faster construction compared to cast-in-place options 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.	<ul style="list-style-type: none">■ Cut-off wall (or clay blanket) may be required at inlet to mitigation potential scour under culvert.■ CSP may not have as long a design life as compared to concrete culvert options.■ Multiple CSPs likely required to achieve desired flow.	<ul style="list-style-type: none">■ Limited risk related to settlement performance.■ If bedrock is encountered higher than anticipated, bedrock excavation may be required to reach desired invert elevation.

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Reviewed by: JMAC



**DRAFT PRELIMINARY FOUNDATION REPORT
KABITOTIKWIA RIVER CULVERT, SITE NO. 48W-196/C**

Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box and Open Footing Culvert Replacements

Culvert Location	Approximate Invert Elevation ¹ (North End / South End)	Culvert Type	Approximate Founding Elevation (North End / South End)	Founding Condition	Factored Geotechnical Axial Resistance at ULS ²	Geotechnical Reaction at SLS for 25 mm of Settlement ²
Hwy 811 STA 10+040	429.5 m / 429.7 m	Pre-Cast Box	429.1 m / 428.8 m	Levelling pad overlying Bedrock/Mass Concrete	1000 kPa	N/A ³
		Open Footing	429.1 m / 428.8 m	Levelling pad overlying Bedrock/Mass Concrete on Bedrock	1000 kPa	N/A ³
		Circular Pipe	429.1 m / 428.8 m	Levelling pad overlying Bedrock/Mass Concrete	N/A	N/A

Notes: 1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing E4928298111.dwg).
2. The factored geotechnical resistance at ULS is estimated based on an assumed preliminary 10 m wide box culvert and a 0.6 m wide open footing; The recommended geotechnical resistance/reaction should be reviewed if the founding elevation differ from those given above. The recommended geotechnical reaction at SLS for 25 mm of settlement is not applicable for footings founded on bedrock.

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



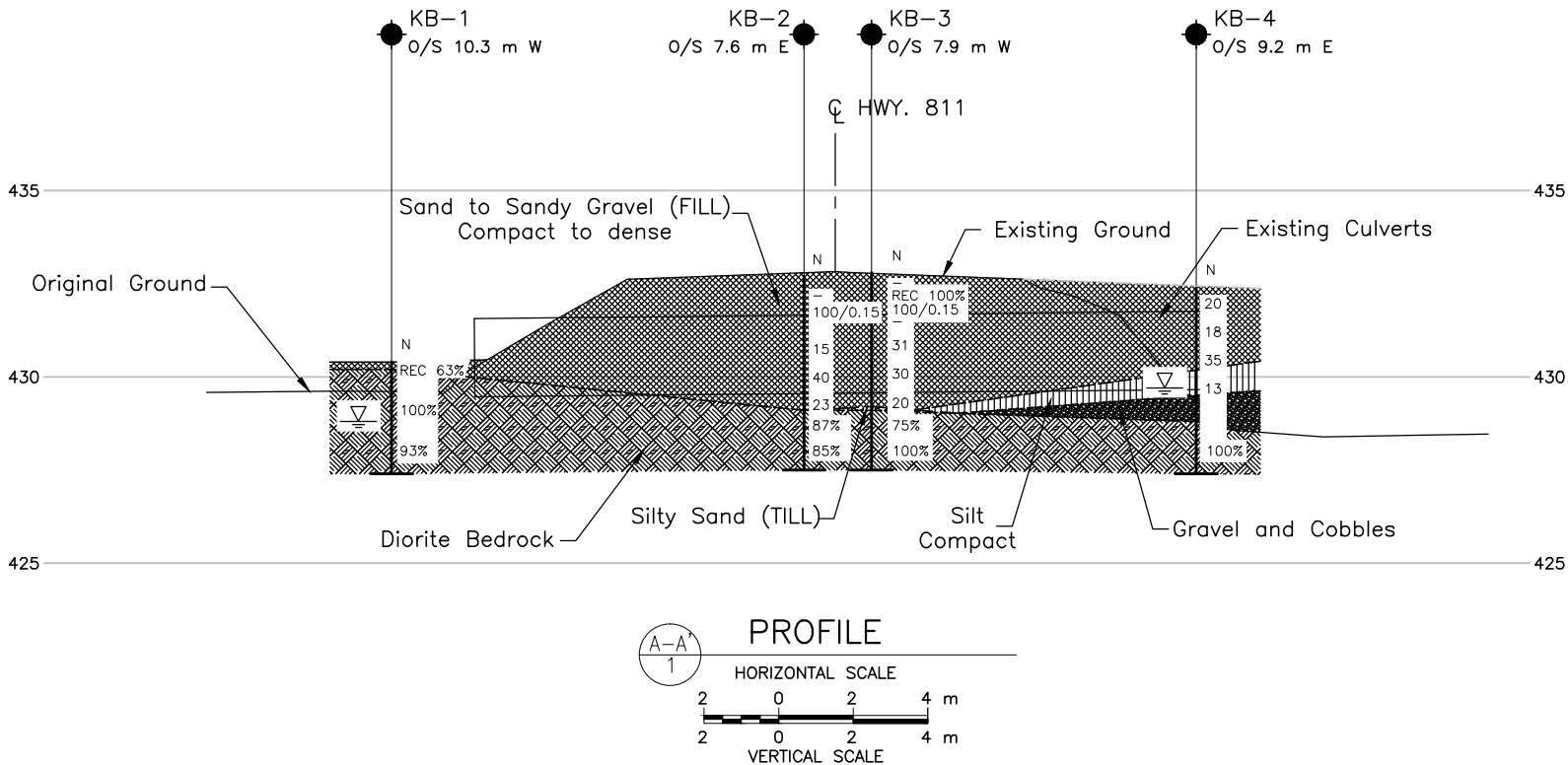
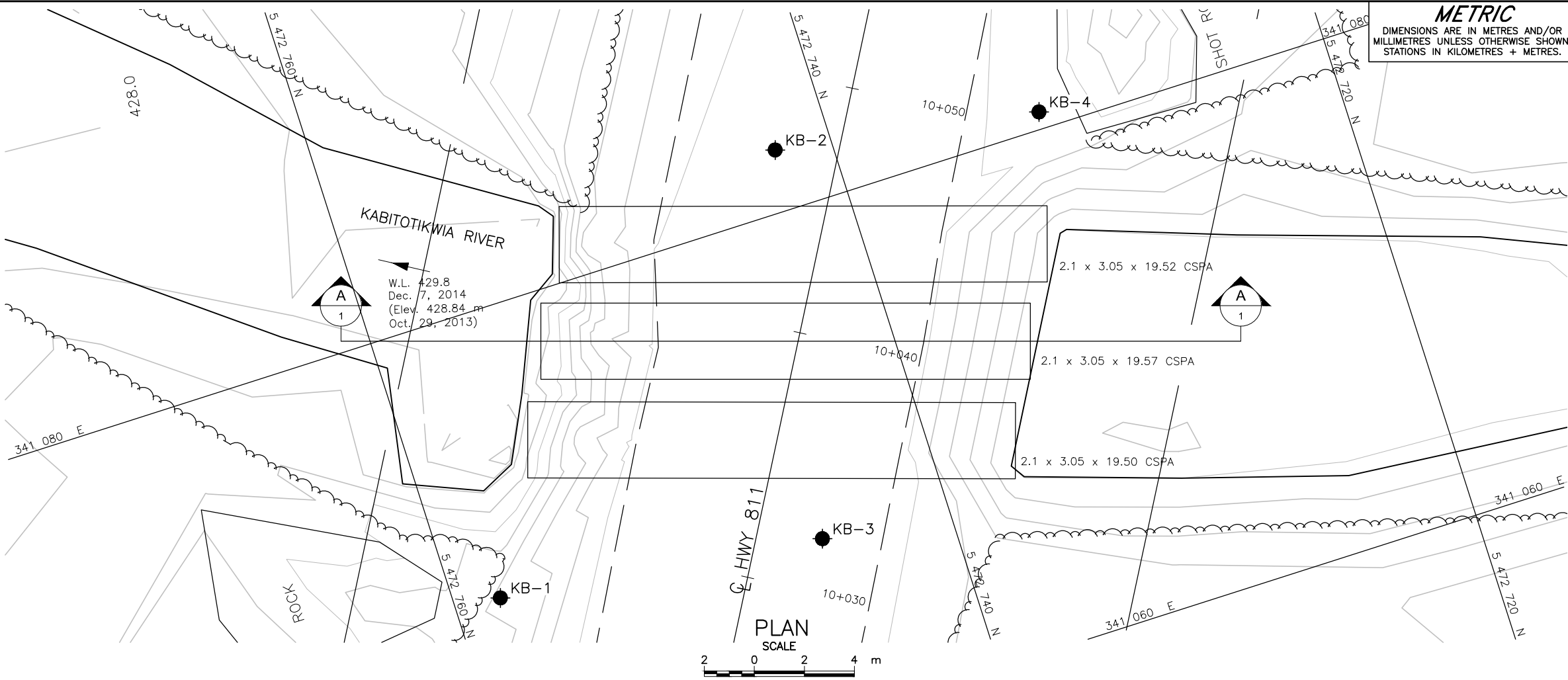
DRAFT PRELIMINARY FOUNDATION REPORT KABITOTIKWIA RIVER CULVERT, SITE NO. 48W-196/C

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

Culvert Location	Pre-Cast Box Culvert		Open Footing Culvert	
	Interface Material	Coefficient of Friction ¹ (tan δ)	Interface Material	Coefficient of Friction ¹ (tan δ)
Hwy 811 STA 10+040	Compacted Granular Fill (Levelling Pad)	0.45	Bedrock Surface/Mass Concrete on Bedrock	0.45
				0.70

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

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

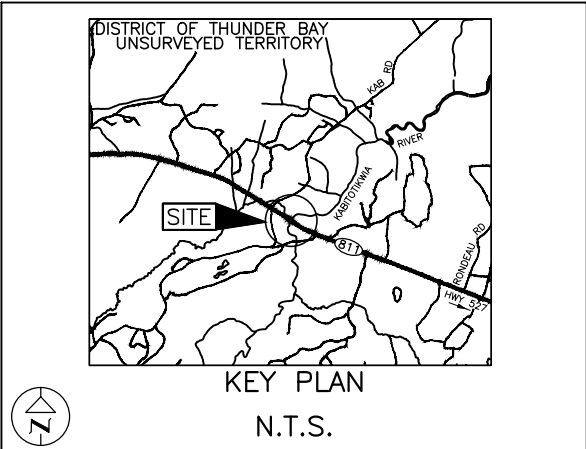


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 6302-14-00

HIGHWAY 811
KABITOTIKWIA RIVER CULVERTS STA 10+040
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



LEGEND			
	Borehole		
N	Standard Penetration Test Value		
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)		
100%	Rock Quality Designation (RQD)		
REC	Recovery		
	WL upon completion of drilling		

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
KB-1	430.4	5472758.2	341068.7
KB-2	432.7	5472742.2	341082.4
KB-3	432.8	5472745.2	341067.1
KB-4	432.4	5472731.7	341080.7

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 Hatch Matt MacDonald, drawing file no. E4928928111, dated DEC 2013, received JAN 27, 2015.

DRAFT

NO.	DATE	BY	REVISION
Geocres No.,			
HWY. 811		PROJECT NO. 1411523	DIST. .
SUBM'D. AC	CHKD. .	DATE: 3/19/2015	SITE: 48W-196/C
DRAWN: TB	CHKD. SEMP	APPD. JMAC	DWG. 1



PHOTOGRAPHS

**Photograph 1: Kabitotikwia River Culverts
South Inlet (Taken from MTO, OSIM 16-Oct-13)**



**Photograph 2: Kabitotikwia River Culverts
North Outlet (Taken from MTO, OSIM 16-Oct-13)**





PHOTOGRAPHS

**Photograph 3: Kabitotikwia River Culverts
South Inlet (Golder – December 7, 2014)**





APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a)	Index Properties
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

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



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

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

PROJECT 1411523		RECORD OF BOREHOLE No KB-1				1 OF 1 METRIC										
G.W.P. 6302-14-00		LOCATION N 5472758.2; E 341068.7				ORIGINATED BY CW										
DIST _____ HWY 811		BOREHOLE TYPE NQ Coring				COMPILED BY AC										
DATUM GEODETIC		DATE December 7, 2014				CHECKED BY SEMP										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
430.4	GROUND SURFACE						20	40	60	80	100					
0.0	Sandy gravel, some silt (FILL)		1	RC	REC 63%											
0.2	Brown Wet															
	DIORITE BEDROCK		1	RC	REC 100%											RQD = 100%
	Bedrock cored from 0.2 m to 3.0 m depth.															
	For coring details see Record of Drillhole KB-1.		2	RC	REC 100%											RQD = 93%
427.4	END OF BOREHOLE															
3.0	Note: 1. Water level at a depth of 1.6 m below ground surface (Elev. 428.8 m) upon completion of drilling.															

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 19/03/15 DATA INPUT:

PROJECT: 1411523

RECORD OF DRILLHOLE: KB-1

SHEET 1 OF 1

LOCATION: N 5472758.2 ;E 341068.7

DRILLING DATE: December 7, 2014

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55-Track

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth RO - Rough MB - Mechanical Break	BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.	RECOVERY TOTAL CORE %	SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	B Angle	DIP W/L CORE AXIS	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diameter Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Refer to Previous Page		430.2 0.2																						
1	CME 55-Track NO Coring	DIORITE Medium to coarse grained Fresh Black-white Very strong			1	GREY 100																				UCS=235 MPa
2					2	GREY 10																				
3		END OF DRILLHOLE		427.4 3.0																						
4																										
5																										
6																										
7																										
8																										
9																										
10																										

DEPTH SCALE

1 : 50



LOGGED: CW

CHECKED: SEMP

SUD-RCK 1411523.GPJ GAL-MISS.GDT 19/03/15 DATA INPUT:

[illegible]

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

SHEET 1 OF 1

DATUM: GEODETIC

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

DRAFT

CHECKED: SEMP

SUD-RCK 1411523.GPJ GAL-MISS.GDT 19/03/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No KB-3				1 OF 1 METRIC						
G.W.P. 6302-14-00		LOCATION N 5472745.2; E 341067.1				ORIGINATED BY MR						
DIST _____ HWY 811		BOREHOLE TYPE NW Casing, NQ Coring and Wash Boring				COMPILED BY AC						
DATUM GEODETIC		DATE December 7, 2014				CHECKED BY SEMP						
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L			WATER CONTENT (%)
432.8	GROUND SURFACE											
0.0	Sand to sandy gravel, trace to some silt (FILL) Compact to dense Brown to grey Wet A 230 mm diameter cobble was encountered at 0.5 m depth.		1	WS	-							
			-	RC	REC 100%							
			2	SS	100/0.45							
			3	WS	-							
			4	SS	31							
			5	SS	30							
			6	SS	20							
429.2												
3.7	Silty SAND, trace gravel (TILL) Grey Wet DIORITE BEDROCK Bedrock cored from 3.7 m to 5.3 m depth. For coring details see Record of Drillhole KB-3.		1	RC	REC 100%							
			2	RC	REC 100%							
427.5												
5.3	END OF BOREHOLE Note: 1. Borehole caved at 1.6 m depth upon completion. Borehole dry to 1.6 m depth upon completion of drilling (Inferred depth to water level Elevation 431.2 m).											

PROJECT: 1411523

RECORD OF DRILLHOLE: KB-3

SHEET 1 OF 1

LOCATION: N 5472745.2 ;E 341067.1

DRILLING DATE: December 7, 2014

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55-Track

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth RO - Rough MB - Mechanical Break	BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.	NOTES WATER LEVELS INSTRUMENTATION
FLUSH	RECOVERY	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA	HYDRAULIC CONDUCTIVITY k, cm/s	DIP W/L CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	Diameter Point Load Index (MPa)	RMC -Q' AVG.
429.1	3.7	1	GREY 100									
427.5	5.3	2	GREY 100									UCS=176 MPa
END OF DRILLHOLE												

DEPTH SCALE





1 : 50



LOGGED: MR

CHECKED: SEMP

SUD-RCK 1411523.GPJ GAL-MISS.GDT 19/03/15 DATA INPUT:

PROJECT 1411523				RECORD OF BOREHOLE No KB-4				1 OF 1 METRIC										
G.W.P. 6302-14-00				LOCATION N 5472731.7; E 341080.7				ORIGINATED BY CW										
DIST _____ HWY 811				BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers, NW Casing, NQ Coring and Wash Boring				COMPILED BY AC										
DATUM GEODETIC				DATE December 6 and 7, 2014				CHECKED BY SEMP										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
432.4 0.0	GROUND SURFACE Sand, some gravel, some silt, trace clay (FILL) Compact to dense Brown Moist Augers grinding from ground surface to 1.5 m depth.		1	SS	20		432										NP	18 64 15 3
			2	SS	18		431											
			3	SS	35													
430.2 2.2	SILT, some sand, some gravel, trace organics, trace clay Compact Brown		4	SS	13		430											
429.5 2.9	Wet GRAVEL and COBBLES		-	RC			429											
428.8 3.6	DIORITE BEDROCK Bedrock cored from 3.6 m to 5.0 m depth. For coring details see Record of Drillhole KB-4.		1	RC	REC 100%		428											RQD = 100%
427.4 5.0	END OF BOREHOLE Note: 1. Borehole caved at 0.6 m depth upon completion. Borehole dry to 0.6 m depth upon completion of drilling (Inferred depth to water level Elevation 431.8 m).																	

PROJECT: 1411523

RECORD OF DRILLHOLE: KB-4

SHEET 1 OF 1

LOCATION: N 5472731.7 ;E 341080.7

DRILLING DATE: December 6 and 7, 2014

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55-Track

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth RO - Rough MB - Mechanical Break	BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.	NOTES WATER LEVELS INSTRUMENTATION
		GROUND SURFACE		428.8									
4	CME 55-Track NQ Coring	DIORITE Medium to coarse grained Fresh Black-white		3.6	1	GREY 100							
5		END OF DRILLHOLE		427.4									
5.0													
6													
7													
8													
9													
10													
11													
12													
13													

DEPTH SCALE

1 : 50



LOGGED: CW

CHECKED: SEMP

SUD-ROK 1411523.GPJ GAL-MISS.GDT 19/03/15 DATA INPUT:



APPENDIX B

Laboratory Test Results



DRAFT PRELIMINARY FOUNDATION REPORT KABITOTIKWIA RIVER CULVERT, SITE NO. 48W-196/C

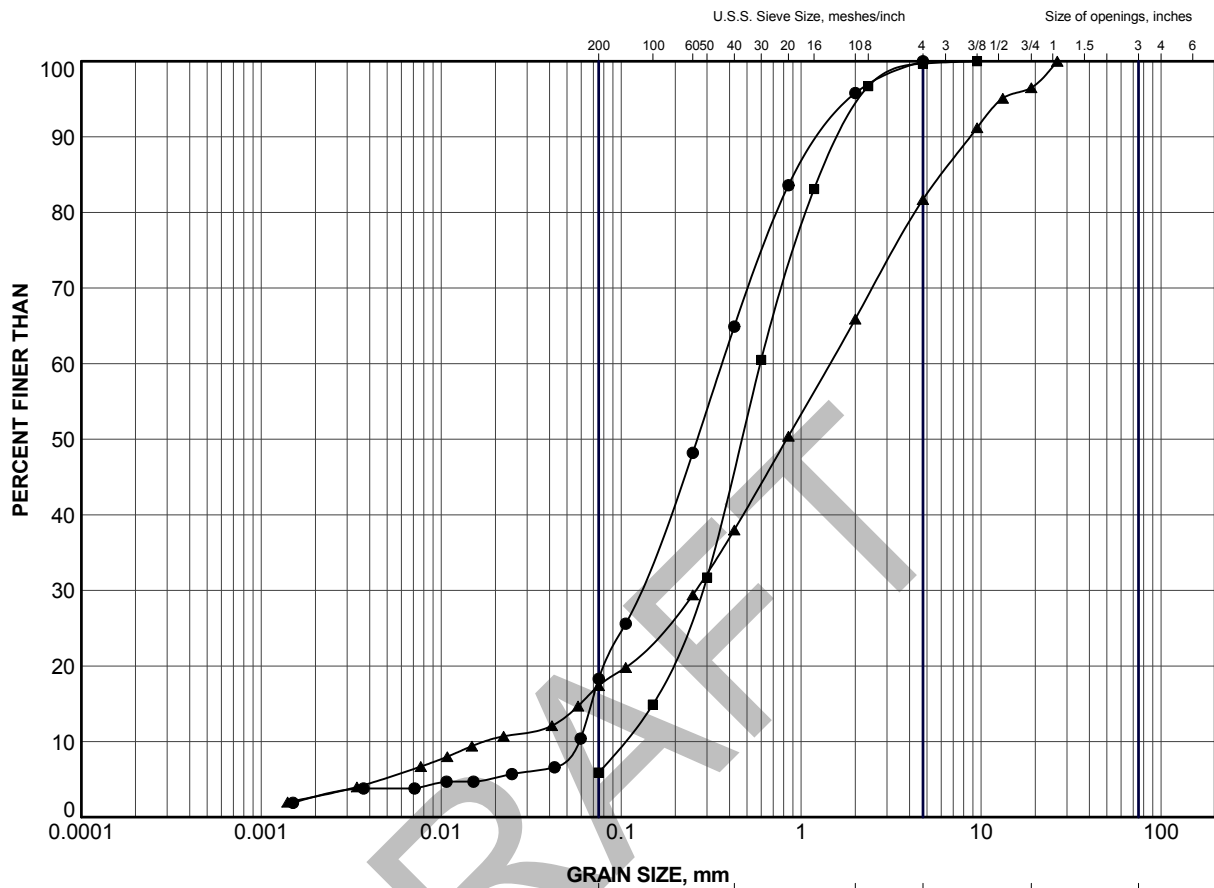
Table B1: Summary of Analytical Testing of Kabitotikwia River Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	0.43
Sulphate (SO4)	mg/L	1.50
Conductivity (EC)	µS/cm	80.7
Resistivity	µohm-cm	<0.33
pH	n/a	7.22

Notes:

1. Sample obtained on February 6, 2015.
2. Analytical testing carried out by ALS Canada Ltd.


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



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KB-2	4	430.1
■	KB-3	3	431.6
▲	KB-4	1	432.1

PROJECT					
HIGHWAY 811 KABITOTIKWIA RIVER CULVERTS STA 10+040					
TITLE					
GRAIN SIZE DISTRIBUTION SAND (FILL)					
PROJECT No. 1411523			FILE No. 1411523.GPJ		
DRAWN	JJL	Mar 2015	SCALE	N/A	REV.
CHECK	SEMP	Mar 2015			
APPR	JMAC	Mar 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE B1		



Borehole KB-1
Elevation 430.2 m to 327.4 m



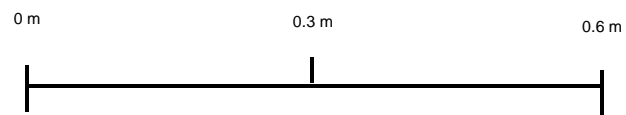
Borehole KB-2
Elevation 429.1 m to 427.5 m




Borehole KB-3
Elevation 429.1 m to 427.5 m



Borehole KB-4
Elevation 428.8 m to 427.4 m



PROJECT				HIGHWAY 811 KABITOTIKWIA RIVER CULVERTS STA 10+040			
TITLE				BEDROCK CORE PHOTOGRAPHS			
		PROJECT No.		1411523		FILE No.	
		DESIGN	AC	Mar. 2015	SCALE	AS SHOWN	REV.
		CADD	--		FIGURE B2		
		CHECK	SEMP	Mar. 2015			
		REVIEW	JMAC	Mar. 2015			

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