September 8, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

KITCHEN CREEK CULVERT - SITE NO. 45-277/C
HIGHWAY 11, DISTRICT OF RAINY RIVER
TOWNSHIP OF CROZIER
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6324-14-00

Submitted to:
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GEOCRES No.: 52C-41

REPORT

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Golder Associates

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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 Kitchen Creek culvert (Site No. 45-277/C). The Kitchen Creek culvert is located in the District of Rainy River, in the Township of Crozier on Highway 11 at STA 11+993, approximately 10.5 km west of the junction of Highway 11 and Highway 602 near Fort Frances. 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 Kitchen Creek culvert is an open footing concrete structure, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

In general, the topography in this area is relatively flat and the land use is considered rural residential. A golf course is located on the south side of the highway abutting up to the right-of-way. The south side of the highway is covered with grass and the north side is bordered with long grass, shrubs and trees. Highway 11 extends in an east-west direction with the culvert perpendicular to the highway in a north-south orientation. At the culvert location, Kitchen Creek flows southerly. The highway grade is at Elevation 354.5 m and the culvert invert is at approximately Elevation 349.8 m at the inlet (north end) and outlet (south end) and the culvert is covered with approximately 2.3 m of roadway fill. The creek water level was measured at Elevation 349.5 m by others in November, 2012 and at Elevation 349.8 m by Golder on February 11, 2015. Surface conditions at the culvert inlet and outlet areas are shown on Photographs 1 to 4, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between February 12 and 15 and on March 20 and 21, 2015, during which time four (4) boreholes (Boreholes KT-1 to KT-4) were advanced at approximately the locations shown on Drawing 1: Boreholes KT-1 and KT-4 were advanced at the toe of slope near the culvert outlet/inlet, respectively; and Boreholes KT-2 and KT-3 were advanced from the existing highway platform. Borehole KT-1 was advanced by portable equipment using NW casing and wash boring techniques and Boreholes KT-2 to KT4 were advanced by a track mounted CME 55 drill rig using 108 mm inside diameter hollow stem augers. All drilling equipment was supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec.

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 manual hammer, in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using an MTO Standard 'N' size vane. The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

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

A sample of the creek water was obtained at the culvert site on February 24, 2015, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters, including pH, resistivity, conductivity, sulphates and chlorides.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by 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 provided by MTO (Drawing BC301111.dwg). The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and summarized below.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation m)	Borehole Depth (m)
KT-1	5386888.1	263784.8	350.2	9.8
KT-2	5386904.1	263777.6	354.5	14.9
KT-3	5386907.6	263785.6	354.5	10.1
KT-4	5386923.2	263774.8	350.9	9.8

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 Kitchen Creek culvert site generally consist of glaciolacustrine plain deposits comprised of clay and silt materials bordering with alluvial plain deposit of sand and silt materials and organic terrain with peat and muck materials.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)[2], the site is underlain by bedrock of the Archean Era, comprised of mafic to intermediate metavolcanic rocks consisting of basaltic and andesitic flows bordering with metasedimentary and massive granodiorite to granite 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 sheets contained in Appendix A. The results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ tests (i.e., SPT 'N'-values

[1] Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52CNW.

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

and undrained shear strengths from field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and granular fill (for boreholes advanced through the embankment), underlain by a cohesive deposit of silty clay to clay. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	'N'-Values (blows) / Shear Strength Consistency or Relative Density	Laboratory Testing
Asphalt	KT-2, KT-3	0.17	354.5	n/a	n/a
Peat (Amorphous)	KT-1	0.7	350.2	See Note 1	n/a
(FILL) Sand to Gravelly Sand, Silty Clay to Clay, Sandy Silt to Sand; brown to grey; frozen to wet	KT-2, KT-3	5.1 – 5.8	354.3	N = 9 – 13 [2, 3, 4] **Loose to compact/ Stiff**	w = 5% – 31% w_l = 48% - 53% w_p = 21% - 25% I_p = 26% - 27% 2 - M (Fig. B1) 2 – MH (Fig. B2) 2 – AL (Fig. B3)
Silty Clay to Clay [5], trace to some sand, trace gravel; grey, frozen to wet	KT-1 to KT-4	4.1 – 9.8 (boreholes terminated in this deposit)	350.9 – 348.5	N = 4 – 15 [6] s_u = >100 **Firm to Very Stiff**	OC = 3% w = 26% - 36% w_l = 43% - 64% w_p = 19% - 28% I_p = 22% - 39% 5 – MH (Fig. B4) 7 – AL (Fig. B5)
Clayey Silt zone	KT-1	2.9	346.1	N = 13 – 14 **Very Stiff**	w = 26% w_l = 32% w_p = 15% I_p = 17% 1 – AL (Fig. B5)

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
AL = Atterberg Limits Test
s_u = Undrained Shear Strength (kPa)
S = Sensitivity
w_p = Plastic Limit (%)
w_l = Liquid Limit (%)
I_p = Plasticity Index (%)

Notes:

[1] In the peat deposit, an SPT 'N'-value of 10 blows per 0.3 m was measured, however, this value is indicative of the frozen state of the material and not representative.

[2] In the fill, two split spoon samples did not penetrate the entire SPT depth inferred to be due to the presence of cobbles.

[3] Six SPT 'N'-values between 26 blows and 100 blows per 0.3 m of penetration were inferred to be due to the frozen nature of the material and are not representative of the relative density of the fill material.

[4] Concrete fragments and decomposed wood pieces were noted within the silty sand fill in Borehole KT-3.

[5] A clayey silt zone was encountered in Borehole KT-1 within the silt clay to clay deposit from approximately 4.1 m to 7.0 m depth. Based on the results of the Atterberg limit test the material is classified as clayey silt of low plasticity.

[6] In the silty clay to clay deposit, SPT 'N'-values of 6 blows and 14 blows per 0.3 m were measured, however, these values are inferred indicative of the frozen state of the material and not representative.

Groundwater Conditions

The groundwater level was measured at the ground surface in Borehole KT-1 (Elevation 350.2 m), however it should be noted that Borehole KT-1 was advanced using NW casing and wash boring techniques. Boreholes KT-2 to KT-3 were observed to be dry upon completion of drilling. The creek ice level was measured at Elevation 349.8 m on February 11, 2015. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

5.0 CLOSURE

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

Report Signature Page

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PART B

PRELIMINARY FOUNDATION DESIGN REPORT
KITCHEN CREEK CULVERT – SITE NO. 45-277/C
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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 Kitchen Creek culvert. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation.

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

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

Based on discussions with HMM, it is assumed that the culvert will be replaced with a culvert of similar dimensions (or larger), along the same alignment as well at similar invert elevations to that of the existing culvert. In addition, it is assumed that there will be no embankment grade raises or widening in the area of the culvert as part of the Hwy 11 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The Kitchen Creek culvert is located in the District of Rainy River, in the Township of Crozier on Highway 11 at STA 11+993, approximately 10.5 km west of the junction of Highway 11 and Highway 602. The highway embankment is constructed of granular and cohesive fill materials and is approximately 4.7 m high relative to the culvert invert and the fill cover on the existing structure is approximately 2.3 m. The existing culvert is a concrete open footing structure the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

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

- A pre-cast open footing with either a pre-cast concrete arch or box.

In this report we have considered the following culvert options:

- A pre-cast concrete box; and
- An open footing (box or arch culvert) supported on either cast-in-place or pre-cast footings.

We understand that a sheet-pile abutment and concrete cap option is not being considered for culvert replacement on the Highway 11 or 17 corridors. A corrugated steel pipe (CSP) culvert would likely decrease the flow-through capacity at this culvert location, thus requiring the use of multiple CSP culverts to meet the flow capacity and CSPs generally have a shorter design life than a concrete culvert. Therefore, a CSP culvert is not considered practical at this site. From a foundation perspective, a pre-cast concrete box culvert, or multiple boxes, sufficiently wide to handle the flow is preferred at this site as the subsurface conditions at the shallow foundation level are suitable for the support of such a structure and require little to no excavation. Other culvert types may be preferred due to construction staging or other considerations such as fisheries requirements related to natural channel substrate. A comparison of culvert types based on advantages/disadvantages and risks/consequences is presented in Table 2.

6.2.2 Foundation Elevations and Frost Protection

6.2.2.1 Box Culvert

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as a box structure is tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the replacement box culvert be founded on a granular bedding/levelling pad placed on the generally stiff to very stiff silty clay to clay stratum as encountered in the boreholes, after sub-excavation of the existing fill and peat as indicated in Section 6.4.2. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3.

6.2.2.2 Open Footing Culvert

Strip footings for an open footing culvert should be founded on the stiff to very stiff silty clay to clay stratum at a minimum depth of 2.3 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation, Frost Penetration Depths for Northern Ontario). In addition, the footings should extend below any existing fill and peat, as indicated in Section 6.4.2. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

6.2.3 Geotechnical Resistances

6.2.3.1 Box Culvert

A box culvert, placed on the properly prepared subgrade and/or properly placed granular pad/backfill at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement, as provided in Table 3. These recommendations are based on the assumed box culvert width of 6 m as noted in Table 3.

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

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

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

6.2.3.2 Open Footing Culvert

Strip footings placed on the properly prepared subgrade, at or below the founding elevation recommended in Table 3, should be designed based on the factored geotechnical axial resistance at ULS and geotechnical reaction at SLS, for 25 mm of settlement, as provided in Table 3. These recommendations are based on the assumed footing width of 0.6 m or 1.2 m as noted in Table 3.

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

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

The loading on the foundation soils below the culvert and the associated settlements at the culvert will be governed by the design height of the overlying and adjacent embankment fill, however it is assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table3) in the design of the culvert and that consideration be given to the width of the footing if different that given in Table 3, and the sequence and staging of construction, particularly if a grade raise or widening is proposed as the settlement under the culvert will occur as a result of any additional soil loading and may be affected by the loading on a wider strip footing.

6.2.4 Resistance to Lateral Loads / Sliding Resistance

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

6.2.5 Stability and Settlement

Given that an embankment grade raise or widening is not proposed as part of the culvert replacement and highway embankment reconstruction, the existing native soils will not experience additional load, and therefore, settlement of the culvert after embankment reconstruction is estimated to be less than 25 mm.

For the subsurface conditions at this site and the reconstructed embankments height up to about 4.7 m above relative to the culvert invert (i.e., to the level of the existing embankment), granular fill embankments at this site will be stable at side slopes inclined at 2 Horizontal to 1 Vertical (2H:1V) or flatter.

Given the presence of the firm to very stiff silty clay to clay subsoils as this site, additional analysis of stability and long-term settlement will be required if a grade raise and/or widening is proposed. Further, depending on the magnitude of the grade raise and/or widening, additional field work and/or specialized laboratory testing may be required.

6.3 Lateral Earth Pressures

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

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

- Select, free draining granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular ‘A’ or Granular ‘B’ Type I, II or III, but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of up to 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness. Weep holes should be installed to allow for positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).
- The granular fill may be placed either in a zone with the width equal to at least 2.3 m behind the back of the walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5 H:1V extending up and back from the rear face of the base of the walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC).

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

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

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

6.4 Construction Considerations

6.4.1 Temporary Roadway Protection

The temporary excavation for the culvert replacement will be made through the existing embankment granular fill comprised of sand to gravelly sand, loose to compact sand to sandy silt and cohesive fill consisting of stiff silty clay to clay, and into native soils which are comprised of firm to very stiff silty clay to clay. All excavations must be carried out in accordance with Ontario Regulation 213, Ontario Occupational Health and Safety Act for Construction Projects (as amended). The granular and cohesive fills and the native silty clay to clay soils are considered to be Type 3 soil above the groundwater table and should be considered 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.

Temporary protection support systems may be required along the highway to facilitate construction staging and maintain traffic during culvert replacement work. The temporary support systems could consist of either driven sheet-piling extended to suitable depth, or soldier piles and lagging where H-piles are driven to a suitable depth and horizontal lagging is installed as the excavation proceeds. Support to the temporary protection system could be in the form of struts and walers and rakers or anchors. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways.

The installation of the sheet-piles for temporary shoring may be impeded by the presence of inferred cobbles and/or buried concrete and wood fragments, as encountered within the fill materials in Borehole KT-2 and KT-3. It may be necessary to excavate and replace the existing fill material in the areas of sheet-pile installation in a series of limited length and narrow trenches. In general, the narrowest suitable excavator bucket should be used. The replacement fill could consist of excavated fill material or imported granular material such as Granular ‘A’ or Granular ‘B’ Type I, II or III provided that 100 per cent of the material passes the 75 mm size and less than 5 per cent passes the 75 µm size. The excavated spoil pile may be re-used to backfill the excavation after removing the cobbles and/or any concrete/wood that may impede the sheet-pile installation. Excavation and replacement should be carried out on the same day to avoid leaving any trench open overnight. Consideration should be given to include an NSSP in the contract to address obstructions. A sample NSSP should be provided at the detail design stage.

6.4.2 Excavation and Replacement Below Culvert

Prior to placement of any bedding or levelling course material, backfill or concrete, all existing fill, organics (peat, etc.) and any softened/loosened or disturbed soils, should be sub-excavated from below the plan limits of the proposed works to the founding levels provided in Table 3.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organics and other unsuitable materials have been removed as noted above, in accordance with OPSS 422 (Pre-cast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for an open footing culvert. Following inspection, the sub-excavated area should be backfilled with granular material meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II or III that is placed and compacted in accordance with OPSS.PROV 501 (Compacting). The use of Granular 'B' Type II is recommended in wet ground conditions or below water and placement should be in accordance with OPSS.PROV 209 (Embankments over Swamps and compressible material).

6.4.3 Culvert Bedding and Backfill

6.4.3.1 Box Culvert

The bedding layer and levelling pad for a pre-cast box culvert should be accordance with OPSS 422 (Pre-cast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the adjacent granular fill during excavation to the invert and bedding level, it is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material be used for bedding purposes. As the native soil below the bedding would be fine grained, it is recommended that a non-woven geotextile be placed between the native soil and the bottom of the bedding. The geotextile should meet the specifications for OPSS 1860 (Geotextiles) Class II, and have a fabric opening size (FOS) not greater than 212 µm. Above the water table (i.e., when placed in dry conditions) 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 as specified in OPSS.PROV 501 (Compacting). In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided with a geometry similar to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts), whether the levelling layer is placed on the native subgrade soil or on the bedding layer, and should be placed in dry conditions.

If the top of the box culvert is located above the frost penetration depth, depending on the embankment thickness over the culvert and the final size and founding elevation of the culvert, a frost taper should be constructed in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts). Although OPSD 803.010 relates to box culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 6 m wide box culvert replacement option.

If the top of the box culvert is located below the frost penetration depth, a frost taper may not be required from a foundation perspective but may be required from a pavement restoration perspective due to the presence of the moderate to highly frost susceptible clay embankment fill.

6.4.3.2 Open Footing Culvert

The excavation and backfilling requirements for the open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures) and also in similar configuration to that shown on OPSD 803.010 as noted in Section 6.4.3.

Should a pre-cast open footing culvert be the selected replacement option, a bedding layer and levelling pad will be required above the native soil. The bedding layer and levelling pad for the pre-cast open footings should follow the recommendations as discussed in Section 6.4.3.1 for the box culvert replacement option.

If the top of the open footing culvert is located above the frost penetration depth, depending on the embankment thickness over the culvert and the final size and founding elevation of the culvert, a frost taper should be constructed in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts). Although OPSD 803.010 also relates to an open footing culvert with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 6 m wide open footing culvert replacement option shown on the preliminary GA drawings.

If the top of the open footing culvert is located below the frost penetration depth, a frost taper may not be required from a foundation perspective but may be required from a pavement restoration perspective due to the presence of the moderate to highly frost susceptible clay embankment fill.

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

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

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

6.4.4 Subgrade Protection

The cohesive native silty clay to clay subgrade will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance it may be necessary to sub-excavate deeper and place a 300 mm thick compacted bedding layer on the prepared subgrade, or alternatively construct a concrete working slab on the subgrade if the concrete footings, or the box culvert, is not placed within four hours after preparation, inspection, and approval of the foundation subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28 day compressive strength of 20 MPa. Consideration should be given to include an NSSP in the contract to address subgrade protection at this site. A sample NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

6.4.5 Erosion Protection

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum thickness of 1 m. The clay seal should extend from a depth of 1 m below the scour level to a minimum vertical height equivalent to the high water level. The seal should also extend a minimum horizontal distance of 2 m on either side of the culvert inlet opening. Alternatively, a 0.6 m thick clay blanket may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height of two times the culvert height or the high water level, whichever is greater.

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

6.4.6 Control of Groundwater and Surface Water

Excavation along the culvert alignment will be required to remove existing fill and organics (peat, etc.) and/or softened overburden soils prior to placement of backfill, bedding material if required, levelling pad and the actual culvert structure. Groundwater flow into the excavation can be expected due to the depth of the excavation below the adjacent creek level and the presence of existing relatively permeable embankment fill. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

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

For both the box and open footing culvert options, the excavations will extend below the creek water level, and potentially below the groundwater level, although the boreholes suggest dry conditions upon completion of drilling, but will likely require temporary shoring with dewatering to allow for construction/placement of the footings and/or placement of bedding/levelling course fill pad in dry conditions. Temporary shoring and dewatering could be in the form of a sheet-pile cut off wall or cofferdam advanced to an appropriate depth to control groundwater inflow from the creek and to prevent base heaving within the excavation. As discussed in Section 6.4.2, replacement backfill can be placed subaqueously if comprised of Granular ‘B’ Type II material, however, dewatering may still be required for footing/box culvert placement as the culvert invert is at or below the creek water level.

Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering). Consideration should be given to include an NSSP in the contract to address unwatering at this site. A sample NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

At this preliminary stage, an accurate prediction of the groundwater pumping volumes cannot be made, as the groundwater and surface water flow rate would be dependent on construction methods adopted by the contractor. However, given the subsurface conditions of the culvert site it is considered that groundwater pumping volumes would not exceed 50 m^3/day either during initial unwatering stages and/or during periods of heavy precipitation, provided that surface water flows are properly managed and directed away from the open excavation. At this time it is considered that a Permit to Take Water (PTTW) would not be required, but such a requirement should be confirmed at the detail design stage of the project.

6.4.7 Obstructions

The contractor should be alerted to the presence of inferred cobble size material within the embankment fill material as noted in Borehole KT-2. Further, the contract should also be alerted to the presence of concrete/wood pieces within the fill, as encountered in Borehole KT-3. An NSSP should be developed at the detail design stage for inclusion into the Contract Documents to alert the contractor to the presence of such obstructions.

6.4.8 Analytical Testing for Construction Materials

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

6.5 Recommendations for Further Work During Detail Design

During the detail design phase, additional field investigation and testing may be required, depending on the final configuration and/or alignment of the culvert and the replacement strategy (i.e., staging). In particular, consideration should be given to drilling additional boreholes advanced to a suitable penetration depth within the silty clay to clay deposit for design of temporary works if the culvert is to be constructed in stages while maintaining one open lane of traffic. The scope and results of this investigation must be reviewed at the time of the detail design to determine if they meet the then-current MTO requirements for the culvert type or staging strategy under consideration, and if additional investigation and analysis is necessary. If a grade raise or widening of the roadway is required at this site, additional settlement and stability analysis will be required. Further, the need for an application for a PTTW should be defined early in the detail design phase of the project as not to delay the start of construction.

7.0 CLOSURE

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

Report Signature Page

GOLDER ASSOCIATES LTD.

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Jorge M. A. Costa, P.Eng.
Designated MTO Contact, Principal

TB/AC/SEMP/JMAC/kp

REFERENCES

Canadian Standards Association (CSA), 2006. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6 06. CSA Special Publication, S6.1 06.

Occupational Health and Safety Act and Regulation for Construction Projects (as amended).

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

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

ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils
ASTM D2573	Standard Test Method for Field Vane Shear Test in Cohesive Soil

Ontario Provincial Standard Specifications (OPSS)

OPSS 422	Construction Specification for Pre-cast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 902	Construction Specification for Excavating and Backfilling – Structures
OPSS 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 209	Construction Specification for Embankments over Swamps and Compressible Soils
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1002	Material Specification for Aggregates - Concrete
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts With Spans Less Than or Equal to 3.0 m
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)

Table 1: Summary of Culvert Details

Culvert Location (Township)	Site #	Approximate Height of Embankment [1] (m)	Existing Culvert			Approximate Invert Elevation[2]	
			Type	Approximate Dimension[2]	Approximate Length (m)	North End of Culvert (m)	South End of Culvert (m)
Hwy 11 STA 11+993 (Township of Crozier)	45-277/C	4.7	Concrete open footing	5.0 m (wide) x 2.6 m (high)	21	349.8	349.8

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 BC301111.dwg).

Prepared by: TB
Checked by: SEMP
Reviewed by: JMAC

Table 2: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	■ Minimizes depth of excavation, protection system (if required) and dewatering requirements compared to open footing option. Minor excavation required for the removal of unsuitable fill to the base of the bedding/levelling course. ■ Allows faster construction resulting in shorter duration for dewatering and surface water pumping. ■ More tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site, or remnants of the peat/fill deposits are not fully removed or 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.	■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Cut-off wall (or clay blanket) required at inlet to mitigate potential scour under culvert. ■ Transportation to and on-site lifting of large pre-cast sections may be required. ■ May require water diversion of the creek channel to accommodate construction of the new culvert using a full width culvert section.	■ Some risk of disturbance of the native silty clay to clay deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II bedding layer. ■ Low risk related to settlement performance.
Open Footing Culvert	■ 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. ■ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Suitable footing founding subgrade at/below the depth of frost penetration. ■ Existing culvert can be used for water diversion while new footings are being constructed adjacent to the existing culvert depending on the width of the new culvert.	■ Excavation depths are greater than for box culvert option, resulting in increased excavation support requirements and additional spoil material to be disposed off-site. ■ Constructing footings in the dry will take longer due to requirements for installation of 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. ■ Likely require two parallel sheet pile walls along each footing founding excavation to the footing founding level and for control of groundwater inflow.	■ High risk of disturbance of the native silty clay to clay deposit during construction; can be somewhat mitigated with use of a concrete working slab or granular working pad but would require greater depth of dewatering for footing construction. ■ Culvert joints may be required to accommodate total and differential settlement (if applicable).

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

Culvert Location (Township)	Approximate Invert Elevation [1] (North End / South End)	Culvert Type	Approximate Backfill/Bedding 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 11 STA 11+993 (Township of Crozier)	349.8 m	Pre-Cast Box [2]	349.4 m (Removal of existing fill materials as required likely as deep as Elev. 348.5 m)	Bedding/Levelling on Replacement fill over Stiff to Very Stiff Silty Clay to Clay	200 kPa	100 kPa
		Open Footing [2] (0.6 m wide)	347.5 m	Stiff to Very Stiff Silty Clay to Clay	200 kPa	150 kPa
		Open Footing [2] (1.2 m wide)				

Notes: 1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing BC301111.dwg).

2. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an assumed 6.0 m wide box culvert and a 0.6 m or 1.2 m wide open footing. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the foundation widths differ from those given above.

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

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

Culvert Location (Township)	Pre-Cast Box Culvert or Open Footing		Cast-in-place Open Footing	
	Interface Material	Coefficient of Friction[1] (tan δ)	Interface Material	Coefficient of Friction[1] (tan δ)
Hwy 11 STA 11+993 (Township of Crozier)	Compacted Granular Fill (Levelling Pad)	0.45	Stiff to Very Stiff Silty Clay to Clay	0.30

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

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

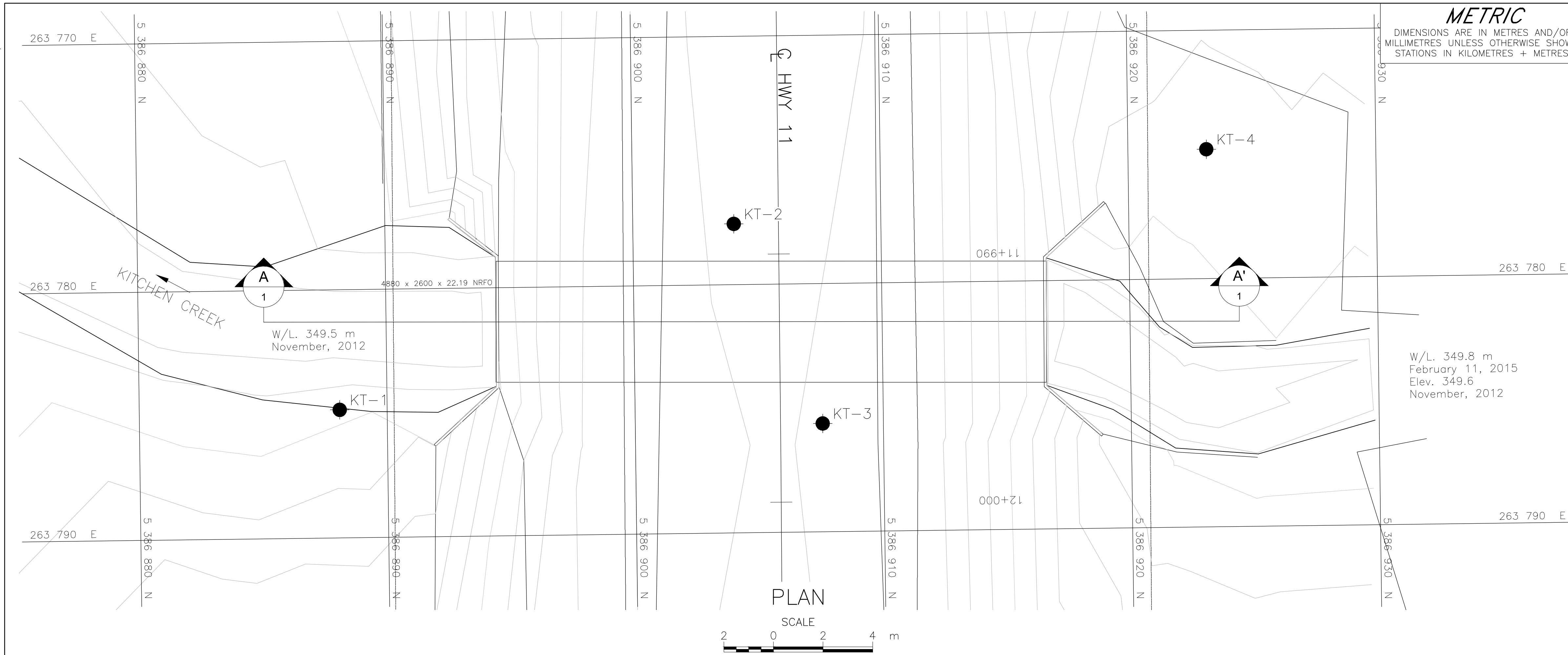
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

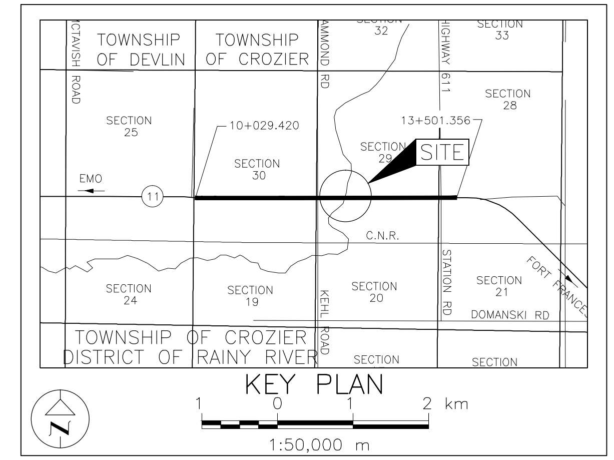
CONT No.
GWP No. 6324–14–00

SHEET

HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates





LEGEND

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

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
KT–1	350.2	5386888.1	263784.8
KT–2	354.5	5386904.1	263777.6
KT–3	354.5	5386907.6	263785.6
KT–4	350.9	5386923.2	263774.8

NOTES

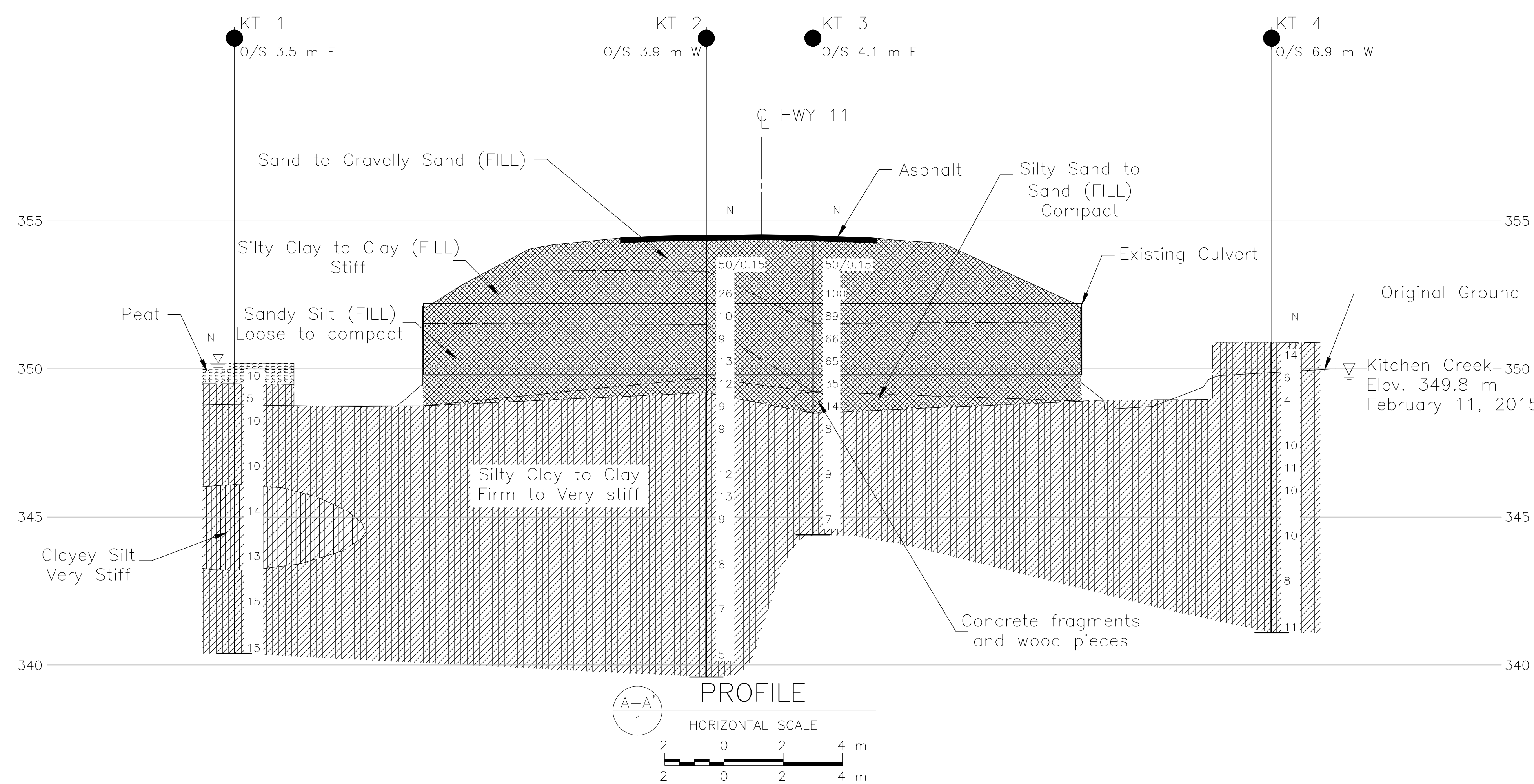
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

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

REFERENCE

Base plans provided in digital format by MTO, drawing file no. BC301111, received FEB 20, 2015.



S.E.M. POOT 90471921 — LICENSED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO — SEP 08, 2015

J.M.A.COSTA — LICENSED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO — SEP 08, 2015

NO.	DATE	BY	REVISION

Geocres No. 52C–41

HWY. 11	PROJECT NO. 1411523		DIST.
SUBM'D. AC	CHKD.	DATE: 8/25/2015	SITE: 45–277/C
DRAWN: JJL	CHKD. SEMP	APPD. JMAC	DWG. 1

PLOT DATE: September 3, 2015
FILENAME: \\golder.gds\gal\Sudbury\CAD–GIS\CAD\Projects\2014\1411523 HWY 26 Culverts Thunder Bay\CIVIL 3D\1411523_Kitchen Creek.dwg

Photograph 1: Kitchen Creek Culvert
North Side - Inlet (Taken from MTO, OSIM_07-26-2013)

Photograph 2: Kitchen Creek Culvert
South Side - Outlet (Taken from MTO, OSIM_07-26-2013)

Photograph 3: Kitchen Creek Culvert
North Side - Inlet (Golder – February 15, 2015)

Photograph 4: Kitchen Creek Culvert
South Side - Outlet (Golder – March 21, 2015)

APPENDIX A

Record of Boreholes

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_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

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

(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 $= \sigma'_p / \sigma'_{vo}$

(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 δ
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

Notes:
1. $\tau = c' + \sigma' \tan \phi'$
2. 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, 60º 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 cm^2 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 Relative Density	**N 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	c_u, s_u 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

Golder Associates

RECORD OF BOREHOLE No KT-1

 METRIC

PROJECT 1411523

G.W.P. 6324-14-00 LOCATION N 5386888.1; E 263784.8 ORIGINATED BY MR

DIST ____ HWY 11 BOREHOLE TYPE Portable equipment - NW Casing and Wash Boring COMPILED BY AC

DATUM GEODETIC DATE March 20 and 21, 2015 CHECKED BY SEMP

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
350.2	GROUND SURFACE						
0.0	PEAT, Amorphous, trace to some sand Dark brown Frozen	1	SS	10	350		
349.5 0.7	SILTY CLAY to CLAY, trace to some sand, trace gravel Firm to very stiff Grey Wet Trace organics above 1.5 m depth.	2	SS	5	349		OC=3.3%
		3	SS	10	348	>100	
		4	SS	10	347	>100	
	Clayey silt zone encountered from 4.1 m to 7.0 m depth. Very stiff	5	SS	14	346 / 345		2 18 48 32
		6	SS	13	344 / 343		
		7	SS	15	342 / 341		
340.4 9.8		8	SS	15			
	END OF BOREHOLE Note: 1. Water level at ground surface (Elev. 350.2 m) upon completion of drilling.						

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L – WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No KT-2

 METRIC

PROJECT 1411523
G.W.P. 6324-14-00
LOCATION N 5386904.1; E 263777.6
ORIGINATED BY DM
DIST
HWY 11
BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers
COMPILED BY AC
DATUM GEODETIC
DATE February 12, 2015
CHECKED BY SEMP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
354.5	GROUND SURFACE					
0.0	ASPHALT (170 mm)					
0.2	Sand to gravelly, some silt (FILL) Brown Frozen. Augers Grinding from surface to 1.2 m depth on inferred cobbles.	1	SS	50/0.15		
353.3 / 1.2	Clay, some sand, trace gravel (FILL) Stiff Brown to grey Frozen* to moist. Augers grinding between 1.5 m and 3.0 m depth on inferred cobbles.	2	SS	26*	w_P–w–w_L plotted	1 18 31 50
		3	SS	10		
351.5 / 3.0	Sandy silt, trace clay, trace organics (FILL) Loose to compact Brown to grey Moist	4	SS	9	w plotted	
		5	SS	13		
349.7 / 4.8	Sand, some silt (FILL) Compact Brown to grey Moist	6 A/B	SS	12	w plotted	1 82 (17)
349.2 / 5.3	CLAY, trace to some sand, trace gravel Stiff to very stiff Grey Wet	7	SS	9		
		8	SS	9		
					>100 (shear strength)	
		9	SS	12	w_P–w–w_L plotted	2 13 34 51
		10	SS	13		
		11	SS	9		
		12	SS	8	w_P–w–w_L plotted	1 11 34 54
		13	SS	7		
		14	SS	5		
339.6					>100 (shear strength)	

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (354 to 340); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No KT-2

 METRIC

PROJECT 1411523
G.W.P. 6324-14-00
LOCATION N 5386904.1; E 263777.6
ORIGINATED BY DM
DIST HWY 11
BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers
COMPILED BY AC
DATUM GEODETIC
DATE February 12, 2015
CHECKED BY SEMP

SOIL PROFILE			SAMPLES									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
14.9	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.										

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

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 31/08/15 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No KT-3

 METRIC

PROJECT 1411523
G.W.P. 6324-14-00 LOCATION N 5386907.6; E 263785.6 ORIGINATED BY DM
DIST HWY 11 BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers COMPILED BY AC
DATUM GEODETIC DATE February 15, 2015 CHECKED BY SEMP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
354.5	GROUND SURFACE						
0.0	ASPHALT (170 mm)						
0.2	Sand to gravelly sand, some silt (FILL) Brown to grey Frozen* Augers grinding in the upper 0.8 m on inferred cobbles.	1	SS	50/0.15*	354		
		2	SS	100*	353		
		3	SS	89*	352	w plotted	21 61 (18)
351.5 / 3.0	Silty clay with sand, trace organics (FILL) Grey Frozen	4	SS	66*	351		
		5	SS	65*	350	wP, w, wL plotted	0 34 34 32
		6	SS	35*			
349.2 / 5.3	Silty sand, trace to some clay, trace organics, trace concrete fragments, decomposed wood pieces (FILL) Compact Black Wet	7	SS	14	349		
348.5 / 6.0	CLAY, trace to some sand Stiff to very stiff Grey Wet Sand interlayers in Sample 8.	8	SS	8	348	wP, w, wL plotted	0 10 33 57
		9	SS	9	347		
					346		
		10	SS	7	345	w plotted	
344.4 / 10.1	END OF BOREHOLE						

Shear strength: >100 (at approx. 346.0 and 344.4)

Note:

1. Borehole dry upon completion of drilling.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; UNIT WEIGHT γ kN/m³

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

Golder Associates

RECORD OF BOREHOLE No KT-4

 METRIC

PROJECT 1411523

G.W.P. 6324-14-00 | LOCATION N 5386923.2; E 263774.8 | ORIGINATED BY MR

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

DATUM GEODETIC | DATE March 21, 2015 | CHECKED BY SEMP

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
350.9	GROUND SURFACE													
0.0	CLAY, trace to some sand Stiff to very stiff Grey Frozen* to wet		1	SS	14*									
			2	SS	6*		350							
			3	SS	4		349							
	Brown, trace to some organics noted from ground surface to 2.1 m depth.							>100						
			4	SS	10		348				0	10	35	55
			5	SS	11		347							
			6	SS	10		346							
			7	SS	10		345							
			8	SS	8		344 / 343							
			9	SS	11		342							
341.1 9.8	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.													

Legend: DCPT scale 20 40 60 80 100; ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED; shear strength 20 40 60 80 100. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; water content 20 40 60. REMARKS & GRAIN SIZE DISTRIBUTION (%).

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

APPENDIX B

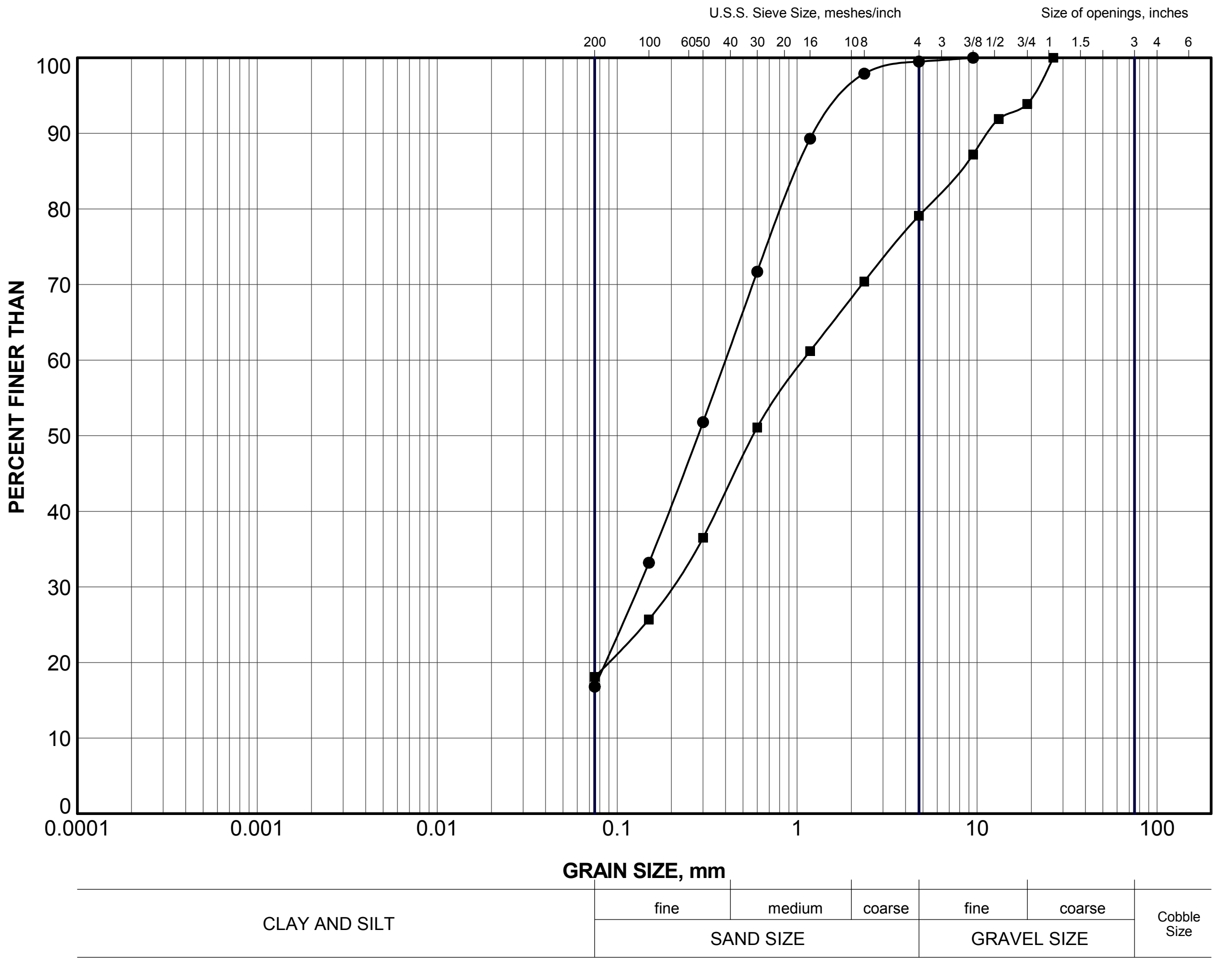
Laboratory Test Results

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

Parameter	Units	Result
Chloride (CL)	mg/L	1.87
Sulphate (SO4)	mg/L	0.82
Conductivity (EC)	µS/cm	239
Resistivity	µohm-cm	<0.33
pH	n/a	7.00

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

Prepared by: TB
Checked by: SEMP
Reviewed by: JMAC



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KT-2	6B	349.5
■	KT-3	3	351.9

PROJECT

HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE

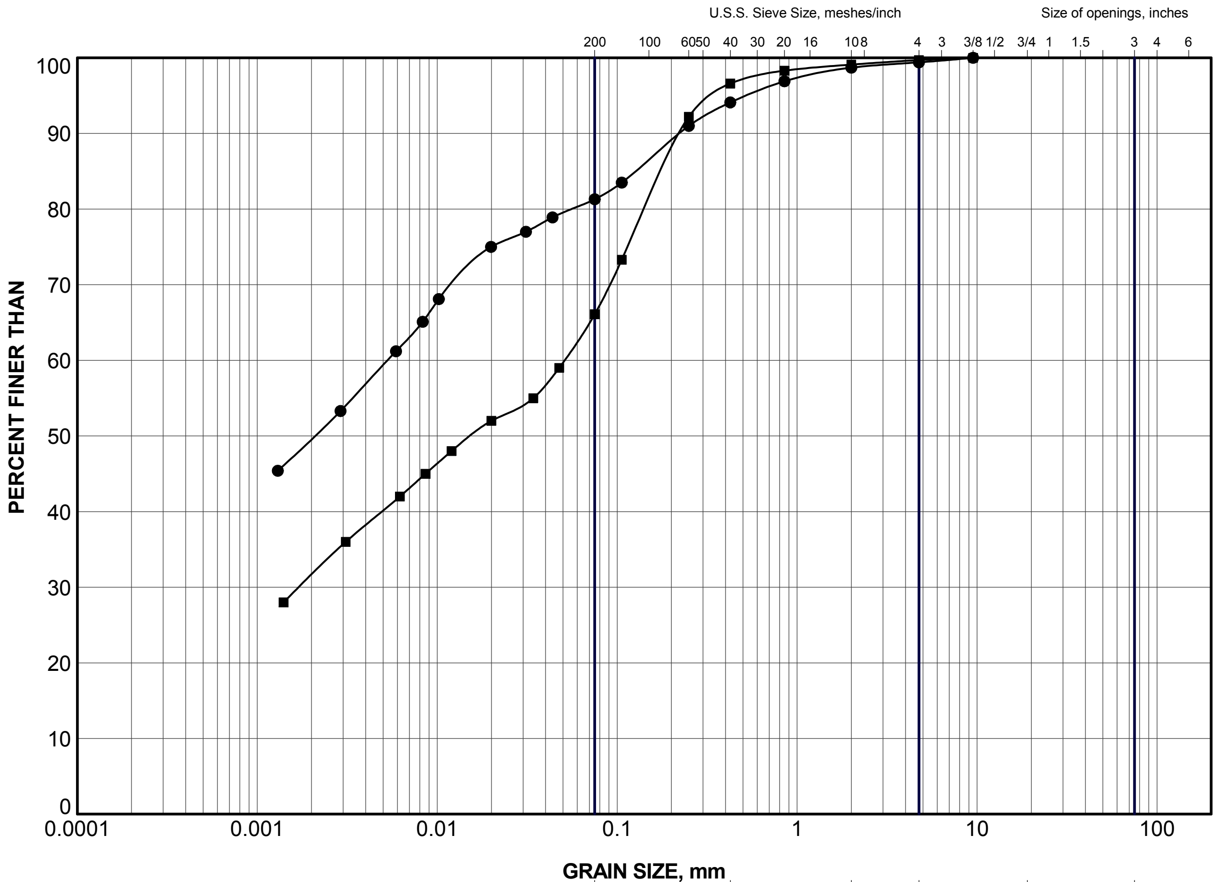
GRAIN SIZE DISTRIBUTION

SAND to GRAVELLY SAND (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A	REV.
CHECK	SEMP	Jun 2015	FIGURE B1	
APPR	JMAC	Jun 2015		

SUD-MTO GSD (NEW) GLDR_LDN.GDT



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KT-2	2	352.7
■	KT-3	5	350.4

PROJECT

HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE

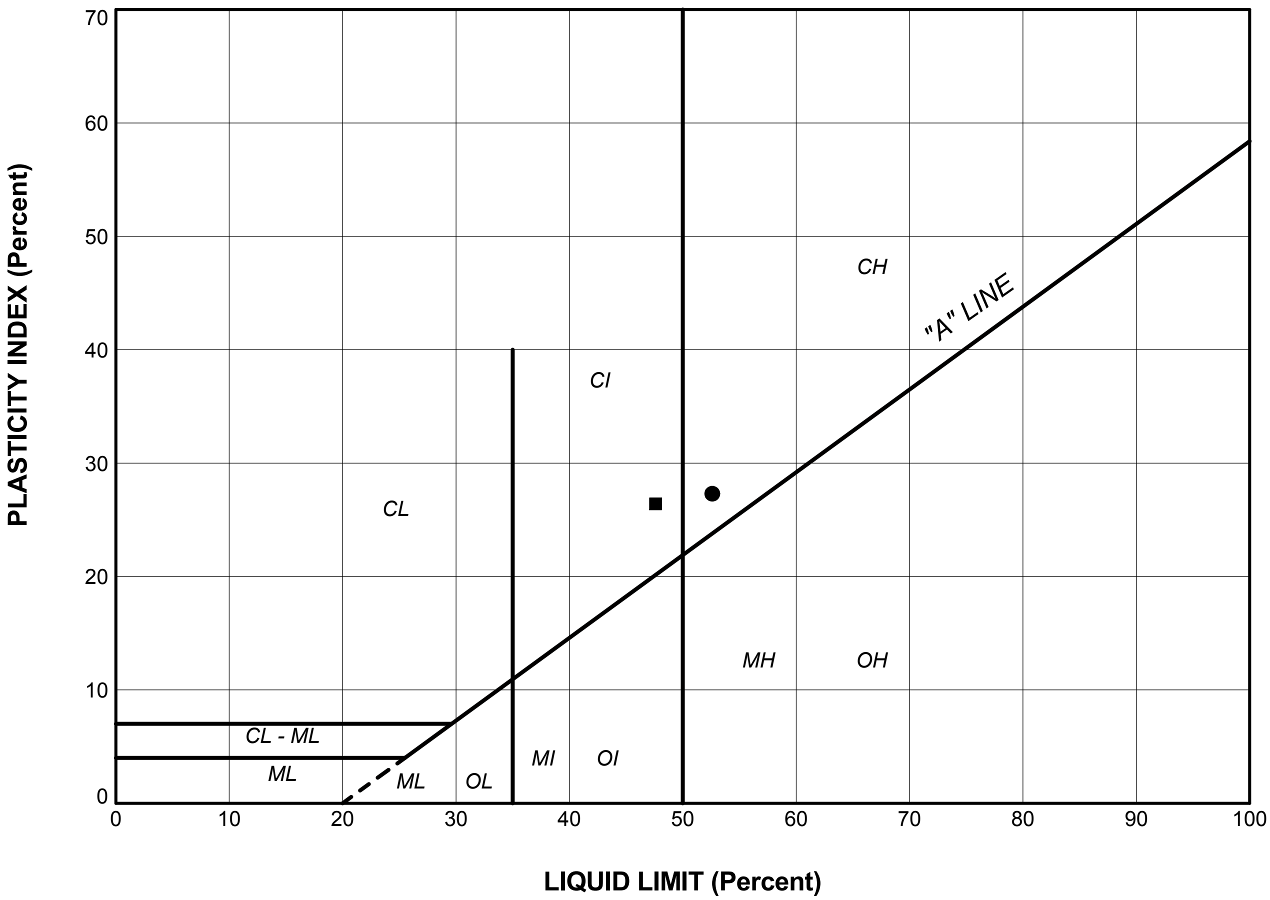
GRAIN SIZE DISTRIBUTION

SILTY CLAY with SAND to CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No. 1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A REV.
CHECK	SEMP	Jun 2015	
APPR	JMAC	Jun 2015	FIGURE B2

SUD-MTO GSD (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	KT-2	2	52.6	25.3	27.3
■	KT-3	5	47.6	21.2	26.4

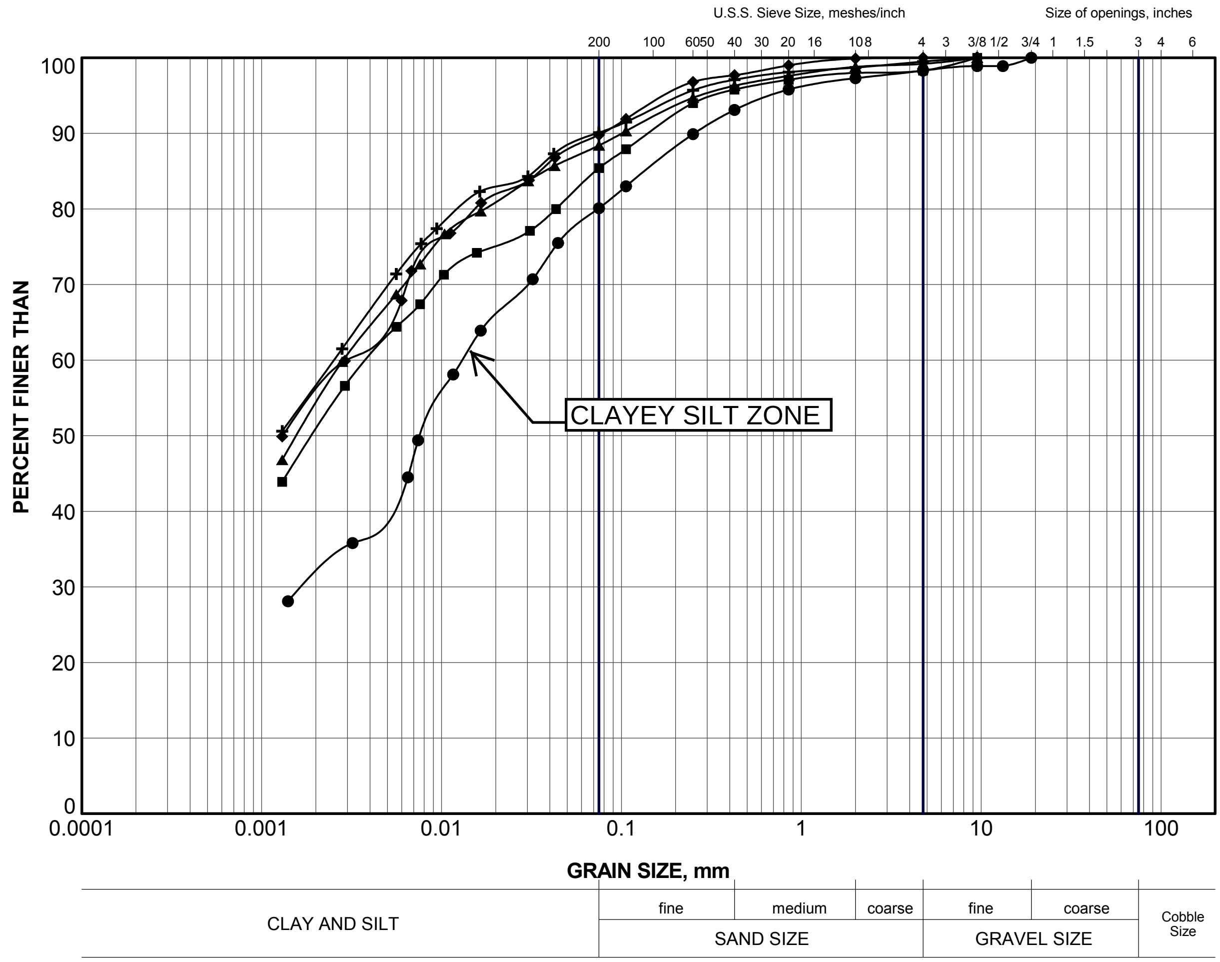
PROJECT
HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE
PLASTICITY CHART
SILTY CLAY with SAND to CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A	REV.
CHECK	SEMP	Jun 2015	FIGURE B3	
APPR	JMAC	Jun 2015		

SUD-MTO PL (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KT-1	5	345.3
■	KT-2	9	346.6
▲	KT-2	12	343.5
+	KT-3	8	348.1
◆	KT-4	4	347.6

PROJECT

HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE

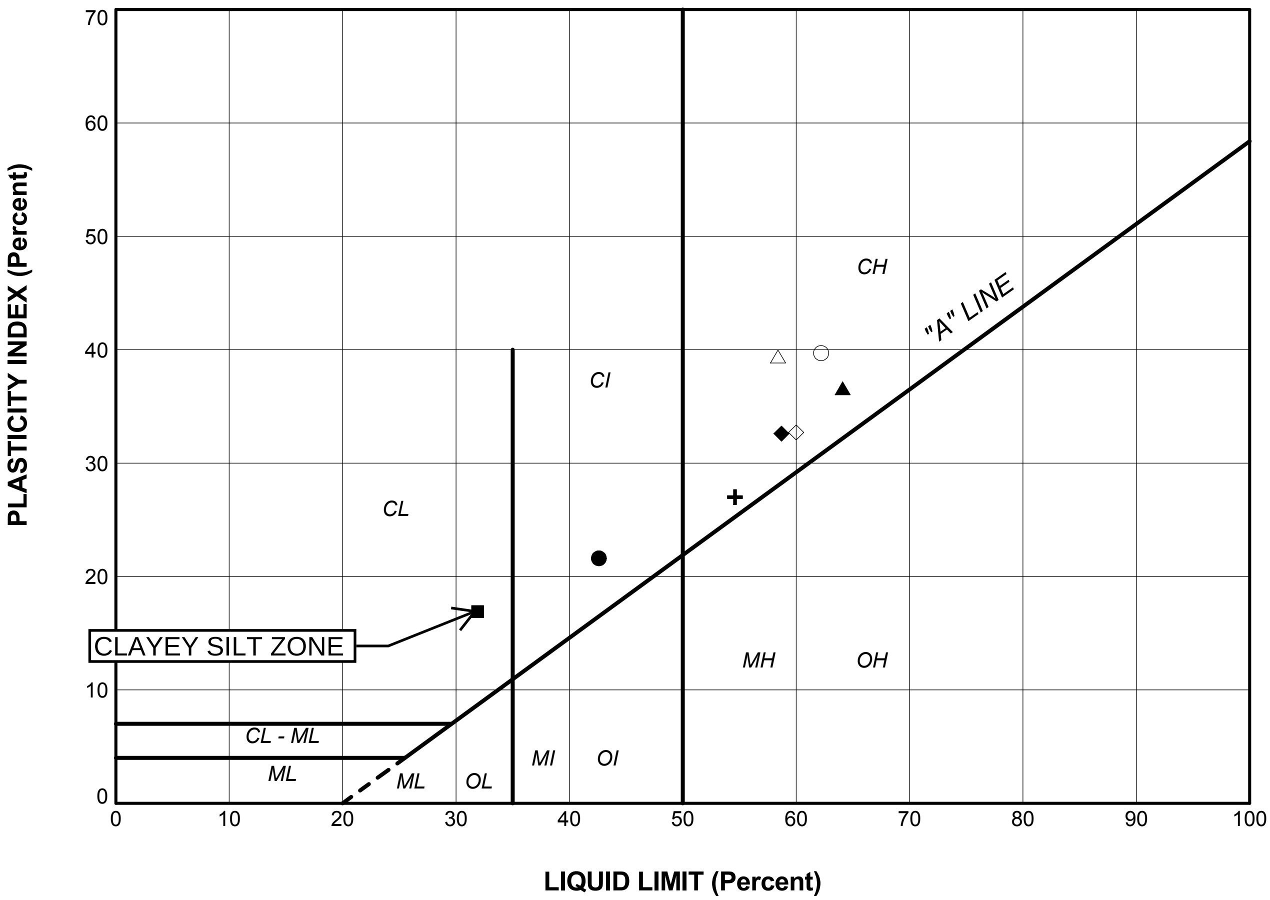
GRAIN SIZE DISTRIBUTION

CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A	REV.
CHECK	SEMP	Jun 2015		
APPR	JMAC	Jun 2015	FIGURE B4	

SUD-MTO GSD (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	KT-1	2	42.6	21.0	21.6
■	KT-1	5	31.9	15.0	16.9
▲	KT-1	7	64.1	27.5	36.6
+	KT-2	9	54.6	27.6	27.0
◆	KT-2	12	58.7	26.1	32.6
◇	KT-3	8	60.0	27.3	32.7
○	KT-4	4	62.2	22.5	39.7
△	KT-4	6	58.4	19.0	39.4

PROJECT
HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE
PLASTICITY CHART
SILTY CLAY to CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A	REV.
CHECK	SEMP	Jun 2015		
APPR	JMAC	Jun 2015	**FIGURE B5**	

SUD-MTO PL (NEW) GLDR_LDN.GDT

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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