July 10, 2018

FOUNDATION INVESTIGATION AND DESIGN REPORT

REPLACEMENT OF JACKPINE CREEK CULVERT - SITE NO. 46-577/C
HIGHWAY 101, PINOGAMI TOWNSHIP, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5266-13-00, WP 5219-13-01

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REPORT

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Table of Contents

PART A

FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by LEA Consulting Ltd. (LEA) on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation engineering services for the rehabilitation of the Jackpine Creek Culvert (Site No. 46-577/C), located on Highway 101, 29 km West of Foleyet in Pinogami Township, Ontario. The key plan showing the general location of this section of Highway 101 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface soil conditions at the existing culvert location by borehole drilling and laboratory testing on selected soil and samples.

The Terms of Reference and Scope of Work for the Foundation Investigation are outlined in MTO's Request for Proposal dated April, 2016. Golder's proposal for foundation engineering services associated with replacement of this structure is contained in Section 17.8 of LEA's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundations engineering services for this project, dated January 11, 2017.

2.0 SITE DESCRIPTION

The existing Jackpine Creek Culvert consists of a 27 m long, 3.4 m diameter corrugated steel pipe. The approximate invert of the culvert is Elevation 364 m and the embankment thickness / depth of cover on the culvert is about 1.9 m. In general, the topography at the culvert site is relatively flat, the ground surface being covered/vegetated with grass, shrubs and trees. The existing highway grade is at Elevation 369 m and the water level in the creek was measured at the culvert site by Golder at Elevation 365.3 m in September 2017.

Photographs at the culvert area are shown on Photographs 1 to 4, following the text of this report.

3.0 INVESTIGATION PROCEDURES

The field work was carried out between September 25 and September 28, 2017, during which time six boreholes (JP-1 to JP-6) were advanced at the locations shown on Drawing 1. The borehole and drillhole records are presented in Appendix A. The field investigation was carried out using the following drilling equipment:

- Boreholes JP-1 and JP-3 to JP-6 were advanced using a CME-55 track-mounted drill rig supplied and operated by Downing Drilling Inc. (Downing) of Grenville-sur-la-Rouge, Quebec.
- Borehole JP-2 was advanced using a portable tripod drill rig supplied and operated by Downing.

The boreholes were advanced using 76 mm inside diameter hollow-stem augers and/or NW casing with wash boring. 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 on the CME-55 drill rig and a manual half-weight hammer (Acker) on the portable drill rig, in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The 'N'-values obtained using the half weight hammer were corrected to those that would have been obtained by a full weight hammer. The groundwater level in the open boreholes was observed during and immediately following 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 staff, who located the boreholes in the field, cleared the site for buried services, directed the drilling and sampling operations and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's Sudbury Laboratory for further examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Index and classification tests consisting of water content, Atterberg limits and grain size distribution were carried out on selected soil samples. The results of the laboratory testing on samples from the boreholes are presented on the borehole records in Appendix A, and on the figures in Appendix B.

A soil sample was obtained on September 25, 2017, in Borehole JP-4, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters including pH, resistivity, conductivity, sulphates and chlorides. The results of the analytical testing are summarized in Table B1 included in Appendix B.

The borehole locations and elevations were measured in the field by Golder personnel, relative to existing site features and surveyed to point HCP-100. The borehole locations (referenced to the MTM NAD83 co-ordinate system), ground surface elevations (referenced to Geodetic datum) and borehole depths are presented on the borehole records in Appendix A and are summarized below.

Borehole	Location (MTM NAD 83, Zone13)		Location (World Geodetic System 84)		Ground Surface Elevation (m)	Borehole (DCPT) Depth (m)
	Northing	Easting	Latitude	Longitude		
JP-1	5326504.2	401004.4	48.070175	-82.708943	367.1	11.3
JP -2	5326517.8	401004.6	48.070297	-82.708937	365.4	7.6
JP -3	5326498.8	401011.4	48.070125	-82.708850	369.0	15.8
JP -4	5326512.1	401019.2	48.070243	-82.708742	369.0	15.5
JP -5	5326503.4	401028.2	48.070164	-82.708624	365.9	9.8
JP -6	5326513.3	401028.1	48.070253	-82.708623	365.6	9.4

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)[1] mapping, the Jackpine Creek Site is located within organic terrain consisting primarily of peat and muck bordered to the north by a ground moraine deposit consisting primarily of sandy till materials and to the south by bedrock knobs.

Based on geological mapping by the Ontario Ministry of Northern Development and Mines (MNDM)[2], the site is underlain by gneissic tonalite bedrock.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil samples, are presented on the borehole records in Appendix A

1 Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41JNW
2 Ontario Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2543

and the laboratory test sheets in Appendix B. The results of the in-situ field tests (i.e., SPT ‘N’-values) as presented on the borehole records and in Section 4 are uncorrected, except for those obtained by use of the half weight hammer as noted in Section 3.0. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profile and cross-section on Drawings 1 and 2 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations. A summary of the subsurface conditions as encountered in Boreholes JP-1 to JP-6 is presented below.

4.2.1 Subsoil Conditions

A description of the soil deposits encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows) / Field Vane Results (kPa) / Consistency or Relative Density	Laboratory Testing
Asphalt	JP-3, JP-4	0.23 – 0.25	369.0	n/a	n/a
(FILL) Sand; Gravelly Sand to Sand and Gravel	JP-1, JP-3, JP-4	1.5 – 5.8	368.8 – 367.1	N = 6 – 47 n/a Very loose to Dense	w = 4% – 11% 3 – M (Fig. B1)
Wood (Fill)	JP-6	0.7	363.3	N = 3 n/a n/a	n/a
Peat (Amorphous/ Fibrous)	JP-1 to JP-3, and JP-5	0.1 – 2.2	365.9 – 365.4	N = 1 – 6 n/a Very soft to firm	w = 135%
Organic Sand; Organic Silt	JP-2 and JP-3	0.7 – 1.0	366.4 – 363.9	N = 4 – 12 n/a Very loose to compact	**n/a**
Silt and Sand	JP-3	2.4	365.3	N= 5 – 8 n/a Loose	w = 18% 1 – MH (Fig. B2) OC= 3.4%

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows) Field Vane Results (kPa) Consistency or Relative Density	Laboratory Testing
Sand	JP-1, JP-2 and JP-5	0.8 – 1.5	363.8 – 363.2	N = 2 – 20 n/a Very loose to compact	w = 11% – 39% 2 – MH (Fig. B3) OC= 2.6%
Silt	JP-1 to JP-6	4.6 – 7.0	362.9 – 361.9	N = 4 - 38 n/a Very loose to dense	w = 19% – 27% 9 – MH (Fig. B4) 1 – AL (NP) 1 – AL (Fig B5.) w_l = 22% w_p= 16% I_p = 6%
Boulder(s)	JP-1 and JP-6	0.4 and 0.3	357.1 and 356.8	-	-
(TILL) Silty Sand; Silt and Sand; Sandy Silt; Silty Sand and Gravel[1], trace clay	JP-1 and JP-3 to JP-6	>0.3–>3.6 (Boreholes terminated in this deposit)	357.2 – 355.5	N = 61 – 121;102/0.15 n/a Very dense	w = 11% – 14% 2 – MH (Fig. B6)

Where:
N = SPT 'N'-value; number of blows for 0.3 m of penetration
s_u = undrained shear strength from in situ field 'N'-vane (kPa)
S = calculated sensitivity
w = natural moisture content (%)
M = sieve analysis
MH = combined sieve and hydrometer analysis
AL = Atterberg limits test
w_p = plastic limit (%)
w_l = liquid limit (%)
I_p = plasticity index (%)
NP = non-plastic test result in Atterberg limits
Oc = organic content test

Notes:
[1]A cobble was encountered in Borehole JP-3 from 13.0 m to 13.1 m; cobbles were encountered in Borehole JP-4 between13.1 m and 13.5 m.

4.3 Refusal

Refusal to further split spoon and casing advancement was recorded in Borehole JP-2 at a depth of 7.6 m (Elevation 357.8 m).

4.4 Groundwater Conditions

The depths to/elevations of unstabilized groundwater levels measured in the open boreholes upon completion of drilling are presented below. It should be noted that the introduction of drilling water to advance NW casing in the boreholes may have impacted the measured groundwater levels. Water levels should be expected to vary depending on the time of year and precipitation events.

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
JP-1	1.6	365.5
JP-2	At ground surface	365.4
JP-3	4.5	364.5
JP-4	2.7	366.3
JP-5	0.9	365.0
JP-6	At ground surface	365.6

The water level in the creek water was measured by Golder on September 29, 2017, at Elevation 365.3 m.

5.0 CLOSURE

The field drilling program was supervised by Mr. Mathew Riopelle. This Foundation Investigation Report was prepared by Ms. Aronne-Kay De Souza, EIT, and the technical aspects were reviewed by Mr. André Bom, P.Eng., a geotechnical engineer and Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., an MTO Designated Foundations Contact and Senior Consultant of Golder, conducted an independent quality control review and technical audit of this report.

Report Signature Page

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PART B

FOUNDATION DESIGN REPORT
REPLACEMENT OF JACKPINE CREEK CULVERT - SITE NO. 46-577/C
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed replacement of the existing Jackpine Creek Culvert (Site 46-577/C) located on Highway 101 about 29 km west of Foleyet. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at the site. The discussion and recommendations presented in this Foundation Design Report (Part B) are intended to provide MTO's designers with sufficient information to assess the feasible foundation alternatives and to design the proposed culvert.

The discussion and recommendations contained in this Foundation Design Report (Part B) shall not be used or relied upon for any other purpose or by any other parties, including the construction contractor or design-build contract. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. The contractor must make their own interpretation based on the factual data in the Foundation Investigation Report (Part A), as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

Golder Associates Ltd. (Golder) has been retained by LEA Consulting Ltd. (LEA) on behalf of MTO to provide recommendations on the foundation aspects for the design of the replacement of the Jackpine Creek Culvert on Highway 101.

A box culvert and open footing culvert are both considered feasible alternatives for replacement of the existing CSP culvert at this site. However, from a foundations perspective, an open footing culvert presents greater challenges due to the existing subsoils at this site and the open footing culvert will have an extended construction schedule and increase the excavation, dewatering and shoring requirements compared to a box culvert; therefore, a box culvert sufficiently wide to handle the creek flow is the preferred alternative culvert type for this site. A pipe culvert alternative may also be considered to accommodate other site constraints (e.g., fisheries requirements related to natural channel substrate). A comparison of culvert types based on advantages, disadvantages and risks/consequences is presented in Table 1.

Based on the General Arrangement (GA) drawing dated June, 2018 provided by LEA, we understand that the proposed replacement culvert is to consist of twin 3 m square precast concrete boxes separated by 1.5 m, with the invert at Elevations 364.0 m and 363.7 m at the inlet and outlet ends, respectively.

We further understand that the alignment of the proposed twin box culvert is approximately consistent with the current (existing) culvert alignment, and that a permanent grade raise or widening is not required for the culvert replacement, relative to the existing embankment. It is understood from LEA that during culvert replacement, a minor widening (i.e., 1 m) is required at the existing shoulders for traffic staging. Based on the existing subsurface conditions, if a permanent grade raise or widening is required in the future, we recommend that a geotechnical engineer be retained to assess the embankment stability and settlement of any new widening/raised section.

6.2 Consequence and Site Understanding Classification

The replacement culvert is being designed in accordance with the current Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC 2014).

In accordance with Section 6.5 of CHBDC (2014) and its Commentary, the proposed culvert and its foundation system are considered to be classified as having a "typical consequence level" associated with exceeding limits states design. This consequence classification should be confirmed by LEA. In addition, given the level of foundation investigation completed at the site, the degree of site and model understanding is considered "typical" as described in Clause 6.5.3.2 of CHBDC (2014). Accordingly, the appropriate corresponding ultimate limit states (ULS) and serviceability limit states (SLS) consequence factors, Ψ, and geotechnical resistance factors at ULS (ϕ_{gu}) and SLS (ϕ_{gs}), from Tables 6.1 and 6.2, respectively, of the CHBDC have been used for design in this report.

6.3 Culvert Foundation Design Recommendations

6.3.1 Founding Level and Geotechnical Resistance

Prior to placing the bedding/levelling pad for the replacement culvert, it is recommended that all organic material (i.e., peat, wood and/or mixed organic soils) encountered below the culvert footprint be sub-excavated and replaced with Ontario Provincial Standard Specification, Provincial Oriented (OPSS.PROV) 1010 (Aggregates) Granular 'B' Type II, which is suitable for placement/use in wet ground conditions, as discussed further in Section 6.6.3.

For the two barrel 3 m wide box culvert separated by 1.5 m, with the underside of the concrete slab at approximately Elevations (363.7 m to 363.4 m at the inlet and outlet ends, respectively, (for an assumed 0.3 m thick slab) and the underside of the compacted granular bedding at approximately Elevation 362.5 m (for a 0.6 m thick bedding layer), a factored ultimate geotechnical resistance at ULS of 350 kPa and a factored serviceability geotechnical resistance at SLS (corresponding to 25 mm of settlement) of 40 kPa, may be used in design. Alternatively, if the culvert can tolerate 50 mm of settlement, a factored serviceability geotechnical resistance at SLS of 80 kPa, may be used in design.

Alternatively, if an open footing culvert is considered for this site, compiled of parallel 1.5 m wide footings founded at approximately Elevation 361.0 m to account for frost as per Section 6.3.2, a factored ultimate geotechnical resistance at ULS of 300 kPa and a factored serviceability geotechnical resistance at SLS (corresponding to 25 mm of settlement) of 90 kPa may be used in design. Alternatively, if the culvert can tolerate 50 mm of settlement, a factored serviceability geotechnical resistance at SLS of 180 kPa may be used in design.

The factored geotechnical resistances provided above are based on the loading applied perpendicular to the base of the culvert/footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of CHBDC (2014) and associated Commentary. The factored geotechnical resistances should be reviewed if the founding elevation and/or the foundation widths differ from those given above.

The loading on the foundation soils below the culvert and the associated settlement at the culvert location will be impacted by loading from the embankment fill immediately adjacent to the culvert. The factored geotechnical serviceability resistance provided above assumes there will not be a temporary and/or permanent grade raise at or adjacent to the culvert location (including during the course of construction).

6.3.2 Frost Protection

Provided that the box culvert is tolerant of small magnitudes or movement related to freeze-thaw cycles, the culvert can be founded above the depth of frost penetration, which is 2.5 m at this site as interpreted from OPSD 3090.100 (Frost Protection Depths for Northern Ontario).

6.3.3 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance should be calculated in accordance with Section 6.10.5 of CHBDC (2014), applying the appropriate consequence and degree of site understanding factors as noted above in Section 6.2. A coefficient of friction, tan δ_i', of 0.4 may be used at the interface between the base of the box culvert and the granular bedding.

6.4 Stability, Settlement and Horizontal Strain

6.4.1 Embankment Stability

The proposed reconstructed embankment adjacent to the culvert is about 5 m high relative to the creek bottom and is stable from a geotechnical perspective if reconstructed of granular material at inclinations of 2 horizontal to 1 vertical (2H:1V), as shown on Figure 1. As discussed in Section 6.1, given the existing subsurface conditions, if a permanent grade raise or widening is required in future relative to the proposed/existing embankment, a stability analysis should be completed for the enlarged geometry.

As discussed in Section 6.1, it is understood that consideration is being given to a temporary widening up to about 1 m for traffic staging during culvert replacement. The temporary embankment widening will consist of side slopes inclined at/graded to 2H:1V without sub-excavation of the existing soils below the widening footprint, including possible organic soils that may be present. The temporary embankment widening is stable from a slope stability consideration, with a FoS of about 1.3 provided the following recommendations are implemented:

- The fill material used for temporary widening should consist of OPSS.PROV1010 (Aggregates) Granular B Type II material.
- New fill should be benched into existing slopes as discussed in Section 6.6.3.
- The fill placed for temporary widening should be removed after construction with the permanent side slopes graded at no steeper than 2H:1V, such that no new granular fill remains over existing soil (fill or organics) beyond the toe of the existing slope (i.e., maintaining the original existing toe of slope).

6.4.2 Settlement and Horizontal Strain

Negligible settlement is expected to occur as a result of the culvert replacement as the proposed embankment geometry adjacent to the culvert will match the existing geometry. During the replacement culvert construction period, minor differential settlement of the foundation soils under the traffic staging the widened area may occur, which may require regrading/repaving of the widened roadway pavement. Provided sustained loading from the culvert on the founding soils remains below the factored SLS value presented in Section 6.3.1 and assuming the loading will be relatively uniform across the footprint of the culvert, settlement of the founding soils is anticipated to similarly be uniform. If the culvert is placed above the frost penetration depth, less than 25 mm of differential settlement may seasonally occur between the culvert centre and ends and therefore a culvert camber is not considered necessary for this site.

6.5 Lateral Earth Pressures

The lateral earth pressures acting on the side walls of the box culvert will depend on the type and method of placement of backfill materials, the nature of the soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls. It should be noted that these design recommendations and parameters assume level (horizontal) backfill and ground surface behind the walls.

Select, free draining granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular ‘A’ or Granular ‘B’ Type II should be used as backfill behind the culvert walls. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting).

The soil parameters provided below for the proposed granular backfill, including at-rest earth pressures, may be used in the design of the box culvert, assuming that the box culvert walls will not allow for lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition). For restrained walls, granular fill should be placed in a zone with the width equal to at least 2.5 m behind the back of the wall (in accordance with Figure C6.20 (a) of the Commentary to the CHBDC). If the excavation/backfilling configuration is not known, the parameters applicable to the existing embankment fill should be used in design.

Fill Type	Unit Weight	Coefficients of Static Lateral Earth Pressure
		At-Rest, K_o
Proposed Granular ‘A’	22 kN/m^3	0.43
Proposed Granular ‘B’ Type II	21 kN/m^3	0.43
Existing Embankment Fill (Gravelly Sand to Sand and Gravel)	20 kN/m^3	0.50

6.6 Construction Considerations

6.6.1 Excavations and Control of Groundwater and Surface Water

It is recommended that all organic soil and wood be removed from below the footprint of the proposed culvert. Where gravelly sand fill is exposed/present below the proposed box culvert bedding, it may be left in place based on the information from the borehole JP-4. Excavations will extend to approximately Elevation 362.5 m, assuming that 500 mm of granular bedding will be placed under the culvert, however, excavations may have to extend deeper in select areas to remove the organic soil and wood and for construction of cut-off wall(s).

Open-cut excavations must be carried out in accordance with the guidelines outlined in the latest edition of the Occupational Health and Safety Act (OHSA) and Regulation for Construction Activities. The existing fill and organic soils are classified as Type 4 soil according to the OHSA. Temporary excavations (i.e., those that are open for a relatively short time period) should be made with side slopes no steeper than 1H:1V above the water level. Open excavations below the water level are not recommended or should be minimized, but if required should be made at side slopes no steeper than 3H:1V.

Temporary protection systems will be required for staged culvert replacement. Recommendations for temporary protection systems are provided in Section 6.6.2.

Creek flows through the existing culvert will need to be diverted/pumped away from the excavation areas during the construction period. 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.

As a result of the excavation, groundwater flow into the excavation can be expected due to the relatively permeable nature of the adjacent granular embankment fill and non-cohesive native soils.

Excavations for the upstream and downstream cast in place or precast cut-off wall and bedding for the culvert will extend below the groundwater level. Due to the existing creek, a groundwater cut-off system (cofferdam or similar measure) is recommended at/near the ends of the culvert to minimize dewatering requirements and the occurrence of potential environmental impacts, as discussed further in Section 6.6.2. Dewatering of all excavations should be carried out in accordance with OPSS.PROV 517 (Dewatering). A Notice to Contractor should be included in the Contract to alert the contractor to the potential issues associated with cofferdams and unwatering of the soils at the site and that the excavation must be unwatered and kept stable during placement of cut-off wall(s) and bedding; an example Notice to Contractor is included in Appendix C.

The silt/sand that will be exposed within the excavation will be susceptible to disturbance from construction traffic and/or ponded water and the exposed surface should be protected from construction traffic and water flow.

6.6.2 Temporary Protection Systems and Cofferdams

Temporary protection systems may be required for traffic staging to allow for the removal of existing fill, culvert, and organic soil below the new culvert footprint and for bedding and culvert placement. Temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). The lateral movement of the temporary shoring systems should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any existing adjacent structures or utilities can tolerate this magnitude of deformation.

It is considered that either a driven, interlocking sheet pile system or a soldier pile and timber lagging system would be suitable for the temporary excavation support at the site, based on the subsurface soil and groundwater conditions. An interlocking sheet pile system would contribute to both ground and, where applicable, groundwater control, and should be driven to a sufficient depth to provide for control of seepage and upward pressure of groundwater from the non-cohesive soils. For a soldier pile and lagging system, it would be necessary to control seepage or include measures to mitigate loss of soil particles through the lagging boards as well as to mitigate for the potential for heave or disturbance of the base of the excavation due to upward groundwater seepage pressures.

The sheet piles or soldier piles would have to be driven or socketted to sufficient depth to provide the necessary passive resistance for the retained soil height, including any surcharge loads behind the protection system within at least a 1H:1V zone relative to the base of the excavation. Lateral support to the sheet piles or soldier piles could be provided in the form of rakers or temporary anchors.

The selection and design of the protection system will be the responsibility of the Contractor.

6.6.3 Subgrade, Bedding and Backfill

The culvert should be constructed consistent with elements shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts) and in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). The subgrade should be inspected following sub-excavation to ensure that all organics and other unsuitable materials have been removed.

The box culvert should be constructed on a minimum 500 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular ‘B’ Type II Material for bedding purposes, with an OPSS 1860 Class II non-woven geotextile, with a filtration opening size not greater than 150 µm separation layer between the granular material and the native subgrade. The granular bedding should be nominally compacted by the construction equipment. The design of the culvert should be based on the bedding having achieved a moderate level of compaction – if a degree of compaction is needed for design, a relative density of 90 per cent of the standard Proctor maximum dry density (SPMDD) should be assumed. In addition, a 75 mm thick layer of uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular ‘A’ or OPSS.PROV 1004 (Aggregates Miscellaneous) concrete fine aggregate should be provided with a geometry similar to that presented on OPSD 803.010 (Backfill and Cover for Concrete Culverts) and should be placed in dry conditions.

Backfill above/behind the culvert walls, including in the space between the two culvert barrels, should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular ‘A’ or Granular ‘B’ Type I, II or III. The granular backfill should be placed in maximum 300 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD of the materials in accordance with OPSS.PROV 501 (Compacting).

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

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

6.6.4 Obstructions

In Borehole JP-6, a 0.7 m thick layer of wood (inferred to be potential remnants of an old corduroy pad) was encountered at about Elevation 363.3 m at a depth of about 2.3 m below ground surface. A Notice to Contractor should be included in the Contract Documents to identify to the contractor of the presence of wood material in the embankment fill; an example is included in Appendix C.

6.6.5 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 cut-off wall comprised of concrete, natural clay or a soil-bentonite mix should be provided at the upstream and downstream ends of the culvert. The concrete or clay cut-off wall should extend to a depth of 1 m below the scour level. If a clay cut-off is adopted, the clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal). In addition, depending on hydraulic conditions resulting in ponding of water against the upstream embankment side slopes, a clay seal/blanket should also be considered on the side slopes up to the high-water level. The clay seal/blanket should be a minimum of 1 m thick constructed of natural clay or soil-bentonite mix. The seal should also extend a minimum horizontal distance of 2 m on either side of the culvert inlet opening. If a geosynthetic clay liner (GCL) is utilized as a seal/blanket in lieu of the natural clay, the GCL should be constructed within the embankment slope to allow for a minimum 0.3 m thick granular (embankment) fill cover to be placed over the GCL to provide for protection from the requisite overlying erosion protection material.

Subject to confirmation by the hydraulic engineer and modifications as necessary based on the hydrology recommendations to be developed by others, taking into consideration the creek flow conditions, creek bed erodibility and any other relevant parameters, erosion protection could consist of a 0.6 m thick layer of rip rap treatment for the inlet and outlet of the culvert consistent with the standard presented in OPSD 810.010 (Rip Rap Treatment) Type B protection. The streambed erosion protection material at the inlet of the culvert should be placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, erosion protection should be provided over the full extent of the granular fill cover placed over the clay seal or GCL.

6.6.6 Analytical Testing for Construction Materials

The results of an analytical test carried out on a soil sample from Borehole JP-4 are presented in Table B1 in Appendix B. The suite of parameters tested is intended to allow the design engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection of steel reinforcing elements.

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

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

7.0 CLOSURE

This detail Foundation Design Report was prepared by Ms. Aronne-Kay De Souza, EIT, and the technical aspects were reviewed by Mr. André Bom, P.Eng., a geotechnical engineer and Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Designated MTO Foundations Contact and Senior Consultant of Golder, conducted an independent quality control review and technical audit of this report.

Report Signature Page

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n:\active\2016\3 proj\1661607 lea_5015-e-0049_ne region\foundations\reporting\r08-jackpine\final\1661607-r08 r-rev0 lea mto jackpine creek fidr 10jul_18.docx

REFERENCES

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

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2543.

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

Ministry of Natural Resources. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society.

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

ASTM International

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

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 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation Frost Penetration Depths for Northern Ontario

Ontario Provincial Standard Specifications (OPSS)

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS 1860	Material Specification for Geotextiles
OPSS.PROV 1205	Material Specification for Clay Seal

Ontario Water Resource Act

Ontario Regulation 903	Wells (as amended)

Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91	Construction Projects (as amended)

Table 1: Comparison of Alternative Culvert Types

Option (Ranking)	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert (1)	■ Minimizes depth of excavation, protection system (if required) and unwatering requirements compared to open footing option. ■ Allows for faster construction resulting in shorter duration for unwatering and surface water pumping. ■ More tolerant of total and differential settlement, if subgrade is disturbed. ■ Backfill/bedding under the culvert may be placed underwater (i.e., Granular 'B' Type II) minimizing water pumping requirements.	■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Cut-off wall (or clay seal) required at inlet to mitigate potential scour under the culvert. ■ Transportation to and on-site lifting of large pre-cast sections will be required. ■ Will require cofferdams and temporary diversion of the creek channel (i.e., pumping around existing culvert). ■ Would require large volume of working slab concrete if base of excavation is disturbed (large area).	■ Risk of disturbance of the native silt deposit at subgrade level during construction, which will be mitigated by Granular 'B' Type II bedding. ■ Lower risk related to settlement performance as box segments can accommodate some total and differential settlement.
Open Footing Culvert (2)	■ May be feasible to construct the culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for unwatering (pumping) of surface water. ■ Readily suitable for construction using concrete or metal sections. ■ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable.	■ Excavation depths are greater than for a box culvert option, resulting in increased excavation support and dewatering requirements and additional spoil material to be disposed off-site. ■ Constructing footings in the dry will take longer due to requirements for installation of a groundwater and surface water control system, dewatering and surface water pumping and excavation in a confined space. ■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site. ■ Greater potential for disturbance of the silt deposit at footing founding level.	■ Moderate risk of disturbance of the native silt deposit during construction both at footing founding level and excavation sides; disturbance of footing founding level can be mitigated with use of a tremie concrete. ■ May require greater depth of dewatering for footing construction. ■ Culvert joints may be required to accommodate the anticipated total and differential settlement.

Option (Ranking)	Advantages	Disadvantages	Risks/Consequences
Pipe Culvert (3)	■ Allows for faster construction resulting in shorter duration for unwatering and surface pumping compared to an open footing culvert. ■ More tolerant of total and differential settlement. ■ Backfill under the culvert may be placed underwater (i.e., Granular 'B' Type II) minimizing or eliminating water pumping requirements.	■ Reduced flow-through capacity compared to box culvert and open footing options with a similar span – additional flow through capacity may have to be provided by multiple pipes. ■ Cut-off wall or clay seal may be required at inlet to mitigate potential scour under the culvert(s). ■ Difficult to compact backfill materials to level of culvert springline. ■ CSP does not have as long a design life as compared to concrete options.	■ Moderate risk of disturbance of the native silt deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular 'B' Type II working pad. ■ Moderate risk related to anticipated total and differential settlement; but lower risk compared to box or open footing option.

MINISTRY OF TRANSPORTATION, ONTARIO

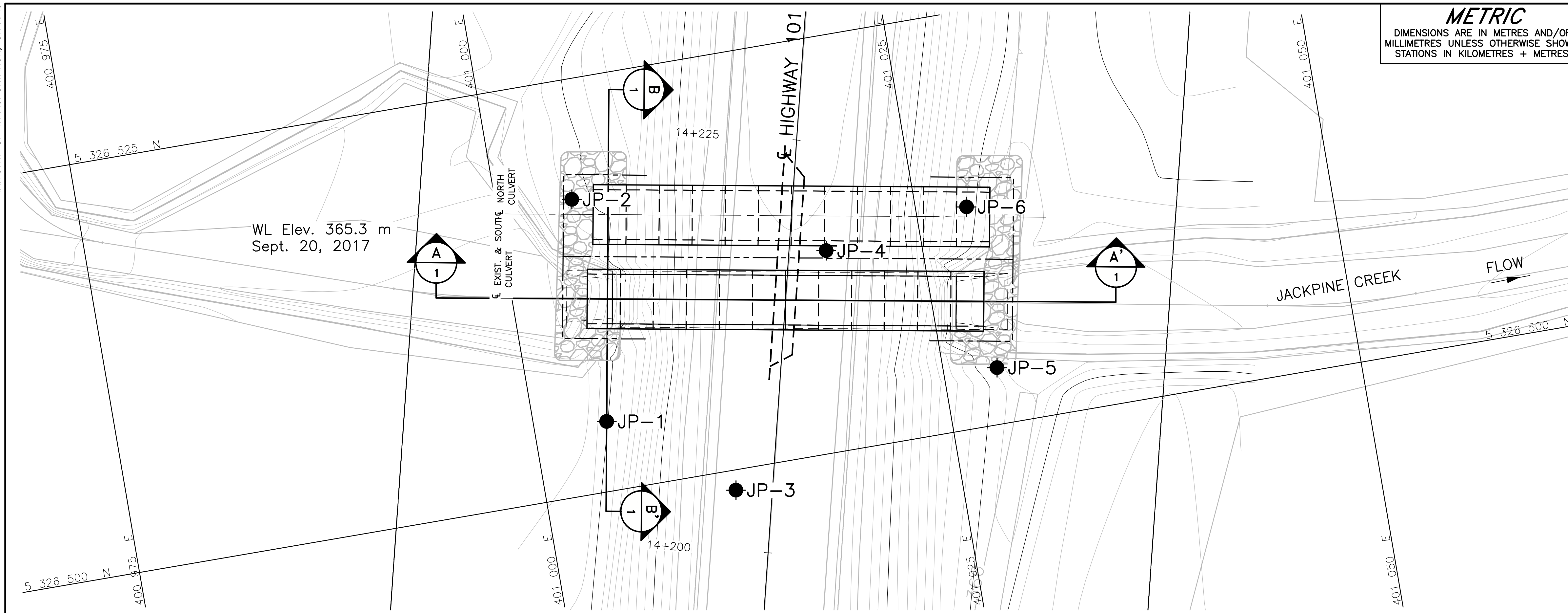
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5219-13-01

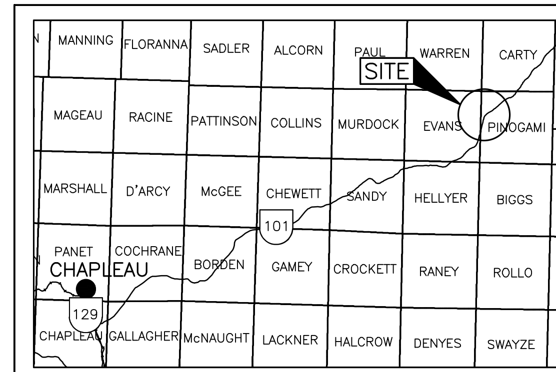
HIGHWAY 101
JACKPINE CREEK CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET .

Golder Associates



PLAN
SCALE
3 0 3 6 m



KEY PLAN
SCALE
10 0 10 20 km

LEGEND

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

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
JP-1	367.1	5326504.2	401004.4
JP-2	365.4	5326517.8	401004.6
JP-3	369.0	5326498.8	401011.4
JP-4	369.0	5326512.1	401019.2
JP-5	365.9	5326503.4	401028.2
JP-6	365.6	5326513.3	401028.1

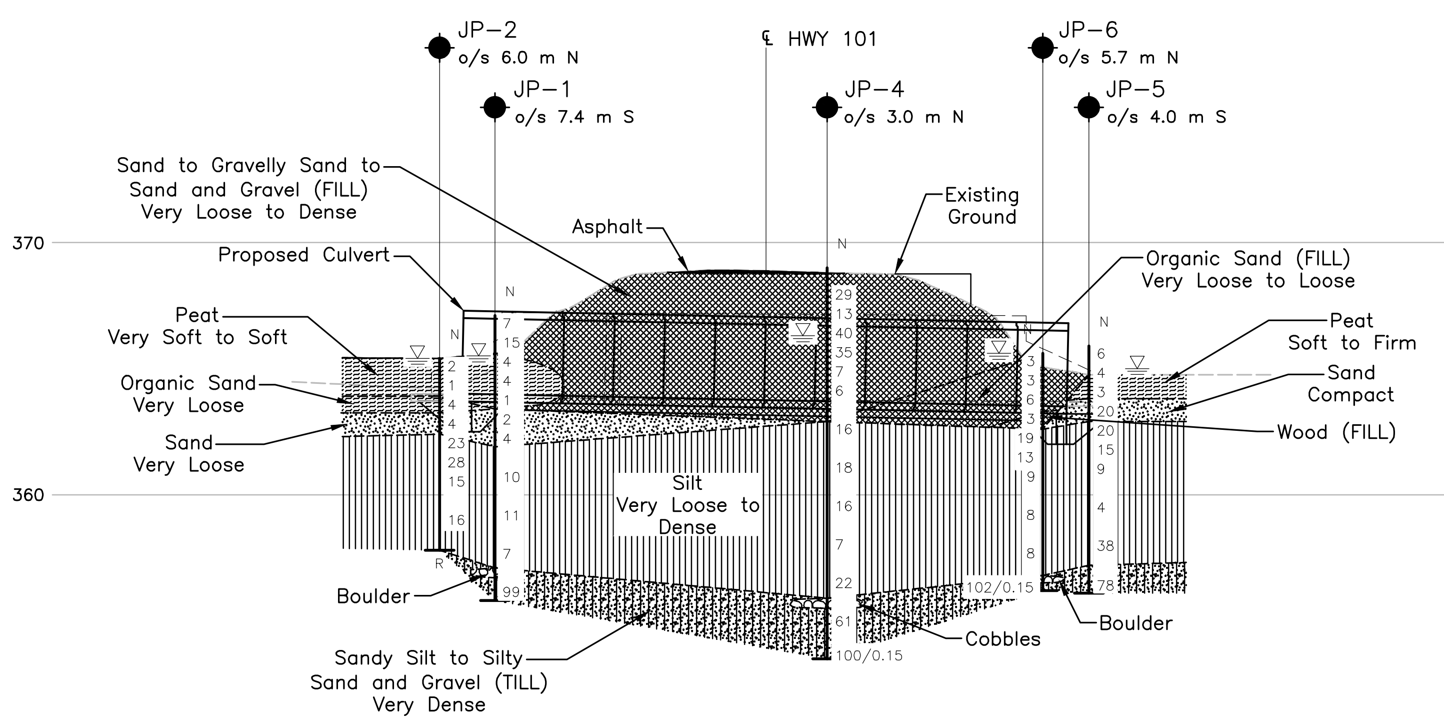
NOTES

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.

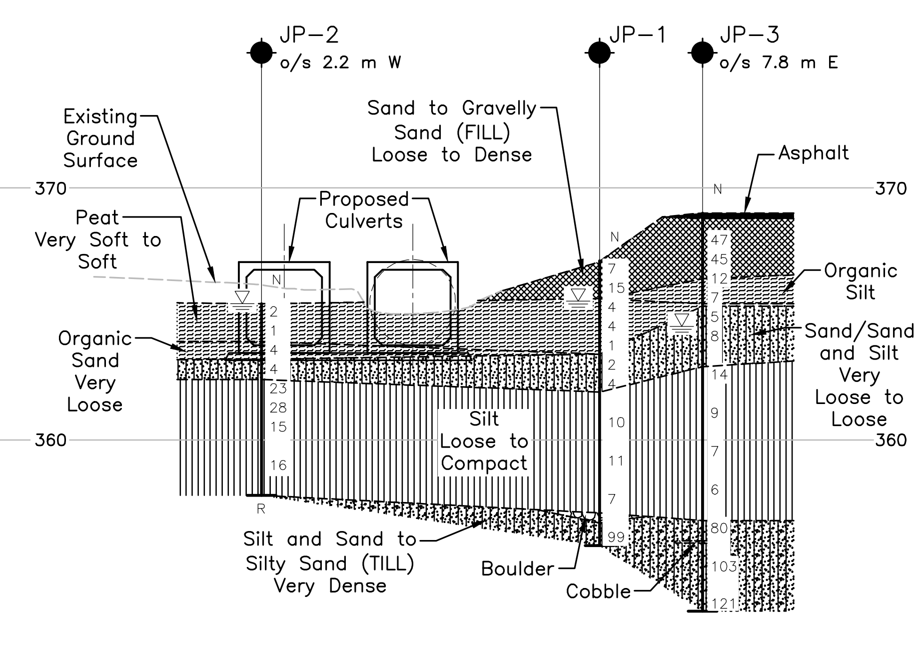
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by LEA, drawing file nos x17197 Jackpine Base.dwg and 17197-Jackpine Culvert-S01-General Arrangement.dwg, received FEB 27, 2018.



PROFILE (A-A' / 1)
HORIZONTAL SCALE
3 0 3 6 m
3 0 3 6 m
VERTICAL SCALE



CROSS-SECTION (B-B' / 1)
HORIZONTAL SCALE
3 0 3 6 m
3 0 3 6 m
VERTICAL SCALE

LICENSED PROFESSIONAL ENGINEER A.J.K. BOM 100075715 July 10, 2018 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA July 10, 2018 PROVINCE OF ONTARIO

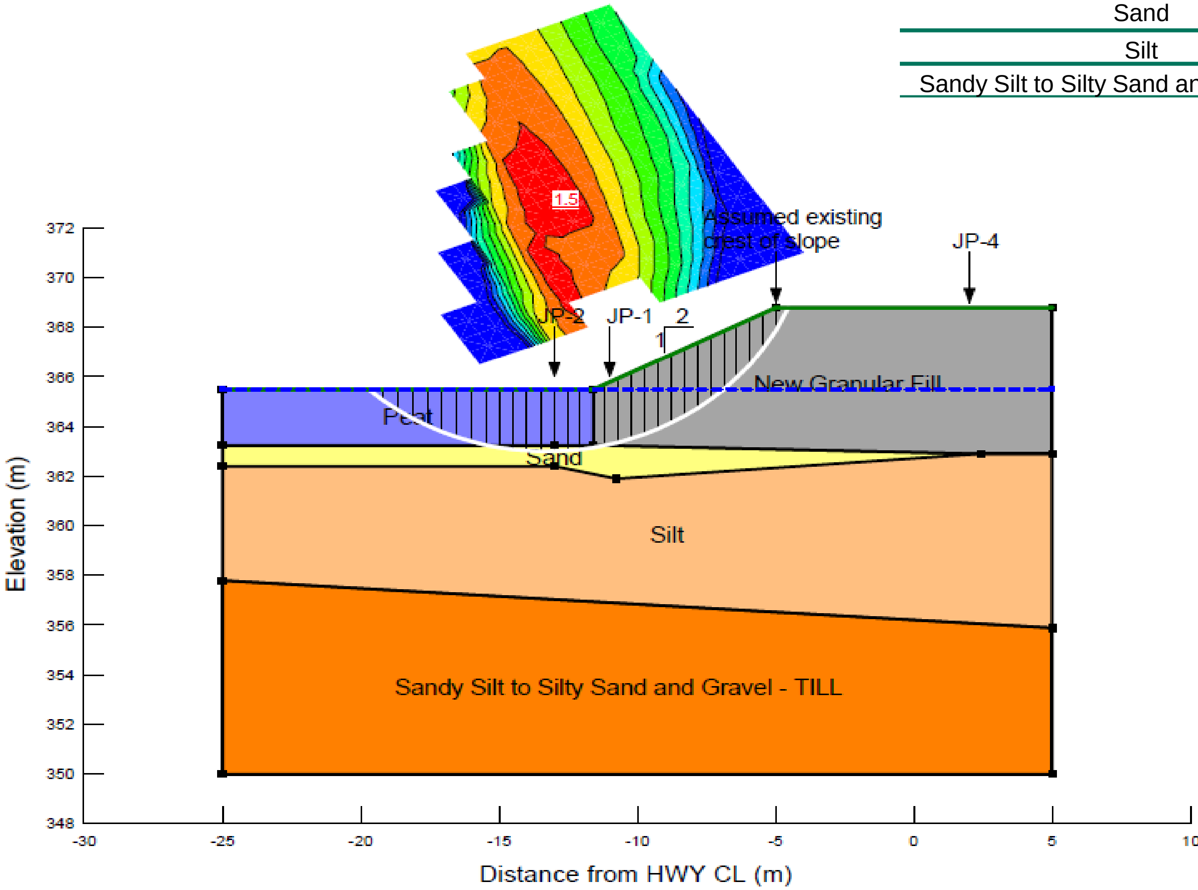
NO.	DATE	BY	REVISION
.	.	.	

Geocres No. 42B-012

HWY. 101	PROJECT NO. 1661607		DIST. .
SUBM'D. AD	CHKD. .	DATE: 7/10/2018	SITE: 46-577/C
DRAWN: TB	CHKD. AB	APPD. JMAC	DWG. 1

PLOT DATE: July 10, 2018
FILENAME: S:\Clients\MTO\1661607\1661607_LEA\40_PROD\Jackpine\1661607_JP_Dwg1.dwg

Material Name	Unit Weight (kN/m^3)	Friction Angle (degrees)
New Granular Embankment Fill	21	35
Peat	12	27
Sand	20	32
Silt	17	28
Sandy Silt to Silty Sand and Gravel (TILL)	20	32



Photograph 1: Jackpine Creek Culvert
East embankment facing south (September 2017)

Photograph 2: Jackpine Creek Culvert
Culvert outlet, looking east (September 2017)

Photograph 3: Jackpine Creek Culvert
North approach, looking south (September 2017)

Photograph 4: Jackpine Creek Culvert
Culvert inlet, looking north-west (September 2017)

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
$\sigma_1, \sigma_2, \sigma_3$	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

* 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 (DCPT); 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

Foundation Design

RECORD OF BOREHOLE No JP-1

 METRIC

PROJECT 1661607
W.P. 5219-13-01
DIST ____ HWY 101
DATUM GEODETIC

LOCATION N 5326504.2; E 401004.4 MTM ZONE 13 (LAT. 48.070175; LONG. -82.708943)
BOREHOLE TYPE NW Casing and Wash Boring
DATE September 27, 2017

ORIGINATED BY MR
COMPILED BY AD
CHECKED BY AB

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
367.1	GROUND SURFACE
0.0	Sand, trace gravel, trace organics (FILL) Loose to compact Brown Moist A 25 mm thick asphalt layer encountered in Sample 2.
365.6 / 1.5	PEAT (Amorphous), trace gravel, trace sand Very soft to soft Black Wet
363.4 / 3.7	SAND, trace to some silt Very loose Dark brown Wet
361.9 / 5.2	SILT, trace sand, trace to some clay Loose to compact Grey Wet
357.1 / 10.0	BOULDER
356.7 / 10.4	SILTY SAND, some gravel, trace clay (TILL) Very dense Grey Wet
355.8 / 11.3	

SAMPLES

NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
1	SS	7						
2	SS	15						
3	SS	4						
4	SS	4						
5	SS	1	134.7					
6	SS	2						
7	SS	4			0	91	9	0
8	SS	10						
9	SS	11		NP	0	0	94	6
10	SS	7						
11	SS	99						

Ground water level symbol (∇) at approx. elevation 365.6.

Elevation scale: 367, 366, 365, 364, 363, 362, 361, 360, 359, 358, 357, 356

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
REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Continued Next Page

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

GOLDER

PROJECT 1661607 | **RECORD OF BOREHOLE No JP-1** | | **METRIC**

W.P. 5219-13-01 | LOCATION N 5326504.2; E 401004.4 MTM ZONE 13 (LAT. 48.070175; LONG. -82.708943) | ORIGINATED BY MR

DIST | HWY 101 | BOREHOLE TYPE NW Casing and Wash Boring | COMPILED BY AD

DATUM GEODETIC | DATE September 27, 2017 | CHECKED BY AB

SOIL PROFILE			SAMPLES			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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE Note: 1. Water level at a depth of 1.6 m below ground surface (Elev. 365.5 m) upon completion of drilling.										

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

GOLDER

RECORD OF BOREHOLE No JP-2

 METRIC

PROJECT 1661607
W.P. 5219-13-01
LOCATION N 5326517.8; E 401004.6 MTM ZONE 13 (LAT. 48.070297; LONG. -82.708937)
ORIGINATED BY MR
DIST HWY 101
BOREHOLE TYPE Portable Tripod, NW Casing, Wash Boring
COMPILED BY AD
DATUM GEODETIC
DATE September 28, 2017
CHECKED BY AB

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
365.4	GROUND SURFACE							
0.0	PEAT (Amorphous) Very soft Black Wet	1	SS	2	365			
		2	SS	1				
363.9 1.5	ORGANIC SAND Very loose Brown to black Wet	3	SS	4	364			
363.2 2.2	SAND, trace to some organics Very loose Dark brown Wet	4	SS	4	363	○	OC = 2.6%	
362.4 3.0	SILT, trace to some clay, trace sand Compact Grey Wet	5	SS	23	362			
		6	SS	28	361	○		0 1 93 6
		7	SS	15	360			
		8	SS	16	359			
		9	SS	-	358			
357.8 7.6	END OF BOREHOLE SPLIT-SPOON AND CASING REFUSAL							

Note:

1. Water level at ground surface (Elev. 365.4 m) upon completion of drilling.

2. Split Spoon samples obtained by driving with a 1/2 weight hammer. SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer.

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

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

GOLDER

RECORD OF BOREHOLE No JP-3

 METRIC

PROJECT 1661607	LOCATION N 5326498.8; E 401011.4 MTM ZONE 13 (LAT. 48.070125; LONG. -82.70885)	ORIGINATED BY MR
W.P. 5219-13-01	BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring	COMPILED BY AD
DIST ___ HWY 101	DATE September 25, 2017	CHECKED BY AB
DATUM GEODETIC		

ELEV DEPTH (m)	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
369.0	GROUND SURFACE								
368.8 / 0.0	ASPHALT (225 mm)								
0.2	Gravelly sand, trace to some silt (FILL) Dense Brown to grey Moist	1	SS	47		368			
		2	SS	45		367	○		23 67 (10)
366.4 / 2.6	ORGANIC SILT, trace sand Loose to compact Black Wet	3	SS	12					
		4	SS	7		366			
365.4 / 3.7	PEAT (Fibrous) Black Wet								
	SILT and SAND, trace gravel, trace clay, trace organics Loose Dark brown Wet	5	SS	5		365	○		OC = 3.4% 5 61 32 2
					▽				
		6	SS	8		364			
362.9 / 6.1	SILT, trace to some clay, trace sand Loose to compact Grey Wet	7	SS	14		363			
						362			
		8	SS	9		361	○		0 0 91 9
						360			
		9	SS	7		359			
		10	SS	6		358			

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

Continued Next Page

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

GOLDER

Foundation Design

RECORD OF BOREHOLE No JP-3

 METRIC

PROJECT 1661607

W.P. 5219-13-01

LOCATION N 5326498.8; E 401011.4 MTM ZONE 13 (LAT. 48.070125; LONG. -82.70885)

ORIGINATED BY MR

DIST ___ HWY 101

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring

COMPILED BY AD

DATUM GEODETIC

DATE September 25, 2017

CHECKED BY AB

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES 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)	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 ---										
356.8 / 12.2	SILTY SAND, trace gravel, trace clay (TILL) Very dense Grey Wet		11	SS	80						
356.0	COBBLE						356				
13.1	SILT and SAND, trace gravel, trace to some clay (TILL) Very dense Grey Wet		12	SS	103		355		○		5 36 50 9
							354				
			13	SS	121						
353.2 / 15.8	END OF BOREHOLE Note: 1. Water level at a depth of 4.5 m below ground surface (Elev. 364.5 m) upon completion of drilling.										

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

PROJECT 1661607

RECORD OF BOREHOLE No JP-4

 METRIC

W.P. 5219-13-01 LOCATION N 5326512.1; E 401019.2 MTM ZONE 13 (LAT. 48.070243; LONG. -82.708742) ORIGINATED BY MR

DIST HWY 101 BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring COMPILED BY AD

DATUM GEODETIC DATE September 25, 2017 CHECKED BY AB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	GR	SA	SI	CL
369.0	GROUND SURFACE									
0.0 368.7	ASPHALT (250 mm)									
0.3	Gravelly sand to sand and gravel, trace to some silt (FILL) Loose to dense Grey to brown Moist to wet	1	SS	29						
		2	SS	13						
		3	SS	40	∇	○	26	62	(12)	
		4	SS	35						
		5	SS	7						
		6	SS	6		○	48	47	(5)	
362.9 6.1	SILT, trace to some clay, trace sand Loose to compact Grey Wet	7	SS	16						
		8	SS	18		○	0	0	95	5
		9	SS	16						
		10	SS	7						

Elevation scale: 368, 367, 366, 365, 364, 363, 362, 361, 360, 359, 358

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 (%)

Continued Next Page

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

RECORD OF BOREHOLE No JP-4

 METRIC

PROJECT 1661607
W.P. 5219-13-01
LOCATION N 5326512.1; E 401019.2 MTM ZONE 13 (LAT. 48.070243; LONG. -82.708742)
ORIGINATED BY MR
DIST HWY 101
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring
COMPILED BY AD
DATUM GEODETIC
DATE September 25, 2017
CHECKED BY AB

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILT, trace to some clay, trace sand Loose to compact Grey Wet	11	SS	22		Wp–w plotted	0 1 80 19
355.9 13.1	COBBLES				356		
355.5 13.5	Sandy SILT, some gravel, trace to some clay (TILL) Very dense Grey Wet	12	SS	61	355	w plotted	13 29 52 6
					354		
353.5		13	SS	100/0.15			
15.5	END OF BOREHOLE Note: 1. Water level at a depth of 2.7 m below ground surface (Elev. 366.3 m) upon completion of drilling.						

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

GOLDER

RECORD OF BOREHOLE No JP-5

 METRIC

PROJECT 1661607

W.P. 5219-13-01

LOCATION N 5326503.4; E 401028.2 MTM ZONE 13 (LAT. 48.070164; LONG. -82.708624)

ORIGINATED BY MR

DIST HWY 101

BOREHOLE TYPE NW Casing and Wash Boring

COMPILED BY AD

DATUM GEODETIC

DATE September 27, 2017

CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
365.9	GROUND SURFACE										
0.0	PEAT (Amorphous), trace sand Soft to firm Black Wet	1	SS	6							
		2	SS	4	∇ (Elev. 365.0)						
		3	SS	3							
363.8 2.1	SAND, some gravel, trace to some silt, trace clay Compact Grey Wet	4	SS	20		○		12	80	6	2
362.9 3.0	SILT, trace to some clay, trace sand Very loose to dense Grey Wet	5	SS	20							
		6	SS	15		○		0	1	94	5
		7	SS	9							
		8	SS	4							
		9	SS	38		○		0	1	86	13
357.2 8.7	SILTY SAND, trace gravel, trace clay (TILL) Very dense Grey Wet	10	SS	78							
356.1 9.8	END OF BOREHOLE Note: 1. Water level at a depth of 0.9 m below ground surface (Elev. 365.0 m) upon completion of drilling.										

ELEVATION SCALE: 365, 364, 363, 362, 361, 360, 359, 358, 357

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

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

RECORD OF BOREHOLE No JP-6

 METRIC

PROJECT 1661607
W.P. 5219-13-01
LOCATION N 5326513.3; E 401028.1 MTM ZONE 13 (LAT. 48.070253; LONG. -82.708623)
ORIGINATED BY MR
DIST HWY 101
BOREHOLE TYPE NW Casing and Wash Boring
COMPILED BY AD
DATUM GEODETIC
DATE September 28, 2017
CHECKED BY AB

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
365.6	GROUND SURFACE					
0.0	Organic sand (FILL) Very loose to loose Grey to brown Wet	1	SS	3		
		2	SS	3		
		3	SS	6		
363.3 / 2.3	Wood (FILL) Brown Wet	4	SS	3		
362.6 / 3.0	SILT, trace to some clay, trace sand Loose to compact Grey Wet	5	SS	19	○	0 1 93 6
		6	SS	13		
		7	SS	9		
		8	SS	8	○	0 1 94 5
		9	SS	8		
356.8	BOULDER					
356.5	SILTY SAND and GRAVEL, trace clay (TILL) Very dense Grey Wet	10	SS	102/0.15		
356.2 / 9.4	END OF BOREHOLE					

Elevation scale: 365, 364, 363, 362, 361, 360, 359, 358, 357

Note:

1. Water level at ground surface (Elev. 365.6 m) upon completion of drilling.

Column headings: 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

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

APPENDIX B

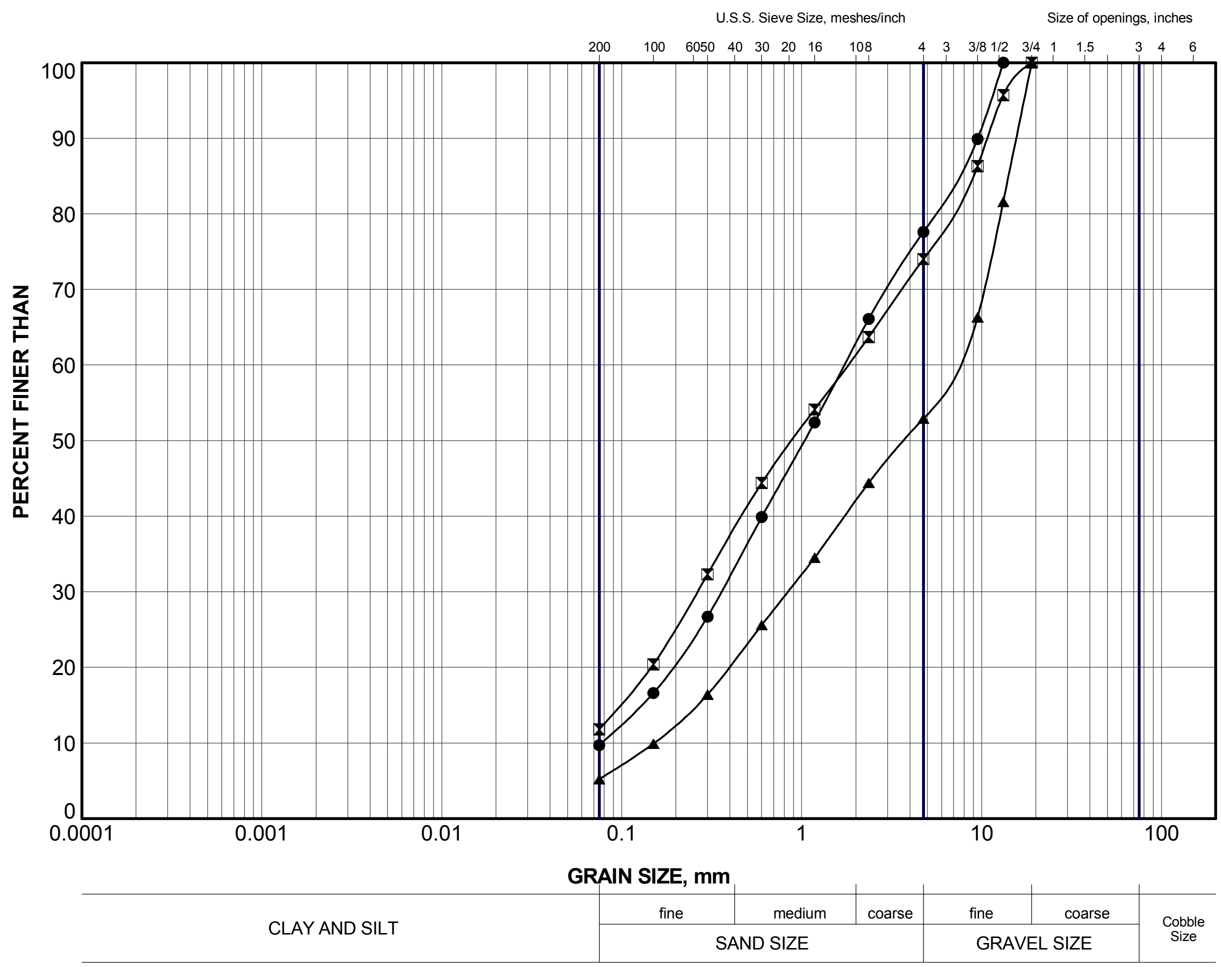
Laboratory Testing

Table B1 - Summary of Analytical Testing of Soil Sample

Parameter	Units	(Borehole JP-4)
Resistivity	ohm-cm	5,900
Conductivity	µmho/cm	171
pH	pH	7.79
Sulphate	µg/g	Not detected
Chloride	µg/g	35

Notes:
1. Sample obtained September 25, 2017
2. Analytical testing carried out by Maxxam Analytics Inc.

Prepared by: AD
Reviewed by: AB



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	JP-3	2	367.2
⧗	JP-4	3	366.4
▲	JP-4	6	364.1

PROJECT

HIGHWAY 101
JACKPINE CREEK CULVERT

TITLE

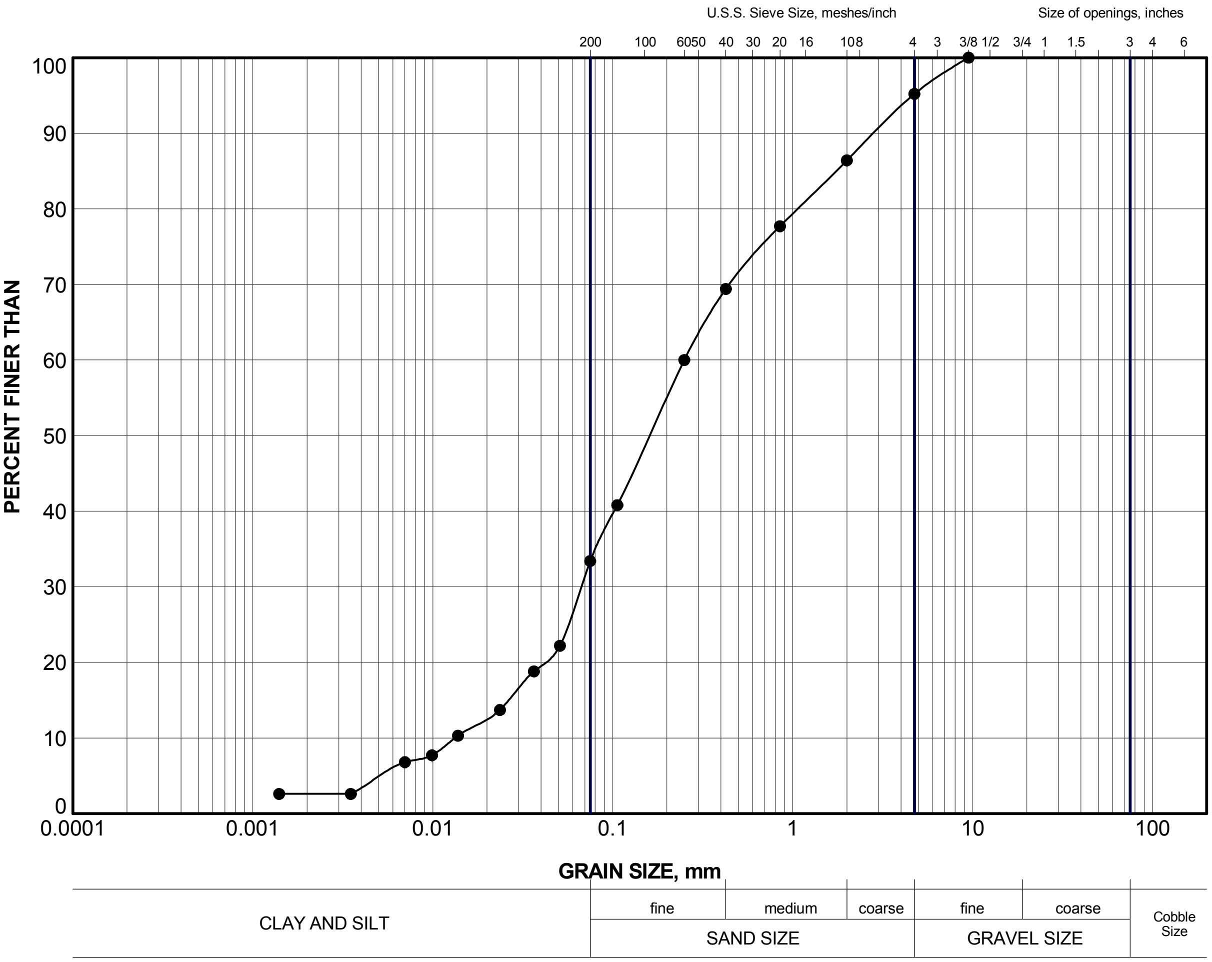
GRAIN SIZE DISTRIBUTION

GRAVELLY SAND to SAND and GRAVEL (FILL)

PROJECT No.		1661607	FILE No.	1661607.GPJ	
DRAWN	TB	Feb 2018	SCALE	N/A	REV.
CHECK	AB	Feb 2018			
APPR	JMAC	Feb 2018	**FIGURE B1**		

Golder Associates
SUDBURY, ONTARIO

SUD-MTO GSD (2016) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	JP-3	5	364.9

PROJECT

HIGHWAY 101
JACKPINE CREEK CULVERT

TITLE

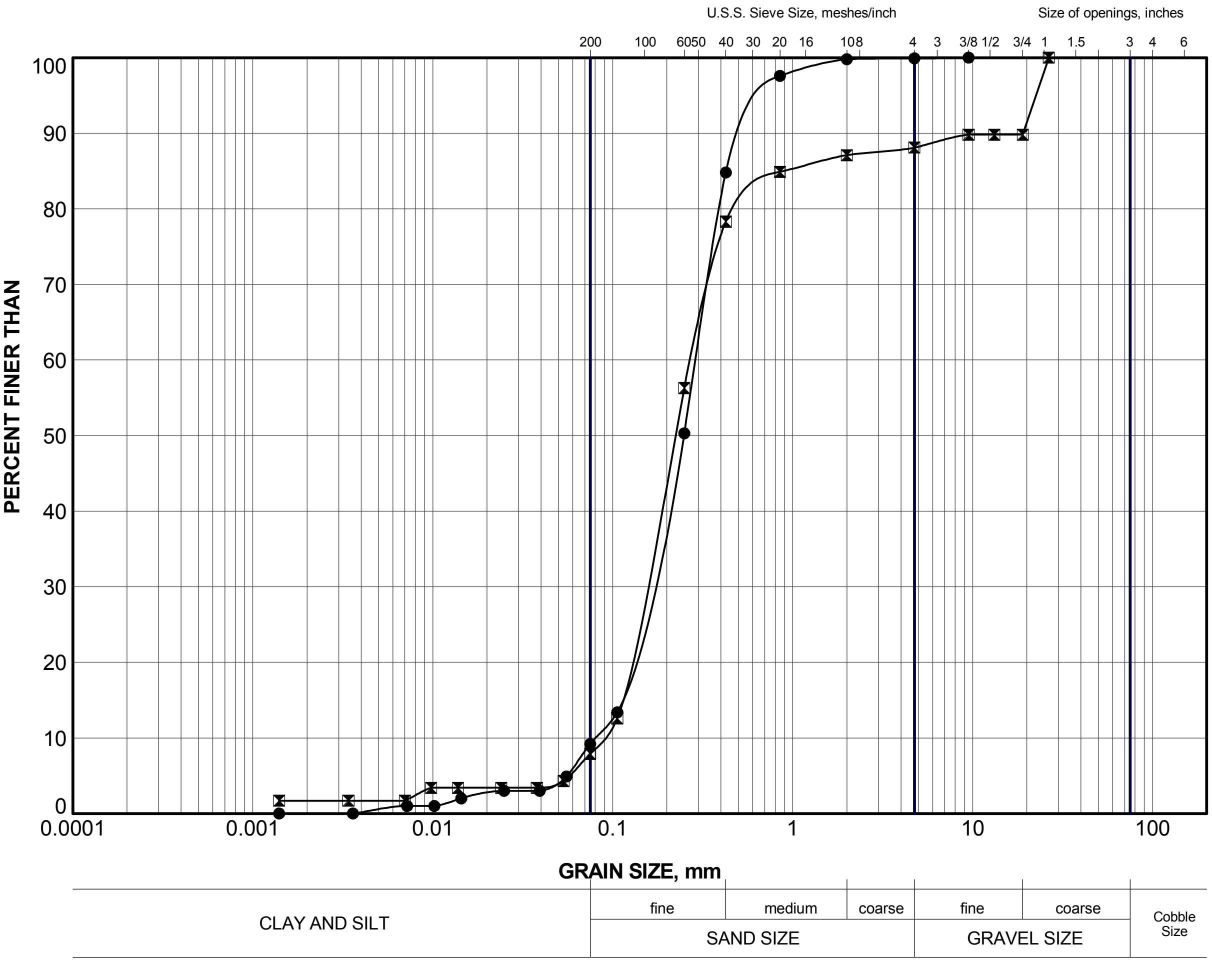
GRAIN SIZE DISTRIBUTION

SILT and SAND

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1661607	FILE No.	1661607.GPJ
DRAWN	TB	Feb 2018	SCALE N/A	REV.
CHECK	AB	Feb 2018		
APPR	JMAC	Feb 2018	**FIGURE B2**	

SUD-MTO GSD (2016) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	JP-1	7	362.2
⧗	JP-5	4	363.3

PROJECT

HIGHWAY 101
JACKPINE CREEK CULVERT

TITLE

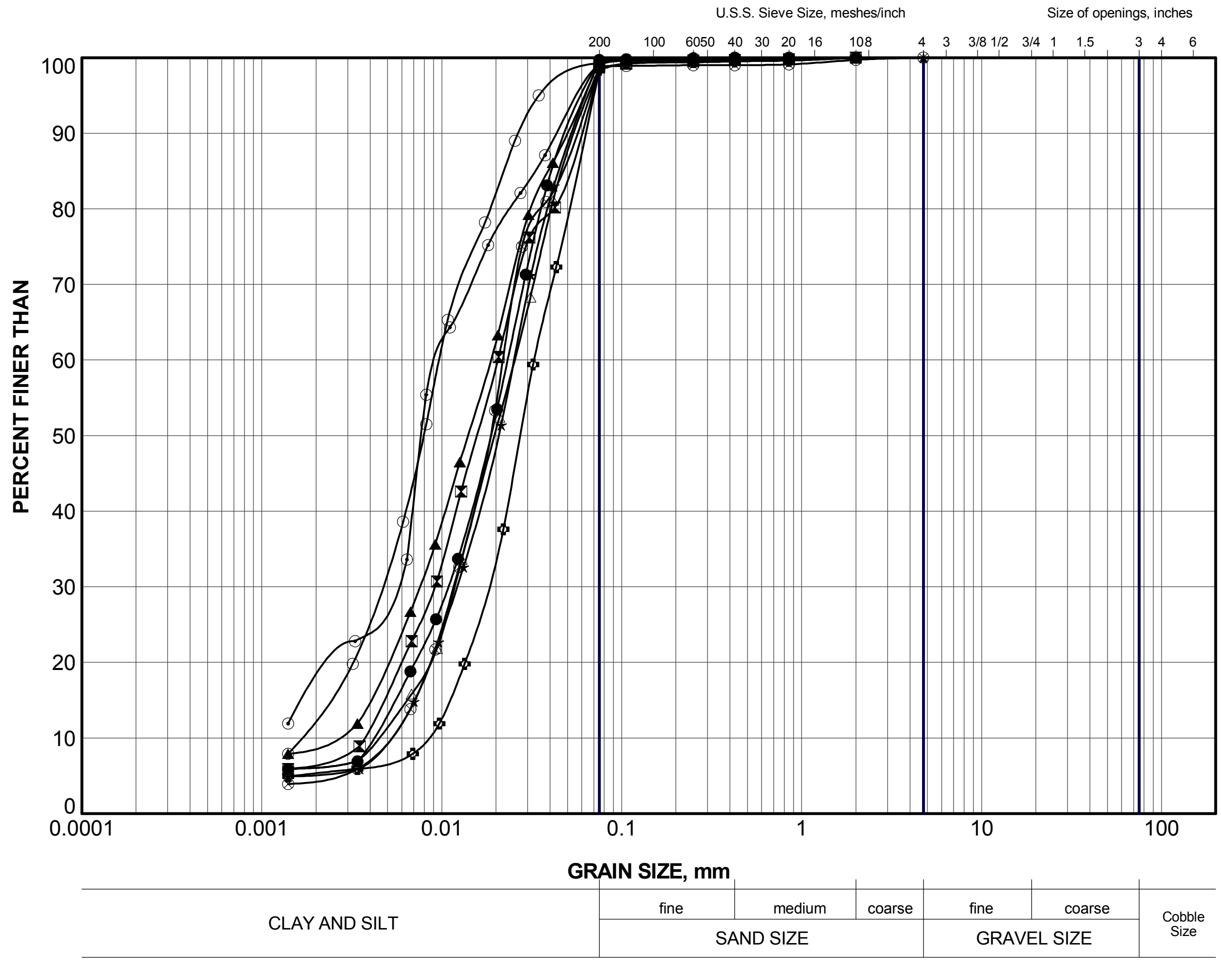
GRAIN SIZE DISTRIBUTION

SAND

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1661607	FILE No.	1661607.GPJ
DRAWN	TB	Feb 2018	SCALE N/A	REV.
CHECK	AB	Feb 2018		
APPR	JMAC	Feb 2018	FIGURE B3	

SUD-MTO GSD (2016) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	JP-1	9	359.2
⧗	JP-2	6	361.3
▲	JP-3	8	361.1
★	JP-4	8	361.1
⊙	JP-4	11	356.5
✤	JP-5	6	361.8
○	JP-5	9	358.1
△	JP-6	5	362.3
⊗	JP-6	8	359.2

PROJECT

HIGHWAY 101
JACKPINE CREEK CULVERT

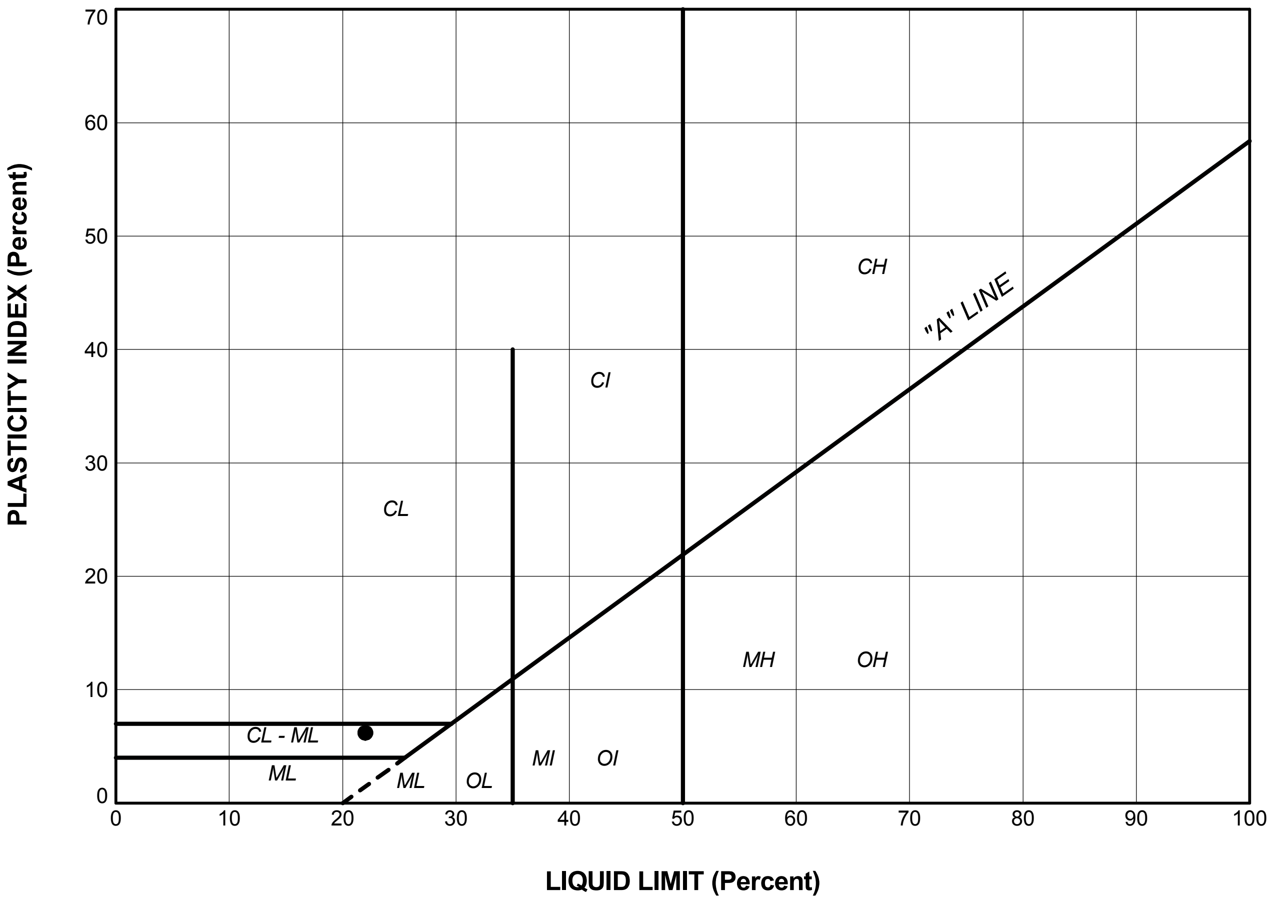
TITLE

GRAIN SIZE DISTRIBUTION
SILT

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1661607	FILE No.	1661607.GPJ
DRAWN	TB	Feb 2018	SCALE N/A	REV.
CHECK	AB	Feb 2018		
APPR	JMAC	Feb 2018	FIGURE B4	

SUD-MTO GSD (2016) 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
●	JP-4	11	22.0	15.8	6.2

PROJECT

HIGHWAY 101
JACKPINE CREEK CULVERT

TITLE

PLASTICITY CHART

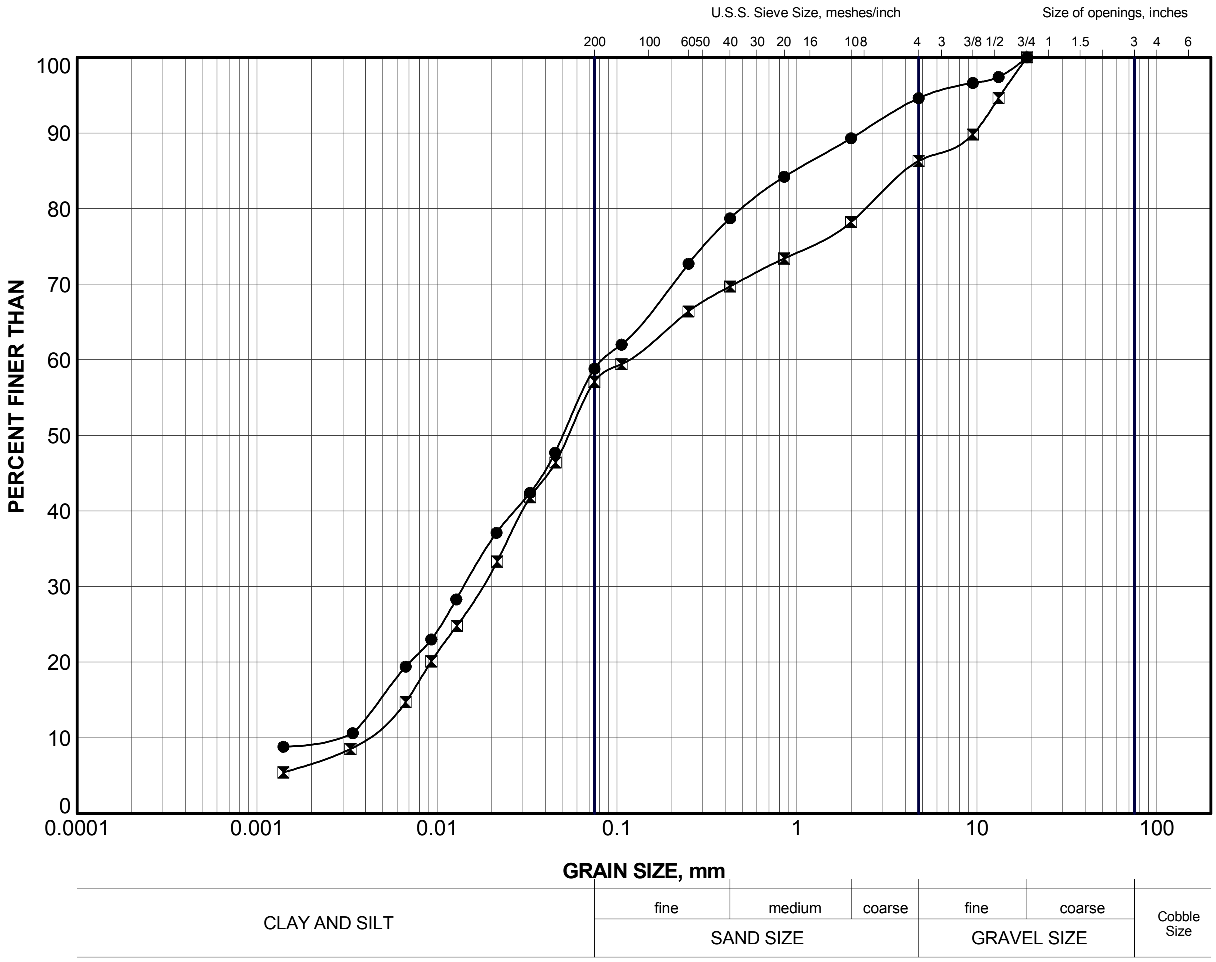
SILT

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1661607	FILE No.	1661607.GPJ
DRAWN	TB	Feb 2018	SCALE N/A	REV.
CHECK	AB	Feb 2018		
APPR	JMAC	Feb 2018		

FIGURE B5

SUD-MTO PL (2016) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	JP-3	12	355.0
⧗	JP-4	12	355.0

PROJECT

HIGHWAY 101
JACKPINE CREEK CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

SANDY SILT to SILT and SAND (TILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1661607	FILE No.	1661607.GPJ
DRAWN	TB	Feb 2018	SCALE N/A	REV.
CHECK	AB	Feb 2018		
APPR	JMAC	Feb 2018	**FIGURE B6**	

SUD-MTO GSD (2016) GLDR_LDN.GDT

APPENDIX C

Notice to Contractor

UNWATERING OF STRUCTURE EXCAVATION - Item No.

Notice to Contractor

Construction of the culvert will require excavations to extend below the groundwater level and the adjacent creek water level. The embankment fill, organic soil and native silt/sand deposits within the excavation may slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate excavation protection and unwatering/dewatering system to enable construction and prevent disturbance to the founding soils.

OBSTRUCTIONS

Notice to Contractor

The Contactor is hereby notified that wood was encountered within the embankment fill at about Elevation 363.3 m (2.3 m depth below ground surface) in Borehole JP-6. Consideration of the presence of this obstruction must be made in selection of appropriate equipment and procedures for sub-excavation and installation of the foundation and temporary shoring and roadway protection systems.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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