FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 66, Station 12+290, Township of Lebel Culvert Replacement Ministry of Transportation, Ontario GWP 5210-14-00

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services related to the replacement of the culvert on Highway 66 at Station 12+290, in the Township of Lebel, Ontario. The culvert site is located along the north shore of Gull Lake, approximately 2 km east of the intersection with Toburn Road. The Key Plan of the general location of this section of Highway 66 and the location of the investigated area are shown on Drawing 1.

The purpose of this foundation investigation is to establish the subsurface conditions at the culvert replacement site by borehole drilling with laboratory testing carried out on selected soil samples.

The Terms of Reference (TOR) and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated February 2018, and the subsequent clarifications/addenda, which forms part of the Consultant's Assignment Number 5017-E-0039 for this project. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project dated November 2018.

2.0 SITE DESCRIPTION

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on the Drawing 1. For the purpose of this report, Highway 66 is oriented in a west-east direction with the culvert positioned perpendicular to the highway generally in a north-south orientation. At the culvert location, the ditch/creek water flows in a north to south direction, into Gull Lake.

The existing culvert consists of an 800 mm diameter, 21 m long Corrugated Steel Pipe (CSP). The culvert inlet (north end) and outlet (south end) inverts are at approximately Elevations 320.0 m and 320.1 m, respectively. In general, the topography to the north, east, and west of the culvert site consist of relatively flat terrain and forested hills; and Gull Lake extends along the south side of the highway. The highway grade at the culvert centreline is approximately Elevation 322 m.

The embankment is approximately 2 m high relative to the culvert invert and the thickness of the soil cover over the culvert is about 1.2 m. The embankment/side slopes at the culvert inclined at about 1 Horizontal to 1 Vertical (1H:1V), are grass covered on the north side and grass/gravel with cobbles and boulders covered on the south side and appear to be performing well, with no visible signs of slope instability or roadway settlement issues. At the time of the subsurface exploration field program the culvert north end was exposed and is in poor condition (bent/corroded and rusted); whereas the south end (outlet) was submerged by Gull Lake, but reportedly is also bent/corroded and rusted through. The ground surface conditions at select locations near the culvert are shown on Photographs 1 to 4.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out on December 13, 2018, and May 6 and 7, 2019, during which time three boreholes (Boreholes C207-1 to C207-3) were advanced at the approximate locations shown on Drawing 1. Boreholes C207-1 and C207-2 were advanced through the roadway embankment and Borehole C207-3 was advanced near the culvert inlet. All boreholes (C207-1 to C207-3) were drilled using a CME 550 Rubber Tire All Terrain drilling rig supplied and operated by Landcore Drilling (Landcrore) of Chelmsford, Ontario.

Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Boreholes C207-1 and C207-2 were advanced using NW casing with wash boring techniques, and NQ coring. Borehole C207-3 was advanced using 108 mm I.D. hollow stem augers. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by a full weight automatic or cathead hammer, in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). In-situ vane shear test were carried out in cohesive soils for determination of undrained shear strengths in accordance with Standard Test Method for Field Vane Shear Test procedures (ASTM 2573), using an MTO standard "N"-size vane. The groundwater level inside the augers/casing was observed and recorded after the completion of drilling. The cored section of the boreholes was backfilled with bentonite to the bedrock surface and the boreholes were backfilled in accordance with Ontario Regulation 903 (wells), as amended. The roadway surface at the boreholes drilled through Highway 66 were capped at ground surface using cold patch asphalt.

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 the soil and bedrock samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions, and Atterberg Limits was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable. One soil sample was submitted to Bureau Vertas Laboratories (formerly Maxxam) of Sudbury, an accredited analytical laboratory, for testing of a suite of corrosivity indicator parameters.

The as-drilled borehole locations were measured relative to highway chainages/station marked on the pavement or offsets from the culvert by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevation at the borehole locations was surveyed by Golder: Borehole C207-1 was surveyed relative to Horizontal Control Point 109 (HCP109); and Boreholes C207-2 and C207-3 were surveyed relative to the highway and culvert centreline provided by AECOM. The MTM NAD 83-CSRS CBN v6-2010.0 (Zone 12) northing and easting coordinates, geographical coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below.

Borehole Number	MTM NAD 83 Northing (m) (Latitude)	MTM NAD 83 Easting (m) (Longitude)	Ground Surface Elevation (m)	Borehole Depth (m)
C207-1	5336569.8 (48.163566)	379639.5 (-79.993844)	322.2	17.1*
C207-2	5336561.5 (48.163492)	379633.7 (-79.993923)	321.9	16.5*
C207-3	5336578.0 (48.163641)	379640.0 (-79.993835)	320.8	9.3

*Including coring for lengths of 3.3 m and 3.1 m in the respective boreholes.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)[1] mapping, the subsoil in the vicinity of the culvert site is comprised of ground moraine (sands) / till.

Based on geological mapping (MNDM)[2], the site is underlain by metasedimentary rocks.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the summary results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The plotted results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT 'N'-values), as presented on the Record of Borehole sheets and discussed in Section 4.2, are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The results of the analytical laboratory testing (by Bureau Veritas Laboratories) are summarized in Section 4.4 and the detailed laboratory testing report is included in Appendix B.

The subsurface conditions will vary between and beyond the borehole locations; however, the factual data presented on the Record of Borehole Sheets governs any interpretation of the site conditions. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

4.2.1 Asphalt/Fill

An approximately 110 mm and 100 mm thick layer of asphalt pavement was encountered in the roadway in Boreholes C207-1 and C207-2, at Elevations 322.2 m and 321.9 m, respectively. A 2.1 m and 2.9 m thick layer of embankment fill, consisting of an upper 0.5 m to 0.6 m thick layer of sand and gravel, and underlain by a 1.1 m to 2.4 m thick layer of sand and sandy silt was encountered below the asphalt in Boreholes C207-1 and C207-2. A 0.6 m thick zone of cobbles and boulders was encountered interlayered within the sand/sandy silt fill in Borehole C207-2 at a depth of 1.7 m below ground surface. Trace organics, rootlets, wood was encountered in the sandy silt fill near the bottom of Borehole C207-2. In Borehole C207-3, a 0.7 m thick layer of gravelly sandy silt fill was encountered from ground surface at Elevation 320.8.

The SPT "N"-values measured within the sand/gravelly sandy silt/sandy silt fill layers range between 1 blow and 76 blows per 0.3 m of penetration, indicating a very loose to very dense compactness condition; with one "N"-value of 50 blows for 0.05 m of penetration measured at the top of the cobbles and boulders zone.

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[1] Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNE

[2] Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543

4.2.2 Sand (Upper Deposit)

A 1.5 m and 0.8 m thick deposit of sand some silt was encountered in Boreholes C207-1 and C207-3, respectively, at Elevations 320.0 m and 320.1 m.

The SPT “N”-values measured within the sand deposit range between 5 blows and 23 blows per 0.3 m of penetration, indicating that the deposit has a loose to compact compactness condition.

Grain size distribution was carried out on two samples of the sand deposit and the results are presented on Figure B-1 of Appendix B. The natural moisture content measured on the samples of the deposit are 15 per cent to 26 per cent.

4.2.3 Silt (Upper Deposit)

A 0.8 m and 0.7 m thick deposit of silt, trace to some sand and trace to some clay at one borehole was encountered in Boreholes C207-1 and C207-3, respectively, underlying the sand deposit at Elevations 318.5 m and 319.4 m.

The SPT “N”-values measured within the silt deposit are 1 blow and 13 blows per 0.3 m of penetration, indicating that the deposit has a very loose to compact compactness condition.

Grain size distribution was carried out on one sample of the silt deposit and the result is presented on Figure B-2 of Appendix B. Atterberg limits testing carried out on a sample of the silt and indicates that the material is non-plastic. The natural moisture content measured on the sample of the deposit is 24 per cent.

4.2.4 Clayey Silt

A clayey silt deposit was encountered in the three boreholes underlaying the silt deposit in Boreholes C207-1 and C207-3 and underlaying the fill in Borehole C207-2. The deposit ranges in thickness from 4.2 m to 4.5 m and was encountered at between Elevations 318.9 to 317.7 m. The upper 1.5 m thick zone of the deposit in Borehole C207-2 is classified as clayey silt with sand, and the overall deposit contains silt laminations throughout.

The SPT “N”-values measured within the clayey silt deposit range from 0 blows (weight of hammer) to 10 blows per 0.3 m of penetration. In-situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 24 kPa to 48 kPa and sensitivity ranging from about 2 to 3. The SPT “N”-values, together with the field vane test results, suggest that the clayey silt deposit is soft to stiff in consistency.

Atterberg limits testing was carried out on five samples of the clayey silt deposit and measured liquid limits ranging between about 20 per cent and 32 per cent, plastic limits ranging between about 13 per cent and 20 per cent and plasticity indices ranging from about 6 per cent to 13 per cent. The Atterberg limits results are presented in Figure B-3 in Appendix B and indicate that the deposit is generally comprised of clayey silt of low plasticity. Grain size distribution analysis was carried out on four samples of the clayey silt deposit and the results are presented on Figure B-4 in Appendix B. The natural moisture content measured on the samples of the clayey silt deposit range from about 24 per cent to 39 per cent.

4.2.5 Silt (Lower Deposit)

A 1.2 m and 1.1 m thick deposit of silt was encountered in Boreholes C207-2 and C207-3, respectively, underlying the clayey silt deposit at Elevation 314.4 m.

The SPT “N”-values measured within the silt deposit are 10 blows and 31 blows per 0.3 m of penetration, indicating that the deposit has a compact to dense compactness condition.

Grain size distribution was carried out on one sample of the silt deposit and the result is presented on Figure B-5 of Appendix B. The natural moisture content measured on the sample of the deposit is 19 per cent.

4.2.6 Silty Sand to Sand (Lower Deposit)

A 1.8 m to 5.2 m thick deposit of silty sand to sand was encountered in Boreholes C207-1 to C207-3, at between Elevations 313.5 m to 313.2. In Borehole C207-1, cobbles were encountered within the deposit from 12.7 m to 13.0 m depths, and in Borehole C207-3, auger grinding was noted from 8.5 m to 9.1 m depth, which could infer the presence of cobbles.

The SPT “N”-values measured within the silty sand to sand deposit range from 3 blows to 60 blows per 0.3 m of penetration with an “N”-value of 100 blows for 0.13 m of penetration on inferred cobbles and an “N’-value of 21 blows for 0.15 m of penetration on bedrock (refer to Section 4.2.7), indicating that the deposit has a very loose to very dense compactness condition.

Grain size distribution was carried out on one sample of the sand zone of the deposit and the result is presented on Figure B-6 of Appendix B. The natural moisture content measured of one sample of the silty sand to sand zone of the deposit is 14 per cent.

4.2.7 Bedrock

Bedrock was encountered and cored in Boreholes C207-1 and C207-2 at depths of 13.9 m and 13.4 m below ground surface, at Elevations 308.3 m and 308.5 m, respectively. The retrieved 3.3 m and 3.1 m lengths of bedrock core are described as fine grained, fresh to slightly weathered, grey, metasedimentary, as described on the Record of Drillholes presented in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B-7 in Appendix B. The Total Core Recovery (TCR) of the bedrock samples is 100 per cent and the Solid Core Recovery (SCR) ranges from about 60 per cent to 95 per cent. The Rock Quality Designation (RQD) of the bedrock core samples ranges between 89 per cent and 100 per cent and based on the Classification in Table 3.10 of CFEM (2006)[3], the bedrock is considered of good to excellent quality.

4.3 Groundwater Conditions

The unstabilized groundwater levels, relative to the ground surface measured inside the casing or augers upon completion of drilling are summarized below. The water level of Gull Lake surveyed by Callon Dietz in June 2019

[3] Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual (CFEM), 4th Edition.

was approximately Elevation 320.4 m. Groundwater and lake water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
C207-1	1.6	320.6
C207-2	1.0	320.9
C207-3	Ground Surface	320.8

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of sand fill recovered from Borehole C207-1. The soil sample was submitted to Bureau Veritas Laboratories for corrosivity testing. The analytical laboratory test results are summarized below, and the detailed analytical laboratory test report is included in Appendix B.

Borehole No.	Sample No.	Depth (m)	Parameters					
			Resistivity (ohm-cm)	Electrical Conductivity (µmho/cm)	Soluble Sulphate (SO4) Content (µg/g)	Chloride (Cl) Content (µg/g)	Sulphide (µg/g)	pH
C207-1	1	0.8 – 1.4	5,000	201	<20[1]	39	<0.50[1]	7.19

Note:
1. The sulphate and sulphide concentrations are below the reportable detection limit of 20 µg/g and 0.50 µg/g, respectively.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle, under the overall direction of Mr. André Bom, P.Eng., an Associate of Golder. This Foundation Investigation Report was prepared by Mr. Trevor Romanyszyn, and Mr. André Bom, P.Eng., an Associate of Golder, provided a technical review of the report. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant for Golder, conducted an independent quality control review of this report.

Signature Page

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PART B

FOUNDATION DESIGN REPORT

HIGHWAY 66, STA 12+290, TOWNSHIP OF LEBEL

CULVERT REPLACEMENT

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5210-14-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of the culvert on Highway 66 at Station 12+290, in the Township of Lebel, Ontario, on the north shore of Gull Lake approximately 2 km east of the intersection with Toburn Road. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface exploration. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess feasible foundation alternatives and culvert types and to design the proposed replacement culvert. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 Proposed Culvert Alignment and Installation Depth

The existing structure consists of a 0.8 m diameter, 21 m long Corrugated Steel Pipe (CSP). The culvert inlet (north end) and outlet (south end) inverts are approximately Elevations 320.0 m and 320.1 m, respectively. The highway grade at the culvert location is approximately Elevation 322.0 m. The existing north slope of the embankment at the culvert location is inclined at about 2.9 Horizontal to 1 Vertical (2.9H:1V), the south slope inclined at about 2H:1V and the embankment is about 2.0 m high relative to the culvert invert. The thickness of soil cover over the culvert is about 1.2 m.

Based on the drawings provided by AECOM via email on July 2, 2019, and our site observations during the foundation exploration work, the existing culvert crosses the Highway 66 embankment on a perpendicular alignment, and we understand from AECOM that the proposed replacement culvert will cross the highway on or near the same alignment and the proposed culvert will consist of a 1.0 m diameter CSP, with similar invert elevations to the existing structure.

We understand from AECOM that a temporary roadway protection system may be required for staging of the culvert replacement in open cut, and that a permanent grade raise or widening of the roadway embankment is not required.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* (CHBDC, 2014) and its *Commentary*, Highway 66, the culvert and its foundation system at Station 12+290 are expected to carry medium traffic volumes and their performance will have potential impacts on other transportation corridors; hence, the culvert foundation system is classified as having a “typical consequence level” associated with exceeding limits states design. In addition, given the typical project-specific foundation investigation carried out at this site (as presented in Part A of the report), in comparison to the degree of site understanding in Section 6.5 of *CHBDC* (2014), the level of confidence for design is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding ultimate limit state (ULS) and serviceability limit state (SLS) consequence factor, Ψ, and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs}, from Tables 6.1 and 6.2 of the *CHBDC* have been used for design, as applicable.

6.3 Assessment of Alternative Culvert Types and Installation Methods

Alternative methods of culvert installation, such as by a trenchless method and open-cut construction have been considered for this site, as presented in Table 1, attached. Based on the existing ground surface profile along the proposed culvert alignment, the existing soil cover over the top of the existing culvert relative to the highway surface grade is about 1.2 m. The proposed replacement culvert is 1.0 m in diameter and is to be constructed at a similar invert to the existing culvert, and therefore the soil cover over the top of the new culvert relative to the highways surface will be about 1.0 m. The resulting soil cover-to-tunnel diameter ratio of the proposed culvert tunnel would be about 0.7, assuming a 1.2 m diameter casing is used, which is not considered a suitable condition for a trenchless installation method. As such, it is considered that a trenchless installation is not be feasible at this site.

Based on the above considerations and comparison of alternative culvert types and construction methods, open-cut excavation is considered the most suitable installation method at this site. Recommendations for the foundation/geotechnical design of a circular culvert installation by open cut excavation are provided below as well as for a box culvert (1 m high by 1 m to 2 m wide), in the event that such a structure is preferred or is more appropriate, given other considerations beyond foundation/geotechnical aspects

6.4 Circular Pipe Culvert Installation by Open Cut

6.4.1 Settlement and Stability

Provided the existing/proposed reconstructed embankment is not widened or raised during or following culvert replacement, settlement of the foundation soils beneath the culvert is not anticipated to be a concern. If a grade raise or widening is being considered, a settlement analysis of the culvert/embankment foundation soils should be carried out. Provided the highway embankment in the area of the culvert is reconstructed using granular fill and the side slopes are graded to the same inclinations as the existing slopes, global stability of the embankment is not considered an issue.

6.4.2 Bedding / Embedment and Cover

Pipe culverts (less than 3 m diameter) should be designed in general accordance with the MTO Gravity Pipe Design Guidelines (2014). It is not necessary to found a pipe culvert below the depth of frost penetration, as pipe culverts are generally tolerant of small magnitudes of movement related to freeze-thaw cycles.

A circular concrete pipe culvert installed by open cut method should be completed in accordance with Ontario Provincial Standard Drawing (OPSD) 802.031 (*Rigid Pipe Bedding, Cover and Backfill)*. If the replacement culvert is to consist of a corrugated steel pipe (CSP) or plastic (HDPE or PVC) pipe installed by open cut method, it should be constructed in accordance with OPSD 802.010 (*Flexible Pipe Embedment and Backfill*) for Type 3 soil.

All unsuitable, deleterious, organic materials, and fill materials are to be removed from the base/below the pipe culvert (and bedding) footprint along its entire alignment. Based on the foundation exploration and existing/proposed culvert invert levels, the subgrade under the replacement culvert will consist of loose to compact sand potentially sandy silt fill near the outlet and is considered suitable for support of the culvert and bedding materials. The bedding layer should be at least 300 mm thick under rigid pipe, and 500 mm under flexible pipe. The bedding should be compatible with the type / class of pipe material, the surrounding subsoil and anticipated loading conditions, and should consist of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material. Depending on the success of the contractor's groundwater control methods, and the quality of the bearing stratum exposed at the base of the excavation, a thicker bedding layer may be required if wet and softened soil conditions, or unsuitable fill or organic material are present at the base of the excavation.

From the top of the bedding to 300 mm above the top of the culvert, OPSS.PROV 1010 (Aggregates) Granular 'A' should be used as cover around the culvert. All bedding, embedment and cover materials should be placed, and culvert construction carried out in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*) and OPSS.PROV 401 (*Trenching, Backfilling and Compacting*), and the bedding/embedment/cover soil should be compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by Special Provision (SP) 105S22. If the bottom of the excavation is wet and dewatering is not satisfactorily maintaining the water level sufficiently below the base of the excavation to allow compaction, it is recommended that OPSS.PROV 1010 (*Aggregates*) Granular 'B' Type II material be used as additional sub-excavation backfill below the bedding, as may be required.

A geotextile (i.e., filter cloth) should be installed between the bedding and the subgrade soil.

6.4.3 Trench Backfill

The excavated embankment fill materials from the culvert site will vary in quality and composition and are comprised of sand and gravel fill, sand fill and gravelly sandy silt fill; and cobbles and boulders may be encountered, as noted present in Borehole C207-2. Fill materials which contain organic materials or boulders should not be reused as trench backfill.

Granular material which meets the requirements of OPSS.PROV 1010 (Aggregates) Select Subgrade Material (SSM) or Granular 'B' Type I may be used as trench backfill. These materials should also be placed and compacted in accordance with OPSS.PROV 501 (Compacting), as amended by SP 105S22.

6.5 Box Culvert Foundations

6.5.1 Founding Level

It is understood that the invert level of the proposed box culvert (i.e., the top of the base slab) will be about the existing invert level. Assuming a 0.2 m thick base slab, the proposed replacement culvert will be founded on the bedding layer at about Elevation 319.8 m 319.9 m, respectively.

It is not necessary to found a pre-cast concrete box culvert at or below the standard depth of frost penetration for frost protection purposes, as pre-cast box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur.

Prior to placement of the culvert bedding, any topsoil, fill cobbles/boulders or deleterious material must be removed. Where any sub-excavation is required, the sub-excavated areas should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II, placed and compacted, in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22. In wet conditions, it is recommended that Granular B Type II be used as sub-excavation backfill and bedding as noted in Section 6.7.2.

6.5.2 Geotechnical Resistances

The 1.0 m (or 2.0 m) wide box culvert box culvert placed on a minimum 300 mm thick bedding layer over a properly prepared subgrade, at the proposed founding elevations noted above, should be designed based on a factored ultimate geotechnical resistance of 100 kPa and a factored serviceability geotechnical resistance (for 25 mm of settlement) of 75 kPa.

The factored geotechnical resistances and corresponding settlement are dependent on the culvert base width, depth of embedment, configuration, and applied loads; the geotechnical resistances should, therefore, be reviewed if the selected culvert width or founding elevation differ from those given above. In addition, these geotechnical resistances are provided for loads applied perpendicular to the base surface of the culvert; 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 its Commentary.

6.5.3 Resistance to Lateral Load/Sliding Resistance

Resistance to lateral forces/sliding between the pre-cast concrete box culvert and the subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC (2014) applying the appropriate consequence and degree of site understanding factors as noted in Section 6.2. For a precast concrete box culvert founded on a compacted Granular ‘A’ or Granular ‘B’ Type II bedding layer, the sliding resistance may be calculated based on an unfactored coefficient of friction, tan δ = 0.5, as interpreted from NAVFAC (1982).

6.6 Lateral Earth Pressures for Design

The lateral earth pressures acting on the walls of the box culvert will depend on the type and method of placement of the backfill materials, the nature of the soils 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 box culvert walls:

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (*Materials Specification for Aggregates*) Granular ‘A’ or Granular ‘B’ Type II, should be used as backfill behind the culvert walls and on top of the culvert as per OPSD 803.010 (*Backfill and Cover for Concrete Culverts).* Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22.
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with the CHBDC (2014) Section 6.12.3 and Figure 6.6. Hand-operated compaction equipment should be used to compact the backfill soils, immediately behind the walls as per OPSS.PROV 501, as amended by SP 105S22. Other surcharge loadings should be accounted for in the design, as required.
- For restrained walls in box culvert design, granular fill should be placed in a zone with the width equal to at least 2.3 m behind the back of the wall equivalent to the depth of frost penetration as interpreted from OPSD 3090.100 (*Foundation Frost Penetration Depth for Northern Ontario* in accordance with Figure C6.20(a) of the *Commentary* to the *CHBDC (2014)*. The pressures acting on the culvert walls/wingwalls-headwalls are based on the adjacent embankment fill material and the following parameters (unfactored) may be used:

Fill Type	Soil Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Sand	20 kN/m^3	0.50	0.33

If the culvert structure does not allow lateral yielding, at-rest earth pressures should be assumed for the foundation design. If the culvert structure allows for lateral yielding, active earth pressures should be used in the foundation design. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.6 of the Commentary to the CHBDC (2014).

6.7 Box Culvert Construction by Open Cut

6.7.1 Settlement and Stability

Provided the existing and the reconstructed embankment is not widened or raised during or following box culvert replacement, settlement of the foundation soils beneath the culvert is not anticipated to be a concern. If an embankment grade raise is required to provide for additional cover thickness to the culvert, a settlement analysis of the culvert / embankment foundation soils should be carried out.

Provided the existing embankment height is maintained, the north and south side slopes are reconstructed no steeper than at 2H:1V, and excavation side slopes graded to match the existing, following culvert replacement, the embankment side slopes will be stable from a global stability perspective.

6.7.2 Bedding / Embedment and Cover

Box culvert bedding and cover should be placed in accordance with OPSD 803.010 (*Backfill and Cover for Concrete Culverts*) and OPSS 422 (*Precast Reinforced Concrete Box Culverts*).

All unsuitable, deleterious, organic materials and fill materials are to be removed from the base/below the culvert (and bedding) footprint along its entire alignment. Based on the foundation exploration and existing/proposed culvert invert levels, the subgrade under the replacement culvert will consist of native loose to compact sand, very loose to compact silt, soft to stiff clayey silt and is considered suitable for support of the bedding materials and culvert. Sub-excavated areas should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II. In wet conditions, it is recommended that Granular B Type II be used as sub-excavation backfill and bedding.

It is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II material be used for bedding and cover purposes. In addition, the 75 mm thick uncompacted levelling pad should consist of OPSS.PROV 1010 Granular 'A' or concrete fine aggregate meeting the gradation requirements specified in OPSS.PROV 1002 (*Aggregates – Concrete*).

All bedding, embedment and cover materials should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22.

A geotextile (i.e., filter cloth) should be installed between the bedding and the subgrade soil.

6.7.3 Trench Backfill

The excavated embankment fill materials from the culvert site will vary in quality and composition and are comprised of sand and gravel fill, to sand fill and gravelly sandy silt fill, and cobbles and boulders may be encountered, as noted present in borehole C207-2. Fill materials which contain organic materials or cobbles/boulders should not be reused as backfill for reconstruction of the highway embankment in the immediate vicinity or over the new culvert.

Granular material which meets the requirements of OPSS.PROV 1010 (Aggregates) SSM or Granular 'B' Type I may be used as trench backfill. These materials should also be placed and compacted in accordance with OPSS.PROV 501 (Compacting), as amended by SP 105S22.

6.8 Analytical Testing of Existing Soil

The results of analytical tests on one sample of the native sand deposit recovered from Borehole C207-1 are summarized in Section 4.4. The potential for sulphate attack and corrosion are discussed in the following paragraphs; however, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class, and ensuring that all aspects of CSA A23.1-14 (2014) Section 4.1.1 "Durability Requirements" are followed when designing concrete elements. The culvert should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

6.8.1 Potential for Sulphate Attack

The analytical test results were compared to CSA A23.1-14 Table 3 ("Additional requirements for concrete subjected to sulphate attack") for the potential sulphate attack on concrete. The water soluble-sulphate concentration measured in the soil sample is less than the reportable detection limit of 0.002 per cent, which is below the exposure class of S-3 (Moderate) and is considered Negligible according to Table 7.2 in the MTO Gravity Pipe Design Guidelines (2014). Therefore, based on the test result for the sample, when the designer is selecting the exposure class for the culvert/structure, the effects of sulphates from within the near surface/culvert invert native soil(s) may not need to be considered. However, as the culvert will extend under the roadway shoulders and be exposed to de-icing salt, concrete should be designed for a "C" type exposure class as defined by CSA A23.1-14 Table 1.

6.8.2 Potential for Corrosion

The soil has a pH of 7.2 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. The resistivity is 5,000 ohm-cm, which indicates that the soil corrosiveness potential is low (6,000>R>4,500 ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). It is also noted that sulphide is considered very corrosive to cast iron/steel materials (Cashman and Preene, 2001), however, the sulphide concentration is less than the reportable detection limit of 0.50 µg/g in the analyzed soil sample.

6.9 Construction Considerations

6.9.1 Open Cut Excavation

The proposed open cut excavation through the embankment and into the subgrade to the base of the culvert bedding level associated with the removal of the existing culvert and construction of the new culvert by open cut and re-construction of the embankment, will advance through the granular embankment fill and cobbles and boulders and potentially into native soils, and is anticipated to extend below the groundwater level. Where space permits for an open cut excavation into these materials, the excavation must be carried out in accordance with the guidelines outlined in the Occupation Health and Safety Act (OHSA) for Construction Activities. Above the water table, the existing fill materials are classified as Type 3 soil, according to OHSA and temporary excavations (i.e., those which are open for a relatively short time period) should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). Below the water table, the existing fill materials, including cobbles and boulders and underlying native soils are classified as Type 4 soil, according to OHSA and temporary excavations (i.e., those which are open for a relatively short time period) into this soil type should be made with side slopes no steeper than 3 horizontal to 1 vertical (3H:1V).

Depending upon the construction procedures adopted by the contractor, groundwater seepage conditions, and weather conditions at the time of construction, some local flattening of the slopes of open cut excavations may be required, especially in looser zones or where localized seepage is encountered. Further, layering of soils and the effectiveness of the contractor's dewatering systems could affect the OHSA classification and, therefore, the classification of soils for OHSA purposes must be made at the time the excavation is open and can be directly observed during construction.

6.9.2 Groundwater / Surface Water Control

The groundwater level is expected to be at or above the proposed culvert founding level along most of its alignment and therefore the excavation for the culvert replacement should be expected to extend below the groundwater level. The groundwater should be lowered to at least 1 m below the base of the excavation to maintain basal stability and allow for construction in dry conditions. Groundwater may be controlled by providing an active dewatering system consisting of an adequate number of sumps and pumps installed and operated in advance/during the excavation, or in combination with temporary support systems, such as a sheet piling wall and/or cofferdams (as required). The contractor is responsible for the assessment of dewatering requirements, which depends on their chosen method of open cut excavation for replacement, as well as on the method and procedure for construction/operation/maintenance and decommissioning. The design of dewatering, unwatering, and temporary flow passage system is the responsibility of the contractor. The contractor is also responsible for confirming that the radius of groundwater drawdown does not impact the existing embankment and any surrounding features.

Active dewatering methods should draw down the groundwater level approximately 1 m below the base of the excavation and shall be designed/carried out in accordance with OPSS.PROV 517 (Dewatering), as amended by Special Provision SP517F01 (Dewatering System/*Temporary Flow Passage System*) recommending that a design engineer be required, to carry out the design of the system. The return period flow estimates in Table A of SP 517F01 shall be filled in by the hydraulic design engineer. Given the loosening potential of the sand, silt and clayey silt, and potentially sandy silt fill, subgrade at this site, the Foundation Designer fill in for Note 1 in Table A should indicate "yes" (see Appendix C). The Culvert Inspection Report by AECOM indicates that utilities may be in conflict with dewatering operations and we understand from AECOM that utilities will be relocated prior to construction. Further considering that relatively minor groundwater lowering is anticipated to be required to facilitate the culvert replacement, the risk of settlement impacts is considered to be low from a foundation perspective, so long as pumping is carried out from properly filtered sumps/well points. Therefore, the Foundation Designer fill-in in Table A of SP 517F01 shall indicate that Pre-Construction Survey is "N/A".

It should be noted that construction water takings in excess of 50 m^3/day are regulated by the Ministry of the Environment, Construction, and Parks (MECP). Takings of groundwater/stormwater for construction dewatering purposes with a combined total less than 400 m^3/day, qualify for self-registration on the MECP's Environmental Activity and Sector Registry (EASR). Registry on the EASR replaces the need to obtain a PTTW for water taking less than 400 m^3/day and a Section 53 approval for discharge to the environment; however, a "Water Taking Plan" and a "Discharge Plan" are required by the MECP if water is taken in accordance with an EASR. If construction water taking will be required at this site, the construction water taking permit and registration under the EASR should be prepared by the Contractor adequality in advance of site excavation work, so as not to unduly affect the construction schedule.

Surface water should be directed away from open excavation areas to prevent ponding of water that could result in disturbance and weakening of the subgrade and/or affect construction as applicable. Depending on the water flow through the watercourse at the time of construction and staging/diversion requirements/limitations, temporary cofferdams may also be required.

6.9.3 Temporary Protection/Dewatering Systems

In order to replace the existing culvert and allow at least one lane of live traffic to pass during construction, and to allow for construction of the culvert replacement in dry conditions, temporary protection systems may be required.

The selection and design of the temporary protection and of the dewatering systems will be the responsibility of the contractor. It is anticipated that a driven interlocking steel sheet pile system is not suitable at this site, due to the presence of cobbles and boulders near the outlet will have to be taken into consideration by the contractor as to the need to use a heavier/thicker sheet pile section and/or remove these obstructions and backfill the excavation with granular material to allow the sheet piles to be driven through the backfill. The contractor may use a soldier pile and lagging system drive the piles through the cobbles/boulders, if required, however, the site would need to be adequately dewatered, prior to installation of the lagging boards, as the cohesionless fills will not have adequate stand-up time to permit installation of the lagging boards. The soldier piles will need to extend to a sufficient depth to provide the necessary passive resistance for the retained soil height, plus any surcharge loads behind the protection system. Lateral support to the soldier pile and lagging wall could be provided in the form of struts, rakers, or temporary anchors, if and as required. Consideration could also be given to the use of a sandbag or inflatable bladder system for surface water control. It is noted that due to permeable nature of the site soils, groundwater seepage through the base of the excavation and/or below the base of temporary protection/dewatering system should be considered in the selection and design of the temporary protection/dewatering system.

The installation of temporary protection systems should be monitored to ensure that vibration levels produced by such construction activity are within tolerable limits and in consultation with the infrastructure/utility and property owners within the zone of influence of the site.

The temporary excavation protection and support systems shall be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*) as amended by SP 105S09. The lateral movement of the protection systems shall meet Performance Level 2 as specified in OPSS.PROV 539, provided that any utilities, if present, can tolerate this magnitude of deformation.

While the selection and design of the temporary protection system will be the responsibility of the contractor, the following information is provided to MTO and its designers to aid in the assessment of feasible alternatives.

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m³)	Angle of Internal Friction, φ (degrees)	Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients[1,2]		
				Active, K_a	At-rest, K_o	Passive, K_p[3]
Existing Embankment Fill – Sand and gravel and compact to very dense sand	20	32	-	0.31	0.47	3.25
Existing Embankment Fill – Very loose gravelly sandy silt / compact sandy silt	19	28	-	0.36	0.53	2.77
Very loose to compact silt	17	28	-	0.36	0.53	2.77
Soft to stiff clayey silt	18	28	25	0.36	0.53	2.77
Very loose to very dense silty sand to sand	20	30	-	0.33	0.50	3.00

Notes:

1. The design groundwater level may be assumed to be Elevation 320.9 m near the inlet and outlet, based on the ground surface and water levels in the boreholes.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
3. The total passive resistance below the base of the excavation (i.e., adjacent to the temporary protection system) may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

It is recommended that the ground surface extending back/upwards from the top of the protection system to the existing Highway 66 surface be graded to an inclination no steeper than 2H:1V. This should be shown on the Contract staging drawings.

The loading from construction equipment as well as any material stockpiles within a distance defined by a 1 horizontal to 1 vertical line drawn from the bottom of the excavation to the existing ground surface should be included as a surcharge in the design of the temporary protection system.

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction or each stage of construction (as required). Vibration and noise controls during extraction of the temporary systems should meet the same tolerable limits used for installation.

6.9.4 Obstructions

Borehole C207-2 encountered cobbles and boulders within the embankment fill, between Elevations 320.2 m and 319.6 m during the drilling exploration, which could affect the installation of temporary protection/cofferdam systems. A Notice to Contractor, to identify to the contractor the possible presence of cobbles and boulders within the fill, should be included in the Contract Documents; a copy of which is included in Appendix C.

6.9.5 Subgrade Protection

For open cut culvert installation, the subgrade soils will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that the granular bedding layer be placed immediately after preparation and approval of the subgrade.

6.9.6 Embankment Reconstruction

Engineered fill for reconstruction of the embankment adjacent to the culvert should consist of OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II. Select Subgrade Material (or Earth Fill) could also be used as trench backfill between the culvert cover and roadway subgrade level as noted in Section 6.4.3 and 6.7.3. The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22, and OPSS.PROV 206 (*Grading*). Embankment side slopes should be constructed no steeper than 2H:1V in granular fill.

6.9.7 Surficial Embankment Stability and Erosion Protection

Depending on the embankment reconstruction procedures, fill material type used, slope geometry, surface treatment, and weather conditions (i.e., precipitation, cycles of wetting-drying, and/or freezing-thawing), surficial instability of the embankment side slopes may occur, which could include localized sloughing and erosion. As such, in order to maintain the integrity of the reconstructed embankment sections, erosion protection measures may be required on the finished embankment slopes.

Based on the specified material types and hence the gradation envelope for embankment reconstruction material granular fill such as OPSS.PROV 1010 (*Aggregates*) Granular 'A', or Granular 'B' Type I and Type II, have a low potential for erosion. For embankments constructed of granular fill, erosion control may be limited to seeding following the construction specifications of OPSS 802 (*Topsoil*) and OPSS.PROV 804 (*Seed and Cover*). On-going maintenance for embankments constructed of this material is not expected to be required once the vegetation has been established.

The specification for OPSS.PROV 1010 (*Aggregates*) SSM allows for much more variation in the gradation of the material compared to Granular 'A', or Granular 'B' Type I, and therefore has the potential to be low - erodible to moderate - erodible. Erosion protection for slopes constructed of SSM should consist of erosion control blankets and seeding. Slopes constructed of SSM and properly protected from erosion should require limited on-going maintenance.

On the south side of the highway along Gull Lake for slope protection from a foundation perspective it is recommended to include a 400 mm thick layer of OPSS.PROV 1004 (Aggregates-Miscellaneous) R-10 Rip-Rap or 500 mm layer of OPSS.PROV 1004 Rock Protection, however the need for extent and composition of the slope protection measures should be assessed by the hydraulic designer.

7.0 CLOSURE

This foundation design report was prepared by Mr. Tibor Berecz, a geotechnical EIT with Golder, and the technical aspects were reviewed by Mr. André Bom, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant with Golder conducted an independent and quality control review of the report.

Signature Page

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https://golderassociates.sharepoint.com/sites/1809001/deliverables/foundations/2. reporting/r17 - leb 207/3. final/1896349-r17 r-rev0 aecom culvert leb 207 hwy 66 27feb_2020.docx

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Canadian Standards Associations (CSA) Group 2014. Canadian Highway Bridge Design Code and Commentary S6-14.

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Cashman, P.M. and Preene M. (2001) Groundwater Lowering in Construction, A Practical Guide. Spoon Press Publisher.

Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNE.

Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543.

Ontario Regulation 903 (Wells).

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

Unified Facilities Criteria, U.S. Navy 1982. NAVFAC DM-7.02

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 Saturated Fine Grained Soils.

Ontario Provincial Standard Drawings (OPSD)

OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less than or Equal to 3.0 m
OPSD 3090.100	Foundation Frost Penetration Depths for Northern Ontario
OPSD 802.010	Flexible Pipe Embedment and Backfill, Earth Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 401	Construction Specification for Trenching, Backfilling and Compacting
OPSS.PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culvert in Open Cut.
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 802	Construction Specification for Topsoil
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS.PROV 1002	Material Specification for Aggregates – Concrete
OPSS.PROV 1004	Material Specification for Aggregates - Miscellaneous

Special Provisions

SP 105S22	Amendment to OPSS 501
SP 105S09	Amendment to OPSS 539

Table 1: Culvert Replacement Alternative Types and Installation Methods – Station 12+290 Township of Lebel

Replacement Alternatives	Advantages	Disadvantages	Risks / Consequences
Trenchless Installation	■ Pipe ramming without significant removal of soils prior to full casing penetration through embankment would likely be suitable. ■ Relatively low cost for pipe ramming. ■ Relatively small site operations footprint. ■ Within size range typical in Ontario. ■ Less traffic disruptions than open cut methods. ■ Various potential trenchless installation methods available, although most would not be suitable/feasible for this site.	■ Adjacent water body will require water-tight cofferdam and may preclude construction of exit shaft and the use of a trenchless installation. ■ Site conditions and pipe/casing size potentially preclude installation by HDD, TBM, PTMT, and TBM methods as well as Jack and Bore; likely restricted to Pipe Ramming. ■ Combination of final pipe (casing) diameter and length of installation may be near the upper limit of feasibility for a pipe installation by pipe ramming. ■ Potential for the presence of wood debris, as encountered in Borehole C207-2 at the embankment fill – native soil interface, if encountered along the trenchless alignment would require shaft excavation from the surface for removal or prevent trenchless installation. ■ Vibrations from pipe driving can lead to densification and settlement of loose granular materials surrounding and overlying the casing/pipe and result in settlement of roadway surface. ■ Alignment control can be difficult when penetrating soils of differing densities. ■ The soil cover thickness is about 1 m which is insufficient to address MTO's CMO Guidelines for Tunnelling (i.e., min 1.5 m cover) and the cover to pipe diameter ratio is less than 1, precluding a trenchless method.	■ Need for removal of soil from within casings because of driving resistance (binding of casings, weight of spoil, wood debris, obstructions) could lead to excess ground losses and surface settlement. ■ Nominal cover thickness results in high-risk trenchless crossing. ■ Inadequate soil cover (thickness or ratio to culvert diameter) potentially leading to loss of soil, road heave, and/or settlement. ■ Potential impacts on utilities reportedly present near the outlet (AECOM Culvert Inspection Report)

Replacement Alternatives	Advantages	Disadvantages	Risks / Consequences
Cut and Cover (Pipe or Box Type Culvert)	■ Risks of ground losses affecting traffic are better controlled than for trenchless methods. ■ Depth of excavation is well within typical limits for conventional excavation support, slopes and dewatering systems. ■ With appropriate planning, excavation methods can be adapted to address obstructions (such as wood debris as encountered in Borehole C207-2) and soft/loose soils. ■ Can accommodate a culvert of various sizes to provide the required flow capacity. ■ Box type culvert can be made adequately large to accommodate required flow capacity and still provide for adequate thickness of soil cover.	■ Traffic disruption (staging of crossing construction). ■ Roadway protection required for staged excavation. ■ Proactive dewatering required (e.g., vacuum well points). ■ A larger diameter pipe type culvert (CSP/Concrete/HDPE) of adequate size to accommodate the required flow would result in reduced cover thickness.	■ Traffic staging problems (e.g., temporary concrete barriers, seasonal construction). ■ Dewatering planning as part of bid may not be adequate and result in real or strategic claims. ■ Relocation utilities that are reportedly present near the outlet.

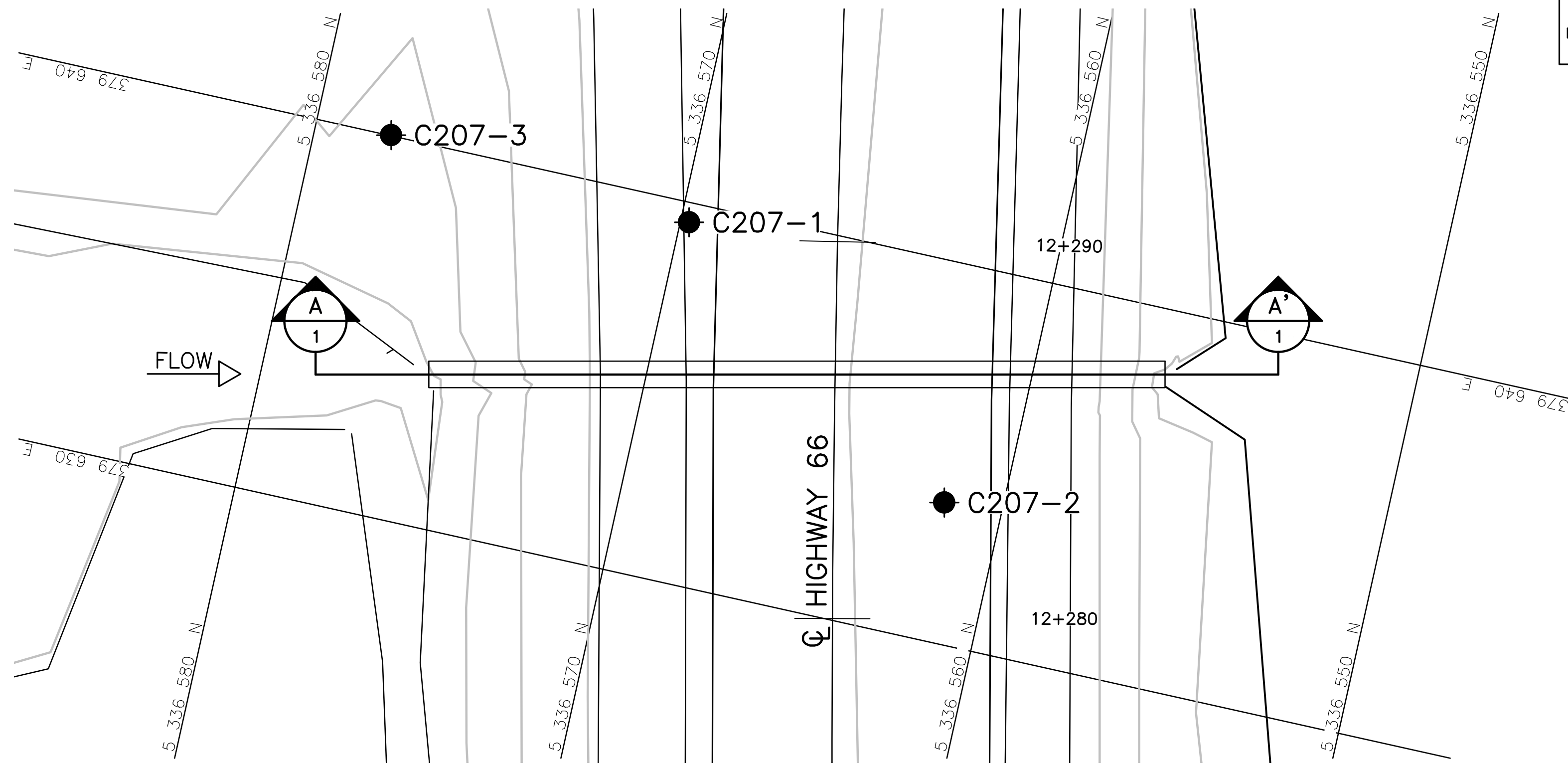
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5210-14-00

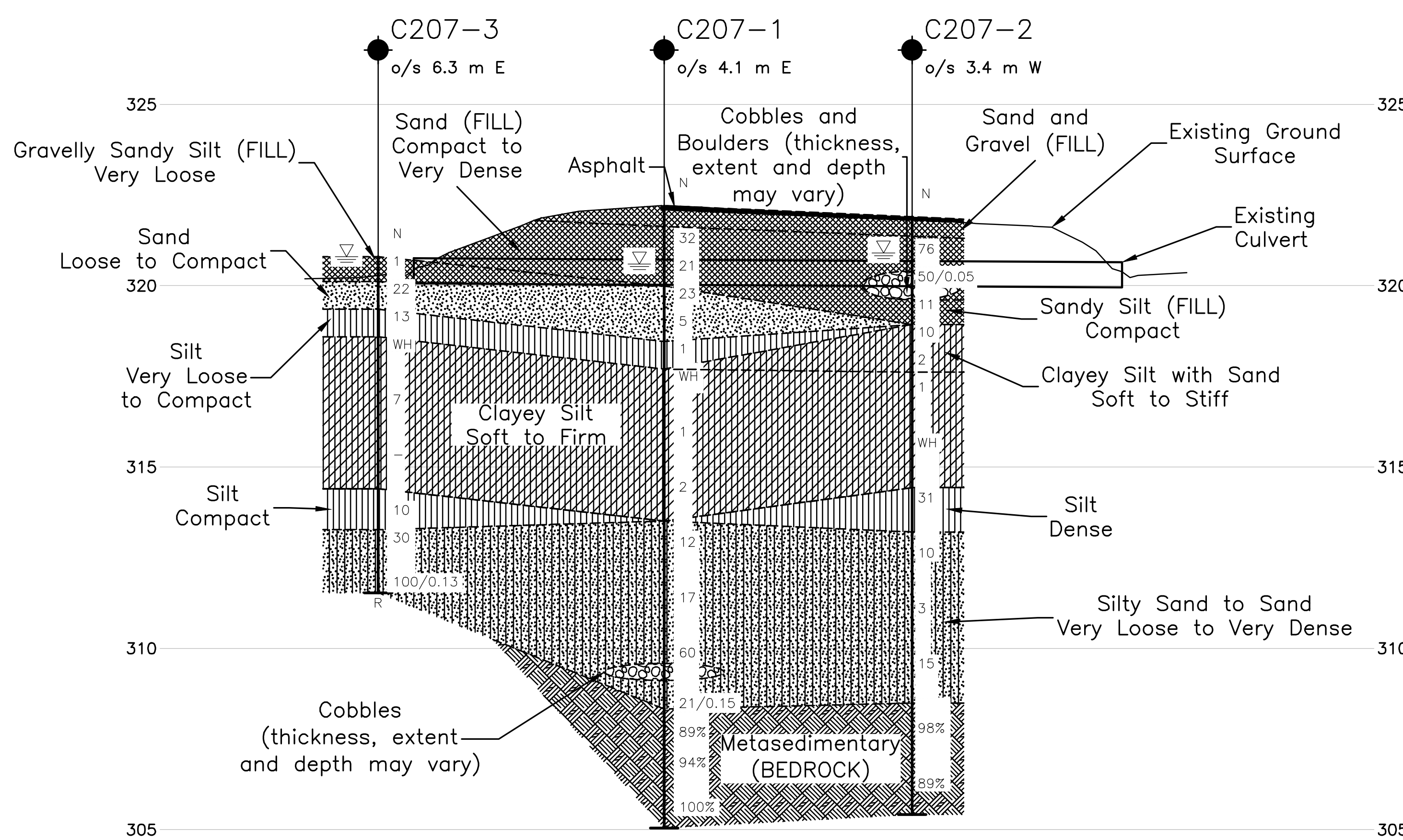
HIGHWAY 66
STATION 12+290
TOWNSHIP OF LEBEL CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

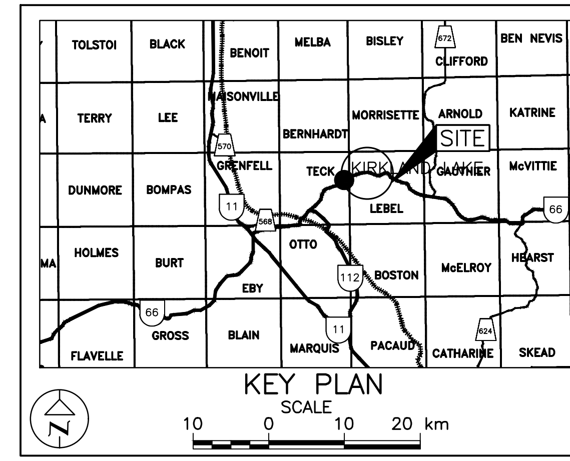
GOLDER



PLAN
SCALE
2 0 2 4 m



A-A'
1
CULVERT CENTERLINE PROFILE
HORIZONTAL SCALE
2 0 2 4 m
2 0 2 4 m
VERTICAL SCALE



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
100%	Rock Quality Designation (RQD)
▽	WL upon completion of drilling

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
C207-1	322.2	5336569.8	379639.5
C207-2	321.9	5336561.5	379633.7
C207-3	320.8	5336578.0	379640.0

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 CALLON DIETZ LTD. drawing file nos. gwp52101400a.dwg, received AUGUST 14, 2019.

NO.	DATE	BY	REVISION

Geocres No. 32D-31

HWY. 66		PROJECT NO. 1896349	DIST.
SUBM'D.	CHKD. TB	DATE: 2/18/2020	SITE:
DRAWN: TR	CHKD. AB	APPD. JMAC	DWG. 1

PLOT DATE: February 20, 2020
FILENAME: S:\Clients\MTO\Hwy65&66\99_PROJ\1896349_AECOM_Hwy65-66-566\40_PROD\0017_R17_LEB207\1896349-0017-RG-0001.dwg

Gull Lake

Photograph 1: Embankment South Slope at Culvert Location, Facing East (June 2019)

Culvert Inlet

Photograph 2: Embankment North Slope at Culvert Location, Facing East (June 2019)

Photograph 3: Culvert Inlet (North End), Facing West (AECOM, October 2018)

Photograph 4: Culvert Outlet (South End at Gull Lake) (AECOM, October 2018)

APPENDIX A

Record of Boreholes

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS
MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS[1,2]

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (*i.e.,* SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (*i.e.,* some sand)
≤ 10	trace (*i.e.,* trace fines)

1. Only applicable to components not described by Primary Group Name.
2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

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.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)
An 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 (u) and sleeve friction (f_s) are recorded electronically at 25 mm penetration intervals.

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, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , 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, Gs)
DS	direct shear test
GS	specific gravity
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 (FV)	field vane (LV-laboratory vane test)
γ	unit weight

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

COARSE-GRAINED SOILS

Compactness[1]

Term	SPT 'N' (blows/0.3m)[2]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

3. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.
4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1,2] (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS
MINISTRY OF TRANSPORTATION, ONTARIO

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 = $(w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c′	effective cohesion
c_u, s_u	undrained shear strength (ϕ = 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

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)
The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)
The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)
The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index
A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis
The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90º angle is horizontal.

Description and Notes
An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN	Joint	PL	Planar
FLT	Fault	CU	Curved
SH	Shear	UN	Undulating
VN	Vein	IR	Irregular
FR	Fracture	K	Slickensided
SY	Stylolite	PO	Polished
BD	Bedding	SM	Smooth
FO	Foliation	SR	Slightly Rough
CO	Contact	RO	Rough
AXJ	Axial Joint	VR	Very Rough
KV	Karstic Void		
MB	Mechanical Break		

PROJECT 1896349

RECORD OF BOREHOLE No C207-1

 METRIC

G.W.P. 5210-14-00 | LOCATION N 5336569.8; E 379639.5 NAD83 MTM ZONE 12 (LAT. 48.163566; LONG. -79.993844) | ORIGINATED BY MR

DIST ____ HWY 66 | BOREHOLE TYPE NW Casing, Wash Boring and NQ Coring | COMPILED BY GM

DATUM GEODETIC | DATE December 13, 2018 | CHECKED BY AB

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
322.2	GROUND SURFACE										
0.0	ASPHALT (110 mm)										
0.1	Sand and gravel (FILL)										
321.6 / 0.6	Sand, trace gravel (FILL) Compact to dense Brown Moist to wet	1	SS	32							
		2	SS	21	∇ (approx. El. 320.9)						
320.0 / 2.2	SAND, some silt, trace gravel, trace clay, trace organics Loose to compact Grey to brown Wet	3	SS	23		w plotted		5	70	17	8
		4	SS	5							
318.5 / 3.7	SILT, some sand, trace to some clay Very loose Grey Wet	5	SS	1		w plotted	NP	0	17	73	10
317.7 / 4.5	CLAYEY SILT, with silt laminations, trace sand Soft to firm Grey w>PL	6	SS	WH		wP and w plotted		0	1	64	35
		7	SS	1							
		8	SS	2		wP–w plotted					
313.5 / 8.7	SILTY SAND, trace to some gravel Compact to very dense Grey Wet	9	SS	12							
		10	SS	17							

Field vane shear strength (+): approx. 24 kPa, sensitivity 2 at El. ~316.4; approx. 24 kPa, sensitivity 2 at El. ~314.9.

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); WATER CONTENT (%) (20 40 60); ELEVATION SCALE 322 to 311; REMARKS & GRAIN SIZE DISTRIBUTION (%).

Continued Next Page

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

GOLDER

RECORD OF BOREHOLE No C207-1

 METRIC

PROJECT 1896349

G.W.P. 5210-14-00

LOCATION N 5336569.8; E 379639.5 NAD83 MTM ZONE 12 (LAT. 48.163566; LONG. -79.993844)

ORIGINATED BY MR

DIST ___ HWY 66

BOREHOLE TYPE NW Casing, Wash Boring and NQ Coring

COMPILED BY GM

DATUM GEODETIC

DATE December 13, 2018

CHECKED BY AB

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	SILTY SAND, trace to some gravel Compact to very dense Grey Wet				310	
		11	SS	60		
	- Cobbles encountered from 12.7 m to 13.0 m depths				309	
308.3		12	SS	21/0.15		
13.9	Metasedimentary (BEDROCK) For coring details see Record of Drillhole C207-1.	1	RC	REC 100%	308	RQD = 89%
		2	RC	REC 100%	307	RQD = 94%
		3	RC	REC 100%	306	RQD = 100%
305.1 17.1	END OF BOREHOLE NOTE: 1. Water level measured inside casing at a depth of 1.6 m below ground surface (Elev. 320.6 m) upon completion of drilling.					

Column headings: SOIL PROFILE (ELEV DEPTH, 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; 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

SUD-MTO 001 S:\CLIENTS\MTO\HWY65&66\02_DATA\GINT\1896349.GPJ GAL-MISS.GDT 19-12-16 TR

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

RECORD OF DRILLHOLE: C207-1

PROJECT: 1896349
LOCATION: N 5336569.8; E 379639.5
NAD83 MTM ZONE 12 (LAT. 48.163566; LONG. -79.993844)
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: December 13, 2018
DRILL RIG: CME550 Buggy
DRILLING CONTRACTOR: Landcore Drilling

SHEET 1 OF 1
DATUM: GEODETIC

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage, PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular, PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN	DISCONTINUITY DATA (TYPE AND SURFACE DESCRIPTION)
		GROUND SURFACE	308.3			
14–17	NW; NQ Coring, December 13, 2018	Metasedimentary Fine grained Fresh Grey	13.9	1	Grey 100	JNIRRo JNIRRo
				2	Grey 100	JNPLSM
				3	Grey 100	
		END OF DRILLHOLE	305.1 17.1			

Depth scale ticks: 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25

Column headings: RECOVERY (TOTAL CORE %, SOLID CORE %), R.Q.D. %, FRACT. INDEX PER 0.3 METRES, B Angle, DIP w.r.t. CORE AXIS, Jr, Ja, Jn, HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}), Diametral Point Load Index (MPa), RMC -Q' AVG., FLUSH, SYMBOLIC LOG

DEPTH SCALE
1 : 60

GOLDER

LOGGED: MR
CHECKED: AB

GOLDER

RECORD OF BOREHOLE No C207-2

 METRIC

PROJECT 1896349			
G.W.P. 5210-14-00	LOCATION N 5336561.5; E 379633.7 NAD83 MTM ZONE 12 (LAT. 48.163492; LONG. -79.993923)		ORIGINATED BY YS
DIST	HWY 66	BOREHOLE TYPE NW Casing, Wash Boring and NQ Coring	COMPILED BY GM
DATUM GEODETIC	DATE May 6 to 7, 2019		CHECKED BY AB

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT / LIMITS	GR	SA	SI	CL
321.9	GROUND SURFACE										
0.0	ASPHALT (100 mm)										
0.1	Sand and gravel (FILL)										
321.3 / 0.6	Sand, some gravel (FILL) Very dense Brown Wet		1	SS	76	∇ (approx. El. 321)					
			2	SS	50/0.05						
320.2 / 1.7	Cobbles and boulders (FILL)										
319.6 / 2.3	Sandy silt, some gravel, trace organics, trace rootlets, trace wood (FILL) Compact Dark brown Wet		3	SS	11						
318.9 / 3.0	CLAYEY SILT with SAND Soft to stiff Grey Wet		4	SS	10		w_P, w plotted	0	37	42	21
			5	SS	2						
317.4 / 4.5	CLAYEY SILT, with silt laminations, trace sand Firm Grey w>PL		6	SS	1						
							Field vane (+), sensitivity 3				
			7	SS	WH		w_P–w_L, w plotted	0	1	64	35
							Field vane (+), sensitivity 3				
314.4 / 7.5	SILT, some gravel, some sand Dense Grey Moist		8	SS	31						
313.2 / 8.7	SILTY SAND to SAND, trace to some gravel Very Loose to compact Grey Wet		9	SS	10						
			10	SS	3		w plotted	15	75	(10)	

Elevation scale: 321 to 310

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 Next Page

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

GOLDER

RECORD OF BOREHOLE No C207-2

 METRIC

PROJECT 1896349			
G.W.P. 5210-14-00	LOCATION N 5336561.5; E 379633.7 NAD83 MTM ZONE 12 (LAT. 48.163492; LONG. -79.993923)	ORIGINATED BY YS	
DIST	HWY 66	BOREHOLE TYPE NW Casing, Wash Boring and NQ Coring	COMPILED BY GM
DATUM GEODETIC	DATE May 6 to 7, 2019	CHECKED BY AB	

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	SILTY SAND to SAND, trace to some gravel Very Loose to compact Grey Wet	11	SS	15	309	
308.5 13.4	Metasedimentary (BEDROCK) For coring details see Record of Drillhole C207-2.	1	RC	REC 100%	308	RQD = 98%
		2	RC	REC 100%	307 306	RQD = 89%
305.4 16.5	END OF BOREHOLE NOTE: 1. Water level measured insode casing at a depth of 1.0 m below ground surface (Elev. 320.9 m) upon completion of drilling.					

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; 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; GR SA SI CL

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

RECORD OF DRILLHOLE: C207-2

PROJECT: 1896349
LOCATION: N 5336561.5; E 379633.7
NAD83 MTM ZONE 12 (LAT. 48.163492; LONG. -79.993923)
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: May 7, 2019
DRILL RIG: CME550 Buggy
DRILLING CONTRACTOR: Landcore Drilling

SHEET 1 OF 1
DATUM: GEODETIC

JN - Joint, FLT - Fault, SHR- Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Cleavage
PL - Planar, CU- Curved, UN- Undulating, ST - Stepped, IR - Irregular
PO- Polished, K - Slickensided, SM- Smooth, Ro - Rough, MB- Mechanical Break
BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN	DISCONTINUITY TYPE AND SURFACE DESCRIPTION
		GROUND SURFACE	308.5			
	NW; NQ Coring, May 7, 2019	Metasedimentary Fine grained Slightly weathered Grey	13.4			JNIRRo
14				1	Grey 100	JNIRRo
15						JNIRRo
				2	Grey 100	JNIRRo
						JNIRRo
16						JNIRRo
			305.4 / 16.5			
		END OF DRILLHOLE				

Other column headings: SYMBOLIC LOG; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.25 METRES; DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, Jr, Ja, Jn); HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.

Depth scale: 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25

DEPTH SCALE
1 : 60

GOLDER

LOGGED: YS
CHECKED: AB

GOLDER

RECORD OF BOREHOLE No C207-3

 METRIC

PROJECT 1896349
G.W.P. 5210-14-00
LOCATION N 5336578.0; E 379640.0 NAD83 MTM ZONE 12 (LAT. 48.163641; LONG. -79.993835)
ORIGINATED BY YS
DIST ___ HWY 66
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
COMPILED BY GM
DATUM GEODETIC
DATE May 7, 2019
CHECKED BY AB

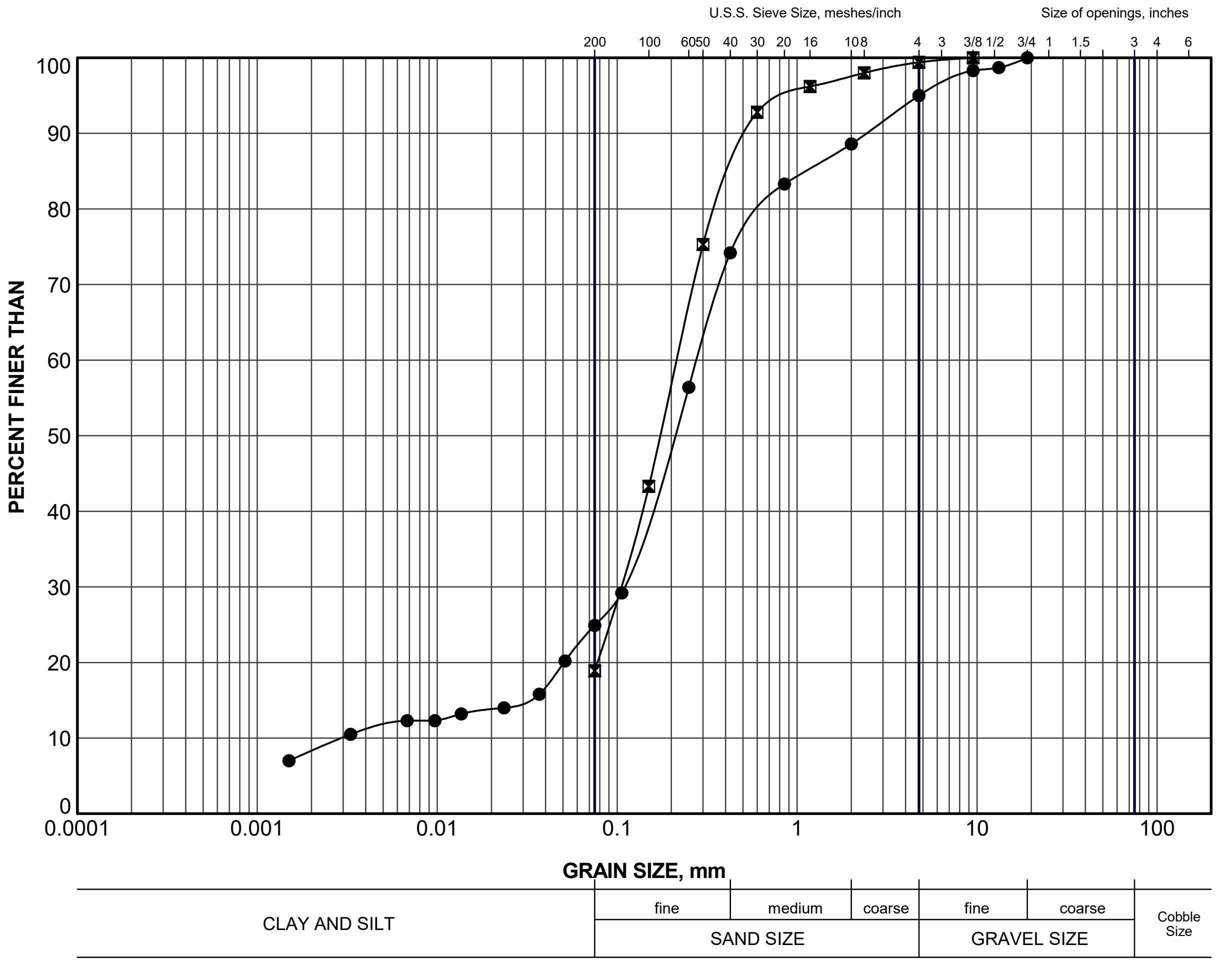
ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	Shear strength (kPa)	Water content (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
320.8	GROUND SURFACE						
0.0	Gravelly sandy silt, trace organics (FILL) Very loose Dark brown Wet	1	SS	1			
320.1 / 0.7	SAND, some silt, trace gravel Compact Grey Wet	2	SS	22		o	1 80 (19)
319.4 / 1.5	SILT, trace to some sand Compact Grey Wet	3	SS	13			
318.6 / 2.2	CLAYEY SILT, with silt laminations Firm Grey w>PL	4	SS	WH		H o	0 9 58 33
					+2 (field vane, approx. elev. 317.3)		
		5	SS	7			
					+2 (field vane, approx. elev. 315.8)		
		6	TO	PH			
314.4 / 6.4	SILT, trace sand, trace to some clay Compact Grey Wet	7	SS	10		o	0 2 90 8
313.3 / 7.5	SAND, some gravel, some silt Compact Grey Wet - Auger grinding from 8.5 m to 9.1 m depth	8	SS	30			
311.5 / 9.3	END OF BOREHOLE HAMMER BOUNCING (I.E. SPOON REFUSAL) NOTE: 1. Water level measured inside augers at ground surface (Elev. 320.8 m) upon completion of drilling.	9	SS	100/0.13			

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (320 to 312); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O 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.

+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

APPENDIX B

Laboratory Test Results



LEGEND

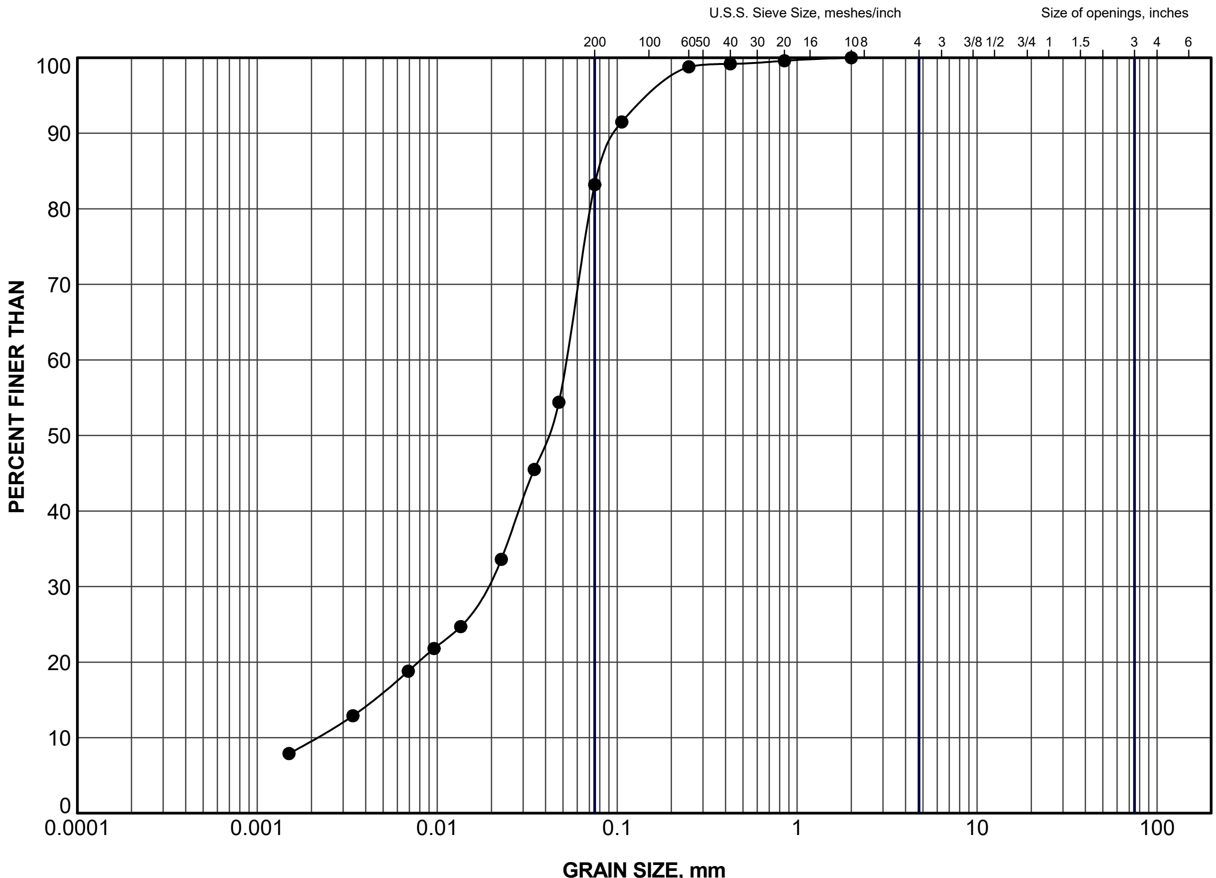
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C207-1	3	319.6
⊠	C207-3	2	319.7

PROJECT	HIGHWAY 66 STATION 12+290 TOWNSHIP OF LEBEL CULVERT
TITLE	**GRAIN SIZE DISTRIBUTION** Sand (Upper Deposit)

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Dec 2019	SCALE N/A	REV.
CHECK	AB	Dec 2019		
APPR	JMAC	Dec 2019	**FIGURE B-1**	

SUD-MTO GSD GLDR_LDN.GDT



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C207-1	5	318.1

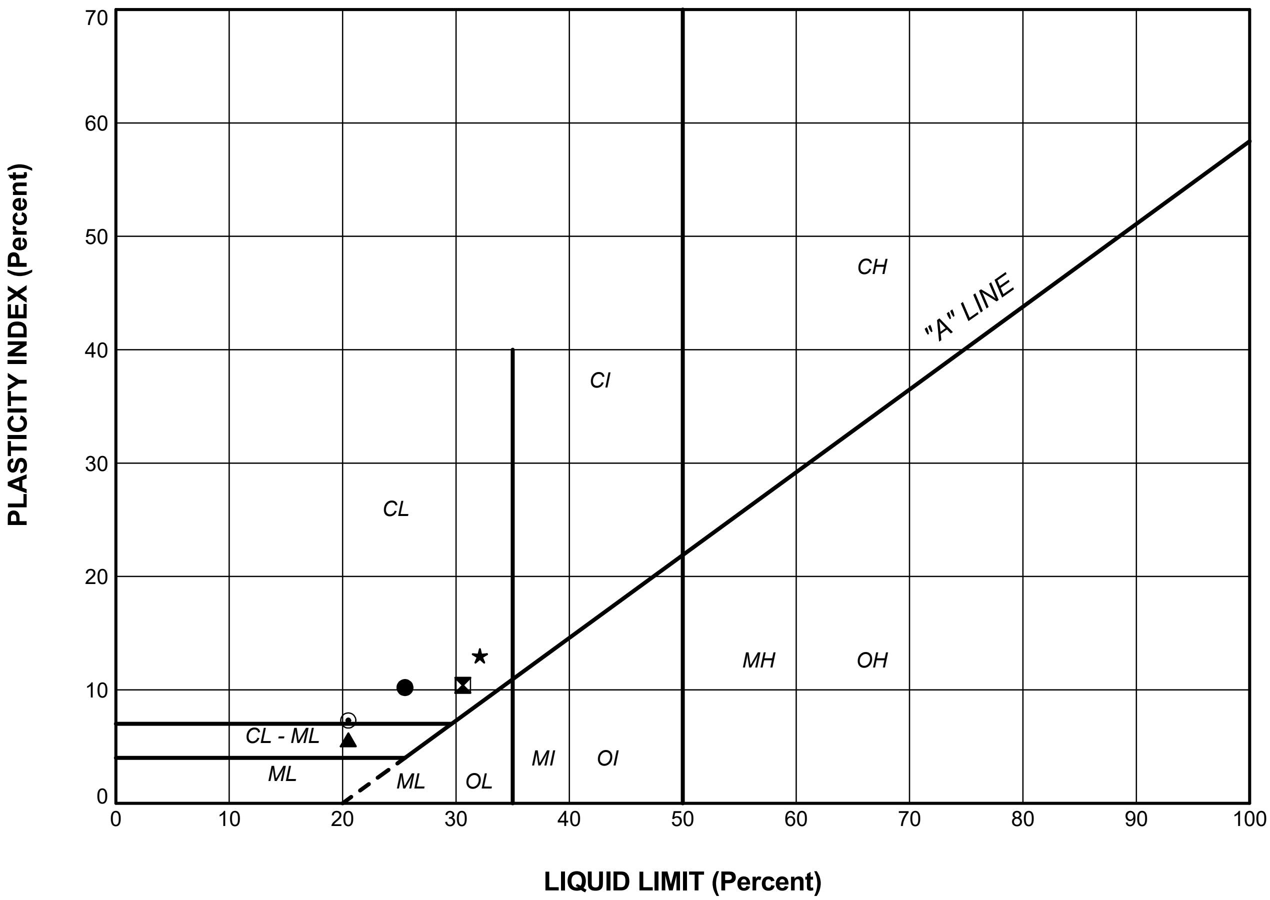
PROJECT
HIGHWAY 66
STATION 12+290
TOWNSHIP OF LEBEL CULVERT

TITLE
GRAIN SIZE DISTRIBUTION
Silt (Upper Deposit)

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Dec 2019	SCALE N/A	REV.
CHECK	AB	Dec 2019		
APPR	JMAC	Dec 2019	**FIGURE B-2**	

SUD-MTO GSD 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
●	C207-1	6	25.5	15.3	10.2
⧗	C207-1	8	30.6	20.2	10.4
▲	C207-2	4	20.5	14.9	5.6
★	C207-2	7	32.1	19.1	13.0
⊙	C207-3	4	20.5	13.2	7.3

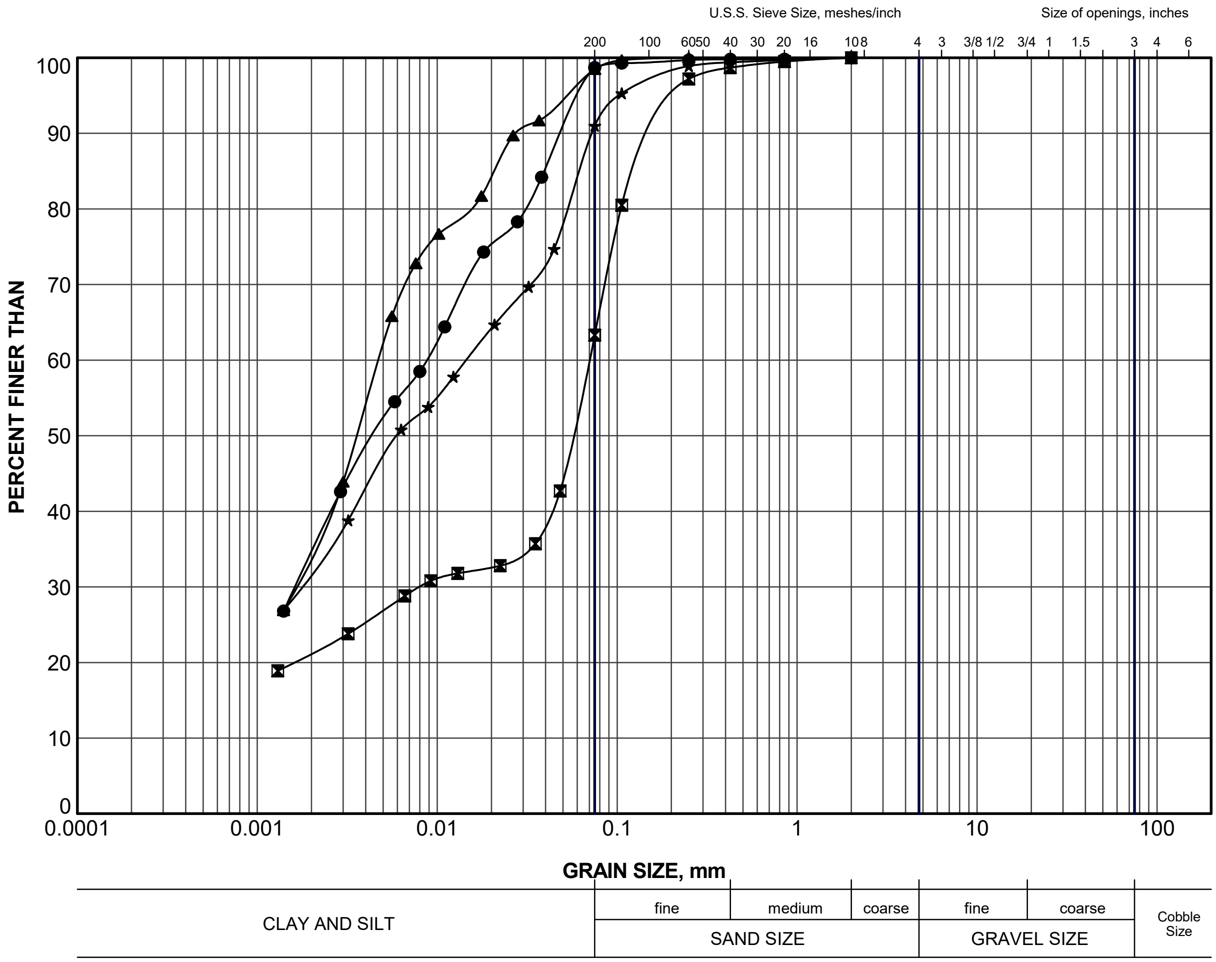
PROJECT
HIGHWAY 66
STATION 12+290
TOWNSHIP OF LEBEL CULVERT

TITLE
PLASTICITY CHART
Clayey Silt

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ	
DRAWN	TR	Dec 2019	SCALE	N/A	REV.
CHECK	AB	Dec 2019	**FIGURE B-3**		
APPR	JMAC	Dec 2019			

SUD-MTO PL GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C207-1	6	317.3
⊠	C207-2	4	318.6
▲	C207-2	7	315.5
★	C207-3	4	318.2

PROJECT

HIGHWAY 66
STATION 12+290
TOWNSHIP OF LEBEL CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

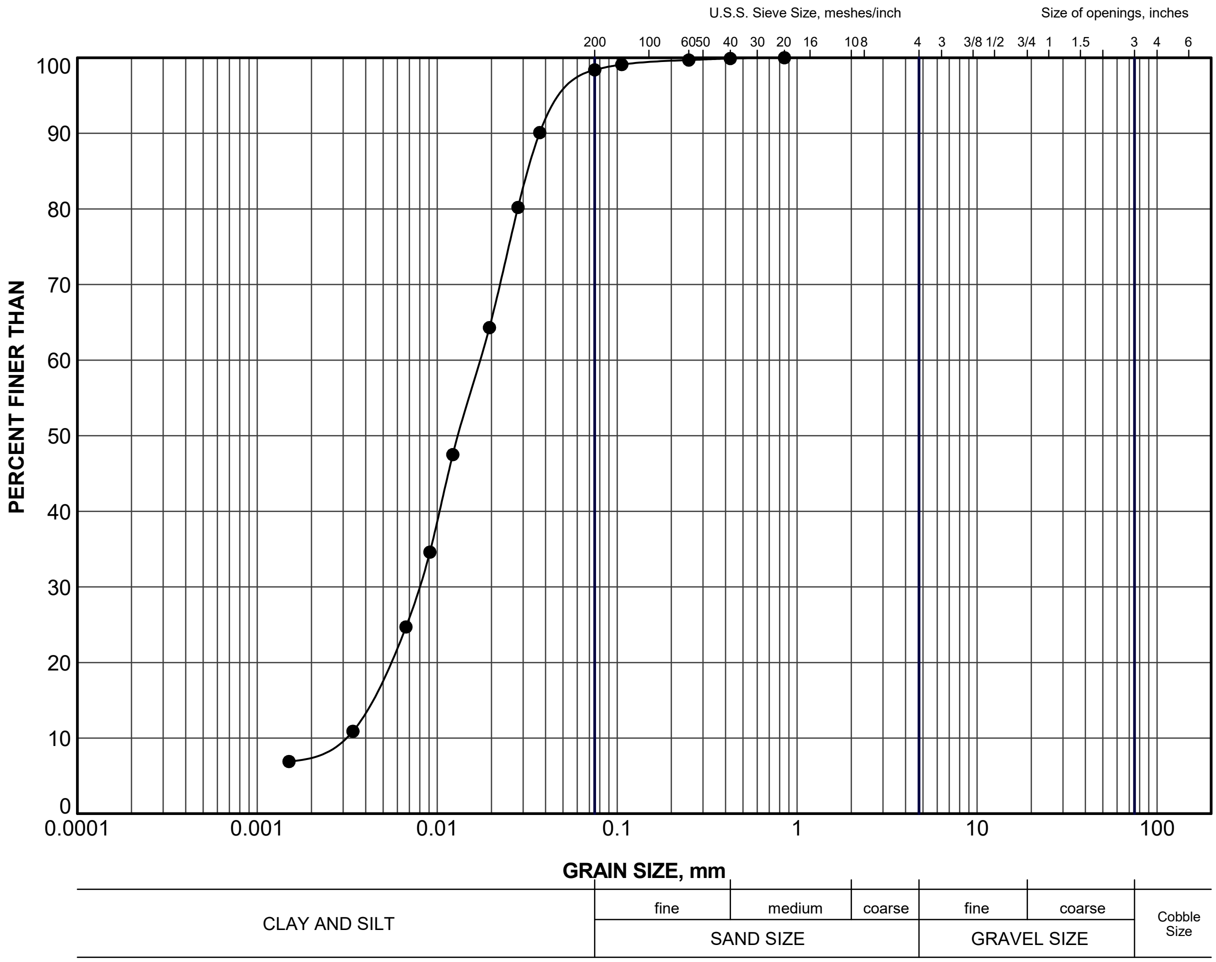
Clayey Silt to Clayey Silt with Sand

GOLDER

SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Dec 2019	SCALE N/A	REV.
CHECK	AB	Dec 2019		
APPR	JMAC	Dec 2019	FIGURE B-4	

SUD-MTO GSD GLDR_LDN.GDT



LEGEND

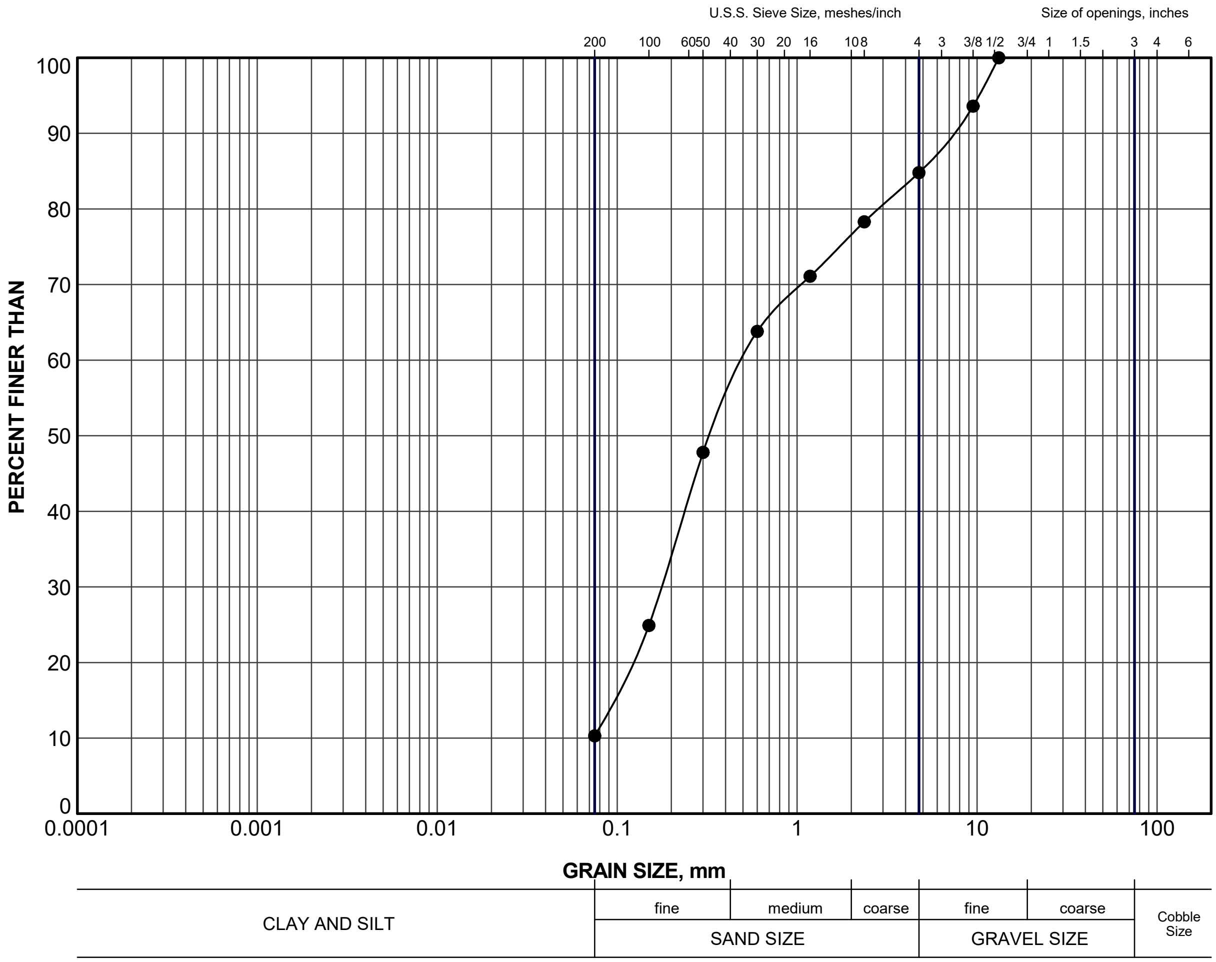
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C207-3	7	313.6

PROJECT	HIGHWAY 66 STATION 12+290 TOWNSHIP OF LEBEL CULVERT
TITLE	**GRAIN SIZE DISTRIBUTION** Silt (Lower Deposit)

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Dec 2019	SCALE N/A	REV.
CHECK	AB	Dec 2019		
APPR	JMAC	Dec 2019	**FIGURE B-5**	

SUD-MTO GSD GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C207-2	10	310.9

PROJECT

HIGHWAY 66
STATION 12+290
TOWNSHIP OF LEBEL CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

Sand (Lower Deposit)

GOLDER
SUDBURY, ONTARIO

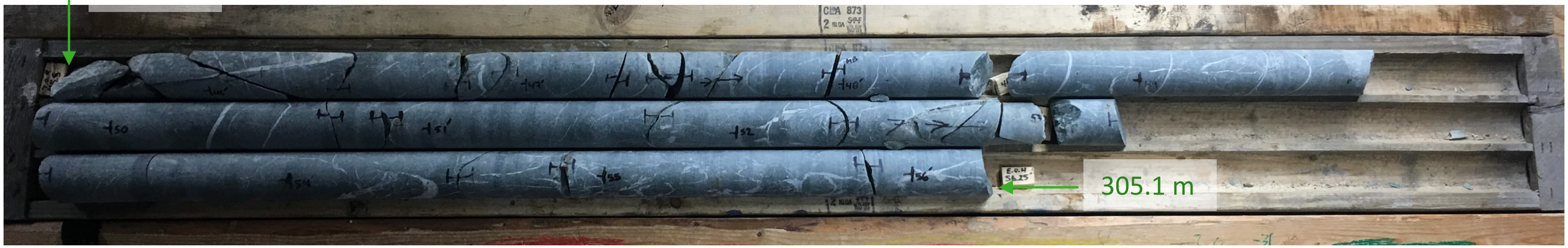
PROJECT No.		1896349	FILE No.	1896349.GPJ
DRAWN	TR	Dec 2019	SCALE N/A	REV.
CHECK	AB	Dec 2019		
APPR	JMAC	Dec 2019	**FIGURE B-6**	

SUD-MTO GSD GLDR_LDN.GDT

Bedrock Core Photographs

Figure B-7

Highway 66, Station 12+290, Township of Lebel Culvert



Borehole C207-1

Elevation 308.3 m to 305.1 m

Borehole C207-2

Elevation 308.5 m to 305.4 m

0 m   0.75 m   1.5 m

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B8X6867
Report Date: 2019/01/02

Golder Associates Ltd
Client Project #: 1896349 PHASE 2100
Site Location: HWY 66
Sampler Initials: MR

RESULTS OF ANALYSES OF SOIL

Maxxam ID		IOM456			IOM456			IOM457		
Sampling Date		2018/12/12 11:15			2018/12/12 11:15			2018/12/12 10:30		
COC Number		62181			62181			62181		
	UNITS	**C209-1A SA1**	**RDL**	**QC Batch**	**C209-1A SA1 Lab-Dup**	**RDL**	**QC Batch**	**C207-1 SA1**	**RDL**	**QC Batch**
CONVENTIONALS										
Sulphide	ug/g	1.49 (1)	0.50	5910060				<0.50 (1)	0.50	5910060
Calculated Parameters										
Resistivity	ohm-cm	2300		5892786				5000		5892786
CONVENTIONALS										
Redox Potential	mV	240	N/A	5899469				240	N/A	5899469
Inorganics										
Soluble (20:1) Chloride (Cl-)	ug/g	220	20	5896372				39	20	5896372
Conductivity	umho/cm	443	2	5898721	447	2	5898721	201	2	5898721
Available (CaCl2) pH	pH	6.65		5898742				7.19		5898742
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	5896374				<20	20	5896374
Physical Testing										
Moisture-Subcontracted	%	20	0.30	5910059				18	0.30	5910059

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable
(1) The soil extract was prepared in the Maxxam Burnaby facility. The analysis was performed in the Maxxam Calgary facility.

Maxxam ID		IOM457	
Sampling Date		2018/12/12 10:30	
COC Number		62181	
	UNITS	**C207-1 SA1 Lab-Dup**	**QC Batch**
Inorganics			
Available (CaCl2) pH	pH	7.24	5898742

QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

APPENDIX C

Non-Standard Special Provisions and Notice to Contractor

OBSTRUCTIONS – Item No.

Notice to Contractor

The contactor shall be alerted to the presence of cobbles and boulders within the embankment fill deposit, as encountered in Borehole C207-2 near the existing culvert outlet, on the alignment of the culvert crossing Highway 66, Station 12+290, Township of Lebel culvert. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for open cut excavations, installation of temporary protection systems.

DEWATERING SYSTEM - Item No.
TEMPORARY FLOW PASSAGE SYSTEM - Item No.

Special Provision No. 517F01 July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

Section 517.01 of OPSS 517 is deleted in its entirety and replaced with the following:

This specification covers the requirements for the design, operation, and removal of a dewatering or temporary flow passage system or both to control water during construction, and the control of the water prior to discharge to the natural environment and sewer systems.

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

Subsection 517.04.01 of OPSS 517 is amended by deleting the first paragraph in its entirety and replacing it with the following:

A dewatering or temporary flow passage system or both shall be designed to control water at the locations specified in the Contract Documents and at any other location where a system is necessary to complete the work. The design of the system shall be sufficient to permit the work at each location to be carried out as specified in the Contract Documents.

Subsection 517.04.01 of OPSS 517 is further amended by deleting the second last paragraph in its entirety and replacing it with the following:

Temporary flow passage systems shall be designed, as a minimum, for a 2 year design storm return period and groundwater discharge, except for the work specified in Table A. For the work specified in Table A, the temporary flow passage system shall be designed, as a minimum, for the design storm return period specified in Table A and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Intensity-Duration Factor (IDF) curve location, site specific minimum return period, return period flow estimates, and other information is provided in Table A. The IDF information can be accessed through the MTO IDF Curve Look up Tool on the Drainage and Hydrology page of MTO's website. The return period flow estimates do not include flow volumes from groundwater discharge. The Owner specifically excludes these flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

Table A

<table>
<tr><td>IDF Curve Location</td><td colspan="3">Latitude: 48.163524</td><td colspan="3">Longitude: -79.993886</td></tr>
<tr><td colspan="7">Temporary Flow Passage Systems</td></tr>
<tr><td rowspan="2">Site Name /
Station Reference</td><td rowspan="2">Minimum
Return Period
(Years)</td><td colspan="4">Return Period Flow Estimates (m^3/s)</td><td rowspan="2">Design Engineer
Requirements
(Note 1)</td></tr>
<tr><td>2
Year</td><td>5
Year</td><td>10
Year</td><td>25
Year</td></tr>
<tr><td>Highway 66, Station 12+290,
Township of Lebel Culvert
Replacement</td><td>***</td><td>****</td><td>****</td><td>****</td><td>****</td><td>Yes</td></tr>
<tr><td colspan="7">Dewatering Systems</td></tr>
<tr><td>Site Name /
Station Reference</td><td colspan="5">Preconstruction Survey Distance (Note 2)
(m)</td><td>Design Engineer
Requirements
(Note 1)</td></tr>
<tr><td>Highway 66, Station 12+290,
Township of Lebel Culvert
Replacement</td><td colspan="5">N/A</td><td>Yes</td></tr>
<tr><td colspan="7">Note:
1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.
2. “N/A” indicates a preconstruction survey is not required.</td></tr>
</table>

NOTES TO DESIGNER:

Designer Fill-in for Table A:

* Enter the latitude and longitude co-ordinates of the IDF Curve as obtained using the MTO IDF Curve Look up Tool. Create additional tables, as necessary, if more than one (1) IDF curve was used on the contract (i.e. on a very long contract there may be two IDF curves used to better represent rainfall events for two (2) different sections of the contract).

** Fill-in site name, work, and station reference as appropriate for the dewatering system and/or temporary flow passage system item locations.

*** For temporary flow passage system item locations, fill-in the minimum design storm return period for the site based on MTO Drainage Design Standard TW-1.

**** For temporary flow passage system item locations, fill-in the design flow rate estimates for the various return periods.

***** Insert “Yes” when recommended by the Foundation Engineer. Insert “No” otherwise.

****** Fill-in the required distance for preconstruction survey if recommended by the Foundation Engineer. Fill-in “N/A” if not recommended.

WARRANT: Always with these tender items.

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