



FOUNDATION INVESTIGATION AND DESIGN REPORT

**Highway 66, Station 18+386, Township of Gauthier
Culvert Replacement
Ministry of Transportation, Ontario
GWP 5210-14-00**

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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 66, STA 18+386, TOWNSHIP OF GAUTHIER
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5210-14-00

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 18+386, in the Township of Gauthier, approximately 6.9 km east of the Highway 66 and Highway 672 intersection. 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 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 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 creek flows in a north to south direction.

The existing culvert consists of a 1.5 m diameter, 40.2 m long Structural Plate Corrugated Steel Pipe (SPCSP) with a 6.2 m long CSP extension at the inlet. As interpreted from AECOM's centreline survey profile drawings, the culvert inlet (north end) and outlet (south end) inverts are at approximately Elevations 268.1 m and 268.0 m, respectively. The highway grade at the culvert location is at approximately Elevation 276.2 m and the highway embankment is about 8 m high relative to the culvert invert. In general, the topography within the vicinity of the culvert consists of relatively flat, thick forested terrain. The ground surface conditions at select locations of the culvert area are shown on Photographs 1 to 4.

At the time of the subsurface exploration field work, the embankment side slopes appeared to be grass covered with some local vegetation growing adjacent to the toes of slope and exhibit some localized shallow erosion gullies. The embankment appeared to be stable with no signs of slope instability or roadway settlement.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out on May 1 to 22, 2019, during which time five boreholes (Boreholes C260-1 to C260-5) were advanced at the approximate locations shown on Drawing 1.

Boreholes C260-1 to C260-3 were advanced from the roadway grade through the roadway embankment and Boreholes C260-4 and C260-5 were advanced near the north and south toes of the highway embankment slopes adjacent to the culvert inlet and outlet, respectively. The boreholes were advanced using a track mounted CME-55LC drilling rig supplied and operated by George Downing Estate Drilling of Grenville-Sur-La-Rouge, Quebec. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

The boreholes were advanced using 76 mm and 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 an automatic or cathead hammer in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). In-situ vane shear tests were carried out in cohesive soils for determination of undrained shear strengths in accordance with Standard Test Method for Field Vane Shear Test in Saturated Fine Grained Soils (ASTM 2573), using an MTO standard “N”-size vane. The water level inside the augers was observed during and upon completion of drilling operations and upon removal of the augers. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 (wells) as amended. The boreholes drilled through Highway 66 were capped at the roadway 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 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, Atterberg limits, organic content, and consolidation (oedometer) was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable. In addition, one soil sample was submitted to Bureau Veritas Laboratories (formerly Maxxam) in Sudbury, Ontario, 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 by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevation at each borehole location was surveyed by Golder relative to the highway and culvert centreline, with the elevation of the 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)
C260-1	5330605.1 (48.107997)	394577.9 (-79.794308)	276.2	20.4
C260-2	5330601.3 (48.107965)	394564.5 (-79.794488)	276.1	15.9
C260-3	5330600.0 (48.107951)	394581.4 (-79.794262)	276.3	15.9
C260-4	5330628.1 (48.108206)	394567.3 (-79.794445)	270.1	9.6
C260-5	5330579.1 (48.107765)	394564.5 (-79.794493)	271.6	9.6

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)¹ mapping, the culvert site is located within a glaciolacustrine plain, with the subsoils consisting primarily of clay.

Based on geological mapping (MNDM)², the site is underlain by mafic to intermediate metavolcanics 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 and in-situ (field) vane undrained shear strengths) 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 and cross-section 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 100 mm thick layer of asphalt pavement was encountered at ground surface in the roadway boreholes (Boreholes C260-1 to C260-3) between Elevations 276.3 m and 276.1 m. A 7.1 m to 9.0 m thick layer of embankment fill, consisting of an upper 0.5 m thick layer of sand and gravel underlain by layers of silt and sand to silty sand to sand, was encountered below the asphalt in the roadway boreholes; and a 0.8 m thick layer of sand fill was encountered at ground surface in Borehole C260-5, at Elevation 271.6 m.

Asphalt coated particles were encountered within the sand and gravel fill in all three roadway boreholes between depths of 0.1 m and 0.2 m. A 0.8 m and 0.4 m thick layer of asphalt and sand fill was encountered within the embankment fill in Boreholes C260-2 and C260-3 at depths of 3.7 m and 4.1 m below ground surface (Elevation 272.4 m and 272.2 m), respectively. The embankment fill contained trace organics below a depth of 5.3 m (Elevation 270.8 m) in Borehole C260-2 and contained trace organics, trace rootlets, and trace wood chips below a depth of 5.3 m (Elevation 271.0 m) in Borehole C260-3. A 0.3 m and 0.15 m thick piece of timber was recovered in Borehole C260-1 below the sand fill at a depth of about 7.3 m and 7.7 m below ground surface

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.

(Elevations 268.9 m and 268.5 m). Based on limited to no sample recovery below this depth, it is inferred that the timber extends to a depth of 9.1 m below ground surface (Elevation 267.1 m) and that the timber may be part of a possible corduroy road.

The SPT “N”-values measured within the silt and sand to sand fill range from 2 blows to 23 blows per 0.3 m of penetration, indicating a very loose to compact compactness condition. The STP “N”-values measured within the asphalt and sand layer within the sand fill are 19 blows and 54 blows for 0.3 m of penetration, indicating a compact to very dense compactness condition. The STP “N”-values measured within the layer of timbers encountered in Borehole C260-1 range from 22 blows to 57 blow per 0.3 m of penetration, suggesting a compact to very dense condition of the timber/soil infilling penetrated.

Grain size distribution testing was carried out on six samples of the silt and sand to sand fill and the results are presented on Figure B-1 in Appendix B. The natural moisture content measured on six samples of the silt and sand to sand fill range from about 5 per cent to 22 per cent.

4.2.2 Organic Silt to Organic Silty Sand

A 2.2 m and 1.4 m thick organic deposit comprised of organic silt to organic silty sand, trace gravel, was encountered at ground surface in Borehole C260-4 and below the sand fill in Borehole C260-5, at Elevations 270.1 m and 270.8 m, respectively.

The SPT “N”-values measured within the organic silt to organic silty sand deposit range from 1 blow to 5 blows per 0.3 m of penetration indicating a very loose to loose compactness condition.

The natural moisture content and the organic content measured on one sample of the organic silt to organic silty sand deposit are about 39 per cent and about 8 per cent, respectively.

4.2.3 Clayey Silt

A 1.2 m thick deposit of clayey silt, trace sand and trace organics was encountered below the organic silt to organic silty sand deposit in Borehole C260-5 at Elevation 269.4 m.

The SPT “N”-value measured within the clayey silt deposit is 6 blows for 0.3 m of penetration, suggesting a firm consistency.

The natural moisture content and the organic content measured on one sample of the clayey silt deposit are about 28 per cent and about 3 per cent, respectively.

4.2.4 Varved Clay and Clayey Silt

A 4.2 m to 6.1 m thick (where fully penetrated), and up to 7.4 thick, cohesive deposit of varved clay and clayey silt, trace sand was encountered below the fill/timber in Boreholes C260-1 to C260-3, below the organic silt to organic silty sand deposit in Borehole C260-4 and below the clayey silt deposit in Borehole C260-5, at depths between 2.2 m and 9.1 m below ground surface, between Elevations 268.9 m and 267.1 m. The clay and clayey silt varves range in thickness from about 5 mm to 25 mm. Borehole C260-4 and C260-5 were terminated within the varved clay and clayey silt deposit.

The SPT “N”-values measured within the varved clay and clayey silt deposit range from 0 blows (weight of hammer – WH) to 7 blows per 0.3 m of penetration. In-situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 38 kPa to 96 kPa and sensitivity ranging from about 2 to 3. The SPN “N”-values, together with the field vane test results, suggest that the varved deposit has a firm to stiff consistency.

Grain size distribution testing was carried out on three samples of the combined clay and clayey silt portions of the varved deposit and the results are presented on Figure B-2. Atterberg limit testing was carried out on eight samples of the combined clay and clayey silt portions of the varved deposit; the test results, which are plotted on Figure B-3A, indicate that the combined soil deposit consists of silty clay of intermediate plasticity and clay of high plasticity. Atterberg limit test was also carried out on one sample of the clayey silt portion of the varved deposit, on one sample of the clay portion of the varved deposit; the test results, which are plotted on Figures B-3B and B-3C, indicate that the varves consist of clayey silt of low plasticity and clay of high plasticity, respectively. The Atterberg limits test results are summarized below with the natural moisture content testing results.

Soil Matrix	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Classification	Moisture Content (%)
Clay and Clayey Silt (Combined)	35 – 53	19 – 24	13 – 31	Intermediate to High Plasticity	33 – 49
Clayey Silt (Component)	32	21	11	Low Plasticity	31
Clay (Component)	77	28	49	High Plasticity	74

One laboratory consolidation (oedometer) test was carried out on a sample of the varved (combined) silty clay to clay and silt deposit obtained from Borehole C260-5 (Sample 5). The results of the consolidation test are provided on Figure B-4 in Appendix B and are summarized below.

Borehole / Sample No.	Sample Elevation (m)	W (%)	γ (kN/m ³)	σ_{vo}' (kPa)	σ_p' (kPa)	e_o	C_c	C_r	c_v (cm ² /s)
C260-5 / Sample 5	266.0	43.5	17.5	50	180	1.2	0.59	0.03	0.009

Notes:

1. Final vertical overburden pressure and coefficient of consolidation are dependent on final loading conditions at the site, and assume no embankment widening or grade raise at this stage.

Where: w_n Natural Moisture content (%)
 γ Unit weight (kN/m³)
 σ_{vo}' Effective overburden pressure (kPa)
 σ_p' Preconsolidation pressure (kPa)
 OCR Overconsolidation Ratio
 e_o Initial void ratio
 C_c Compression index
 C_r Recompression index
 c_v Coefficient of consolidation in the normally consolidated range (cm²/s)

4.2.5 Layered Clayey Silt and Silt

A 2.6 m to 7.1 m thick deposit of layered cohesive clayey silt and non-cohesive silt was encountered below the varved clay and clayey silt deposit in Boreholes C260-1 to C260-3, between Elevations 263.0 m and 262.8 m. Boreholes C260-1 to C260-3 were terminated within this deposit between Elevations 260.4 m and 255.8 m.

The SPT “N”-values measured within the layered clayey silt and silt deposit range from 3 blows to 14 blows per 0.3 m of penetration. In-situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 77 kPa to 91 kPa, with two test results being greater than 100 kPa, and sensitivity of about 2. The SPN “N”-values, together with the field vane test results, suggest that the layered clayey silt and silt deposit has a stiff consistency / very loose to compact compactness condition.

Grain size distribution testing was carried out on two samples of the clayey silt portion of the layered deposit and on two samples of the silt portion of the layered deposit, and the results are presented on Figure B-5A and B-5B, respectively. Atterberg limits and moisture content testing was also carried out on two samples of the clayey silt portion of the layered deposit and on two samples of the silt portion of the layered deposit. The results of the Atterberg limits testing are presented on Figures B-6A and B-6B, respectively, and are summarized below with the natural moisture content testing results. One sample of the silt portion of the deposit indicates a non-plastic result.

Soil Matrix	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Classification	Moisture Content (%)
Clayey Silt	29 and 32	19 and 20	9 and 13	Low Plasticity	28 and 32
Silt	25	21 and Non-Plastic	4	Non-Plastic to Slightly Plastic	20 and 31

4.3 Groundwater Conditions

The unstabilized groundwater levels relative to ground surface measured inside the open boreholes upon completion of drilling or/and upon removal of the augers are summarized below. Groundwater and creek 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)
C260-1	6.3	269.9
C260-2	Dry	-
C260-3	10.1 / 6.0 ¹	266.2 / 270.3 ¹
C260-4	0.1 ¹	270.0 ¹
C260-5	0.2 ¹	271.4 ¹

Notes:

1. Water level upon removal of augers.

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of the varved clay and clayey silt, recovered from Borehole C260-1. The soil sample was submitted to Bureau Veritas Laboratories of Sudbury, Ontario 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 ($\mu\text{mho/cm}$)	Soluble Sulphate (SO ₄) Content ($\mu\text{g/g}$)	Chloride (Cl) Content ($\mu\text{g/g}$)	Sulphide ($\mu\text{g/g}$)	pH
C260-1	12	9.1 – 9.8	4,000	252	<20 ¹	61	<0.30 ¹	8.1

Notes:

1. The sulphate and sulphide concentrations are below the reportable detection limit of 20 $\mu\text{g/g}$ and 0.30 $\mu\text{g/g}$, respectively.

Redox potential testing was carried out on the sample noted above and yielded a value of -200.8 mV. The redox potential laboratory test results, provided by Eurofins Environmental Testing, can be found in Appendix B.

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. This Foundation Investigation Report was prepared by Ms. Anastasia Poliacik, P.Eng., a geotechnical engineer of Golder. Mr. André Bom, P.Eng., reviewed the report. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant with Golder, conducted an independent quality control review of this report.

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PART B
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HIGHWAY 66, STA 18+386, TOWNSHIP OF GAUTHIER
CULVERT REPLACEMENT
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of the culvert crossing Highway 66 at about Station 18+386, Township of Gauthier, Ontario. These 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 Options

The existing culvert to be replaced consists of a 1.5 m diameter, 40.2 m long Structural Plate Corrugated Steel Pipe (SPCSP) with a 6.2 m long CSP extension at the inlet. Based on the drawings provided by AECOM via email on August 14, 2019, and our site observations during the foundation exploration work, the existing culvert crosses the existing Highway 66 embankment on a skew. At the time of the subsurface exploration field work, the embankment side slopes appeared to be grass covered with some local vegetation growing adjacent to the toes of slope and exhibit some localized shallow erosion gullies. The embankment appeared to be stable with no signs of slope instability or roadway settlement.

The existing embankment north side slope at the culvert location is inclined at about 2 Horizontal to 1 Vertical (2H:1V) and is about 8 m high relative to the culvert invert at the inlet, and the existing embankment south side slope at the culvert location is inclined at about 3H:1V to 2H:1V and is about 8 m high relative to the culvert outlet. The invert at the inlet and outlet of the existing culvert is about Elevations 268.1 m and 268.0 m, respectively.

It is understood from AECOM that the existing culvert is undersized, and the proposed replacement culvert will cross the highway on or near the same alignment and will consist of a 2.8 m wide by 1.8 m high concrete box culvert. The replacement culvert will have an invert level about 300 mm below the existing invert elevations, at Elevation 267.8 m and 267.7 m at the culvert inlet and outlet, respectively.

We understand from AECOM that a temporary roadway protection system is being considered 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*, the culvert crosses Highway 66 at Station 18+386, the highway and foundation system 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 Installation Methods

Alternative methods of culvert installation, such as by open cut construction and trenchless method have been considered for this site, as presented in Table 1, attached. Open cut construction is considered suitable to accommodate the box culvert. Based on the existing ground surface profile along the proposed culvert alignment, the existing soil cover over the top of the pipe culverts relative to the highway surface grade is about 6.0 m, and the ratio of existing soil cover-to-pipe diameter is about 4.0. An assumed proposed replacement pipe culvert of about 2.0 m in diameter would result in a soil cover-to-tunnel diameter ratio of about 2.7, assuming a 2.2 m diameter liner is used, which is considered a suitable condition for a trenchless installation method, and the actual ratio will depend on the installation method and size of liner actually used.

Recommendations for the foundation/geotechnical design of a box culvert installed by open-cut construction are provided in Section 6.4 and a pipe culvert installed by trenchless methods are provided in Section 6.5.

6.4 Box Culvert

6.4.1 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 300 mm below the existing invert level (i.e., Elevations 267.8 m and 267.7 m at the culvert inlet and outlet, respectively). Assuming a 0.2 m thick base slab, the proposed replacement culvert will be founded at about Elevation 267.6 m and 267.5 m and the culvert inlet and outlet, respectively. It is recommended that the box culvert and levelling pad be constructed on a minimum 300 mm thick bedding layer at Elevations 267.3 m and 267.2 m.

It is not necessary to found a pre-cast 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, any topsoil, timber, fill, or deleterious material must be removed, and the subgrade should be inspected by a qualified geotechnical engineer. 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.

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

6.4.2 Geotechnical Resistances

A 2.8 m wide box culvert box culvert, 40.2 m long, placed on a 300 mm thick bedding layer over 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 40 kPa. The factored serviceability geotechnical resistance considers both the influence factor and the SLS factor from CHBDC (2014).

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.

6.4.3 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 6.3.1. For a precast concrete box culvert founded on the compacted granular bedding layer, the sliding resistance may be calculated based on the unfactored coefficient of friction, $\tan \Phi'$, which can be taken as follows, as interpreted from NAVFAC (1982):

- Precast concrete box culvert to compacted granular bedding (Granular 'A' or Granular 'B' Type II): $\tan \delta = 0.5$

6.4.4 Lateral Earth Pressures for Design

The lateral earth pressures acting on the walls of the 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 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 wingwalls or headwalls if required at this site, (retaining walls that are restrained), granular fill should be placed in a zone with the width equal to at least 2.4 m (equivalent to the depth of frost penetration as interpreted from OPSD 3090.100 (*Foundation Frost Penetration Depth for Northern Ontario*), behind the back of the wall on Figure C6.20(a) of the Commentary to the CHBDC (2014). For unrestrained walls, fill should be placed within the wedge-shaped zone defined by a line drawn flatter than 1 horizontal to 1 vertical (1H:<1V) extending up and back from the rear face of the footing or pile cap on Figure C6.20(b) of the Commentary to the CHBDC (2014).

- For restrained walls in box culvert design, granular fill should be placed in a zone with the width equal to at least 2.4 m behind the back of the wall (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)*.

6.4.5 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.

Global stability analyses of the reconstructed embankment in the culvert area were carried out using the commercially available program SLIDE 2018, produced by Rocscience, Inc., employing the Morgenstern-Price method of analysis. As the replacement culvert is not a structural culvert, a target minimum Factor of Safety of 1.3 was considered appropriate for adoption for the design of the embankment slopes under static conditions. As the subsurface soils underlying the culvert area are comprised of a deposit of varved clayey silt and clay, a reduction factor of 25 per cent was applied to the average undrained shear strength measured by the field vanes (i.e., approximate average of 50 kPa, factored value of 40 kPa), as interpreted from published technical literature on stratified clay deposits by Lo and Milligan (1967), considering that the varved clay deposit is present immediately under the embankment/culvert footprint.

The parameters used in the global slope stability analyses and the results of global slope stability analyses carried out for the short-term (temporary) condition is shown in Figure 1 and for the long-term (permanent) condition is shown in Figure 2. The slope stability analyses indicate that a Factor of Safety greater than 1.3 was calculated against global instability. The proposed reconstructed embankment (not widened or raised) will be stable from a slope stability perspective if it is reconstructed of granular material and with side slopes at an inclination no steeper than 2H:1V.

6.4.6 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, cobbles/boulders, 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 existing soils at the proposed bedding elevation are anticipated to consist of silty sand fill, varved clay, and clayey silt, and possibly timber as encountered in Borehole C260-1. It is anticipated that minimal sub-excavation will be required to found the culvert bedding on the native varved clay and clayey silt deposit, which 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.

6.4.7 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, silt and sand fill, and potentially cobbles and boulders. The existing cobbles and 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*) 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 Assessment of Trenchless Installation Methods

6.5.1 Subsurface Conditions and Tunnelman's Ground Classification

We understand that consideration may be given to replacement of the culvert by a trenchless method. The soil conditions encountered along the proposed culvert alignment are relatively variable, and generally include timber at Borehole C260-1, varved clay and clayey silt at Borehole C260-2, silty sand fill at Borehole C260-3, organic silt to organic silty sand at Borehole C260-4, and clayey silt at Borehole C260-5. The groundwater level measured inside the open boreholes on completion of drilling in Boreholes C260-4 and C260-5, nearest the existing culvert, are Elevations 270.0 m and 271.4 m. Therefore, the groundwater level is expected to be at about the proposed culvert/tunnel horizon (i.e., at about the culvert invert).

Correlating the soil classification noted above with the Tunnelman's Ground Classification System (Heuer, 1974, modified from Terzaghi, 1950), the varved clay and clayey silt deposit and the clayey silt deposit can be considered "squeezing", and the silty sand fill and organic silt to organic silty sand deposit can be considered "running" to "cohesive running" above the groundwater level and "flowing" below the groundwater table. It is expected that these soils, when exposed fully above groundwater or after dewatering, may be able to stand unsupported for a limited length of time prior to "running" or exhibiting "cohesive running" behaviour (in the order of a few minutes to hours). Below groundwater levels, the existing embankment fill and native soils will be unable to stand unsupported for any length of time and will exhibit "flowing" behaviour and destabilize any overlying materials.

6.5.2 General Description of Trenchless Technologies

The contractor should be responsible for choosing the method and equipment for the crossing trenchless installation, unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted by the contractor, however this report provides guidance on the influence of ground behaviour on some possible pipe culvert tunnel/trenchless installation methods. It should not be construed that the contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information from the investigation. Trenchless work should be carried out in accordance with MTO's SP titled "*Pipe Installation by Trenchless Method*" provided in Appendix C for inclusion into the Contract Documents.

For the proposed culvert installation for this project, a number of trenchless installation methods were considered for completeness, though the practicality of some of these techniques for this site may be doubtful if not entirely unsuitable. The trenchless techniques considered from a general perspective include horizontal directional drilling (HDD), horizontal auger boring – Jack and Bore, pipe ramming, micro-tunneling by MTBM, pilot tube micro-tunneling (PTMT), tunnel boring machine (TBM), tunnel digging machine (TDM - i.e., open face shield tunnelling), and manual tunnelling (MTD). In brief, these construction methods involve the following:

- **Horizontal Directional Drilling (HDD):** HDD involves drilling of a relatively small diameter pilot hole (on the order of 100 to 150 mm) using a remotely controlled and steerable drill bit on a flexible string of drill rods, while the bore is supported using a bentonite slurry. Once the pilot hole is complete, the bore is typically reamed in one or more passes to a larger diameter, and then the final pipe is pulled through the bore (using the drill rods to pull the pipe into place). HDD equipment is available for drilling in both bedrock and overburden, but drilling is very challenging in bouldery ground. Deep entrance and exit pits are generally not required; however, larger laydown areas are required to install the final pipe, and the crossing typically needs to be longer to accommodate the shallow entry and exit angles for the drilling equipment (on the order of 10 to 30 degrees from horizontal). Bores are typically limited to less than 1 m in diameter. Control of line and grade to the degree needed for gravity flow at shallow storm or sanitary sewer slopes may be problematic.
- **Horizontal Auger Boring – “Jack and Bore”:** In Ontario, a traditional “jack and bore” operation involves pushing a steel pipe (casing) horizontally into the ground by jacking while simultaneously cutting the ground with an auger head operating near the leading end of the steel pipe. The spoil is generally removed from within the casing using an auger boring machine. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. Jacking and receiving pits are required. Typically, there is limited ability to steer the casing during jacking. This method is only applicable to construction in soils and may not be feasible in bouldery soils (e.g., glacial till). In some cases, contractors will run the auger cutting head in front of the lead end of the casing to advance the pipe in difficult ground; however, this approach can lead to high risks for ground losses (settlement, sinkholes). This method is also not feasible in running or flowing ground (dry or saturated sand and silt).

In some cases, traditional “jack and bore” equipment is supplemented with a specialized rotating cutting head, sometimes referred to as a “small boring unit”. These cutting heads are welded to the lead end of steel casings, can sometimes include limited alignment adjustment capabilities, and can be fitted with rock disc cutters. In the right ground conditions (e.g., hard glacial till, weathered rock), the small boring heads can be advantageous. However, these systems are not well suited to and should not be used in saturated and potentially flowing ground conditions. Further, these systems should not be confused with micro-tunnelling systems that operate using very different principles of ground support.

- **Pipe Ramming:** Pipe ramming uses a pneumatic tool to hammer a steel pipe or casing into the ground. The pipe is almost always driven “open” to thereby direct the soil into the pipe interior instead of compacting it outside the pipe. The leading edge of the pipe typically has a small overcut to reduce friction between the carrier pipe and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting. Pipe ramming methods are also better suited for penetrating through/displacing potential obstructions, such as cobbles and boulders in comparison to jack and bore installation method, though this method can still be obstructed by cobbles and boulders depending on their size, number, and their positions relative to the pipe leading edge. Pipe ramming has also been used to accomplish culvert replacement in which a larger diameter pipe is rammed through the ground immediately around an existing pipe and both the existing pipe and ground are removed from within the rammed pipe by manual methods. This technique is sometimes called “pipe eating” or “pipe swallowing.” Partial or full removal of materials from within the pipe, to facilitate driving, should not be carried out if the ground through which the pipe is being driven consists of saturated granular soils (silt, sand, gravel). As with traditional jack and bore methods, flowing ground conditions and/or operating the cleanout augers beyond, at or near the leading edge of the casing can result in significant ground losses, excessive surface settlement and, in some cases, sinkholes that propagate to the surface.

- **Micro-tunnelling Boring Machine (MTBM):** MTBM is a method of installing pipes in bores ranging from 0.6 to 3 metres in diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic slurry at the cutting face to minimize ground losses. The process is essentially remote-controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry, and the necessity for personnel to enter the bore is eliminated. Micro-tunnelling equipment is generally more suited to tunnelling through overburden. Availability of this equipment in the project area is limited.

Some MTBMs are promoted as being able to “crush” cobbles with internal cone crushing systems. Others have been promoted as capable of passing boulders of as much as 1/3 of the bore diameter. However, both approaches to managing larger stones can be highly problematic and incapable of completing construction in boulder ground. Large numbers of cobbles can also “choke” these machines and result in failure of the bore. In bouldery ground, where the boulders can be firmly held in place by the surrounding soil matrix, equipping MTBMs with rock-disc cutters can be successful. In all cases, detailed review of the conditions and equipment configuration are needed prior to construction to achieve a reasonable probability of success.

- **Pilot Tube Micro-tunnelling (PTMT):** PTMT employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and final pipes. The guidance system comprises a target with LEDs mounted in the steering head of the equipment that is monitored through a TV monitor. The PTMT operation includes pilot boring and reaming; and since this technique is used for smaller size pipes, the equipment and space required for this operation is smaller than what is normally required for pipe jacking or micro-tunnelling. PTMT can obtain an accuracy of 10 mm per 100 m of pipe length; however, the accuracy depends on the ground conditions, the accuracy of the guidance system, and the operator’s skill. The “pilot tube” is advanced in a similar fashion to horizontal directional drilling with a guidance system used to control alignment and grade.

In this method, a bore hole is drilled with a steering head connected to pilot tubes whose size is smaller than the required casing size. A steering head is used for pilot boring and adjustment of alignment and grade, and the bore hole is subsequently enlarged by a reamer with an auger string inside the casing used to remove

cuttings. Temporary casings, if applicable, or the final pipe follows the reamer into the ground. Configurations of “reamer” tools varies widely within the industry, with some including rotating cutting tools, while others are a simplified cage-like head that allows soils to be forced into the openings as the larger diameter pipe is pulled and pushed into the ground. These reamer systems can have a significant influence on both the feasibility and risks of using this method and should be evaluated with caution.

- **Tunnel Boring Machine (TBM):** TBM tunnelling operations involve the advance of a steerable machine with a rotating cutter head that is jacked horizontally into the ground at the lead end of the pipe or temporary lining system. Successive sections of temporary liner pipe or the final product pipe advance behind the TBM by pipe jacking. Alternatively, steel liner plates, steel ribs, and wood lagging or segmental precast concrete liner systems can be installed as the TBM advances. The spoil is removed from the tunnel as the TBM is advanced, using a combination of screw augers (in some instances), conveyor belts, or mucking cars. The cutting head is driven and steered by an operator inside the TBM, and the TBM head and face may be partially open or provided with doors to allow for access to the face. Specialized earth pressure balance or slurry shield TBMs are available, which pressurize the face of the excavation and improve face stability. Jacking and receiving pits are required. Locally, this method is generally used for construction in overburden, and open-faced machines have been used in cohesive and bouldery soils that exhibit significant “stand up time” (e.g., glacial till). Excavations through sandy soils below groundwater levels typically require dewatering to maintain face stability when using open faced machines.
- **Tunnel Digging Machine (TDM):** “Tunnel digging machine (TDM) tunnelling,” also called open-face shield tunnelling, involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Typically, the temporary tunnel liner (i.e., steel casing, steel ribs and lagging, steel liner plates, etc.) will be constructed from within the shield or final pipe would be jacked in sections from the launching shaft. Unlike traditional “jack and bore” methods, this method allows personnel to enter the tunnel to allow more control over the operations, such as for removal of obstructions. However, similar to jack and bore, groundwater lowering is necessary to control cohesionless soils below the groundwater level. Machine-assisted excavation generally requires a tunnel diameter of about 1.8 m or more. In some instances, vacuum well points installed from within the tunnel at an angle through the face (sometimes called “lances”) can be used to control groundwater levels as the tunnel progresses.
- **Manual Tunnelling:** Manual excavation within an open-face shield involves excavating the soils using pneumatic or hand tools working within a full-circumference tunnelling shield or at the lead end of the pipe. Typically, the temporary tunnel liner (i.e., steel casing, steel ribs and lagging, steel liner plates, etc.) will be constructed from within a shield, or final pipe would be jacked in sections from the launching shaft. This method includes personnel within the tunnel to allow control over the operations and removal of obstructions. Groundwater lowering is necessary to control cohesionless soils below the groundwater level. Manual excavation generally requires a tunnel diameter of about 1.2 m or more, though in some circumstances smaller diameters and small square tunnels can be constructed depending on groundwater conditions. As for the TDM methods, drainage lances can be used in some cases to proactively dewater the ground from within the tunnel as the tunnel face advances.

6.5.3 Assessment for Feasible Installation Methods

Based on the ground conditions at the culvert site and the anticipated relatively short tunnel length of 40.2 m, HDD, TBM, and PTMT methods are likely not suitable and are not cost-effective. The diameter of the culvert will preclude the use of HDD, TDM, or TBM systems. The timber (i.e., as encountered in Boreholes C260-3) that may be present along the tunnel horizon would likely preclude the use of HDD, traditional “jack and bore,” and MTBM.

Due to the potential presence of timber along the tunnel alignment and the larger culvert size at this site manual tunneling with a hooded shield and dewatering is likely to be the most feasible and suitable trenchless installation method for pipe culvert installation in the anticipated ground conditions, however pipe ramming may be considered an alternative trenchless method for this site. It should be noted that interventions to remove obstructions (i.e., timber) may be necessary and the contractor should be prepared to implement such interventions at this site. The following geotechnical issues/risks associated with the trenchless construction that should be considered and evaluated at this site are:

- Ground or Road Heave – culverts installed at shallow depth and with diameters that are relatively large as compared to the depth of burial are particularly susceptible to heaving the roadway if the pipe is rammed into place – i.e., having a cover to diameter (C/D) ratio of less than about 2, which is not the case at this site given the 2.2 m diameter liner required to accommodate the 2.0 m diameter culvert and about 5.8 m thickness of soil cover.
- Obstructions – Timber, as encountered in Borehole C260-1, can obstruct or foul trenchless construction equipment if encountered within the tunnel alignment while boring. As the culvert would be installed close to or along the interface between the original ground surface and the overlying roadway embankment there is a high risk at this site of encountering such timber (inferred to be part of an old corduroy roadway), depending on how the ground was prepared prior to embankment placement. In culvert sites that had such cases, pipe ramming and manual tunneling are the least susceptible to equipment fouling and damage if wood debris is encountered.
- Ground or Road Settlement – Given that the water level at this site would likely be at/near the culvert invert, and within the tunnel horizon at the time of construction, there is the potential for flow of saturated granular soils (silty sand) and groundwater back through the spoils within the casing and towards the entrance pit. Such flow could cause significant loss of ground at and above the face of excavation. For any method that requires groundwater control for managing risks of ground losses, gravity flow to sumps and pumps or into permeable linings should not be relied upon except as a supplement to a fully designed vacuum well point or eductor system.

The trenchless methods that are to be considered not suitable at this site have been noted in MTO's SP titled "*Pipe Installation by Trenchless Methods*", which is included in Appendix C.

As a general guideline, the depth of cover above the crown of the new pipe installation should be greater than or equal to the cut diameter of whatever trenchless system is used to excavate the ground or the largest pipe diameter that will be installed, whichever is greater. Similarly, the separation between newly installed pipes should be at least one, and preferably two tunnel diameters, in both the vertical and horizontal directions. Oversize casings (if separate casing and pipes will be used) or oversize final pipes should be installed to permit final adjustments of the invert channel elevations for final flow control given the challenges associated with maintaining alignment. Selection of casing size should consider the potential for misalignment over the tunnel length due to ground conditions (i.e., timber), access to the tunnel face (if potentially necessary), proposed tunneling methodology and the length of the tunnel drive. We understand from AECOM that a 2 pass-system is not typical for centreline culverts in MTO's Northeast Region. However, a 2-pass lining may be advantageous to facilitate some methods of tunnelling and for achieving final alignment control, depending on the final hydraulic opening and lining design requirements. In general, a settlement monitoring program should be implemented that is consistent with OPSS.PROV 539 (Temporary Protection Systems) for shoring systems at the pits if these are near the roadway, as discussed further in Section 6.6.3. Settlement monitoring of the trenchless crossing (refer to Section 6.6.8) should also be carried out over the entire centreline length of the new culvert alignment at the edge

of all pavements, in landscape areas leading to the pavement from the entry pit and at perpendicular off-sets of about 2 m from the centre line at all pavement shoulder edges for a distance equal to the depth from road surface to invert, as per MTO's SP titled "*Pipe Installation by Trenchless Method*", which is included in Appendix C. Contingency plans for traffic management and road repair should be in-place to rapidly mitigate or limit any distress to the overlying highway embankment, if needed.

6.6 Analytical Testing of Existing Soil

The results of analytical tests on one sample of the varved clay and clayey silt recovered from Borehole C260-1 is 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).

6.6.1 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%, 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.

6.6.2 Potential for Corrosion

The soil has a pH of 8.1 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. The resistivity is 4,000 ohm-cm, which indicates that the soil corrosiveness is Moderate ($2,000 < R < 4,500$ 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 0.30 µg/g in the analyzed soil sample.

6.7 Construction Considerations

6.7.1 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 potentially through the timber encountered in Borehole C260-1, and into the organic silt to organic silty sand deposit, clayey silt deposit, and/or the varved clay and clayey silt deposit. Excavations for construction of entry/exit pits for trenchless installation will also extend through such soils (except the timber zone potentially). Open-cut excavations are anticipated to extend to or 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 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/softer 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.

6.7.2 Groundwater / Surface Water Control

The groundwater level is expected to be within the proposed culvert horizon along most of its alignment; 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 contractor is also responsible for confirming that the radius of groundwater drawdown does not impact the existing embankment and any surrounding features.

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 or lining operations, 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.

Groundwater and surface water control will be required for excavation and construction of the culvert replacement and for any trenchless lining option being considered. Dewatering operations must be in accordance with OPSS.PROV 517 (*Dewatering*) and MTO's SP 517F01 (*Temporary Flow Passage System*), a copy of which is included in Appendix C, recommending that a design engineer be required.

6.7.3 Temporary Protection Systems

In order to replace the existing culvert and allow at least one lane of live traffic to pass during construction, temporary protection systems will likely be required. The temporary excavation protection and support systems should 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 should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any utilities, if present, can tolerate this magnitude of deformation.

It is anticipated that a driven interlocking steel sheet pile system is not suitable at this site, due to the potential presence of timber below the embankment fill. The contractor may use a soldier pile and lagging system; 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 wall could be provided in the form of struts, rakers, or temporary anchors, if and as required.

Vibratory equipment for the installation of temporary protection systems may be used at this site provided that it does not impact the embankment or nearby buried infrastructure or structures, if present. The installation of temporary protection systems by vibratory equipment should be monitored to ensure the 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.

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/m ³)	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
Embankment Fill – Loose to compact silt and sand to silty sand to sand / compact to very dense asphalt and sand / compact to very dense timber/soil	19	30	-	0.33	0.50	3.00
Very loose to loose organic silt to organic silty sand	16	28	-	0.36	0.53	2.77
Firm clayey silt	18	28	40	0.36	0.53	2.77
Firm to stiff varved clay and clayey silt	18	28	40 ⁴	0.36	0.53	2.77
Stiff / very loose to compact layered clayey silt and silt	18	30	80	0.33	0.50	3.00

Notes:

1. The design groundwater level may be assumed to be Elevation 270 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.
4. Derived from the in-situ vane shear test results reduced by 25 per cent for varved stratum.

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 2 horizontal to 1 vertical (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 installation and extraction of any temporary systems should meet the same tolerable limits used for installation.

6.7.4 Obstructions

Borehole C260-1 encountered about 300 mm and 150 mm thick pieces of timber and it is inferred that the timber may be present between Elevation 269.0 m and 267.1 m, which would affect the installation of temporary protection systems. A Notice to Contractor to identify to the contractor the possible presence of deleterious material, such as timber from old corduroy road, should be included in the Contract Documents; a copy of which is included in Appendix C.

6.7.5 Subgrade Protection

For open cut culvert installation and entry/exit pit construction, 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; or a concrete working slab, as per SP FOUN 0001, be placed on the subgrade in the case of the entry/exit pits.

6.7.6 Embankment Reconstruction

Engineered fill for reconstruction of the embankment after open cut culvert replacement should consist of OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type I or Type II material. The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*) and OPSS.PROV 206 (*Grading*). Embankment side slopes should be constructed no steeper than 2H:1V in granular fill.

6.7.7 Surficial Embankment Stability and Erosion Protection

If the culvert is replaced by open cut methods, depending on the selected embankment reconstruction, fill material type, 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 new embankments, erosion protection measures may be required depending on the fill type selected for construction.

Based on the cohesive foundation soils at this site, it is recommended that the proposed embankment geometry not be widened or raised relative to the existing geometry during construction or permanently.

Based on the specified material types and hence the gradation envelope, granular fill such as OPSS.PROV 1010 (*Aggregates*) Granular 'A', or Granular 'B' Type I or 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 or Type II, 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.

6.7.8 Instrumentation and Monitoring Program

An instrumentation and monitoring program is recommended at the culvert location if a trenchless installation method is used for culvert construction to:

- Document the effects of the culvert installation on the overlying highway and adjacent underground utilities/services, if applicable.
- Potentially identify adverse ground movement trends that could occur due to the construction methods and equipment or unforeseen ground conditions.
- Evaluate the contractor's compliance with the settlement limits specified in the Contract Documents.
- Allow adjustments to be made to the culvert installation methods such that the settlement limits established are not exceeded.

The SP for "*Pipe Installation by Trenchless Method*" (Appendix C) contains the details of the settlement monitoring program to be implemented to measure ground settlement at the existing roadway prior to, during and following the proposed installation. If a trenchless installation method is adopted, a site-specific Supply/Installation of Instrumentation Plan and a Monitoring Plan for embankment construction/staging options and settlement monitoring should be prepared for the contractor and Contract Administrator (CA) assignment for inclusion in the Contract Documents/Provided to the CA.

It is also recommended that, to the extent practicable and possible, the weight or volume of ground removed from beneath the highway be measured and compared to the theoretical cut hole volume on a frequency of at least once per 3 m section of tunnel / pipe installed. On-site observations of construction operations and measurements of grout and/or lubricant volumes should assist in identifying atypical conditions that could be indicative of unacceptable ground losses.

Provision should be included in the Contract Documents for rehabilitation of the Highway 66 paved surface and embankment along the culvert alignment in the event of settlement during the installation process. It is understood from AECOM that granular driving restrictions will govern timing of paving such that if settlement occurs, repairs would be performed during the Contract.

Further, the location (depth/alignment), type and tolerances to movement and vibrations of any existing buried utilities (functioning or decommissioned) would have to be clearly established prior to any trenchless installation operation, and the Review Level and Alert Level tolerances for settlement confirmed in the SP for "*Pipe Installation by Trenchless Method*" included in Appendix C.

6.7.9 Grouting

Post installation grouting to fill the annular space between the carrier pipe (culvert) and the casing may need to be carried out after the permanent culvert pipe is installed within the casing as noted in MTO's SP titled "*Pipe*

Installation by Trenchless Method", which is included in Appendix C. For any installations at which the settlement monitoring or excavation volume monitoring indicates that pavement settlement or ground loss might have occurred, or where signs of ground loss have been noted, provision should also be made for a program of compensation grouting above the casing pipe and/or repair of the pavements.

7.0 CLOSURE

This Foundation Design report was prepared by Ms. Anastasia Poliacik, P.Eng., a geotechnical engineer of Golder. Mr. Andre Bom, P.Eng., reviewed the report. 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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REFERENCES

- Canadian Standards Associations (CSA) Group 2014. Canadian Highway Bridge Design Code and Commentary S6-14.
- Canadian Standards Association (CSA), 2014. CSA A23.1-09 Concrete Materials and Methods of Construction (R2014).
- Cashman, P.M. and Preene M. (2001) Groundwater Lowering in Construction, A Practical Guide. Spoon Press Publisher.
- Heuer, R.E. (1974) Important Parameters in Soft Ground Tunneling. Proceedings of Specialty Conference on Subsurface Exploration for Underground Excavation and Heavy Construction. ASCE, New York.
- Lo, K.Y. and Milligan, V. 1967. Journal of the Soil Mechanics and Foundations Division, Vol. 93, Issue 1, Pg. 1-15.
- Ministry of Transportation, Ontario, MTO Gravity Pipe Design Guidelines, April 2014.
- 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 802.010	Flexible Pipe Embedment and Backfill, Earth Excavation
OPSD 3090.100	Foundation Frost Penetration Depths for Northern Ontario
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.PROV 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

Special Provisions

SP 105S22 Amendment to OPSS 501

SP 105S09 Amendment to OPSS 539

Proprietary Software:

Rocscience Inc. SLIDE 2018

Table 1: Culvert Replacement Alternatives – Station 18+386 Township of Gauthier

Replacement Alternatives	Advantages	Disadvantages	Risks
Cut and Cover (Box Culvert)	<ul style="list-style-type: none"> ■ Risks of ground losses affecting traffic are better controlled than for trenchless methods. ■ Depth of excavation is within typical limits for conventional excavation support, slopes, and dewatering systems. ■ With appropriate planning, excavation methods can be adapted to address obstructions (i.e., timber) and soft/loose soils. ■ Box type culvert can be made adequately large to accommodate required flow capacity. 	<ul style="list-style-type: none"> ■ Traffic disruption (staging of crossing construction). ■ Roadway protection required for staged excavation. ■ Proactive dewatering required (potentially vacuum well points). 	<ul style="list-style-type: none"> ■ Difficulties may be experienced during installing temporary roadway protection system if obstructions (i.e., buried timber) are present and therefore lagging is preferred over sheet piles. ■ 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.
Pipe Ramming	<ul style="list-style-type: none"> ■ Installed without significant removal of soils prior to full casing penetration through embankment. ■ Relatively low cost. ■ Relatively small site operations footprint. ■ Within size range typical in Ontario. ■ Better than other low-cost technologies for penetrating ground that contains numbers of cobbles and small boulders. 	<ul style="list-style-type: none"> ■ Combination of ground density, final pipe diameter and length of installation may be near the upper limit of feasibility for a single pipe installation – telescoping casing sizes may assist with feasibility. ■ Density of ground in some areas may encourage/require premature removal of soils from within the casing. ■ Concentrations of cobbles and boulders, large boulders or large pieces of wood (structural timbers, stumps, logs) could obstruct operations. ■ Obstructions may require shaft excavation from the surface. ■ 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 or when encountering cobbles and boulders. 	<ul style="list-style-type: none"> ■ Timbers render pipe ramming a high-risk option since timbers are more likely to fully obstruct pipe ramming than occasional cobbles and boulders if the timbers are of a large size as may have been used for temporary support or a former timber culvert. ■ Telescoping casing would likely require partial removal of soils from within the pipe to reduce potential for jamming and obstruction and, therefore, flowing ground risks may require additional mitigation (localized dewatering). ■ Need for removal of soil from within casings because of driving resistance (binding of casings, weight of spoil, obstructions) could lead to excess ground losses and surface settlement.

Replacement Alternatives	Advantages	Disadvantages	Risks
Manual Tunneling with Hooded Shield and Dewatering	<ul style="list-style-type: none"> ■ Relatively low cost. ■ Relatively small site operations footprint. ■ Within size range typical in Ontario. ■ Best for penetrating ground that includes cobbles and boulders of all sizes. ■ Manual tunnelling with hooded shield and dewatering may be the only tunnelling method capable of penetrating through timbers. ■ Driving plates or bars ahead of excavation into the crown of the tunnel (spiling, forepoling) can be used to help control loose or ravelling ground. 	<ul style="list-style-type: none"> ■ An oversize tunnel diameter (compared to desired pipe size) may be necessary to better facilitate tunnelling. ■ Full alignment length must be dewatered in advance of excavation using proactive methods from surface and/or within tunnel. ■ Inadequate groundwater control can lead to excess ground losses and surface settlement. ■ Spiling or forepoling may be required to control ravelling ground, increasing cost and schedule. ■ "Two pass" lining system may be required (e.g., steel liner plates followed by pre-cast concrete panels). 	<ul style="list-style-type: none"> ■ Dewatering planning as part of bid may not be adequate and result in real or strategic claims. ■ Inadequate dewatering could lead to ground losses and excess surface settlement. ■ Potential risk to encounter timber along tunnel alignment.

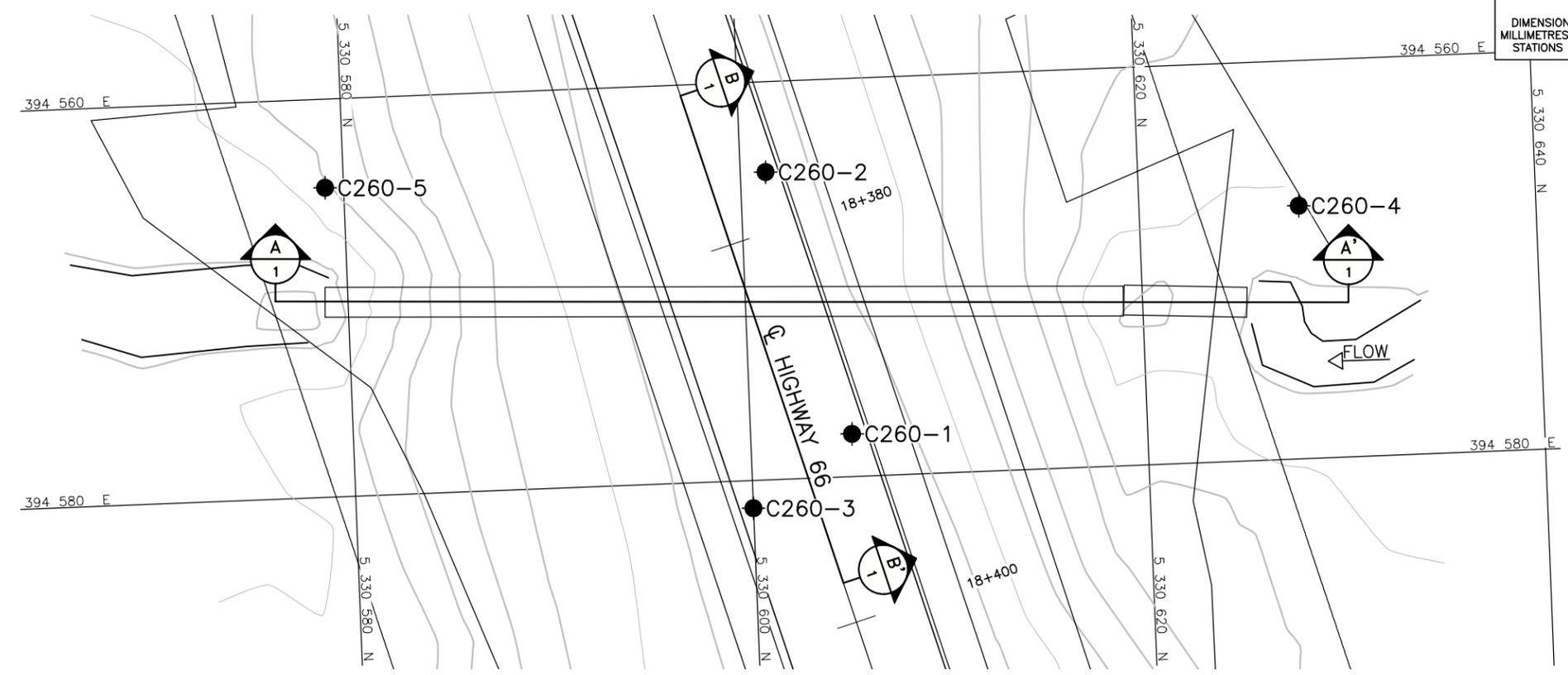
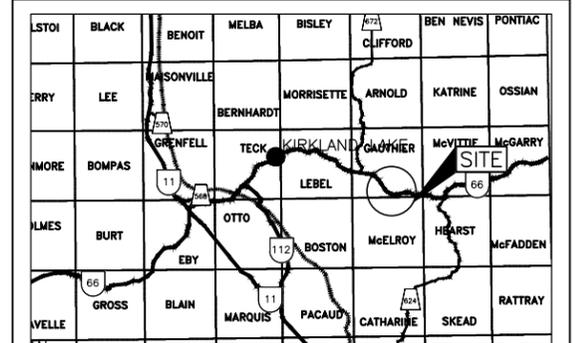
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. GWP No. 5210-14-00



HIGHWAY 66
STATION 18+386
TOWNSHIP OF GAUTHIER CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



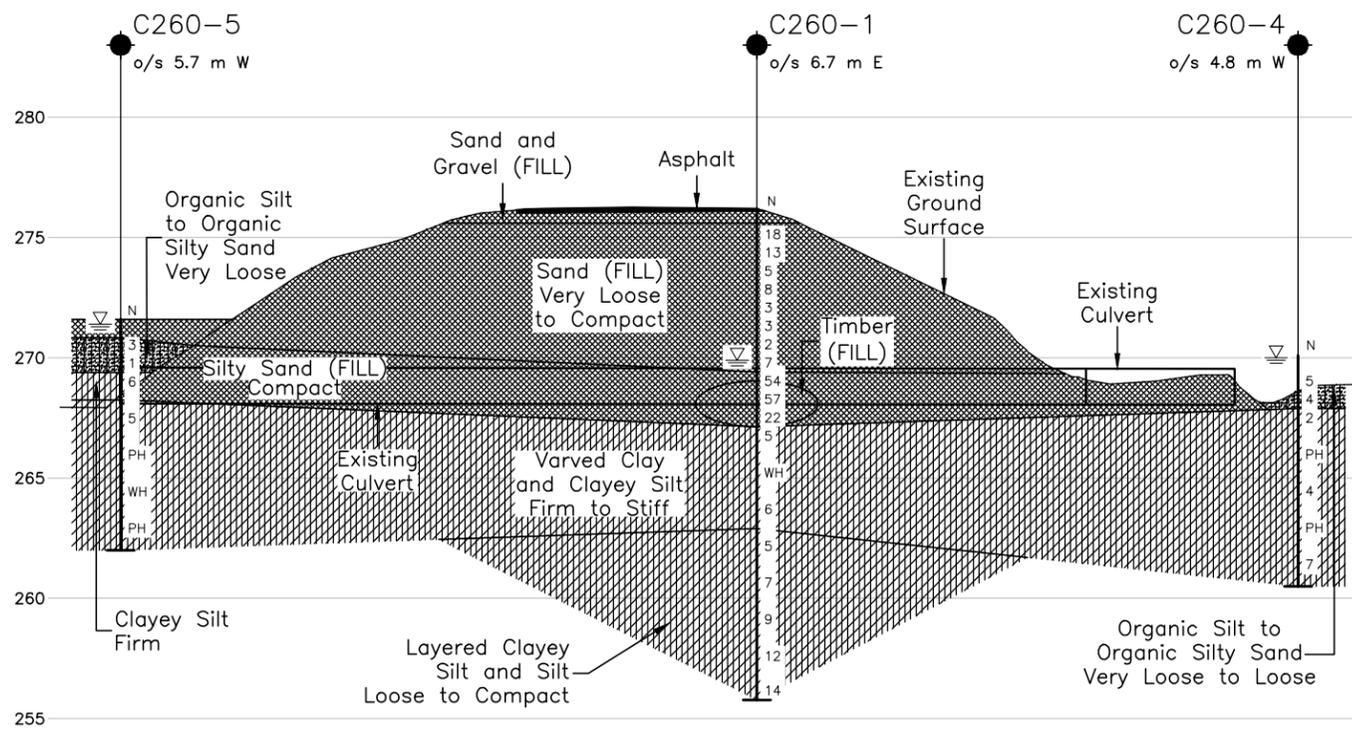
PLAN
SCALE
3 0 3 6 m

LEGEND

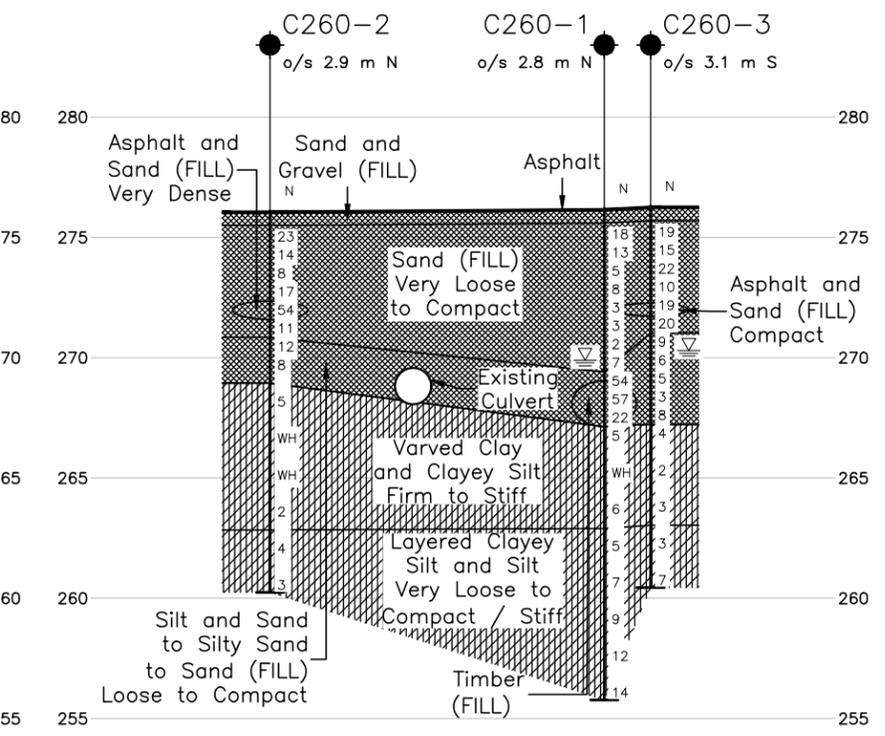
- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ▽ WL upon completion of drilling

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
C260-1	276.2	5330605.1	394577.9
C260-2	276.1	5330601.3	394564.5
C260-3	276.3	5330600.0	394581.4
C260-4	270.1	5330628.1	394567.3
C260-5	271.6	5330579.1	394564.5



A-A'
1
CULVERT CENTERLINE PROFILE
HORIZONTAL SCALE
3 0 3 6 m
VERTICAL SCALE
3 0 3 6 m



B-B'
1
HIGHWAY CENTERLINE PROFILE
HORIZONTAL SCALE
3 0 3 6 m
VERTICAL SCALE
3 0 3 6 m



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 no. gwp52101400b.dwg, received AUGUST 14, 2019.

NO.	DATE	BY	REVISION

Geocres No. 32D-26

HWY. 66	PROJECT NO. 1896349	DIST. .
SUBM'D. TB	CHKD. AP	DATE: 2/20/2020
DRAWN: TR	CHKD. AB	APPD. JMAC
		SITE: .
		DWG. 1



Photograph 1: Drilling Rig set up at Borehole C260-2, looking East (May 2019)



Photograph 2: North End of Culvert (Inlet) (May 2019)



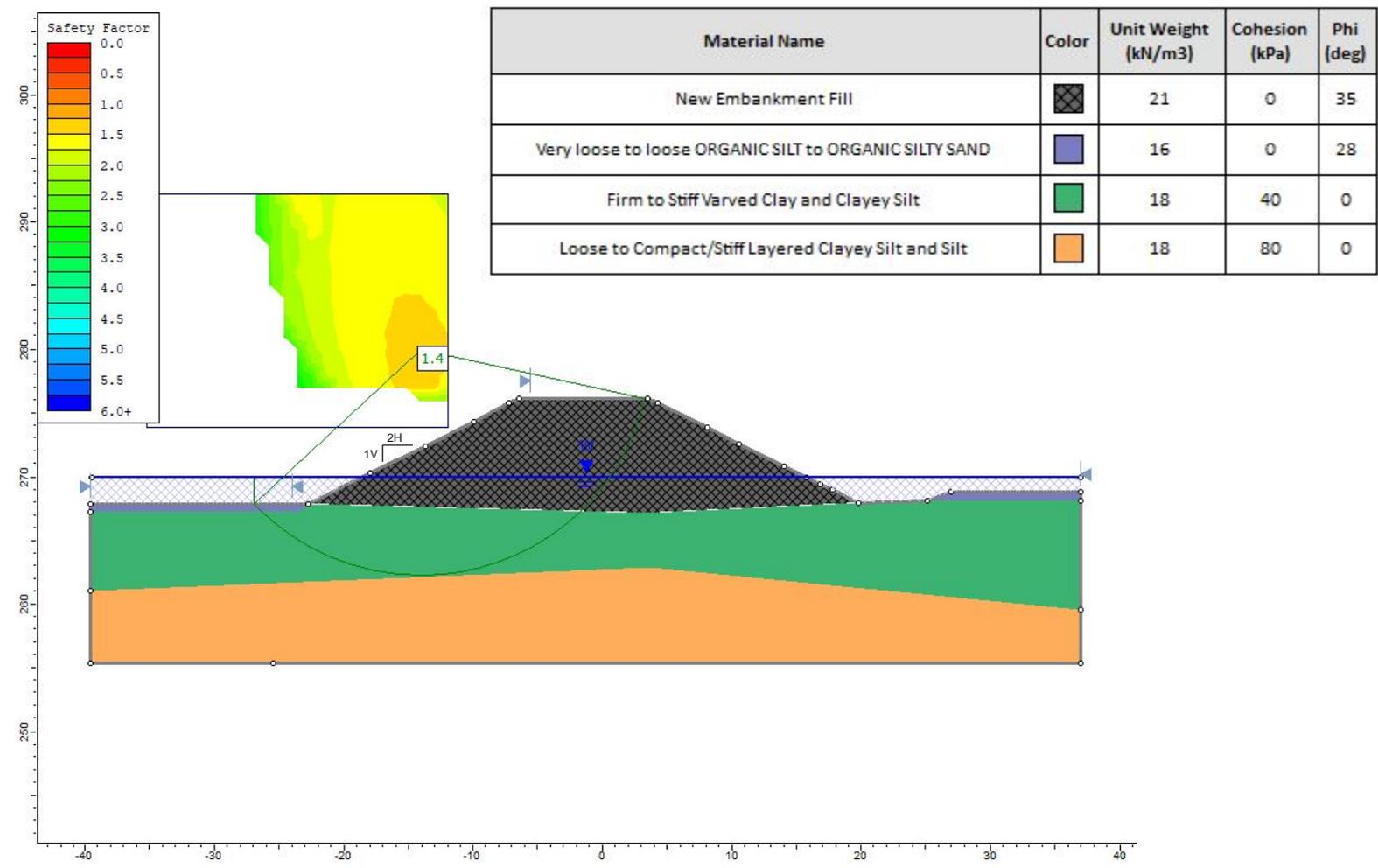
Photograph 3: Drilling Rig Setup at Borehole C260-5, Near Culvert Outlet (May 2019)



Photograph 4: South End of Culvert (Outlet) (May 2018)

Figure 1

Global Stability Analysis – Short-term Condition Highway 66, Sta. 18+386, Township of Gauthier Culvert

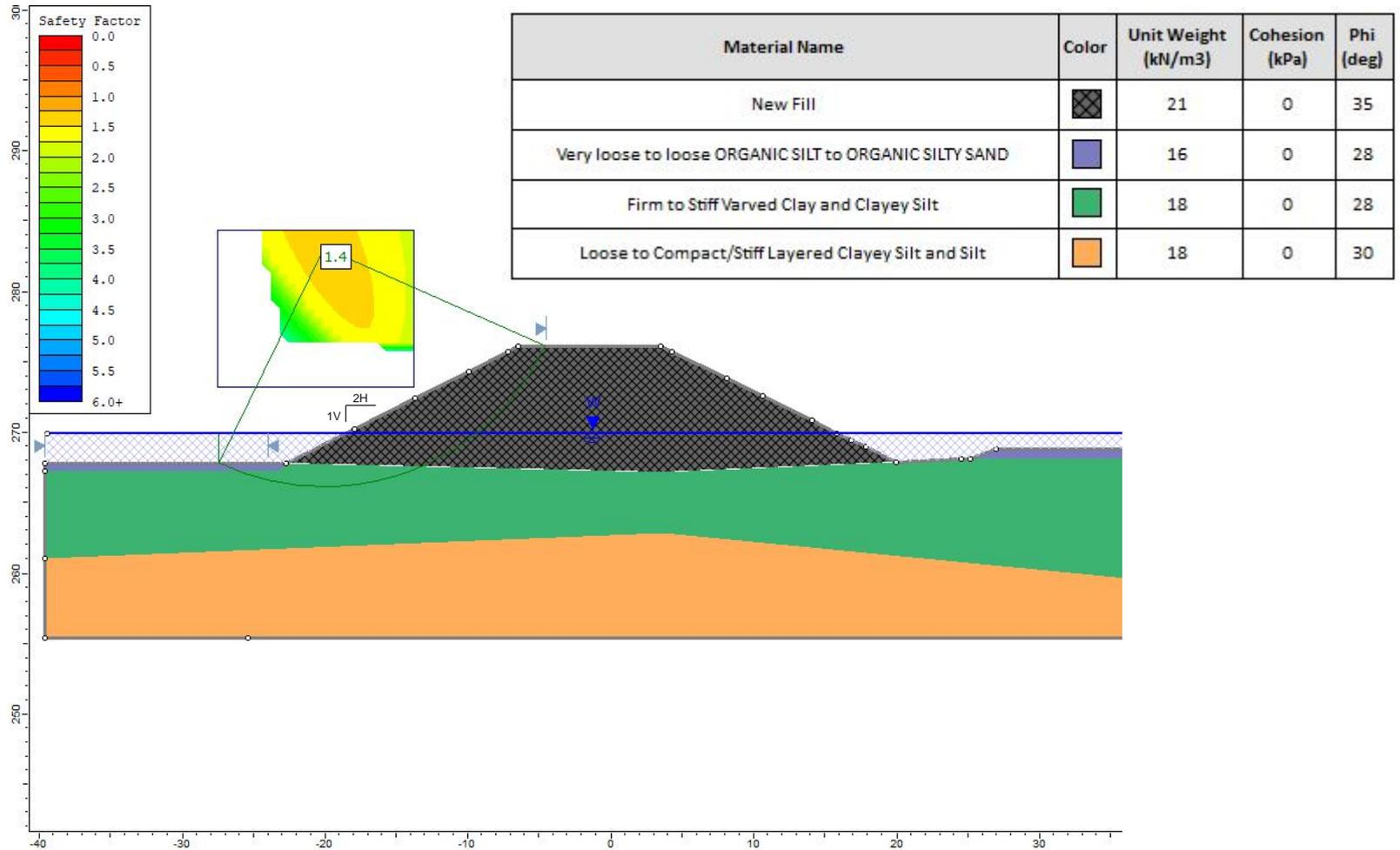


Date: October 2019
Project No: 1896349-R11

Analysis By: AMP Reviewed By: AB

Figure 2

Global Stability Analysis – Long-term Condition Highway 66, Sta. 18+386, Township of Gauthier Culvert



Date: October 2019
Project No: 1896349-R11

Analysis By: AMP Reviewed By: AB

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	19 to 75	0.75 to 3
	Fine	4.75 to 19	(4) to 0.75
SAND	Coarse	2.00 to 4.75	(10) to (4)
	Medium	0.425 to 2.00	(40) to (10)
	Fine	0.075 to 0.425	(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>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

- Only applicable to components not described by Primary Group Name.
- 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 cm² 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, G _s)
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)
Y	unit weight

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

COARSE-GRAINED SOILS

Compactness¹

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

- 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 grain size. 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.
- 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

- SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
- 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
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
U	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

* 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 = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1

2

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

RECORD OF BOREHOLE No C260-1 2 OF 2 **METRIC**

PROJECT 1896349

G.W.P. 5210-14-00 LOCATION N 5330605.1; E 394577.9 NAD83 MTM ZONE 12 (LAT. 48.107997; LONG. -79.794308) ORIGINATED BY MR

DIST HWY 66 BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers COMPILED BY TR

DATUM GEODETIC DATE May 1, 2019 CHECKED BY AMP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
--- CONTINUED FROM PREVIOUS PAGE ---						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)					
						20	40	60	80	100	20	40	60			
262.9	CLAY and CLAYEY SILT, varved, trace sand Firm to stiff Grey Wet		14	SS	6											
13.3	CLAYEY SILT and SILT, layered Loose to compact / stiff Grey Wet		15	SS	5				+ ²						H ○	0 0 76 24
			16	SS	7					+ >100 kPa						
			17	SS	9									○	NP	0 1 84 15
			18	SS	12											
			19	SS	14											
20.4	END OF BOREHOLE NOTE: 1. Water level at a depth of 6.3 m below ground surface (Elev. 269.9 m) inside augers upon completion of drilling. 2. Borehole dry and caved to a depth of 4.6 m below ground surface (Elev. 271.6 m) upon removal of augers.															

SUD-MTO 001 S:\CLIENTS\MT\HWY65&66\02_DATA\GINT\1896349.GPJ GAL-MISS.GDT 10-7-19 TR

PROJECT <u>1896349</u>	RECORD OF BOREHOLE No C260-2	2 OF 2	METRIC
G.W.P. <u>5210-14-00</u>	LOCATION <u>N 5330601.3; E 394564.5 NAD83 MTM ZONE 12 (LAT. 48.107965; LONG. -79.794488)</u>	ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>66</u>	BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>	COMPILED BY <u>TR</u>	
DATUM <u>GEODETIC</u>	DATE <u>May 2, 2019</u>	CHECKED BY <u>AMP</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
	--- CONTINUED FROM PREVIOUS PAGE ---					20 40 60 80 100	○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× REMOULDED						
262.8	CLAY and CLAYEY SILT, varved Firm to stiff Grey Wet		12	SS	2											
13.3	CLAYEY SILT and SILT, layered Very loose to loose / stiff Grey Wet		13	SS	4			+ 2			—				0 0 75 25	
260.2			14	SS	3			+ 2								
15.9	END OF BOREHOLE NOTE: 1. Borehole dry upon completion of drilling and removal of augers.															

SUD-MTO 001 S:\CLIENTS\MT\Hwy65&66\02_DATA\GINT\1896349.GPJ GAL-MISS.GDT 10-7-19 TR

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

PROJECT <u>1896349</u>	RECORD OF BOREHOLE No C260-3	2 OF 2	METRIC
G.W.P. <u>5210-14-00</u>	LOCATION <u>N 5330600.0; E 394581.4 NAD83 MTM ZONE 12 (LAT. 48.107951; LONG. -79.794262)</u>	ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>66</u>	BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>	COMPILED BY <u>TR</u>	
DATUM <u>GEODETIC</u>	DATE <u>May 2, 2019</u>	CHECKED BY <u>AMP</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
	--- CONTINUED FROM PREVIOUS PAGE ---					20 40 60 80 100	○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× REMOULDED						
263.0	CLAY and CLAYEY SILT, varved Stiff Grey Wet - Approximately 5 mm to 25 mm varying thickness of clay and silt varves throughout deposit		14	SS	3	264										
13.3	CLAYEY SILT and SILT, layered, trace sand Very loose to loose / stiff Grey Wet		15	SS	3	263			2 +							0 1 82 17
						262										
260.4			16	SS	7	261			2 +							
15.9	END OF BOREHOLE NOTE: 1. Water level at a depth of 10.1 m below ground surface (Elev. 266.2 m) inside augers upon completion of drilling. 2. Borehole caved to a depth of 9.4 m below ground surface (Elev. 266.9 m) upon removal of augers. 3. Water level at a depth of 6.0 m below ground surface (Elev. 270.3 m) upon removal of augers.															

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

PROJECT <u>1896349</u>	RECORD OF BOREHOLE No C260-4	1 OF 1	METRIC
G.W.P. <u>5210-14-00</u>	LOCATION <u>N 5330628.1; E 394567.3 NAD83 MTM ZONE 12 (LAT. 48.108206; LONG. -79.794445)</u>	ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>66</u>	BOREHOLE TYPE <u>76 mm I.D. Hollow Stem Augers, NW Casing</u>	COMPILED BY <u>TR</u>	
DATUM <u>GEODETIC</u>	DATE <u>May 22, 2019</u>	CHECKED BY <u>AMP</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
						20	40	60	80	100						
270.1	GROUND SURFACE															
0.0	ORGANIC SILT to organic SILTY SAND, trace gravel Very loose to loose Dark brown to brown Wet	[Strat Plot]	1	SS	5											
			2	SS	4											
267.9	CLAY and CLAYEY SILT, varved Stiff Grey Wet - Approximately 5 mm to 25 mm varying thickness of clay and silt varves throughout deposit	[Strat Plot]	3	SS	2							-----	○			OC=7.7%
2.2			4	TO	PH				+2							
			5	SS	4				+2							
			6	TO	PH				+3							
			7	SS	7				+2			-----	○			
261									+2							
260.5	END OF BOREHOLE								+2							
9.6	NOTE: 1. Borehole caved to a depth of 4.5 m below ground surface (Elev. 265.6 m) upon removal of augers. 2. Water level at a depth of 0.1 m below ground surface (Elev. 270.0 m) upon removal of augers.															

SUD-MTO 001 S:\CLIENTS\MT\HWY65&66\02_DATA\GINT\1896349.GPJ GAL=MISS.GDT 10-7-19 TR

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

PROJECT <u>1896349</u>	RECORD OF BOREHOLE No C260-5	1 OF 1	METRIC
G.W.P. <u>5210-14-00</u>	LOCATION <u>N 5330579.1; E 394564.5 NAD83 MTM ZONE 12 (LAT. 48.107765; LONG. -79.794493)</u>	ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>66</u>	BOREHOLE TYPE <u>76 mm I.D. Hollow Stem Augers, NW Casing</u>	COMPILED BY <u>TR</u>	
DATUM <u>GEODETIC</u>	DATE <u>May 22, 2019</u>	CHECKED BY <u>AMP</u>	

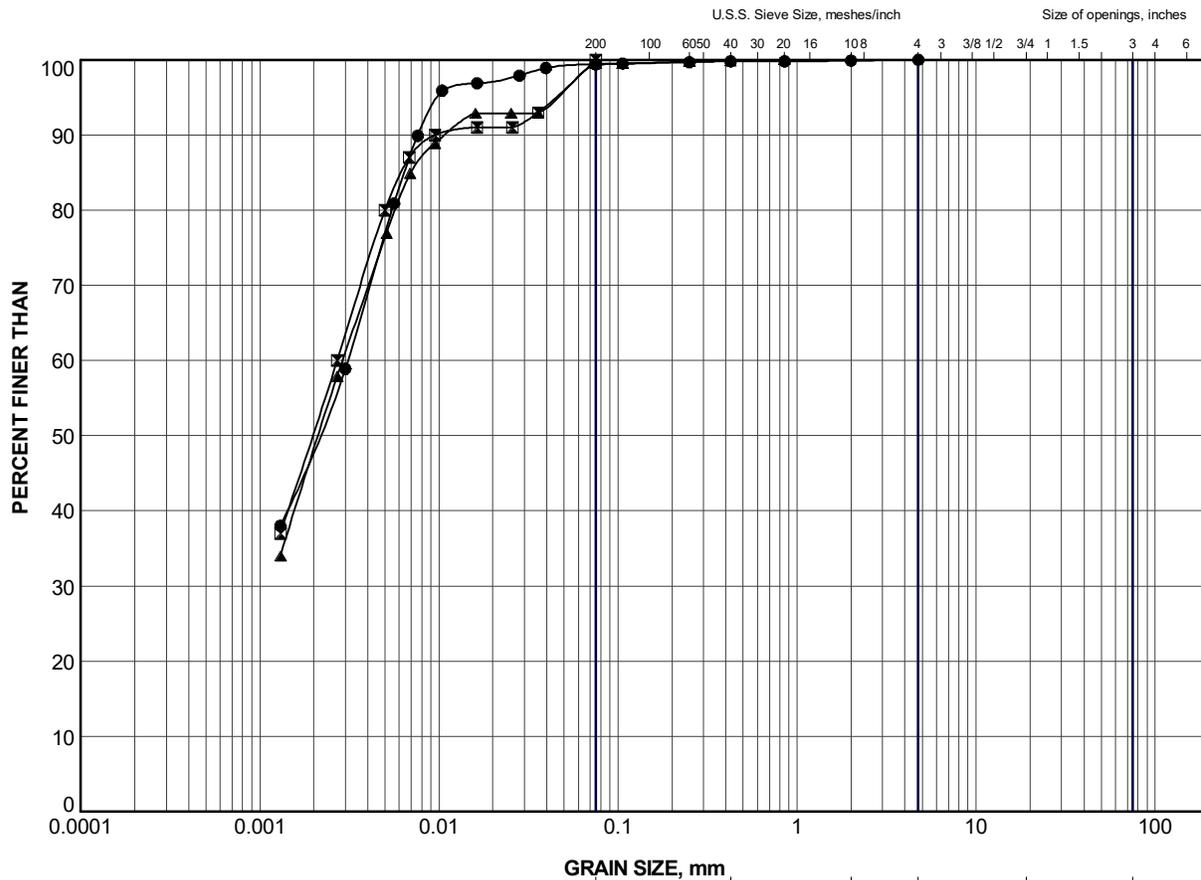
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
						20	40	60	80	100						
271.6	GROUND SURFACE	[Hatched]														
0.0	Sand, trace gravel, trace organics (FILL) Brown Moist	[Hatched]														
270.8	0.8	[Dotted]														
	ORGANIC SILT to organic SILTY SAND, trace gravel Very loose Dark brown Wet	[Dotted]	1	SS	3											
		[Dotted]	2	SS	1											
269.4	2.2	[Cross-hatched]														
	CLAYEY SILT, trace sand, trace organics, trace wood Firm Grey Wet	[Cross-hatched]	3	SS	6							○		OC=2.6%		
268.2	3.4	[Diagonal-hatched]														
	CLAY and CLAYEY SILT, varved Firm to stiff Grey Wet - Approximately 5 mm to 25 mm varying thickness of clay and silt varves throughout deposit	[Diagonal-hatched]	4	SS	5				+	2						
		[Diagonal-hatched]	5A 5B 5C	TO	PH										17.5	
		[Diagonal-hatched]	6	SS	WH											
		[Diagonal-hatched]	7	TO	PH											
262.0	9.6	[Diagonal-hatched]														
	END OF BOREHOLE	[Diagonal-hatched]														
	NOTE: 1. Borehole caved to a depth of 4.7 m below ground surface (Elev. 266.9 m) upon removal of augers. 2. Water level at a depth of 0.2 m below ground surface (Elev. 271.4 m) upon removal of augers.															

SUD-MTO 001 S:\CLIENTS\MT\HWY656866\02_DATA\GINT\1896349.GPJ GAL-MISS.GDT 10-7-19 TR

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

APPENDIX B

Laboratory Test Results



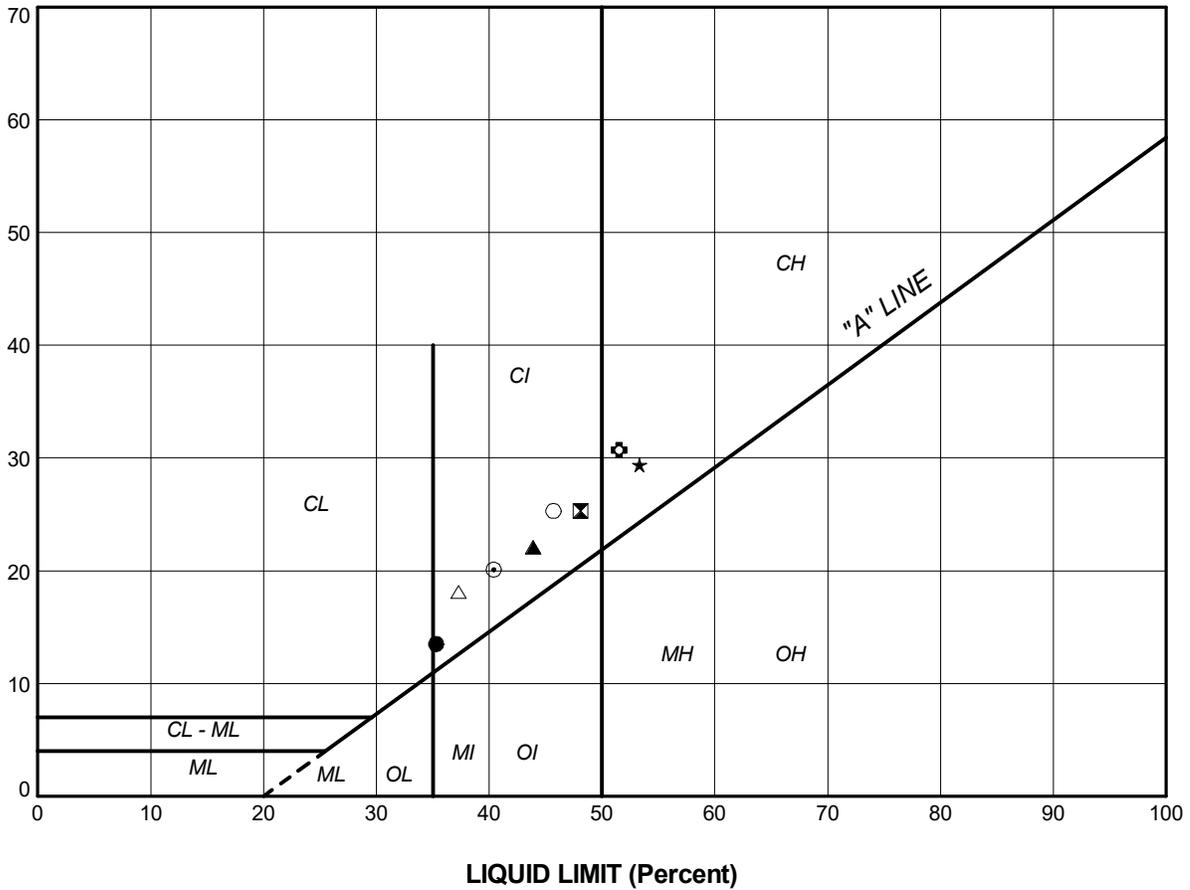
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C260-1	13	265.2
⊠	C260-2	10	266.7
▲	C260-3	13	265.3

PROJECT	HIGHWAY 66 STATION 18+386 TOWNSHIP OF GAUTHIER CULVERT				
TITLE	GRAIN SIZE DISTRIBUTION CLAY and CLAYEY SILT, varved (combined Clay and Clayey Silt components)				
 GOLDER SUDBURY, ONTARIO	PROJECT No.	1896349	FILE No.	1896349.GPJ	
	DRAWN	TR	Oct 2019	SCALE	N/A
	CHECK	AMP	Oct 2019	REV.	
	APPR	JMAC	Oct 2019	FIGURE B-2	

PLASTICITY INDEX (Percent)



SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

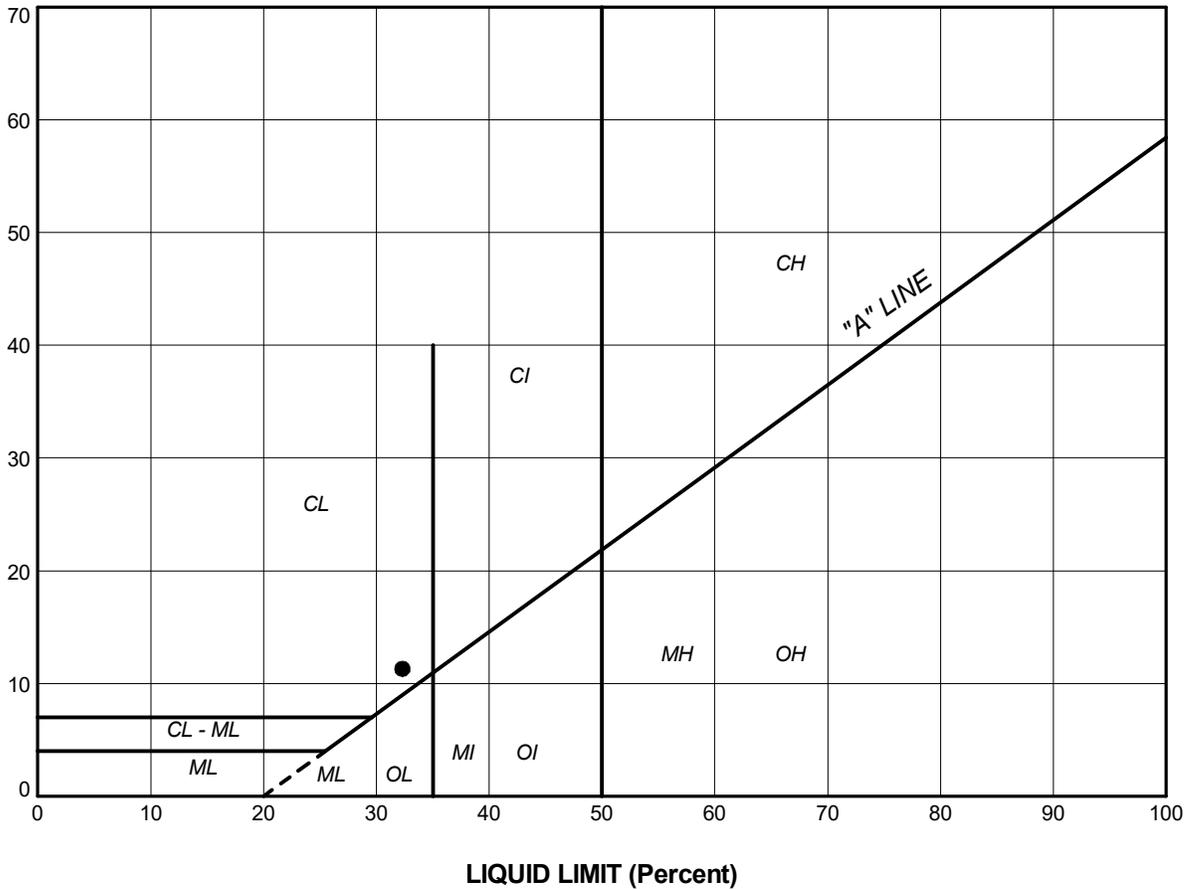
LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C260-1	13	35.3	21.8	13.5
⊠	C260-2	10	48.1	22.8	25.3
▲	C260-3	13	43.9	21.8	22.1
★	C260-4	3	53.3	23.9	29.4
⊙	C260-4	7	40.4	20.3	20.1
⊕	C260-5	4	51.5	20.8	30.7
○	C260-5	5C	45.7	20.4	25.3
△	C260-5	6	37.3	19.2	18.1

PROJECT		HIGHWAY 66 STATION 18+386 TOWNSHIP OF GAUTHIER CULVERT		
TITLE		PLASTICITY CHART CLAY and CLAYEY SILT, varved (combined Clay and Clayey Silt components)		
PROJECT No.		1896349	FILE No.	
DRAWN		TR	Oct 2019	SCALE N/A
CHECK		AMP	Oct 2019	REV.
APPR		JMAC	Oct 2019	FIGURE B-3A
 GOLDER SUDBURY, ONTARIO				

SUD-MTO-PL_GLDR_LDN.GDT

PLASTICITY INDEX (Percent)



SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

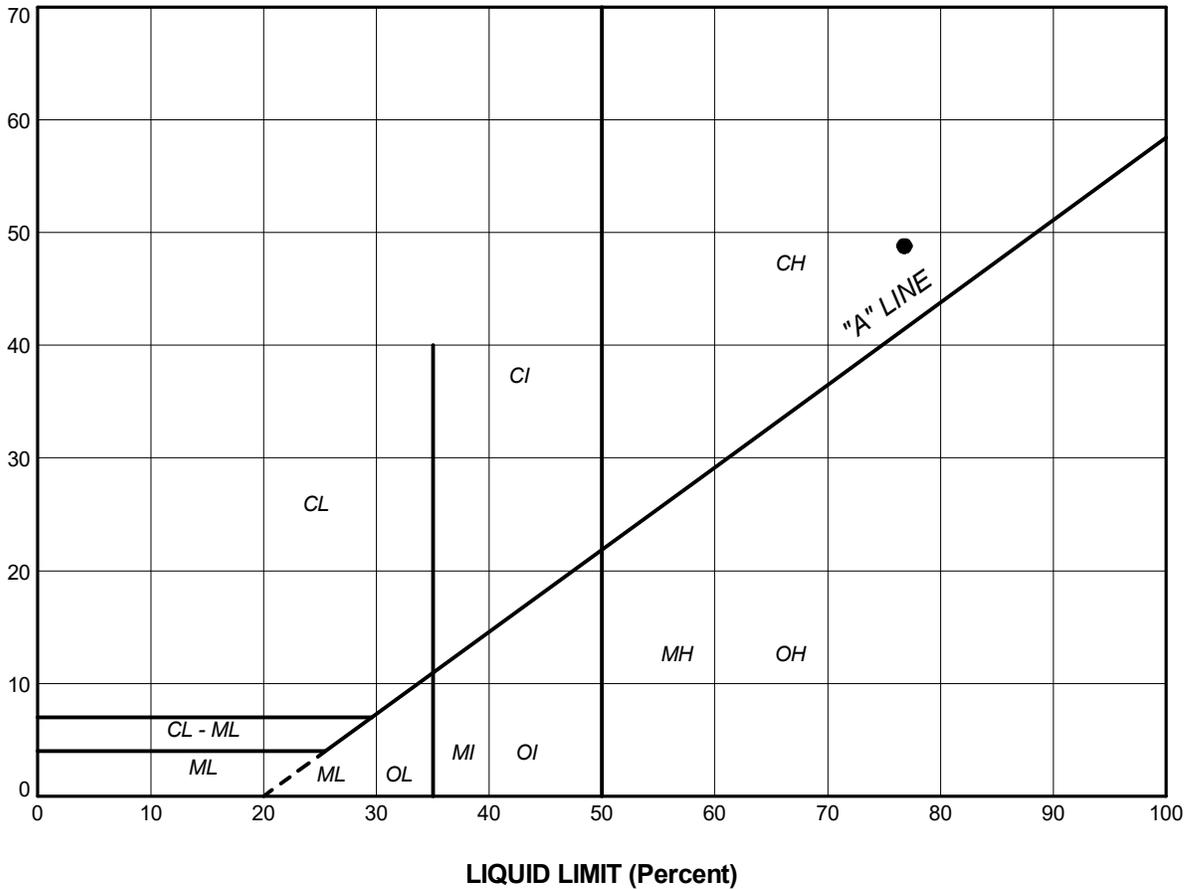
LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C260-5	5A	32.3	21.0	11.3

PROJECT					HIGHWAY 66 STATION 18+386 TOWNSHIP OF GAUTHIER CULVERT				
TITLE					PLASTICITY CHART CLAY and CLAYEY SILT, varved (Clayey Silt component)				
PROJECT No.			1896349		FILE No.			1896349.GPJ	
DRAWN	TR	Oct 2019	SCALE	N/A	REV.				
CHECK	AMP	Oct 2019							
APPR	JMAC	Oct 2019							
 GOLDER SUDBURY, ONTARIO			FIGURE B-3B						

SUD-MTO PL_GLDR_LDN.GDT

PLASTICITY INDEX (Percent)



SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C260-5	5B	76.8	28.0	48.8

PROJECT					HIGHWAY 66 STATION 18+386 TOWNSHIP OF GAUTHIER CULVERT				
TITLE					PLASTICITY CHART CLAY and CLAYEY SILT, varved (Clay component)				
PROJECT No.			1896349		FILE No.			1896349.GPJ	
DRAWN	TR	Oct 2019	SCALE	N/A	REV.				
CHECK	AMP	Oct 2019							
APPR	JMAC	Oct 2019							
 GOLDER SUDBURY, ONTARIO			FIGURE B-3C						

SUD-MTO PL_GLDR_LDN.GDT

CONSOLIDATION TEST SUMMARY

FIGURE 4
Pg. 1 of 4

SAMPLE IDENTIFICATION

Project Number	1896349-2100	Sample Number	5
Borehole Number	C260-5	Sample Depth, m	5.7

TEST CONDITIONS

Test Method	B	Load Duration, hr	24
Oedometer Number	1	Load Increment Ratio	1
Date Started	June 27, 2019		
Date Completed	July 9, 2019		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.53	Unit Weight, kN/m ³	17.48
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m ³	12.18
Area, cm ²	31.61	Specific Gravity, measured	2.735
Volume, cm ³	80.07	Solids Height, cm	1.151
Water Content, %	43.50	Volume of Solids, cm ³	36.37
Wet Mass, g	142.75	Volume of Voids, cm ³	43.69
Dry Mass, g	99.48	Degree of Saturation, %	99.0

TEST COMPUTATIONS

Stress σ_v' kPa	End of Primary Deformation ¹	Specimen Height ²	End of Primary Void Ratio ³	Average Height	Time ¹ t_{90} sec	Coefficient of Consolidation c_v cm ² /s	Modulus of Volume Compressibility m_v m ² /kN	Hydraulic Conductivity ⁴ k_v cm/s	Total Work w kJ/m ³
	ΔH_{EOP} mm	H_{EOI} cm	e_{EOP}	$(H_p + H_{EOI})/2$ cm					
0	0.00	2.533	1.201	2.533					
9	0.03	2.527	1.199	2.530	375	3.62E-03	1.25E-04	4.43E-08	0
17	0.02	2.520	1.194	2.524	265	5.10E-03	2.33E-04	1.17E-07	0
34	0.03	2.508	1.188	2.514	240	5.58E-03	1.81E-04	9.88E-08	0
69	0.06	2.487	1.174	2.497	101	1.30E-02	1.77E-04	2.26E-07	0
137	0.15	2.412	1.148	2.450	60	2.12E-02	1.77E-04	3.67E-07	2
273	0.55	2.262	1.048	2.337	406	2.85E-03	3.31E-04	9.25E-08	11
547	1.27	2.033	0.856	2.147	375	2.61E-03	3.20E-04	8.18E-08	50
1095	0.83	1.916	0.695	1.974	240	3.44E-03	1.33E-04	4.50E-08	121
547	-0.06	1.920	0.669	1.918					
137	-0.20	1.936	0.682	1.928					
34	-0.24	1.955	0.699	1.945					
9	-0.19	1.975	0.716	1.965					

Note:

¹ Root Time Method (Taylor, 1942).

² Specimen height corrected for apparatus deformation and presented for end of increment.

³ Void ratio for unloading (i.e. rebound) calculated for the end of increment.

⁴ Hydraulic conductivity calculated using coefficient of consolidation based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.97	Unit Weight, kN/m ³	20.60
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m ³	15.63
Area, cm ²	31.61	Specific Gravity, measured	2.735
Volume, cm ³	62.43	Solids Height, cm	1.151
Water Content, %	31.82	Volume of Solids, cm ³	36.37
Wet Mass, g	131.13	Volume of Voids, cm ³	26.06
Dry Mass, g	99.48		

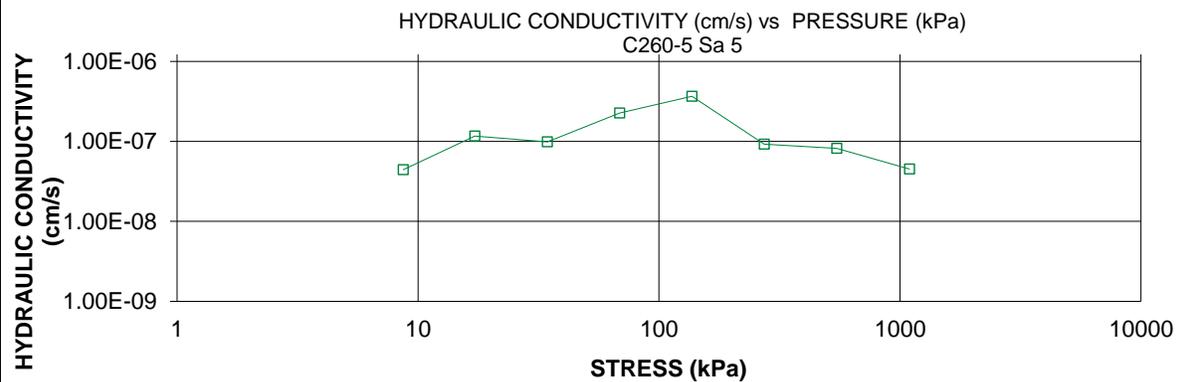
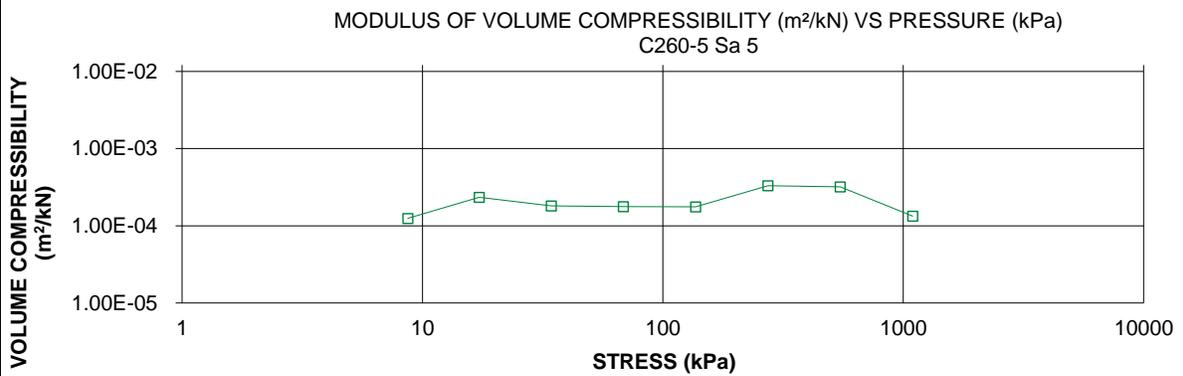
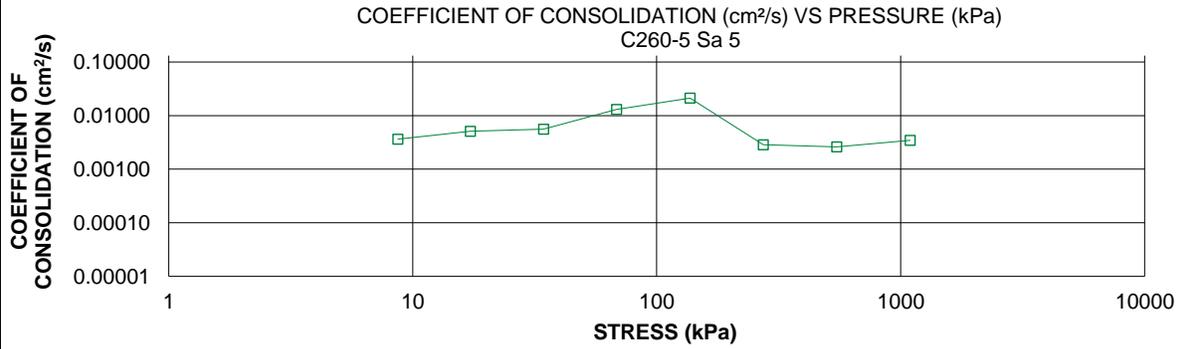


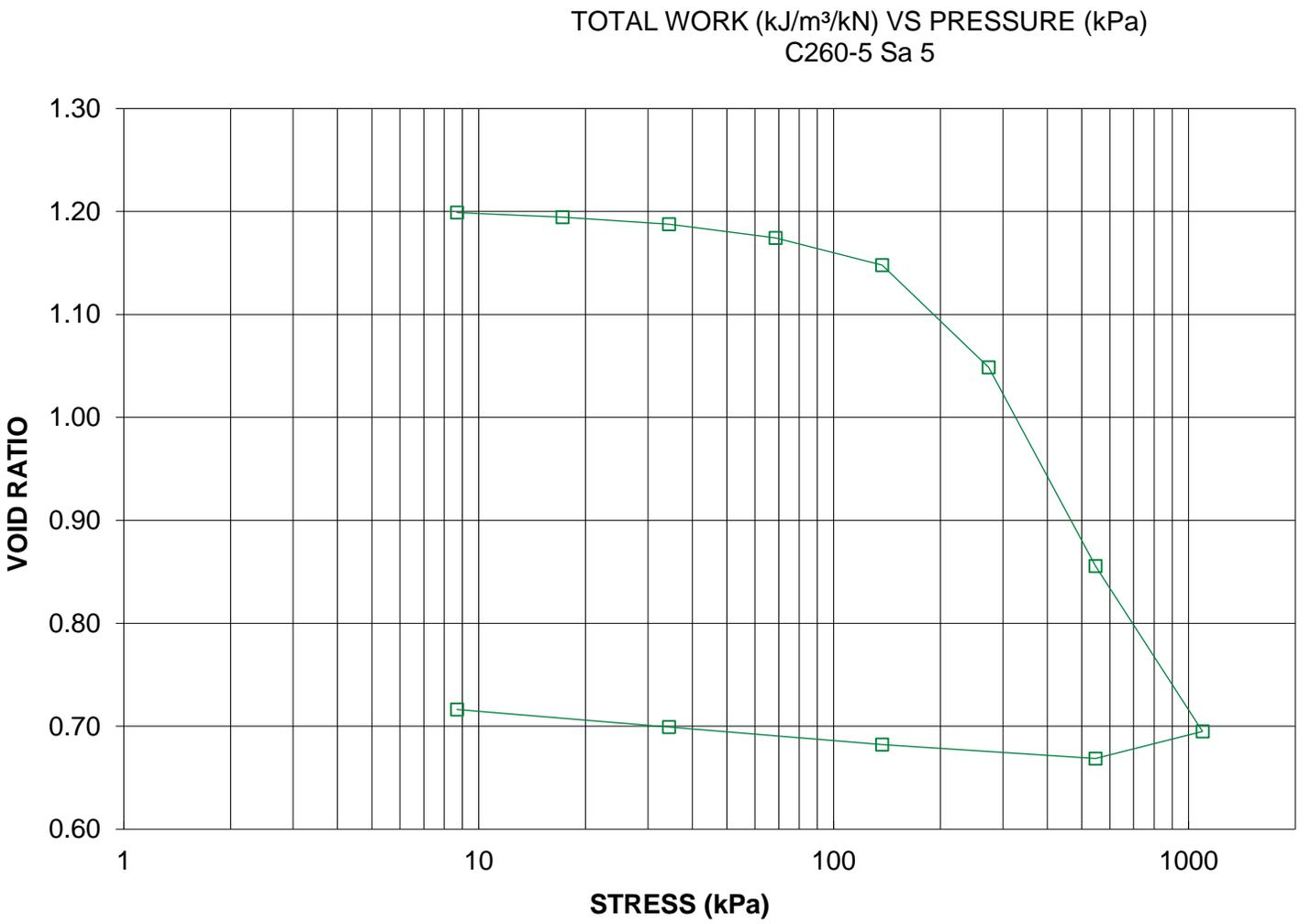
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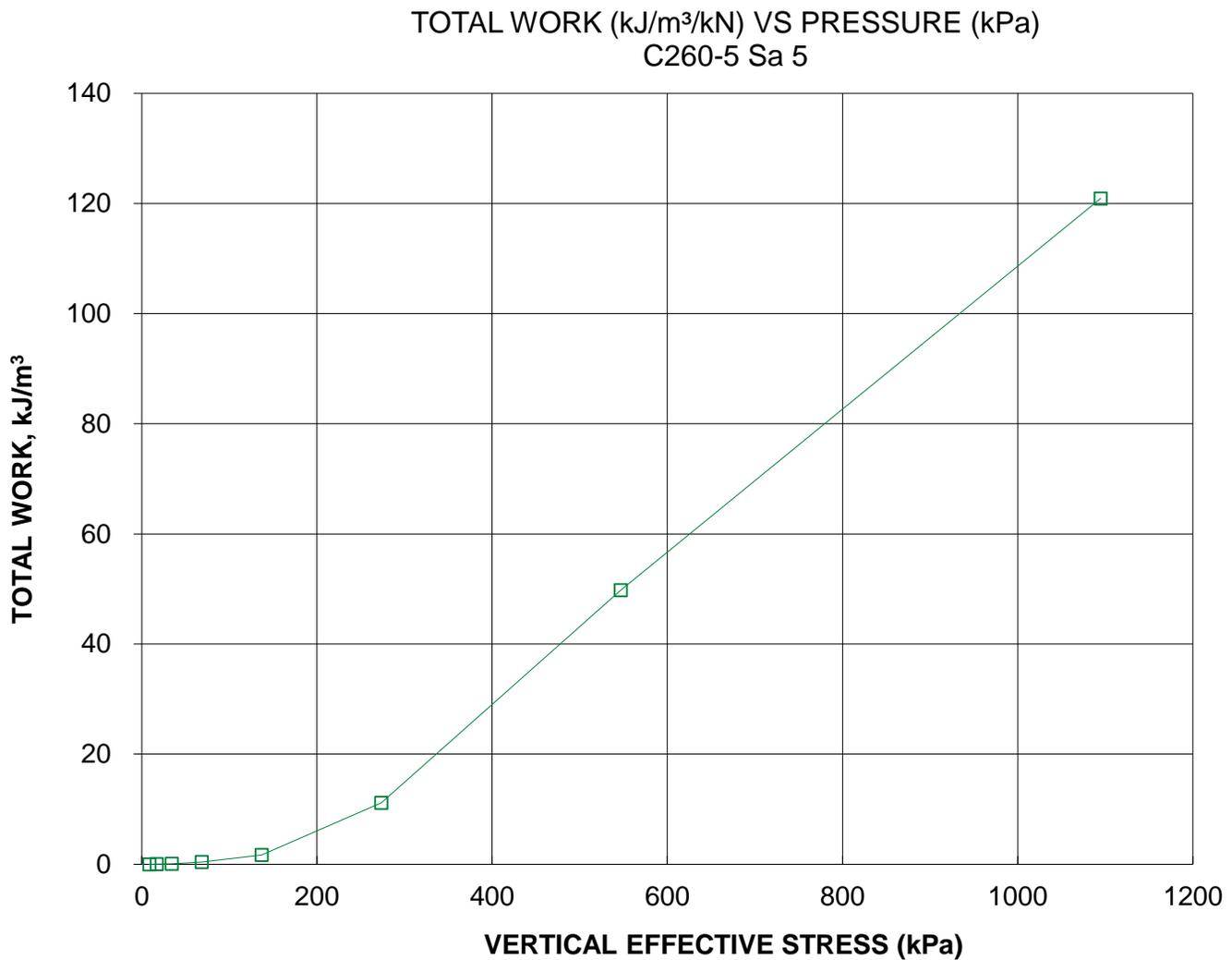
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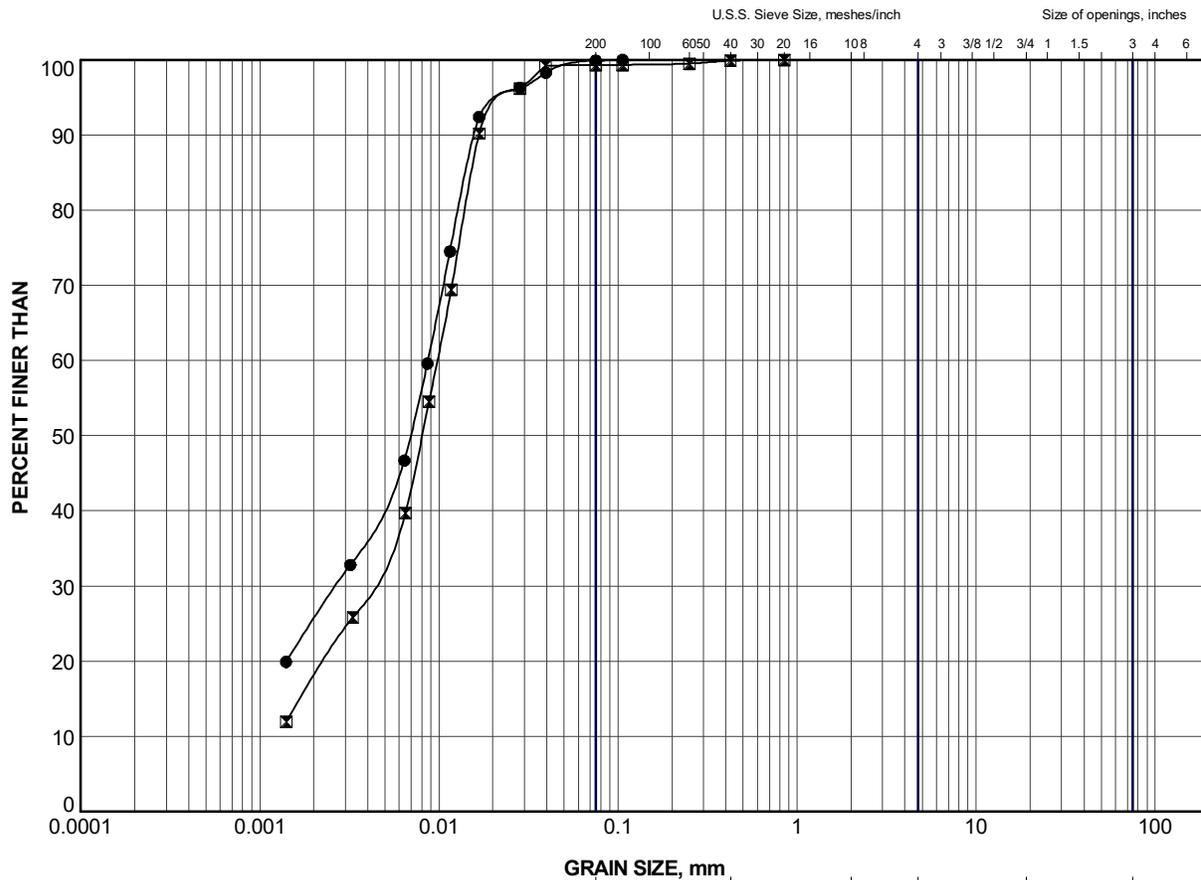
CONSOLIDATION TEST SUMMARY

FIGURE 4
Pg. 2 of 4







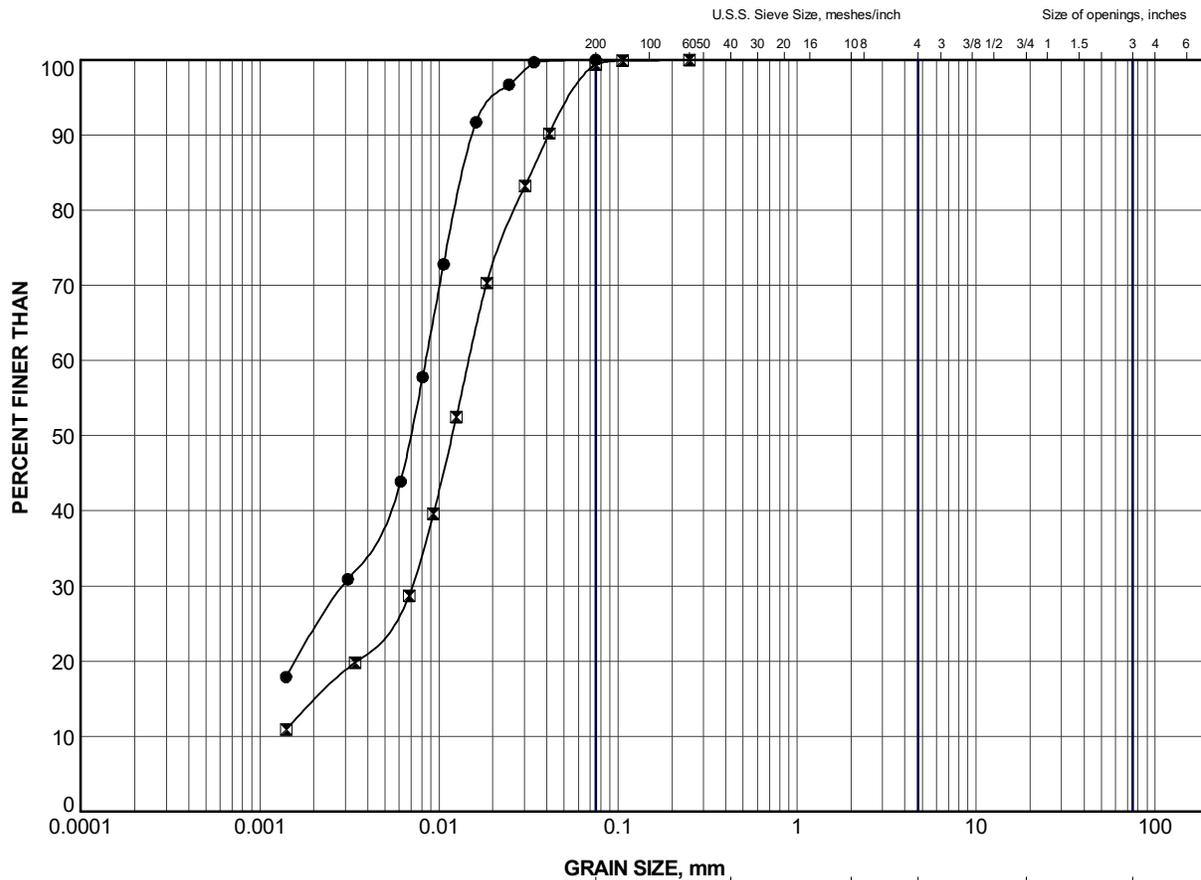


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C260-2	13	262.1
■	C260-3	15	262.3

PROJECT	HIGHWAY 66 STATION 18+386 TOWNSHIP OF GAUTHIER CULVERT				
TITLE	GRAIN SIZE DISTRIBUTION CLAYEY SILT and SILT, layered (Clayey Silt component)				
PROJECT No.	1896349	FILE No.	1896349.GPJ		
DRAWN	TR	Oct 2019	SCALE	N/A	REV.
CHECK	AMP	Oct 2019			
APPR	JMAC	Oct 2019	FIGURE B-5A		
 GOLDER SUDBURY, ONTARIO					



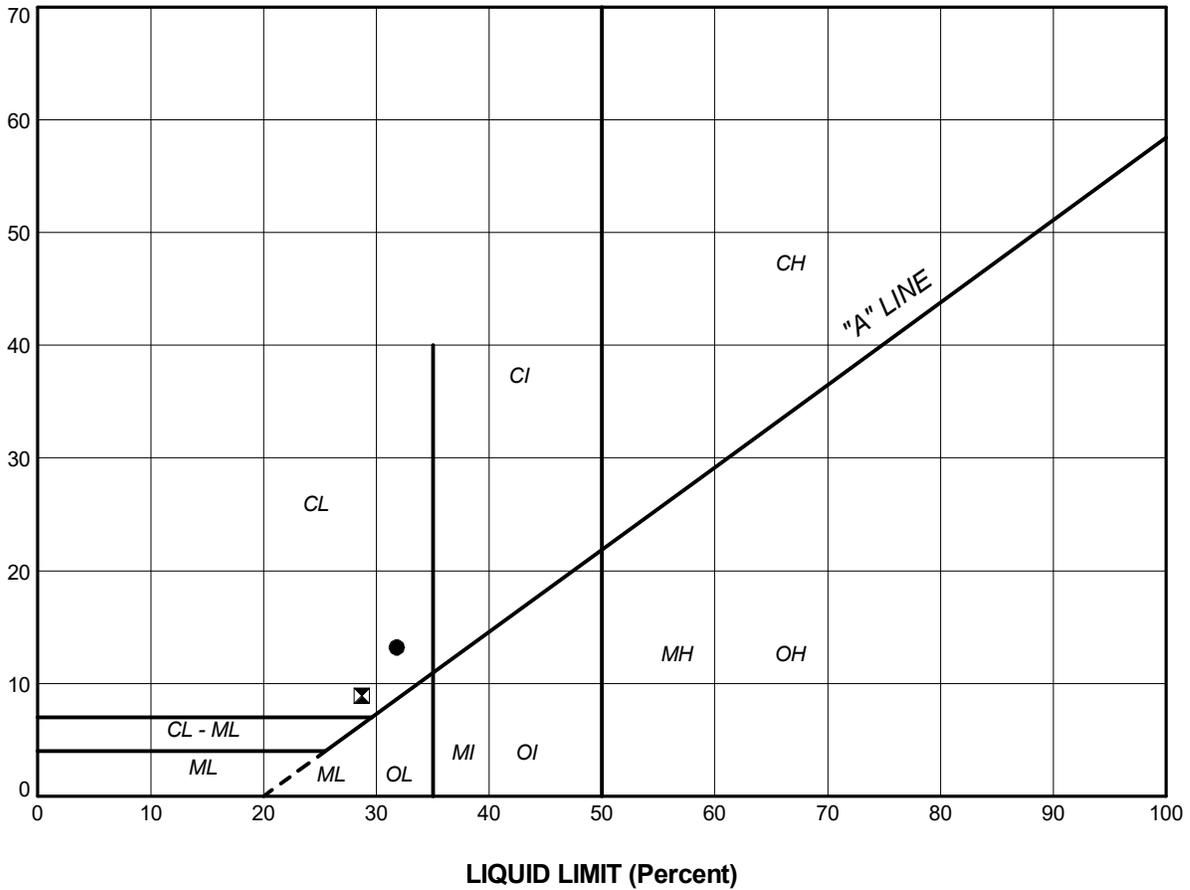
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C260-1	15	262.2
⊠	C260-1	17	259.1

PROJECT	HIGHWAY 66 STATION 18+386 TOWNSHIP OF GAUTHIER CULVERT				
TITLE	GRAIN SIZE DISTRIBUTION CLAYEY SILT and SILT, layered (Silt component)				
 GOLDER SUDBURY, ONTARIO	PROJECT No.	1896349	FILE No.	1896349.GPJ	
	DRAWN	TR	Oct 2019	SCALE	N/A
	CHECK	AMP	Oct 2019	REV.	
	APPR	JMAC	Oct 2019	FIGURE B-5B	

PLASTICITY INDEX (Percent)



SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

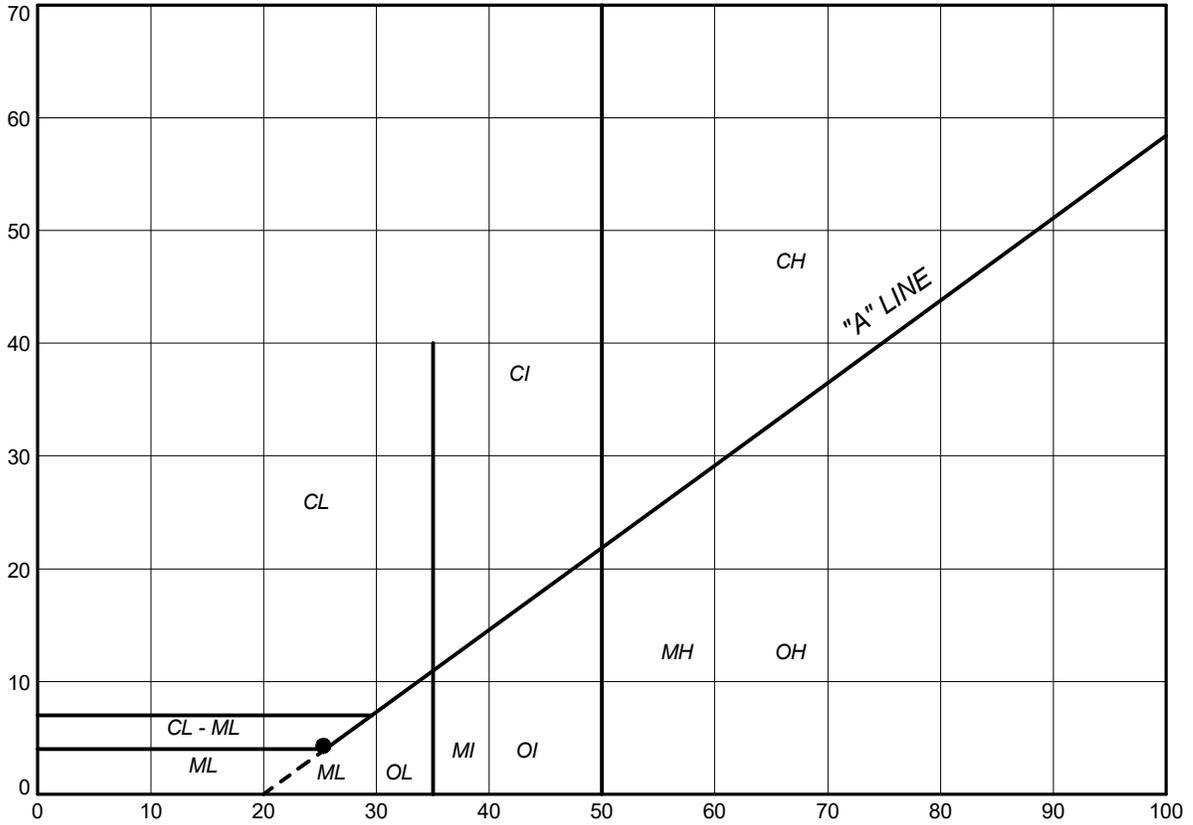
LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C260-2	13	31.8	18.6	13.2
⊠	C260-3	15	28.7	19.8	8.9

PROJECT					HIGHWAY 66 STATION 18+386 TOWNSHIP OF GAUTHIER CULVERT				
TITLE					PLASTICITY CHART CLAYEY SILT and SILT, layered (Clayey Silt component)				
PROJECT No.			1896349		FILE No.			1896349.GPJ	
DRAWN		TR	Oct 2019		SCALE		N/A	REV.	
CHECK		AMP	Oct 2019		FIGURE B-6A				
APPR		JMAC	Oct 2019						
 GOLDER SUDBURY, ONTARIO									

SUD-MTO PL_GLDR_LDN.GDT

PLASTICITY INDEX (Percent)



LIQUID LIMIT (Percent)

SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C260-1	15	25.3	21.0	4.3

PROJECT					HIGHWAY 66 STATION 18+386 TOWNSHIP OF GAUTHIER CULVERT				
TITLE					PLASTICITY CHART CLAYEY SILT and SILT, layered (Silt component)				
PROJECT No.			1896349		FILE No.			1896349.GPJ	
DRAWN		TR	Oct 2019		SCALE		N/A	REV.	
CHECK		AMP	Oct 2019		FIGURE B-6B				
APPR		JMAC	Oct 2019						
 GOLDER SUDBURY, ONTARIO									

SUD-MTO PL_GLDR_LDN.GDT



Your Project #: 1896349(2100)
 Site Location: HWY 66
 Your C.O.C. #: 127611

Attention: Andre Bom

Golder Associates Ltd
 33 Mackenzie Street
 Suite 100
 Sudbury, ON
 Canada P3C 4Y1

Report Date: 2019/06/03
 Report #: R5736732
 Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: B9D3975

Received: 2019/05/17, 09:00

Sample Matrix: Soil
 # Samples Received: 8

Analyses	Quantity	Date	Date	Laboratory Method	Reference
		Extracted	Analyzed		
Chloride (20:1 extract)	8	2019/05/22	2019/05/23	CAM SOP-00463	SM 4500-Cl E m
Conductivity	8	2019/05/23	2019/05/23	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 3)	8	2019/05/23	2019/05/29	BBY8SOP-00017	BCMoe BCLM Dec2000 m
Sulphide in Soil (1)	8	2019/05/23	2019/05/30	BBY6SOP-00052 BBY6SOP-00006	EPA-821-R-91-100 m
pH CaCl2 EXTRACT	8	2019/05/22	2019/05/22	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	8	2019/05/18	2019/05/23	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	8	2019/05/22	2019/05/23	CAM SOP-00464	EPA 375.4 m
Redox Potential (2, 4)	8	N/A	N/A		

Remarks:

Bureau Veritas Laboratories are accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by BV Labs are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in BV Labs profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and BV Labs in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

BV Labs liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. BV Labs has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by BV Labs, unless otherwise agreed in writing. BV Labs is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested. When sampling is not conducted by BV Labs, results relate to the supplied samples tested.

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Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

- (1) This test was performed by Campo to Burnaby - Offsite
- (2) This test was performed by Sub from Campo to Env. Testing Canada (Eurofins)
- (3) Offsite analysis requires that subcontracted moisture be reported.
- (4) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode.



Your Project #: 1896349(2100)
Site Location: HWY 66
Your C.O.C. #: 127611

Attention: Andre Bom

Golder Associates Ltd
33 Mackenzie Street
Suite 100
Sudbury, ON
Canada P3C 4Y1

Report Date: 2019/06/03
Report #: R5736732
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: B9D3975
Received: 2019/05/17, 09:00

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Alisha Williamson, Project Manager
Email: Alisha.Williamson@bvlabs.com
Phone# (613)274-0573

=====

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VERITAS

BV Labs Job #: B9D3975
Report Date: 2019/06/03

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

RESULTS OF ANALYSES OF SOIL

BV Labs ID		JTI430			JTI430		JTI431	JTI432		
Sampling Date		2019/04/30 10:30			2019/04/30 10:30		2019/05/01 16:15	2019/05/03 10:45		
COC Number		127611			127611		127611	127611		
	UNITS	C263-1	RDL	QC Batch	C263-1 Lab-Dup	QC Batch	C260-1	C236-1	RDL	QC Batch

CONVENTIONALS										
Sulphide	ug/g	<0.30	0.30	6150574			<0.30	0.84	0.30	6150574
Calculated Parameters										
Resistivity	ohm-cm	2700		6129977			4000	2400		6129977
Inorganics										
Soluble (20:1) Chloride (Cl-)	ug/g	120	20	6133046			61	260	20	6133046
Conductivity	umho/cm	366	2	6135430			252	413	2	6135430
Available (CaCl2) pH	pH	7.95		6133358	8.09	6133358	8.05	6.31		6133358
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	6133048			<20	<20	20	6133048
Physical Testing										
Moisture-Subcontracted	%	33	0.30	6150575			31	15	0.30	6150575
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate										



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VERITAS

BV Labs Job #: B9D3975
Report Date: 2019/06/03

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

RESULTS OF ANALYSES OF SOIL

BV Labs ID		JTI432			JTI433	JTI434	JTI435	JTI436		
Sampling Date		2019/05/03 10:45			2019/05/04 14:47	2019/05/08 12:39	2019/05/11 16:36	2019/05/14 08:49		
COC Number		127611			127611	127611	127611	127611		
	UNITS	C236-1 Lab-Dup	RDL	QC Batch	C267-1	C228-1	C227-1	C256-1	RDL	QC Batch

CONVENTIONALS										
Sulphide	ug/g				<0.30	<0.30	<0.30	<0.30	0.30	6150574
Calculated Parameters										
Resistivity	ohm-cm				23000	12000	2500	22000		6129977
Inorganics										
Soluble (20:1) Chloride (Cl-)	ug/g				<20	29	250	<20	20	6133046
Conductivity	umho/cm				43	84	405	46	2	6135430
Available (CaCl2) pH	pH				7.74	6.56	7.00	6.30		6133358
Soluble (20:1) Sulphate (SO4)	ug/g				<20	<20	<20	<20	20	6133048
Physical Testing										
Moisture-Subcontracted	%	15	0.30	6150575	21	20	20	20	0.30	6150575
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate										



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VERITAS

BV Labs Job #: B9D3975
Report Date: 2019/06/03

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

RESULTS OF ANALYSES OF SOIL

BV Labs ID		JT1437			JT1437		
Sampling Date		2019/05/14 15:03			2019/05/14 15:03		
COC Number		127611			127611		
	UNITS	C213-1 SA2	RDL	QC Batch	C213-1 SA2 Lab-Dup	RDL	QC Batch
CONVENTIONALS							
Sulphide	ug/g	<0.30 (1)	0.30	6150574	<0.30	0.30	6150574
Calculated Parameters							
Resistivity	ohm-cm	11000		6129977			
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	6133046			
Conductivity	umho/cm	88	2	6135430			
Available (CaCl2) pH	pH	7.60		6133358			
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	6133048			
Physical Testing							
Moisture-Subcontracted	%	15	0.30	6150575			
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate (1) Matrix Spike exceeds acceptance limits due to matrix interference. Reanalysis yields similar results.							



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VERITAS

BV Labs Job #: B9D3975
Report Date: 2019/06/03

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

TEST SUMMARY

BV Labs ID: JTI430
Sample ID: C263-1
Matrix: Soil

Collected: 2019/04/30
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6133046	2019/05/22	2019/05/23	Deonarine Ramnarine
Conductivity	AT	6135430	2019/05/23	2019/05/23	Kazzandra Adeva
Moisture (Subcontracted)	BAL	6150575	2019/05/23	2019/05/29	Lolita Obusan
Sulphide in Soil	SPEC/UVVS	6150574	2019/05/23	2019/05/30	David Huang
pH CaCl2 EXTRACT	AT	6133358	2019/05/22	2019/05/22	Gnana Thomas
Resistivity of Soil		6129977	2019/05/23	2019/05/23	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6133048	2019/05/22	2019/05/23	Alina Dobreanu
Redox Potential	COND	6142427	2019/05/27		Katherine Szozda

BV Labs ID: JTI430 Dup
Sample ID: C263-1
Matrix: Soil

Collected: 2019/04/30
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
pH CaCl2 EXTRACT	AT	6133358	2019/05/22	2019/05/22	Gnana Thomas

BV Labs ID: JTI431
Sample ID: C260-1
Matrix: Soil

Collected: 2019/05/01
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6133046	2019/05/22	2019/05/23	Deonarine Ramnarine
Conductivity	AT	6135430	2019/05/23	2019/05/23	Kazzandra Adeva
Moisture (Subcontracted)	BAL	6150575	2019/05/23	2019/05/29	Lolita Obusan
Sulphide in Soil	SPEC/UVVS	6150574	2019/05/23	2019/05/30	David Huang
pH CaCl2 EXTRACT	AT	6133358	2019/05/22	2019/05/22	Gnana Thomas
Resistivity of Soil		6129977	2019/05/23	2019/05/23	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6133048	2019/05/22	2019/05/23	Alina Dobreanu
Redox Potential	COND	6142427	2019/05/27		Katherine Szozda

BV Labs ID: JTI432
Sample ID: C236-1
Matrix: Soil

Collected: 2019/05/03
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6133046	2019/05/22	2019/05/23	Deonarine Ramnarine
Conductivity	AT	6135430	2019/05/23	2019/05/23	Kazzandra Adeva
Moisture (Subcontracted)	BAL	6150575	2019/05/23	2019/05/29	Lolita Obusan
Sulphide in Soil	SPEC/UVVS	6150574	2019/05/23	2019/05/30	David Huang
pH CaCl2 EXTRACT	AT	6133358	2019/05/22	2019/05/22	Gnana Thomas
Resistivity of Soil		6129977	2019/05/23	2019/05/23	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6133048	2019/05/22	2019/05/23	Alina Dobreanu
Redox Potential	COND	6142427	2019/05/27		Katherine Szozda



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VERITAS

BV Labs Job #: B9D3975
Report Date: 2019/06/03

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

TEST SUMMARY

BV Labs ID: JTI432 Dup
Sample ID: C236-1
Matrix: Soil

Collected: 2019/05/03
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture (Subcontracted)	BAL	6150575	2019/05/23	2019/05/29	Lolita Obusan

BV Labs ID: JTI433
Sample ID: C267-1
Matrix: Soil

Collected: 2019/05/04
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6133046	2019/05/22	2019/05/23	Deonarine Ramnarine
Conductivity	AT	6135430	2019/05/23	2019/05/23	Kazzandra Adeva
Moisture (Subcontracted)	BAL	6150575	2019/05/23	2019/05/29	Lolita Obusan
Sulphide in Soil	SPEC/UVVS	6150574	2019/05/23	2019/05/30	David Huang
pH CaCl2 EXTRACT	AT	6133358	2019/05/22	2019/05/22	Gnana Thomas
Resistivity of Soil		6129977	2019/05/23	2019/05/23	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6133048	2019/05/22	2019/05/23	Alina Dobreanu
Redox Potential	COND	6142427	2019/05/27		Katherine Szozda

BV Labs ID: JTI434
Sample ID: C228-1
Matrix: Soil

Collected: 2019/05/08
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6133046	2019/05/22	2019/05/23	Deonarine Ramnarine
Conductivity	AT	6135430	2019/05/23	2019/05/23	Kazzandra Adeva
Moisture (Subcontracted)	BAL	6150575	2019/05/23	2019/05/29	Lolita Obusan
Sulphide in Soil	SPEC/UVVS	6150574	2019/05/23	2019/05/30	David Huang
pH CaCl2 EXTRACT	AT	6133358	2019/05/22	2019/05/22	Gnana Thomas
Resistivity of Soil		6129977	2019/05/23	2019/05/23	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6133048	2019/05/22	2019/05/23	Alina Dobreanu
Redox Potential	COND	6142427	2019/05/27		Katherine Szozda

BV Labs ID: JTI435
Sample ID: C227-1
Matrix: Soil

Collected: 2019/05/11
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6133046	2019/05/22	2019/05/23	Deonarine Ramnarine
Conductivity	AT	6135430	2019/05/23	2019/05/23	Kazzandra Adeva
Moisture (Subcontracted)	BAL	6150575	2019/05/23	2019/05/29	Lolita Obusan
Sulphide in Soil	SPEC/UVVS	6150574	2019/05/23	2019/05/30	David Huang
pH CaCl2 EXTRACT	AT	6133358	2019/05/22	2019/05/22	Gnana Thomas
Resistivity of Soil		6129977	2019/05/23	2019/05/23	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6133048	2019/05/22	2019/05/23	Alina Dobreanu
Redox Potential	COND	6142427	2019/05/27		Katherine Szozda



BUREAU
VERITAS

BV Labs Job #: B9D3975
Report Date: 2019/06/03

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

TEST SUMMARY

BV Labs ID: JTI436
Sample ID: C256-1
Matrix: Soil

Collected: 2019/05/14
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6133046	2019/05/22	2019/05/23	Deonarine Ramnarine
Conductivity	AT	6135430	2019/05/23	2019/05/23	Kazzandra Adeva
Moisture (Subcontracted)	BAL	6150575	2019/05/23	2019/05/29	Lolita Obusan
Sulphide in Soil	SPEC/UVVS	6150574	2019/05/23	2019/05/30	David Huang
pH CaCl2 EXTRACT	AT	6133358	2019/05/22	2019/05/22	Gnana Thomas
Resistivity of Soil		6129977	2019/05/23	2019/05/23	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6133048	2019/05/22	2019/05/23	Alina Dobreanu
Redox Potential	COND	6142427	2019/05/27		Katherine Szozda

BV Labs ID: JTI437
Sample ID: C213-1 SA2
Matrix: Soil

Collected: 2019/05/14
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	6133046	2019/05/22	2019/05/23	Deonarine Ramnarine
Conductivity	AT	6135430	2019/05/23	2019/05/23	Kazzandra Adeva
Moisture (Subcontracted)	BAL	6150575	2019/05/23	2019/05/29	Lolita Obusan
Sulphide in Soil	SPEC/UVVS	6150574	2019/05/23	2019/05/30	David Huang
pH CaCl2 EXTRACT	AT	6133358	2019/05/22	2019/05/22	Gnana Thomas
Resistivity of Soil		6129977	2019/05/23	2019/05/23	Anastassia Hamanov
Sulphate (20:1 Extract)	KONE/EC	6133048	2019/05/22	2019/05/23	Alina Dobreanu
Redox Potential	COND	6142427	2019/05/27		Katherine Szozda

BV Labs ID: JTI437 Dup
Sample ID: C213-1 SA2
Matrix: Soil

Collected: 2019/05/14
Shipped:
Received: 2019/05/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphide in Soil	SPEC/UVVS	6150574	2019/05/30	2019/05/30	David Huang



GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	6.7°C
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Sample JTI430 [C263-1] : Sample analyzed past method specified hold time for Sulphide in Soil. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Sample JTI431 [C260-1] : Sample analyzed past method specified hold time for Sulphide in Soil. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Sample JTI432 [C236-1] : Sample analyzed past method specified hold time for Sulphide in Soil. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Sample JTI433 [C267-1] : Sample analyzed past method specified hold time for Sulphide in Soil. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Sample JTI434 [C228-1] : Sample analyzed past method specified hold time for Sulphide in Soil. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Sample JTI435 [C227-1] : Sample analyzed past method specified hold time for Sulphide in Soil. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Sample JTI436 [C256-1] : Sample analyzed past method specified hold time for Sulphide in Soil. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Sample JTI437 [C213-1 SA2] : Sample analyzed past method specified hold time for Sulphide in Soil. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Results relate only to the items tested.



BUREAU
VERITAS

BV Labs Job #: B9D3975
Report Date: 2019/06/03

QUALITY ASSURANCE REPORT

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

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
6133046	Soluble (20:1) Chloride (Cl-)	2019/05/23	NC	70 - 130	105	70 - 130	<20	ug/g	8.1	35
6133048	Soluble (20:1) Sulphate (SO4)	2019/05/23	NC	70 - 130	109	70 - 130	<20	ug/g	1.1	35
6133358	Available (CaCl2) pH	2019/05/22			101	97 - 103			1.8	N/A
6135430	Conductivity	2019/05/23			103	90 - 110	<2	umho/cm		
6150574	Sulphide	2019/05/30	47 (1)	75 - 125	106	75 - 125	<0.50	ug/g	NC	30
6150575	Moisture-Subcontracted	2019/05/29					<0.30	%	2.0	20

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.



BUREAU
VERITAS

BV Labs Job #: B9D3975
Report Date: 2019/06/03

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

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Anastassia Hamanov, Scientific Specialist

David Huang, BBY Scientific Specialist

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Invoice Information		Report Information (if differs from invoice)				Project Information (where applicable)				Turnaround Time (TAT) Required				
Company Name: <u>GOLDER ASSOCIATES</u>		Company Name:				Quotation #:				<input checked="" type="checkbox"/> Regular TAT (5-7 days) Most analyses				
Contact Name: <u>Andre Bom</u>		Contact Name:				P.O. #/ AFE#:				PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS				
Address: <u>33 Mackenzie St</u>		Address:				Project #: <u>1896349 (2100)</u>				Rush TAT (Surcharges will be applied)				
Phone: <u>(705) 529-6861</u> Fax:		Phone: Fax:				Site Location: <u>Hwy 66</u>				<input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days				
Email: <u>Andre_Bom@golder.com</u>		Email:				Site #:				Date Required:				
MDE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY						Site Location Province:				Rush Confirmation #:				
Regulation 153		Other Regulations				Analysis Requested				LABORATORY USE ONLY				
<input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Med/ Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agr/ Other <input type="checkbox"/> Table _____ FOR RSC (PLEASE CIRCLE) Y / N		<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> MISA <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> PWQO Region <input type="checkbox"/> Other (Specify) <input type="checkbox"/> REG 558 (MIN. 3 DAY TAT REQUIRED)				FIELD FILTERED (CIRCLE) Metals / Hg / Cr VI BTEX / PHE F1 PHC/F2 - F4 VOCS REG 153 METALS & INORGANICS REG 153 ICPMS METALS REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B) <u>Corrosivity</u>				CUSTODY SEAL Y (N) Present Intact <u>N</u> <u>87.5°C</u>				
Include Criteria on Certificate of Analysis: Y / N						HOLD - DO NOT ANALYZE				COOLING MEDIA PRESENT: (Y) / N				
SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM										COMMENTS				
SAMPLE IDENTIFICATION		DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / Cr VI	BTEX / PHE F1	PHC/F2 - F4	VOCS	REG 153 METALS & INORGANICS	REG 153 ICPMS METALS	REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B)	17-May-19 09:00 Alisha Williamson B9D3975 URE ENV-946	
1	C 263-1	2019/04/30	10:30	Soil	3								X	Received in Sudbury
2	C 260-1	2019/05/01	16:15	Soil	3								X	
3	C 236-1	2019/05/03	10:45	Soil	3								X	
4	C 267-1	2019/05/07	14:47	Soil	3								X	
5	C 228-1	2019/05/08	12:39	Soil	3								X	
6	C 227-1	2019/05/11	16:36	Soil	3								X	
7	C 256-1	2019/05/14	08:49	Soil	3								X	
8	C 213-1 Sa2	2019/05/14	15:03	Soil	3								X	
9														
10														
RELINQUISHED BY: (Signature/Print)		DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)		DATE: (YYYY/MM/DD)	TIME: (HH:MM)	MAXXAM JOB #						
<u>M. Riopelle</u>		2019/05/17	09:10	<u>B. Ki / Bradley Francis</u>		2019/05/17	9:00							
				<u>Robert / Robert K. ...</u>		2019/05/18	09:41							

Unless otherwise agreed to in writing, work submitted on this Chain of Custody is subject to Maxxam's standard Terms and Conditions. Signing of this Chain of Custody document is acknowledgment and acceptance of our terms which are available for viewing at www.maxxam.ca/terms. Sample container, preservation, hold time and packages information can be viewed at <http://www.maxxam.ca/wp-content/uploads/Ontario-COC.pdf>.

4/0/0 2/0/3

Client: Maxxam Analytics Inc.
6740 Campobello Road
Mississauga, ON
L5N 2L8
Attention: Ms. Alisha Williamson
PO#:
Invoice to: Maxxam Analytics Inc.

Report Number: 1907932
Date Submitted: 2019-05-22
Date Reported: 2019-05-27
Project: B9D3975
COC #: 843738

Page 1 of 3

Dear Alisha Williamson:

Please find attached the analytical results for your samples. If you have any questions regarding this report, please do not hesitate to call (613-727-5692).

Report Comments:

APPROVAL: _____

Addrine Thomas, Inorganics Supervisor

All analysis is completed at Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) unless otherwise indicated.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by CALA, Canadian Association for Laboratory Accreditation to ISO/IEC 17025 for tests which appear on the scope of accreditation. The scope is available at: <http://www.cala.ca/scopes/2602.pdf>.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is licensed by the Ontario Ministry of the Environment, Conservation, and Parks (MECP) for specific tests in drinking water (license #2318). A copy of the license is available upon request.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by the Ontario Ministry of Agriculture, Food, and Rural Affairs for specific tests in agricultural soils.

Please note: Field data, where presented on the report, has been provided by the client and is presented for informational purposes only. Guideline values listed on this report are provided for ease of use (informational purposes) only. Eurofins recommends consulting the official provincial or federal guideline as required. Unless otherwise stated, measurement uncertainty is not taken into account when determining guideline or regulatory exceedances.

Certificate of Analysis

Client: Maxxam Analytics Inc.
 6740 Campobello Road
 Mississauga, ON
 L5N 2L8
 Attention: Ms. Alisha Williamson
 PO#:
 Invoice to: Maxxam Analytics Inc.

Report Number: 1907932
 Date Submitted: 2019-05-22
 Date Reported: 2019-05-27
 Project: B9D3975
 COC #: 843738

Group	Analyte	MRL	Units	Guideline	Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1427831 Soil 2019-04-30 JT1430-C263-1	1427832 Soil 2019-05-01 JT1431-C260-1	1427833 Soil 2019-05-03 JT1432-C236-1	1427834 Soil 2019-05-04 JT1433-C267-1
Redox Potential	REDOX Potential		mV			-212.9	-200.8	-249.4	-139.0

Group	Analyte	MRL	Units	Guideline	Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1427835 Soil 2019-05-08 JT1434-C228-1	1427836 Soil 2019-05-11 JT1435-C277-1	1427837 Soil 2019-05-14 JT1436-C256-1	1427838 Soil 2019-05-14 JT1437-C213-1 SA2
Redox Potential	REDOX Potential		mV			-108.9	-167.3	-95.6	-50.9

Guideline = * = **Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

Client: Maxxam Analytics Inc.
 6740 Campobello Road
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Report Number: 1907932
 Date Submitted: 2019-05-22
 Date Reported: 2019-05-27
 Project: B9D3975
 COC #: 843738

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 366194 Analysis/Extraction Date 2019-05-24 Analyst AET Method C SM2580B			
REDOX Potential	99 mV	100	
Run No 366284 Analysis/Extraction Date 2019-05-24 Analyst AET Method C SM2580B			
REDOX Potential		100	

Guideline = * = **Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

APPENDIX C

**Non-Standard Special Provisions
and Notice to Contractor**

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

January 2019

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

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1.0	SCOPE
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10.0	BASIS OF PAYMENT
1.0	SCOPE

This specification covers the requirements for the installation of pipe by a selected trenchless method.

2.0 REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 Management of Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 401 Trenching, Backfilling, and Compacting

OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers

OPSS 403 Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut

OPSS 404 Support Systems

OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines

OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering
OPSS 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004	Aggregates - Miscellaneous
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene (PE) Plastic Pipe Products

CSA Standards

B182.6	Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
A3000	Cementitious Materials Compendium
W59	Welded Steel Construction (Metal Arc Welding)

American Society for Testing and Materials (ASTM) International Standards

A 252	Standard Specification for Welded and Seamless Steel Pipe Piles
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

17025	General Requirements for the Competence of the Testing and Calibration Laboratories
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3.0 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore means a method of forming a horizontal bore in the subsurface by simultaneously or alternately jacking into the ground a casing pipe and rotating a cutter head at the lead end of an auger flight with removal of material from inside the casing by using continuous-flight augers.

Backreamer or Reamer means a cutting head suitably designed for the subsurface conditions that is attached to drilling equipment and used to enlarge the bore

Bore Path means a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer means the Engineer retained by the Contractor who produces the design and working drawings and other engineering documents required of the Contractor. The Design Engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario, shall not be an employee of the Contractor and shall be independent from the Design Engineer.

Digger Shield/Hand Mining means a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking a casing pipe, with or without a protective shield at the lead end, into the ground while tunnelling and removal of earth and rock is completed using manually-operated tools (e.g., pneumatic spades, rams, shovels, breaker bars, etc.) or a “digger” type shield with a hydraulic excavator arm or “road-header” rock cutting machine to remove materials from inside the shield and liner pipe.

Horizontal Directional Drilling (HDD) means horizontal directional boring or guided boring.

Drilling Fluids means a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Hydraulic Fracture or “Frac Out” means a condition where the drilling fluid’s pressure in the bore is sufficient to fracture the soil and/or rock materials and allow the drilling fluids to migrate to the surface at an unplanned location.

Earth Pressure Balance (EPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of mixed earth, rock and any drilling fluids or additives (spoil) as maintained by and in a chamber behind the cutting face of a tunnel boring machine through which spoil can pass only by manner of controlled-load relieving gates or an internal screw-conveyor that is separate from subsequent spoil conveyance systems (e.g., flight augers, belt conveyor, spoil bucket rail cars, etc.). Trenchless systems that apply pressure to the excavated face of the ground only through mechanical and jacking forces on metal parts of the machinery (e.g., steel parts of cutting tools, adjustable gates or doors at cutting face, etc.) will not be considered equivalent to EPB systems.

Excavation means all materials encountered regardless of type and extent and shall include removal of natural soil, boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA) means areas specified in the Contract Documents that are prohibited from entry or use.

Fill means man-made mixture of previously placed or handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Guidance System means an electronic system capable of indicating the position, depth and orientation of the drill head during the directional drilling process.

Hand Mining means a method of forming a horizontal bore in the subsurface by simultaneously jacking ahead while tunnelling advances using hand-mining (man-entry operation or “Jack and Mine”) or a “digger” type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Inadvertent Returns means the unexpected flow of fluids, saturated materials (or flowing soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation means the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Microtunnelling means an underground method of constructing a passage by using a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

Pilot Bore means the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking means a method for installing steel casing, concrete pipe or other acceptable material in the subsurface utilizing hydraulically operated jacks of adequate number and capacity for the smooth and uniform advancement of the casing or pipe.

Pipe means pipe culverts, pipe storm and sanitary sewers, watermain pipe, conduits and ducts.

Pipe Ramming means a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Project Superintendent means an individual representing the Contractor that oversees the trenchless or tunnelling operation qualified to provide the services specified in the Contract Documents.

Pullback means that part of the HDD method in which the drilling equipment is pulled back through the bore path to the entry point.

Reaming means a process for enlarging the bore path

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m³ or greater.

Shaft means an excavation used as entry and/or exit points, alternatively called entry/exit pits, from which the trenchless method is initiated for the installation of the pipe product.

Slurry Pressure Balance (SPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a TBM or MTBM through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

Strike Alert means a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry means a mixture of soil and/or rock cuttings, and drilling fluid.

Soil means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Spoil means mix of earth cuttings, rock cuttings, water (groundwater or added water), bentonite, polymers and/or other additives that is discharged from the trenchless construction systems.

Trenchless Installation means an underground method of constructing a passage open at both ends that involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

Trenchless Contractor means the subcontractor retained by the Prime Contractor qualified to provide the services specified in the Contract Documents.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnel boring machine (MTBM) operated by personnel at a remote control station or excavation using a shield to support the opening and protect workers.

Zone of Influence means a zone defined by lines projected outward and upward at 45 degrees from horizontal to the ground surface from the vertical and horizontal alignment of the pipe constructed using trenchless/tunnel methods.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

The Contractor shall determine the most appropriate method of installation for each location within the terms of this specification.

The installation method selected for each pipe crossing shall be designed for the subsurface conditions as reported in the Contract Documents.

The detailed design of the installation method selected to carry out the work as specified in the Contract Documents shall be completed.

Based on the ground conditions at the culvert site crossing Highway 66, Station 18+386, Township of Gauthier and the anticipated relatively short tunnel distance of about 40 m, HDD, TBM, Tunnel Digging Machine (TDM) Pilot Tube Micro-tunnelling and (PTMT), MTBM and Auger Jack and Bore methods are likely not suitable or cost-effective methods for culvert installation. The diameter of the culvert will also preclude the use of HDD.

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names and the demonstrated project experience of the Project Superintendent, Trenchless contractor, Design Engineer, and Design Checking Engineer shall be submitted to the Contract Administrator.

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five years' demonstrated experience on projects with similar scope and complexity.

During construction, the project superintendent shall not change without written permission from the Contract Administrator. A proposal for a change in the project superintendent shall be submitted at least one week prior to the actual change in project superintendent.

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five years' demonstrated experience on projects with similar scope and complexity

4.02.01.03 Design Engineer

The Design Engineer shall have a minimum of five years' demonstrated experience on projects with similar scope and complexity

4.02.01.04 Design Checking Engineer

The Design Checking Engineer shall have a minimum of five years' demonstrated experience on projects with similar scope and complexity

4.02.02 Working Drawings

Three sets of Working Drawings for the trenchless installation method selected shall be submitted to the Contract Administrator (CA) for purposes of documentation and quality assurance at least two week prior to the commencement of the work. All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

The working drawings shall be submitted to the Contract Administrator under cover with a Request to Proceed.

The Contractor shall not proceed with the work until a Notice to Proceed has been received from the Contract Administrator

A copy of the Working Drawings shall be kept at the site during construction.

Information and details shown on the Working Drawings shall include, but not be limited to:

a) Plans and Details:

- i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work;
- ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the work.
- iii. A list of personnel, including backup personnel, and their qualifications and experience.
- iv. A safety plan including the company safety manual and emergency procedures.
- v. The work area layout.
- vi. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- vii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
- viii. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails.
- ix. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- x. Excavated materials disposal plan.
- xi. Locations of protection systems.

b) Designs

- i. Primary liner design (e.g., steel liner plates, steel ribs and wood lagging, steel casing pipe, etc.),
- ii. Design assumption and material data when materials other than those specified are proposed for use.
- iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- i. Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.
- ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance, Slurry Pressure Balance
- iii. Manufacturer data sheets for drilling systems.
- iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and EPB TBM and MTBM operations.
- v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
- vi. Compressive strength of concrete pipe products.
- vii. Pipe class for all steel pipe products.
- viii. Steel for Permanent Casings
 - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
 - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.
 - The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory
- ix. The Contractor shall submit the followings to the Contract Administrator two weeks prior to construction:
 - type, source, and physical and chemical properties of bentonite, polymer or other additives;
 - source of water;
 - method of mixing;
 - the water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
 - details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunnelling fluids or EPB spoil; and method of disposal of the slurry, drilling fluids and associated spoil

d) Upstream/Downstream Portal Installation Procedure:

- i. The access shaft or entry/exit pit details, as applicable.
- ii. Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- i. Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in.
- ii. Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- i. Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;
- ii. Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;
- iii. Equipment and methods for removal of cobbles and boulders;
- iv. Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, SPB and EPB pressures;
- v. Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;
- vi. Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;
- vii. Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship of target operating conditions to ground conditions;
- viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;
- ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

Methods, equipment, frequency and repeatability (accuracy and precision) of data collection to be employed for measuring and monitoring shall be submitted for:

- i. Maintaining the alignment of the installation;
- ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
- iii. Jacking forces on pipes, linings and cutting tools;
- iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
- v. Grout injection pressures and volumes;
- vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.);
- vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction

4.02.03 Quality Control Certificate

The Contractor shall submit a Quality Control Certificate to the Contract Administrator for documentation and quality assurance purposes, prepared and stamped by the Design and Design Checking Engineers, a minimum of two weeks prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Quality Control Certificate sealed and signed by the Design and Design Checking Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

- Site Surveying (as noted in Section 4.02)
- Excavation for pits including dewatering of excavations
- Jacking/Ramming/Directional Drilling of Casing/Liner
- Installation of the Product
- Grouting Operations

Each Quality Control Certificate shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

The Contractor shall submit a Request to Proceed to the Contract Administrator upon completion of each of the milestones.

The Contractor shall not proceed to the subsequent operation until a Notice to Proceed has been received from the Contract Administrator

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design and Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

5.0 MATERIALS

5.01 Pipe

5.01.01 General

The product shall be concrete pipe, steel pipe or high density polyethylene pipe as specified.

All joints shall be suitable for jacking operations as specified in the working drawings.

Fittings shall be suitable and compatible with the class and type of pipe with which they will be used.

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

Steel casing pipe shall meet a straightness tolerance of 1.5 mm/m. When placed anywhere on the pipe parallel to the pipe axis, there shall not be a gap more than 1.5 mm between a 1 m long straightedge and the pipe.

5.01.03 HDPE Pipe

High density polyethylene (HDPE) pipe according to OPSS 1840 shall be used in accordance with ASTM D3350.

Fittings shall be according to CAN/CSA-B182.6 or ASTM F894 and suitable for the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed according to the manufacturer's recommended procedures and ASTM D2657. Where conflicts exist between the manufacturer's instructions and ASTM D2657, the manufacturer's instructions are to be followed.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified on the Working Drawings.

5.03 Steel Reinforcement

Steel reinforcement for concrete work shall be according to OPSS 1440.

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the working drawings.

Selection of drilling fluid type shall be based on the soils encountered in the subsurface investigation.

The drilling fluids shall be mixed according to the manufacturer's recommendations.

Slurry shall be mixed according to the submitted slurry design and be appropriate for the anticipated subsurface conditions. The viscosity of slurry used for SPB tunnelling shall be no less than 40 seconds Marsh Funnel viscosity, as defined by ASTM D6910, measured prior to introduction of groundwater and spoil and as required to ensure:

- a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding

- ground and groundwater pressures at excavation face;
- b) lubricate installation of primary liners as required;
- c) transport spoil through pipe systems;

5.06 Grout

Purging grout shall conform to the requirements of OPSS 1004 wetted with only sufficient water to make the mixture plastic

6.0 EQUIPMENT

6.01 Auger Jack & Bore

Except in the case of dewatering to at least 1 m below the tunnel/bore invert for the full length of the pipe alignment, Auger Jack & Bore shall not be used and will not be permitted where subsurface conditions indicate that saturated gravel, sand and silt soils may be encountered at pipe level or within one pipe diameter above or below outside pipe dimensions.

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the equipment with which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

The lead end of the auger shall be maintained at least one pipe diameter inside the lead end of the casing. The auger cutting tools shall not extend to or beyond the lead end of the casing at any time unless specific exception is provided by the Ministry prior to construction. Submittals shall identify anticipated jacking forces for advancing casing ahead of leading edge of auger cutting tools in addition to friction forces that are to be overcome by jacking systems

6.02 Pipe Ramming

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the entry pit to the exit pit through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

Specific details of the equipment with which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Horizontal Directional Drilling

6.03.01 General

The Horizontal Directional Drilling equipment shall consist of a directional drilling rig and a drilling fluid

mixing and delivery system to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

- a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.
- b) Have drill rod that is suitable for both the drill and the product pipe installation.
- c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.
- d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.
- e) Contain a guidance system to accurately guide boring operations.
- f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.
- g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein. Specific details of tunnelling equipment included in the submission shall be

provided for:

- a) rock or boulder breaking and removal;
- b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;
- c) jacking systems;
- d) alignment control systems;

Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use. Use of explosives is prohibited without specific application and acceptance by the Ministry prior to construction.

6.05 Microtunnelling Equipment

The Contractor shall be responsible for selecting microtunnelling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils that will be encountered.

The Contractor shall employ microtunnelling equipment that will be capable of handling the various anticipated ground conditions.

The MTBM shall also be capable of controlling loss of soil ahead of and around the machine and shall provide continuous pressurized support of the excavated face.

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
 - ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 - iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - iv. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vi. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
 - vii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.

- viii. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control - Provide an MTBM that includes an active direction control system with the following features:
 - i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
 - ii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

- a) Has the main jacks mounted in a jacking frame located in the launch shaft.
- b) Has a jacking frame that successively pushes towards a receiving shaft, a string of Product Pipe that follows the microtunnelling excavation equipment.
- c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.
- d) The main jack station may be complemented with the use of intermediate jacking stations as required.
- e) Has a capacity at least 20 percent greater than the calculated maximum jacking load.
- f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
- g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
- h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
- i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

The Contractor shall determine the type of spoil separation equipment needed for each drive based on the geotechnical information available and other project constraints.

6.05.03 Electrical Equipment, Fixtures and Systems

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.

Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

7.0 CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be subject to the limitations presented in the following subsections.

The Project Superintendent shall supervise the work at all times.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

The Contractor shall submit records of the alignment and depth of the installation to the Contract Administrator at the completion of the installation.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contractor, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, procedures, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS 539.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

The Contractor is alerted that cobbles and boulders are expected within the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles shall be expected to be routine and will not be considered cause for delay

or additional compensation and the Contractor's trenchless equipment shall be appropriately equipped and operated for these conditions. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions such as, but not limited to wood debris, roots, and stumps, and construction debris consisting of (broken asphalt, concrete etc.) are expected within the trenchless alignment as identified in the Contract Documents. Accordingly, the Contractor shall address methods for the removal of obstructions in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and the Contractor's expected method of and schedule for removal.

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- b) A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- d) Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavated volume (e.g., maximum cut diameter) shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has passed fully through and beyond the zone of influence of any overlying infrastructure.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

For horizontal directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9 m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for HDD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor’s submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor’s methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback, fill and abandon the hole and re-drill from the

location along the bore path before the deviation.

If a drill hole beneath highways, roads, watercourses or other infrastructure must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence and subsurface water conveyance.

The Contractor shall maintain drilling fluid pressure and circulation throughout the HDD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Losses to Surface (“Frac-Out”)

To reduce the potential for hydraulic fracturing of the hole during horizontal directional drilling, a minimum depth of cover of 5 m shall be maintained between the top of pipe and the surface of any pavements or beds of water courses. Sections of the pipe close to the entry and exit pit with less than 5 m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled for the full length of the bore to prevent frac-out for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Once a fluid loss or frac-out event is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to collect all fluids discharged to surface, mitigate and prevent additional fluid loss.

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.0 General

The product shall be jointed according to manufacturer’s recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be contravened.

Product shall be allowed to recover to static conditions from thermal and installation stresses before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product pipe shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product pipe is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from

being transferred to the product. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product pipe shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator.

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the walls of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

7.05 Tunnelling Installation

7.05.01 General

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall provide ventilation and lighting in accordance with OSHA requirements for the entire length of the tunnel installed as tunneling progresses.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the wall of the excavated volume shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. If an unexpanded liner is used, the space outside the liner plates shall be filled at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property. Grout mix design shall be chemically and thermally compatible with all pipe systems.

7.06 Microtunnelling

7.06.01 General

Excavation of soil, rock and fill shall be done in a manner to control and prevent groundwater inflow to the tunnel.

The MTBM shall be capable of fully supporting the face and shall accommodate the removal of boulders and other obstructions from the face. Continuous ground support shall be maintained during excavation.

The tunnel is to be kept well drained at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times.

In the event that excavation threatens to endanger personnel, the Work, adjacent property, roadways, railways, waterways, or the public in any way, the Contractor shall cease excavation. The Contractor shall then evaluate the methods of construction and revise as necessary to ensure the safe continuation of the Work.

The Contractor shall maintain the tunnel excavation line and grade to provide for construction of the product within the specified tolerances.

7.06.02 Method of Installation

The installation procedure to be used shall be subject to the following limitations:

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour working days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

The space between the Casing and the wall of the excavation shall be kept filled with lubricant during the pipe jacking operation. Upon completion of pipe jacking, the space between the Casing and the wall of the excavation shall be filled with grout that is compatible with the Casing.

The Casing shall act as a support system to maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the Casing.

The Casing shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting.

7.07 Instrumentation and Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

7.07.01 Surface Monitoring Points

Surface settlement points for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at intervals of 5 m or less along the tunnel alignment centreline and as arrays of three points in each shoulder of the highway crossing and centred on the tunnel alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM). Surface markers shall be recessed or otherwise designed for safe passage of vehicles at highway speeds and protected from snow removal equipment in the event that work occurs during snow removal seasons.

7.07.02 In-Ground Monitoring Points

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface or below frost penetration depth whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.03 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two weeks prior to the start of works to permit baseline surveying to be completed. The settlement monitoring points shall be clearly labelled for easy field identification. The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation. Instruments damaged by the Contractor's operations or other causes shall be replaced and surveyed at the time of installation within 24 hours at no additional cost. At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work and restore the surface at instrument locations.

7.07.03 Monitoring and Reporting Frequency

The Contractor shall survey and otherwise obtain elevations of all settlement monitoring points at the following time intervals:

- a) Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- b) Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals; and
- c) Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrator for information purposes on a weekly basis.

Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07.03 Benchmarks

Two independent benchmarks shall be used for all settlement monitoring surveying and shall be located sufficiently outside the zone of influence such that the benchmarks are not influenced by any trenchless or other construction activity or weather conditions (e.g., frost heave). All surveying shall be reported using the geodetic datum and coordinate system as defined in the Contract Documents.

7.08 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.07, the following represents trigger levels that define magnitude of movement and corresponding action:

- a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
 - i. The cause of the settlement has been identified.
 - ii. The Contractor submits a corrective/preventive plan.
 - iii. Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - iv. The CA deems it is safe to proceed.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Where a protection system is made necessary because of the Contractor's operations (e.g., choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

- (a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.
- (b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

OBSTRUCTIONS – Item No.

Notice to Contractor

The contractor shall be alerted to the presence of timber within the fill along the alignment of the culvert crossing Highway 66, Station 18+386, Township of Gauthier. 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 and installation of the culvert by trenchless methods.

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

IDF Curve Location	Latitude: 48.107954	Longitude: -79.794401				
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m ³ /s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
Highway 66, Station 18+386, Township of Gauthier Culvert Replacement	***	****	****	****	****	Yes
Dewatering Systems						
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)				Design Engineer Requirements (Note 1)	
Highway 66, Station 18+386, Township of Gauthier Culvert Replacement	N/A				Yes	
<p>Note:</p> <p>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.</p> <p>2. "N/A" indicates a preconstruction survey is not required.</p>						

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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