



**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**Highway 65, Station 11+775, Township of Kerns  
Culvert Replacement  
Ministry of Transportation, Ontario  
GWP 5204-14-00**

Submitted to:

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**PART A**

FOUNDATION INVESTIGATION REPORT  
HIGHWAY 65, STA 11+775, TOWNSHIP OF KERNS  
CULVERT REPLACEMENT  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5204-14-00

## 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 65 at Station 11+775, in the Township of Kerns, Ontario, approximately 1.3 km west of the intersection with McCool Road. The Key Plan of the general location of this section of Highway 65 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 the Drawing 1. For the purpose of this report, Highway 65 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 south-north direction.

The existing culvert consists of a 1.2 m diameter, 35 m long Corrugated Steel Pipe (CSP). At the inlet of the culvert, a wooden catch basin is connected to the outlet of a separate pipe that extends parallel to the highway on the south side towards the east. The culvert inlet (south end) and outlet (north end) inverts are approximately Elevations 228.4 m and 227.1 m, respectively. In general, the topography within the vicinity of the culvert consists of sloping ground on the side of a hill that eventually leads into a valley where the highway crosses the Wabi River. The site is surrounded by relatively flat farm land and light forest cover with the Wabi River located about 200 m west of the site. At the culvert location, the highway grade is at approximately Elevation 233.5 m and the embankment is up to approximately 6.4 m high relative to the culvert invert at the outlet. The ground surface conditions at select locations near the culvert, are shown on Photographs 1 to 4. In general, the existing embankment sloped at about 2H:1V at the culvert location, did not show signs of instability at the time of our site visit in November 2018.

## 3.0 INVESTIGATION PROCEDURES

Field work for this subsurface investigation was carried out between November 19 to 23, 2018, and February 22 and 23, 2019, during which time, five boreholes (Boreholes C78-1 to C78-5) were advanced at approximately the locations shown on Drawing 1. Boreholes C78-1 to C78-3 were advanced through the roadway embankment using a track mounted CME-55LC drilling rig supplied and operated by George Downing Estate Drilling (Downing) of Grenville-Sur-La-Rouge, Quebec. Borehole C78-4 was advanced near the toe of the highway embankment adjacent to the culvert outlet, using a portable tripod rig supplied and operated by Landcore

Drilling (Landcore) of Chelmsford, Ontario. Borehole C78-5 was advanced near the toe of the highway embankment slope adjacent to the culvert inlet using a portable tripod rig supplied and operated by Downing for the upper 2.1 m portion of the borehole and the lower portion of the borehole, from 2.1 m to the bottom of the borehole, was advanced by Landcore's portable tripod rig. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Boreholes C78-1 to C78-3 were advanced through the roadway using 108 mm I.D. Hollow Stem Augers and Boreholes C78-4 and C78-5 were advanced at the toes of the embankment slopes using NW casing with wash boring techniques. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers, driven by a full weight automatic or cathead hammer (except the upper 2.1 m portion of Borehole C78-5), in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The split-spoon sampler utilized by Downing's portable equipment in the upper 2.1 m portion of Borehole C78-5 to obtain Samples 1 to 3 was driven by a half-weight hammer, and the SPT "N"-values shown on the borehole record have been adjusted to the inferred values that would have been obtained using a standard weight (63.6 kg) hammer. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using an MTO Standard "N" size vane. The groundwater level inside the augers/casing was observed and recorded during the drilling operations. The boreholes were backfilled in accordance with Ontario Regulation 903 (as amended). The roadway surface at the boreholes drilled through Highway 65 were capped at ground surface using cold patch asphalt.

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

The as-drilled borehole locations were measured relative to the highway chainage/station and centreline marked on the pavement by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevations at the borehole locations were surveyed relative to the highway and culvert centreline, with the elevation of the centrelines 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)
C78-1	5278400.7 (47.639146)	390080.9 (-79.864988)	232.8	15.9
C78-2	5278391.4 (47.639059)	390104.4 (-79.864677)	233.9	16.5
C78-3	5278399.4 (47.639132)	390093.9 (-79.864816)	233.5	20.4
C78-4	5278415.9 (47.639282)	390083.9 (-79.864945)	227.3	9.8
C78-5	5278379.7 (47.638955)	390098.1 (-79.864764)	231.1	9.8

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)<sup>1</sup> mapping, the culvert site is located within a glaciolacustrine plain, and the subsoils in the area primarily consist of clay and sand.

Based on geological mapping of bedrock in Ontario (MNDM)<sup>2</sup>, the site is underlain by mafic and related intrusive rocks and mafic dikes.

### 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 detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT 'N' values), as presented on the Record of Borehole sheets and discussed in Section 4.2, are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The results of the analytical laboratory testing (by Maxxam) 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 major soil deposits and groundwater conditions encountered in the boreholes is provided below.

<sup>1</sup> Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 31MNW

<sup>2</sup> Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543



It should be noted that the interpreted stratigraphy, shown on Drawing 1, is a simplification of the subsurface conditions.

#### 4.2.1 Asphalt/Fill

Asphalt was encountered in Boreholes C78-1 to C78-3 at ground surface between Elevation 233.9 m and 232.8 m. The asphalt ranges in thickness from about 200 mm to 240 mm. In Borehole C78-2, the asphalt was underlain by 100 mm of sand and gravel fill, which was underlain by an additional 80 mm of asphalt. An approximately 1 m to 1.6 m thick layer of sand and gravel to sand (fill) was encountered below the asphalt, underlain by an approximately 0.8 m to 1.6 m thick layer of silty clay fill with the surface between Elevation 232.5 m and 231.4 m, in turn underlain by a 0.8 m to 1.4 m thick layer of sand to silty sand (fill) with the surface between Elevation 230.9 m and 230.5 m. In Borehole C78-3, a 2.1 m thick layer of organic silty clay was encountered at Elevation 229.0 m. Trace wood pieces were encountered in the silty clay fill in Borehole C78-2 from 2.3 m to 2.9 m depth and in the organic silty clay in Borehole C78-3 from 5.0 m to 5.2 m depth. Trace to some asphalt fragments were encountered in the samples of the sand to silty sand (fill) in Boreholes C78-1 to C78-3. The sand to silty sand fill was noted to contain pieces of asphalt with a hydrocarbon odour in Sample 4 from Borehole C78-2 and Samples 4 and 5 in Borehole C78-3.

Borehole C78-4 encountered 0.6 m of silty sandy topsoil (fill) from ground surface at Elevation 227.3 m and Borehole C78-5 encountered 0.6 m of silty clay fill from ground surface at Elevation 231.1 m. In Borehole C78-5, the silty clay fill was underlain by 0.9 m of sand fill.

The SPT “N”-values measured within the sand to silty sand fill range between 5 and 50 blows per 0.3 m of penetration, indicating a loose to dense compactness condition. The SPT “N”-values measured within the silty clay, organic silty clay and topsoil (fill) range between 2 and 14 blows per 0.3 m of penetration, suggesting a soft to stiff consistency.

The water content measured on two samples of the silty clay fill in Boreholes C78-2 and C78-3 is 26% and 28% and on two samples of the organic silty clay fill in Borehole C78-3 is about 17% and 41%. An organic content test was carried out on Sample 7A from Borehole C78-3 and returned an organic content of 5.7%.

Atterberg limits testing was carried out on three selected samples of the silty clay to organic silty clay (fill), which measured liquid limits ranging from about 35 to 44%, plastic limits ranging from about 17 to 24% and plasticity indices ranging from about 17 to 20%. The Atterberg limit test results are shown on the plasticity chart on Figure B1 in Appendix B and indicate a cohesive deposit of low to intermediate plasticity. The results of grain size distribution tests completed on two samples of the silty clay fill are shown on Figure B2 in Appendix B.

#### 4.2.2 Silty Clay

In Boreholes C78-1 and C78-2, a 1.5 m and 1.4 m thick deposit of black to grey to brown silty clay, with trace to some organics (including wood pieces) was encountered underlying the fill at Elevations 229.8 m and 230.1 m, respectively.

The SPT “N”-values measured within the deposit are between 6 blows and 14 blows per 0.3 m of penetration, suggesting that the deposit has a firm to stiff consistency.

The water content measured on two samples of the silty clay deposit are 29% and 31%.

Atterberg limits testing was carried out on two samples of the clayey deposit, which measured liquid limits of about 35 and 40%, plastic limits of about 19 and 21% and plasticity indices of about 16 and 19%. Two Atterberg limit test results are shown on the plasticity chart on Figure B3 in Appendix B and indicate a cohesive deposit of intermediate plasticity. The results of grain size distribution tests completed on two samples of the deposit are shown on Figure B4 in Appendix B.

#### 4.2.3 Upper Silt

A 0.8 m thick deposit of grey silt with silty clay layers was encountered underlying the silty clay deposit in Borehole C78-1 at Elevation 228.3 m.

An SPT “N”-value measured within the silt deposit was 8 blows per 0.3 m of penetration, indicating a loose compactness condition.

#### 4.2.4 Clayey Silt to Silty Clay

A deposit of grey clayey silt to silty clay was encountered below the silt in Borehole C78-1, below the silty clay with trace to some organics in Borehole C78-2, and below the fill in Boreholes C78-3 to C78-5. The deposit was encountered from Elevations 229.6 m to 226.7 m and was 11.7 m thick in Borehole C78-3. Boreholes C78-1, C78-2, C78-4, and C78-5 were terminated after exploring the deposit to depths ranging from about 8.3 m to 11.3 m.

The SPT “N”-values in the clayey silt to silt clay deposit range from 0 blows (i.e., weight of hammer) to 7 blows per 0.3 m of penetration. In-situ shear vane testing carried out at frequent intervals within the deposit, measured shear strengths ranging from about 48 kPa to greater than 100 kPa, indicating a firm to very stiff consistency.

The water content measured on 13 samples of the clayey silt to silty clay deposit ranges from 30 to 41%.

Atterberg limits testing was carried out on eight selected samples of the cohesive deposit, which measured liquid limits ranging from about 26 to 39%, plastic limits ranging from about 16 to 21% and plasticity indices ranging from about 8 to 18%. The Atterberg limit test results are shown on the plasticity chart on Figure B3 in Appendix B and indicate a cohesive deposit of low to intermediate plasticity. The results of grain size distribution tests completed on four samples of the clayey silt to silty clay deposit are shown on Figure B4 in Appendix B.

#### 4.2.5 Lower Silt

In Borehole C78-3, a deposit of grey silt was encountered below the clayey silt to silty clay deposit at Elevation 215.2 m. Borehole C78-3 was terminated after exploring the silt deposit to a depth of 2.1 m.

Two SPT “N”-values measured within the silt deposit were 4 blows and 8 blows per 0.3 m of penetration, indicating a very loose to loose compactness condition.

### 4.3 Groundwater Conditions

The unstabilized groundwater levels relative to ground surface measured inside the casing or augers upon completion of drilling are summarized below. The watercourse was observed to be generally dry or frozen at the time of the investigation. Groundwater and watercourse levels in the area are subject to seasonal fluctuations and variations due to precipitation events. It is anticipated that water levels will be higher in the Spring and during periods of heavy precipitation, and perched groundwater conditions can be expected within the fill soils above the cohesive deposits.

Borehole No.	Depth Below Ground Surface to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
C78-1	Dry	n/a
C78-2	Dry	n/a
C78-3	Dry/4.8 <sup>1</sup>	228.7
C78-4	0 <sup>2</sup>	227.3
C78-5	0 <sup>2</sup>	231.1

Notes: n/a = not applicable

1. Borehole dry upon completion of drilling; however, when augers were drilled to 6.1 m depth, the water level inside hollow stem augers was at 4.8 m depth below ground surface.
2. Boreholes C78-4 and C78-5 were advanced using NW casing and wash boring techniques. As such, the measured groundwater levels were taken after introduction of water during wash boring and may not be representative of the in-situ groundwater conditions.

### 4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a soil sample recovered from Borehole C78-3. The soil sample was submitted to Maxxam Analytics 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 (µmho/cm)	Soluble Sulphate (SO <sub>4</sub> ) Content (µg/g)	Sulphide (µg/g)	Soluble Chloride (Cl) Content (µg/g)	pH
C78-3	7B	6.6-6.7	2,400	416	<20 <sup>1</sup>	0.62	140	7.70

Note:

1. The sulphate concentration is below the reportable detection limit of 20 µg/g.

## 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. Kirsten Janssen, EIT and Mr. André Bom, P.Eng. provided a technical review of the report. Mr. Kevin Bentley, P.Eng., an MTO Foundations Designated Contact and Associate with Golder, conducted an independent quality control review of this report.

## Signature Page

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**PART B**

FOUNDATION DESIGN REPORT  
HIGHWAY 65, STA 11+775, TOWNSHIP OF KERNS  
CULVERT REPLACEMENT  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5204-14-00

## 6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design and recommendations for the replacement of the culvert crossing Highway 65 at about Station 11+775, Township of Kerns, Ontario, approximately 1.2 km west of the intersection with McCool Road. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation. 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. This foundation investigation and design 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 1.2 m diameter, 35 m long Corrugated Steel Pipe (CSP). It is understood that consideration is being given to rehabilitation of the existing culvert using trenchless (specifically lining) techniques. There were no visual signs of embankment or pavement distress (i.e., no observed slope instability, major cracking, or settlement) in the immediate vicinity of the culvert (see Photographs 1 to 4). The integrity of the existing culvert should be checked and if there is evidence of soil migration through the existing culvert or presence of voids surrounding the culvert and within the roadway embankment, it is recommended that a full culvert replacement be performed.

The inlet of the existing culvert is connected to a wooden catch basin at the south toe of slope, which also connects to the outlet of a separate circular pipe that extends easterly from the catch basin, along the south embankment toe/ditch. Based on the drawings provided by AECOM, via email on June 13, 2019, and our site observations during the foundation exploration work, the existing culvert crosses the existing Highway 65 embankment on a skew alignment; and we understand from AECOM that the proposed replacement culvert will cross the highway on or near the same alignment and will be of similar circular diameter. The existing embankment at the culvert location is sloped at about 2H:1V and is between about 5.1 m and 6.4 m high, relative to the culvert invert at the inlet (south end) and outlet (north end), respectively. The invert at the inlet and outlet of the existing culvert is about Elevations 228.4 m and 227.1 m, 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. We further understand that a full road closure and temporary detour is not being considered for traffic staging during culvert replacement operations.

### 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 65 and the highway and culvert and foundation system are expected to

carry medium traffic volumes, and its 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,  $\Psi$ , and geotechnical resistance factors,  $\phi_{gu}$  and  $\phi_{gs}$ , from Tables 6.1 and 6.2 of the CHBDC have been used for design, as applicable.

## 6.3 Circular Culvert Installation by Open Cut Excavation

### 6.3.1 Settlement and Stability

Provided the existing/proposed reconstructed embankment is not widened or raised during or following culvert replacement/rehabilitation, 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.

Due to the presence of the relatively thick cohesive deposit at this site, if temporary widening is considered for traffic staging and culvert replacement, the extent and duration of temporary widening should be minimized as much as possible, to minimize settlement of the foundation soil. It is understood from discussion with AECOM that any temporary widening, if required, would be less than 0.5 m; thus, settlement is not considered to be a concern.

The existing/proposed reconstructed embankment (after lining or culvert replacement) is considered to be stable from a global slope stability perspective for the short-term and long-term (i.e., permanent conditions), based on a typical consequence factor when referring to CHBDC (2014) for this site. The results of a global slope stability analysis carried out using an idealized model for the long-term/permanent existing embankment configuration shown in Figure 1, indicates a Factor of Safety of 1.44 was calculated against global instability, as discussed further in Section 6.5.7. The major soil strata and selected soil parameters are shown on Figures 1, based on the results of the foundation exploration. If the culvert is replaced and the embankment reconstructed of granular material with side slopes at an inclination of 2 horizontal to 1 vertical (2H:1V) or flatter, a greater Factor of Safety against global instability would be achieved.

### 6.3.2 Bedding / Embedment and Cover

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

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

All unsuitable, deleterious, organic materials and fill materials are to be removed from the base/below the culvert (and bedding) footprint along its entire alignment. Based on the foundation exploration and existing/proposed culvert invert levels, the subgrade will consist of native firm to very stiff clayey silt to silty clay soil and is



considered suitable for support of the culvert and bedding materials. The bedding should be 300 mm thick and be compatible with the type/class of pipe material, the surrounding subsoil and anticipated loading conditions, and should consist of OPSS.PROV 1010 (Aggregates) Granular 'A' material. Depending on the success of the contractor's groundwater control methods, and the quality of the bearing stratum exposed at the base of the excavation, a thicker bedding layer may be required at some locations where wet and softened soil conditions, unsuitable fill, or organic material are present at the base of the excavation. Therefore, the Contract Documents should include a provision for additional thickness of compacted Granular 'A' bedding, if required.

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

#### 6.3.2.1 Trench Backfill

The excavated embankment fill materials from the culvert site will vary in quality and composition, and are comprised of sand and gravel to sand, sand to silty sand, silty clay, and organic silty clay. The existing organic and clayey fill materials and native clayey soil should not be reused as backfill for reconstruction of the highway embankment in the immediate vicinity or over the new culvert. The sand to silty sand fill was noted to contain pieces of asphalt with a hydrocarbon odour in Sample 4 from Borehole C78-2 and Samples 4 and 5 in Borehole C78-3, and therefore should not be reused on site.

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, provided these materials are free of organics, or other deleterious material (wood, construction rubble). These materials should also be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

### 6.4 Analytical Testing of Existing Soil

The results of analytical tests on one sample of clayey silt to silty clay recovered in Borehole C78-3 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.

#### 6.4.1 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.

## 6.4.2 Potential for Corrosion

The soil has a pH of 7.7 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. The resistivity is 2,400 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 at a concentration of about 0.62 µg/g was detected in the analyzed test sample; and sulphide is considered very corrosive to cast iron/steel materials (Cashman and Preene, 2001). 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. The culvert should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

## 6.5 Construction Considerations

### 6.5.1 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 embankment, will generally advance through sand and gravel to sand, sand to silty sand, silty clay, and organic silty clay and into the clayey silt to silty clay native soils. The excavation is 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.

### 6.5.2 Groundwater/Surface Water Control

The groundwater level is expected to be at or above the proposed culvert 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/rehabilitation in the dry. 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 (or rehabilitation), 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 (*Construction Specification for Dewatering*) and MTO's Special Provision 517F01 (*Temporary Flow Passage System*), recommending that a design engineer be required. Depending on the design of the diversion/cofferdam and dewatering systems, if construction water pumping rates are anticipated to exceed 50 m<sup>3</sup>/day, an Environmental Activity Section Registry (EASR) or Permit to Take Water (PTTW) will be required, as per the recently introduced changes to the *Environmental Protection Act* by the Ontario Ministry of Environment and Climate Change (MOECC)/Ministry of the Environment, Conservation and Parks (MECP).

### 6.5.3 Temporary Protection Systems

In order to replace/rehabilitate 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*). 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 would be suitable and constructible at this site, as the Standard Penetration Test (SPT) "N"-values measured within the embankment fill are typically less than 30 blows per 0.3 m of penetration and within the clayey silt to silty clay stratum are typically less than about 20 blows per 0.3 m of penetration. The contractor may elect to 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 and saturated silt deposit will not have adequate stand-up time to permit installation of the lagging boards.

The sheet piles or 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 sheet pile wall or 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 use of vibratory installation techniques is anticipated to be feasible, as there does not appear to be any vibration sensitive structures on or near the highway at this location; however, there is an old wooden catch basin at the south toe of slope where the current culvert terminates. Although no GA drawing has been provided at this stage, it is

understood that the wood catch basin is to be abandoned or replaced and may be sensitive to vibrations during construction. Staging construction to reduce the risk of damaging the catch basin while in operation due to excessive vibrations, should be considered in the Contract. 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, $\gamma$ (kN/m <sup>3</sup> )	Angle of Internal Friction, $\phi$ (degrees)	Undrained Shear Strength, $s_u$ (kPa)	Lateral Earth Pressure Coefficients <sup>1/2</sup>		
				Passive, $K_p^3$	Active, $K_a$	At-rest, $K_o$
Embankment Fill – Loose to dense sand to silty sand	20	32	-	3.25	0.32	0.47
Embankment Fill – Firm to stiff silty clay/organic silty clay	18	28	50	2.77	0.36	0.53
Firm to very stiff clayey silt to silty clay	17	-	40 - 80	-	-	-
Very loose to loose silt	18	28	-	2.77	0.36	0.53

Notes:

1. The design groundwater level may be assumed to be Elevation 231 m near the inlet and 227.5 m near the outlet, based on the ground surface and water levels in the boreholes.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
3. The total passive resistance below the base of the excavation (i.e., adjacent to the temporary protection system) may be calculated based on the values of  $K_p$  indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

It is recommended that the ground surface extending back/upwards from the top of the protection system to the existing Highway 65 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). At this site, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work. If partial removal is required, rather than full removal, an NSSP amending OPSS.PROV 539 should be included in the Contract; an example NSSP is included in Appendix C. Vibration and noise controls during extraction of any temporary systems should meet the same tolerable limits used for installation.

#### 6.5.4 Obstructions

Evidence of boulders and cobbles were not directly encountered during the drilling exploration, but based on experience on similar projects, cobbles and boulders can be present within highway embankment fill, especially near the fill/native interface, which could affect the installation of temporary protection systems. There is also the potential for the presence of wood debris and organic material (as encountered in the fill material in Boreholes C78-2 and C78-3, and below the fill in Boreholes C78-1 and C78-2), including roots and tree stumps, at the interface of fill and native soils under the existing embankment, due to possible poor stripping practices during the embankment construction. In addition, a wooden catch basin is present at the culvert inlet and a pipe is located parallel to the south embankment toe, extending from the catch basin to the east. A Notice to Contractor to identify to the contractor the possible presence of cobbles, boulders, and deleterious material within the fill soils, and wood/trees at the fill and native soil interface, as well as the wooden catch basin and pipe, should be included in the Contract Documents; a copy of which is included in Appendix C.

#### 6.5.5 Subgrade Protection

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

#### 6.5.6 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 2 Horizontal to 1 Vertical (2H:1V) in granular fill.

#### 6.5.7 Embankment Stability and Settlement

Limit equilibrium slope stability analyses were performed for the reconstruction of the embankment at this location using GeoStudio 2019 software, employing the Morgenstern-Price method of analysis. For all analyses, the Factor of Safety (FoS) of numerous potential failure surfaces was computed in order to establish the minimum FoS. The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. A minimum factored FoS of 1.3 in the short-term/temporary undrained condition and FoS of 1.5 in the long term/permanent condition would be targeted as per the CHBDC (2014) for an embankment approaching a structure. Figures 1 and 2 present the results of the stability analyses for the existing slope with the critical long-term (drained) FoS calculated to be 1.44 and short-term (undrained) FoS calculated to be 2.43. The calculated FoS values are appropriate for the embankment at this site considering the design requirements, site conditions, field data available, and no structures are nearby.

#### 6.5.8 Surficial Embankment Stability and Erosion Protection

If the culvert is replaced, depending on the selected embankment 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 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 hydro-seeding and vegetation following the construction specifications of OPSS.PROV 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 hydro-seeding. Slopes constructed of SSM and properly protected from erosion should require limited on-going maintenance.

## 7.0 CLOSURE

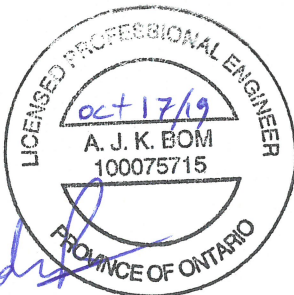
This foundation design report was prepared by Ms. Kirsten Janssen, a member of the geotechnical group with Golder, and the technical aspects were reviewed by Mr. André Bom, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Kevin Bentley, P.Eng., an MTO Foundations Designated Contact and Associate with Golder conducted an independent and quality control review of the report.

## Signature Page

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[https://golderassociates.sharepoint.com/sites/1809001/deliverables/foundations/2\\_reporting/r08-ker178/3\\_final/1896349-r08-rev0-aecom culvert 78 \(ker 178\) hwy 65 fidr 17oct\\_2019.docx](https://golderassociates.sharepoint.com/sites/1809001/deliverables/foundations/2_reporting/r08-ker178/3_final/1896349-r08-rev0-aecom%20culvert%2078%20(ker%20178)%20hwy%2065%20fidr%2017oct_2019.docx)

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Canadian Standards Association (CSA), 2014. CSA A23.1-14 Concrete Materials and Methods of Construction (R2014)

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

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)

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 802.010 Flexible Pipe Embedment and Backfill, Earth Excavation

OPSD 802.031 Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 206 Construction Specification for Grading

OPSS.PROV 401 Construction Specification for Trenching, Backfilling and Compacting

OPSS, PROV 421 Construction Specification for Pipe Culvert Installation in Open Cut

OPSS.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. PROV 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

Special Provisions

SP 517F01 Temporary Flow Passage System



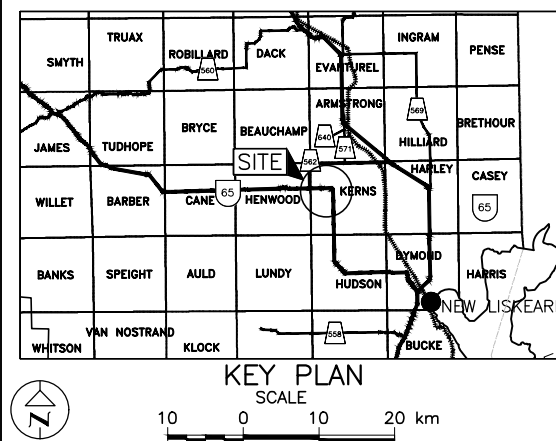
CONT No.  
GWP No. 5204-14-00





# HIGHWAY 65

STATION 11+775 TOWNSHIP OF KERNS CULVERT

## BOREHOLE LOCATIONS AND SOIL STRATA



### LEGEND

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

BOREHOLE CO-ORDINATES (NAD83 MTM ZONE 12)			
No.	ELEVATION	NORTHING	EASTING
C78-1	232.8	5278400.7	390080.9
C78-2	233.9	5278391.4	390104.4
C78-3	233.5	5278399.4	390093.9
C78-4	227.3	5278415.9	390083.9
C78-5	231.1	5278379.7	390098.1



## NOTES

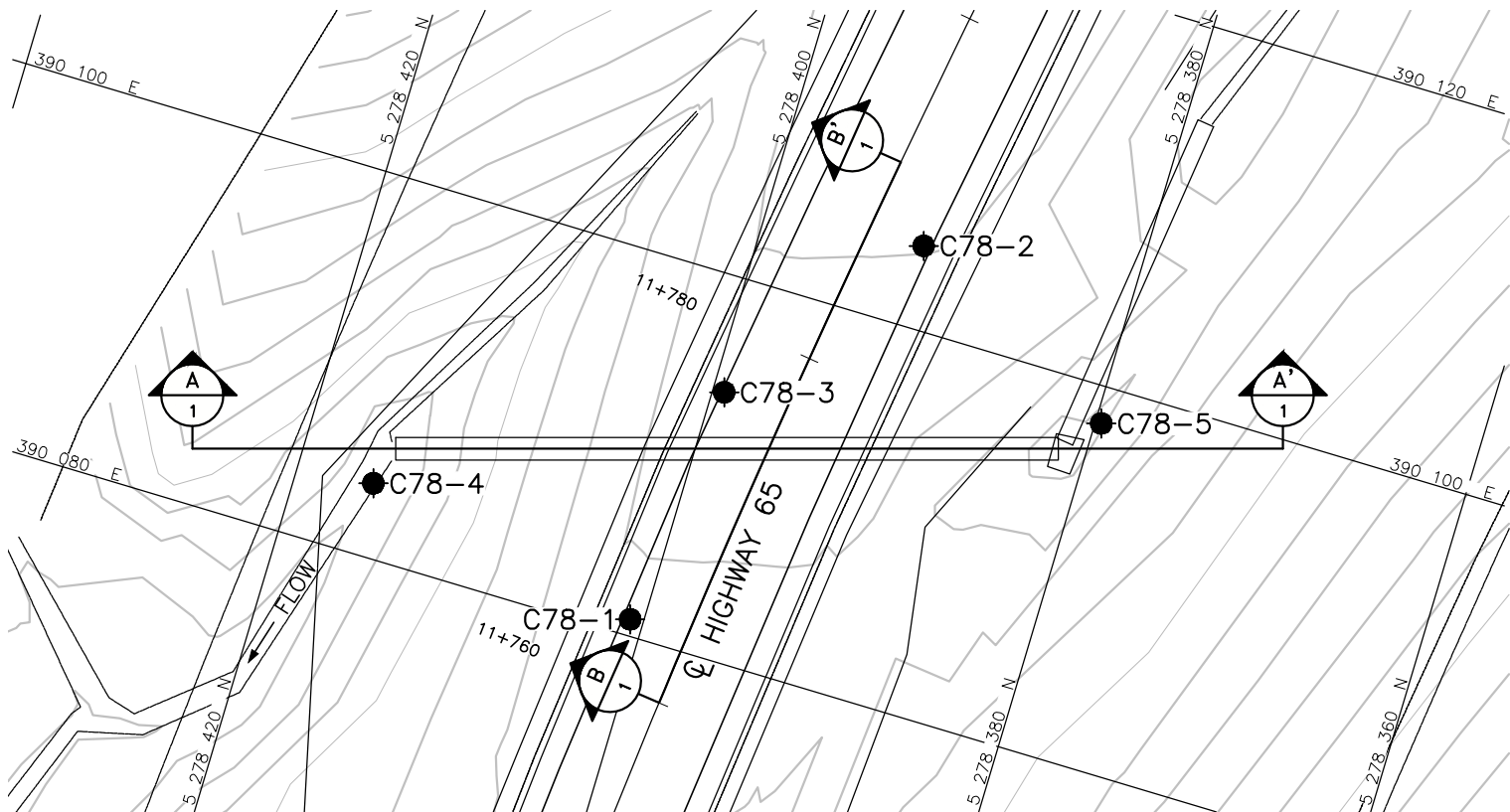
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

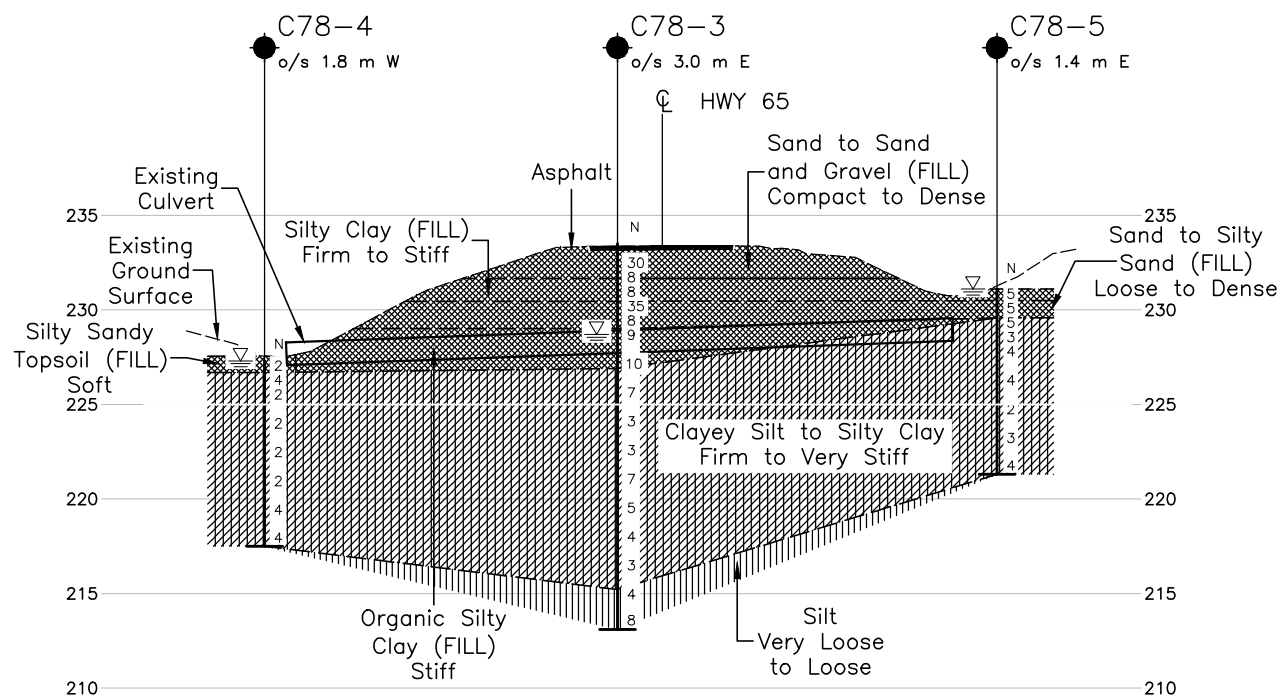
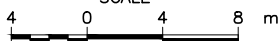
## REFERENCE

Base plans provided in digital format by AECOM LTD. drawing file no. B065KER SITE 178.dwg, received JUNE 13, 2019.

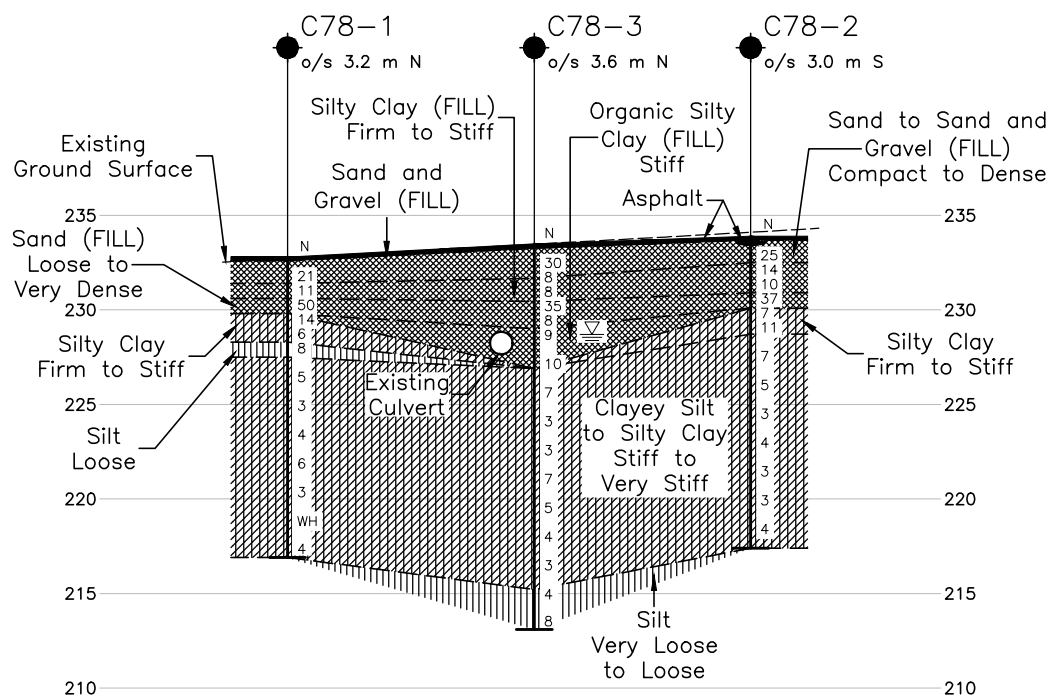
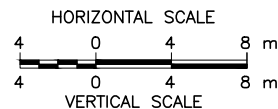
NO.	DATE	BY	REVISION		
Geocres No. 31M-128					
HWY. 65		PROJECT NO. 1896349			DIST. .
SUBM'D. KJ	CHKD. TB	DATE: 10/16/2019		SITE: .	
DRAWN: TR	CHKD. AB	APPD. KJB		DWG. 1	



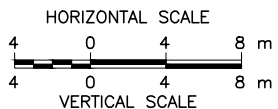
## PLAN



### CULVERT CENTRELINE PROFILE



HIGHWAY CENTRELINE PROFILE

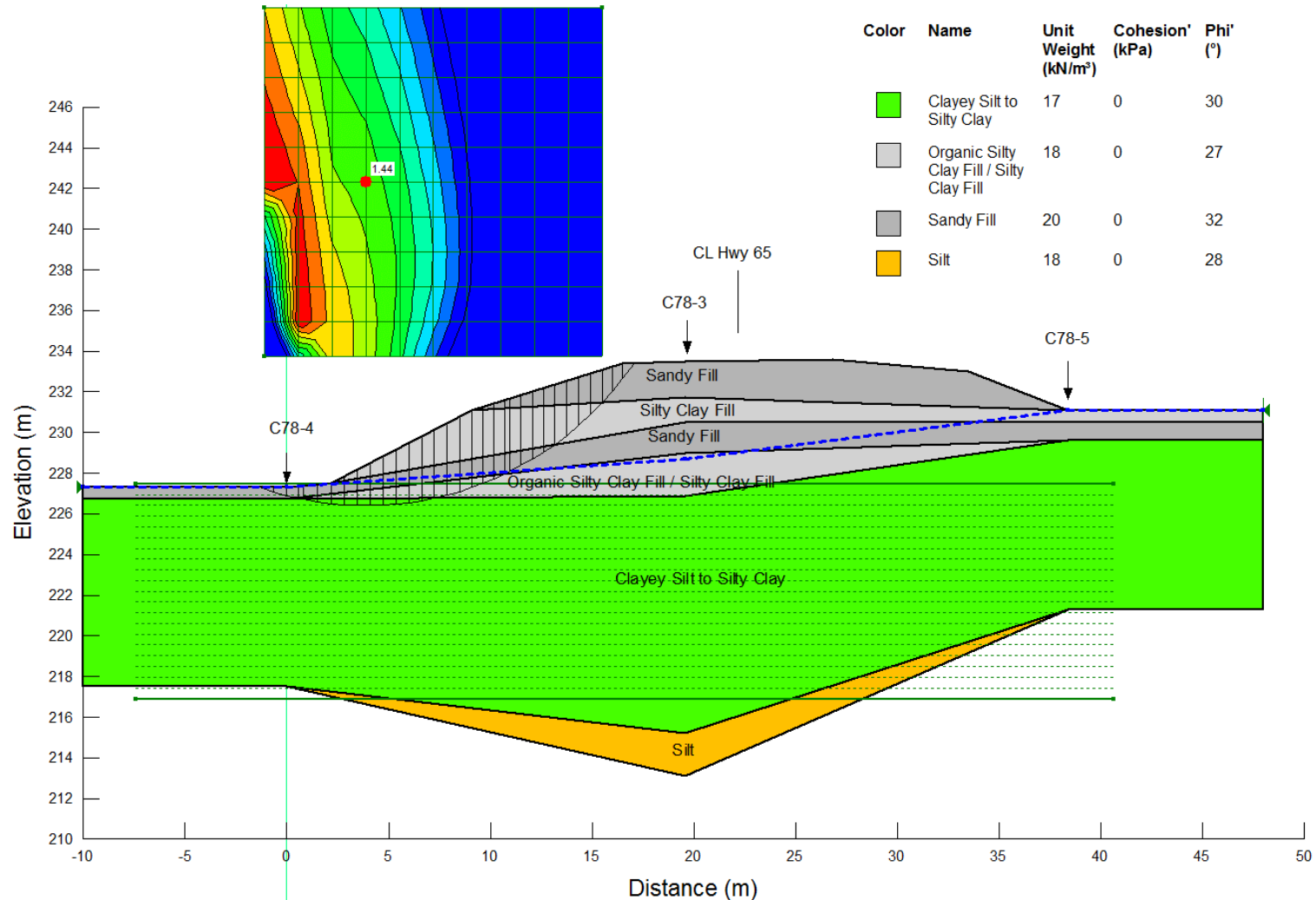




# Global Stability Analysis – Effective Stress Figure 1

## Highway 65, Sta. 11+775, Township of Kerns Culvert

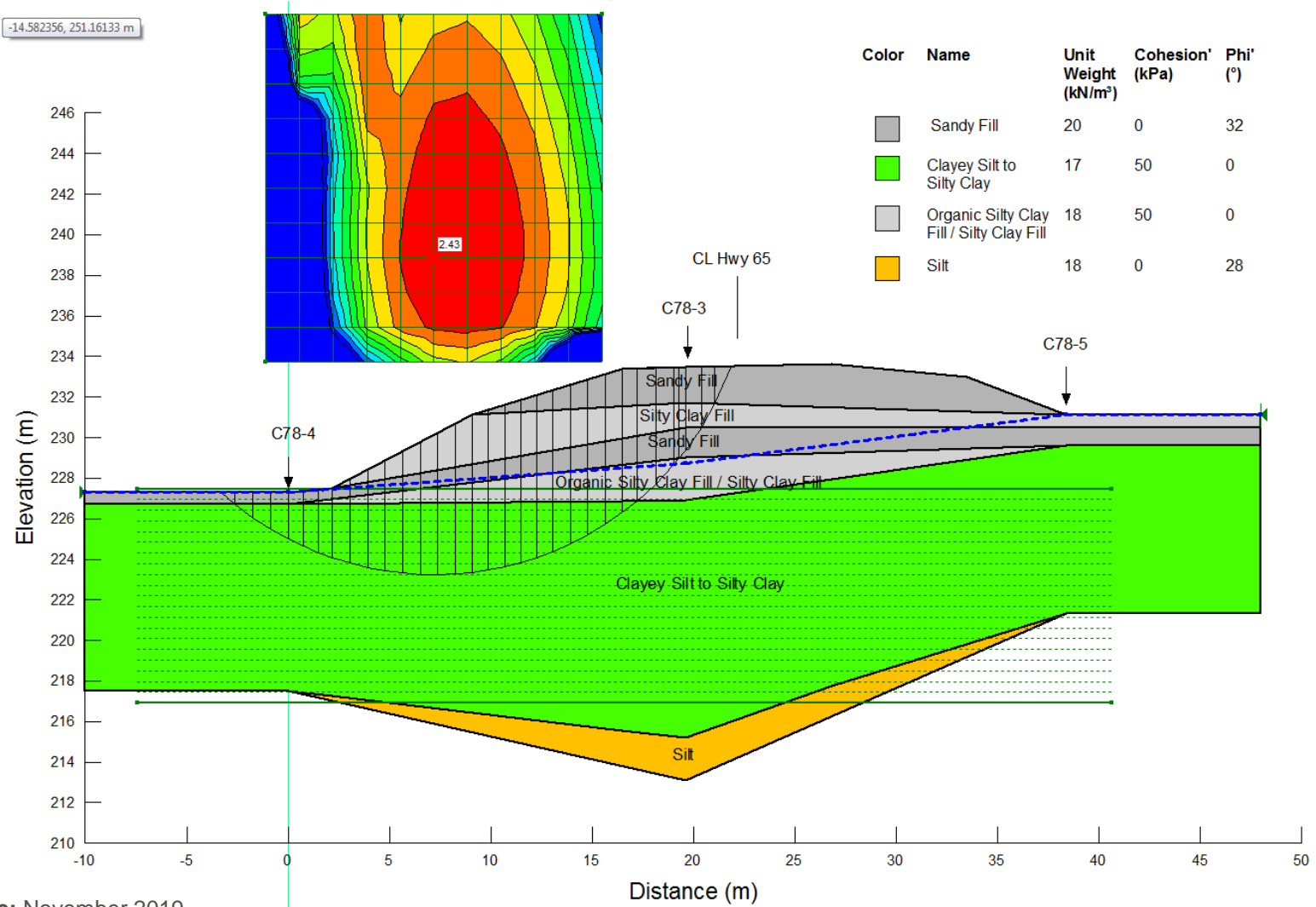
### Existing Embankment



Date: October 2019  
Project No: 1896349-R08

Analysis By: KJ Reviewed By: AB/KJB

# Global Stability Analysis – Total Stress Figure 2 Highway 65, Sta. 11+775, Township of Kerns Culvert Existing Embankment



Date: November 2019  
Project No: 1896349-R08

Analysis By: KJ Reviewed By: AB/KJB



**Photograph 1: Road Surface at Culvert, Facing West (November 2018)**



**Photograph 2: Road Surface at Culvert, Facing East (November 2018)**





**Photograph 3: Culvert Embankment and Outlet (North Side) from Roadway Surface (November 2018)**



**Photograph 4: Culvert Embankment and Inlet (South Side) from Roadway Surface (November 2018)**

**APPENDIX A**

# Record of Boreholes

## LIST OF SYMBOLS

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

### I. GENERAL

$\pi$	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

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

#### (a) Index Properties (continued)

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

#### (b) Hydraulic Properties

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

#### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_{\alpha}$	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
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

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

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

Notes: 1  
2

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

## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

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

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

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

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

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

#### (b) Cohesive Soils Consistency

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

### IV. SOIL TESTS

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

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

### V. MINOR SOIL CONSTITUENTS

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

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



PROJECT <u>1896349</u>		<b>RECORD OF BOREHOLE No C78-1</b>				2 OF 2 <b>METRIC</b>	
G.W.P. <u>5204-14-00</u>		LOCATION <u>N 5278400.7; E 390080.9 NAD83 MTM ZONE 12 (LAT. 47.639146; LONG. -79.864988)</u>				ORIGINATED BY <u>MR</u>	
DIST <u>          </u> HWY <u>65</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>				COMPILED BY <u>GM</u>	
DATUM <u>GEODETIC</u>		DATE <u>November 19, 2018</u>				CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub>	W	W <sub>L</sub>		
								20	40	60	80	100					
	--- CONTINUED FROM PREVIOUS PAGE ---																
	CLAYEY SILT to SILTY CLAY Stiff to very stiff Grey w>PL		11	SS	3												
			12	SS	WH												
			13	SS	4												
216.9																	
15.9	END OF BOREHOLE																
	NOTES:  1. Borehole dry upon completion of drilling.																

PROJECT 1896349		RECORD OF BOREHOLE No C78-2				1 OF 2 METRIC										
G.W.P. 5204-14-00		LOCATION N 5278391.4; E 390104.4 NAD83 MTM ZONE 12 (LAT. 47.639059; LONG. -79.864677)				ORIGINATED BY MR										
DIST _____ HWY 65		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY GM										
DATUM GEODETIC		DATE November 22, 2018				CHECKED BY AB										
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa		WATER CONTENT (%)		γ	GR SA SI CL			
							20 40 60 80 100	○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED	W <sub>p</sub> W W <sub>L</sub>						
233.9	GROUND SURFACE															
0.0	ASPHALT (200 mm)															
	Sand and gravel (FILL)															
	ASPHALT (80 mm)															
0.5	Sand and gravel (FILL)															
	Sand, some gravel (FILL)															
	Compact Brown Frozen to moist		1	SS	25		233									
232.5	Silty clay (FILL)															
1.4	Stiff Grey w>PL		2	SS	14		232									
	- Trace wood pieces from 2.3 m to 2.9 m															
			3	SS	10											
230.9	Sand, some gravel, trace asphalt pieces, trace non-plastic fines, hydrocarbon odour (FILL)															
3.0	Dense Grey to black Wet		4	SS	37		231									
230.1	SILTY CLAY, trace to some organics, trace wood pieces															
3.8	Firm to stiff Black to grey w>PL		5	SS	7		230									
			6	SS	11											
228.7	CLAYEY SILT to SILTY CLAY															
5.2	Stiff to very stiff Grey w>PL															
			7	SS	7		228									
			8	SS	5		226									
			9	SS	3		225									
			10	SS	4		223									
							222									

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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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PROJECT <u>1896349</u>		<b>RECORD OF BOREHOLE No C78-2</b>				2 OF 2 <b>METRIC</b>	
G.W.P. <u>5204-14-00</u>		LOCATION <u>N 5278391.4; E 390104.4 NAD83 MTM ZONE 12 (LAT. 47.639059; LONG. -79.864677)</u>				ORIGINATED BY <u>MR</u>	
DIST <u>          </u> HWY <u>65</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>				COMPILED BY <u>GM</u>	
DATUM <u>GEODETIC</u>		DATE <u>November 22, 2018</u>				CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
	--- CONTINUED FROM PREVIOUS PAGE ---																
	CLAYEY SILT to SILTY CLAY Stiff to very stiff Grey w>PL		11	SS	3												
						221											
			12	SS	3	220											
						219											
			13	SS	4	218											
217.4																	
16.5	END OF BOREHOLE																
	NOTES:  1. Borehole dry upon completion of drilling.																




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

PROJECT <u>1896349</u>		<b>RECORD OF BOREHOLE No C78-3</b>				2 OF 2 <b>METRIC</b>	
G.W.P. <u>5204-14-00</u>		LOCATION <u>N 5278399.4; E 390093.9 NAD83 MTM ZONE 12 (LAT. 47.639132; LONG. -79.864816)</u>				ORIGINATED BY <u>MR</u>	
DIST <u>          </u> HWY <u>65</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>				COMPILED BY <u>GM</u>	
DATUM <u>GEODETIC</u>		DATE <u>November 20, 2018</u>				CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub>	W	W <sub>L</sub>			
								○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × REMOULDED										
	--- CONTINUED FROM PREVIOUS PAGE ---																	
	CLAYEY SILT to SILTY CLAY Stiff to very stiff Grey w>PL		11	SS	7													
215.2	SILT Very loose to loose Grey Wet		15	SS	4													
18.3																		
213.1	END OF BOREHOLE		16	SS	8													
20.4																		
NOTES: 1. When augers were drilled to 6.1 m depth, water level inside hollow stem augers was 4.8 m below ground surface. 2. Borehole dry upon completion of drilling.																		

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PROJECT <u>1896349</u>		<b>RECORD OF BOREHOLE No C78-4</b>				1 OF 1 <b>METRIC</b>											
G.W.P. <u>5204-14-00</u>		LOCATION <u>N 5278415.9; E 390083.9 NAD83 MTM ZONE 12 (LAT. 47.639282; LONG. -79.864945)</u>				ORIGINATED BY <u>MR</u>											
DIST <u>          </u> HWY <u>65</u>		BOREHOLE TYPE <u>Portable Equipment, NW Casing, Wash Boring</u>				COMPILED BY <u>GM</u>											
DATUM <u>GEODETIC</u>		DATE <u>February 22, 2019</u>				CHECKED BY <u>AB</u>											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
227.3	GROUND SURFACE																
0.0	Silty sandy topsoil (FILL) Soft Brown to black Frozen		1	SS	2												
226.7																	
0.6	CLAYEY SILT to SILTY CLAY Firm to stiff Grey w>PL		2	SS	4												
			3	SS	2												
			4	SS	2												
			5	SS	2												
			6	SS	2												
			7	SS	4												
			8	SS	4												
217.5																	
9.8	END OF BOREHOLE																
	NOTES:  1. Water level at ground surface (Elev. 227.3 m) inside casing upon completion of drilling and wash boring activities.																

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PROJECT 1896349			RECORD OF BOREHOLE No C78-5			1 OF 2 METRIC															
G.W.P. 5204-14-00			LOCATION N 5278379.7; E 390098.1 NAD83 MTM ZONE 12 (LAT. 47.638955; LONG. -79.864764)			ORIGINATED BY MR															
DIST _____ HWY 65			BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring			COMPILED BY GM															
DATUM GEODETIC			DATE November 23, 2018 and February 23, 2019			CHECKED BY AB															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ					
								20 40 60 80 100	20 40 60 80 100	20 40 60	W <sub>p</sub>	W	W <sub>L</sub>								
231.1	GROUND SURFACE																				
0.0	Silty clay, trace organics (FILL) Firm Dark brown w>PL		1	SS	5		231														
230.5	Sand, trace gravel (FILL) Loose Orange brown Moist		2	SS	5		230														
229.6	CLAYEY SILT to SILTY CLAY Stiff Grey w>PL		3	SS	5		229														
1.5			4	SS	3		228														
			5	SS	4		227														
			6	SS	4		226														
			7	SS	2		225														
			8	SS	3		224														
			9	SS	4		223														
221.3	END OF BOREHOLE						222														
9.8																					

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

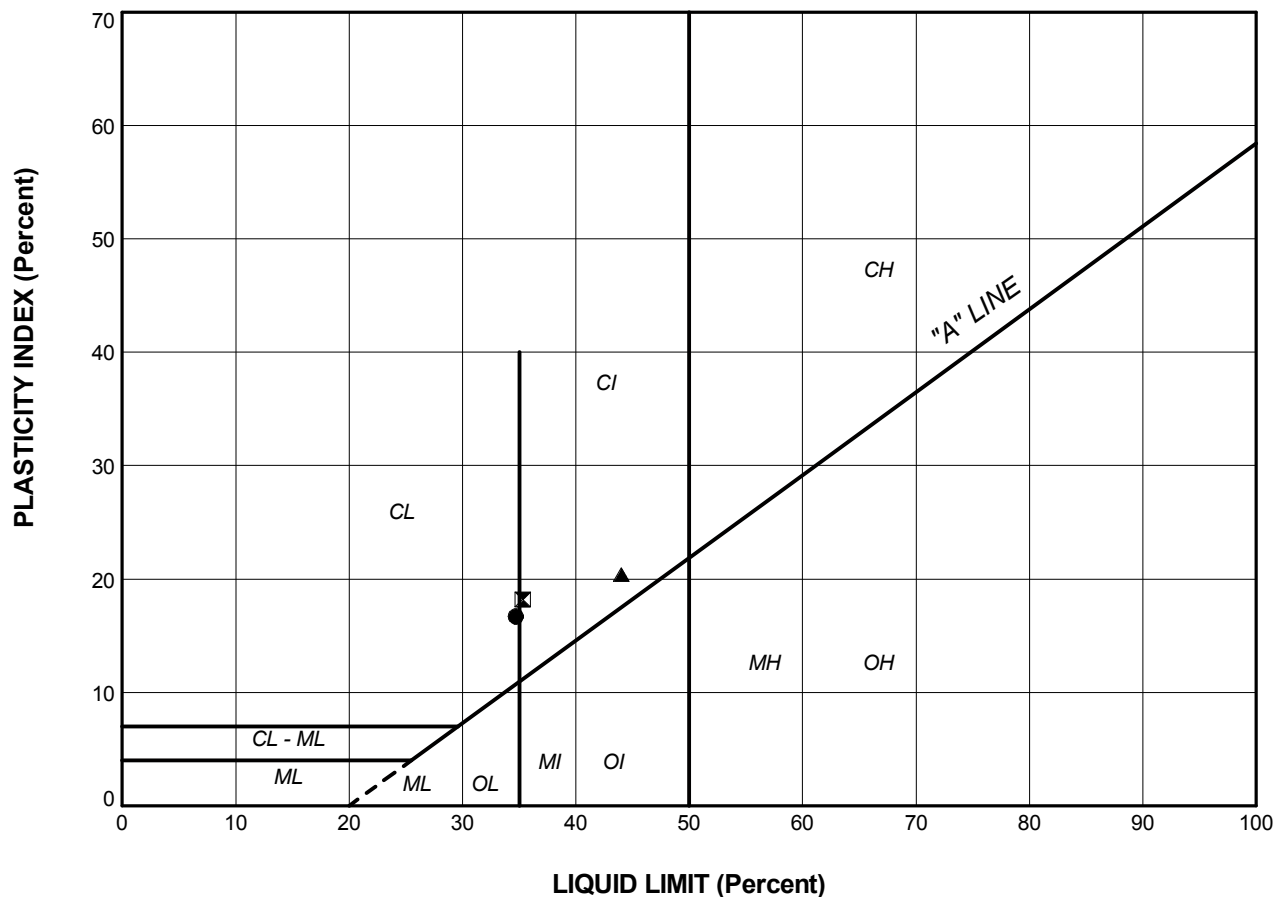
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PROJECT <u>1896349</u>		<b>RECORD OF BOREHOLE No C78-5</b>				2 OF 2 <b>METRIC</b>											
G.W.P. <u>5204-14-00</u>		LOCATION <u>N 5278379.7; E 390098.1 NAD83 MTM ZONE 12 (LAT. 47.638955; LONG. -79.864764)</u>				ORIGINATED BY <u>MR</u>											
DIST <u>          </u> HWY <u>65</u>		BOREHOLE TYPE <u>Portable Equipment, NW Casing, Wash Boring</u>				COMPILED BY <u>GM</u>											
DATUM <u>GEODETIC</u>		DATE <u>November 23, 2018 and February 23, 2019</u>				CHECKED BY <u>AB</u>											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W <sub>p</sub>	W			W <sub>L</sub>
	--- CONTINUED FROM PREVIOUS PAGE ---						20   40   60   80   100 ○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × REMOULDED					20   40   60 WATER CONTENT (%)					
	NOTES:  1. Borehole drilled to 2.1 m depth on Nov. 23, 2018 and from 2.1 m to 9.8 m on Feb. 23, 2019.  2. Water level at ground surface (Elev. 231.1 m) inside casing upon completion of drilling and wash boring activities.  3. Split spoon samples 1 to 3 obtained by driving with a half weight hammer. SPT 'N' values have been adjusted to the inferred values that would be measured using a standard weight hammer. Split spoon samples 4 to 9 obtained by driving a full weight hammer.																




**APPENDIX B**

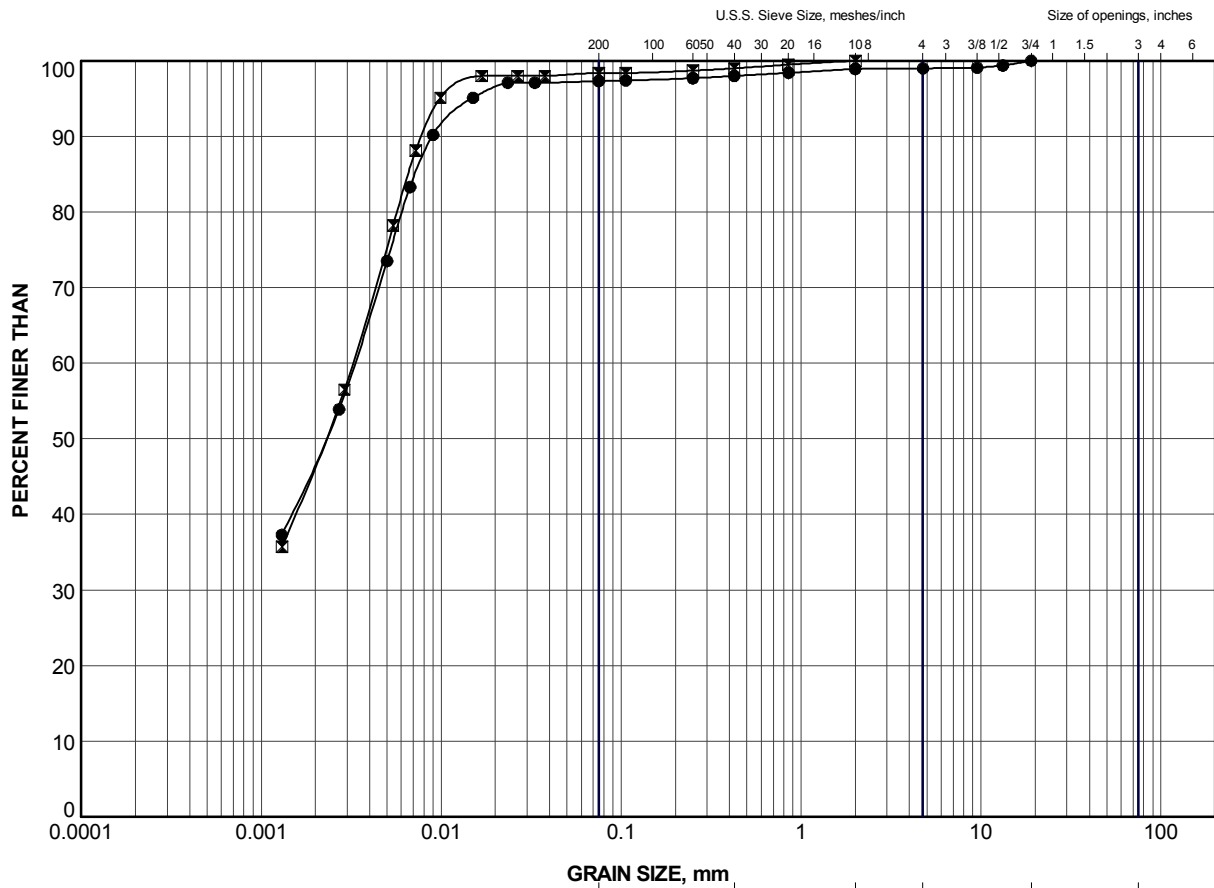
# Laboratory Test Results



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C78-2	3	34.7	18.0	16.7
⊠	C78-3	6	35.3	17.1	18.2
▲	C78-3	7A	44.0	23.6	20.4

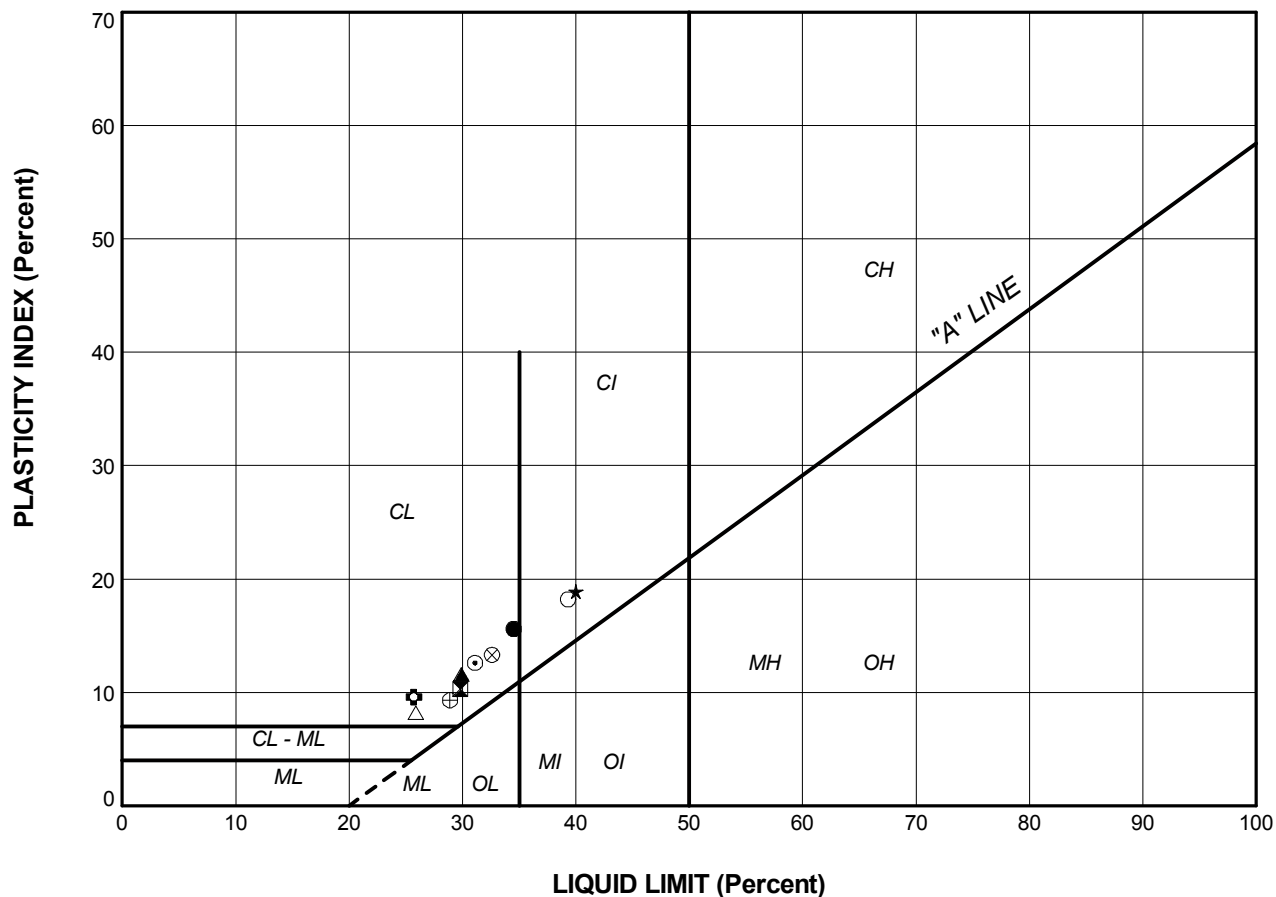
PROJECT						HIGHWAY 65 STATION 11+775 TOWNSHIP OF KERNS CULVERT					
TITLE						<b>PLASTICITY CHART</b> Silty Clay to Organic Silty Clay (FILL)					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Oct 2019	SCALE	N/A	REV.	<b>FIGURE B-1</b>					
CHECK	AB	Oct 2019									
APPR	KJB	Oct 2019									
 <b>GOLDER</b> SUDBURY, ONTARIO											



### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C78-2	3	231.3
×	C78-3	3	230.9

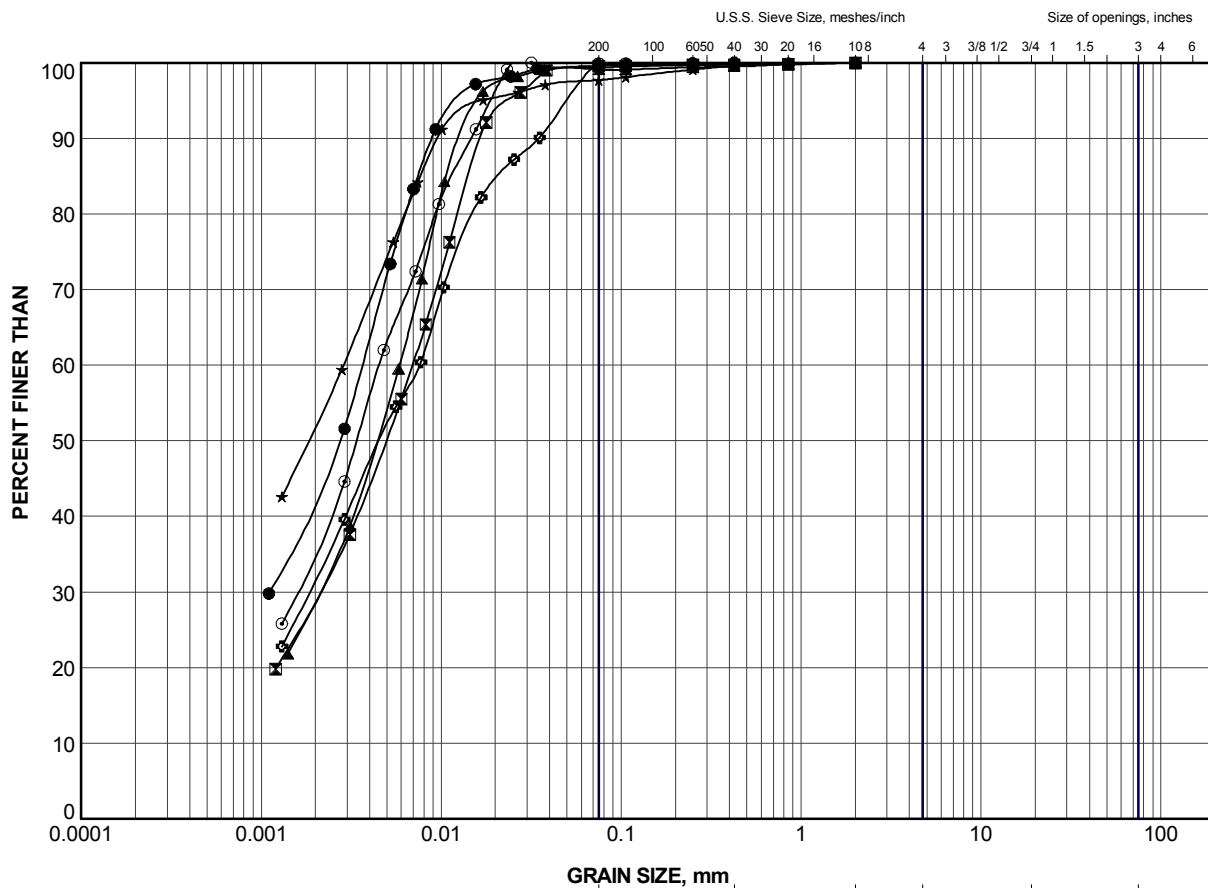
PROJECT		HIGHWAY 65 STATION 11+775 TOWNSHIP OF KERNS CULVERT			
TITLE		<b>GRAIN SIZE DISTRIBUTION</b> Silty Clay (FILL)			
PROJECT No.		1896349		FILE No. 1896349.GPJ	
DRAWN	TR	Oct 2019	SCALE	N/A	REV.
CHECK	AB	Oct 2019	<b>FIGURE B-2</b>		
APPR	KJB	Oct 2019			
GOLDER		SUDBURY, ONTARIO			



### LEGEND


SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C78-1	5	34.5	18.9	15.6
⊠	C78-1	8	29.8	19.5	10.3
▲	C78-1	11	29.9	18.3	11.6
★	C78-2	6	40.0	21.1	18.9
⊙	C78-2	9	31.1	18.5	12.6
⊕	C78-3	10	25.7	16.1	9.6
○	C78-4	3	39.3	21.1	18.2
△	C78-4	6	25.9	17.7	8.2
⊗	C78-5	3	32.6	19.3	13.3
⊕	C78-5	7	28.9	19.6	9.3

PROJECT		HIGHWAY 65 STATION 11+775 TOWNSHIP OF KERNS CULVERT			
TITLE		<b>PLASTICITY CHART</b> Clayey Silt to Silty Clay			
PROJECT No.		1896349		FILE No.	
DRAWN		TR	Oct 2019	SCALE	N/A
CHECK		AB	Oct 2019	REV.	
APPR		KJB	Oct 2019	<b>FIGURE B-3</b>	
 <b>GOLDER</b> SUDBURY, ONTARIO					



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C78-1	5	228.7
⊠	C78-1	8	224.9
▲	C78-1	11	220.3
★	C78-2	6	229.0
⊙	C78-2	9	224.5
⊛	C78-3	10	222.5

PROJECT		HIGHWAY 65 STATION 11+775 TOWNSHIP OF KERNS CULVERT			
TITLE		<b>GRAIN SIZE DISTRIBUTION</b> Clayey Silt to Silty Clay			
PROJECT No.		1896349		FILE No. 1896349.GPJ	
DRAWN	TR	Oct 2019	SCALE	N/A	REV.
CHECK	AB	Oct 2019			
APPR	KJB	Oct 2019			
 <b>GOLDER</b> SUDBURY, ONTARIO			<b>FIGURE B-4</b>		

### RESULTS OF ANALYSES OF SOIL

<b>Maxxam ID</b>		IKA229		
<b>Sampling Date</b>		2018/11/20 12:12		
<b>COC Number</b>		62170		
	<b>UNITS</b>	<b>C78-3 SA 1</b>	<b>RDL</b>	<b>QC Batch</b>
<b>CONVENTIONALS</b>				
Sulphide	ug/g	0.62	0.50	5872398
<b>Calculated Parameters</b>				
Resistivity	ohm-cm	2400		5859836
<b>CONVENTIONALS</b>				
Redox Potential	mV	140	N/A	5865933
<b>Inorganics</b>				
Soluble (20:1) Chloride (Cl-)	ug/g	140	20	5862969
Conductivity	umho/cm	416	2	5863312
Available (CaCl2) pH	pH	7.70		5864763
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	5862489
<b>Physical Testing</b>				
Moisture-Subcontracted	%	24	0.30	5872397
RDL = Reportable Detection Limit QC Batch = Quality Control Batch N/A = Not Applicable				

**APPENDIX C**

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

**OBSTRUCTIONS – Item No.**

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Notice to Contractor

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The contractor shall be alerted to the potential presence of cobbles, boulders, wood, and asphalt fragments within the fill deposits along the alignment of the Highway 65, Station 11+775, Township of Kerns culvert. In addition, a wooden catch basin and pipe is located at the south toe of the embankment slope at the culvert inlet. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for open cut excavations and installation of temporary protection systems.



**TEMPORARY PROTECTION SYSTEM – Item No.**

---

Non-Standard Special Provision

---

**Amendment to OPSS 539, November 2014**

**593.07.02          Removal of Protection Systems**

Subsection 539.07.02 of OPSS 539 is deleted in its entirety and replaced with the following:

Protection systems shall be removed from the right-of-way unless it is specified in the Contract Documents that the protection system may be left in place.

Where piles are left in place, the top shall be removed to at least 1.2 m below the finishing grade or ground surface.

The method and sequence of removal shall be such that there shall be no damage to the new work, existing work or facility being protected.

All disturbed areas shall be restored to an equivalent to better condition than existing prior to the commencement of construction.



**[golder.com](http://golder.com)**