January 10, 2019

FOUNDATION INVESTIGATION AND DESIGN REPORT

STRUCTURAL BUNDLE - 11 STRUCTURES ON HIGHWAYS 129, 532 AND 556
HIGHWAY 556 - SILVER CREEK CULVERT REPLACEMENT, 25.9 KM EAST OF HIGHWAY 17 (SITE NO. 38S-0039/C0)
HODGINS TOWNSHIP, ALGOMA DISTRICT, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5378-11-00 ; WP 5307-14-01

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REPORT

Golder Associates

Table of Contents

PART A

FOUNDATION INVESTIGATION REPORT
STRUCTURAL BUNDLE – 1 STRUCTURE ON HIGHWAY 556
HIGHWAY 556 – SILVER CREEK CULVERT REPLACEMENT, 25.9 KM EAST OF HIGHWAY 17 (SITE NO. 38S-0039/C0)
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the detail design of the replacement of a culvert on Highway 556 (Site No. 38S-0039/C0) in the Hodgins Township, Algoma District, Ontario.

The purpose of the field investigation is to establish the subsurface conditions at the location of the proposed replacement culvert by methods of borehole drilling, in-situ testing and laboratory testing on selected soil samples.

This report summarizes the factual results of field and laboratory work (including field investigation procedures, borehole stratigraphy, and geotechnical and analytical laboratory test results) as well as a description of the interpreted soil and groundwater conditions at the Silver Creek culvert site.

The Terms of Reference and Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal dated May 2016 (Agreement No. 5016-E-0029) as well as change request letter dated April 24, 2018 which was approved by MTO on June 11, 2018 (Change Order No. C05016E0029001). Golder's proposal for foundation engineering services is contained in Section 17.8 of AECOM's Technical Proposal for this assignment.

2.0 PROJECT AND SITE DESCRIPTION

2.1 Project Description

The existing culvert at the site conveys the Silver Creek under Highway 556 in south to north direction. The culvert was constructed in 1976, but there are no records of the culvert being rehabilitated since that time. It is understood that the existing culvert underwent a structural assessment in 2015 and was identified as being in fair structural condition with minor deterioration of several elements, and more significant deterioration of the structural steel coatings. It is understood that the culvert is to be replaced with a new concrete box culvert.

2.2 Site Description

The site of the proposed culvert replacement is located about 25.9 km east of Highway 17 in the Hodgins Township, Algoma District, Ontario, at approximately Station 12+254.

The existing Silver Creek culvert consist of a Structural Plate Corrugated Steel Pipe Arch (SPCSPA) culvert with a span of approximately 3.9 m and measuring about 22.1 m in length. The fill above the obvert of the culvert ranges in thickness from about 0.4 m (near the edges of the highway embankment) to about 1.0 m (near the travelled portion of highway). Concrete cut-off walls surrounding the open ends of the culvert are located at the inlet and outlet of the culvert. The culvert location is shown on Drawing 1 and on Photographs 1 and 2 (on the following page).

The Silver Creek at the location of the culvert is generally less than 5 m wide and flows in a northly direction. At the time of the investigation, the creek was relatively shallow (less than 0.1 m deep) near the inlet of the culvert, however, the creek was deeper near the outlet where an approximately 2 m deep and 10 m wide scour pool was located. The downstream end of Silver Creek flows into the Goulais River about 120 m north of the culvert.

Highway 556 at the location of the culvert consists of an approximately 3.5 m to 4 m high earth fill embankment (with rock fill/rip-rap protection along the face of the slopes near the culvert) and carries one lane of traffic in each direction. The travelled portion of the highway consists of an asphalt surface which is at approximately Elevation 195.4 m in the vicinity of the existing culvert.

Photograph 1: Inlet of the existing Silver Creek Culvert on the south side of Highway 556 (looking north/downstream)

Photograph 2: Outlet of the existing culvert on the north side of Highway 556 (looking southwest)

Roadway entrances to residential properties are located on the north side of Highway 556, immediately west and approximately 30 m east of the culvert, as well as on the south side of Highway 556, approximately 55 m east of the culvert. Overhead electrical transmission lines run along the highway on the south side of Highway 556 (i.e., immediately above the inlet). The overhead lines also cross the highway about 15 m west and about 50 m east of the culvert.

The topography of the area in the immediate vicinity of the culverts is relatively flat to undulating and is located within the Goulais River valley.

3.0 FIELD INVESTIGATION PROCEDURES

The fieldwork at the site was carried out over five days between August 14 and August 18, 2018, during which time three boreholes (designated as Boreholes SCC-01 to SCC-03) were advanced near the existing culvert. Boreholes SCC-01 and SCC-03 were advanced near the inlet and outlet of the existing culvert, respectively. Borehole SCC-02 was advanced through the Highway 556 embankment on the eastbound lane.

The subsurface soil conditions encountered in the boreholes are shown in detail on the Records of Boreholes in Appendix A. Lists of abbreviations and symbols are also provided in Appendix A to assist in the interpretation of the borehole records. The locations of the as-drilled boreholes are shown in plan on Drawing 1.

The boreholes were advanced using portable drilling equipment and a truck-mounted drill rig. Boreholes SCC-01 and SCC-03 were advanced using portable drilling equipment comprised of a tripod and a cathead. Borehole SCC-01 was advanced near the inlet with the equipment set up on the existing ground/creek bed, where the creek water level was relatively shallow (i.e., less than about 0.1 m deep); and Borehole SCC-03 was advanced near the outlet (i.e., within the scour pool) on a drilling platform. The portable drilling equipment was supplied and operated by Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario. These two boreholes were advanced through the overburden using 'BW' casing with wash boring techniques. Borehole SCC-02 was advanced using a CME-75 truck-mounted drill rig supplied and operated by Landcore Drilling Inc. of Chelmsford, Ontario. The borehole was advanced using 210 mm outer diameter, continuous flight, hollow-stem augers.

In the two boreholes advanced near the inlet and outlet of the culvert, the soil samples were generally obtained at intervals of depth of about 0.75 m within about 2 m to 3 m below the creek bed followed by sampling at intervals of depth of about 1.5 m; while in the one borehole advanced on Highway 556, the soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m. All soil samples were collected using a 50 mm outer diameter split-spoon sampler driven by a manual hammer (within Boreholes SCC-01 and SCC-03 advanced using the portable drilling equipment) or an automatic hammer (within Borehole SCC-02 advanced using the truck-mounted drill rig) in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586, *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*). Field vane shear tests were carried out in the cohesive soils encountered in Boreholes SCC-01 and SCC-03 for assessment of undrained shear strengths (ASTM D2573, *Standard Test Method for Field Vane Shear Strength Test in Cohesive Soil*) using an MTO Standard 'B'-size vane given the smaller diameter of the boreholes advanced by portable equipment. Dynamic Cone Penetration Tests (DCPTs) were also carried out in all boreholes following the soil sampling operation.

The boreholes, including the DCPTs, were advanced to depths ranging between about 16.8 m and 26.8 m below existing ground or water surface. Upon completion of drilling operations, the boreholes were backfilled to or to near ground surface with bentonite grout, in accordance with Ontario Regulation 903 (as amended); and Borehole SCC-02 was capped with cold patch asphalt.

Prior to commencement of field work, Golder arranged for the clearance of underground utilities/services. The field work was observed on a full-time basis by a member of Golder's engineering staff who monitored the drilling and sampling operations and logged the boreholes in the field. The soil samples were transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual/tactile examination and geotechnical laboratory testing.

Geotechnical index testing (i.e., water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the geotechnical laboratory testing are summarized on the borehole records in Appendix A and the results of the geotechnical testing are provided in Appendix B. All of the laboratory tests were carried out in accordance with MTO Laboratory and/or ASTM Standards, as appropriate.

One soil sample was selected from Borehole SCC-02 for corrosivity testing. The selected soil sample was submitted, under chain-of-custody procedures, to Maxxam Analytics of Mississauga, Ontario (a Standards Council of Canada accredited laboratory) for analysis of a suite of corrosivity parameters including pH, sulphate, sulphide, chloride and resistivity/conductivity.

Temporary benchmarks were established and surveyed near the existing Silver Creek culvert by Callon Dietz Inc. prior to the drilling crews mobilizing to site. Upon completion of drilling operations, borehole offsets and corresponding ground surface elevation differences were recorded and tied-in to the surveyed benchmark locations to determine the as-drilled borehole locations and ground surface elevations. The borehole survey information, including northing and easting coordinates (presented in the MTM NAD83 Zone 13 and latitude/longitude coordinate systems) and the ground surface elevations (referenced to Geodetic datum), are provided on the borehole records in Appendix A, presented on Drawing 1, and summarized below.

Borehole No.	Approximate Location	Coordinates (MTM NAD83 Zone 13)		Ground / Water [1] Surface Elevation	Borehole Depth [4]
		Northing (Latitude)	Easting (Longitude)		
SCC-01	Inlet of culvert; south of Highway 556	5178620.4 m (46.747135°)	298978.8 m (-84.076192°)	192.3 m [2]	17.1 m [5]
SCC-02	Eastbound lane of Highway 556, east of the culvert	5178634.4 m (46.747261°)	298984.7 m (-84.076115°)	195.5 m [3]	26.8 m [5]
SCC-03	Outlet of culvert; north of Highway 556	5178649.4 m (46.747396°)	298985.9 m (-84.076099°)	191.8 m [2]	16.8 m [5]

Notes:

1. Water surface refers to the top of the water in the Silver Creek at the time of the investigation.
2. Boreholes SCC-01 and SCC-03 were advanced using portable drilling equipment near the inlet and outlet of the culvert, respectively.
3. Borehole SCC-02 was advanced using a truck-mounted drill rig through the Highway 556 embankment.
4. The borehole depth includes the depth of DCPT penetration carried out at the bottom of each open borehole.
5. The termination depth of Boreholes SCC-01 and SCC-03 was measured from the water surface in the Silver Creek. The water depth in the creek at the time of drilling was measured at about 0.1 m and 2.1 m in the respective boreholes.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)[1] mapping, the Silver Creek culvert site is located within a valley train consisting primarily of gravelly and sandy soils which "are mainly confined to the larger river valleys and usually occur as flat, terraced landforms" (McQuay, 1980). The granular deposits are variable in

1 Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41KNE, Study Number 91.

thickness and are generally underlain by varved silt and clay to glacial till and bedrock. The valley train is bordered by bedrock knobs.

Based on geological mapping developed by the Ontario Ministry of Northern Development and Mines (MNDM)[2], the site is underlain by bedrock from the gneissic tonalite suite of rocks comprised of tonalite to granodiorite (foliated to gneissic) with minor supracrustal inclusions.

4.2 Overview of Local Subsurface Conditions

The subsurface soil and groundwater conditions encountered in the boreholes advanced at this site, together with the results of the in-situ and geotechnical/analytical laboratory testing, are presented on the borehole records (provided in Appendix A) and the laboratory test figures/sheets (provided in Appendices B and C). The results of the in-situ field tests (i.e., SPT 'N'-values and field vane undrained shear strengths) as presented on the borehole records are uncorrected, and the 'N'-values are based on SPT sampling procedures carried out with a manual hammer at the locations of Boreholes SCC-01 and SCC-03 and an automatic hammer at the location of Borehole SCC-02.

The stratigraphic boundaries shown on the borehole records and on the soil strata profile (i.e., Drawing 1) are inferred from observations of drilling progress, generally non-continuous sampling and in-situ testing, and therefore represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions encountered at the Silver Creek culvert site consists of embankment fill (associated with Highway 556) or water (associated with Silver Creek) underlain by an extensive deposit of varved silt to clayey silt and silty clay to clay. In places, cobbles and boulders are present on the creek bed.

Detailed descriptions of the subsurface conditions encountered in the boreholes at this site are provided in the following subsections.

4.2.1 Water

Water was encountered above the creek bed in Boreholes SCC-01 and SCC-03 which were advanced in the Silver Creek near the inlet and outlet of the existing culvert, respectively. The water surface elevation and water depth at each borehole location is summarized below.

Borehole Designation	Approximate Location	Water Surface Elevation	Approximate Water Depth
SCC-01	About 4 m south of culvert inlet	192.3 m	0.1 m
SCC-03	About 4 m north of culvert outlet	191.8 m	2.1 m

As noted above, cobbles and boulders were observed on/above the creek bed near the inlets and outlets of the culvert, especially along the creek leading up to the inlet (refer to Photograph 3 below) and north of the scour pool near the outlet (refer to Photograph 4 on the following page), although cobbles and boulders are also visible around and at the bottom of the scour pool.

2 Ontario Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2544.

Photograph 3: Cobbles and boulders near the inlet and along the creek (looking south/downstream from top of Highway 556)

Photograph 4: Cobbles and boulders around and at the bottom of the scour pool as well as along the creek north of the scour pool (looking north/upstream from top of Highway 556)

4.2.2 Asphalt

An approximately 50 mm thick layer of asphalt was encountered in Borehole SCC-02 which was advanced through the Highway 556 embankment on the eastbound lane (east of the existing culvert). The top of the asphalt layer is at about Elevation 195.5 m.

4.2.3 Sandy Gravel to Gravelly Sand (Fill)

An approximately 3.9 m thick layer of sandy gravel to gravelly sand fill associated with the Highway 556 embankment was encountered below the asphalt in Borehole SCC-02 at about Elevation 195.4 m and a 2.2 m thick layer sandy gravel fill was encountered below the creek bed Borehole SCC-01 at about Elevation 192.2 m. The fill encountered in Borehole SCC-01 (advanced near the inlet) contains cobbles and boulders; while the granular fill encountered in Boreholes SCC-02 contains cobbles and rock fragments (see Photograph 5). It is further noted that difficult auger advancement was noted between depths of about 0.1 m and 2.3 m below existing ground surface in Borehole SCC-02.

Photograph 5: Cobbles and rock fragments – auger sample recovered from the upper portion of the embankment fill (in Borehole SCC-02) where difficulty with auger advancement was encountered.

The SPT 'N'-values measured within the fill range from 8 blows per 0.3 m of penetration to 50 blows for 0.15 m of penetration, indicating a loose to very dense state of compactness. The lower SPT "N"-values (i.e., 8 blows and 24 blows per 0.3 m) were encountered near the lower portion of the fill in Boreholes SCC-01 and SCC-02, respectively.

The water content measured on a sample of the gravelly sand recovered from Borehole SCC-02 is approximately 9%.

It is noted that is was not possible to schedule grain size distribution laboratory tests on the fill materials due to poor sample recovery during Standard Penetration Testing which is attributed to the gravelly/cobbley nature of the fill encountered at the site.

4.2.4 Varved Silt to Clayey Silt and Silty Clay to Clay

An extensive varved deposit comprised of silt to clayey silt laminae and silty clay to clay laminae was encountered underlying the sandy gravel fill in Borehole SCC-01, underlying the gravelly sand fill in Borehole SCC-02, and at the creek bed in Borehole SCC-03. The varved nature of the cohesive deposit is shown on Photograph 6 (on the following page); however, it is difficult to distinguish/classify the different types of laminae based on a visual inspection.

Photograph 6: Silt to clayey silt laminae (light grey colour) and silty clay laminae (dark grey colour)

The top of the varved deposit ranges between about Elevations 191.6 m and 189.7 m. All three boreholes were terminated within this deposit between about Elevations 182.6 m and 179.7 m. The thickness of the sampled portion of the varved cohesive deposit ranges from approximately 7.5 m to 11.9 m. DCPTs were also carried out at the bottom of each open borehole (i.e., below the last collected soil sample). The DCPTs were terminated at elevations ranging between about 175.2 m and 168.7 m. The blow counts (from the DCPTs) at these elevations generally range between 20 blows and 40 blows per 0.3 m of penetration.

The SPT ‘N’-values measured within the varved cohesive deposit range between 0 blows (weight of hammer) and 12 blows per 0.3 m of penetration. In-situ vane tests carried out within this deposit measured undrained shear strength ranging from about 80 kPa to greater than 136 kPa. The sensitivity (defined as the quotient between the undisturbed shear strength and the remoulded shear strength) ranges between about 1 and 5, but typically varies from 2 to 4. The in-situ field vane test results indicate that the varved deposit has a predominantly stiff to very stiff consistency. However, given the presence of generally stronger/stiffer silt to clayey silt laminae, the measured undrained shear strengths may not be representative of the operative shear strength of the varved deposit or of the weaker silty clay to clay laminae.

The water content measured on 21 samples of this deposit ranges between about 45% and 52%. An organic content test carried out on a sample recovered from the upper portion of the varved cohesive deposit from Borehole SCC-03 is approximately 1.9% (by weight).

The results of grain size distribution tests carried out on six samples of the varved silt to clayey silt and silty clay to clay deposit are shown on Figure B1 in Appendix B. Atterberg limits tests were carried out on ten samples of the varved clay deposit. The tests measured liquid limits between about 36% and 51%, plastic limits between about 21% and 23%, and plasticity indices between about 16% and 27%. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B2 in Appendix B, and indicate that the soil is classified as silty clay of intermediate plasticity to clay of high plasticity. The results also suggest that the soil consists predominantly of silty clay, but this may not be a true representation of the overall varved deposit. These results can be attributed to the difficulty in attempting to separate the two types of laminae for laboratory testing purposes. The silt to clayey silt laminae, which were identified in the field and the laboratory based on tactile examination, have been mixed with portions of the more plastic laminae, yielding 'average' Atterberg limits indicative of a cohesive material of intermediate plasticity.

4.3 Groundwater Conditions

Given the presence of the Silver Creek, the groundwater level is anticipated to be at or near the creek surface. The water level in Borehole SCC-02 (advanced from the top of the Highway 556 embankment) was noted to be at a depth of about 3.5 m below existing highway surface, corresponding to approximately Elevation 192.0 m, upon completion of drilling which is similar to the elevation of the surface of the adjacent creek. Boreholes SCC-01 and SCC-03 were advanced using wash-boring techniques, which introduced water into the boreholes.

The water level surveyed at the surface of the Silver Creek during the field investigation is at about Elevation 192.3 m at the location of Borehole SCC-01 (i.e., near the inlet) and at about Elevation 191.8 m at the location of Borehole SCC-03 (i.e., near the outlet).

The water level in the creek and the degree of saturation of the embankment fill (or the potential presence of a perched water table within the fill) is subject to seasonal fluctuations and precipitation events. Water levels in the creek and within the fill are expected to be higher during wet seasons and sustained periods of precipitation.

4.4 Analytical Testing of Soil

One soil sample was selected from Borehole SCC-02 (advanced through the highway embankment) and submitted to Maxxam Analytics Ontario for corrosivity testing. The analytical laboratory test results are provided on the Certificates of Analysis presented in Appendix C, and summarized below.

Borehole Designation	Sample No.	Average Approx. Sample Depth [2] (m)	Average Approx. Sample Elevation (m)	Material Type	Resistivity (ohm·cm)	Conductivity (μmho/cm)	pH	Chloride (Cl) Content (ppm or μg/g)	Sulphate (SO_4) Content (ppm or μg/g)
SCC-02 [1]	SA 4	3.9	191.6	Varved Silt to Clayey Silt and Silty Clay to Clay	5,800	171	8.6	<20 [1]	<20 [1]

Note:
1. The sulphate and chloride concentrations measured on samples recovered from Borehole SCC-02 are below the reportable detection limit of 20 μg/g.

It is noted that the sulphide concentration measured on the soil sample recovered from Borehole SCC-02 and was also analyzed and is less than 0.55 μg/g (i.e., below the reportable detection limit of 55 μg/g).

5.0 CLOSURE

The field work for this investigation was supervised by members of Golder's engineering staff. The Foundation Investigation Report was prepared by Ms. Alysha Kobylinski, B.A.Sc. and reviewed by Mr. Tomasz Zalucki, P.Eng., a geotechnical engineer at Golder. Mr. Paul Dittrich, P.Eng., a Principal and MTO Foundations Designated Contact for Golder, conducted an independent quality control review of the report.

Report Signature Page

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PART B

FOUNDATION DESIGN REPORT
STRUCTURAL BUNDLE – 1 STRUCTURE ON HIGHWAY 556
HIGHWAY 556 – SILVER CREEK CULVERT REPLACEMENT, 25.9 KM EAST OF HIGHWAY 17 (SITE NO. 38S-0039/C0)
HODGINS TOWNSHIP, ALGOMA DISTRICT, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5378-11-00 ; WP 5307-14-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of the Silver Creek culvert under Highway 556 (Site No. 38S-0039/C0). These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the field investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and carry out the design of the culvert foundations. The foundation investigation report, discussion and recommendations are intended for the use of MTO and its designers and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor.

Contractors must make their own interpretation based on the factual data presented in the Foundation Investigation Report (Part A of this 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 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 General

The existing culvert consists of a Structural Plate Corrugated Steel Pipe Arch (SPCSPA) culvert with a span of approximately 3.9 m and measuring about 22.1 m in length. The fill above the obvert of the culvert ranges in thickness from about 0.4 m (near the edges of the highway embankment) to about 1.0 m (near the travelled portion of highway). Concrete cut-off walls surrounding the open ends of the culvert are located at the inlet and outlet.

It is understood that the existing culvert will be replaced with a new precast concrete box culvert having a 4.8 m span and a 2.4 m rise (inside dimensions). The thickness of the side walls and top/base slab of the precast concrete box culvert is proposed to be 350 mm and 300 mm, respectively. The invert at the inlet and outlet of the new culvert is proposed at Elevations 191.7 m and 191.8 m, respectively. Precast concrete wingwalls will also be cantilevered from both sides of the new culvert on the north side of Highway 556 (i.e., near the outlet).

It is further understood that the construction works will not involve platform widening of the existing Highway 556 embankment in the vicinity of the Silver Creek and that there will be no raising of the existing highway grade.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the 2014 *Canadian Highway Bridge Design Code* (CHBDC 2014) and its *Commentary*, the proposed culvert and its foundation system are located below a roadway expected to carry low to medium traffic volumes, but its performance will have potential impacts on other transportation corridors, hence 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 Foundation Investigation Report (i.e., Part A)), 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 ULS and 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.

6.3 Replacement Culvert

6.3.1 Factored Geotechnical Resistances

As noted above, a precast concrete box culvert founded at approximately Elevation 191.5 m will be constructed as part of the replacement strategy at the Silver Creek site. It is not necessary to found the proposed precast box culvert at or below the standard depth for frost protection purposes (i.e., 2.0 m in this area), as this type of culvert is tolerant of small magnitudes of movement related to freeze-thaw cycles. The factored ultimate and serviceability geotechnical resistances for the precast box culvert option founded on a 0.3 m thick granular bedding layer placed on properly prepared subgrade are as follows:

Culvert Type	Culvert Size (outer dimensions)	Founding Soils	Factored Ultimate Geotechnical Resistance	Factored Serviceability Geotechnical Resistance for 25 mm of Settlement
Precast Concrete Box	5.5 m wide by 3.0 m high	■ Southern portion of culvert: 0.3 m of compacted Granular 'A' material (granular bedding) over 1.2 m of loose to very dense sandy gravel fill with cobbles and boulders (1) over generally stiff to very stiff varved silt to clayey silt and silty clay to clay. ■ Central portion of culvert: 0.3 m of compacted Granular 'A' material (granular bedding) over generally stiff to very stiff varved silt to clayey silt and silty clay to clay. ■ Northern portion of culvert: 0.3 m of compacted Granular 'A' material (granular bedding) over existing granular fill (2) over generally stiff to very stiff varved silt to clayey silt and silty clay to clay.	200 kPa	75 kPa

Notes:
1. Given the presence of cobbles and boulders within the granular fill, excavation equipment must be capable of excavating through such obstructions (refer to Section 6.6.4).
2. Borehole SCC-03 was advanced within the scour pool (near the outlet) and the top of the creek bed was surveyed at about Elevation 189.7 m (i.e., about 1.5 m below the base of the proposed culvert). Consequently, it is unknown what material is founded directly below the northern portion of the culvert. However, based on the adjacent boreholes, the culvert will likely be founded on existing granular fill over the varved cohesive deposit.

The factored ultimate resistances presented above are based on loading applied perpendicular to the base slab of the culvert. Where the load is not applied perpendicular to the base slab of the culvert, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the *CHBDC* (2014) and its *Commentary*.

As noted in Section 6.1, it is understood that concrete wingwalls, about 2.1 m long and up to 4 m high (with the base of the walls at about Elevation 190.5 m), will be cantilevered from both sides of the new culvert on the north side of Highway 556 (i.e., near the outlet). Considering that the wingwalls will be affixed to the culvert and act as structural units, bearing capacities for the walls are not required.

6.3.2 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces/sliding resistance between the precast concrete box culvert and granular bedding as well as between the granular bedding and the native subgrade soils shall be calculated in accordance with Section 6.10.5 of the *CHBDC* (2014). The unfactored coefficient of friction (tan δ) and effective cohesion (where applicable) between the various interface materials is summarized below.

Interface Materials	Unfactored Coefficient of Friction (tan δ)	Effective Cohesion, c'
Precast concrete box culvert on Granular 'A' material	0.45	0 kPa
Granular 'A' material on gravelly sand fill to sandy gravel fill	0.70	0 kPa
Granular 'A' material on varved silt to clayey silt and silty clay to clay	0.47 (long-term)	60 kPa (short-term)

6.3.3 Culvert Bedding, Cover and Backfill

Culvert construction, including placement of bedding, cover and backfill should be in accordance with the relevant Ontario Provincial Standards for Roads and Public Works as summarized below.

Culvert Replacement Option	Ontario Provincial Standard Drawing: Bedding, Cover and Backfill	Ontario Provincial Standard Specification: Culvert Construction
Concrete Precast Box Culvert	OPSD 803.010 – Backfill and Cover for Concrete Culverts [1]	OPSS 422 – Precast Reinforced Concrete Box Culverts

Note:
1. OPSD 803.010 is applicable to concrete culverts with spans less than 3 m. However, the proposed 5.5 m wide precast box culvert should be constructed in general accordance with this specification.

The culvert bedding should be minimum 300 mm thick and consist of OPSS.PROV 1010 (*Aggregates*) Granular 'A' material, placed and compacted in-the-dry. In addition, a minimum 75 mm thick uncompacted levelling layer consisting of OPSS.PROV 1010 Granular 'A' material or concrete fine aggregate meeting the graduation requirements specified in OPSS.PROV 1002 (*Aggregates – Concrete*) should be provided as shown on OPSD 803.010 (*Backfill and Cover for Concrete Culverts*) for culvert construction.

The culvert bedding should be placed on properly prepared subgrade whether comprised of native soil or sub-excavation backfill. However, taking into consideration that the bedding may be placed on native fine-grained soils (i.e., varved silt to clayey silt and silty clay to clay) it is recommended that a non-woven geotextile be placed between the subgrade soils and the bottom of the bedding. The geotextile should meet the specification for OPSS 1860 (*Geotextiles*) Class II and have a Filtration Opening Size (FOS) not greater than 212 µm. The bedding, cover and backfill should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 95% of the Standard Proctor maximum dry density of the material as specified in OPSS.PROV 501 (*Compacting*). If the subgrade is expected to be disturbed due to construction traffic and/or ponded water and the bedding cannot be placed in a timely manner, a concrete working slab will be required on the subgrade as outlined in Section 6.6.5.

The backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II material. The granular backfill should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

If backfill placement for the reconstruction of the highway embankments along and over the culvert is required, it should be carried out in accordance with OPSD 208.010 (*Benching of Earth Slopes*) to integrate the new fill with the existing embankment fill along the cut faces.

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

6.4 Lateral Earth Pressures

The lateral earth pressures acting on the walls of the new precast concrete box culvert and associated wingwalls will depend on the type and method of placement of the backfill material, the nature of the soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culvert walls, including wingwalls. These design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope (in accordance with Figure C6.17 of the *Commentary* to the CHBDC, 2014).

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II should be used as backfill behind the walls and on top of the culvert for a thickness not less than 300 mm. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (*Compacting*).
- Surcharge loadings should be accounted for in the design as required.
- For restrained structures, granular fill should be placed in a zone with the width equal to at least 2.0 m behind the back of the wall (in accordance with Figure C6.20(a) of the *Commentary* to the *CHBDC, 2014*). For unrestrained structures, fill should be placed within a wedge-shaped zone defined by a line drawn at 1 horizontal to 1 vertical (1H:1V) extending up and back from the rear face of a footing or bottom of a structure (in accordance with Figure C6.20(b) of the *Commentary* to the CHBDC, 2014). The lateral pressures should be based on the proposed embankment fill/backfill and existing soils/fill, where applicable, 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
New Granular 'A'	21 kN/m^3	0.43	0.27
New Granular 'B' Type II	21 kN/m^3	0.43	0.27
Generally Loose to Compact Gravelly Sand to Sandy Gravel (Fill)	21 kN/m^3	0.43	0.27

If the culvert design does not allow lateral yielding of the culvert walls (e.g., a rigid box culvert), at-rest earth pressures should be assumed for the geotechnical design. Where the culvert design does allow lateral yielding of the walls (e.g., wingwalls), active earth pressures should be used in the geotechnical design of the wall structure. 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*.

6.5 Highway Embankment

As noted in Section 6.1, it is understood that no grade raise and no embankment widening is required along Highway 556 as part of the culvert replacement construction. However, the highway embankment slopes next to the culvert will be reconstructed as part of the new culvert construction and backfilling. The side slopes of the highway embankment are expected to be constructed at an inclination of 1.5 horizontal to 1 vertical (1.5H:1V) in order to achieve the following:

i) Limit the length of the culvert to no more than 22 m;

ii) Avoid construction of headwalls and wingwalls on both sides of the culvert (already required on the north side); and,

iii) Avoid additional efforts and potential issues with acquiring/occupying additional right-of-way.

The following sections present the method used to evaluate static global stability of the highway embankment adjacent to the Silver Creek culvert, the geotechnical fill/soil parameters used in the analyses, and results of the stability analyses.

6.5.1 Method of Analysis

Two-dimensional, limit equilibrium, slope stability analyses were performed using the commercially available program Slide 2018, developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. Morgenstern-Price is a general method of slices which is based on equilibrium of forces and moments acting on each slice of soil mass above the potential failure surface. For all analyses, the Factors of Safety of numerous potential failure surfaces were computed in order to establish the minimum Factor of Safety. The Factor of Safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. For the purpose of the stability analysis, the Factor of Safety is equal to the inverse of the product of the consequence factor, Ψ, and the geotechnical resistance factor, ϕ_{gu}. (i.e., $FoS = 1/(\Psi \cdot \phi_{gu})$). Accordingly, minimum Factors of Safety of 1.3 and 1.5 have been used for the design of the highway embankment slopes for the short-term/temporary and long-term/permanent conditions, respectively, as per Table 6.2 of CHBDC (2014).

6.5.2 Parameter Selection

For the native granular soils encountered at this site, effective stress parameters were estimated from empirical correlations based on the results of the in-situ Standard Penetration Tests (SPT). The correlations proposed by Peck et al. (1974) and U.S. Navy (1986) were employed and the results were adjusted using engineering judgment based on precedent experience in similar soil conditions.

For the cohesive varved clayey deposit encountered at the site, total stress parameters were employed in the stability analyses for the short-term, undrained conditions (i.e., temporary conditions). The total stress parameters (i.e., average mobilized undrained shear strength, s_u) for the cohesive soils were assessed based on the results of in-situ field vane shear tests.

Where appropriate, Bjerrum's correction factor was employed to estimate the average mobilized undrained shear strength from the results of the in-situ field vane tests as follows:

$$s_{u(mob)} = \mu s_{u(FV)} \qquad \text{(after Bjerrum, 1973)}$$

where,
$s_{u(mob)}$ = average mobilized undrained shear strength (kPa)
$s_{u(FV)}$ = undrained shear strength from field vane test (kPa)
μ = Bjerrum's correction factor based on plasticity index

For the extensive varved silt to clayey silt and silt clay to clay deposit at this site, an additional reduction factor of 25% was employed to account for the angle of minimum shearing resistance (as described in Lo and Milligan, 1967). A plot of the corrected undrained shear strengths versus elevation is shown on Figure 1. It is noted that with Bjerrum's correction factor and the additional reduction factor of 25%, the corrected undrained shear strength of the varved cohesive deposit generally varies between about 60 kPa and 85 kPa. For the short-term/temporary slope stability analysis, the lower bound of the undrained shear strength of 60 kPa (above Elevation 186.5 m) transitioning to an undrained shear strength of 85 kPa (below Elevation 182.5 m) was utilized, as shown in the design line on Figure 1, was assigned to the varved cohesive deposit.

Effective stress parameters were also employed to evaluate the stability of the highway embankment based on the long-term, drained conditions (i.e., permanent conditions). The effective stress parameters (i.e., effective friction angle (ϕ') and effective cohesion (c')) for the cohesive (varved clay) deposit were estimated from empirical correlations based on the plasticity index as well values reported in literature (Milligan et al., 1962). The correlations proposed by Mitchell (1993), Kulhawy and Mayne (1990), and Ladd et al. (1977) were employed and the results were adjusted using engineering judgment based on precedent experience in similar soil conditions.

The simplified stratigraphy together with the foundation engineering parameters employed for the different fill and soil types encountered at the site are summarized below.

Fill / Soil Type	Top Elevation	Thickness	Bulk Unit Weight, γ	Effective Friction Angle, ϕ'	Undrained Shear Strength, s_u
New Granular 'A' or Granular 'B' Type II	Hwy 556: 195.5 m	Hwy 556: ~3.9 m	21 kN/m^3	38°	--

Fill / Soil Type	Top Elevation	Thickness	Bulk Unit Weight, γ	Effective Friction Angle, ϕ'	Undrained Shear Strength, s_u
Sandy Gravel (Fill)	South of Hwy 556: 192.2 m	South of Hwy 556: ~2.2 m	21 kN/m^3	35°	--
Varved Silt to Clayey Silt and Silty Clay to Clay	191.6 m to 189.7 m	7.5 m to 11.9 m (not fully penetrated)	19 kN/m^3	25° to 34° [1]	60 kPa - 85 kPa (see Figure 1)

Note:
1.The effective friction of the intermediate to high plasticity clayey laminae is estimated to be 25 degrees, and the effective friction angle of the silt to low plasticity clayey laminae is estimated to be 34 degrees.

In areas where rip-rap protection is required (i.e., along the face of the highway embankment side slopes and within the scour pool at the outlet of the proposed culvert), a bulk unit weight of 21 kN/m^3 and an effective friction angel of 50 degrees was assigned to the material.

For the purpose of the stability analyses, the groundwater level was assumed to be at the creek surface (i.e., at Elevation 192.4 m, as surveyed in October 2017).

6.5.3 Results of Analyses

The results of global slope stability analyses along the north and south side of the highway embankment immediately adjacent to the new culvert are summarized as follows:

- **North Side**
  - Geometry: up to about 4 m high culvert wingwall with 1.5H:1V slope in front of the wingwall (see Figures 2 and 3).
  - Factor of Safety (Temporary/Short-Term Condition): 1.2 – see Figure 2.
  - Factor of Safety (Permanent/Long-Term Condition): 1.0 – see Figure 3.

- **South Side**
  - Geometry: 1.5H:1V side slope covered (or blanketed) with a minimum 0.5 m thick layer of R-50 rip-rap (see Figures 2 and 3).
  - Factor of Safety (Temporary/Short-Term Condition): 1.4 – see Figure 2.
  - Factor of Safety (Permanent/Long-Term Condition): 1.4 – see Figure 3.

The Factor of Safety associated with the permanent/long-term condition is lower than the temporary/short-term condition on the north side of the highway embankment due to the relatively low value for the effective friction angle assumed for horizontal shearing along the clayey laminae of the varved clay deposit. On the south side of the highway embankment, the potential failure surface associated with the minimum Factor of Safety does not extend into the varved clay deposit and consequently, the Factor of Safety is the same for both conditions.

In order to satisfy a minimum Factor of Safety equal to or greater than 1.5 for the long-term/permanent on the south side of the highway embankment, it is recommended that the embankment side slope adjacent to the culvert be covered (or blanketed) with a minimum 0.8 m thick layer (measured perpendicular to the face of the slope) of R-50 rip-rap (refer to Figures 4 and 5) in accordance with OPSS.PROV 1004 (*Aggregates – Miscellaneous*). The rip-rap particles should be angular (i.e., not rounded or sub-rounded) to offer an adequate Factor of Safety against surficial slope instability. In addition, it is recommended that a non-woven geotextile separator, satisfying the requirement of OPSS 1860 (*Geotextiles*), be placed along the side slopes between the rip-rap and the granular fill to prevent migration of fines into the rip-rap.

On the north side of the highway embankment, the varved cohesive deposit should be sub-excavated down to Elevation 189.0 m between the wingwall of the culvert and toe of the slope in front of the wingwall, and replaced with R-50 rip-rap wrapped in a non-woven geo-textile separator. The slope in front of the wingwall should also be comprised of rip-rap material wrapped in non-woven geotextile separator. Additionally, a 0.8 m thick layer of the varved cohesive deposit should be sub-excavated 7 m north of the toe of the slope (i.e., within the scour pool) and replaced with rip-rap. This overall configuration will ensure that the minimum Factor of Safety is equal to 1.5 and 1.3 during the short-term/temporary and long-term/permanent condition, respectively (refer to Figures 4 and 5).

6.6 Construction Considerations

This section identifies key construction considerations that may impact the design and construction of the new culvert.

6.6.1 Temporary Open-Cut Excavations

It is expected that temporary excavations will extend to down to approximately Elevation 190.1 m in order to facilitate removal of the existing culvert and installation of the new precast box culvert, including placement of granular bedding for the new culvert. As such, the excavation will extend through the existing highway embankment fill (comprised of gravelly sand to sandy gravel) as well as sandy gravel fill and potentially varved silt to clayey silt and silty clay to clay. The founding subgrade should be inspected to ensure that any organic soils or other unsuitable materials have been removed in accordance with OPSS 422 (*Precast Reinforced Concrete Box Culverts*) prior to construction of the precast concrete box culvert. Any sub-excavated areas should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates*) Granular ‘A’ or Granular ‘B’ Type II and placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

All excavations must be carried out in accordance with Ontario Regulation 213 (*Ontario Occupation Health and Safety Act for Construction Projects*), as amended, and OPSS 902 (*Excavating and Backfilling – Structures*).

The portion of the existing embankment fill above the groundwater table/perched water level can be can classified as a Type 3 soil according to OHSA. The soils below the groundwater table/creek level (i.e., bottom portion of the embankment fill, sandy gravel fill, and varved silt to clayey silt and silty clay to clay deposit) would be classified as Type 4 soils; however, if dewatered, these soils can be classified as Type 3 soils. Temporary excavations in Type 3 soils should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). Temporary excavations in Type 4 soils should be made with side slopes no steeper than 3H:1V.

Cobbles and boulders were observed at the surface of the creek bed near the inlets and outlets of the existing culvert; cobbles and rock fragments were also encountered within the embankment fill. Consequently, construction equipment must be capable of excavating through these obstructions (refer to Section 6.6.4).

All temporary excavations should be observed by a qualified geotechnical engineer and reviewed during construction to confirm that the soil and groundwater conditions encountered are as anticipated in this document.

6.6.2 Temporary Cofferdams and Roadway Protection Systems

Temporary cofferdams near the inlets and outlets of the culvert and temporary roadway protection systems along Highway 556 in the vicinity of Silver Creek will be required to support the installation/construction of the new culvert and allow vehicular traffic along the highway during excavation/construction operations, respectively.

The depth of water in the creek near the inlet of the culvert (i.e. up to about 0.1 m deep as measured during the field investigation at the inlet) and downstream of the scour pool near the outlet of the culvert (based on visual observations, but not measured) is relatively shallow. As such, considering that the excavations for the culvert bedding placement and construction will only penetrate up to about 1.2 m below the creek bed near the inlet (based on Borehole SCC-01; at the outlet the excavation will be well above the bottom of the scour pool which will need to be drained), it may be possible to construct the temporary cofferdams and divert the creek water using one of the following methods:

- Small inflatable bladder cofferdams;
- Water dams consisting of industrial grade, impermeable, composite fabrics formed into flexible tubes containing one or more chambers; or,
- Multiple rows of large sand bags (‘super-bags’ or ‘bulk-bags’) lined with an impermeable barrier (poly-material).

Further, given the relatively constrained access to the site as a result of close proximity to residential driveways and dwellings, the use of smaller, and more modular or inflatable cofferdams may be preferred as these systems can be maneuvered by small equipment and/or by hand. However, the viability and effectiveness of such systems will depend on the creek water level at the time of construction as well as the available space between where the diversion structure(s)/temporary cofferdams will be located relative to the excavation for the new culvert. As noted in Section 6.6.1, the soils below the creek bed are considered Type 4 soils and as such, temporary unsupported excavations will have to be made with side slopes no steeper than 3H:1V. The spacing required to accommodate this slope, relative to the restrictions imposed by the right-of-way will need to be considered when determining if an unsupported excavation using one of the above methods is practical or not.

If water levels in the creek are high, if the working area is restricted and/or if deeper sub-excavation is required to remove weak/softened soils before bedding placement, it may be necessary to install a proper groundwater cut-off system (comprised of an interlocking steel sheet piles) to avoid excavation instability, a “boiling” or “quick” condition that would loosen/soften any of the cohesionless soils and/or cause disturbance of the foundation subgrade within the footprint of the excavation area. If required, a more robust/watertight cofferdam system for this site would consist of interlocking, steel sheet piles driven to a suitable depth.

For the temporary roadway protection system, consideration could be given to driven steel sheet piles or a soldier pile and lagging system whereby more rigid steel H-piles would be driven (or placed in augered holes backfilled with concrete) to a suitable depth and horizontal timber lagging installed between the H-piles as the excavation proceeds to retain the embankment fill. The latter system assumes that groundwater is not perched up in the highway embankment fill and that the lower portions of the existing fill (i.e., below the creek water level) could be adequately retained and seepage would not be excessive. Otherwise, a perched water level in the embankment fill, or where the embankment fill exists below the creek level, could result in some water seepage/inflow into the excavation and may cause migration of fine-grained soil particles through the lagging boards (which are not considered watertight) potentially resulting in subsidence of the highway surface.

The temporary cofferdams and protection systems at this site should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems)*. The temporary protection systems extending through the highway embankment should be designed in accordance with Performance Level 2. The lateral movement of the temporary cofferdam system should include an evaluation of base stability, soil squeezing stability and hydraulic uplift as defined in the Canadian Foundation Engineering Manual (CFEM, 2006). The contractor is responsible for the design and construction of all temporary cofferdams and protection systems.

For conceptual purposes, to aid the designer in assessing the approximate construction cost of the temporary cofferdam and roadway protection systems, a preliminary design of the systems may be carried out using the parameters provided below.

Fill / Soil Type	Bulk Unit Weight, γ	Internal Angle of Friction, ϕ'	Undrained Shear Strength, s_u	Lateral Earth Pressure Coefficients [1]		
				K_p (Passive)[2]	K_o (At-Rest)	K_a (Active)
Loose to Compact Gravelly Sand to Sandy Gravel (Fill)	21 kN/m^3	35°	--	3.70	0.43	0.27
Very Dense Gravelly Sand (Fill)	21 kN/m^3	38°	--	4.20	0.38	0.24
Generally Stiff to Very Stiff Silt to Clayey Silt and Silty Clay to Clay	19 kN/m^3	25°	60 kPa to 85 kPa [3]	2.46	0.58	0.41

Notes:

1. 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 in accordance with Figures C6.17 and C6.18 of the Canadian Highway Bridge Design Code (CHBDC, 2014).
2. The total passive resistance below the base of the excavation (i.e., within the sheet pile cofferdam or temporary protection system enclosure) 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 Canadian Highway Bridge Design Code (CHBDC, 2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.
3. For cohesive deposits, an assessment for both the drained (ϕ') and undrained (s_u) cases should be made to establish the more conservative earth pressure condition for design.

The installation of sheet piles and/or steel H-piles for temporary cofferdams and roadway protection systems may be impeded by the presence of cobbles/boulders at the creek bed near the inlet and outlet of the culvert and potential presence of cobbles and rock fragments within the granular highway embankment. Given the presence of these obstructions, consideration should be given to protecting the tips of the piles and/or the use of heavier pile sections and/or pre-excavation to loosen or remove the larger cobbles and boulders prior to pile installation.

6.6.3 Control of Groundwater and Surface Water

Although the excavations may extend into the varved cohesive deposit below the creek bed, the silty laminae are water bearing and more permeable than the silty clay to clay laminae. In addition, the excavations will extend through the lower portion of the existing granular embankment fill and sandy gravel fill below the creek level. As such, some form of groundwater control will be required to allow for construction to be carried out in-the-dry.

The method and extent of groundwater control required will ultimately depend on the type of temporary cofferdams and roadway protection selected by the contractor (described in Section 6.6.2). If temporary shoring is comprised of sheet pile cut-off walls, the requirements for groundwater control will be lessened. However, if temporary shoring is comprised of soldier pile and timber lagging (through the roadway embankment) and inflatable bladders, flexible tubes or sand bags (for cofferdams around the culvert inlet and outlet), the requirements for groundwater control could be more extensive. The contractor is responsible for the design and installation of all groundwater control measures giving due consideration to the type of temporary shoring selected as well as the requirements for maintaining the stability/integrity of the culvert foundation subgrade and for construction of the culvert and bedding in-the-dry. To address dewatering for this site, groundwater control measures should be carried out in accordance with OPSS.PROV 517 (*Dewatering*), as modified by the Non-Standard Special Provision FOUN0003 (*Dewatering of Structure Excavation*). A copy of the Non-Standard Special Provision FOUN0003 is provided in Appendix D. If construction water pumping volumes are anticipated to exceed 50 m^3/day, an Environmental Activity Section Registry (EASR) will be required as per the changes to the Environmental Protection Act by the Ontario Ministry of Environment, Conservation and Parks (MECP).

Surface water should be directed away from the excavation area(s) to prevent ponding of water that could result in disturbance and loosening/softening of the foundation subgrade, particularly the gravelly sand encountered under the embankment and the extensive cohesive deposit.

6.6.4 Obstructions

As described in Section 4.2.1, cobbles/boulders were noted at the surface of the creek bed; and cobbles and rock fragments were also encountered within the existing embankment fill as noted in Section 4.2.3. Consequently, construction equipment, including equipment/tools used to install temporary cofferdam and roadway protection systems should be capable of excavating through such obstructions. It is recommended that a Notice to Contractor be included in the contract documents to address obstructions (refer to Appendix D).

6.6.5 Subgrade Protection

The overburden soils exposed at the founding level, especially the clayey silt to silt and the silty clay to clay laminae (if exposed), will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance, a concrete working slab should be paced on the subgrade if the precast concrete box culvert and associated bedding is not placed within four hours after preparation, inspection and approval of the subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a 28-day compressive strength of not less than 20 MPa. A sample Non-Standard Special Provision to address this requirement is included in Appendix D.

As an alternative to construction of a concrete working slab, which could impact/extend the construction schedule, consideration can be given to constructing a minimum 0.6 m thick granular pad below the 75 mm thick levelling layer placed immediately below the base of the precast concrete box culvert. In order to reduce dewatering and temporary shoring requirements, the bottom portion of the granular pad (i.e., below the culvert bedding) could be constructed in wet conditions by end-dumping Granular ‘B’ Type II material with nominal compactive effort. The upper 0.3 m of the granular pad (i.e., the culvert bedding) should consist of Granular ‘A’ material compacted to at least 95% of the Standard Proctor maximum dry density of the material as specified in OPSS.PROV 501 (*Compacting*) and as described in Section 6.3.3. A minimum 75 mm thick uncompacted levelling layer consisting of OPSS.PROV 1010 Granular ‘A’ material or concrete fine aggregate meeting should be placed above the Granular ‘A’ material (i.e., the bedding), as described in Section 6.3.3.

The earth excavation for the granular pad and construction of the granular pad in wet conditions should be carried out simultaneously. A Non-Standard Special Provision to address the earth excavation and construction of the uncompacted portion of the granular pad in wet conditions is included in Appendix D.

6.6.6 Frost Tapers

Frost tapers, if required, should be constructed in general accordance with OPSD 803.010 (*Backfill and Cover for Concrete Culverts*) for the new precast box culvert. Considering that there will be no change in the Highway 556 grade in the vicinity of Silver Creek and given that the embankment fill in the immediate proximity of the culvert is generally comprised of material with a low degree of frost susceptibility (i.e., gravelly sand to sandy gravel), and given that Highway 556 is a secondary highway, it is understood that frost tapers may not be required.

6.6.7 Erosion Protection

Provisions should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring, although the risk may not be very high given the predominantly cohesive founding soils), or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles, and potentially settlement of the overlying roadway surface), a clay seal or concrete cut-off wall should be provided at the upstream end of the culvert.

If a clay seal is adopted, the clay material should meet the requirements of OPSS.PROV 1205 (*Clay Seal*), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level, to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and to a minimum vertical height equivalent to the high water level, including along the embankment slope. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height corresponding to the high-water level.

The requirements for the design of erosion protection measures for the inlet and outlet of the culvert should also be assessed by the hydraulics design engineer. Typically, rip-rap treatment for the outlet of a culvert should be consistent with the standard presented in OPSD 810.010 (*Rip-Rap Treatment for Sewer and Culvert Outlets*). However, given the presence of a scour/plunge pool at the outlet of the culvert which acts as an energy dissipation feature, the hydraulics design engineer should consider this when designing the erosion protection in this area. Placement of rip-rap/rock protection will be required immediately in front of the outlet. Erosion protection for the inlet of the culvert should generally follow the standard presented in OPSD 810.010, with the rock protection/rip-rap placed up to the toe of slope level, in combination with the cut off wall noted above.

In order to reduce erosion of the embankment side slopes due to surface water runoff and to achieve the required Factor of Safety for the long-term permanent condition of the side slopes, rip-rap/rock protection with a minimum thickness of 1 m must be placed along the embankment side slopes.

6.6.8 Analytical Testing of Construction Materials

The results of analytical tests carried out on one sample of the varved silt to clayey and silty clay to clay deposit recovered from Borehole SCC-02 (advanced through the highway embankment) are presented in Section 4.4 and on the Certificates of Analysis in Appendix C.

The analytical test result of the soil sample was compared to Table 7.1 (Relative Effect of Resistivity on Corrosion Potential/Aggressiveness (from NCHRP 1978)), as presented in the Federal Highway Administration/National Highway Institute Publication No. FHWA-NHI-14-007 (Federal Highway Administration, 2015), to assess the relative level of corrosion potential on buried steel in contact with soil. The resistivity values measured on the soil sample is 5,800 ohm·cm. These results indicate "mildly corrosive" (i.e., resistivity between 5,000 ohm·cm and 10,000 ohm·cm).

Given that the existing culvert will likely be replaced with a new precast concrete box culvert, the analytical test results were also compared to CSA A23.1 Table 3 (*Additional requirements for concrete subjected to sulphate attack*) to assess the potential severity of sulphate attack on concrete during its service life. The sulphate concentration measured on the soil sample was less than 0.002%, which is below the moderate degree of exposure (i.e., below the class S-3 exposure limits). Based on the one soil sample tested, the effects of sulphates from the varved cohesive deposit in contact with the concrete structure may not need to be considered. However, if the proposed structure is expected to be exposed to de-icing salt or other solutions, consideration should be given by the designer to designing the concrete structure for a "C" type exposure class as defined by CSA A23.1 Table 1.

It is also noted that the measured pH level was about 8.6, suggesting that the soils are basic (i.e., pH greater than 7).

Ultimately, it is the designer's decision to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 (*Durability Requirements*) are satisfied.

7.0 CLOSURE

The Foundation Design Report was prepared by Ms. Alysha Kobylinski, B.A.Sc. and reviewed Mr. Tomasz Zalucki, P.Eng., a geotechnical engineer with Golder. Mr. Paul Dittrich, P.Eng., a Principal and MTO Foundations Designated Contact for Golder, conducted an independent quality control review of the report.

Report Signature Page

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JAN. 10, 2019
PROVINCE OF ONTARIO

Paul Dittrich, Ph.D., P.Eng.
MTO Foundations Designated Contact, Principal

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T. ZALUCKI
100128614
Jan. 10, 2019
PROVINCE OF ONTARIO

Tomasz Zalucki, P.Eng.
Geotechnical Engineer

AK/TZ/JPD/ak

https://golderassociates.sharepoint.com/sites/14262g/deliverables/04-final fidr/silver creek culvert/1670846-12-rpt-rev0-silver creek culvert fidr-20190110.docx

REFERENCES

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Peck, R.B., Hanson, W.E., and Thornburn, T.H. 1974. Foundation Engineering, 2nd Edition, John Wiley and Sons, New York.

Terzaghi, K. and Peck, R.B. 1967. Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley and Sons, New York.

Unified Facilities Criteria U.S. Navy. 1986. NAVFAC Design Manual 7.02. Soil Mechanics, Foundation and Earth Structures. Alexandria, Virginia.

ASTM International:

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

Canadian Standards Association (CSA):

CAN/CSA A23.1-14	Concrete Materials and Methods of Concrete Construction

Commercial Software:

Slide 2018 by Rocscience Inc.

Ontario Occupational Health and Safety Act:

Ontario Regulation 213	Construction Projects (as amended)

Ontario Provincial Standard Specifications (OPSS), Construction:

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling – Structures

Ontario Provincial Standard Specifications (OPSS), Materials:

OPSS.PROV 1002	Material Specification for Aggregates - Concrete
OPSS PROV 1004	Material Specification for Aggregates - Miscellaneous
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

Ontario Provincial Standard Drawings (OPSD):

OPSD 208.010	Benching of Earth Slopes
OPSD 802.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Treatment for Sewer and Culvert Outlets

Ontario Regulations:

R.R.O 1990, Regulation 903	Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40

DRAWINGS

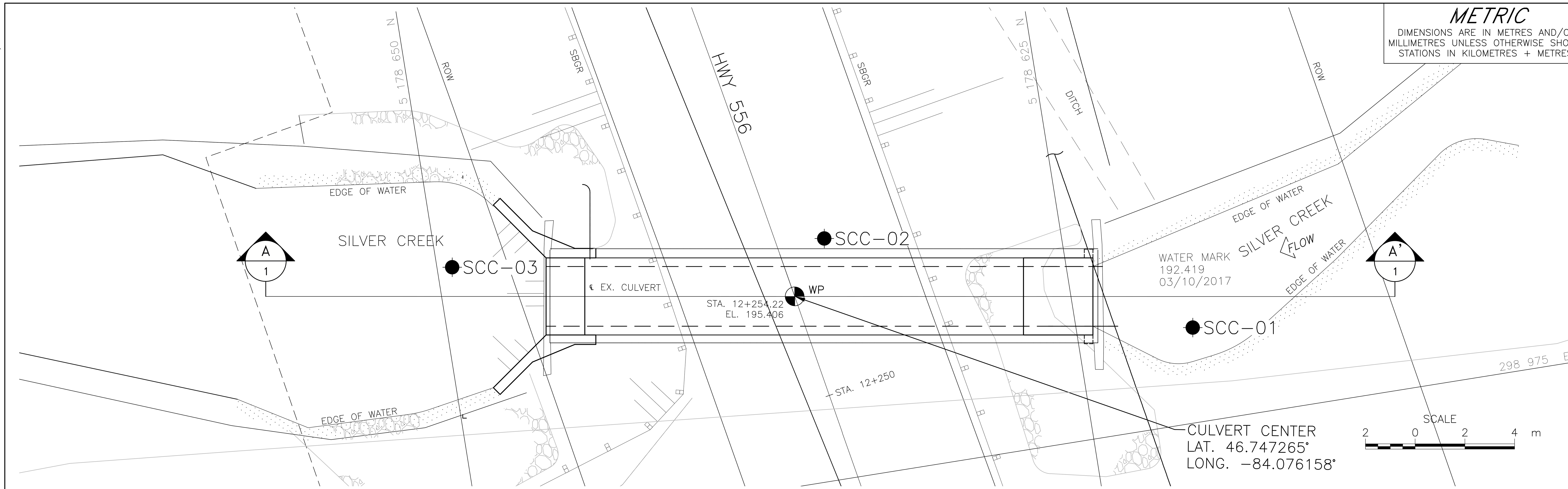
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5307-14-01

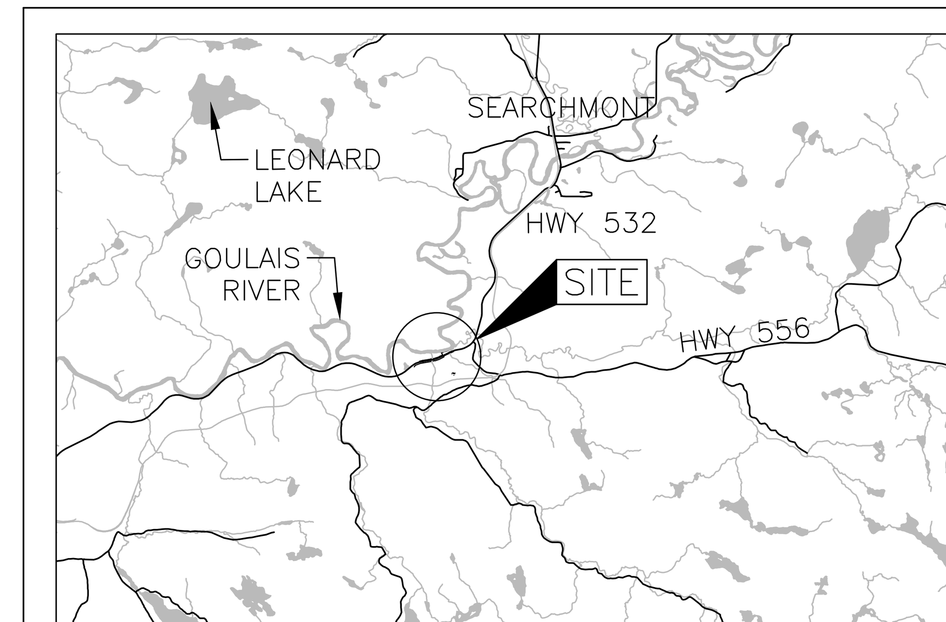
HIGHWAY 556
SILVER CREEK CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates



PLAN



KEY PLAN
SCALE
2 0 2 4 km

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 (MTM NAD83 ZONE 13)

No.	ELEVATION	NORTHING	EASTING
SCC-01	192.3	5178620.4	298978.8
SCC-02	195.5	5178634.4	298984.7
SCC-03	191.8	5178649.4	298985.9

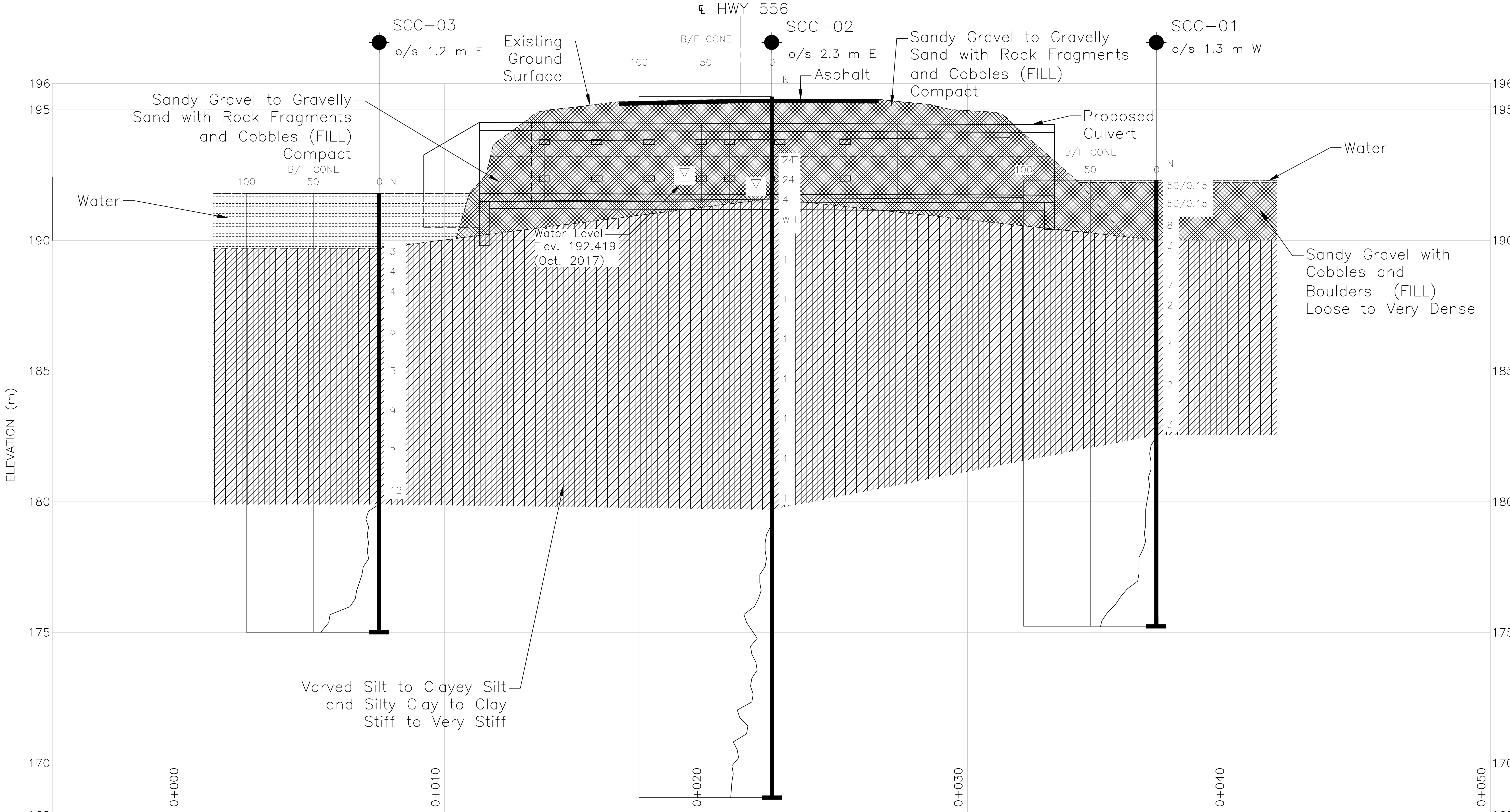
NOTES

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, drawing file no. 60546679-S100.dwg, received AUG 24, 2018.



A-A 1 CULVERT PROFILE

LICENSED PROFESSIONAL ENGINEER J.P. DITTRICH Jan. 11, 2019 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER T.ZALUCKI 100128614 Jan. 11, 2019 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

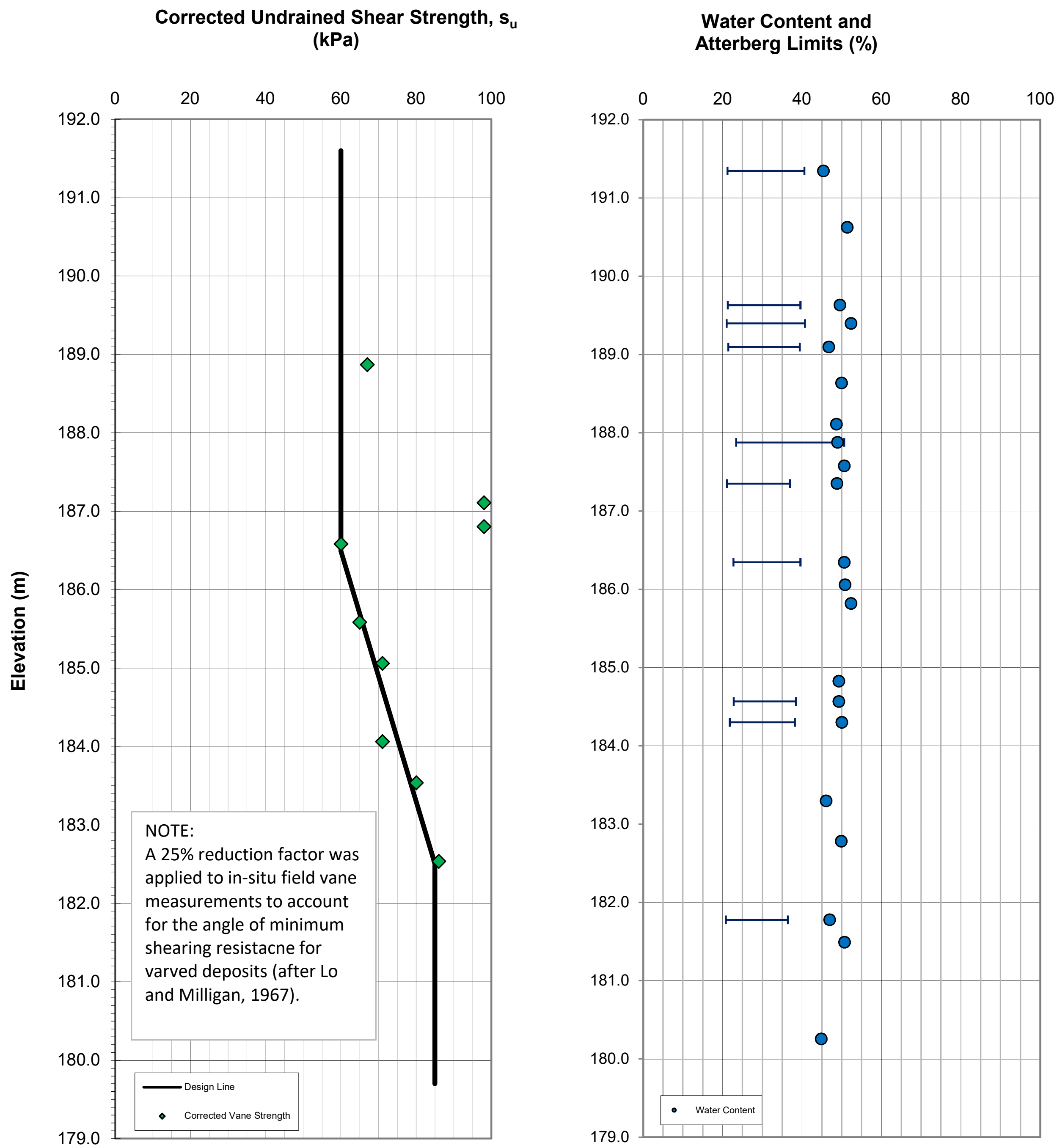
Geocres No. 41K-113

HWY. 556	PROJECT NO. 1670846		DIST. ALGOMA
SUBM'D. AK	CHKD. TZ	DATE: 1/11/2019	SITE: 38S-0039/C0
DRAWN: TR	CHKD. JPD	APPD. JPD	DWG. 1

FIGURES

CORRECTED UNDRAINED SHEAR STRENGTH AND WATER CONTENTS / ATTERBRG LIMITS OF THE VARVED COHESIVE DEPOSIT
Highway 556 - Silver Creek Culvert

FIGURE 1



Date: January 10, 2019
Project No: 1670856

Prepared By: TZ
Checked By: JPD

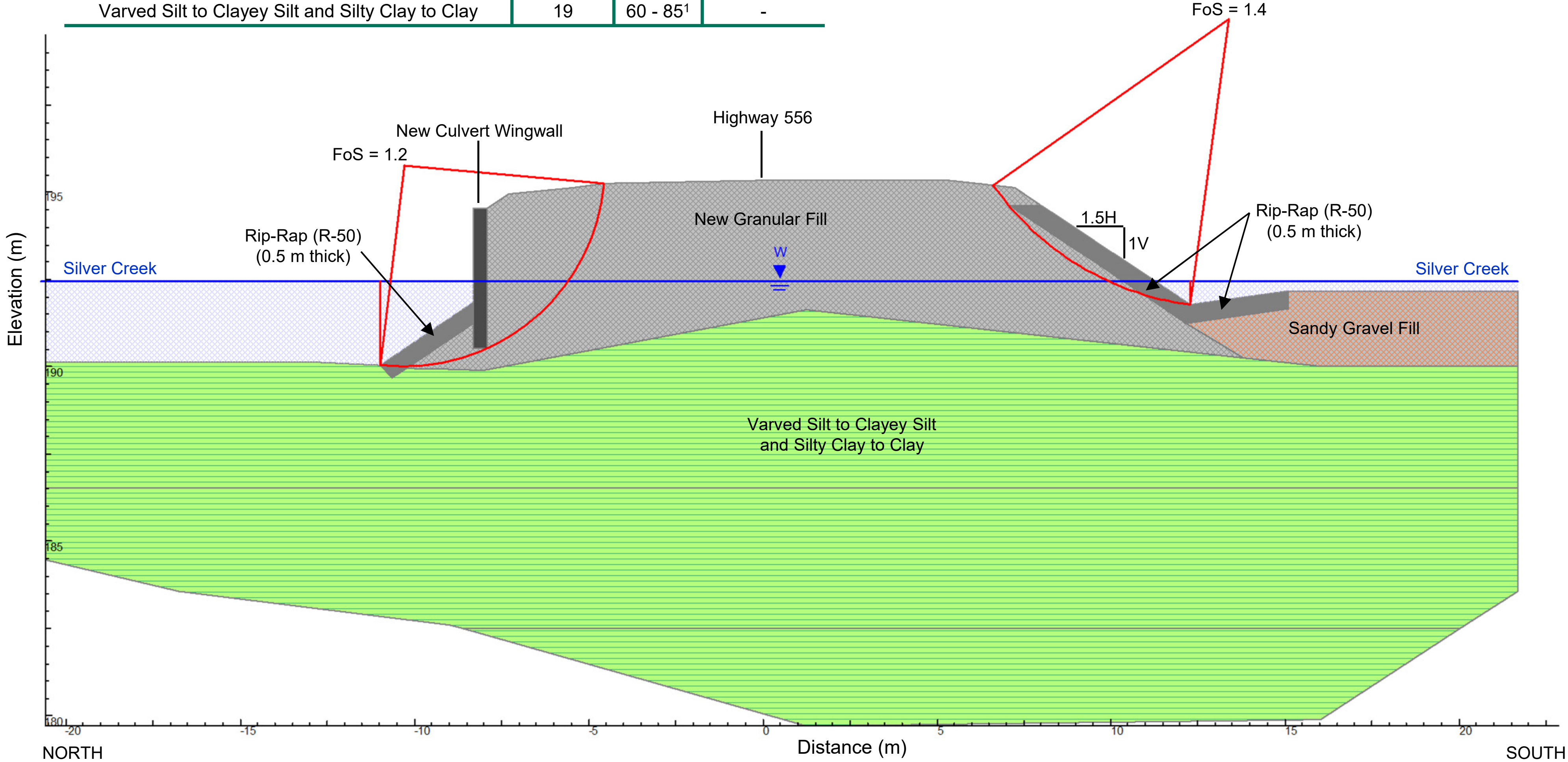
Golder Associates Ltd.

Highway 556 – Silver Creek Culvert Replacement
Global Slope Stability (Temporary/Short-Term Condition)
Highway Embankment at Station 12+260

Figure 2

Material Name	γ (kN/m³)	s_u (kPa)	ϕ' (degrees)
New Granular Fill	21	-	38
Sandy Gravel Fill	21	-	35
Rip-Rap (R-50)	21	-	50
Varved Silt to Clayey Silt and Silty Clay to Clay	19	60 - 85[1]	-

NOTES:
1. Refer to Figure 1 for a detailed plot of the undrained shear strength versus elevation for the varved silt to clayey silt and silty clay to clay deposit.
2. The R-50 rip-rap layers should satisfy the requirements of OPSS.PROV 1004 and the minimum thickness, where specified on the figure, should be measured perpendicular to the face of the slope.



Date: January 10, 2019
Project No: 1670846

Analysis By: AK/TZ **Reviewed By:** JPD

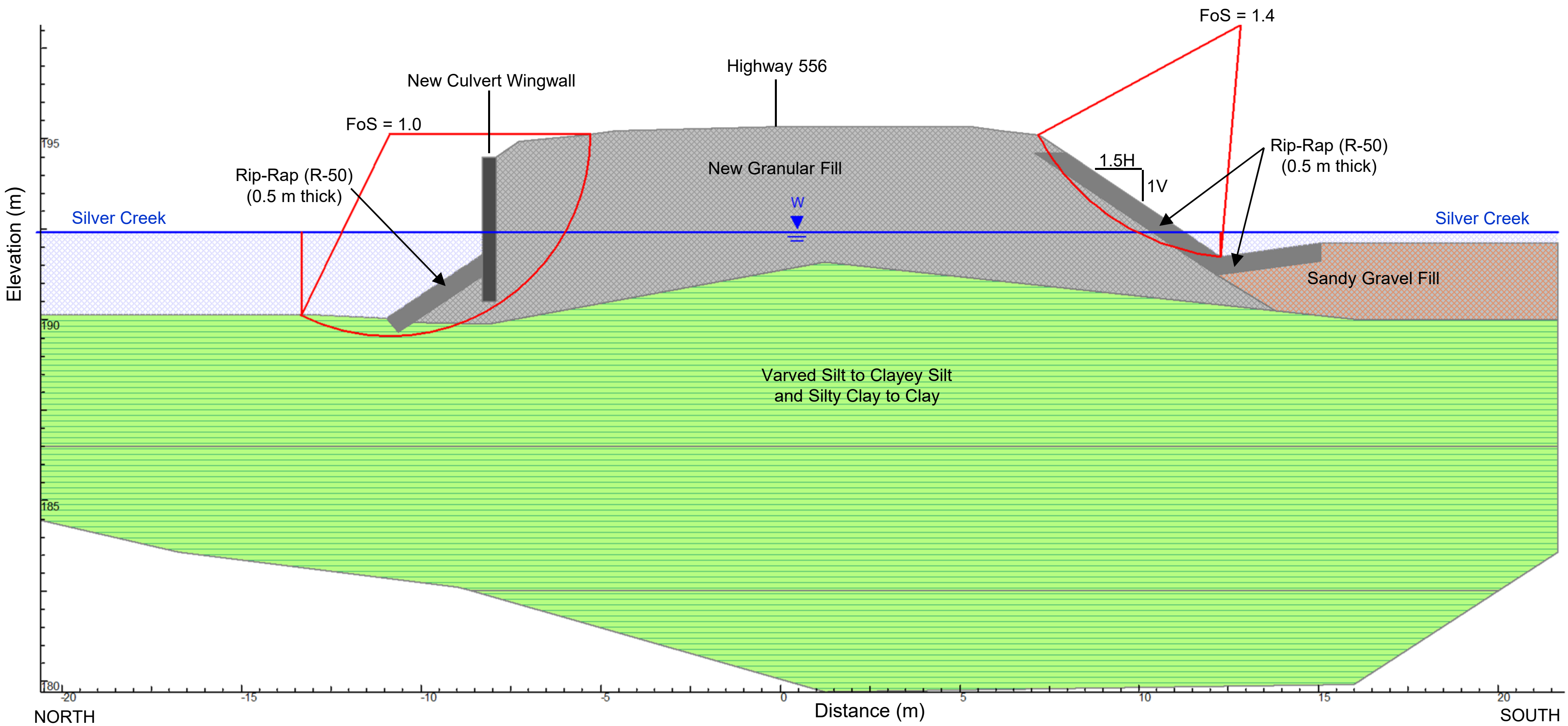
Golder Associates

Highway 556 – Silver Creek Culvert Replacement
Global Slope Stability (Permanent/Long-Term Condition)
Highway Embankment at Station 12+260

Figure 3

Material Name	γ (kN/m³)	s_u (kPa)	φ' (degrees)
New Granular Fill	21	-	38
Sandy Gravel Fill	21	-	35
Rip-Rap (R-50)	21	-	50
Varved Silt to Clayey Silt and Silty Clay to Clay	19	-	25

NOTE:
1. The R-50 rip-rap layers should satisfy the requirements of OPSS.PROV 1004 and the minimum thickness, where specified on the figure, should be measured perpendicular to the face of the slope.



Date: January 10, 2019
Project No: 1670846

Analysis By: AK/TZ **Reviewed By:** JPD

Golder Associates

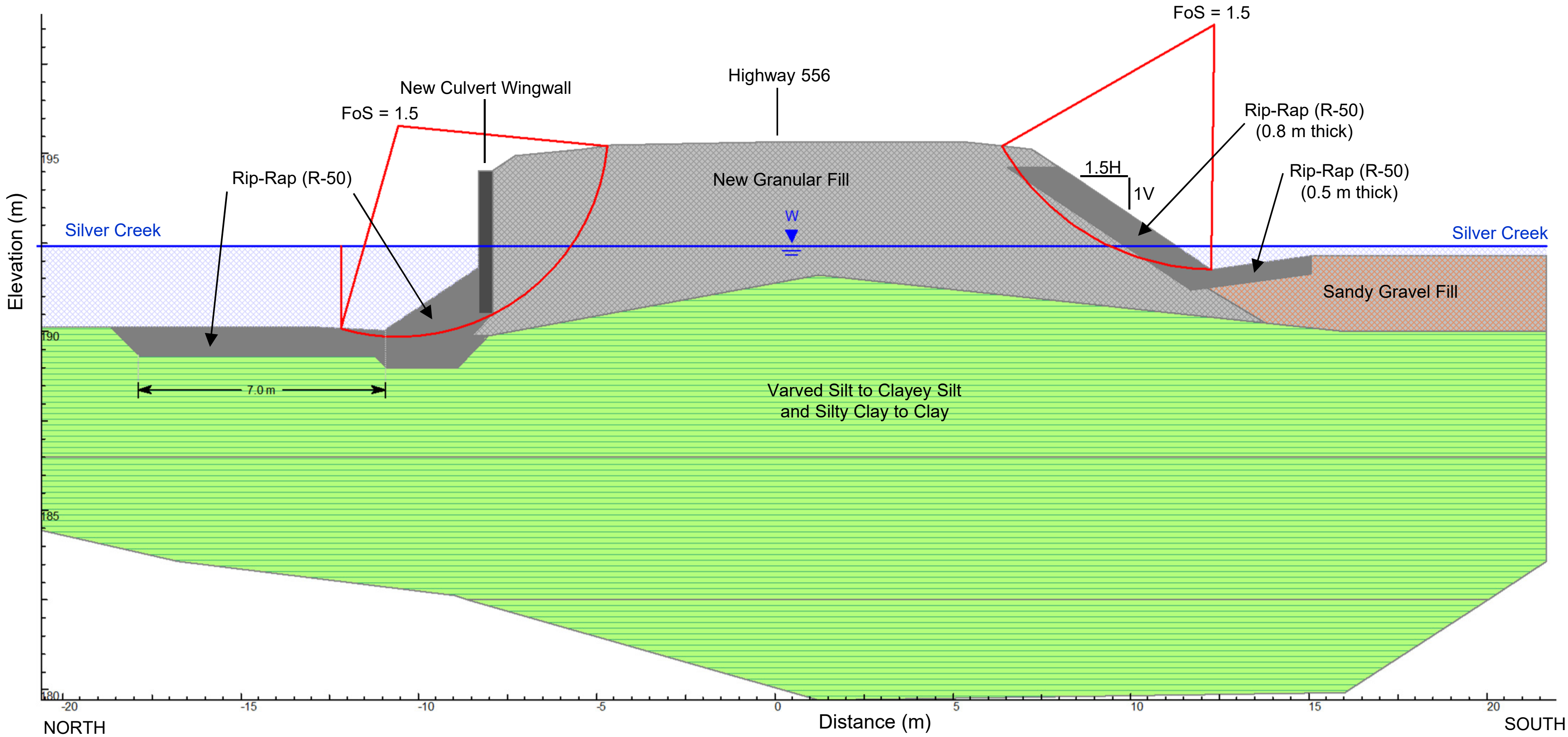
Highway 556 – Silver Creek Culvert Replacement
Global Slope Stability (Temporary/Short-Term Condition)
Highway Embankment at Station 12+260 (Additional Rip-Rap Protection)

Figure 4

Material Name	γ (kN/m³)	s_u (kPa)	ϕ' (degrees)
New Granular Fill	21	-	38
Sandy Gravel Fill	21	-	35
Rip-Rap (R-50)	21	-	50
Varved Silt to Clayey Silt and Silty Clay to Clay	19	60 - 85[1]	-

NOTES:

1. Refer to Figure 1 for a detailed plot of the undrained shear strength versus elevation for the varved silt to clayey silt and silty clay to clay deposit.
2. The R-50 rip-rap layers should satisfy the requirements of OPSS.PROV 1004 and the minimum thickness, where specified on the figure, should be measured perpendicular to the face of the slope.



Date: January 10, 2019

Project No: 1670846

Analysis By: AK/TZ **Reviewed By:** JPD

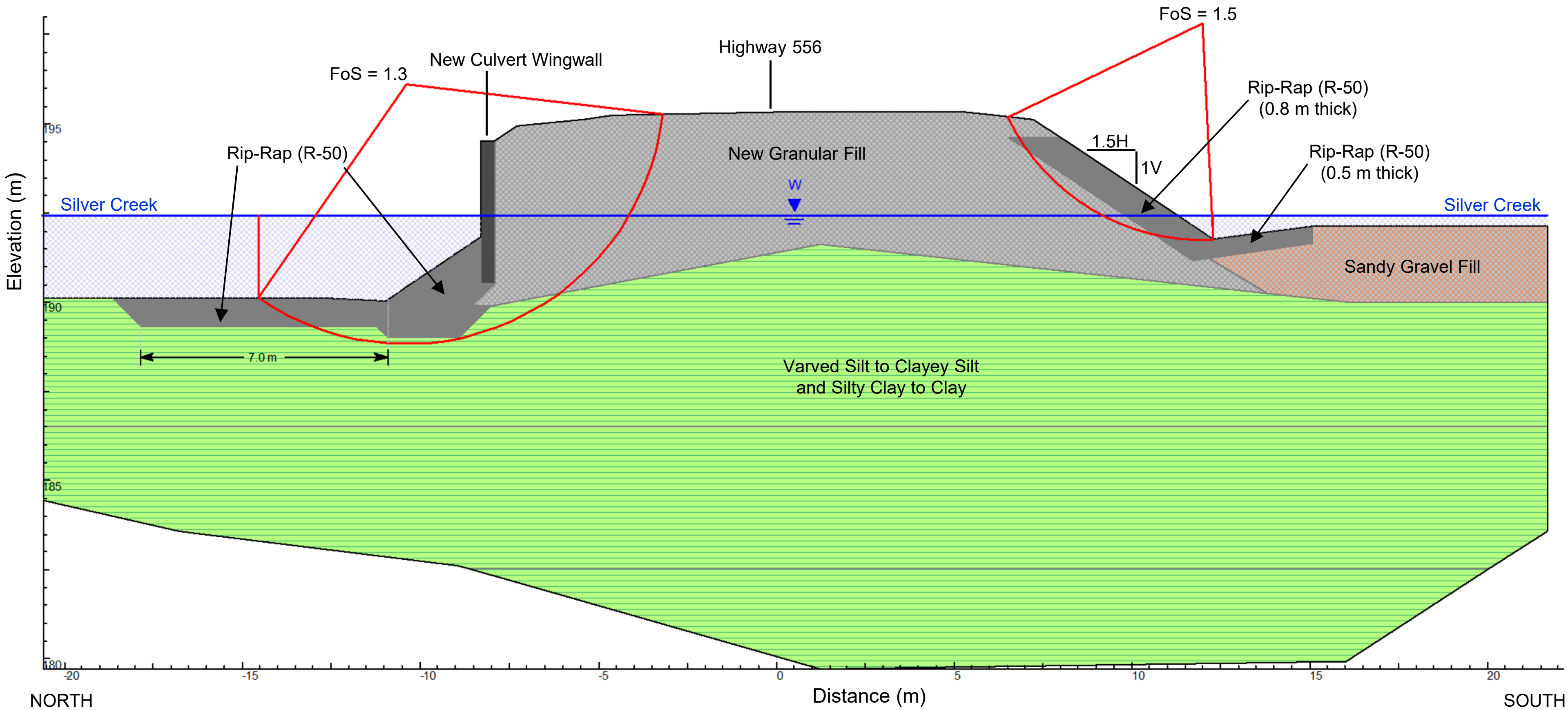
Golder Associates

Highway 556 – Silver Creek Culvert Replacement
Global Slope Stability (Permanent/Long-Term Condition)
Highway Embankment at Station 12+260 (Additional Rip-Rap Protection)

Figure 5

Material Name	γ (kN/m³)	s_u (kPa)	ϕ' (degrees)
New Granular Fill	21	-	38
Sandy Gravel Fill	21	-	35
Rip-Rap (R-50)	21	-	50
Varved Silt to Clayey Silt and Silty Clay to Clay	19	-	25

NOTE:
1. The R-50 rip-rap layers should satisfy the requirements of OPSS.PROV 1004 and the minimum thickness, where specified on the figure, should be measured perpendicular to the face of the slope.



Date: January 10, 2019
Project No: 1670846

Analysis By: AK/TZ **Reviewed By:** JPD

Golder Associates

APPENDIX A

Records of Borehole Sheets

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
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. $\tau = c' + \sigma' \tan \phi'$
2. shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d:

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

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

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils

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

IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

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

GOLDER

RECORD OF BOREHOLE No SCC-01

SHEET 1 OF 2 **METRIC**

PROJECT 1670846

G.W.P. 5307-14-01

LOCATION N 5178620.4; E 298978.8 MTM NAD 83 ZONE 13 (LAT. 46.747135; LONG. -84.076192)

ORIGINATED BY MB

DIST ALGOMA HWY 556

BOREHOLE TYPE Portable Equipment - Wash Boring; BW Casing

COMPILED BY AK

DATUM Geodetic

DATE August 16 to 18, 2018

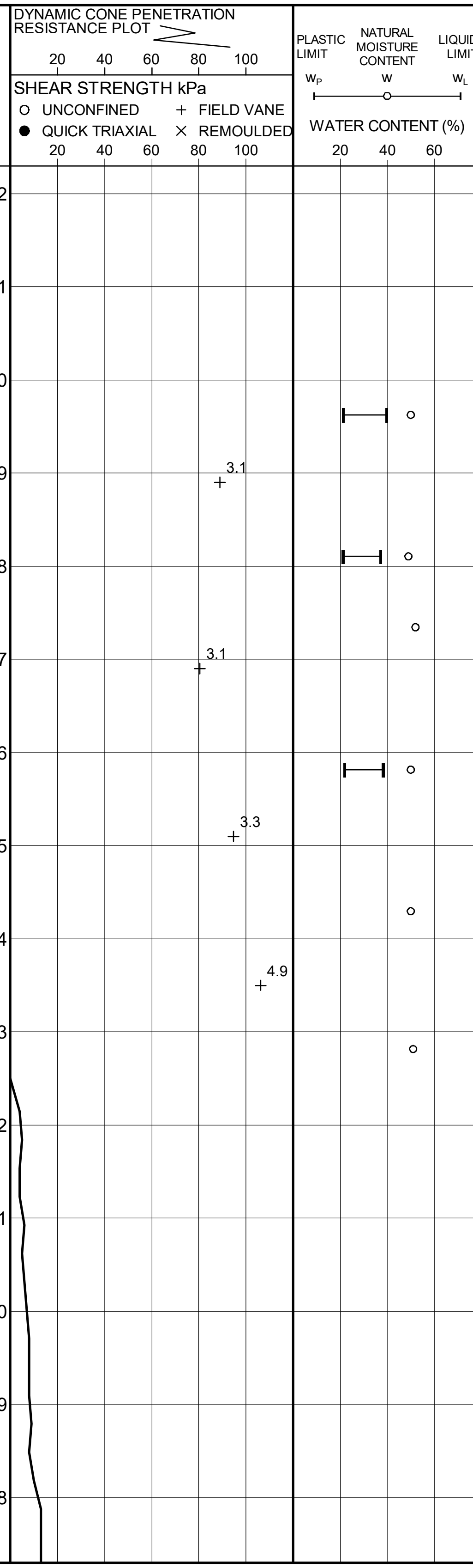
CHECKED BY TZ

ELEV DEPTH	DESCRIPTION	STRAT PLOT
192.3	WATER SURFACE	
0.0	WATER (80 mm)	
0.1	Sandy gravel with cobbles and boulders (FILL) Loose to very dense Grey and red Wet	
190.0 2.3	Varved SILT to CLAYEY SILT and SILTY CLAY, trace sand Stiff to very stiff Grey Wet	
182.6 9.8	END OF BOREHOLE Dynamic Cone Penetration Test (DCPT)	

SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	50/0.15				
2	SS	50/0.15				
3	SS	8				
4	SS	3	0	5	49	46
6	SS	7	0	4	57	39
7	SS	2				
8	SS	4				
9	SS	2				
10	SS	3				

GROUND WATER CONDITIONS

ELEVATION SCALE: 192, 191, 190, 189, 188, 187, 186, 185, 184, 183, 182, 181, 180, 179, 178



UNIT WEIGHT γ kN/m³

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No SCC-01

SHEET 2 OF 2 **METRIC**

PROJECT 1670846

G.W.P. 5307-14-01

DIST ALGOMA HWY 556

DATUM Geodetic

LOCATION N 5178620.4; E 298978.8 MTM NAD 83 ZONE 13 (LAT. 46.747135; LONG. -84.076192)

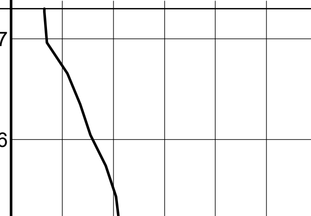
BOREHOLE TYPE Portable Equipment - Wash Boring; BW Casing

DATE August 16 to 18, 2018

ORIGINATED BY MB

COMPILED BY AK

CHECKED BY TZ

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100) / SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE Dynamic Cone Penetration Test (DCPT)						177 176				
175.2 17.1	END OF DCPT NOTE: 1. Borehole SCC-01 advanced in Silver Creek near the inlet (south side of Highway 556) of the existing culvert.										

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

GOLDER

RECORD OF BOREHOLE No SCC-02

SHEET 1 OF 2 **METRIC**

PROJECT 1670846
G.W.P. 5307-14-01
LOCATION N 5178634.4; E 298984.7 MTM NAD 83 ZONE 13 (LAT. 46.747261; LONG. -84.076115)
ORIGINATED BY LJS
DIST ALGOMA HWY 556
BOREHOLE TYPE 210 mm O.D. Continuous Flight Hollow Stem Augers
COMPILED BY AK
DATUM Geodetic
DATE August 15, 2018
CHECKED BY TZ

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
195.5	GROUND SURFACE					
0.0	ASPHALT (50 mm)					
0.1	Sandy gravel with rock fragments and cobbles (FILL) Compact Brown Moist to wet	1	SS	24		
192.5 3.0	Gravelly sand, trace silt (FILL) Compact Brown Wet	2	SS	24	∇ (approx. El. 192)	
191.6 3.9	Varved SILT to CLAYEY SILT and SILTY CLAY to CLAY, trace to some sand Stiff to very stiff Grey Wet	3A / 3B	SS	4		
		4	SS	WH		
		5	SS	1		0 7 53 40
		6	SS	1		
		7	SS	1		
		8	SS	1		0 11 51 38
		9	SS	1		
		10	SS	1		

Elevation scale: 195, 194, 193, 192, 191, 190, 189, 188, 187, 186, 185, 184, 183, 182, 181

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

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

GOLDER

RECORD OF BOREHOLE No SCC-02

SHEET 2 OF 2 **METRIC**

PROJECT 1670846

G.W.P. 5307-14-01

LOCATION N 5178634.4; E 298984.7 MTM NAD 83 ZONE 13 (LAT. 46.747261; LONG. -84.076115)

ORIGINATED BY LJS

DIST ALGOMA HWY 556

BOREHOLE TYPE 210 mm O.D. Continuous Flight Hollow Stem Augers

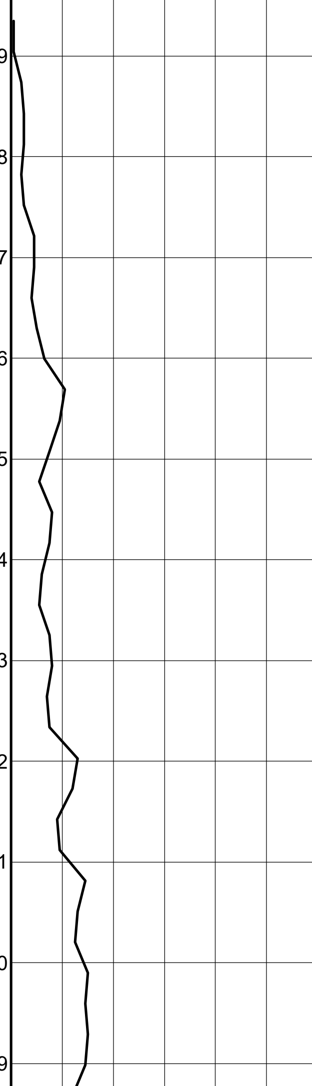
COMPILED BY AK

DATUM Geodetic

DATE August 15, 2018

CHECKED BY TZ

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
			11	SS	1		180				
179.7 / 15.8	END OF BOREHOLE Dynamic Cone Penetration Test (DCPT)						179, 178, 177, 176, 175, 174, 173, 172, 171, 170, 169				
168.7 / 26.8	END OF DCPT										



NOTES:

1. Borehole SCC-02 advanced on the eastbound lane of Highway 556, east of the existing culvert.

2. Water level measured at a depth of about 3.5 m below ground surface (Elev. 192.0 m) upon completion of drilling.

3. Consisting of varved clay estimated based on comparison of index testing and field vane testing in adjacent boreholes SCC-01 and SCC-03.

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

RECORD OF BOREHOLE No SCC-03

SHEET 1 OF 2 **METRIC**

PROJECT 1670846

G.W.P. 5307-14-01 LOCATION N 5178649.4; E 298985.9 MTM NAD 83 ZONE 13 (LAT. 46.747396; LONG. -84.076099) ORIGINATED BY MB

DIST ALGOMA HWY 556 BOREHOLE TYPE Portable Equipment - Eash Boring; BW Casing COMPILED BY AK

DATUM Geodetic DATE August 14 to 16, 2018 CHECKED BY TZ

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS
191.8	WATER SURFACE				
0.0	WATER				
189.7 / 2.1	Varved SILT to CLAYEY SILT and SILTY CLAY to CLAY, trace to some sand; Stiff to very stiff; Grey; Wet; - Organics encountered between depths of about 2.1 m and 2.8 m (between about Elev. 189.7 m and 189.0 m)	1	SS	3	OC=1.9%
		2	SS	4	
		3	SS	4	
		4	SS	5	GR 0, SA 5, SI 52, CL 43
		5	SS	3	
		6	SS	9	
		7	SS	2	GR 0, SA 7, SI 57, CL 36
		8	SS	12	
179.9 / 11.9	END OF BOREHOLE; Dynamic Cone Penetration Test (DCPT)				

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

Elevation scale: 191, 190, 189, 188, 187, 186, 185, 184, 183, 182, 181, 180, 179, 178, 177

Field vane sensitivity values plotted (approx. elevation): 2.1 and 2.2 (about 187), 4.0 (about 185.6), 1.6 (about 184.1), 1.0 (about 182.6)

Continued Next Page

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

GOLDER

Foundation Design

RECORD OF BOREHOLE No SCC-03

SHEET 2 OF 2 **METRIC**

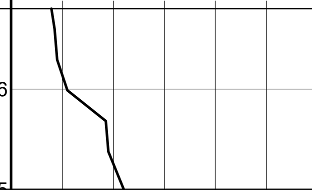
PROJECT 1670846

G.W.P. 5307-14-01 LOCATION N 5178649.4; E 298985.9 MTM NAD 83 ZONE 13 (LAT. 46.747396; LONG. -84.076099) ORIGINATED BY MB

DIST ALGOMA HWY 556 BOREHOLE TYPE Portable Equipment - Eash Boring; BW Casing COMPILED BY AK

DATUM Geodetic DATE August 14 to 16, 2018 CHECKED BY TZ

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE Dynamic Cone Penetration Test (DCPT)						176				
175.0 16.8	END OF DCPT NOTE: 1. Borehole SCC-03 advanced in Silver Creek near the outlet (north side of Highway 556) of the existing culvert.						175				



Legend: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L.

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

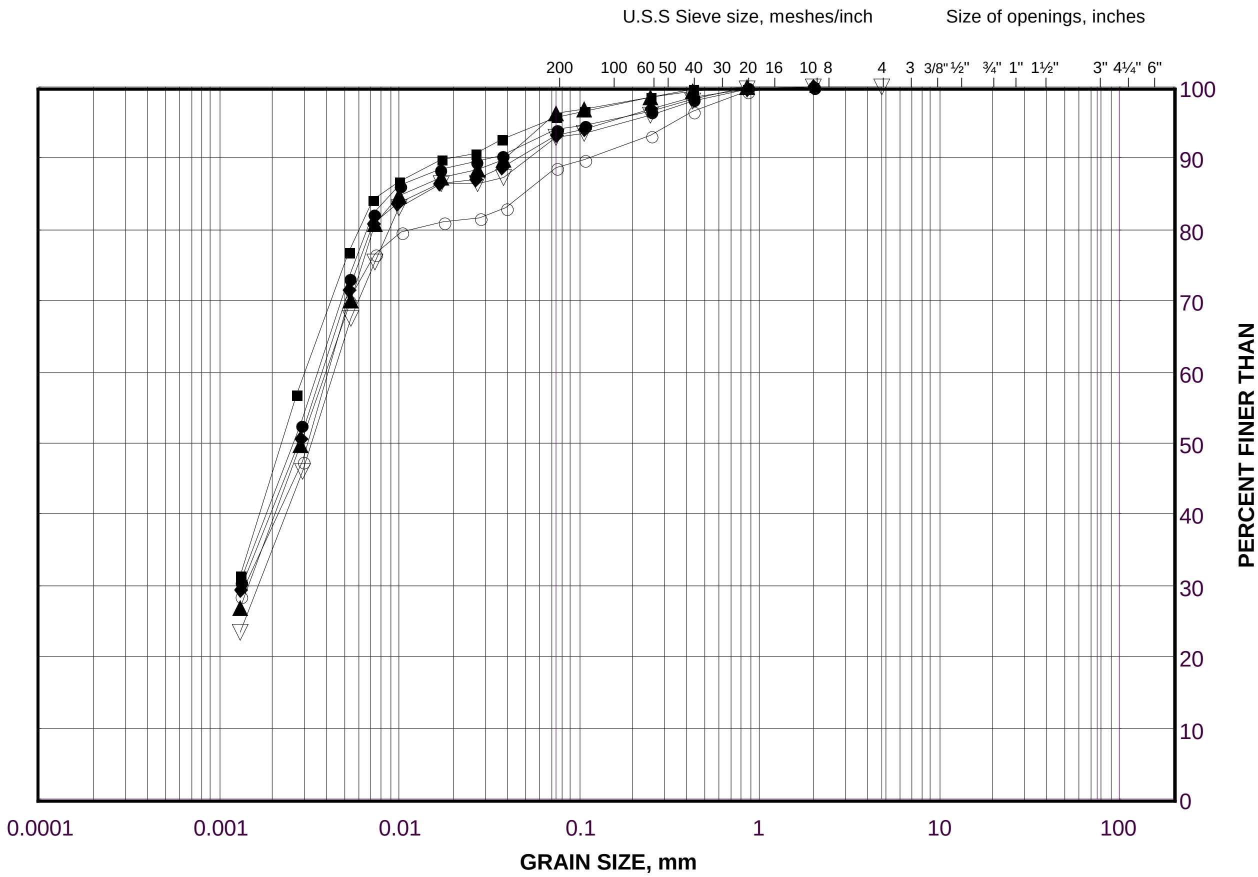
APPENDIX B

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Varved Silt to Clayey Silt and Silty Clay to Clay

FIGURE B1



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

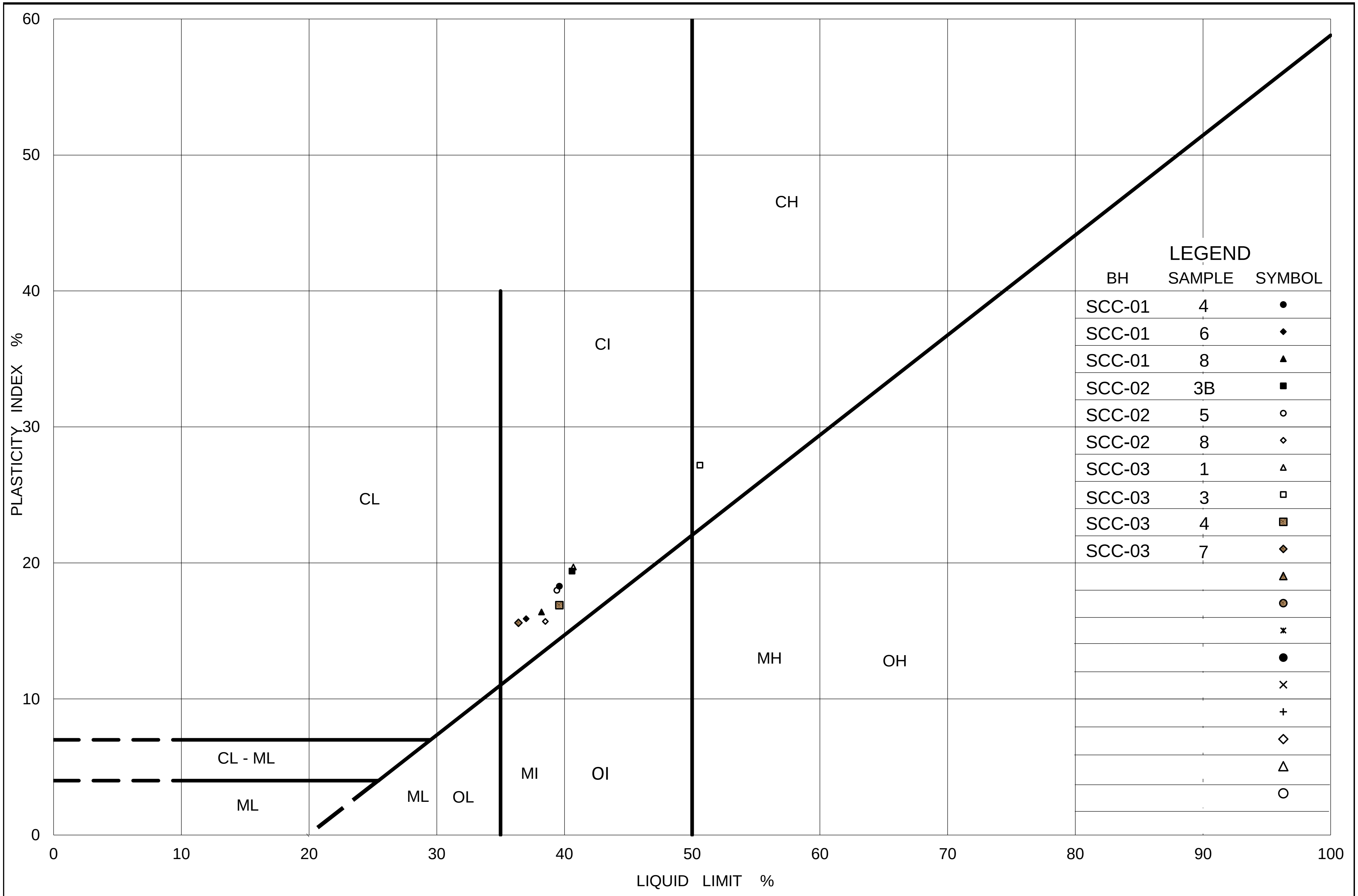
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	SCC-03	4	186.3
■	SCC-01	4	189.6
◆	SCC-02	5	189.1
▲	SCC-01	6	188.1
▽	SCC-03	7	181.8
❍	SCC-02	8	184.5

Project Number:1670846

Checked By: TZ

Golder Associates

Date: 09-Oct-18



Ministry of Transportation

Ontario

PLASTICITY CHART
Varved Silty Clay to Clay

Figure No. B2

Project No. 1670846

Checked By: TZ

APPENDIX C

Analytical Laboratory Test Results

Maxxam
A Bureau Veritas Group Company

Your Project #: 1670846
Your C.O.C. #: 384711-01-01

Attention: Tom Zalucki

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2018/09/11
Report #: R5394328
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B8M3564
Received: 2018/08/29, 12:17

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	1	N/A	2018/09/04	CAM SOP-00463	EPA 325.2 m
Conductivity	1	N/A	2018/09/04	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	1	2018/09/04	2018/09/04	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	1	2018/08/30	2018/09/04	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	1	N/A	2018/09/04	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam 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 Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam 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.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam 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 Maxxam, unless otherwise agreed in writing. Maxxam 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 Maxxam, results relate to the supplied samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

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

Your Project #: 1670846
Your C.O.C. #: 384711-01-01

Attention: Tom Zalucki

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2018/09/11
Report #: R5394328
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B8M3564
Received: 2018/08/29, 12:17

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Ema Gitej, Senior Project Manager
Email: EGitej@maxxam.ca
Phone# (905)817-5829
==
Maxxam 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.

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

SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		HPJ678			HPJ678		
Sampling Date		2018/08/15 14:00			2018/08/15 14:00		
COC Number		384711-01-01			384711-01-01		
	UNITS	**SCC-02 SA4**	**RDL**	**QC Batch**	**SCC-02 SA4 Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters							
Resistivity	ohm-cm	5800		5707341			
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	5712194			
Conductivity	umho/cm	171	2	5712636	174	2	5712636
Available (CaCl2) pH	pH	8.56		5712501			
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	5712195	<20	20	5712195

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

Maxxam Job #: B8M3564
Report Date: 2018/09/11

Golder Associates Ltd
Client Project #: 1670846
Sampler Initials: ML

TEST SUMMARY

Maxxam ID: HPJ678
Sample ID: SCC-02 SA4
Matrix: Soil

Collected: 2018/08/15
Shipped:
Received: 2018/08/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5712194	N/A	2018/09/04	Deonarine Ramnarine
Conductivity	AT	5712636	N/A	2018/09/04	Tahir Anwar
pH CaCl2 EXTRACT	AT	5712501	2018/09/04	2018/09/04	Gnana Thomas
Resistivity of Soil		5707341	2018/09/04	2018/09/04	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5712195	N/A	2018/09/04	Alina Dobreanu

Maxxam ID: HPJ678 Dup
Sample ID: SCC-02 SA4
Matrix: Soil

Collected: 2018/08/15
Shipped:
Received: 2018/08/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5712636	N/A	2018/09/04	Tahir Anwar
Sulphate (20:1 Extract)	KONE/EC	5712195	N/A	2018/09/04	Alina Dobreanu

GENERAL COMMENTS

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

Package 1	1.7°C

Results relate only to the items tested.

Maxxam Job #: B8M3564
Report Date: 2018/09/11

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1670846
Sampler Initials: ML

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**UNITS**	**Value (%)**	**QC Limits**
5712194	Soluble (20:1) Chloride (Cl-)	2018/09/04	NC	70 - 130	102	70 - 130	<20	ug/g	0.52	35
5712195	Soluble (20:1) Sulphate (SO4)	2018/09/04	99	70 - 130	96	70 - 130	<20	ug/g	NC	35
5712501	Available (CaCl2) pH	2018/09/04			101	97 - 103			0.13	N/A
5712636	Conductivity	2018/09/04			103	90 - 110	<2	umho/cm	1.9	10

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).

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

VALIDATION SIGNATURE PAGE

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

Ewa Pranjic, M.Sc., C.Chem, Scientific Specialist

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Maxxam

Maxxam Analytics International Corporation o/a Maxxam Analytics
6740 Campobello Road, Mississauga, Ontario Canada L5N 2L8 Tel:(905) 817-5700 Toll-free:800-563-6266 Fax:(905) 817-5779 www.maxxam.ca

CHAIN OF CUS

29-Aug-18 12:17
Ema Gitej
B8M3564
PS4 env-1305

Page of

Use Only:

INVOICE INFORMATION:

Company Name:	#1326 Golder Associates Ltd
Contact Name:	Central Accounting: 1111
Address:	6925 Century Avenue Suite # 100 Mississauga ON L5N 7K2
Phone:	(905)567-4444 Fax: (905)567-6561
Email:	~~Jennifer_lee@golder.com~~, maxxam@golder.com; st → AP_CustomerService@golder.com

REPORT INFORMATION (if differs from invoice):

Company Name:	
Contact Name:	Tom Zalucki
Address:	
Phone:	905 567 4444 Fax:
Email:	tzalucki@golder.com

PROJECT INFORMATION:

Quotation #:	~~B70916~~
P.O. #:	
Project #:	1670846
Project Name:	
Site #:	
Sampled By:	

BOTTLE ORDER #: 384711

C#384711-01-01

PROJECT MANAGER: Mathura Thirukkumaran

Regulation 153 (2011): Table 1, Table 2, Table 3, Table ___; Res/Park, Ind/Comm, Agri/Other; Medium/Fine, Coarse; For RSC

Other Regulations: CCME, Reg. 558, MISA, PWQO, Other ___; Sanitary Sewer Bylaw, Storm Sewer Bylaw, Municipality ___

SPECIAL INSTRUCTIONS

Include Criteria on Certificate of Analysis (Y/N)? ___

Note: For MOE regulated drinking water samples - please use the Drinking Water Chain of Custody Form

SAMPLES MUST BE KEPT COOL (< 10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

TURNAROUND TIME (TAT) REQUIRED:

PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS

Regular (Standard) TAT:
(will be applied if Rush TAT is not specified):
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)
Date Required: ___ Time Required: ___
Rush Confirmation Number: ___ (call lab for #)

ANALYSIS REQUESTED (Please be specific):

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Regulated Drinking Water ? (Y/N)	Metals Field Filtered ? (Y/N)	Chloride & SO_4 (20:1 extract)	Conductivity/Resistivity	pH $CaCl_2$ EXTRACT	Sulphide (Maxxam 8)							# of Bottles	Comments
1		SCC-02 SA 4	Aug 15, 2018	2pm	Soil			X	X	X	X							2	
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			

*RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time:	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time:	# Jars Used and Not Submitted
Martin Legroulx	18/08/29	10 am	GURVINDER SINGH	2018/08/29	12:17	

Laboratory Use Only

Time Sensitive	Temperature (°C) on Receipt	Custody Seal	Yes	No
	2/1/2	Present	✓	
		Intact	✓	

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

White: Maxxam Yellow: Client

Maxxam Analytics International Corporation o/a Maxxam Analytics

Maxxam
A Bureau Veritas Group Company

Success Through Science®

Your Project #: Campobello job# B8M3564

Attention: EMA GITEJ

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2018/09/10
Report #: R2616906
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B874287
Received: 2018/08/31, 12:13

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Sulphide in Soil	1	2018/09/04	2018/09/10	BBY6SOP-00052,	EPA-821-R-91-100 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam 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 Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam 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.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam 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 Maxxam, unless otherwise agreed in writing. Maxxam 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 Maxxam, results relate to the supplied samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Your Project #: Campobello job# B8M3564

Attention: EMA GITEJ
MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2018/09/10
Report #: R2616906
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B874287
Received: 2018/08/31, 12:13

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Namita Sahni, Burnaby Project Manager
Email: NSahni@maxxam.ca
Phone# (604)639-2614
==
This report has been generated and distributed using a secure automated process.
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Maxxam Job #: B874287
Report Date: 2018/09/10

MAXXAM ANALYTICS
Client Project #: Campobello job# B8M3564
Sampler Initials: ML

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		UF1080		UF1080		
Sampling Date		2018/08/15 14:00		2018/08/15 14:00		
	UNITS	**SCC-02 SA4**	**RDL**	**SCC-02 SA4 Lab-Dup**	**RDL**	**QC Batch**
MISCELLANEOUS						
Sulphide	ug/g	<0.70 (1)	0.70	<0.55	0.55	9128307

RDL = Reportable Detection Limit

Lab-Dup = Laboratory Initiated Duplicate

(1) Matrix spike exceeds acceptance limits due to matrix interference. Re-analysis yields similar results.

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam Job #: B874287
Report Date: 2018/09/10

MAXXAM ANALYTICS
Client Project #: Campobello job# B8M3564
Sampler Initials: ML

TEST SUMMARY

Maxxam ID: UF1080
Sample ID: SCC-02 SA4
Matrix: Soil

Collected: 2018/08/15
Shipped:
Received: 2018/08/31

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphide in Soil	SPEC	9128307	2018/09/04	2018/09/10	Faisal Khater

Maxxam ID: UF1080 Dup
Sample ID: SCC-02 SA4
Matrix: Soil

Collected: 2018/08/15
Shipped:
Received: 2018/08/31

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphide in Soil	SPEC	9128307	2018/09/04	2018/09/10	Faisal Khater

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

GENERAL COMMENTS

Sample UF1080 [SCC-02 SA4] : Sample analyzed past method specified hold time for Moisture. Sample received past method specified hold time for Moisture. 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 received past method specified hold time for Sulphide in Soil. Sample received past method specified hold time for Sulphide in Soil.

Results relate only to the items tested.

Maxxam Job #: B874287
Report Date: 2018/09/10

QUALITY ASSURANCE REPORT

MAXXAM ANALYTICS
Client Project #: Campobello job# B8M3564
Sampler Initials: ML

			Matrix Spike		Spiked Blank		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
9128307	Sulphide	2018/09/10	56 (1,2)	75 - 125	96	75 - 125	<0.50	ug/g	NC (3)	30

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 (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.

(2) Matrix Spike Parent ID [UF1080-01]

(3) Duplicate Parent ID [UF1080-01]

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam Job #: B874287
Report Date: 2018/09/10

MAXXAM ANALYTICS
Client Project #: Campobello job# B8M3564
Sampler Initials: ML

VALIDATION SIGNATURE PAGE

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

Andy Lu, Ph.D., P.Chem., Scientific Specialist

Maxxam 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.

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APPENDIX D

Special Provisions and Non-Standard Special Provisions

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Special Provision No. FOUN0003 March 8, 2018

Amendment to OPSS 902, November 2010

OPSS 902, November 2010, Construction Specification for Excavating and Backfilling - Structures is amended as follows:

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517 Dewatering
OPSS 805 Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517.

Dewatering System means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517.

Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517.

Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a two-year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of 100 metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website https://www.ontario.ca/environment-and-energy/map-well-records or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

Clause 902.04.02.03 of OPSS 902 is deleted in its entirety.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

NOTES TO DESIGNER:

<u>Designer Fill-Ins</u>

* Fill in the design storm return period according to MTO Drainage Design Standard TW-1.

** Fill in the preconstruction survey distance as recommended by the foundation engineer.

WARRANT: Include with this standard tender item **<u>only</u>** on the recommendation of a foundation engineer.

CUSTODIAN: Tony Sangiuliano, MERO - Foundation Group.

NOTICE TO CONTRACTOR – Obstructions During Installation of Temporary Cofferdam Systems

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Special Provision

The Contactor is advised of the presence of cobbles within the existing embankment fill and cobbles/boulders encountered within the existing fill and on/within the creek bed within the vicinity of the inlet and outlet of the existing culvert, located at approximately Station 12+254 (Hodgins Township).

Consideration of the presence of the cobbles and boulders must be made in the selection of appropriate equipment/tools for excavation and/or installation of temporary cofferdams and roadway protection systems.

WORKING SLAB – Item No.

Non-Standard Special Provision

The subgrade soils within the footprint of the proposed culvert may be susceptible to disturbance and loosening/softening from construction traffic and ponded water.

If the precast concrete box culvert is not placed on the prepared subgrade within four hours of its inspection and approval, a concrete working slab of 20 MPa compressive strength at 28-days with minimum thickness of 100 mm, shall be placed on the foundation subgrade. A minimum 75 mm thick uncompacted levelling pad consisting of Granular ‘A’ material (OPSS.PROV 1010) or concrete fine aggregate (meeting the grading requirements specified in OPSS.PROV 1002) shall be provided on top of the concrete working slab to support the precast concrete box culvert.

EARTH EXCAVATION AND GRANULAR PAD CONSTRUCTION– Item No.

Non-Standard Special Provision

Where a concrete working slab is not adopted to protect the culvert subgrade from disturbance, the Contractor shall construct a minimum 0.6 m thick granular pad on top of the subgrade and below the 75 mm thick uncompacted levelling layer placed immediately below the base of the precast concrete box culvert.

The excavation for and construction of the granular pad first lift (up to 0.5 m thick) and potentially below water shall be carried out simultaneously as specified herein.

The subexcavation within the culvert footprint shall be carried out in strips, with widths of no more than 5 m perpendicular to the culvert alignment, over the length of the culvert footprint. Each strip excavation shall be backfilled as outlined below before excavation of the subsequent adjacent strip commences. For the first segment of excavation, once the removal of the overburden material has been completed, the construction of the granular pad (potentially in wet conditions) shall commence immediately in general accordance with the following procedure:

- The lower portion of the granular pad (i.e., excluding the upper 0.3 m of the granular pad which will be comprised of the compacted culvert bedding), together with backfill of any subexcavation, shall be constructed of Granular 'B' Type II material meeting the specification outlined in OPSS.PROV 1010 (Aggregates).
- For backfill of any subexcavation below the water level, construction of the granular pad shall be carried out in lifts of not more than 0.5 m in thickness. The surface of each such lift shall be compacted/tamped by the bucket of a backhoe/excavator of at least 35,000 kg operating weight with a minimum of two passes to cover the entire surface of the lift.
- The upper 0.3 m of the granular pad placed above water (i.e., the culvert bedding placed in dry conditions) shall be constructed in accordance with the requirements of OPSS 902 and compacted to at least 95% of the Standard Proctor maximum dry density of the material in accordance with OPSS.PROV 501.
- In addition, a minimum 75 mm thick uncompacted levelling layer consisting of OPSS.PROV 1010 Granular 'A' material or concrete fine aggregate meeting the graduation requirements specified in OPSS.PROV 1002 should be placed above the culvert bedding and immediately below the base of the culvert as shown on OPSD 803.010.

The Contractor shall be responsible for maintaining the stability of the excavation and the integrity of the granular pad constructed in wet conditions as the work is carried out.

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