April 19, 2017

FOUNDATION INVESTIGATION AND DESIGN REPORT

Blake Creek Culvert Replacement
Site No. 46-490
Highway 17, STA 11+970, Lorne Township, Sudbury, Ontario
GWP 5173-12-00

Submitted to:
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GEOCRES No.: 41I-349

REPORT

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Golder Associates

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FOUNDATION INVESTIGATION REPORT
BLAKE CREEK CULVERT REPLACEMENT –
SITE NO. 46-490
HIGHWAY 17, STA 11+970, LORNE TOWNSHIP,
SUDBURY, ONTARIO GWP 5173-12-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Limited (MMM) on behalf of Ministry of Transportation, Ontario (MTO) to provide Foundation Engineering services for the replacement of the Blake Creek Culvert (Site No. 46-490), located at about STA 11+970 on Highway 17 in Lorne Township, District Sudbury, approximately 19 km east of Espanola, Ontario.

The purpose of this investigation is to establish the subsurface conditions at the replacement culvert location, by borehole drilling and in situ and laboratory testing on selected soil samples. The investigation area is shown on the Key Plan on Drawing 1.

2.0 SITE DESCRIPTION

The existing culvert is a 6.1 m wide by 1.8 m high open footing rigid frame structure under approximately 2 m of embankment fill cover. The embankment fill is about 5 m high above the surrounding topography, which is primarily low-lying. Visual inspection of the culvert, by others, suggests that the culvert has experienced settlement of about 0.8 m at the midspan which is consistent with consolidation settlement over time. However, there are no reported culvert settlement problems or recent pavement re-grading works. The highway in this area exhibits a sag in the vertical profile that is understood to be approximately equal to the amount of settlement observed within the culvert, which has not been corrected in past pavement rehabilitation events.

In general, the topography in the area of the culvert consists of rolling terrain with sparsely populated treed areas, lakes, and areas of standing water/swamps. Blake Creek flows in a south-north direction at the location of the culvert, traversing under the highway. The ground surface varies between Elevation 212 m at the highway road grade to about Elevations 209 m to 208 m at the north and south toe of the embankment at the borehole locations, respectively.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the foundation investigation at Blake Creek culvert was carried out between August 18 and 24, 2016, during which time a total of 3 boreholes (designated as BH16-1 to BH16-3) were advanced in proximity to the culvert alignment. In addition, Dynamic Cone Penetration Tests (DCPTs) were advanced from the bottom of Boreholes 16-2 and 16-3.

The boreholes were advanced using a CME 75 truck-mounted drill rig, supplied and operated by Landcore Drilling of Sudbury, Ontario. The boreholes were advanced through the overburden using either nominal 152 mm diameter solid stem augers, 165 mm outside diameter hollow stem augers or NW casing with wash boring in the case of Borehole 16-1. In general, soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). Samples of the cohesive soils were obtained using 76 mm O.D. thin walled Shelby Tubes (ASTM D1587) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using MTO Standard ‘N’ size vanes.

The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled with cementitious bentonite grout upon completion in accordance with Ontario Regulation 903 Wells (as amended). .

The fieldwork for this foundation investigation was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground utilities present in the area, observed drilling, sampling, and in-situ testing operations, logged the boreholes, and examined the soil samples. The soil samples were identified in the field, placed in appropriate containers, labelled, and transported with care to Golder's Sudbury geotechnical laboratory where the samples underwent further visual examination and laboratory testing. Classification testing (water content, Atterberg limits and grain size distribution) and consolidation testing was carried out on selected soil samples. All of the laboratory tests were carried out to MTO Laboratory Standards and/or ASTM Standards, as appropriate. The results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A and presented in the laboratory test figures provided in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed in the field by Golder technical staff, referenced to the highway centerline and existing culvert and were subsequently converted into MTM NAD 83 (Zone 12) coordinates for the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile drawing provided by MMM. The borehole locations in the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are summarized below.

Borehole	Location (m)		Ground Surface Elevation (m)	Depth of Borehole / DCPT (m)
	Northing	Easting		
16-1	5,131,900.2	263,096.6	209.1	23.0
16-2	5,131,874.8	263,099.1	212.0	13.4 / 22.6
16-3	5,131,861.7	263,077.6	208.4	10.7 / 26.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This area of Highway 17 is located in the Penokean Hills physiographic region, within the Canadian Shield, as described in *The Geomorphic Systems of North America* by Graf (1987)[1]. The Penokean Hills are typically characterized by low-grade metamorphic rocks, with the ranges of hills resulting from differential erosion of faulted or gently folded strata. This region is underlain by bedrock comprised of mainly undifferentiated igneous and metamorphic rock, exposed at surface or covered by a discontinuous, thin layer of drift (MNDM, 2016)[2]. Based on geological mapping by the Ministry of Natural Resources (Map 2542)[3], the site is underlain by rocks of the Paleoproterozoic Era belonging to the Huronian Supergroup and Elliot Lake Group consisting of conglomerate, wacke, arkose, quartz arenite, argillite, limestone and dolostone. Areas of mafic and related intrusive rocks comprised of diabase sills, dykes and related granophyre are also present in the vicinity of the site. There are localized areas of glaciolacustrine deposits of silt and clay, with minor sand layers.

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[1] Graf, W. L. 1987. *Geomorphic systems of North America*. Geological Society of America, Inc.: Boulder, Colorado.

[2] The Ministry of Natural Development and Mines, Ontario, 2016. OGSEarth: Quaternary Geology [Electronic Map] 1:1,000,000.

[3] Ministry of Natural Resources. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey - Map 2542

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The results of the in situ field tests (i.e., SPT ‘N’ values and undrained shear strengths from field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The detailed results of geotechnical laboratory testing are contained in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoil conditions encountered at the site consist of asphalt and sand and gravel embankment fill or surficial sandy silt to silt and sand deposits at the embankment toes underlain by an extensive deposit of soft to stiff silty clay to clay. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

4.2.1 Topsoil/Asphalt

A 0.1 m and 0.4 m thick layer of topsoil was encountered in Boreholes 16-1 and 16-3, respectively. A 0.1 m thick layer of asphalt was encountered in Borehole 16-2 constituting the roadway pavement.

4.2.2 Fill

A deposit of non-cohesive fill comprised of sand, trace silt to gravelly sand to sand and gravel, trace to some silt was encountered below the topsoil or asphalt layers in all boreholes. The fill in Borehole 16-1 contains trace organics. The top of this fill layer varied between Elevation 211.9 m and 208 m, and the thickness of the deposit ranges from 0.5 m to 3.9 m being thickest beneath the road surface.

The SPT ‘N’-values measured with the fill deposit range from 5 to 42 blows per 0.3 m of penetration, indicating a very loose to dense relative density.

The natural water content measured on three samples of the fill deposit ranges from about 2 per cent to 6 per cent with one value of 27 percent, likely associated with the organics within the overlying topsoil in Borehole 16-3. The result of a grain size distribution test completed on one sample of the sand and gravel fill is shown on Figure B1 in Appendix B.

4.2.3 Sandy Silt to Silt and Sand

A deposit of sandy silt to silt and sand, trace organics, was encountered below the fill in Boreholes 16-1 and 16-3, located at the toes of the embankment. The surface of the deposit is at Elevations 208.2 m to 207.5 m and the thickness of the deposit is 1.1 m to 0.6 m, in the respective boreholes.

The SPT ‘N’-values measured within the silty sand to silt and sand deposit range from 3 to 4 blows per 0.3 m of penetration, indicating a very loose relative density.

The natural water content measured on one sample of the sandy silt to silt and sand deposit was 32 per cent. One sample yielded a non-plastic Atterberg limit test result.

4.2.4 Clayey Silt to Clay

A cohesive deposit was encountered in all boreholes below the fill or silty sand to silt and sand deposit. The deposit is comprised of a 1.5 m to 1.1 m thick upper stratum of clayey silt, trace to with sand in Boreholes 16-2 and 16-3, respectively, and of silty clay to clay below the clayey silt and below the sandy silt in Borehole 16-1. Trace organics was encountered in the clayey silt portion of the deposit in Borehole 16-2 below the embankment fill. The lower 0.6 m of the deposit in Borehole 16-1 is also comprised of clayey silt. The surface of the cohesive deposit ranges from Elevation 208.0 m to 206.9 m, and the thickness of the deposit is 20.4 m in Borehole 16-1 where it was fully penetrated, and may be about 18.6 m as inferred from the DCPT in Borehole 16-2 and 25.3 m as inferred from the DCPT in Borehole 16-3.

The SPT ‘N’-values measured within the clayey silt portion of the cohesive deposit are 2 blows and 6 blows per 0.3 m of penetration; one in situ field vane test in the clayey silt stratum measured and undrained shear strength greater than 96 kPa. The results of the SPT and field vane test suggest that the clayey silt stratum is soft to stiff in consistency. The SPT ‘N’-values measured within the silty clay to clay deposit are 0 blows (weight of hammer) per 0.3 m of penetration. In situ field vane tests carried out within this deposit measured undrained shear strengths ranging from about 20 kPa to 58 kPa, and the sensitivity is calculated to range from about 2 to 7. The field vane tests results indicate that the silty clay to clay has a soft to stiff consistency.

The natural water content measured on seventeen samples of the cohesive deposit ranges from about 17 per cent to about 67 per cent, with the average natural water content being approximately 53 percent. The grain size distributions of six samples of this cohesive deposit are shown on Figures B2A and B2B in Appendix B.

Atterberg limits tests were completed on nine samples of the cohesive deposit. The results of two Atterberg limits tests on samples from the upper zone of clayey silt indicate liquid limits of about 23 per cent and 30 per cent, plastic limits of about 16 per cent and 20 per cent, corresponding to plasticity indices of about 7 per cent and 10 per cent. The results of these Atterberg limits tests are shown on the plasticity chart on Figures B3A and B3B in Appendix B, and indicates that material/zone is classified as clayey silt of low plasticity. The remaining seven Atterberg limits tests were performed on the silty clay to clay portion of the cohesive deposit and indicate liquid limits ranging from about 43 per cent to 57 per cent, plastic limits ranging from about 20 per cent to 24 per cent and plasticity indices ranging from about 19 per cent to 34 per cent. The results of these Atterberg limits tests are shown on the plasticity chart on Figure B3B in Appendix B, and indicate that the material is classified as silty clay of intermediate plasticity to clay of high plasticity.

Laboratory consolidation tests were carried out on four specimens of the silty clay to clay portion of the cohesive deposit obtained from Shelby tube samples in all three boreholes. Preconsolidation pressures ranging between 100 kPa and 145 kPa were estimated from the void ratio versus logarithmic pressure plot and from the total work versus pressure plot. Bulk unit weights ranging of about 15.9 kN/m^3 to 17.3 kN/m^3 and a specific gravity between 2.75 and 2.77 were measured on the consolidation test specimens. Details of the test results are shown on Figure B6 to B7 in Appendix B and the test results are summarized below.

Borehole Sample No.	Sample Depth/ Elevation	σ_{vo}' (kPa)	σ_p' (kPa)	σ_p' - σ_{vo}' (kPa)	OCR	C_c	C_r	c_v (cm^2/s)	e_o
16-1 SA 8	9.2 m / 199.9 m	60	135	75	2.2	0.65	0.05	3.1×10^{-3}	1.77
16-2 SA 8	8.0 m / 204.0 m	100	100	0	1	0.26	0.04	7.0×10^{-4}	1.41
16-2 SA 11	12.4 m / 199.6 m	140	145	5	1	0.34	0.04	2.2×10^{-3}	1.32
16-3 SA 5	4.8 m / 203.6 m	75	140	65	1.9	0.64	0.06	3.5×10^{-3}	1.79

Note: For the stress range between effective overburden stress and the embankment stress (due to a 4 m high embankment) that is 30 kPa $_v$ 285 kPa

where: $_{vo}$’ is the effective overburden stress in kPa
$_p$’ is the preconsolidation stress in kPa
OCR is overconsolidation ratio
C_c is the compression index
C_r is the recompression index
e_o is initial void ratio
c_v is the coefficient of consolidation in cm^2/s

4.2.5 Silt and Sand

A 0.6 m thick deposit of sit and sand, some gravel, trace clay was encountered below the clayey silt stratum in Borehole 16-1 at Elevation 186.7 m. One SPT test attempted within this deposit resulted in the split spoon bouncing after 15 blows and no penetration.

4.2.6 Groundwater Conditions

In general, the recovered soil samples were described as wet. Borehole 16-1 was drilled on the north side of the embankment and encountered a water level at ground surface (Elevation 209.1 m) upon completion of drilling. Boreholes 16-2 and 16-3 encountered a water level at depths of 11.9 m and 7.6 m below ground surface, respectively, corresponding to Elevations 200.1 m and 200.8 m, upon completion of drilling. The groundwater levels are not stabilized and should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is higher during the wet seasons and thereafter periods of heavy precipitation.

4.2.7 Analytical Testing

The results of an analytical test on a sample of the silty sand taken from Borehole 16-1 and a sample of the upper portion of the cohesive deposit was taken from Borehole 16-3 are provided in Appendix C. The suite of parameters tested include pH, sulphate, sulphide, chloride, resistivity, and conductivity.

5.0 CLOSURE

The foundation investigation program was supervised by Mr. Adam Core, P.Eng., and Mr. Imran Khalid, B.A.Sc. This report was prepared by Ms. Alysha Kobylinski, B.A.Sc., and the technical aspects were reviewed by Sarah E. M. Poot, P.Eng., a senior geotechnical engineer and an Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant of Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.

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PART B

FOUNDATION DESIGN REPORT
BLAKE CREEK CULVERT REPLACEMENT –
SITE NO. 46-490
HIGHWAY 17, STA 11+970, LORNE TOWNSHIP,
SUDBURY, ONTARIO GWP 5173-12-00

April 19, 2017
Report No. 1535723

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides detail foundation engineering design recommendations for the proposed replacement of the Blake Creek Culvert (Site No. 46-490) at STA 11+970 on Highway 17 as part of the resurfacing contract in this area. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at this site.

The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

It is understood that the existing culvert at STA 11+970 has experienced approximately 0.8 m of settlement at its mid-span, which is consistent with consolidation settlement over time. The subsoils at this site consist of granular embankment fill or surficial sandy silt to silt and sand deposits at the embankment toes, underlain by an extensive deposit of soft to stiff silty clay to clay.

6.1 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the 2014 Canadian Highway Bridge Design Code and its Commentary (CHBDC, 2014), the proposed culvert and its foundation system is considered to be classified as having a “typical consequence level” associated with exceeding limits states design. In addition, given the level of foundation investigation completed to date at this location 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, from Table 6.1 and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs}, from Table 6.2 of the CHBDC (2014) have been used for design.

6.2 Foundation Options for Culvert Replacement

It is understood that the replacement of the Blake Creek Culvert is required as the culvert has undergone settlement of about 0.8 m at the mid-span, as well as experienced overall deterioration. The existing culvert is an open footing rigid frame structural concrete structure. Details regarding the existing culvert and the potential extension length are provided in Table 1 following the text of this report. It is understood that the replacement culvert will be of approximately the same size as the existing 6 m wide open footing culvert. The culvert will be replaced on the existing alignment with a proposed invert of Elevation 207.4 m at both the inlet and outlet.

A box culvert is considered to be feasible for the replacement of the Blake Creek culvert. Due to the presence of the cohesive deposit of limited strength, the height of the existing embankment, and the limited geotechnical resistance available, an open footing concrete culvert is not considered feasible. The use of a circular corrugated steel pipe (CSP) or concrete pipe(s) for the replacement of the Blake Creek culvert was not considered feasible due to less tolerance to settlement and the size required to accommodate flow at this site.

The advantages and disadvantages associated with both the box culvert, open footing culvert and circular pipe replacement options are summarized in Table 2 following the text of this report. From a foundations perspective, the pre-cast box culvert is the preferred option for the following reasons:

- Pre-cast box culverts minimize the depth of excavation compared to open footings;
- Pre-cast box culvert segments can be installed in a shorter time span when compared to cast-in-place open footing culverts, resulting in shorter durations of road construction activities and water pumping; and
- Pre-cast box culvert segments are more tolerant of total and differential settlement that could result from some limited Highway 17 embankment raising and road widening at the culvert location.

Recommendations for the replacement of the existing culvert with a box culvert are provided in the following sections.

6.3 Box Culvert Foundation Elevation and Resistances

It is not necessary to found a pre-cast box culvert at the standard depth for frost protection purposes, as the box structure is tolerant to small magnitudes of movement related to freeze-thaw cycles and increased loading from pavement structure regrading and padding, should these be necessary. The box culvert should be founded on the native subgrade soils below any existing fill, deleterious soils and organic materials on a properly prepared subgrade. Recommended founding elevations and sub-excavation requirements for the box culvert replacement, based on an assumed base slab thickness of 250 mm are provided below.

The subgrade for the box culvert should be inspected by a qualified geotechnical inspector to ensure that all existing fill, organic soils or other deleterious material have been removed. In addition, the bedding, levelling pad and backfill requirements both for any subexcavation replacement and around/over the culvert should be in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut) for a pre-cast rigid frame culvert. The replacement box culvert should be provided with at least 300 mm of OPSS.PROV 1010 Granular ‘A’ material or Granular ‘B’ Type II for bedding purposes, or alternatively a 100 mm thick concrete working slab, overlain by a 75 mm thick levelling pad, as discussed in Section 6.6.4.

Depending on flow conditions and the water level upstream of the culvert at the time of construction, diverting of the flow may be required to allow for culvert replacement. Based on the water level measured in the boreholes upon completion of drilling, excavations for the box culvert replacement will likely be below the groundwater level. The design of the replacement box culvert placed on the properly prepared subgrade, at or below the founding elevation, should be based on the following factored geotechnical resistance at Ultimate Limit States (ULS) and factored geotechnical resistance at Serviceability Limit States (SLS), for 25 mm of settlement, based on a 6 m wide box; which would result in a maximum of 25 mm of settlement. Also provided in the table are geotechnical resistances for an assumed 1 m wide wing wall footings that we understand may be required at the culvert ends. The wing walls should be founded at the same depth as the box culvert.

Foundation	Width	Proposed Invert Elevation (north/south) (m)	Approximate Sub-Excavation level (north/south) (m)	Founding Conditions	Factored Geotechnical Resistance at ULS	Factored Serviceability Geotechnical Resistance at SLS (for 25 mm of settlement)
Culvert	6 m	207.4/207.4	206.8/206.8	Firm clayey silt to clay	100 kPa	85 kPa
Wing Walls	1 m				100 kPa	85 kPa

The geotechnical resistances provided above are dependent on the foundation size, configuration and applied loads and the geotechnical resistances should therefore be reviewed if the culvert width or founding elevation differs significantly from the values given. These values also assume that there will not be any changes to the embankment geometry (height or widening) that could result in further consolidation settlement. If the wing walls vary substantially from that currently proposed, we should have the opportunity to review these recommendations.

The geotechnical resistances provided are for loads that will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the footing, inclination of the load should be taken into account in accordance with Clauses 6.10.3 and 6.10.4 of the CHBDC (2014).

Resistance to lateral forces / sliding resistance between the base of the box culvert and granular bedding material should be calculated in accordance with Section 6.10.5 and Section C6.10.5 of the CHBDC (2014) and it's Commentary. An unfactored coefficient of friction, tan δ, between the base of the pre-cast concrete and the Granular 'A' levelling layer is 0.45.

6.4 Stability, Settlement and Horizontal Strain

Based on the staging and profile drawings provided to us by MMM, traffic signals or grade lowering will be required to facilitate the staged replacement of the existing culvert. Given the past consolidation settlement at this site, we do not recommend raising the grade or widening the embankment in the final or temporary configuration at the site. Further, we do not recommend the use of a new embankment detour for staging as this may also induce additional settlement under the culvert and final embankment. We understand that consideration is being given to shortening the length of the culvert by steepening the embankment north side slope from the current 3H:1V inclination to 2H:1V for the reconstructed slope over and in the immediate vicinity of the new culvert. The results of stability and settlement analysis are presented in the following sections.

6.4.1 Stability

Limit equilibrium slope stability analyses for the regraded/steepened embankment north side slope at 2H:1V were carried out using the commercially available program Slide (version 6.0), developed by Rocscience Inc., engaging the Morgenstern-Price method of slope stability analysis. Factors of Safety (FoS) of numerous potential failure surfaces were computed for the critical embankment cross-section to establish the minimum FoS for the embankment and subsoils. The FoS 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 FoS 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, a target minimum FoS of 1.3 and 1.5 has been used for the design of the embankment slopes for temporary (short-term, undrained) and permanent (long-term, drained) conditions, respectively, as per Table 6.2 of CHBDC (2014). The stability analyses assume that all organics and other deleterious materials are removed below the final embankment footprint.

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

For the cohesive soils present at site, the applicable engineering parameters shown on Figure 1 were selected based on four consolidation tests that were carried out on relatively undisturbed samples of the cohesive deposit (two samples obtained from the two boreholes drilled at the toes of the existing embankment slopes). In addition, empirical correlations based on the results of the SPT and in situ vane values determined during the geotechnical investigation and laboratory water content and Atterberg limits test results were considered.

For the purpose of the stability analysis, the water level was assumed to be at the existing ground surface of the surrounding topography, at Elevation 207.8 m. A summary of the soil parameters are presented below.

Soil Deposit	**Bulk Unit Weight (kN/m^3)**	**Effective Friction Angle**	**Undrained Shear Strength (kPa)**
Compact to dense Sand and Gravel (Embankment) Fill	21	35°	-
Very loose Sand to Sandy Silt Firm Clayey Silt with Sand	18	30°	-
Soft to Stiff Clayey Silt to Clay	16	-	Upper - 25
			Linearly Increasing 25 + 6.67/m (to 45)
			Lower - 45

The results of the stability analyses indicate that a factor of safety greater than 1.33 is achieved for a granular embankment side slope, up to about 5 m high and maintained at 2 horizontal to 1 vertical (2H:1V) as shown on Figure 2. Alternatively, the embankment in the area of the culvert could be reconstructed using rock fill with side slopes no steeper than 1.25 horizontal to 1 vertical (1.25H:1V). In this case, the rock backfill to the culvert should be well-graded and restricted to a maximum size of 300 mm and be properly “chinked” along the contact with the embankment fill. It should be noted that the Factor of Safety against deep-seated slope failure will not be adequate for any grade raise at this site.

6.4.2 Settlement

To estimate the magnitude of expected settlement of the embankment and subsoils should a grade raise/widening or detour be implemented, settlement analyses were carried out using the commercially available program Settle^{3D} (version 3.0), developed by Rocscience Inc. The settlement analyses assume that any organic material is removed below the final embankment footprint prior to placing fill.

The simplified stratigraphy and the associated unit weights and strengths employed for the estimation of settlement of the foundation soils are shown on Figure 1 and simplified below for Boreholes 16-1 and 16-3 at the toes of the embankment. The immediate compression of the non-cohesive overburden soils were modelled by estimating an elastic modulus of deformation based on the SPT ‘N’-values and using correlations proposed by Bowles (1984) and Kulhawy and Mayne (1990). These estimated values were compared with the typical range of expected values for similar soil types, as outlined in CHBDC and tempered, as appropriate, by engineering judgement.

Soil Deposit	Bulk Unit Weight	Elastic Modulus	P_c’	e_o	C_c	C_r	c_v
Silt and Sand	19 kN/m^3	10 MPa	–	–	–	–	-
Silty Clay to Clay	18 kN/m^3	N/A	130 kPa	1.77	0.64	0.064	3.8x10^{-3} cm^2/s

For a hypothetical 1 m grade raise, the result of the analysis indicates an estimated primary consolidation settlement of 250 mm beneath the centerline of the embankment tapering to about 70 mm at the culvert ends. The consolidation settlement is time dependent and based on the measured c_v values from the consolidation tests it is estimated that approximately 90% of primary consolidation will occur in about 12 years, for the approximately 25 m thick clay deposit.

The existing culvert has reportedly experienced settlement of about 0.8 m at the mid-span which is consistent with consolidation settlement of the clay deposit under 5 m of embankment fill, although secondary consolidation (i.e. creep) may still be occurring. Based on a secondary compression index, $C\alpha\varepsilon$ of 0.006 derived from empirical correlations with water content and the results of the consolidation testing, it is estimated that 150 mm of creep settlement will occur per log cycle of time. For the culvert constructed in 1955, the first log cycle of time would extend from 1955 to 1967 and the second log cycle from 1965 to 2055. In the second log cycle, the estimated annual rate of settlement is about 1.7 mm, resulting in a post-construction creep settlement for the first 20 years after culvert replacement of about 35 mm. This magnitude of settlement meets the post-construction embankment performance criteria outlined in Section 1.1 of MTO’s Embankment Settlement Criteria for Design, dated July 2010 and thus embankment settlement mitigation measures are not considered necessary.

In addition, there does not appear to be a recent history of settlement problems or pavement re-grading, suggesting that settlement may have stabilized with minimal creep occurring. Therefore, we recommend that there be no change to the final embankment configuration height or width, with the exception of steepening the north side slope as discussed above, which will not impact settlement. Further, as noted in Section 6.4.1, an adequate factor of safety against deep-seated slope failure would likely not be achieved for a raised embankment without implementing mitigation measures and procedures during construction, such as staged construction or utilization of light weight fill for the embankment fill mass.

6.4.3 Horizontal Strain

Horizontal strain along the culvert is not expected to occur provided the proposed embankment geometry does not change from the currently proposed geometry, or the reconstructed side slopes are steepened to 2H:1V for each fill or 1.25H:1V for culvert rock backfill. For the estimated 35 mm of post-construction settlement over the next 20 years, constructing the box culvert with a camber is not deemed necessary. Should the embankment be widened or raised or a longer than 20 year design life is a condition of the replacement structure, a reassessment of the potential magnitude of horizontal strain and need for a camber will be required.

6.5 Lateral Earth Pressures for Design

The lateral earth pressures acting on the side walls and wing walls of the culvert will depend on the type and method of placement of backfill materials, the nature of 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 recommendations provided below are made concerning the design of the culvert walls. 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.

- 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 culvert walls, and on top of the culvert for a thickness of not less than 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness and properly compacted. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting). Weep holes, where applicable, should be installed to provide positive drainage of the granular backfill.

- For restrained walls in box culvert design, 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). The pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	**Soil Unit Weight**	**Coefficients of Static Lateral Earth Pressure**	
		At-Rest, K_o	**Active, K_a**
Granular ‘A’	22 kN/m^3	0.43	0.27
Granular ‘B’ Type II	21 kN/m^3	0.43	0.27

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

6.6 Construction Considerations

6.6.1 Surface Water and Groundwater Control

The base of the sub-excavation required for the box culvert construction will be below the groundwater and creek water levels. Although the groundwater inflow is not expected to be excessive given the presence of cohesive deposit comprising the subgrade at the culvert site, which is of relatively low hydraulic conductivity, sandy silt to silt and sand layers were encountered at the toes of the embankment slopes near the culvert ends which are more permeable. It is likely that standard pumping from sumps alone will not be adequate at this site and consideration should be given to temporary channel diversion (by means of a temporary culvert or other method) around the culvert site and dewatering prior to excavating operations to allow for the founding level to be exposed in-the-dry. Therefore, a groundwater control system may be in the form of a sheet-pile cut off wall or cofferdam advanced to an appropriate depth to control groundwater inflow from the creek and to prevent base heaving of the foundation subgrade. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade. Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering).

An accurate prediction of the groundwater pumping volumes cannot be made at this time, as the flow rate would be dependent on construction methods adopted by the contractor. Even with the creek water flow diverted and the unwatering system installed to mitigate groundwater inflows, pumping volumes could exceed 50,000 L/day during initial drawdown stages and/or during periods of heavy precipitation. An application under the Environment Activity Section Registry (EASR) of the Ontario Ministry of Environment and Climate Change (MOECC) should be submitted in the event that the pumping volumes exceed 50,000 L/day. Under the EASR, a Permit to Take Water (PTTW) is not required for water taking for construction site dewatering for volumes less than 400,000 L/day.

6.6.2 Construction Staging and Temporary Protection Systems

Since the potential for settlement is a concern at this site we do not recommend the use of a temporary detour embankment to allow for traffic flow. Therefore, consideration is being given to staging the culvert replacement by means of temporary traffic signals or by lowering the grade which creates a wider platform which maintains 2 lanes of traffic flow. In either case, the culvert replacement will be carried out in stages where the north and south sections of the culvert will be replaced separately.

The temporary excavations for the culvert replacement will be made through the existing granular embankment fill and into native soils, which are described in detail in Section 4.2 of this report. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. According to OHSA, the existing fill would be classified as Type 3 soil and the native sandy silt, silt and sand, and the cohesive materials would be classified as Type 4 soils and as such, temporary open-cut excavations through the embankment fill and native cohesive soils should be made with side slopes inclined no steeper than 1H:1V and 3H:1V, respectively. All temporary protection systems and cofferdams should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). The lateral movement of the temporary shoring and cofferdams should meet Performance Level 2 as specified in OPSS.PROV 539. The selection and design of the protection systems and cofferdams is the responsibility of the Contractor.

The temporary protection systems, and cofferdams, should be assessed for both the drained ( ) and undrained cases (su), based on the more conservative earth pressure conditions for the parameters given below. The earth pressure coefficients noted in Section 6.5 are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.

Soil Type	Unit Weight (γ, kN/m^3)	Internal Angle of Friction (ϕ, degrees)	Cohesion (kPa)	Coefficients of Earth Pressure		
				Active, K_a	At Rest, K_o	Passive, K_p
Existing Sand and Gravel (Fill) (very loose to dense)	21	35	-	0.64	0.43	3.69
Sandy Silt/Silt and Sand (very loose)	19	28	-	0.68	0.53	2.77
Clayey Silt and Sand (soft to stiff)	18	30	-	0.67	0.50	3.00
Silty Clay to Clay (soft to firm)	18	27	25	0.69	0.55	2.66
Silty Clay to Clay (firm to stiff)			45			

Design of the temporary support systems, including cofferdams, should include an evaluation of base stability, soil squeezing stability and the hydraulic uplift stability as defined in the CFEM (2006).

Consideration could be given to either partial or full removal of the temporary protection systems upon completion of construction or after each stage of construction (as required). Where possible, full removal of the temporary protection systems should be considered to mitigate potential impediments to future rehabilitation / reconstruction work at the culvert sites.

6.6.3 Excavation and Replacement Below Culvert

Although not anticipated to be present in the immediate footprint of the culvert, all organics, where encountered, and any softened soils, should be sub-excavated from below the plan limits of the proposed works prior to placement of any bedding material, fill or concrete.

Although not specified in OPSS 422 (Precast Reinforced Concrete Box Culverts) for a pre-cast box culvert, the subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organics and other unsuitable materials have been removed.

The native (silty clay to clay) subgrade soils will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance, a concrete working slab could be placed on the subgrade if the box culvert (bedding/levelling course and structure) is not placed within four hours after preparation, inspection, and approval of the foundation subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28 day compressive strength of 20 MPa.

6.6.4 Culvert Bedding, Backfill and Cover

6.6.4.1 Bedding

The bedding, levelling pad and backfill requirements for pre-cast rigid frame culverts should be in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut). The box culvert replacement should be provided with at least 300 mm of OPSS.PROV 1010 Granular ‘A’ material for culvert bedding purposes, or alternatively a 100 mm thick concrete working slab as noted in Section 6.6.3. If a concrete working slab is utilized, a 75 mm thick layer of OPSS 1010 Granular ‘A’ or concrete fine aggregate meeting the gradation requirements set out in OPSS.PROV 1002 (Material Specification for Aggregates – Concrete) should be placed on top of the concrete working slab to provide a “levelling pad” for the box culvert replacement or extension.

As an alternative to using Granular ‘A’ for bedding or using a concrete working slab for subgrade protection, consideration could be given to the use of OPSS.PROV 1010 Granular ‘B’ Type II for bedding material placed in wet conditions. The Granular ‘B’ Type II should be compacted by the construction equipment, such as tamping with the backhoe bucket and/or grading/levelling by bulldozer, such that a minimum of 90 percent of SPMDD should be achievable. A 75 mm levelling pad above the bedding would still be required to seat the culvert and this levelling pad could consist of uncompacted Granular ‘A’ or OPSS.PROV 1002 concrete fine aggregate.

6.6.4.2 Backfill

Backfill behind the culvert walls and above the culvert(s) should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular ‘A’ or Granular ‘B’ Type I, II, III material. The granular backfill should be placed in maximum 200 mm thick lifts and compacted as per OPSS 422 (Precast Reinforced Concrete Box Culverts) in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm to not less than 95 per cent Standard Proctor Maximum Dry Density of the material.

Backfill placement for reconstruction of the roadway embankments along and over the culvert should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the existing embankment fill and new fill, or rock backfill, along the cut faces. A frost taper is not required at this location.

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

6.6.5 Erosion Protection

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring of the bedding or any native soil) or around the culvert, a concrete cut-off wall or a clay seal should be provided at the upstream end of the culvert. Alternatively, if a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum thickness of 1 m, if constructed of natural clay or soil bentonite mix. The clay seal should extend to a depth of 1 m below the scour level or to bedrock, whichever is shallower, and also to a minimum vertical height equivalent to the high water level, and should extend a minimum horizontal distance of 2 m on either side of the culvert inlet opening or across the full width of the face of the new granular culvert backfill zone, whichever is greater. If a geosynthetic clay liner (GCL) is utilized in lieu of the 1 m thick clay seal then the GCL should be positioned within the embankment slope to allow for 0.3 m of granular (embankment) fill cover to be placed over the GCL and covered with the requisite erosion protection material.

The requirements for and design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. As a minimum, rip rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip Rap Treatment). Erosion protection for the inlet of the culvert should also follow the standard presented in OPSD 810.010 (Rip Rap Treatment) similar to the outlet but with the rip rap placed up to the toe of slope level, in combination with the cut-off measures noted above.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Alysha Kobylinski, B.A.Sc., a member of the geotechnical engineering group. The technical aspects were reviewed by Ms. Sarah Poot, P.Eng., a senior geotechnical engineer and an Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.

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ACK/SEMP/JMAC/nh

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Canadian Foundation Engineering Manual. 2006. Fourth Edition, Canadian Geotechnical Society: Richmond, British Columbia.

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

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Kulhawy, F.H. and Mayne, P.W. 1990. Manual on Estimating Soil Properties for Foundation Design. EL 6800, Research Project 1493 6. Prepared for Electric Power Research Institute, Palo Alto, California.

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

STANDARDS:

ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D1587	Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
ASTM D2573	Standard Test Method for Field Vane Shear Test in Cohesive Soil

Ministry of Transportation Ontario

Embankment Settlement Criteria for Design, July 2010

Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91 Construction Projects as amended by O. Reg. 443/09

Ontario Provincial Standard Drawing:

OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets

Ontario Provincial Standard Specification:

OPSS 422	Construction Specifications for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specifications for Compacting
OPSS 517	Construction Specifications for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specifications for Temporary Protection Systems
OPSS.PROV 1002	Material Specifications for Aggregates - Concrete
OPSS.PROV 1010	Material Specifications for Aggregates – Base, Subbase, Select Subgrade, Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal

Ontario Water Resources Act:

R.R.O. 1990, Regulation 903

Commercial Software:

Slide (Version 6.0) by Rocscience Inc.

Settle^{3D} (Version 3.0) by Rocscience Inc.

Table 1: Summary of Existing Culvert Details

Culvert Location (Township)	Site No.	Approximate Height of Embankment [1]	Existing Culvert			Approximate Culvert Invert Elevation[2]	
			Type	Approximate Dimension	Approximate Length	Inlet (South)	Outlet (North)
STA 11+970 (Lorne)	46-490	~ 5 m	Open footing rigid frame	6.1 m wide x 1.8 m high	36.5 m	206.6 m	207.1 m

Notes: 1. Embankment height is relative to existing ground surface level at the toe of embankment adjacent to the culvert.

2. Culvert inlet and outlet represent reversed flow at this site due to deformations over time.

Prepared By: ACK
Checked By: SEMP
Reviewed By: JMAC

Table 2: Comparison of Culvert Replacement Options

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	■ Minimizes the depth of excavation, excavation support and dewatering requirements compared to open footing culvert. ■ Compared to cast-in-place open footings, the use of pre-cast box segments is expected to allow for faster construction, resulting in shorter duration for potential dewatering and surface water pumping. More tolerant of total and differential settlement.	■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Concrete cut-off wall required at inlet end to mitigate potential scour under/along culvert. ■ Transportation and on-site lifting of large pre-cast sections will be required. ■ Groundwater control would still be required (albeit less than for open footing culvert extension). Slightly higher geotechnical resistance on upper portion of the clayey silt/ silty clay to clay deposit.	■ Limited risk related to settlement performance provided embankment geometry does not change. ■ Some risk of disturbance of the subgrade during construction; can be mitigated with appropriate groundwater control and use of a concrete working slab.
Cast-In-Place Open Footing Culvert	■ Will have a longer lifespan than a culvert of CSP construction. Would likely satisfy fisheries requirements related to natural channel substrate, if applicable, provided existing subgrade below existing culvert is acceptable	■ Will take longer to construct cast-in-place culverts. ■ Requires unwatering and surface water pumping for construction of footings in dry conditions. ■ Less tolerant of total and differential settlement. ■ Requires greater depth of excavation (to below depth of frost penetration). Low geotechnical resistance on soft silty clay to clay deposit.	■ High risk of damage if settlement occurs in future. Some risk of disturbance of the subgrade during construction; can be mitigated with appropriate groundwater control and use of a concrete working slab

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Circular Pipe Culvert (CSP or Concrete)	■ Allows for faster construction compared to cast-in-place options resulting in shorter duration for dewatering and surface water pumping. ■ More tolerant of total and differential settlement if the highway embankment is raised or widened for staging.	■ Cut-off wall may be required at inlet to mitigation potential scour under culvert. ■ CSP may not have as long a design life as compared to concrete culvert options. ■ Multiple or larger diameter CSPs or concrete pipes likely required to accomodate desired flow. ■ Will not satisfy fisheries requirements related to natural channel substrate, if applicable at this site. ■ More difficult to compact the culvert bedding fill in the haunches zone of the culvert.	■ Limited risk related to settlement performance provided embankment geometry does not change. ■ Shorter lifespan of CSP construction

Prepared By:	ACK
Checked By:	SEMP
Reviewed By:	JMAC

MINISTRY OF TRANSPORTATION, ONTARIO

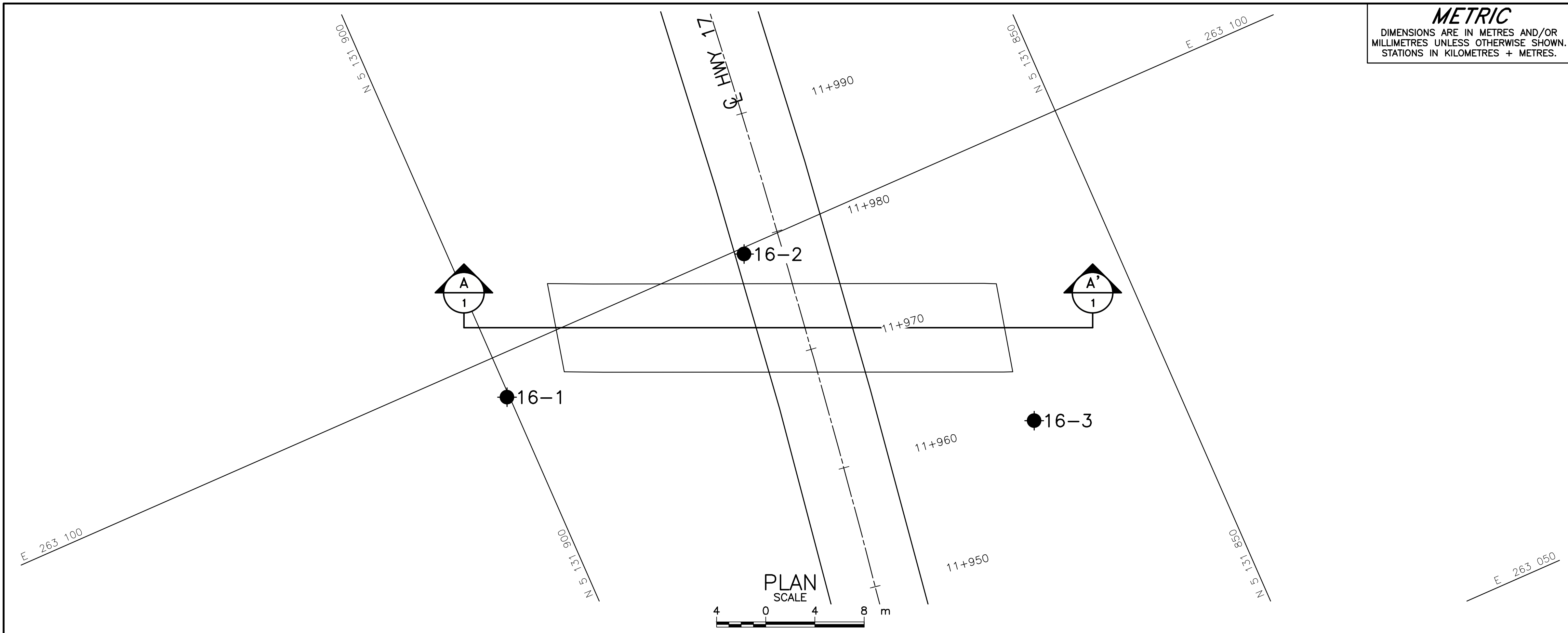
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

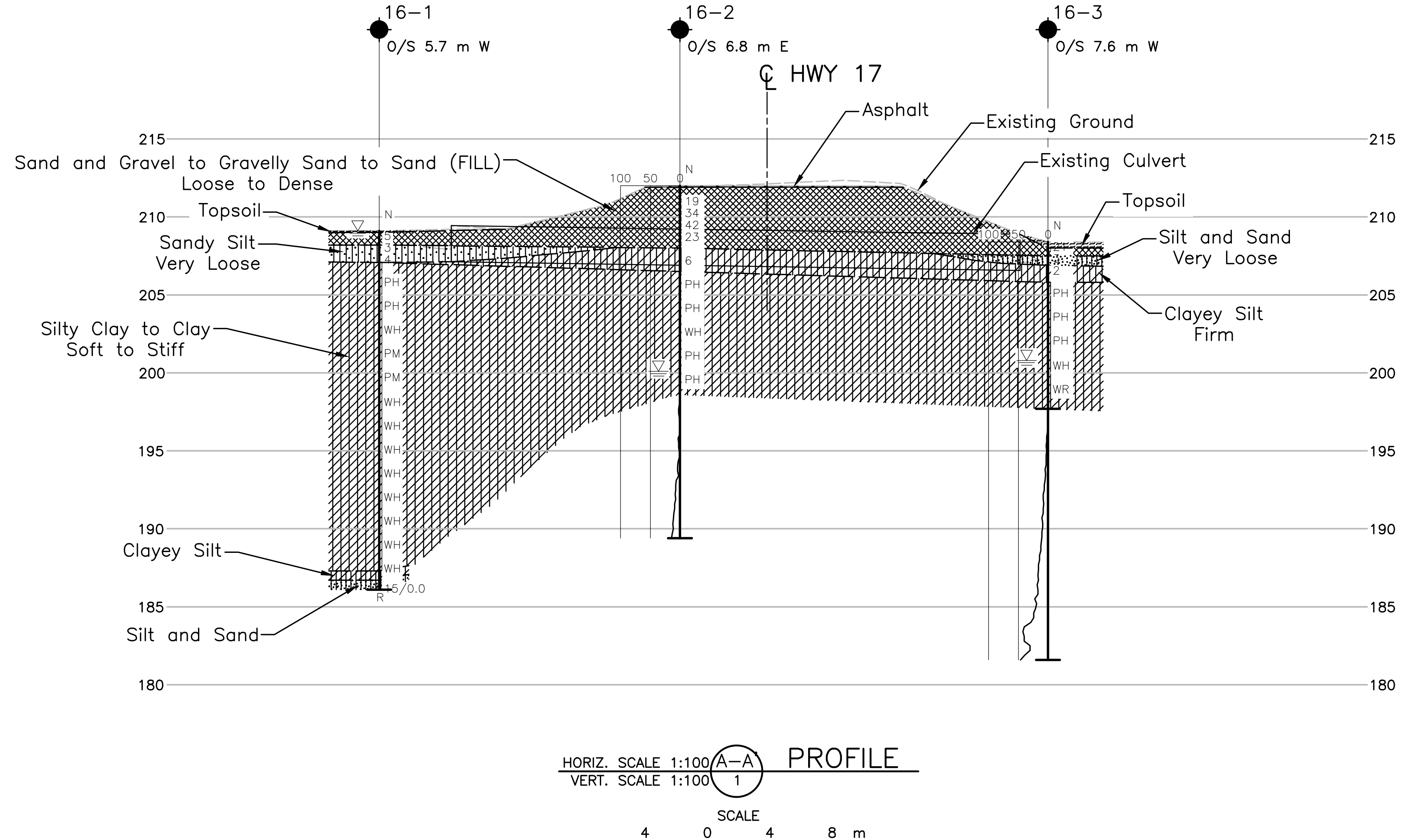
CONT No.
GWP No. 5173–12–00

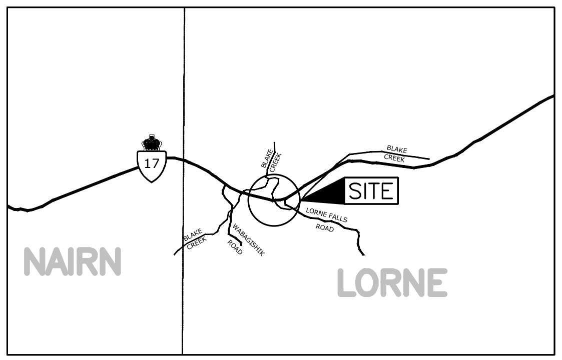
BLAKE CREEK CULVERT
HIGHWAY 17
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
.

Golder Associates







KEY PLAN
N.T.S.

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
R	Refusal

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
16–1	209.1	5131900.2	263096.6
16–2	212.0	5131877.9	263099.5
16–3	208.4	5131861.7	263077.6

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.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MMM, drawing file nos. Hwy 17 Existing Topo Blake Creek , received JULY 05, 2016. Key Plan received NOV 04, 2016.

S.E.M. POOT
90471921
MAR 22, 2017

J.M.A. COSTA
MAR 22, 2017

NO.	DATE	BY	REVISION
.	.	.	.

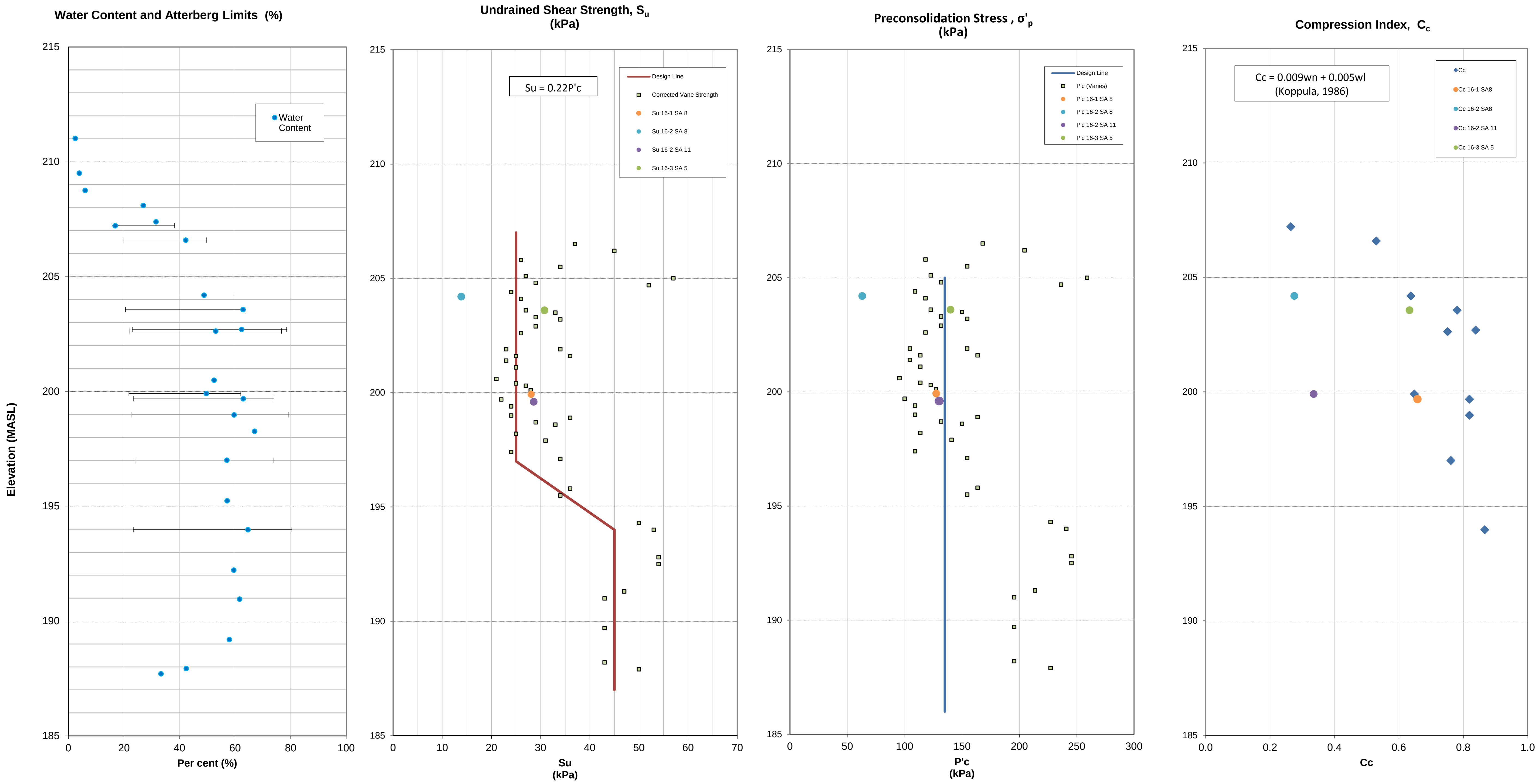
Geocres No. 41I–349

HWY. 17		PROJECT NO. 1535723	DIST. SUDBURY
SUBM'D.	CHKD. ARV/ACK	DATE: 3/22/2017	SITE: 46–490
DRAWN: JJL/TB	CHKD. SEMP	APPD. JMAC	DWG. 1

PLOT DATE: March 23, 2017
FILENAME: S:\Clients\MTO\1535723_MTO_HWY_17\99_PROJ\1535723_Hwy_17\1535723_Blake_Creek.dwg

SUMMARY PLOT OF ENGINEERING PARAMETERS FOR COHESIVE DEPOSITS
Highway 17 - Blake Creek Culvert Replacement
STA 11+790

FIGURE 1

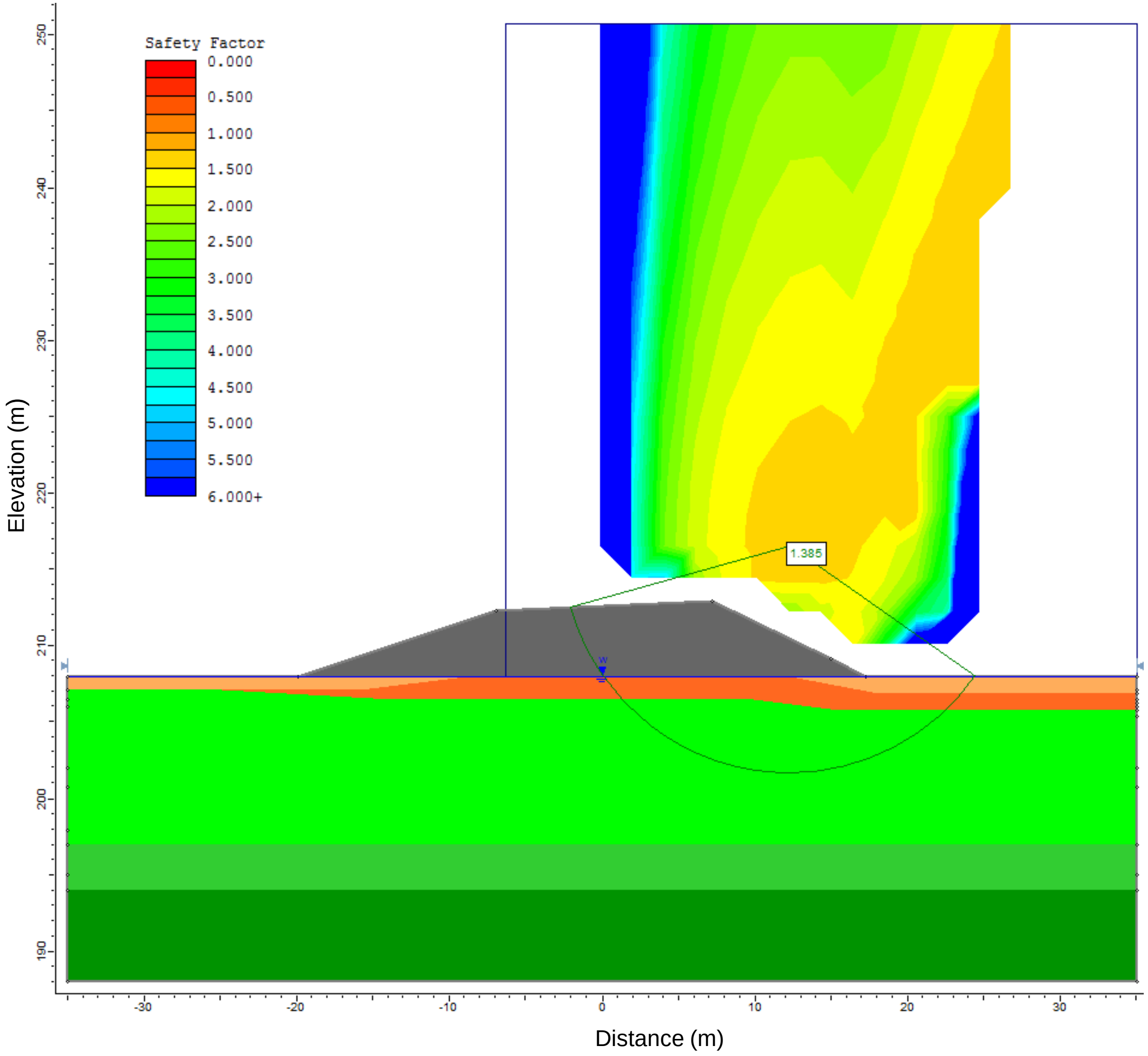


Date: April 2
Project No: 1535723

Prepared By: ACK
Checked By: SEMC

Highway 17 – STA 11+970 Slope Stability
Blake Creek Culvert – North Side Slope

Figure 2



Material Name		Unit Weight (kN/m³)	Cohesion (kPa)	Friction Angle (degrees)
Embankment Fill	⬛	21	0	35
Sandy Silt to Silt and Sand	🟧	19	0	28
Clayey Silt with Sand	🟧	18	0	30
Upper Cohesive	🟩	18	25	-
Transition Cohesive	🟩		25 + 6.67/m	-
Lower Cohesive	🟩		45	-

NOTES:

1. All dimensions are in metres
2. 2H:1V slope on North Side of embankment
3. Cohesive layer transition zone cohesion linearly increases with depth

Date: April 2017
Project Number: 1535723

Analysis: ACK **Reviewed by:** SEMP

APPENDIX A

Record of Boreholes

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
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

(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

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

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance (DCPT); N_d:

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

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

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils

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

IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

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

RECORD OF BOREHOLE No 16-1

1 OF 3 **METRIC**

PROJECT 1535723

G.W.P. 5173-12-00

DIST SUDBURY HWY 17

DATUM GEODETIC

LOCATION N 5131900.2; E 263096.6 MTM ZONE 12 (LAT. 46.32554; LONG. -81.5416)

BOREHOLE TYPE Power Auger with Solid Stem Augers to 3.0 m, then NW Casing with Wash Boring

DATE August 23 and 24, 2016

ORIGINATED BY AC

COMPILED BY ACK

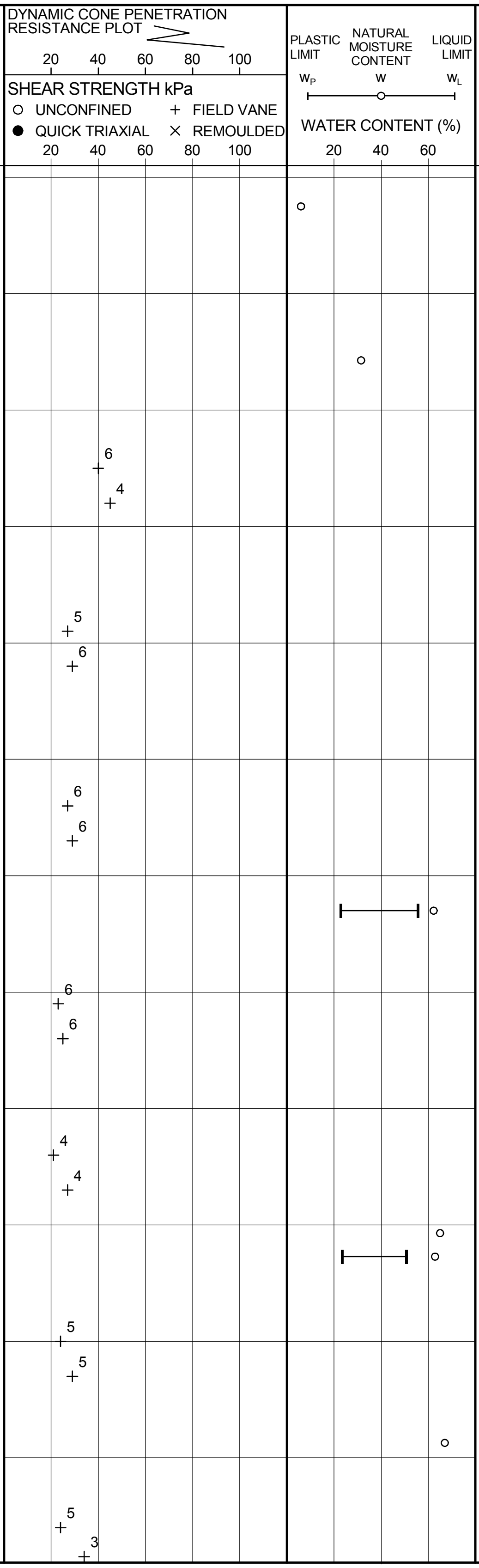
CHECKED BY ARV

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
209.1	GROUND SURFACE
0.0	TOPSOIL
0.1	Gravelly sand, trace organics (FILL) Loose Brown Moist
208.2 / 0.9	Sandy SILT, trace organics Very loose Grey Wet
207.1 / 2.0	CLAY Soft to stiff Grey Wet Reddish-brown laminations between 10.7 m and 12.8 m depth.

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
1A 1B	SS	5					
2A 2B	SS	3					
3A 3B	SS	4	NP				
4	TO	PH					
5	TO	PH					
6	SS	WH		0	0	36	64
7	TO	PM					
8	TO	PM	16.2				
9	SS	WH					



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

Continued Next Page

PROJECT 1535723

RECORD OF BOREHOLE No 16-1

2 OF 3 **METRIC**

G.W.P. 5173-12-00

LOCATION N 5131900.2; E 263096.6 MTM ZONE 12 (LAT. 46.32554; LONG. -81.5416)

ORIGINATED BY AC

DIST SUDBURY HWY 17

BOREHOLE TYPE Power Auger with Solid Stem Augers to 3.0 m, then NW Casing with Wash Boring

COMPILED BY ACK

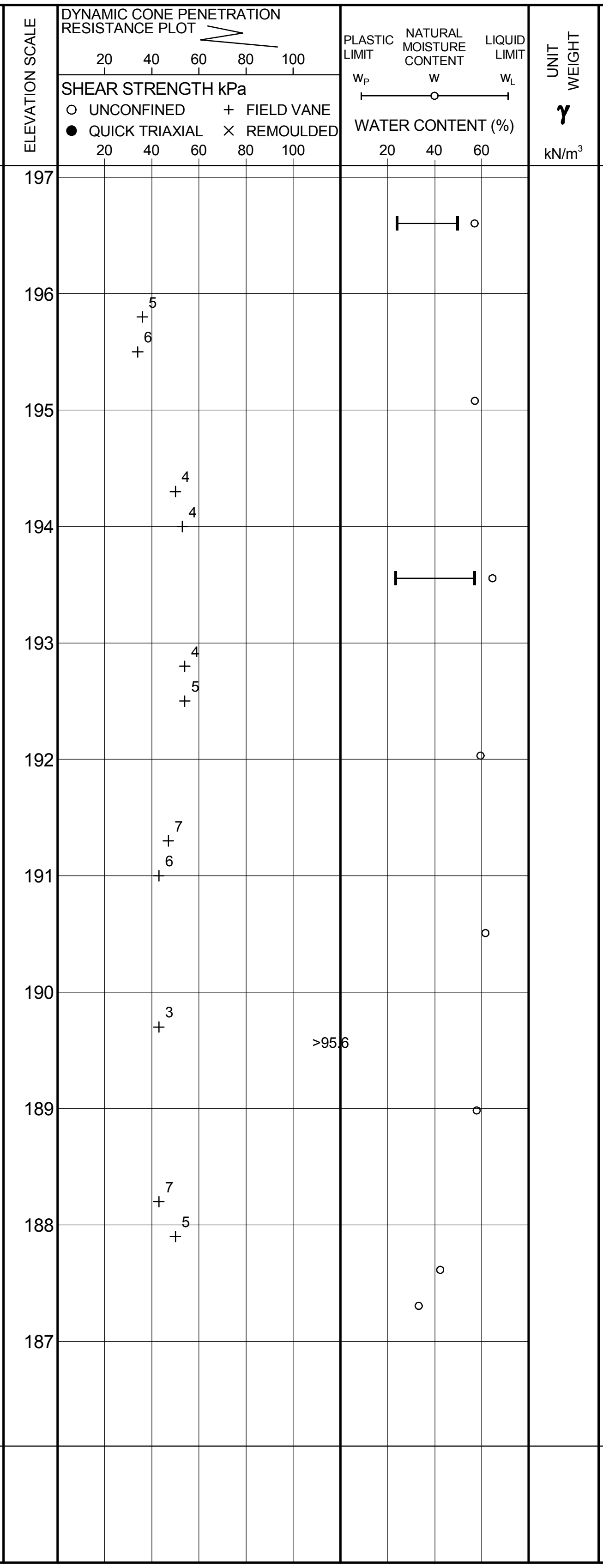
DATUM GEODETIC

DATE August 23 and 24, 2016

CHECKED BY ARV

--- CONTINUED FROM PREVIOUS PAGE ---

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	CLAY Soft to stiff Grey Wet	10	SS	WH	0	0	32	68
		11	SS	WH				
		12	SS	WH				
		13	SS	WH				
		14	SS	WH				
	Casing resistance observed at 19.5 m depth.	15	SS	WH				
		16A 16B	SS	WH				
187.3 21.8	CLAYEY SILT Grey Wet							
186.7 22.4	SILT and SAND, some gravel, trace clay Grey Wet	17	SS	15/0.0				
186.1 23.0	Split-spoon bouncing							



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

RECORD OF BOREHOLE No 16-1

3 OF 3 **METRIC**

PROJECT 1535723

G.W.P. 5173-12-00

LOCATION N 5131900.2; E 263096.6 MTM ZONE 12 (LAT. 46.32554; LONG. -81.5416)

ORIGINATED BY AC

DIST SUDBURY HWY 17

BOREHOLE TYPE Power Auger with Solid Stem Augers to 3.0 m, then NW Casing with Wash Boring

COMPILED BY ACK

DATUM GEODETIC

DATE August 23 and 24, 2016

CHECKED BY ARV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION *--- CONTINUED FROM PREVIOUS PAGE ---*	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	END OF BOREHOLE SPLIT-SPOON REFUSAL Notes: 1. Water level at ground surface (Elev. 209.1 m) upon completion of drilling.										

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

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

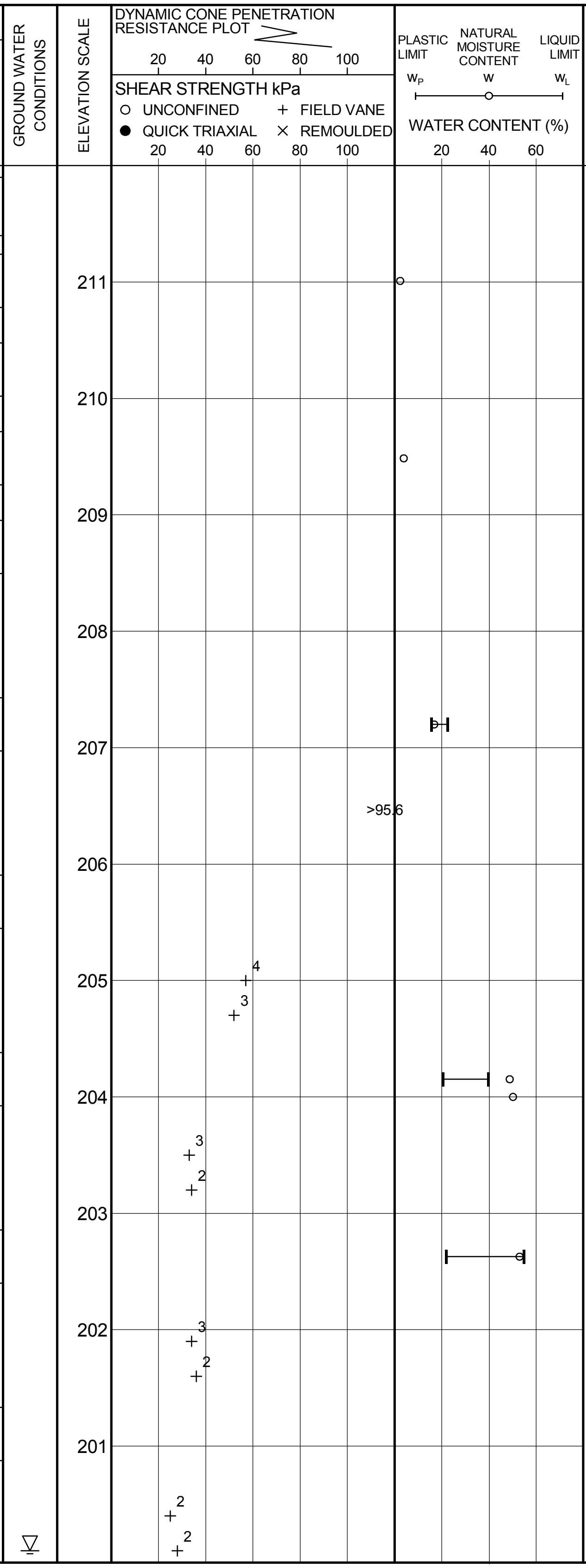
RECORD OF BOREHOLE No 16-2

1 OF 2 **METRIC**

PROJECT 1535723
G.W.P. 5173-12-00
DIST SUDBURY HWY 17
DATUM GEODETIC
LOCATION N 5131877.9; E 263099.5 MTM ZONE 12 (LAT. 46.32531; LONG. -81.5416)
BOREHOLE TYPE Power Auger with 165 mm O.D. Continous Flight Hollow Stem Augers
DATE August 18, 2016
ORIGINATED BY AC
COMPILED BY ACK
CHECKED BY ARV

ELEV DEPTH	SOIL PROFILE DESCRIPTION
212.0	GROUND SURFACE
0.0	ASPHALT (115 mm)
0.1	Sand and gravel, trace to some silt (FILL) Compact to dense Brown Moist
208.0 4.0	CLAYEY SILT with SAND, trace gravel, trace organics Firm Grey Wet
206.5 5.5	SILTY CLAY to CLAY Firm to stiff Grey Wet

SAMPLE NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
1	CS	-					
2	SS	19					
3	SS	34					
4	SS	42		35	58	(7)	
5	SS	23					
6	SS	6		2	40	40	18
7	SS	PH					
8	TO	PH	17.0 17.1				
9	SS	WH		0	0	36	64
10	TO	PH					



Continued Next Page

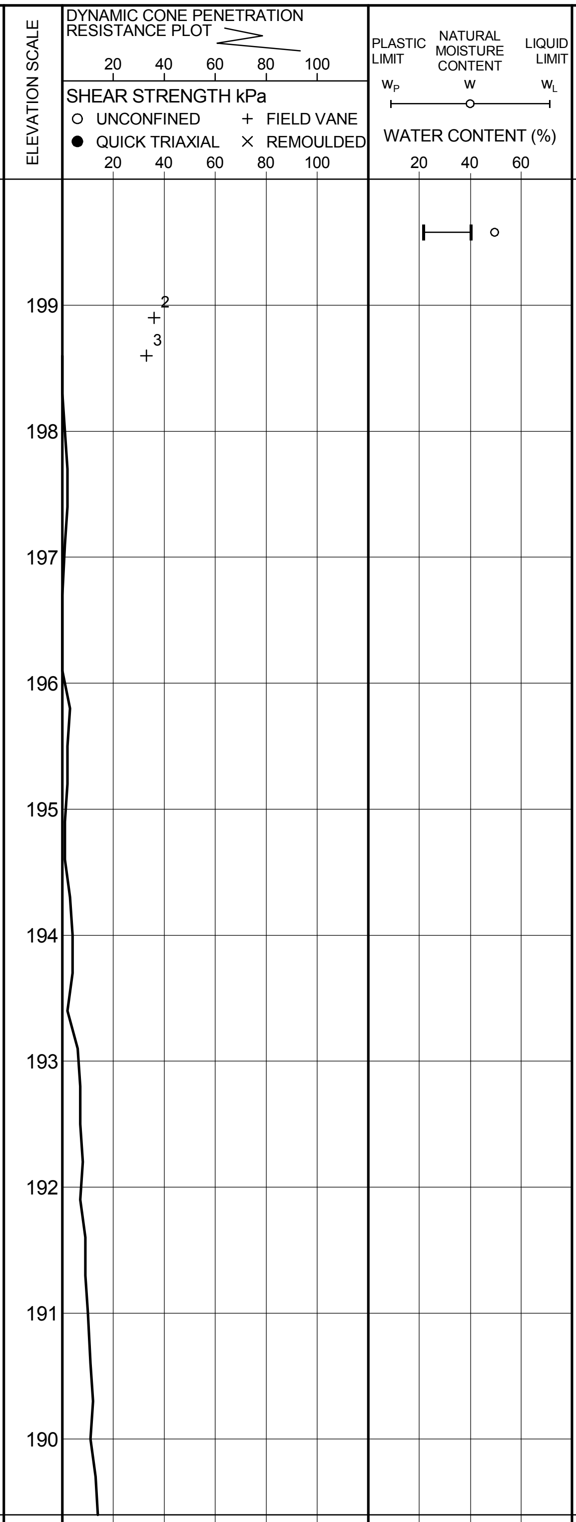
+3, ×3: Numbers refer to Sensitivity
○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-2

2 OF 2 **METRIC**

PROJECT 1535723
G.W.P. 5173-12-00
DIST SUDBURY HWY 17
DATUM GEODETIC
LOCATION N 5131877.9; E 263099.5 MTM ZONE 12 (LAT. 46.32531; LONG. -81.5416)
BOREHOLE TYPE Power Auger with 165 mm O.D. Continous Flight Hollow Stem Augers
DATE August 18, 2016
ORIGINATED BY AC
COMPILED BY ACK
CHECKED BY ARV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			
	--- CONTINUED FROM PREVIOUS PAGE ---							
	SILTY CLAY to CLAY Firm to stiff Grey Wet	▨	11	TO	PH		17.3	
198.6 13.4	END OF BOREHOLE START OF DCPT							
189.4 22.6	END OF DCPT Notes: 1. Water level at a depth of 11.9 m below ground surface (Elev. 200.1 m) upon completion of drilling.							



+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

SUD-MTO 001 MTM ZN INC LAT/LONG 1535723_HWY17.GPJ GAL-MISS.GDT 29/11/16 DATA INPUT:

RECORD OF BOREHOLE No 16-3

1 OF 3 **METRIC**

PROJECT 1535723		
G.W.P. 5173-12-00	LOCATION N 5131861.7; E 263077.6 MTM ZONE 12 (LAT. 46.32519; LONG. -81.5418)	ORIGINATED BY AC
DIST SUDBURY HWY 17	BOREHOLE TYPE Power Auger with 165 mm O.D. Continous Flight Hollow Stem Augers	COMPILED BY ACK
DATUM GEODETIC	DATE August 24, 2016	CHECKED BY ARV

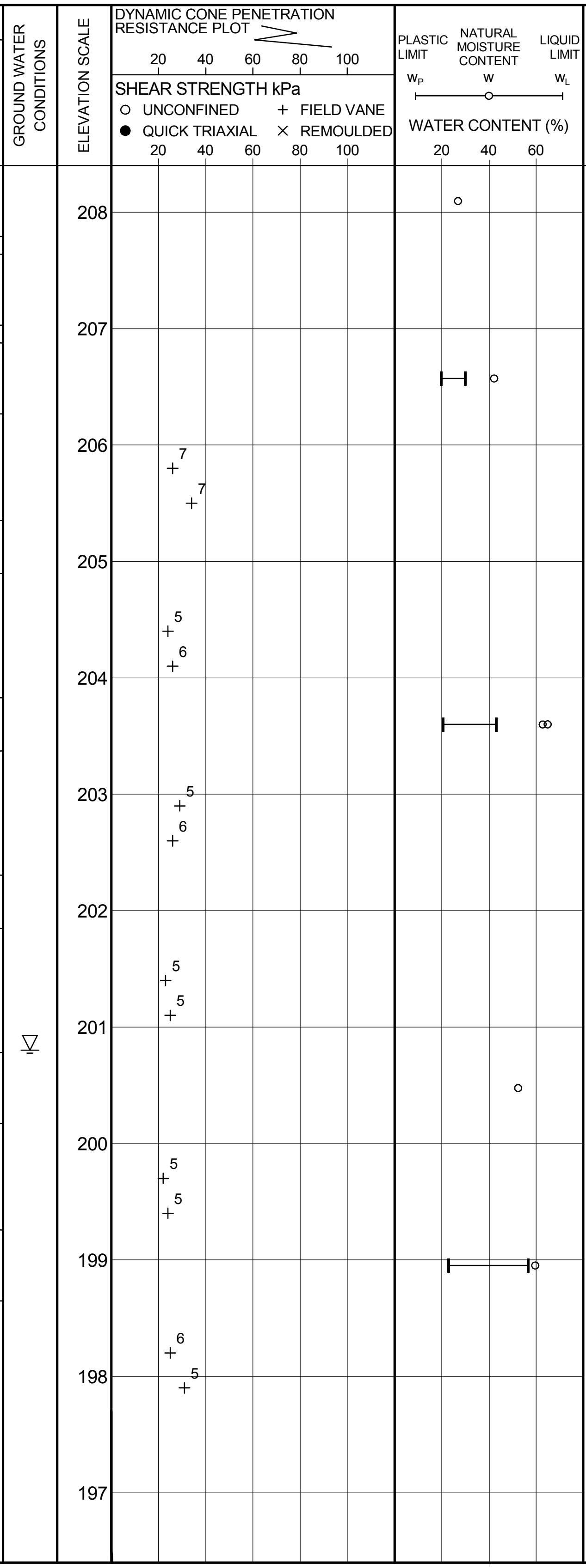
SOIL PROFILE

ELEV DEPTH	DESCRIPTION
208.4	GROUND SURFACE
0.0	TOPSOIL
208.0 0.4	Sand, trace silt (FILL) Compact Brown Moist
207.5 0.9	SILT and SAND, trace clay, trace organics Very loose Brown Moist
206.9 1.5	CLAYEY SILT, trace sand Firm Grey Wet
205.8 2.6	SILTY CLAY to CLAY, trace sand Soft to firm Grey Wet
197.7 10.7	END OF BOREHOLE START OF DCPT

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
1	SS	21					
2	SS	3					
3	SS	2		0	1	61	38
4	TO	PH					
5	TO	PH	15.9				
6	TO	PH					
7	SS	WH					
8	SS	WR		0	1	33	66

REMARKS & GRAIN SIZE DISTRIBUTION (%)



+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

Continued Next Page

RECORD OF BOREHOLE No 16-3

2 OF 3 **METRIC**

PROJECT 1535723
G.W.P. 5173-12-00
LOCATION N 5131861.7; E 263077.6 MTM ZONE 12 (LAT. 46.32519; LONG. -81.5418)
ORIGINATED BY AC
DIST SUDBURY HWY 17
BOREHOLE TYPE Power Auger with 165 mm O.D. Continous Flight Hollow Stem Augers
COMPILED BY ACK
DATUM GEODETIC
DATE August 24, 2016
CHECKED BY ARV

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

Continued Next Page

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

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

SUD-MTO 001 MTM ZN INC LAT/LONG 1535723_HWY17.GPJ GAL-MISS.GDT 29/11/16 DATA INPUT:

Golder Associates

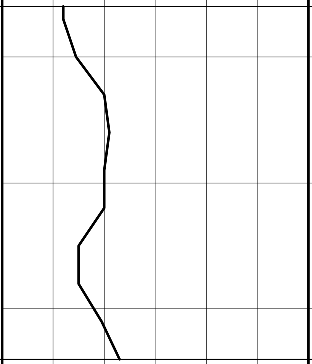
PROJECT 1535723

RECORD OF BOREHOLE No 16-3

3 OF 3 **METRIC**

G.W.P. 5173-12-00
LOCATION N 5131861.7; E 263077.6 MTM ZONE 12 (LAT. 46.32519; LONG. -81.5418)
ORIGINATED BY AC
DIST SUDBURY HWY 17
BOREHOLE TYPE Power Auger with 165 mm O.D. Continous Flight Hollow Stem Augers
COMPILED BY ACK
DATUM GEODETIC
DATE August 24, 2016
CHECKED BY ARV

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
							184				
							183				
							182				
181.6 26.8	END OF DCPT Notes: 1. Water level at a depth of 7.6 m below ground surface (Elev. 200.8 m) upon completion of drilling.										

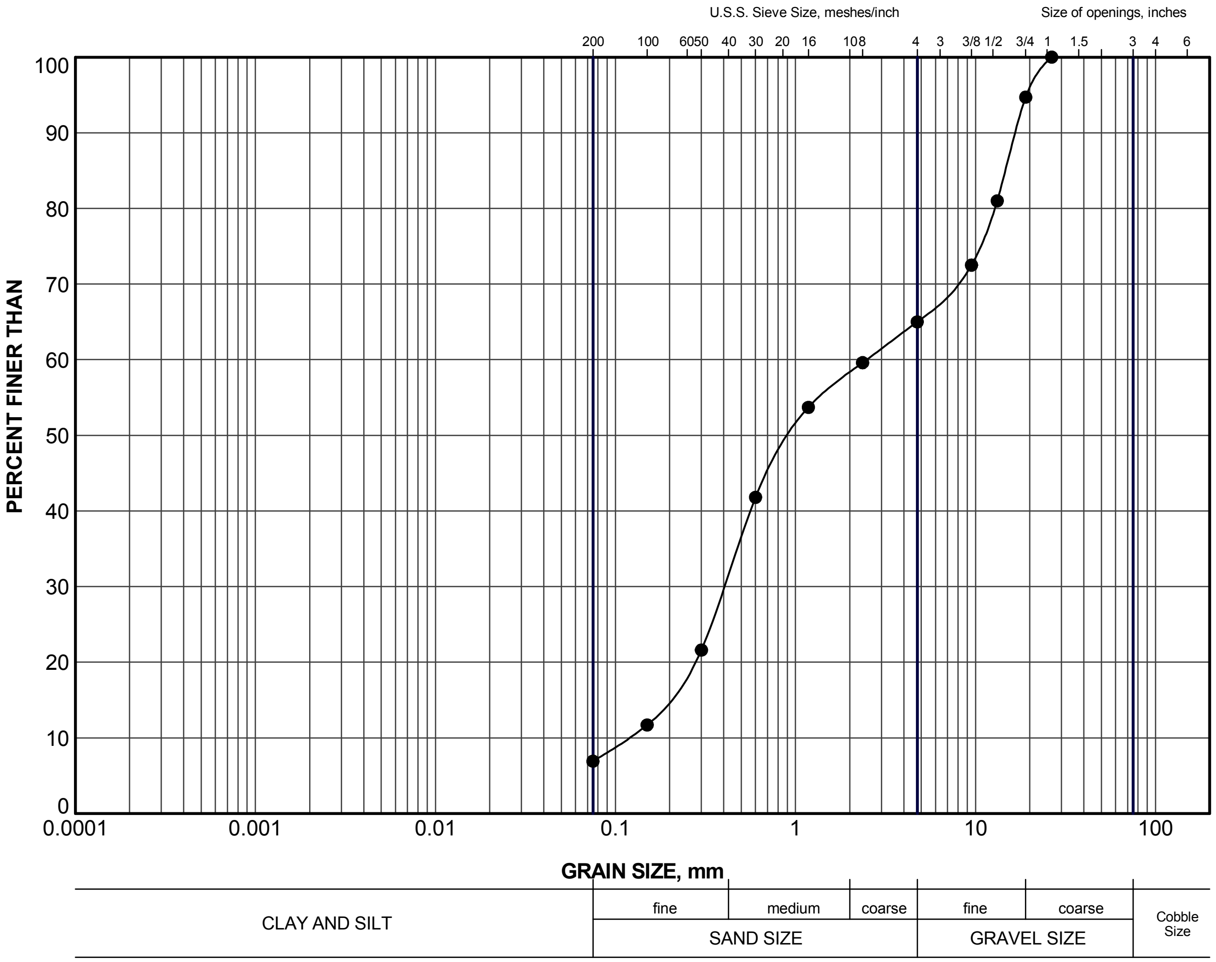


$+^3, \times^3$: Numbers refer to Sensitivity

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

APPENDIX B

Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	16-2	4	209.5

PROJECT

HIGHWAY 17
Blake Creek Culvert

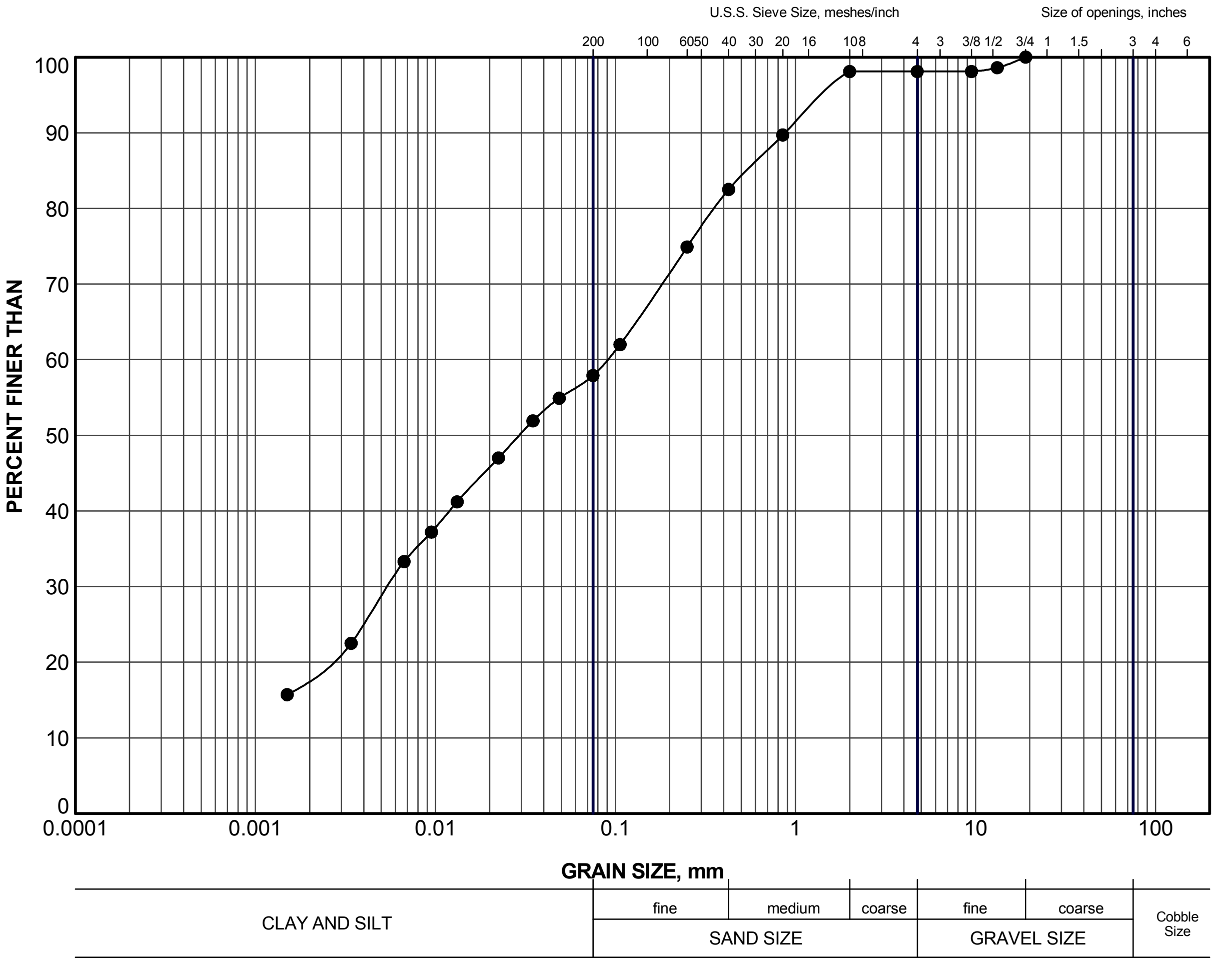
TITLE

GRAIN SIZE DISTRIBUTION

SAND and GRAVEL (FILL)

PROJECT No.		1535723	FILE No. 1535723_HWY17.GPJ
DRAWN	JJL	Nov 2016	SCALE N/A REV.
CHECK	ARV	Nov 2016	
APPR	SEMP	Nov 2016	**FIGURE B1**

Golder Associates
SUDBURY, ONTARIO



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	16-2	6	207.2

PROJECT

HIGHWAY 17
Blake Creek Culvert

TITLE

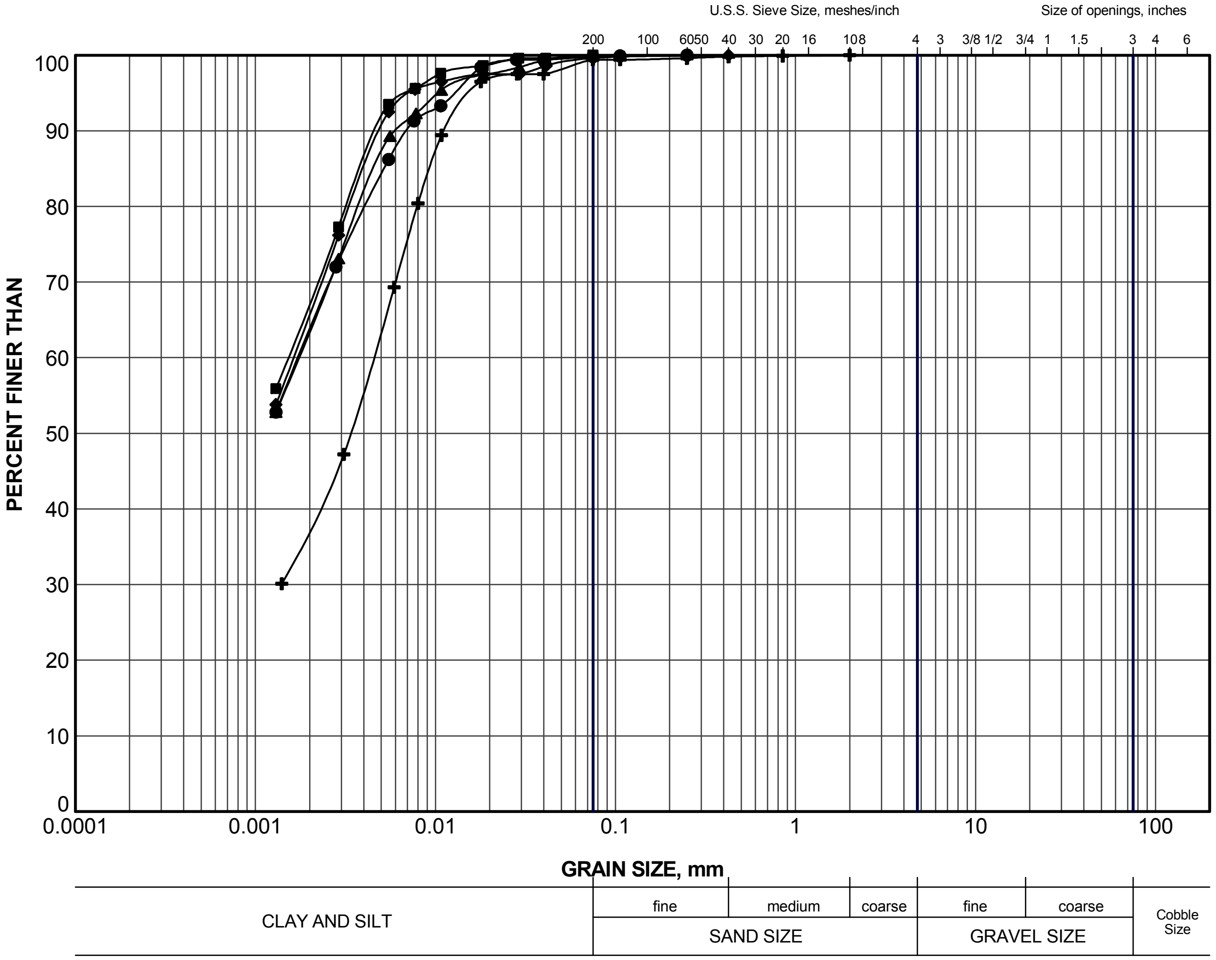
GRAIN SIZE DISTRIBUTION

CLAYEY SILT to CLAYEY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1535723	FILE No. 1535723_HWY17.GPJ	
DRAWN	JJL	Nov 2016	SCALE N/A	REV.
CHECK	ARV	Nov 2016	**FIGURE B2A**	
APPR	SEMP	Nov 2016		

SUD-MTO GSD (2016) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	16-1	6	202.7
■	16-1	10	196.6
▲	16-2	9	202.6
✚	16-3	3	206.6
◆	16-3	8	199.0

PROJECT

HIGHWAY 17
Blake Creek Culvert

TITLE

GRAIN SIZE DISTRIBUTION

CLAYEY SILT to CLAY

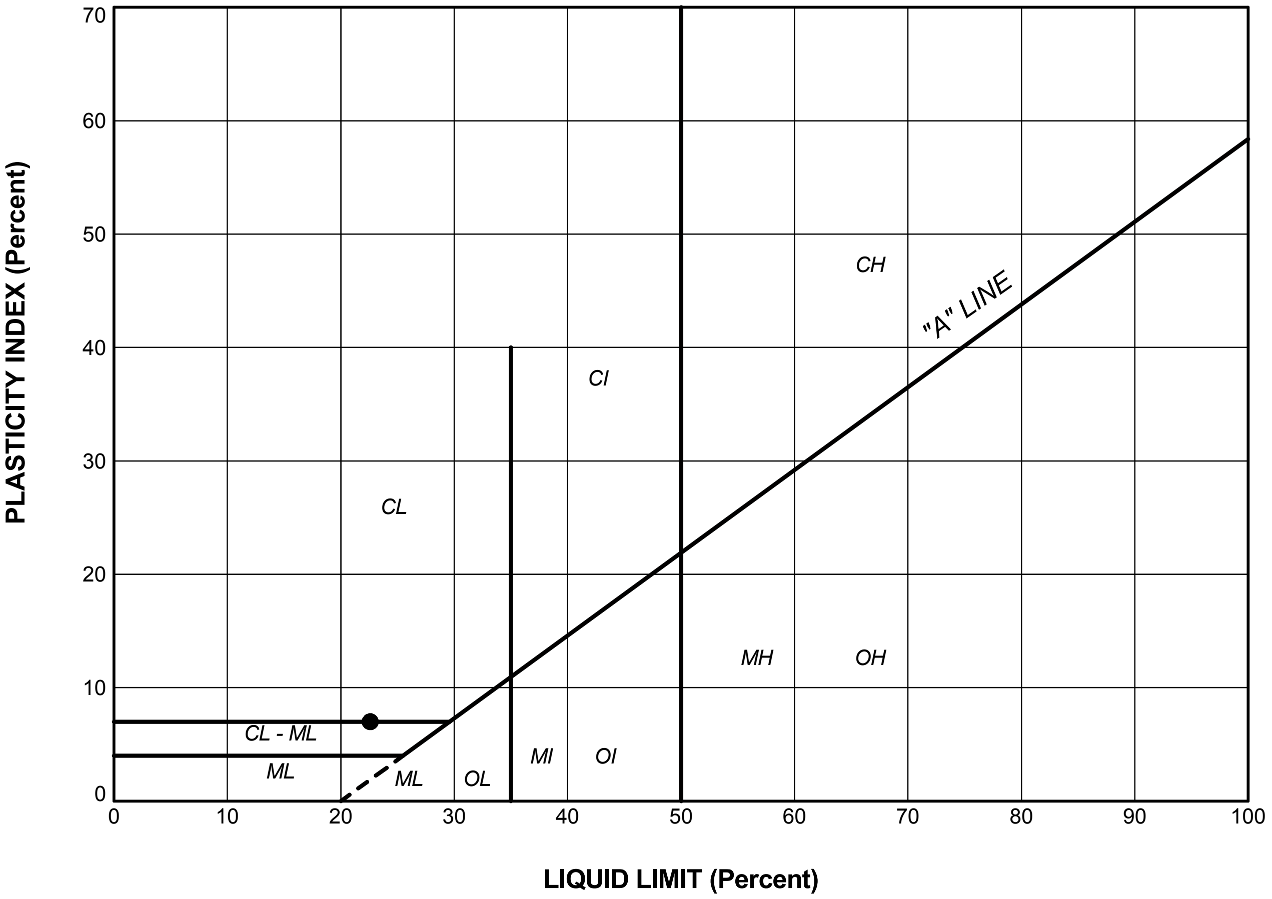
Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1535723
DRAWN	JJL	Nov 2016
CHECK	ARV	Nov 2016
APPR	SEMP	Nov 2016

FILE No. 1535723_HWY17.GPJ
SCALE N/A
REV.

FIGURE B2B

SUD-MTO GSD (2016) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	16-2	6	22.6	15.6	7.0

PROJECT

HIGHWAY 17
Blake Creek Culvert

TITLE

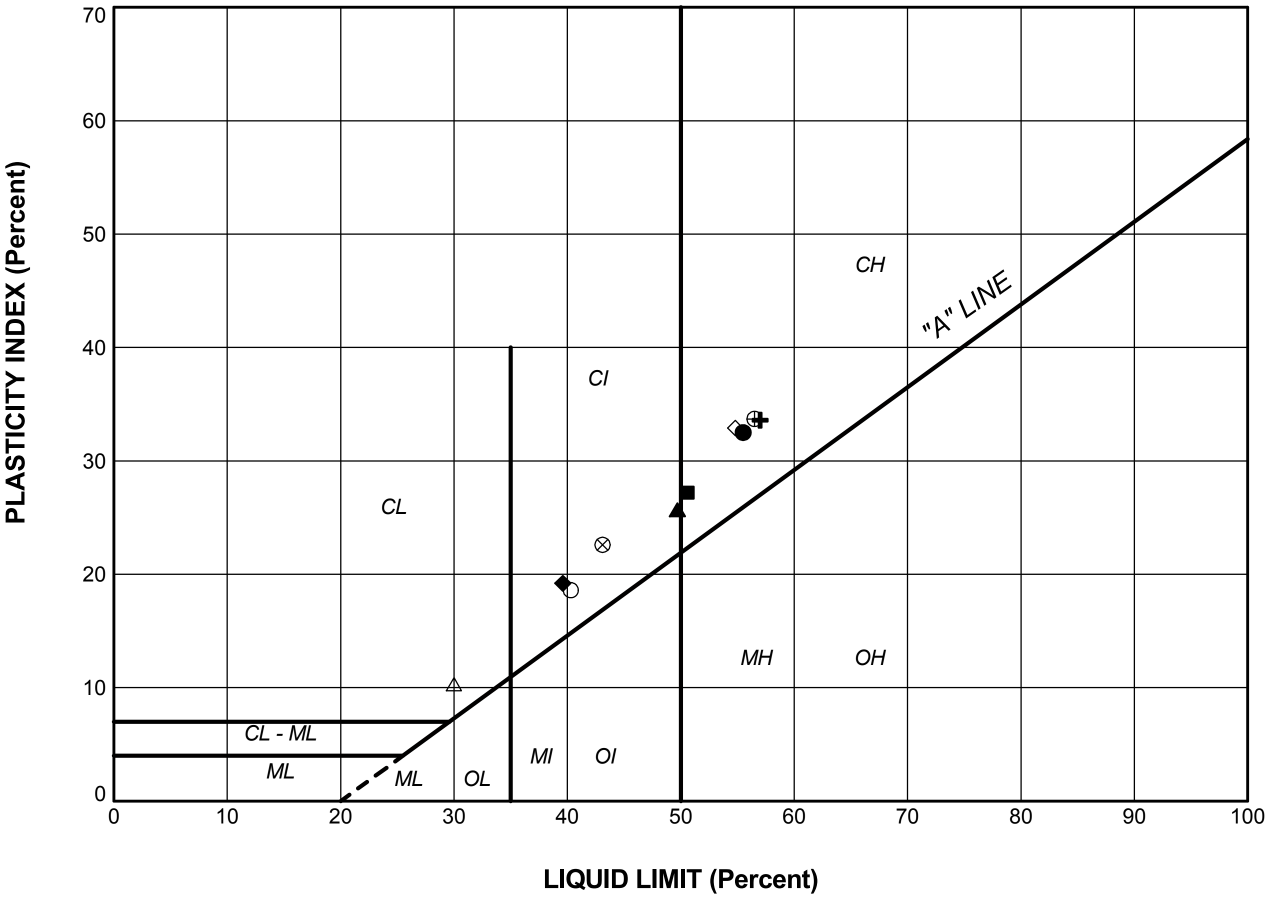
PLASTICITY CHART

CLAYEY SILT with SAND

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1535723	FILE No.	1535723_HWY17.GPJ	
DRAWN	JJL	Nov 2016	SCALE	N/A	REV.
CHECK	ARV	Nov 2016			
APPR	SEMP	Nov 2016	FIGURE B3A		

SUD-MTO PL (2016) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	16-1	6	55.5	23.0	32.5
■	16-1	8	50.6	23.4	27.2
▲	16-1	10	49.7	24.0	25.7
✚	16-1	12	57.0	23.4	33.6
◆	16-2	8	39.6	20.4	19.2
◇	16-2	9	54.8	21.9	32.9
○	16-2	11	40.3	21.7	18.6
△	16-3	3	30.0	19.7	10.3
⊗	16-3	5	43.1	20.5	22.6
⊕	16-3	8	56.5	22.8	33.7

PROJECT
HIGHWAY 17
Blake Creek Culvert

TITLE
PLASTICITY CHART
CLAYEY SILT to CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1535723	FILE No.	1535723_HWY17.GPJ
DRAWN	JJL	Nov 2016	SCALE N/A	REV.
CHECK	ARV	Nov 2016	**FIGURE B3B**	
APPR	SEMP	Nov 2016		

SUD-MTO PL (2016) GLDR_LDN.GDT

CONSOLIDATION TEST SUMMARY
Highway 17 STA 11+970 Blake Creek Culvert

FIGURE B4
Page 1 of 4

SAMPLE IDENTIFICATION

Project Number	1535723	Sample Number	8
Borehole Number	16-1	Sample Depth, m	9.17

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	2		
Date Started	9/19/16		
Date Completed	10/4/16		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.52	Unit Weight, kN/m3	16.150
Sample Diameter, cm	6.36	Dry Unit Weight, kN/m3	9.790
Area, cm2	31.74	Specific Gravity, measured	2.768
Volume, cm3	80.06	Solids Height, cm	0.910
Water Content, %	64.96	Volume of Solids, cm3	28.873
Wet Mass, g	131.84	Volume of Voids, cm3	51.186
Dry Mass, g	79.92	Degree of Saturation, %	101.435

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv, cm^2/s	mv m^2/kN	k cm/s
0	2.522	1.773	2.522				
4	2.521	1.772	2.521	93	0.0145	1.03E-04	1.46E-07
13	2.520	1.770	2.520	135	0.0100	4.94E-05	4.83E-08
31	2.514	1.764	2.517	470	0.0029	1.22E-04	3.43E-08
66	2.503	1.752	2.509	240	0.0056	1.23E-04	6.72E-08
137	2.452	1.696	2.478	1500	0.0009	2.88E-04	2.45E-08
277	2.180	1.397	2.316	5415	0.0002	7.68E-04	1.58E-08
558	2.037	1.240	2.109	2160	0.0004	2.02E-04	8.64E-09
1118	1.938	1.131	1.988	1058	0.0008	7.01E-05	5.43E-09
558	1.947	1.141	1.943				
137	1.980	1.177	1.964				
31	2.016	1.217	1.998				
4	2.048	1.252	2.032				

Note:
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	2.05	Unit Weight, kN/m3	16.66
Sample Diameter, cm	6.36	Dry Unit Weight, kN/m3	12.06
Area, cm2	31.74	Specific Gravity, measured	2.77
Volume, cm3	65.01	Solids Height, cm	0.910
Water Content, %	38.18	Volume of Solids, cm 3	28.87
Wet Mass, g	110.43	Volume of Voids, cm 3	36.14
Dry Mass, g	79.92		

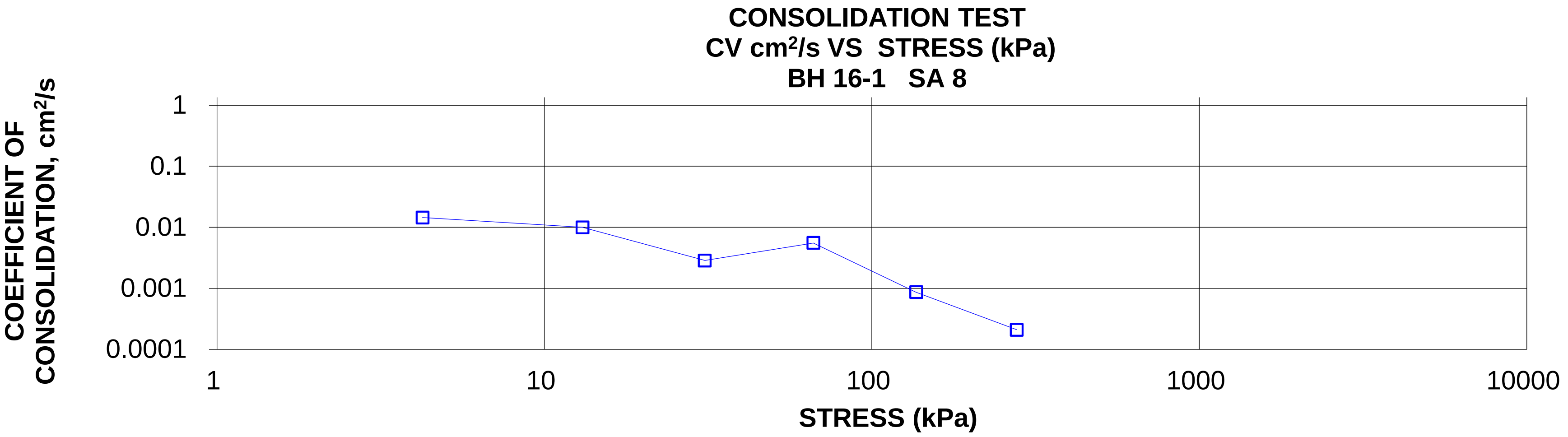
Prepared By: TG

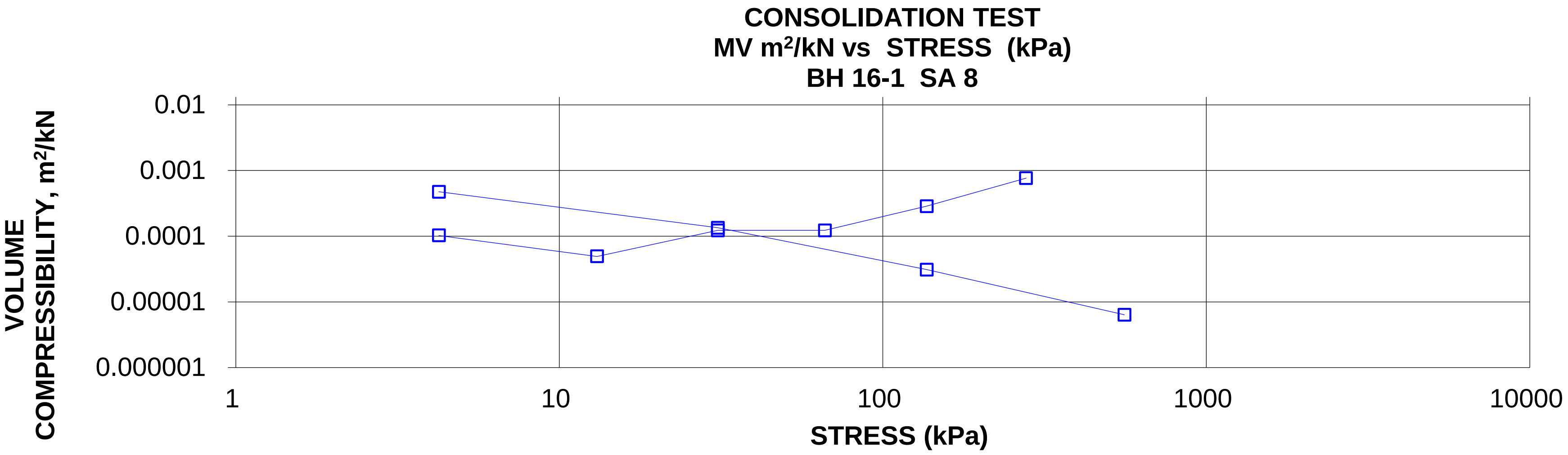
Golder Associates

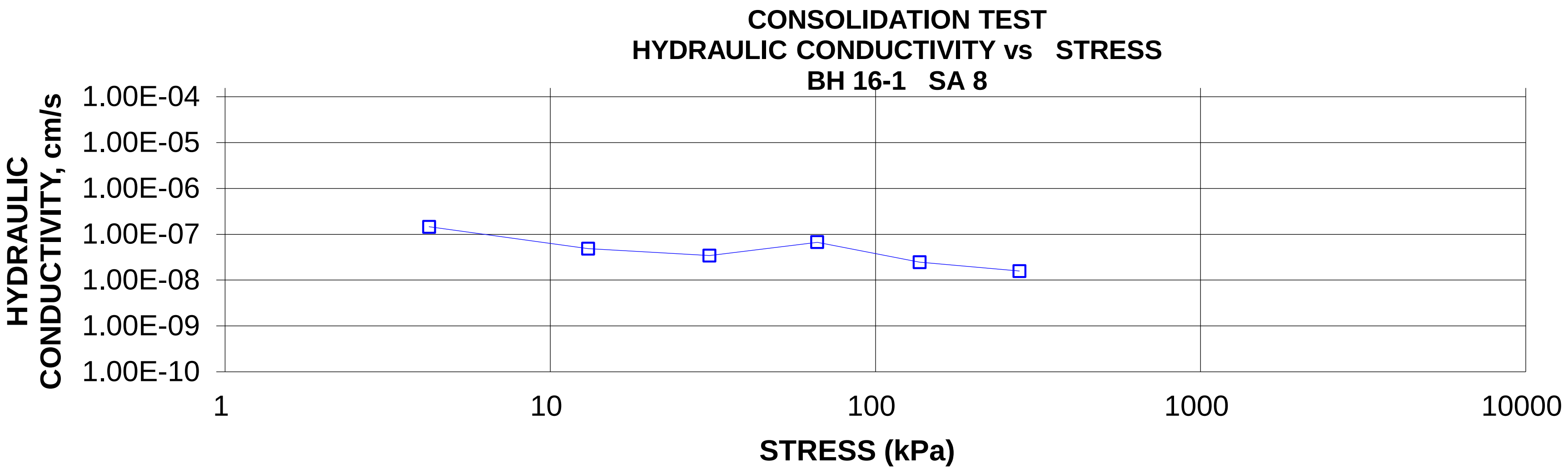
Checked By: MT

CONSOLIDATION TEST SUMMARY
Highway 17 STA 11+970 Blake Creek Culvert

FIGURE B4
Page 2 of 4







Project No. 1535723
Prepared By: TG

Golder Associates

Checked By: MT

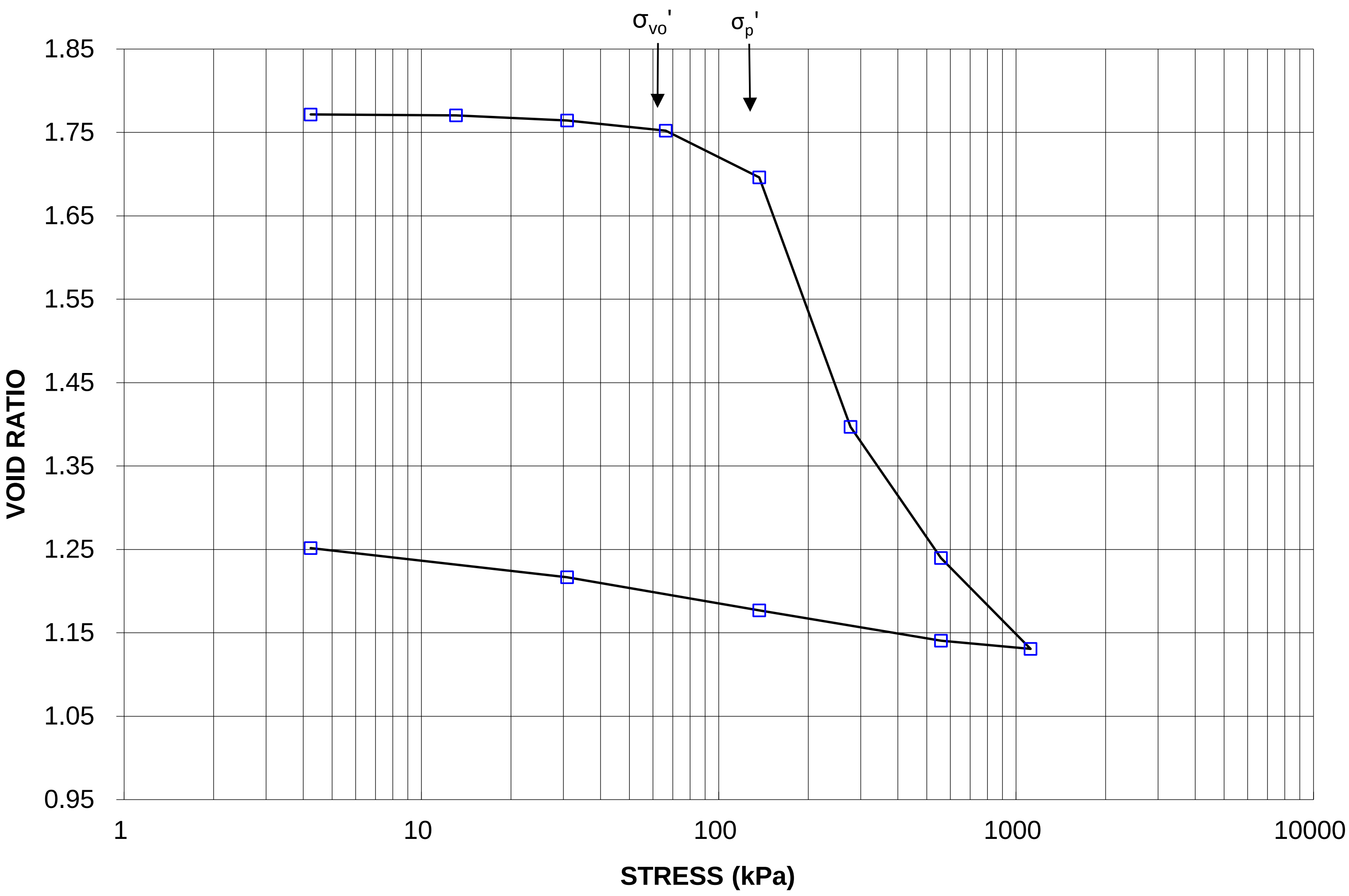
Project No. 1535723

Prepared By: TG

Golder Associates

Checked By: MT

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 16-1 SA 8



CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE B4
Page 3 of 4

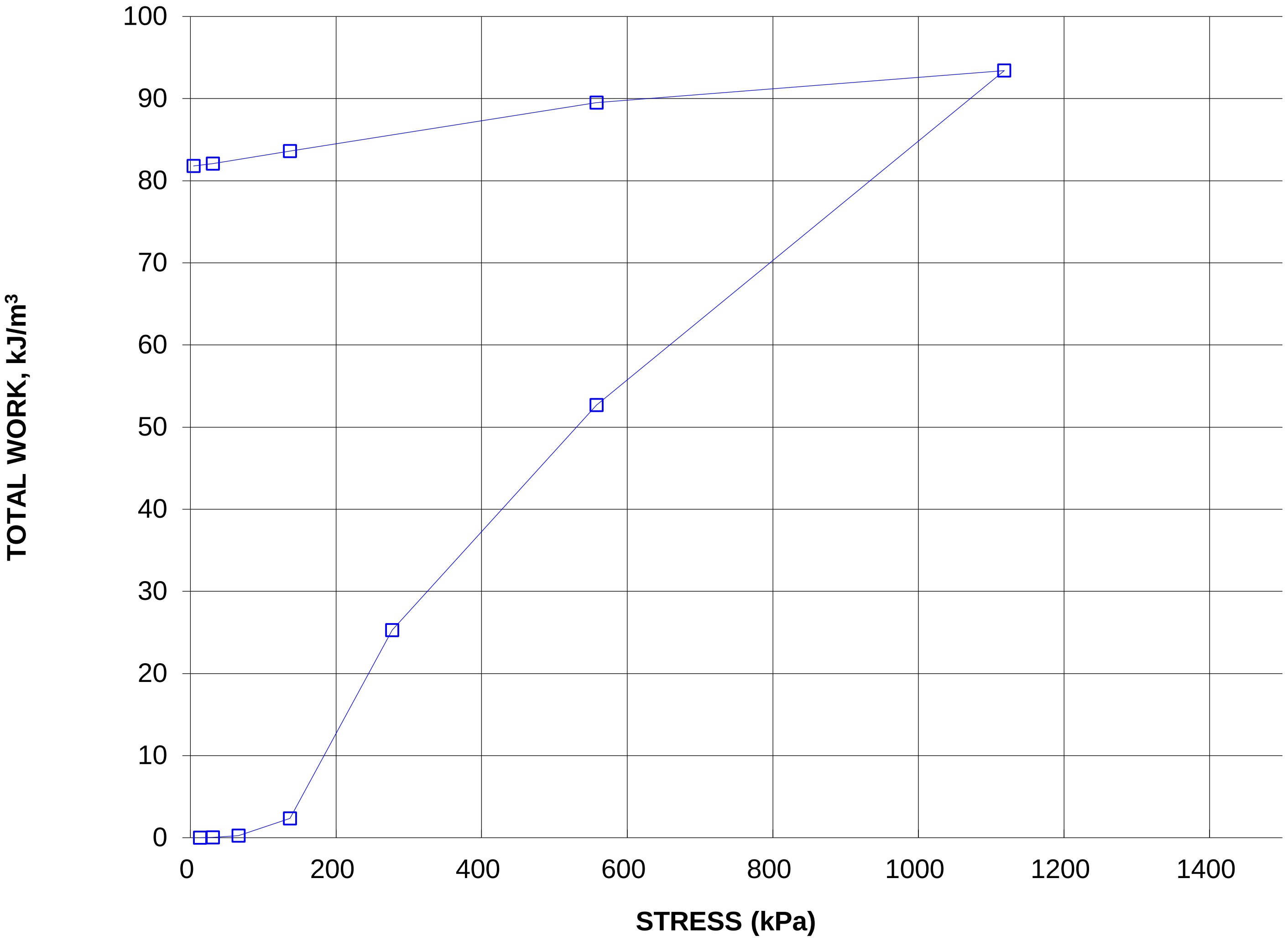
Project No. 1535723

Prepared By: TG

Golder Associates

Checked By: MT

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 16-1 SA 8



CONSOLIDATION TEST
TOTAL WORK VS STRESS

FIGURE B4
Page 4 of 4

CONSOLIDATION TEST SUMMARY

Highway 17 STA 11+970 BH 16-2 SA 8

FIGURE B5

Page 1 of 4

SAMPLE IDENTIFICATION

Project Number:	1535723	Sample Number:	8
Borehole Number:	16-2	Sample Depth, m:	8.02

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	2		
Date Started	9/9/16		
Date Completed	9/19/16		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.522	Unit Weight, kN/m^3	17.05
Sample Diameter, cm	6.358	Dry Unit Weight, kN/m^3	11.22
Area, cm^2	31.74	Specific Gravity, Measured	2.756
Volume, cm^3	80.06	Solids Height, cm	1.047
Water Content, %	51.95	Volume of Solids, cm^3	33.24
Wet Mass, g	139.20	Volume of Voids, cm^3	46.82
Dry Mass, g	91.61		

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv, cm^2/s	mv m^2/kN	k cm/s
0	2.522	1.408	2.522				
4	2.513	1.400	2.518	3840	3.50E-04	8.23E-04	2.82E-08
13	2.504	1.391	2.509	540	2.47E-03	4.20E-04	1.02E-07
31	2.486	1.374	2.495	2018	6.54E-04	4.04E-04	2.59E-08
66	2.455	1.344	2.470	1500	8.62E-04	3.45E-04	2.92E-08
137	2.392	1.285	2.424	2160	5.76E-04	3.53E-04	2.00E-08
277	2.289	1.186	2.341	2381	4.88E-04	2.92E-04	1.39E-08
558	2.217	1.117	2.253	1441			
1117	2.145	1.048	2.181	437			
558	2.154	1.057	2.149				
137	2.188	1.089	2.171				
31	2.225	1.125	2.206				
4	2.250	1.149	2.237				

Note:
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	2.25	Unit Weight, kN/m3	16.96
Sample Diameter, cm	6.36	Dry Unit Weight, kN/m3	12.58
Area, cm2	31.74	Specific Gravity, measured	2.76
Volume, cm3	71.43	Solids Height, cm	1.047
Water Content, %	34.83	Volume of Solids, cm 3	33.24
Wet Mass, g	123.52	Volume of Voids, cm 3	38.19
Dry Mass, g	91.61		

Prepared By: TG

Golder Associates

Checked By: MT

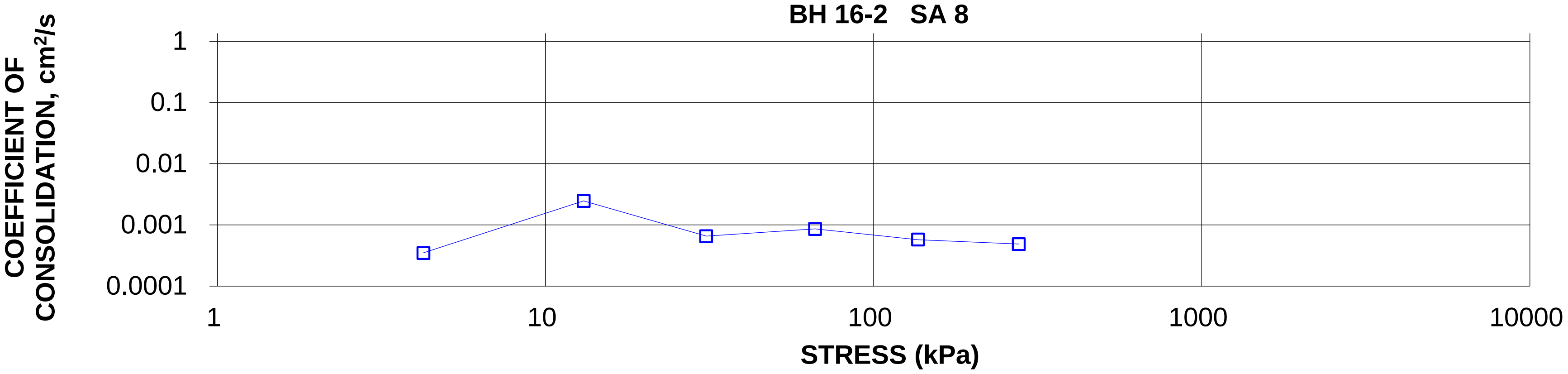
CONSOLIDATION TEST SUMMARY

Highway 17 STA 11+970 BH 16-2 SA 8

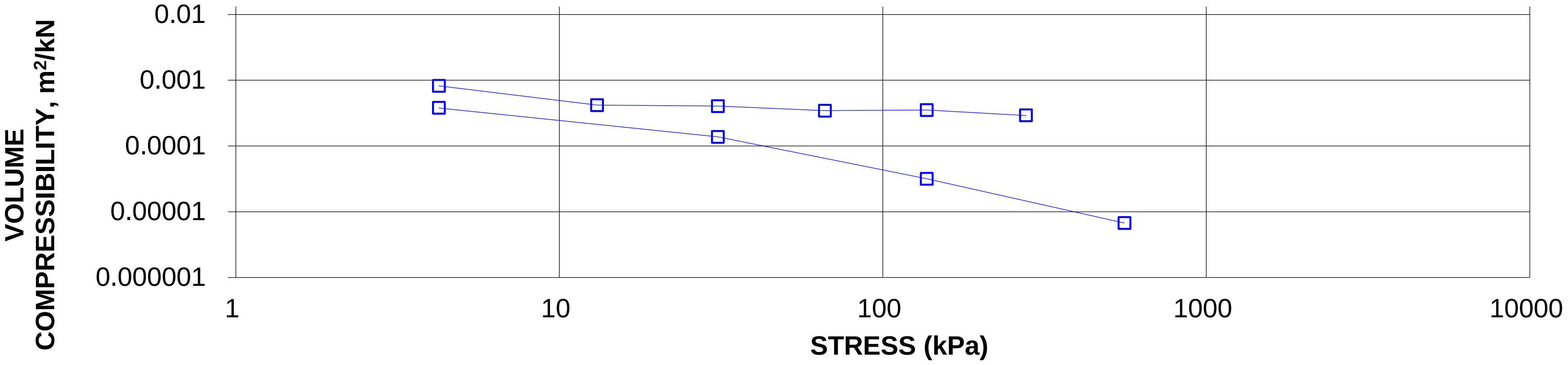
FIGURE B5

Page 2 of 4

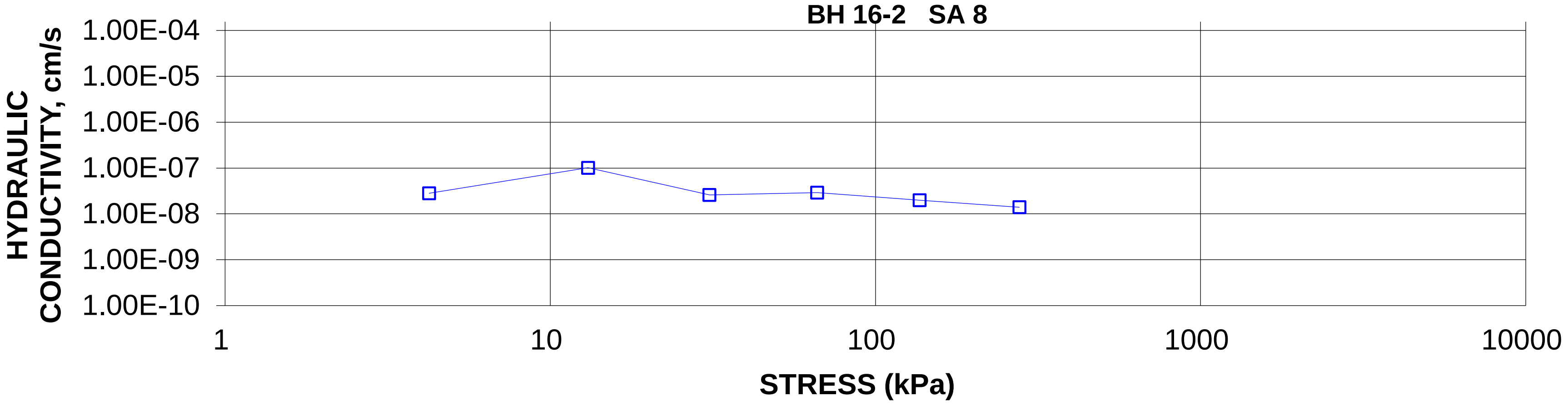
CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH 16-2 SA 8



CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 16-2 SA 8



CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 16-2 SA 8



Project No. 1535723
Prepared By: TG

Golder Associates

Checked By: MT

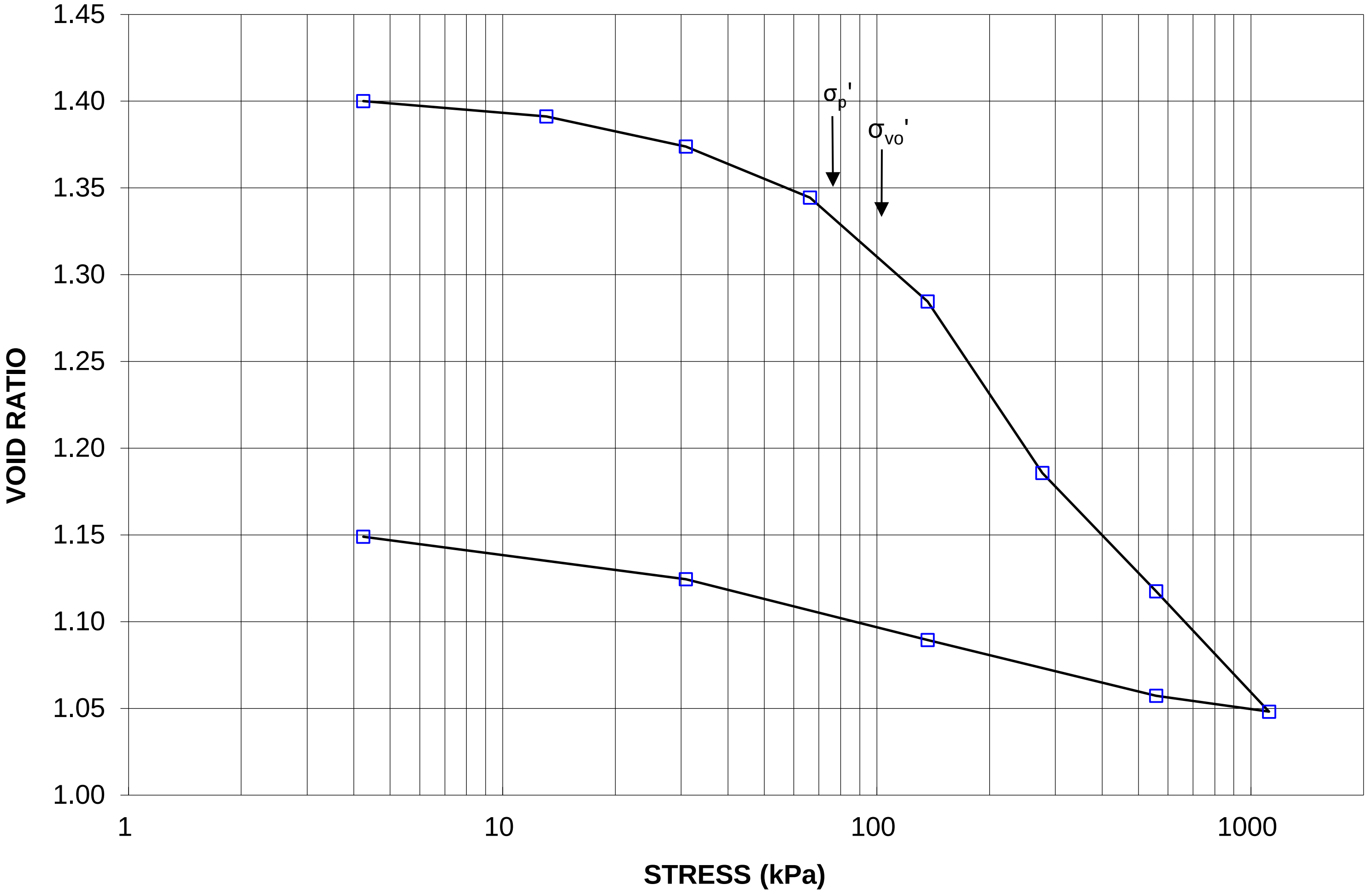
Project No. 1535723

Prepared By: TG

Golder Associates

Checked By: MT

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 16-2 SA 8



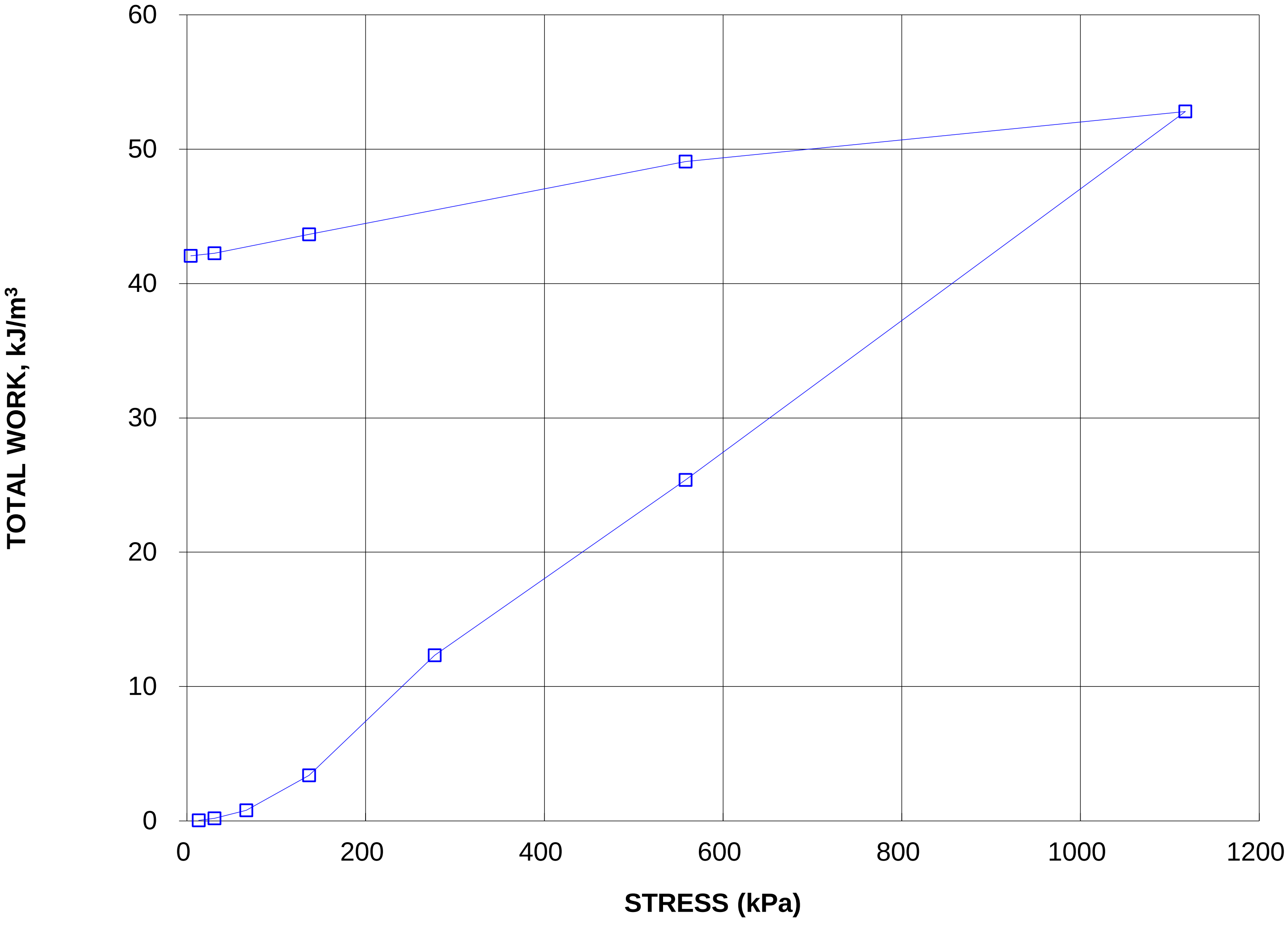
CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE B5
Page 3 of 4

Project No. 1535723
Prepared By: TG

Golder Associates

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 16-2 SA 8



Checked By: MT

CONSOLIDATION TEST
TOTAL WORK VS STRESS

FIGURE B5
Page 4 of 4

CONSOLIDATION TEST SUMMARY

Highway 17 STA 11+970 Blake Creek Culvert

FIGURE B6

Page 1 of 4

SAMPLE IDENTIFICATION

Project Number	1535723	Sample Number	11
Borehole Number	16-2	Sample Depth, m	12.4

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	1		
Date Started	9/19/16		
Date Completed	10/4/16		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.54	Unit Weight, kN/m3	17.28
Sample Diameter, cm	6.36	Dry Unit Weight, kN/m3	11.71
Area, cm2	31.74	Specific Gravity, measured	2.77
Volume, cm3	80.75	Solids Height, cm	1.097
Water Content, %	47.54	Volume of Solids, cm3	34.82
Wet Mass, g	142.30	Volume of Voids, cm3	45.93
Dry Mass, g	96.45	Degree of Saturation, %	99.8

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv, cm^2/s	mv m^2/kN	k cm/s
0	2.544	1.319	2.544				
9	2.538	1.313	2.541	614	0.0022	2.90E-04	6.34E-08
18	2.532	1.308	2.535	540	0.0025	2.32E-04	5.74E-08
35	2.521	1.298	2.527	540	0.0025	2.51E-04	6.17E-08
69	2.502	1.281	2.512	614	0.0022	2.22E-04	4.74E-08
143	2.455	1.238	2.478	676	0.0019	2.53E-04	4.78E-08
285	2.345	1.137	2.400	2160	0.0006	3.04E-04	1.68E-08
570	2.246	1.047	2.295	866	0.0013	1.37E-04	1.72E-08
1140	2.158	0.967	2.202	540	0.0019	6.07E-05	1.13E-08
570	2.166	0.975	2.162				
143	2.195	1.001	2.181				
35	2.228	1.031	2.212				
9	2.260	1.060	2.244				

Note:
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	2.26	Unit Weight, kN/m3	17.65
Sample Diameter, cm	6.36	Dry Unit Weight, kN/m3	13.18
Area, cm2	31.74	Specific Gravity, measured	2.77
Volume, cm3	71.74	Solids Height, cm	1.097
Water Content, %	33.84	Volume of Solids, cm 3	34.82
Wet Mass, g	129.09	Volume of Voids, cm 3	36.92
Dry Mass, g	96.45		

Prepared By: TG **Golder Associates** Checked By: MT

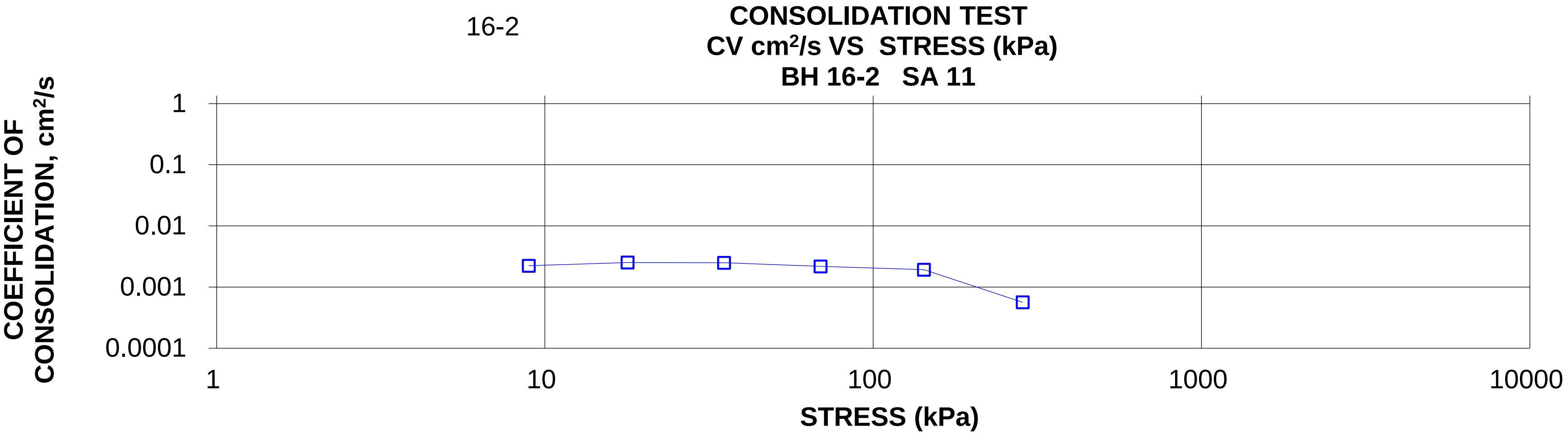
CONSOLIDATION TEST SUMMARY

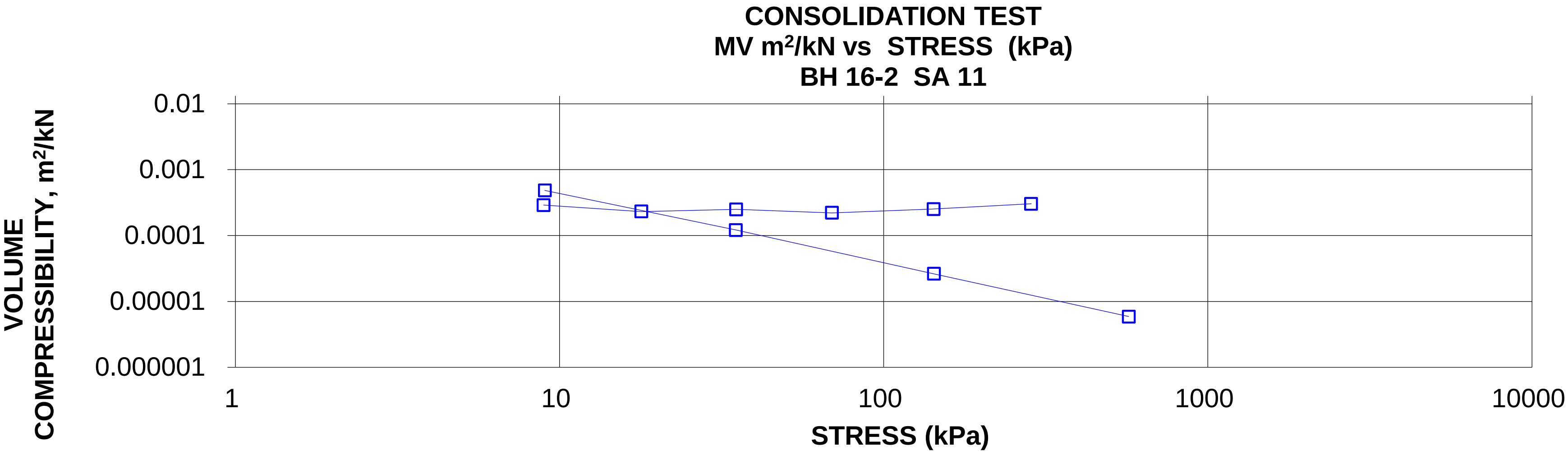
Highway 17 STA 11+970 Blake Creek Culvert

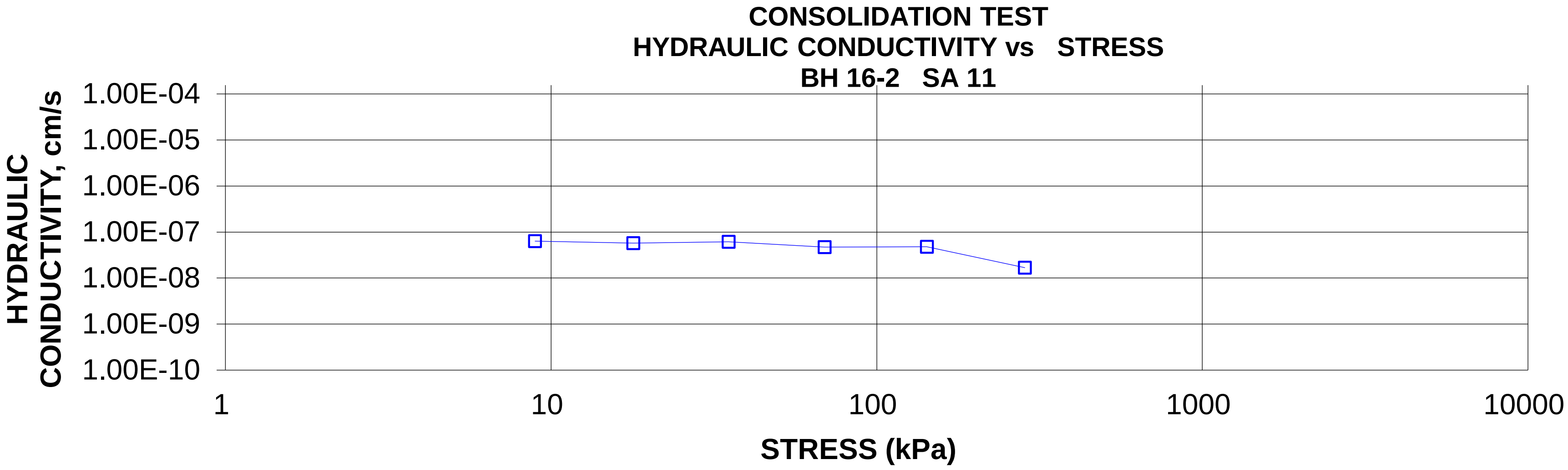
FIGURE B6

Page 2 of 4

16-2







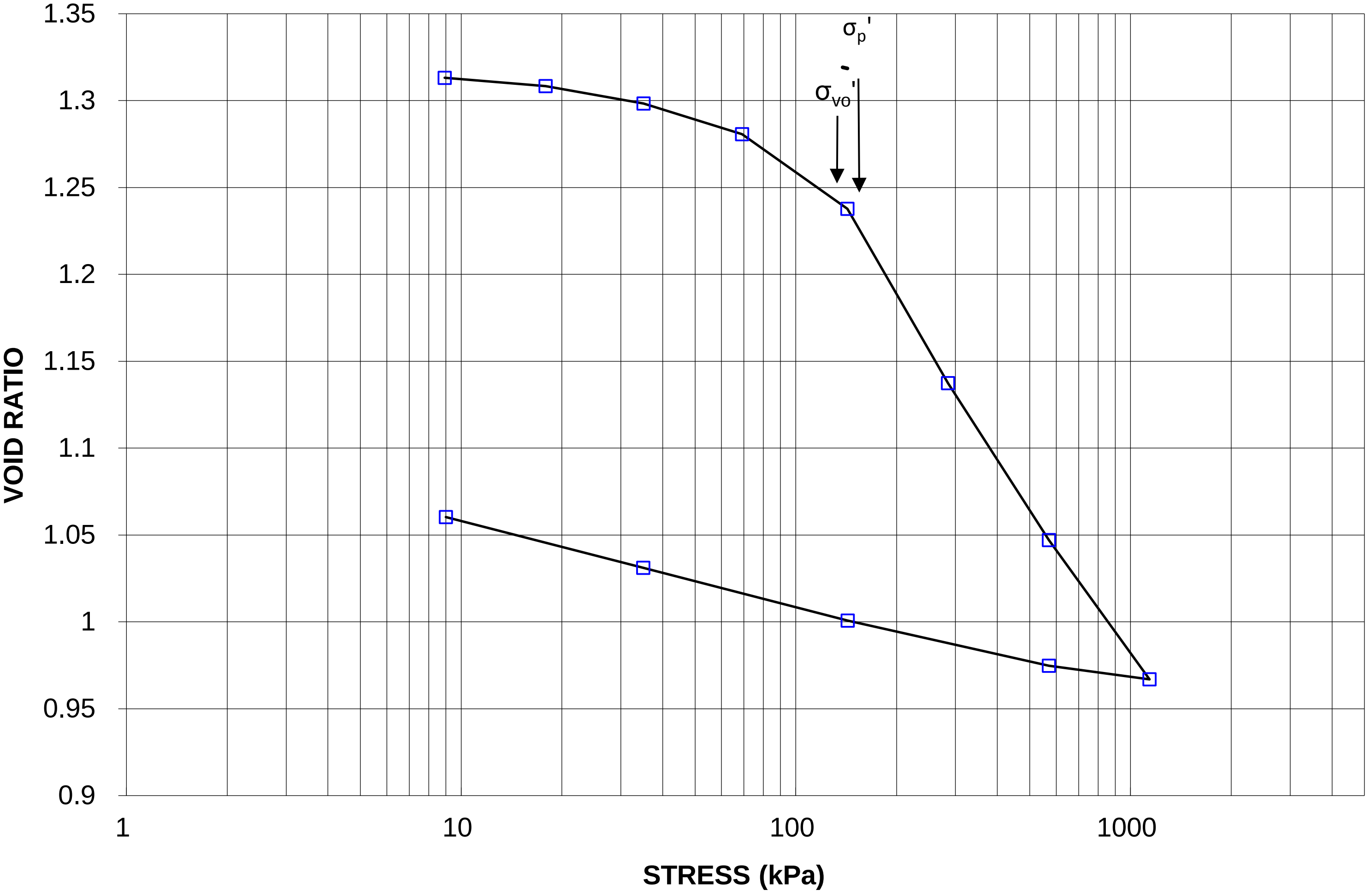
Project No. 1535723

Prepared By: TG

Golder Associates

Checked By: MT

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 16-2 SA 11



CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

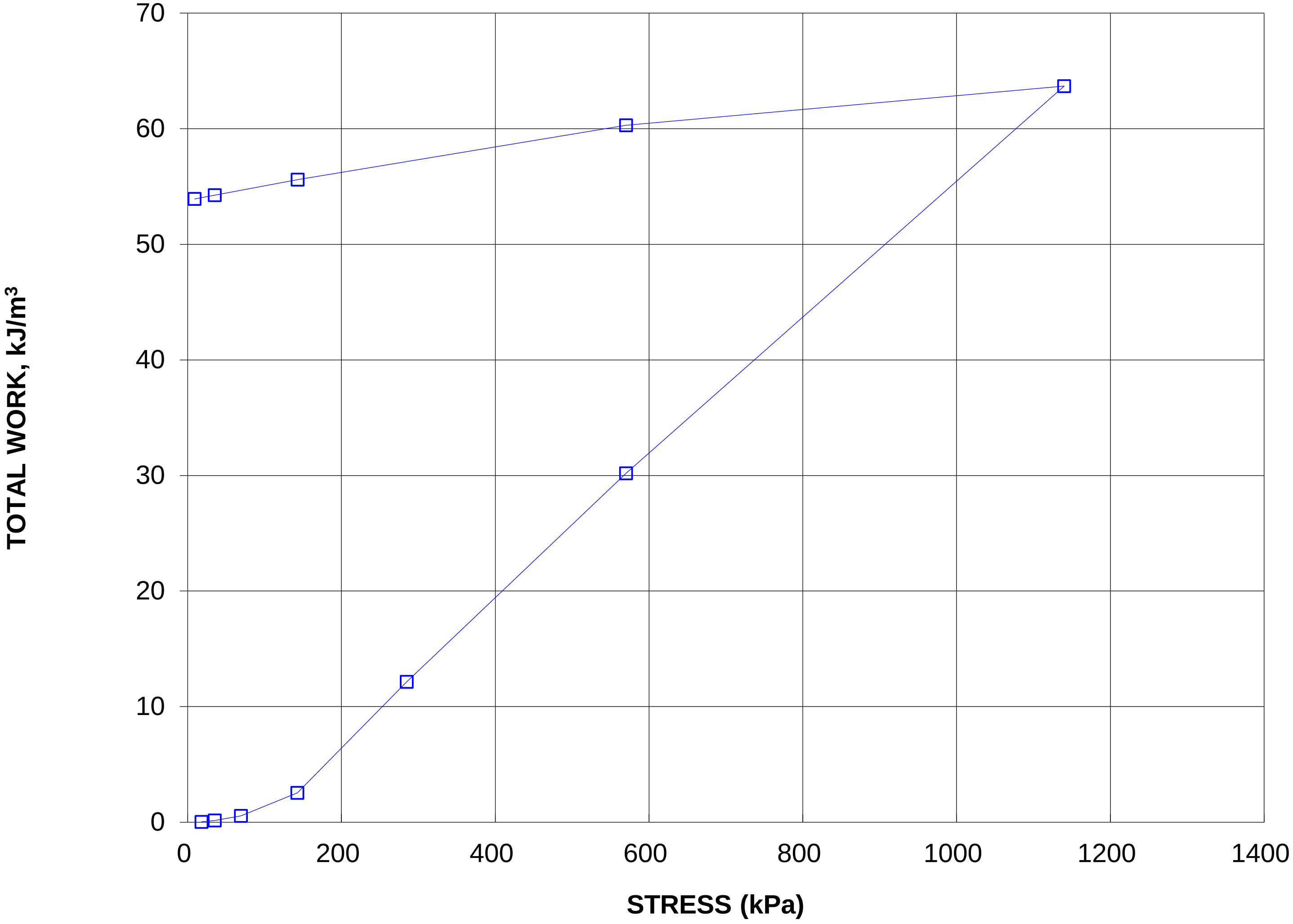
FIGURE B6
Page 3 of 4

Project No. 1535723
Prepared By: TG

Golder Associates

Checked By: MT

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 16-2 SA 11



CONSOLIDATION TEST
TOTAL WORK VS STRESS

FIGURE B6
Page 4 of 4

CONSOLIDATION TEST SUMMARY
Highway 17 STA 11+970 Blake Creek Culvert

FIGURE B7

SAMPLE IDENTIFICATION

Project Number	1535723	Sample Number	5
Borehole Number	16-3	Sample Depth, m	4.80

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	1		
Date Started	9/9/16		
Date Completed	9/19/16		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.54	Unit Weight, kN/m3	15.92
Sample Diameter, cm	6.36	Dry Unit Weight, kN/m3	9.66
Area, cm2	31.74	Specific Gravity, measured	2.75
Volume, cm3	80.75	Solids Height, cm	0.913
Water Content, %	64.85	Volume of Solids, cm3	28.98
Wet Mass, g	131.12	Volume of Voids, cm3	51.78
Dry Mass, g	79.54	Degree of Saturation, %	99.6

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv, cm^2/s	mv m^2/kN	k cm/s
0	2.544	1.787	2.544				
9	2.540	1.782	2.542	317	4.32E-03	1.94E-04	8.19E-08
18	2.536	1.778	2.538	290	4.70E-03	1.69E-04	7.80E-08
35	2.523	1.763	2.529	735	1.85E-03	3.01E-04	5.45E-08
69	2.504	1.742	2.513	290	4.61E-03	2.21E-04	9.97E-08
143	2.483	1.719	2.493	317	4.16E-03	1.12E-04	4.58E-08
285	2.175	1.382	2.329	4438	2.59E-04	8.50E-04	2.16E-08
570	2.065	1.262	2.120	1750			
1140	1.974	1.163	2.020	1561			
570	1.985	1.174	1.980				
143	2.021	1.213	2.003				
35	2.063	1.260	2.042				
9	2.091	1.291	2.077				

Note:
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	2.09	Unit Weight, kN/m3	16.36
Sample Diameter, cm	6.36	Dry Unit Weight, kN/m3	11.75
Area, cm2	31.74	Specific Gravity, measured	2.75
Volume, cm3	66.38	Solids Height, cm	0.913
Water Content, %	39.21	Volume of Solids, cm 3	28.98
Wet Mass, g	110.73	Volume of Voids, cm 3	37.40
Dry Mass, g	79.54		

Prepared By: TG

Golder Associates

Checked By: MT

CONSOLIDATION TEST SUMMARY

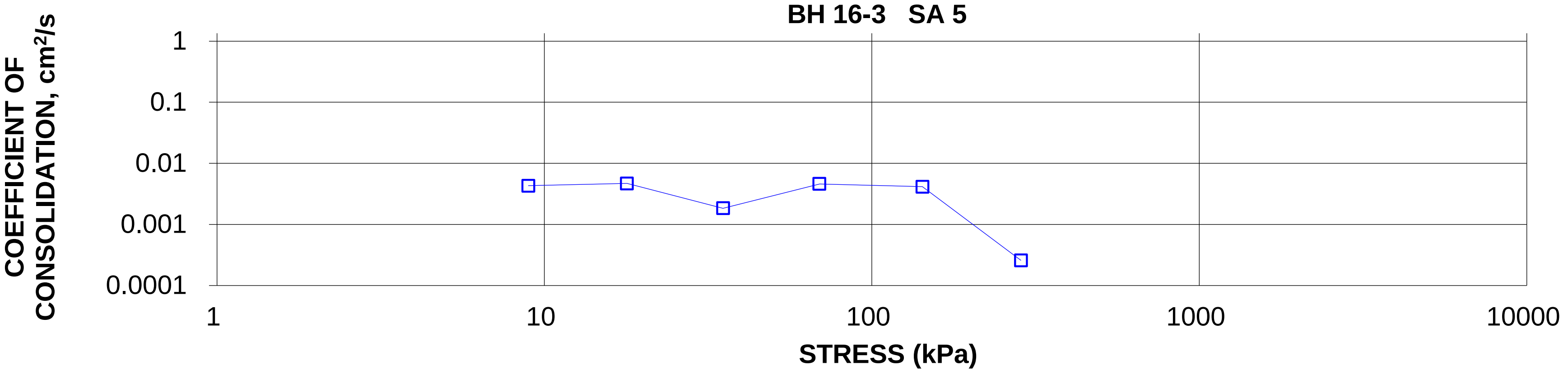
Highway 17 STA 11+970 Blake Creek Culvert

FIGURE B7

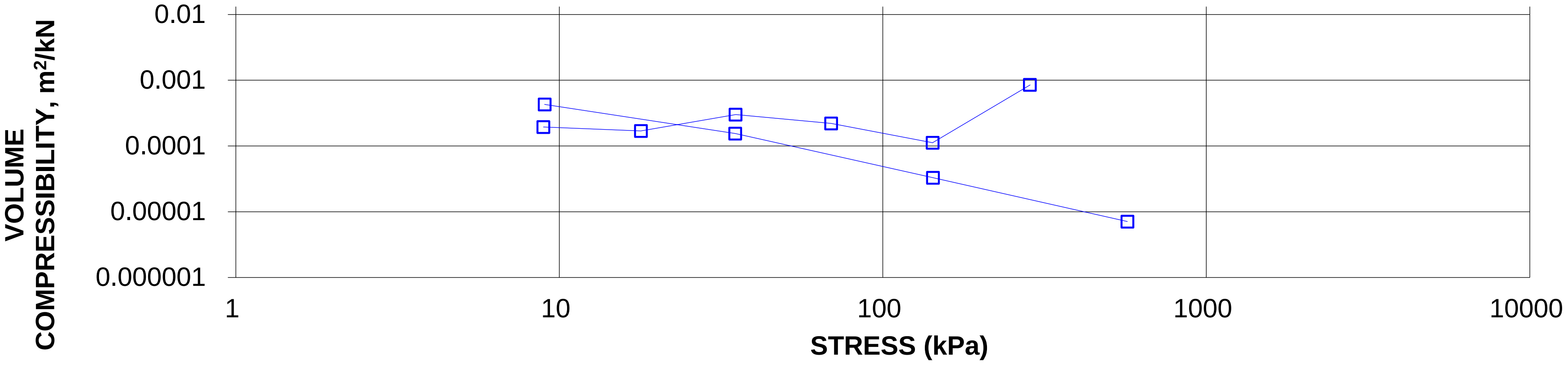
Page 2 of 4

16-3

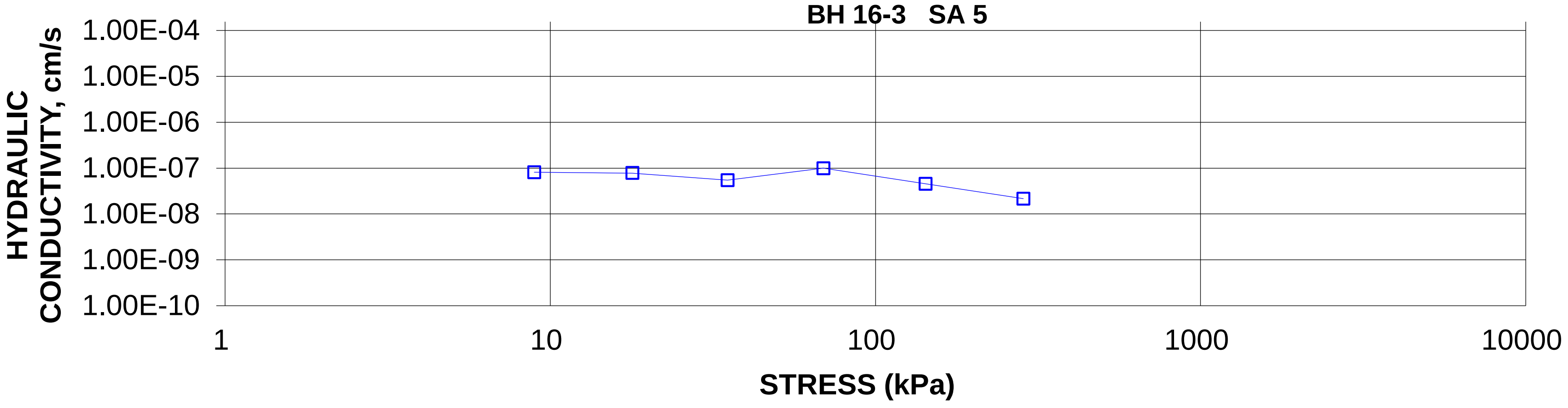
CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH 16-3 SA 5



CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 16-3 SA 5



CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 16-3 SA 5



Project No. 1535723
Prepared By: TG

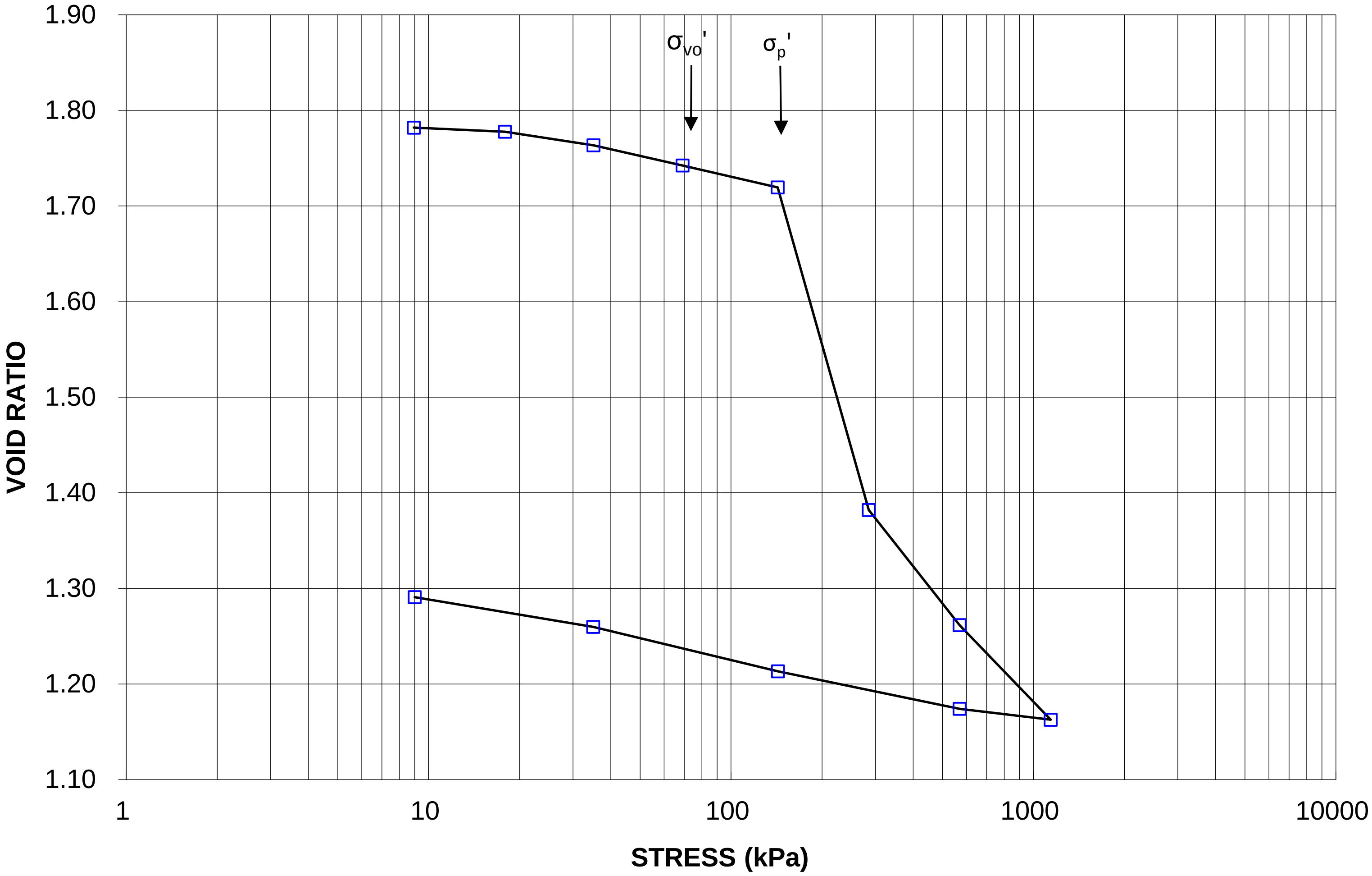
Golder Associates

Checked By: MT

Project No. 1535723

Prepared By: TG

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 16-3 SA 5



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CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE B7
Page 3 of 4

Project No. 1535723

Prepared By: TG

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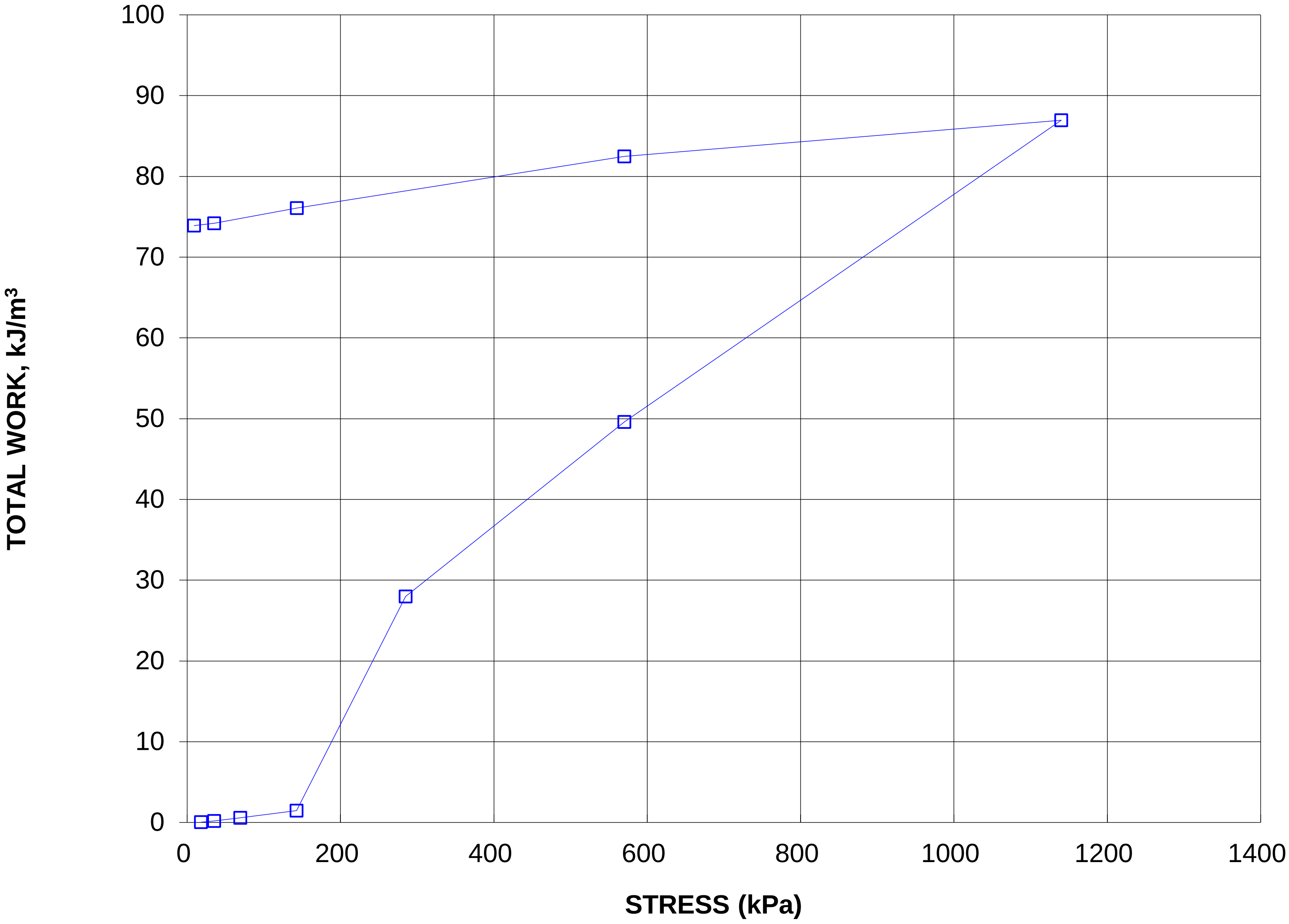
CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 16-3 SA 5



CONSOLIDATION TEST
TOTAL WORK VS STRESS

FIGURE B7
Page 4 of 4

APPENDIX C

Analytical Test Results

Your P.O. #: 1535723
Your Project #: 1535723
Site Location: BLAKE CREEK CULVERT
Your C.O.C. #: NA

Attention:Adam Core

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

Report Date: 2016/09/30
Report #: R4185473
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6I2210
Received: 2016/08/25, 09:09

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	2	N/A	2016/08/31	CAM SOP-00463	EPA 325.2 m
Conductivity	2	N/A	2016/08/31	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	2	2016/08/30	2016/08/30	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	2	2016/08/26	2016/08/31	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	2	N/A	2016/08/31	CAM SOP-00464	EPA 375.4 m
Oxidation-Reduction Potential (1, 2)	2	2016/08/29	2016/09/30	SLA SOP-00101	In house

Remarks:

Maxxam Analytics has performed all analytical testing herein in accordance with ISO 17025 and the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act. All methodologies comply with this document and are validated for use in the laboratory. The methods and techniques employed in this analysis conform to the performance criteria (detection limits, accuracy and precision) as outlined in the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act.

Maxxam Analytics is accredited for all specific parameters as required by Ontario Regulation 153/04. Maxxam Analytics is limited in liability to the actual cost of analysis unless otherwise agreed in writing. There is no other warranty expressed or implied. Samples will be retained at Maxxam Analytics for three weeks from receipt of data or as per contract.

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

(1) This test was performed by Maxxam Sladeview Petrochemical
(2) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode.

Encryption Key

Ema Gitej
30 Sep 2016 10:06:50 -04:00

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.

Total Cover Pages : 1

RESULTS OF ANALYSES OF SOIL

Maxxam ID		CYO660	CYO661	CYO661		
Sampling Date		2016/08/23 10:00	2016/08/24 12:00	2016/08/24 12:00		
COC Number		NA	NA	NA		
	UNITS	**16-1 SA#2B 3'-4.5'**	**16-3 SA#3 5'-7'**	**16-3 SA#3 5'-7' Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters						
Resistivity	ohm-cm	1900	1200			4636743
Inorganics						
Soluble (20:1) Chloride (Cl)	ug/g	200	400		20	4640865
Conductivity	umho/cm	537	831	757	2	4641008
Available (CaCl2) pH	pH	7.26	7.43			4639135
Soluble (20:1) Sulphate (SO4)	ug/g	ND	ND		20	4640868
Subcontracted Analysis						
Oxidation-Reduction Potential	mV	+160	+132	+132		4639029

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate
ND = Not detected

TEST SUMMARY

Maxxam ID: CYO660
Sample ID: 16-1 SA#2B 3'-4.5'
Matrix: Soil

Collected: 2016/08/23
Shipped:
Received: 2016/08/25

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4640865	N/A	2016/08/31	Deonarine Ramnarine
Conductivity	AT	4641008	N/A	2016/08/31	Neil Dassanayake
pH CaCl2 EXTRACT	AT	4639135	2016/08/30	2016/08/30	Neil Dassanayake
Resistivity of Soil		4636743	2016/08/31	2016/08/31	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4640868	N/A	2016/08/31	Deonarine Ramnarine
Oxidation-Reduction Potential	PH	4639029	2016/08/29	2016/09/30	Grace Sison

Maxxam ID: CYO661
Sample ID: 16-3 SA#3 5'-7'
Matrix: Soil

Collected: 2016/08/24
Shipped:
Received: 2016/08/25

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4640865	N/A	2016/08/31	Deonarine Ramnarine
Conductivity	AT	4641008	N/A	2016/08/31	Neil Dassanayake
pH CaCl2 EXTRACT	AT	4639135	2016/08/30	2016/08/30	Neil Dassanayake
Resistivity of Soil		4636743	2016/08/31	2016/08/31	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4640868	N/A	2016/08/31	Deonarine Ramnarine
Oxidation-Reduction Potential	PH	4639029	2016/08/29	2016/09/30	Grace Sison

Maxxam ID: CYO661 Dup
Sample ID: 16-3 SA#3 5'-7'
Matrix: Soil

Collected: 2016/08/24
Shipped:
Received: 2016/08/25

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	4641008	N/A	2016/08/31	Neil Dassanayake
Oxidation-Reduction Potential	PH	4639029	2016/08/29		Grace Sison

GENERAL COMMENTS

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

Package 1	7.7°C

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

			Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**UNITS**	**Value (%)**	**QC Limits**	**% Recovery**	**QC Limits**
4639029	Oxidation-Reduction Potential						+109	mV	0	20	+247	238 - 248
4639135	Available (CaCl2) pH	2016/08/30			98	97 - 103			1.6	N/A		
4640865	Soluble (20:1) Chloride (Cl)	2016/08/31	104	70 - 130	104	70 - 130	ND, RDL=20	ug/g	NC	35		
4640868	Soluble (20:1) Sulphate (SO4)	2016/08/31	NC	70 - 130	110	70 - 130	ND, RDL=20	ug/g	NC	35		
4641008	Conductivity	2016/08/31			100	90 - 110	ND,RDL=2	umho/cm	9.3	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.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

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 spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of 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 (one or both samples < 5x RDL).

Maxxam Job #: B6I2210
Report Date: 2016/09/30

Golder Associates Ltd
Client Project #: 1535723
Site Location: BLAKE CREEK CULVERT
Your P.O. #: 1535723
Sampler Initials: AC

VALIDATION SIGNATURE PAGE

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

Eva P

ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO
CHARTERED
Eva Pranjic
CHEMIST

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

ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO
CHARTERED
Grace M. Sison
CHEMIST

Grace Sison, B.Sc., C.Chem, Senior Project Manager - Petroleum Division

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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.

IMMEDIATE TEST

Maxxam
A Bureau Veritas Group Company

6740 Campobello Road, Mississauga, Ontario L5N 2L8
Phone: 905-817-5700 Fax: 905-817-5779 Toll Free: 800-563-6266
CAM FCD-01191/2

CHAIN OF COUSTODY RECORD

Page 1 of 1

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)	
Company Name:	Golder Associates	Company Name:		Quotation #:	
Contact Name:	Adam Core	Contact Name:		P.O. #/ AFE#:	1535723
Address:	33. Mackenzie St Sudbury	Address:		Project #:	1535723
				Site Location:	Blake Creek Culvert
Phone:	705-524-6861 Fax: 705-524-1981	Phone:	Fax:	Site #:	
Email:	A.Core@golder.com	Email:		Sampled By:	

Turnaround Time (TAT) Required

☒ Regular TAT (5-7 days) Most analyses

PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS

Rush TAT (Surcharges will be applied)

☐ 1 Day ☐ 2 Days ☐ 3-4 Days

Date Required:

Rush Confirmation #:

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153

☐ Table 1 ☐ Res/Park ☐ Med/ Fine
☐ Table 2 ☐ Ind/Comm ☐ Coarse
☐ Table 3 ☐ Agri/ Other
☐ Table ____
FOR RSC (PLEASE CIRCLE) Y / N

Other Regulations

☐ CCME ☐ Sanitary Sewer Bylaw
☐ MISA ☐ Storm Sewer Bylaw
☐ PWQO Region ____
☐ Other (Specify) ____
☐ REG 558 (MIN. 3 DAY TAT REQUIRED)

Include Criteria on Certificate of Analysis: Y / N

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

Analysis Requested (REFER TO BACK OF COC)

	SAMPLE IDENTIFICATION	DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CrVI	BTEX/ PHC F1	PHCs F2 - F4	VOCs	REG 153 METALS & INORGANICS	REG 153 ICPMS METALS	REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B)		Corrosivity Package							HOLD- DO NOT ANALYZE
1	16-1 Sa#2B 3'-4.5'	2016/08/23	10:00am	Soil										✓							
2	16-3 Sa#3 5'-7'	2016/08/24	12:00pm	Soil										✓							
3		labelled 2016/24/08 on jar																			
4																					
5	Received in Sudbury																				
6																					
7																					
8																					
9																					
10																					

LABORATORY USE ONLY

CUSTODY SEAL Y / [✓ N]		COOLER TEMPERATURES
Present	Intact	
N		9, 7, 7°C

COOLING MEDIA PRESENT: [✓ Y] / N

COMMENTS

RELINQUISHED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)
	2016/08/25	9:09am	Bradley Frazer	2016/08/25	9:09
			[illegible]	2016/08/26	09:23

4/4/4

25-Aug-16 09:09
Ema Gitej
B6I2210
KP7 ENV-1115

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

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North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

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