



November 27, 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

DEER CREEK CULVERT AT STA 11+815, SITE 43-165/C
HIGHWAY 17 REHABILITATION BETWEEN WARREN AND VERNER
FROM HIGHWAY 539 EASTERLY TO 0.2 KM EAST
OF WEST JUNCTION OF HIGHWAY 64
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 300-98-00, WP 5081-05-01

Submitted to:

Morrison Hershfield Limited
2440 Don Reid Drive
Ottawa, ON K1H 1E1



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REPORT





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PART A

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH), on behalf of the Ministry of Transportation, Ontario (MTO), to provide foundation engineering services for the rehabilitation of the Highway 17 Deer Creek culvert (Site 43-165/c) at STA 11+815 in the Municipality of West Nipissing, Ontario. The Key Plan showing the general location of this section of Highway 17 and the location of the investigated area are shown on Drawing 1. The purpose of this investigation is to establish the subsurface conditions at the location of the culvert by borehole drilling, in situ testing and laboratory testing on selected soil samples.

2.0 SITE DESCRIPTION

The Deer Creek culvert is located on Highway 17 east of the Town of Warren approximately 3 km east of the junction with Highway 539. In general, the topography in the area of the overall project limits consists of flat terrain primarily utilized as farmland, with moderate tree cover. The existing highway grade is at about Elevation 208 m with Deer Creek crossing under the embankment about 8 m below the existing highway grade. The side slopes of the existing embankment are inclined at about 1.5 Horizontal to 1 Vertical (1.5H:1V). Rock fill is present on the embankment side slopes with some pieces at least 1 m size. The existing culvert consists of 26 m long, twin 6.1 m square cell concrete boxes.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between January 24 and February 10, 2014, during which time a total of six boreholes were advanced at the approximate locations shown on Drawing 1:

- three boreholes for the culvert alignment (Boreholes DE-1, DE-4 and DE-5);
- one borehole for the proposed roadway protection (Borehole DE-2); and
- two boreholes for the proposed cofferdam (Boreholes DE-3 and DE-6).

Boreholes DE-1 and DE-2, located on the existing highway embankment, were advanced to depths of 20.4 m and 14.8 m, respectively, below ground surface using a truck-mounted CME 75 drill rig outfitted with 108 mm inside diameter continuous flight hollow-stem augers, 150 mm outer diameter (O.D.) continuous flight solid stem augers, and/or 'NW' casing with wash boring techniques. Boreholes DE-3 to DE-6, located at or beyond the existing toe of slope, were advanced by wash boring methods with portable equipment using NQ casing. A Dynamic Cone Penetration Test (DCPT) was advanced adjacent to Boreholes DE-1 and DE-3 to DE-5 to depths between 14.9 m and 20.4 m below ground/ice surface.

The drilling equipment was supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. Soil samples were obtained at intervals of depths of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler driven by an automatic hammer at Boreholes DE-1 and DE-2 and a manual hammer at Boreholes DE-3 to DE-6, and performed in accordance with Standard Penetration Test (SPT) procedure (ASTM D1586). Selected samples of the cohesive soils were obtained using 76 mm O.D. thin-walled 'Shelby' tubes (ASTM D1587, Standard Practice for Thin-Walled Tube Sampling) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573,



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Standard Test Method for Field Vane Strength Shear Test) using MTO Standard 'N' size vanes. The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendix A. All boreholes were backfilled with bentonite upon completion of drilling in accordance with Ontario Reg. 903 (as amended).

The fieldwork was supervised throughout by members of our technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are presented on the Record of Borehole sheets in Appendix A and are also included in Appendix B.

A sample of the creek water was obtained on March 10, 2014, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table B1 in Appendix B, together with the detailed analytical laboratory test results.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to the marked stations and offsets on the highway or the ends of the culvert, as applicable. The MTM NAD 83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depth at each borehole are presented on the Record of Borehole sheets in Appendix A and are summarized below.

Borehole	Borehole Location		Ground Surface Elevation (m)	Borehole/DCPT Depth Below Ground/Ice Surface (m)
	Northing	Easting		
DE-1	5144162.2	245673.4	208.2	20.4/20.4
DE-2	5144163.7	245640.8	208.4	14.8
DE-3	5144187.0	245672.5	202.4	15.8/16.7
DE-4	5144189.8	245653.0	202.0	15.8/16.8
DE-5	5144143.7	245655.8	202.9	17.4/14.9*
DE-6	5144137.3	245674.8	202.7	15.8*

*includes 0.3 m thick layer of ice



4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on terrain mapping (Ontario Geological Survey¹), the site is located on a glaciolacustrine plain in an area of sand and silt deposits with a bedrock knob located within approximately 100 m to the south of the site.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions, as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil core samples, are given on the Record of Borehole sheets in Appendix A. The results of the in situ tests (i.e., SPT “N”-values and undrained shear strengths from the field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. Detailed results of the laboratory testing of the soil samples are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets and on the stratigraphic profile and cross-section shown on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface stratigraphy at the site consists of embankment fill (where encountered) underlain by a surficial deposit of cohesionless soils consisting of sandy silt to gravelly sand, underlain by clayey silt to silty clay, which in turn is underlain by a silt to silt and sand deposit. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

Boreholes DE-1 and DE-2 penetrated a layer of asphalt 150 mm thick at Elevation 208.2 m and 208.4 m, respectively, underlain by a fill deposit comprised of sand and gravel to gravelly sand about 8.6 m and 7.0 m thick, respectively. In Boreholes DE-1 and DE-2, auger refusal on cobbles and/or boulders was noted at depths of 0.8 m (Elevation 207.4 m) and 1.4 m (Elevation 207.4 m) and NW casing and NQ coring techniques were required to advance the boreholes through the fill with recovery of cobbles/boulders ranging in thickness from 90 mm to 300 mm.

The SPT ‘N’-values measured within the sand and gravel to gravelly sand fill range between 8 blows and 63 blows per 0.3 m of penetration indicating a loose to very dense relative density. Two SPT ‘N’-values measured within the fill did not penetrate the full sample depth as spoon refusal was encountered, inferred to be as a result of the cobbles/boulders within the fill.

The natural moisture content measured on a selected sample of the fill is about 12 per cent.

¹ Southern Ontario Engineering Geology Terrain Study, 1980. Ontario Geological Survey.



4.2.2 Clayey Silt to Silt

From ground surface in Boreholes DE-3 and DE-4, a deposit of clayey silt to silt was encountered at Elevation 202.4 and 202.0 m, with a thickness of 1.1 m and 0.8 m, respectively.

Two SPT 'N'-values measured within this deposit are 1 blow and 2 blows per 0.3 m of penetration, indicating a very soft consistency.

4.2.3 Sandy Silt to Gravelly Sand

A deposit of sandy silt, sand and silt, silty sand, sand and/or gravelly sand was encountered below the fill in Boreholes DE-1 and DE-2, below the clayey silt to silt in Boreholes DE-3 and DE-4 and from ground surface below a 0.3 m thick layer of snow/ice in Boreholes DE-5 and DE-6. Some organics were noted in the upper 1.2 m of the sandy silt deposit in Boreholes DE-5 and DE-6. Casing refusal was encountered in Borehole DE-6 at a depth of 0.9 m below ground surface (1.2 m below the ice surface) inferred to be on a boulder and the borehole was relocated 0.3 m to the east to continue sampling. The surface of the sandy silt to gravelly sand deposit was encountered between Elevations 202.6 m and 199.5 m and the deposit is between about 2.9 m and 6.1 m thick.

The SPT 'N'-values measured within this deposit range between 2 blows and 25 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

Grain size analyses were carried out on six samples of this deposit and the results are represented on Figure B1 in Appendix B.

An Atterberg limits test was carried out on a sample of the sandy silt in Borehole DE-4 and indicates that the material is non-plastic.

The natural moisture content measured on selected samples of the sandy silt to gravelly sand ranges between about 20 per cent and 28 per cent, with one sample measuring a water content of 45 per cent, the higher value being attributed to the organics in the sample.

4.2.4 Clayey Silt to Silty Clay

A deposit of clayey silt to silty clay was encountered below the sandy silt to gravelly sand deposit in all of the boreholes with the surface of the deposit encountered between about Elevations 197.2 m and 195.9 m. The thickness of the deposit in Boreholes DE-1 and DE-3 to DE-6 is between about 7.0 m and 9.4 m and Borehole DE-2 did not fully penetrate the deposit after exploring for about 3.1 m. Sand and/or silt laminations/layers were observed within the deposit as noted on the borehole logs.

The SPT 'N'-values measured within the clayey silt to silty clay deposit generally range between 0 blows (weight of hammer) and 5 blows per 0.3 m of penetration and 'N'-values in the sand and/or silt laminations/layers range from 6 blows to 25 blows per 0.3 m of penetration. In situ field vane testing measured undrained shear strengths ranging from 26 kPa to greater than 100 kPa, with a sensitivity between 2 and 4. The in situ vane test results indicate that the deposit generally has a firm to very stiff consistency, with the shear strength results greater than 100 kPa likely a result of the presence of silt laminations/layers in the cohesive layer tested.



Atterberg limits testing were carried out on twelve samples of the cohesive deposit and measured liquid limits ranging from about 29 per cent to 42 per cent, plastic limits ranging from about 16 per cent to 21 per cent, and plasticity indices ranging from about 13 per cent to 21 per cent. The results, which are plotted on a plasticity chart on Figures B2 in Appendix B, indicate that the tested samples of the overall deposit consist of clayey silt of low plasticity to silty clay of intermediate plasticity.

The results of the grain size distribution testing completed on one sample of the silt interlayer in Borehole DE-6 is shown on Figure B3 in Appendix B. An Atterberg limits test was also carried out on one sample of the silt interlayer in Borehole DE-6 and indicates that the material is non-plastic.

The natural moisture content measured on selected samples of the clayey silt to silty clay deposit ranges between about 27 per cent and 44 per cent; whereas, the natural moisture content measured on three samples of the silt interlayer ranges between 22 per cent and 35 per cent.

4.2.5 Silt to Silt and Sand

A deposit of silt to sandy silt to silt and sand, some clay, was encountered below the clayey silt to silty clay deposit in Boreholes DE-1 and DE-3 to DE-6. The surface of this deposit was encountered between Elevations 189.5 m and 187.1 m and sampled boreholes did not fully penetrate the deposit after exploring for thicknesses of between approximately 0.9 m and 4.0 m.

The SPT 'N'-values measured within this deposit range between 11 blows and 28 blows per 0.3 m of penetration, indicating a compact relative density.

Grain size analyses were carried out on four samples of this deposit and the results are represented on Figure B3 in Appendix B.

Atterberg limits testing carried out on four samples of the silt to silt and sand deposit indicates that the material is non-plastic.

The natural moisture content measured on selected samples of the silt to silt and sand deposit ranges between about 25 per cent and 29 per cent.

4.2.6 Groundwater Conditions

In Borehole DE-1, the borehole caved at 12.2 m upon the completion of drilling and the borehole was noted to be dry to this depth. The unstabilized water level in Borehole DE-2 upon completion of drilling was at a depth of 7.2 m below roadway level, corresponding to Elevation 201.2 m. The unstabilized water levels in Boreholes DE-3 to DE-6 upon completion of drilling range between 1.3 m and 2.6 m below ground surface, between Elevations 201.4 m and 200.1 m. On January 31, 2014, the ice surface in the creek on the south side of the embankment was surveyed at Elevation 200.9 m.

Groundwater levels encountered in the boreholes shortly after drilling may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Groundwater levels are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.



5.0 CLOSURE

The drilling program was supervised by Mr. Gabriel Mathieu, Mr. Trevor Moxam and Mr. Mat Riopelle. This report was prepared by Mr. Matthew Thibeault, EIT and reviewed by Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report



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Report Signature Page

GOLDER ASSOCIATES LTD.

Matthew Thibeault

Matthew Thibeault, EIT
Geotechnical Engineering Intern



André Bom, P.Eng
Geotechnical Engineer



Jorge M.A. Costa, P.Eng
Designated MTO Contact, Principal

MT/AB/JMAC/kp

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PART B

FOUNDATION DESIGN REPORT

DEER CREEK CULVERT AT STA 11+815, SITE 43-165/C

HIGHWAY 17 REHABILITATION BETWEEN WARREN AND VERNER

FROM HIGHWAY 539 EASTERLY TO 0.2 KM EAST

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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides an interpretation of the factual geotechnical data obtained during the investigation and conclusions and recommendations on the foundation aspects of design of the proposed works. The recommendations provided are intended for the guidance of the design engineer. Where comments are made on construction, they are provided to highlight aspects of construction that could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the subsurface information provided as such interpretation may affect their proposed construction methods, costs, equipment selection, scheduling and the like.

6.1 General

The existing Deer Creek culvert structure consists of a 26 m long 6.1 m square box twin cell. The existing inlet/outlet invert is about Elevation 201 m and the structural design drawings for the existing culvert structure dated August 20, 1948 indicate that “the top of the floor slab shall be made at the elevation of the stream bed”. The top of the existing embankment is at Elevation 208 m and the existing side slopes of the 8 m high embankment are inclined at about 2 Horizontal:1 Vertical (2H:1V).

We understand that the culvert will be rehabilitated only (i.e., not replaced). As part of the Highway 17 rehabilitation to be carried out in the vicinity of the culvert, a grade raise to the existing embankment of about 150 mm may be required. Further, we understand that there will be no change to the inclination of or additional fill to the embankment side slopes.

Should it be considered necessary to replace the existing culvert with a culvert of similar dimensions to those of the existing structure (i.e. 2 cells about 6 m wide each), the recommendations provided in the following sections of the report may be used for the foundation design of a replacement structure.

6.2 Culvert Types

The analysis and recommendations presented in this report assume that the replacement of the Deer Creek culvert, if required, would consist of a concrete box culvert of similar dimensions as the existing culvert. Due to the presence of the cohesive deposit of limited strength (firm) and the height of the existing embankment, an open bottom concrete culvert (on strip footings) at this site is not considered feasible.

6.3 Stability

Limit equilibrium slope stability analyses were performed for the proposed embankment geometry, based on the a culvert being replaced, using the commercially available program GeoStudio 2007 (Version 7.23), produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. For all analyses, the Factor of Safety (FoS) of numerous potential failure surfaces was computed in order to establish the minimum FoS. The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. A target minimum FoS of 1.3 is normally adopted on MTO projects for the design of embankment slopes under static conditions. This FoS is considered adequate for the embankment at this site considering the design



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requirements and the field data available and is based on deep-seated, global failure surfaces that would affect the operation of the roadways. The stability analyses were performed to check that the target minimum FoS was achieved for the embankment height and geometry at the culvert location.

The analyses assume that, for a full culvert replacement, the organic soils (if present) beneath the culvert and embankment will be removed prior to construction of the new culvert/re-constructed embankment. The analyses assume that new granular fill (sand and gravel, Granular 'A' or 'B' Type I or II), is used for embankment reconstruction, and would be keyed into the existing fill as per OPSD 208.010 (Benching of Earth Slopes) and constructed with 2H:1V side slopes or flatter.

For the cohesionless fill and native cohesionless soils, effective stress parameters were employed in the stability analysis assuming drained conditions and the parameters were estimated from empirical correlations using the results of the in situ SPT 'N'-values. The correlations proposed by NAVFAC (1982) were employed and the results were tempered by engineering judgment based on precedent experience in similar soils.

For the cohesive layers, total stress parameters were employed in the analysis. The total stress parameters (i.e., undrained shear strength – s_u) for the cohesive soil were assessed based primarily on the results of the in situ field vane tests. Bjerrum's (1973) correction factor as a function of the plasticity index of the soil was employed to estimate the average mobilized undrained shear strength from the results of the in situ field vane tests. The high undrained shear strength test results from the field vane test inferred to intercept silt layers/seams were not used in the estimate of the average shear strength.

The piezometric condition required in the analyses is based on the groundwater level consistent with the creek surface elevation.

The simplified stratigraphy together with the associated strength and unit weight employed for the different native soil types at the culvert location are summarized below.

Soil Type	Unit Weight (kN/m^3)	Undrained Shear Strength (kPa)	Angle of Internal Friction (°)
New Granular Fill	21	-	35
Sandy Silt to Gravely Sand	19	-	28
Clayey Silt to Silty Clay	17	25 to 60 kPa (increasing with depth)	-
Silt to Silt and Sand	19	-	30

The stability analysis performed on the embankment cross-section at the culvert location indicates that the embankment will have a FoS of 1.3 or greater for deep-seated, global failure surfaces that would impact the operation of the roadway, as shown on Figure 1.

6.4 Settlement

Based on a proposed grade raise of about 150 mm and the side slope being reconstructed at the same inclination as the existing embankment, the total and differential settlement of the foundation soil below the



culvert will be less than 25 mm. However, if a greater increase to the existing embankment grade or a widening is required along the side slopes, the magnitude of settlement will be different than that estimated for the presently proposed construction and measures to mitigate settlement may be required.

It is recommended that OPSS.PROV1010 (Aggregates) Granular 'A' or 'B' Type I or II be used for embankment reconstruction at the culvert location. Where granular fill will be placed below the water level, Granular 'B' Type II should be used. The material placed above the water level should be compacted in accordance with OPSS 501 (Compacting). Compression settlement of the fill placed below water and from properly compacted embankment fill above water is expected to occur during construction.

6.5 Horizontal Strain

Horizontal strain along the culvert is not expected to occur provided the proposed grade raise and side slope geometry is consistent with the embankment cross-section presented in Section 6.4. Should the embankment be widened to a greater extent than what is currently proposed or raised compared with the existing geometry, a reassessment of the potential magnitude of horizontal strain will be required.

As a result, replacement of the culver can be carried out concurrent with embankment reconstruction without the need for any foundation mitigation measures or provision of a camber to the culvert designed to tolerate the estimated and total differential settlement noted above.

6.6 Geotechnical Resistance

For the box culvert replacement, we recommend that a factored geotechnical axial resistance at Ultimate Limit States (ULS) of 200 kPa be used for design of a 12 m wide box culvert founded on a properly prepared subgrade comprised of compact sandy silt to silty sand underlain by the firm to very stiff clayey silt to silt clay. The geotechnical resistance at SLS (for 25 mm settlement) for a 12 m wide box culvert constructed on the properly prepared granular subgrade may be taken as 100 kPa.

It should be noted that at this site, the loading on the foundation soils below the culvert will be governed by any grade raise and widened embankment fills. If a grade raise or widening is constructed, the structural engineer must exercise caution when utilizing the value(s) of the geotechnical axial resistance at Serviceability Limit States (SLS) in the design of the culvert and that consideration be given to the sequence and staging of construction.

The geotechnical resistances are given for loads applied perpendicular to the surface of the base of the replacement culvert. Where loads are not applied perpendicular to the base of the culvert, inclination of the loads should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the Canadian Highway Bridge Code (CHBDC) and its Commentary. For the estimation of the factored ULS value, a minimum culvert embedment depth of 2 m was used in this analysis.

6.6.1 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of a concrete box culvert and the granular fill/bedding should be calculated in accordance with Section 6.7.5 of the CHBDC. The following summarizes the



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unfactored values of coefficient of friction for the interface materials for a precast and cast-in-place concrete box culvert.

Interface Materials	Coefficient of Friction
Precast Concrete Box on Compacted Granular 'B' Type II	$\tan \delta = 0.45$
Cast-in-Place Concrete on Compacted Granular 'B' Type II	$\tan \delta = 0.58$

These values represent unfactored values.

6.6.2 Frost Protection

The estimated frost penetration depth for the Sturgeon Falls area is 2.0 m, as per OPSD 3090.101 (Foundation Frost Penetration Depths for Southern Ontario).

Box culverts are typically not provided with the standard depth for frost protection as box culverts are tolerant to small magnitudes of movement related to freeze-thaw cycles should these occur. The box culverts should, however, be founded below any existing fill and surficial organic materials. It is recommended that the box culvert segments be placed on a minimum thickness of 300 mm of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II bedding material. If placed in the wet, Granular "B" Type II material should be used.

6.7 Lateral Earth Pressures – Culverts and Wing Walls

The lateral earth pressures acting on the side walls and wing walls of the culverts 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 following recommendations are made concerning the design of the culverts and wing walls. It should be noted that these design recommendations and parameters are applicable to 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 requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II but with less than 5 percent passing the 200 sieve (0.075 mm) should be used as backfill behind the culverts and wing walls. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper immediately behind the culvert walls should be in accordance with OPSD 3101.150 (Walls, Abutment, Backfill) and OPSD 3121.150 (Walls Retaining, Backfill).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culverts and wing walls, in accordance with CHBDC Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS 501 (Compaction). Other surcharge loadings should be accounted for in the design as required.



- Granular fill may be placed either in a zone with the width equal to at least 2.0 m behind the back of the wing walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5H:1V extending up and back from the rear face of the base of the wing walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC). The pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	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 allows for lateral yielding, active earth pressures may be used in the foundation design. If the culvert structure does not allow for lateral yielding, at-rest earth pressures should be assumed for culvert design. The movement to allow active pressures to develop within the backfill, and thereby assume a restrained structure, may be taken as per Table C6.6 of the Commentary to the CHBDC.

6.8 Culvert Construction Considerations

6.8.1 Excavations, Subgrade Preparation, Bedding and Backfill Above Base of Culvert

Construction of the pre-cast concrete box culvert with respect to excavation, bedding, backfilling and cover materials should be carried out in accordance with OPSS 422 (Concrete Box Culverts and Box Sewers in Open Cut).

All excavations must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended by Ontario Regulation 443). In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of the existing Highway 17. Temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems) and is discussed further in Section 6.8.2.

Prior to the placement of any bedding material and fill for new construction, all organic soils where encountered should be stripped from the plan limits of the proposed works. The native subgrade soils may be susceptible to disturbance from construction traffic and/or ponded water. In order to limit this degradation, it is recommended that a concrete working slab be placed on the subgrade if culvert construction is not carried out within four hours after preparation, inspection and approval of the subgrade. A sample Non-Standard Special Provision (NSSP) to address this requirement is included in Appendix C.

For a cast-in-place box culvert replacement, groundwater control will be required as discussed in Section 6.8.4. As an alternative to a working slab discussed above, the box culvert could be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material for bedding purposes and partial frost protection. The Granular 'B' Type II may likely be placed in the wet and when nominally compacted



(i.e., with an excavator shovel) should achieve a density of 90 per cent of the Standard Proctor Maximum Dry Density (SPMDD). The structural design of the culvert should take into consideration the conditions for bedding placement and compaction in accordance with the requirements of Section 7.8.3.6 of the *CHBDC*.

The depth of backfill during placement around the culvert should be maintained equal on both sides of the culvert with one side not exceeding the other by more than 500 mm.

The culvert should be designed for the full overburden stress and appropriate live loads, assuming a fill unit weight of 22 kN/m³ for Granular 'A' and 21 kN/m³ for Granular 'B' Type II backfill above and surrounding the culvert.

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.

As discussed in Section 6.3, the new granular fill will need to be keyed into the existing fill as per OPSD 208.010 (Benching of Earth Slopes).

Present practice by MTO is to include a 2 m wide bench in the embankment slope geometry such that the uninterrupted slope height is not greater than 8 m for an earth embankment (and 10 m for a rock fill slope), as per OPSD 202.010 (Slope Flattening). As the existing embankment is up to 8 m high, but may be raised only slightly to accommodate pavement reconstruction, the embankment side slopes should be re-constructed to match the adjacent side slopes and not incorporate a mid slope bench.

6.8.2 Temporary Shoring

Temporary protection systems are required to support the embankment fill during the culvert replacement. The temporary support systems could consist of driven steel sheet piling. However, as cobbles and boulders are present within the existing embankment fill at this site, it will likely be more practical to install soldier piles and lagging where the H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds. Support to the system could be in the form of struts and walers or rakers and anchors.

Excavation of the rock fill presently on the embankment slopes to install temporary shoring could lead to sloughing of the embankment fill above the excavation.

The Contractor should be alerted to the cobble and boulder obstructions within the existing embankment fill; an example NSSP (or Notice to Contractor) to be included in the Contract Documents is presented in Appendix C.

The temporary excavation support system should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539. The contractor is responsible for the complete detailed design of the protection system.

The design of braced soldier pile and lagging walls should be based on a rectangular earth pressure distribution using the design parameters given below. Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system. Passive toe



FOUNDATION REPORT HIGHWAY 17 DEER CREEK CULVERT, SITE 43-165/C

restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter.

The unfactored triangular earth pressure distribution (p in kN/m^2 ; increasing with depth), can be calculated as follows:

$$p = K_a (\gamma H + q)$$

where H = the depth of the excavation at any point (m)

$$K_a = \text{active coefficient of earth pressure}$$
$$\gamma = \text{soil unit weight (kN/m}^3\text{)}$$
$$q = \text{surcharge for traffic and other loading (kN/m}^2\text{)}$$

For a braced excavation in granular fill and native cohesionless soils, the unfactored rectangular earth pressure distribution (p in kN/m^2 ; constant with depth), can be calculated as follows:

$$p = 0.65 K_a (\gamma H + q)$$

where H = the total depth of the excavation (m)

$$K_a = \text{active coefficient of earth pressure}$$
$$\gamma = \text{soil unit weight (kN/m}^3\text{)}$$
$$q = \text{surcharge for traffic and other loading (kN/m}^2\text{)}$$

For a braced excavation in cohesive soil, the unfactored rectangular earth pressure distribution (p in kN/m^2 ; varying with depth), can be calculated as follows:

$$p = 0 \text{ at ground surface increasing linearly to a depth of } 0.25 H_T \text{ to:}$$
$$p = \gamma H_T - 4mS_u \text{ at } 0.25 H_T \text{ and from } 0.25 H_T \text{ to } H_T \text{ below ground surface}$$

where H_T = the total depth of the excavation (m)

$$\gamma = \text{soil unit weight (kN/m}^3\text{)}$$
$$q = \text{surcharge for traffic and other loading (kN/m}^2\text{)}$$
$$m = \begin{matrix} 0.4 & \text{if an extensive soft clay layer underlies the excavation} \\ 1.0 & \text{if more resistant layer is present at the excavation base} \end{matrix}$$
$$S_u = \text{undrained shear strength (kN/m}^2\text{)}.$$

The support systems may be designed using the following parameters:



FOUNDATION REPORT HIGHWAY 17 DEER CREEK CULVERT, SITE 43-165/C

SOIL TYPE	COEFFICIENT OF EARTH PRESSURE			INTERNAL ANGLE OF FRICTION (ϕ , degrees)	UNIT WEIGHT (γ , kN/m ²)	UNDRAINED SHEAR STRENGTH (S_u , kPa)
	Active, K_a	At Rest, K_o	Passive, K_p			
Existing Embankment Fill	0.33	0.50	3.0	30	20	-
Clayey Silt to Silty Clay	0.37	0.55	2.7	27	17	25 at Elev 196 m to 60 kPa at Elev 188 m
Silt, Sand and Silt, Sand, Gravelly Sand	0.36	0.53	2.8	28	19	-

The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficients should be adjusted accordingly.

6.8.3 Erosion Protection

Provisions should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert location and at the creek bends at either end of the culvert. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a concrete cut-off wall or clay seal should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including along the embankment slope. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height of two times the culvert height or the high water level, whichever is greater.

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 for Sewer and Culvert Outlets). Erosion protection for the inlet of the culverts should follow the standard presented in OPSD 810.010 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. Similarly, rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culvert.

6.8.4 Control of Groundwater and Surface Water

Excavation within the plan limits of the proposed culvert replacement and wing walls will require the removal of organics (where encountered), existing fill, and native soils prior to the placement of bedding material, and construction of the box culvert replacement and wing walls. The existing culvert flows will need to be diverted/piped during construction.



Surficial water seepage into the excavation should be expected and will be heavier during periods of sustained precipitation. Seepage from the granular fills and near surface native fine granular materials should be expected, particularly after precipitation events. It is anticipated that this surficial seepage can be controlled by using properly filtered sumps within a shored/braced excavation.

As cast-in-place concrete will be required for culvert replacement, dewatering will be required for construction in-the-dry. The excavation will be advanced through cohesionless soils above the clay deposit and appropriate unwatering of the water-bearing granular soil deposits will be required to maintain the water level below the founding level during excavation and construction. It is recommended that an NSSP be included in the Contract to address unwatering for the site; a sample NSSP is included in Appendix C.

6.8.5 Analytical Testing for Construction Materials

The analytical test results on a sample of creek water taken adjacent to the culvert site are summarized in Table B1 in Appendix B, together with the detailed analytical laboratory test results. The suite of parameters tested is intended to allow the structural engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection.

7.0 CLOSURE

This report was prepared by Mr. Matthew Thibeault, EIT and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and a Principal with Golder, conducted an independent quality control review of the report.



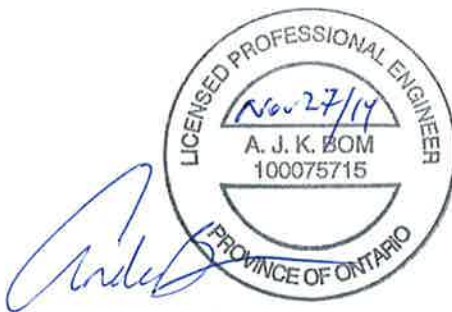
FOUNDATION REPORT HIGHWAY 17 DEER CREEK CULVERT, SITE 43-165/C

Report Signature Page

GOLDER ASSOCIATES LTD.

Matthew Thibeault

Matthew Thibeault, EIT
Geotechnical Engineering Intern



André Bom, P.Eng
Geotechnical Engineer



Jorge M.A. Costa, P.Eng
Designated MTO Contact, Principal

MT/AB/JMAC/kp

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\\golder.gds\gal\whitby\active\2013\1184 pavement and materials\13-1184-0074 mh hwy 17 warren to verner\1191-foundation\reporting\final\r01 - deer\13-1184-0074-r1 rpt 14nov27 final fdr deer creek.docx



REFERENCES

- Bjerrum, L., 1973. Problems of Soil Mechanics and Construction of Soft Clays and Structurally Unstable Soils. State of the Art Report, Session 4. Proceedings, 8th International Conference on Soil Mechanics and Foundation Engineering, Moscow, Vol. 3, pp. 111-159.
- Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-06. 2006. CSA Special Publication, S6.1-06. Canadian Standard Association.
- Unified Facilities Criteria, NAVFAC Design Manual, DM-7.2. Soil Mechanics, Foundation and Earth Structures. U.S. Navy, 1982, Alexandria, Virginia.
- Ontario Geological Survey. Southern Ontario Engineering Geology Terrain Study, 1980.

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

Commercial Software

GeoStudio 2007 (Version 7.23) by Geo-Slope International Ltd.

Ontario Occupational Health and Safety Act

- Ontario Regulation 213/91 Construction Projects
- Ontario Regulation 443/09 Amendment to Ontario Regulation 213

Ontario Provincial Standard Drawing

OPSD 202.010	Slope Flattening using Surplus Excavated Material on Earth or Rock Fill Embankment
OPSD 208.010	Benching of Earth Slopes
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSD 3101.150	Walls, Abutment, Backfill
OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirement

Ontario Provincial Standard Specification

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems



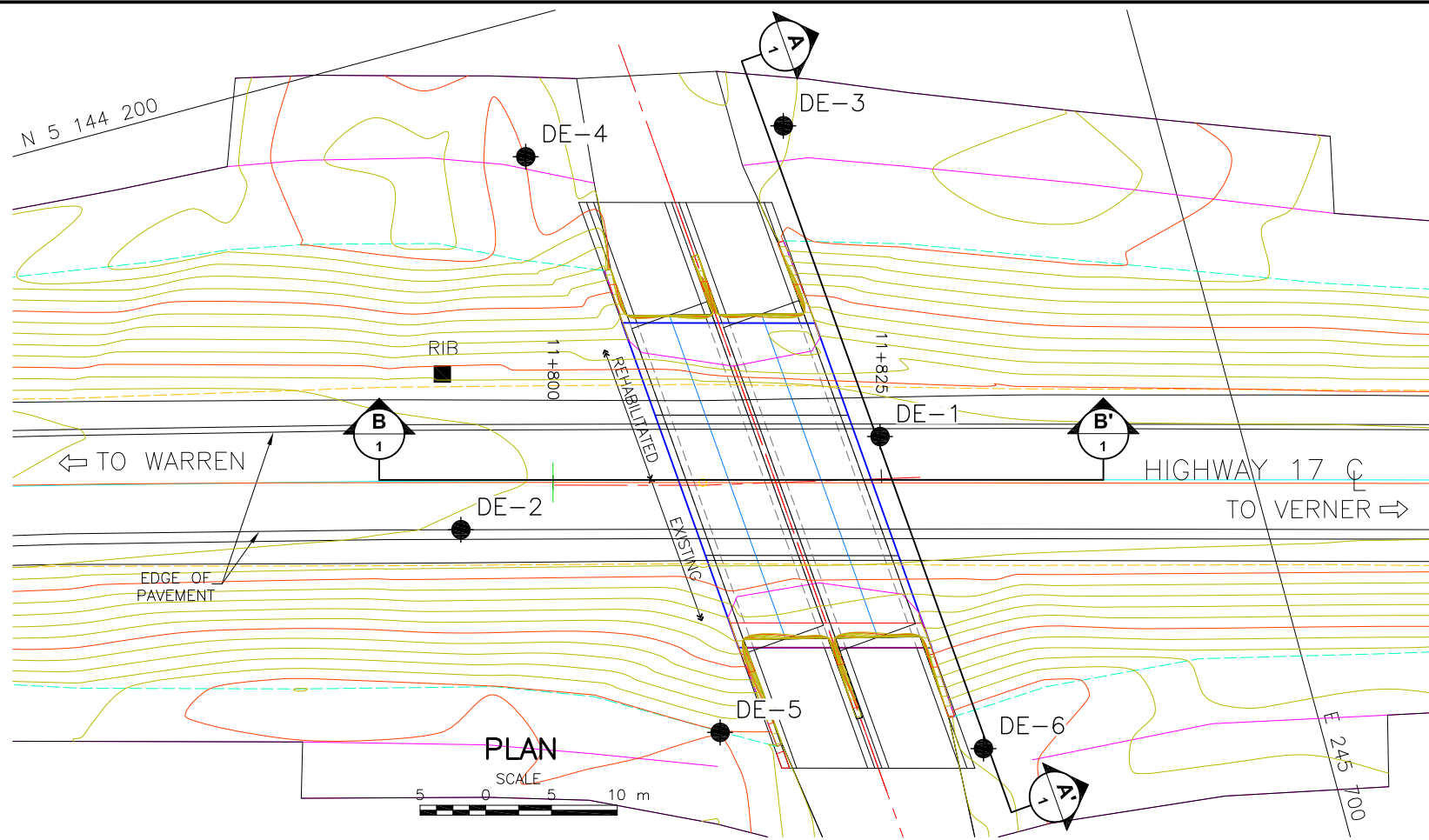
FOUNDATION REPORT HIGHWAY 17 DEER CREEK CULVERT, SITE 43-165/C

OPSS.PROV1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

OPSS 1205 Clay Seal

Ontario Water Resources Act

Ontario Regulation 372/97 Amendment to Ontario Regulation 903



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

CONT No.
WP No. 5081-05-01

HIGHWAY 17
DEER CREEK CULVERT - STA 11+815
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

SCALE
0 8 km

LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
DE-1	208.2	5144162.2	245673.4
DE-2	208.4	5144163.7	245640.8
DE-3	202.4	5144187.0	245672.5
DE-4	202.0	5144189.8	245653.0
DE-5	202.9	5144143.7	245655.8
DE-6	202.7	5144137.3	245674.8

NOTES

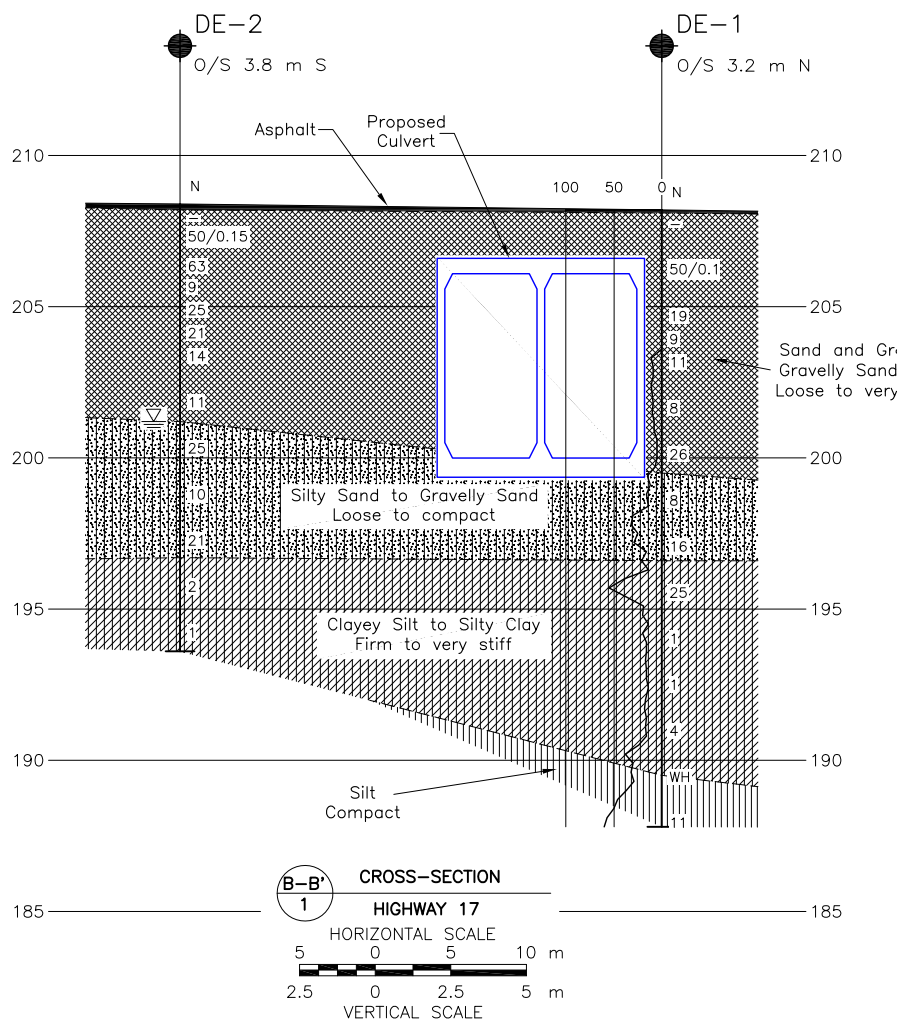
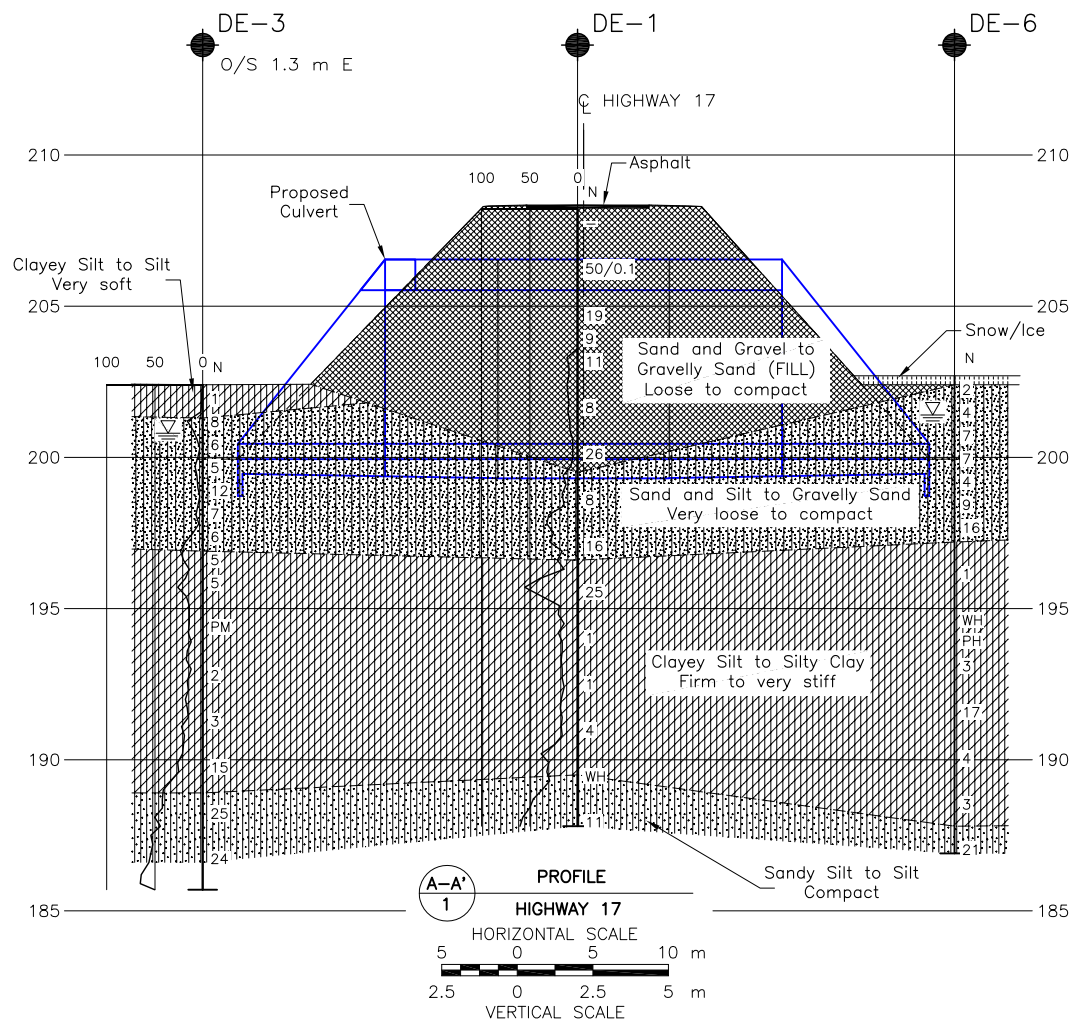
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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 Morrison Hershfield, drawing file no. X-1130113_Base Plan.dwg, received NOV 13, 2014 and 43-165C_01.dwg, received NOV 13, 2014.



Sandy Silt to Gravelly SandUnit Weight: 19 kN/m³

Phi: 28 °

New Granular FillUnit Weight: 21 kN/m³

Phi: 35 °

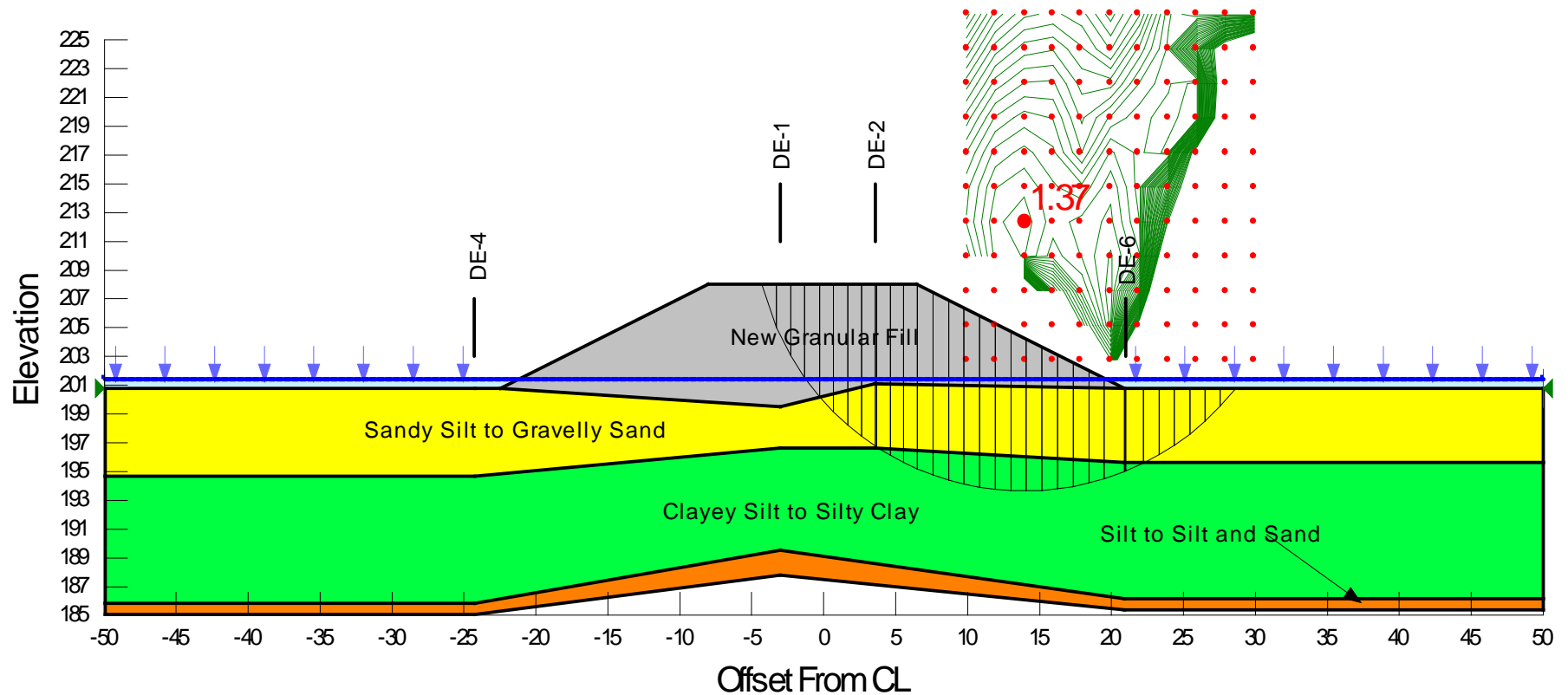
Clayey Silt to Silty ClayUnit Weight: 17 kN/m³

Upper Cohesion: 25 kPa

Rate of Change: 4.38 kPa/m

Silt to Silt and SandUnit Weight: 19 kN/m³

Phi: 30 °



PROJECT				
HIGHWAY 17 – Deer Creek Culvert				
TITLE				
STABILITY ANALYSIS EMBANKMENT SOUTH SIDE SLOPE				
PROJECT No. 13-1184-0074		FILE No. ----		
DESIGN	MT	April 2014	SCALE AS SHOWN	REV.
CADD	--			
CHECK	AB	April 2014	FIGURE 1	
REVIEW	JMAC	April 2014		





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
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

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

(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 = σ'_p / σ'_{vo}

(d) Shear Strength

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

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

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² 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	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test 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

PROJECT <u>13-1184-0074</u>		RECORD OF BOREHOLE No DE-1		1 OF 2		METRIC	
W.P. <u>5081-05-01</u>		LOCATION <u>N 5144162.2; E 245673.4</u>		ORIGINATED BY <u>TM</u>			
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>Solid Stem Augers, NW Casing, Wash Boring</u>		COMPILED BY <u>MT</u>			
DATUM <u>GEODETIC</u>		DATE <u>February 5 and 6, 2014</u>		CHECKED BY <u>DAM</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa						WATER CONTENT (%)			
							<div><div><div>○ UNCONFINED</div><div>● QUICK TRIAXIAL</div></div><div><div>+ FIELD VANE</div><div>× REMOULDED</div></div></div>						<div><div>W_p</div><div>W</div><div>W_L</div></div>			
208.2	GROUND SURFACE						20	40	60	80	100					
0.7	ASPHALT (150 mm)		1	AS	-											
	Sand and gravel to gravelly sand (FILL) Loose to compact Brown Moist to wet															
	Auger refusal at 0.8 m depth. Switched to NW casing.		-	SS	50/0.1											
	No sample recovered at 1.5, 3.0 and 3.8 m depths.															
	Cobbles/Boulders as follows:															
	Depth (m) Thickness (mm)															
	0.8 150															
	1.1 100															
	2.1 300		2	SS	19											
	2.7 150															
	5.8 120															
	7.1 90															
	7.3 90		-	SS	9											
			3	SS	11											
			4	SS	8											
			5	SS	26											
199.5																
8.7	SAND to Gravelly SAND, some silt, trace clay Loose to compact Grey Wet		6	SS	8											
			7	SS	16											
196.6																
11.6	CLAYEY SILT to SILTY CLAY Firm to very stiff Grey Wet		8	SS	25											
	Approximately 0.8 m thick sandy silt layer at 12.5 m depth.															
			9	SS	1											

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No DE-1			2 OF 2 METRIC															
W.P. 5081-05-01			LOCATION N 5144162.2; E 245673.4			ORIGINATED BY TM															
DIST HWY 17			BOREHOLE TYPE Solid Stem Augers, NW Casing, Wash Boring			COMPILED BY MT															
DATUM GEODETIC			DATE February 5 and 6, 2014			CHECKED BY DAM															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p W W _L 20 40 60			kN/m ³					
189.5	CLAYEY SILT to SILTY CLAY Firm to very stiff Grey Wet		10	SS	1		193														
							192	3													
			11	SS	4		191														
			12A	SS	WH		190														
18.7	SILT, some sand, some clay Compact Grey Wet		12B				189														
187.8			13	SS	11		188														
20.4	END OF BOREHOLE Note: 1. Borehole caved at 12.2 m upon completion of drilling. Borehole dry to 12.2 m depth. 2. DCPT advanced 1 m east of Borehole DE-1, preaugered to 4.6 m.																				

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT <u>13-1184-0074</u>		RECORD OF BOREHOLE No DE-2		1 OF 2 METRIC	
W.P. <u>5081-05-01</u>		LOCATION <u>N 5144163.7; E 245640.8</u>		ORIGINATED BY <u>TM</u>	
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring</u>		COMPILED BY <u>MT</u>	
DATUM <u>GEODETIC</u>		DATE <u>February 6 and 10, 2014</u>		CHECKED BY <u>DAM</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								20	40	60	80	100			W _p	W	W _L
208.4	GROUND SURFACE																
0.0	ASPHALT (150 mm)																
0.2	Sand and gravel to gravelly sand (FILL) Loose to very dense Brown Moist Augers grinding between 1.1 m and 1.4 m depth. Auger refusal at 1.4 m depth, switched to NW Casing and recovered 300 mm boulder at 1.4 m depth. No sample recovered at 2.3 m depth.		1	AS	-												
			2	SS	50/0.15												
			3	SS	63												
			-	SS	9												
			4	SS	25												
		5	SS	21													
		6	SS	14													
		7	SS	11													
201.2																	
7.2	Silty SAND to SAND, trace clay, trace organics Compact Grey Wet		8	SS	25												
			9	SS	10												
			10	SS	21												
196.7																	
11.7	SILTY CLAY Very stiff Grey Wet		11	SS	2												
			12	SS	1												
193.6																	
14.8																	

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

Continued Next Page

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

PROJECT <u>13-1184-0074</u>		RECORD OF BOREHOLE No DE-2				2 OF 2 METRIC										
W.P. <u>5081-05-01</u>		LOCATION <u>N 5144163.7; E 245640.8</u>				ORIGINATED BY <u>TM</u>										
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring</u>				COMPILED BY <u>MT</u>										
DATUM <u>GEODETIC</u>		DATE <u>February 6 and 10, 2014</u>				CHECKED BY <u>DAM</u>										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
	--- CONTINUED FROM PREVIOUS PAGE ---															
	END OF BOREHOLE Note: 1. Water level at a depth of 7.2 m below ground surface (Elev. 201.2 m) upon completion of drilling.															


SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No DE-3			1 OF 2 METRIC													
W.P. 5081-05-01			LOCATION N 5144187.0; E 245672.5			ORIGINATED BY MR													
DIST HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT													
DATUM GEODETIC			DATE February 5, 2014			CHECKED BY DAM													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED			WATER CONTENT (%) W _p — W — W _L			γ			GR SA SI CL		
202.4	GROUND SURFACE							20	40	60	80	100	20	40	60	kN/m ³			
0.0	CLAYEY SILT to SILT, trace to some sand, trace to some organics Very soft Moist (frozen) Grey		1	SS	1		202												
201.3	SAND, trace to some silt, trace clay Loose to compact Grey Wet		2A	SS	8		201												
1.1			2B																
			3	SS	6		200												
			4	SS	5														
	Approximately 0.6 m thick organic (wood fragments) layer at 3.0 m depth.		5	SS	12		199												
			6	SS	7		198												
			7	SS	6														
196.9	CLAYEY SILT to SILTY CLAY Firm to stiff Grey Wet		8A	SS	5		197												
5.5			8B																
	Silt laminations above 7.2 m depth.		9	SS	5		196												
			10	TO	PM		195												
			11	SS	2		194												
			12	SS	3		193												
			13	SS	15		192												
	Silt laminations below 12.2 m depth.		14	SS	25		191												
188.9	SILT and SAND, trace to some clay Compact Grey Wet						190												
13.5							189												
							188												

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

Continued Next Page

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

PROJECT 13-1184-0074				RECORD OF BOREHOLE No DE-3				2 OF 2 METRIC										
W.P. 5081-05-01				LOCATION N 5144187.0; E 245672.5				ORIGINATED BY MR										
DIST HWY 17				BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY MT										
DATUM GEODETIC				DATE February 5, 2014				CHECKED BY DAM										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100						
186.6	SILT and SAND, trace to some clay Compact Grey Wet		15	SS	24		187											
15.8	END OF BOREHOLE																	
185.7								186										
16.7	END OF DYNAMIC CONE PENETRATION TEST Note: 1. Water level at a depth of 1.6 m below ground surface (Elev. 200.8 m) upon completion of drilling. 2. DCPT advanced 0.4 m north of Borehole DE-3.																	

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No DE-4			1 OF 2 METRIC		
W.P. 5081-05-01			LOCATION N 5144189.8; E 245653.0			ORIGINATED BY MR		
DIST HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT		
DATUM GEODETIC			DATE February 3 and 4, 2014			CHECKED BY DAM		
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100 PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%)
202.0	GROUND SURFACE							
0.0	CLAYEY SILT to SILT, trace to some sand, trace to some organics Very soft Grey Moist (frozen)		1	SS	2			
201.2	Sandy SILT to Silty SAND, trace to some clay, trace gravel, trace organics Very loose to loose Grey to brown Moist		2	SS	2			
0.8			3	SS	3			
			4	SS	5			
			5	SS	3			
			6	SS	6			
			7	SS	7			
195.9	CLAYEY SILT to SILTY CLAY Firm to very stiff Grey Wet		8	SS	2			
6.1			9	SS	22			
			10	SS	2			
			11	TO	PM			
			12	SS	3			
			13	SS	4			
			14	SS	8			
187.1								

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT		RECORD OF BOREHOLE				No DE-4		2 OF 2		METRIC								
W.P. 5081-05-01		LOCATION N 5144189.8; E 245653.0				ORIGINATED BY MR												
DIST _____ HWY 17		BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY MT												
DATUM GEODETIC		DATE February 3 and 4, 2014				CHECKED BY DAM												
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa										
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) 20 40 60						
14.9	SILT, trace to some clay, trace sand Compact Grey Wet		15	SS	28													
186.2	END OF BOREHOLE																	
15.8																		
185.2	END OF DYNAMIC CONE PENETRATION TEST																	
16.8	Note: 1. Water level at a depth of 1.9 m below ground surface (Elev. 200.1 m) upon completion of drilling. 2. DCPT advanced 0.5 m north of Borehole DE-4.																	

PROJECT		13-1184-0074		RECORD OF BOREHOLE		No DE-5		1 OF 2		METRIC			
W.P.		5081-05-01		LOCATION		N 5144143.7; E 245655.8		ORIGINATED BY		GM			
DIST		HWY 17		BOREHOLE TYPE		NW Casing, Wash Boring		COMPILED BY		MT			
DATUM		GEODETIC		DATE		January 24 to 29, 2014		CHECKED BY		DAM			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	20 40 60		
202.9	SNOW SURFACE												
0.0	SNOW/ICE												
202.6			1	SS	7								
0.3	Sandy SILT, some organics Very loose to loose Brown Moist		2	SS	2								
201.4													
1.5	Sandy SILT to Silty SAND Very loose to loose Brown Moist to wet		3	SS	7								
			4	SS	5								
			5	SS	2								
	Approximately 0.6 m thick silt layer at 3.8 m depth.		6	SS	2								
	Approximately 0.1 m thick sand layer at 4.6 m.		7A 7B	SS	12								
			8A 8B	SS	2								
196.5	CLAYEY SILT Firm to stiff Brown Wet												
6.4			9	SS	4								
	Silt laminations at 9.1 m depth.		10	SS	7								
	Approximately 0.3 m thick silty sand layer encountered at 10.7 m depth.		11	SS	6								
			12	SS	3								
189.5	SILT, trace to some clay Compact Grey Wet		13	SS	24								
13.4													

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

Continued Next Page

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

PROJECT		13-1184-0074				RECORD OF BOREHOLE No DE-5				2 OF 2 METRIC							
W.P.		5081-05-01		LOCATION		N 5144143.7; E 245655.8				ORIGINATED BY		GM					
DIST		HWY 17		BOREHOLE TYPE		NW Casing, Wash Boring				COMPILED BY		MT					
DATUM		GEODETIC		DATE		January 24 to 29, 2014				CHECKED BY		DAM					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
			14	SS	18		187										
185.5			15	SS	23		186										
17.4	END OF BOREHOLE																
	Note: 1. Water level at a depth of 2.6 m below ground surface (Elev. 200.3 m) upon completion of drilling. 2. DCPT advanced 1 m west of Borehole DE-5.																


SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No DE-6			1 OF 2 METRIC															
W.P. 5081-05-01			LOCATION N 5144137.3; E 245674.8			ORIGINATED BY GM															
DIST _____ HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT															
DATUM GEODETIC			DATE January 30, 2014			CHECKED BY DAM															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
202.7	SNOW SURFACE							20 40 60 80 100	20 40 60	W _p W W _L											
0.0	SNOW/ICE							20 40 60 80 100	20 40 60												
202.4			1	SS	2		202														
0.3	SILT and SAND, some organics Very loose Brown Moist		2	SS	4		201														
201.2	Casing refusal at 1.5 m depth below the ice surface on probable cobble or boulder (hammer bouncing). Moved borehole 0.3 m east and advanced casing to 1.5 m depth without sampling.		3	SS	7		200														
1.5	SAND and SILT to Silty SAND, trace to some clay Very loose to compact Grey Wet		4	SS	7		199														
	Approximately 0.6 m thick sand layer at 3.0 m depth.		5	SS	4		198														
			6	SS	9		197														
			7	SS	16		196														
197.2			8	SS	1		195														
5.5	SILTY CLAY Firm to stiff Grey Wet		9	SS	WH		194														
			10	TO	PH		193														
			11	SS	3		192														
	Approximately 1.5 m thick silt layer at 10.7 m depth.		12	SS	17		191														
			13	SS	4		190														
			14	SS	3		189														
187.8							188														

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT <u>13-1184-0074</u>				RECORD OF BOREHOLE No DE-6				2 OF 2 METRIC										
W.P. <u>5081-05-01</u>		LOCATION <u>N 5144137.3; E 245674.8</u>				ORIGINATED BY <u>GM</u>												
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>NW Casing, Wash Boring</u>				COMPILED BY <u>MT</u>												
DATUM <u>GEODETIC</u>		DATE <u>January 30, 2014</u>				CHECKED BY <u>DAM</u>												
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)					
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED </div>					<div style="display: flex; justify-content: space-between;"> W_p W W_L </div>						
14.9	Sandy SILT		15	SS	21													
186.9	Compact Grey Wet																	
15.8	END OF BOREHOLE																	
	Note: 1. Water level at a depth of 1.3 m below ground surface (Elev. 201.4 m) upon completion of drilling.																	



APPENDIX B

Laboratory Test Results



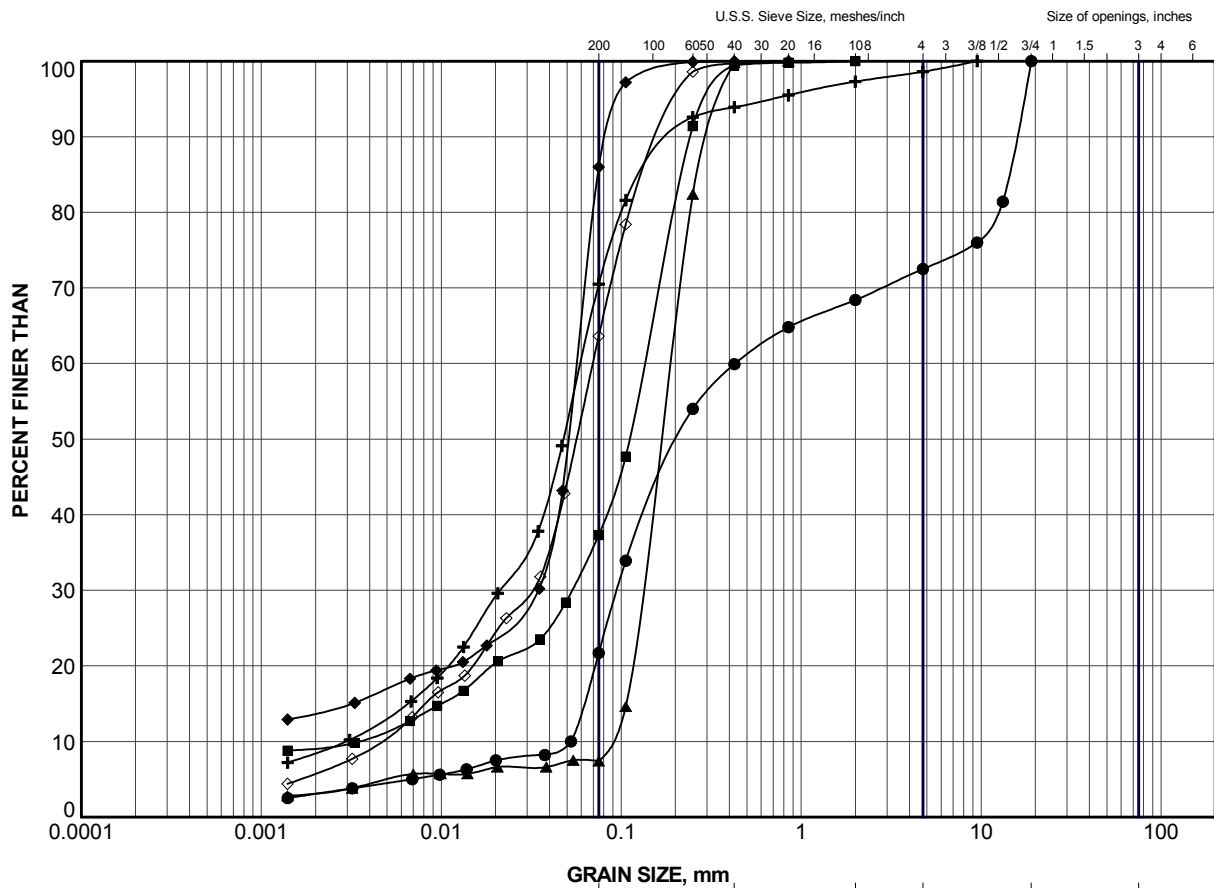
FOUNDATION INVESTIGATION AND DESIGN REPORT HIGHWAY 17 DEER CREEK CULVERT, SITE 43-165/C

Table B1 - Summary of Analytical Testing of Deer Creek Water Sample

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	11
Dissolved Sulphate	mg/L	1	8
Conductivity	µohm/cm	1	230
Resistivity	ohm-cm	n/a	4300
pH	n/a	n/a	7.51

- Notes:
1. Sample obtained on March 10, 2014.
 2. Analytical testing carried out by Maxxam Analytics.

Checked by: AB



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	DE-1	6	198.8
■	DE-2	8	200.5
▲	DE-3	6	198.3
+	DE-4	2	200.9
◆	DE-5	6	198.8
◇	DE-6	2	201.6

PROJECT

HIGHWAY 17
DEER CREEK CULVERT STA 11+815

TITLE

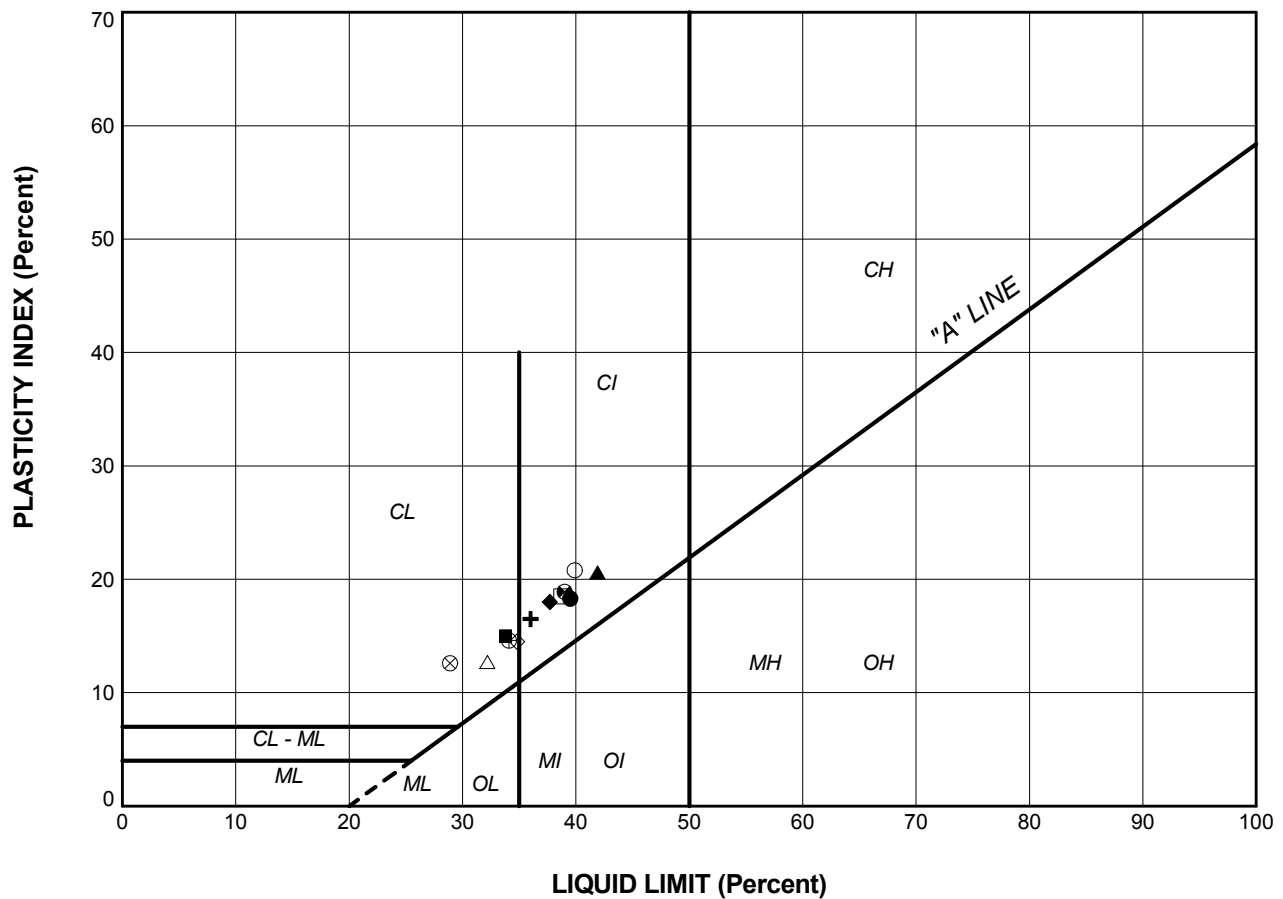
GRAIN SIZE DISTRIBUTION
SANDY SILT to GRAVELLY SAND



**Golder
Associates**
SUDBURY, ONTARIO

PROJECT No.	13-1184-0074	FILE No.	13-1184-0074.GPJ
DRAWN	TB	May 2014	SCALE N/A
CHECK	AB	May 2014	REV.
APPR	JMAC	May 2014	

FIGURE B1




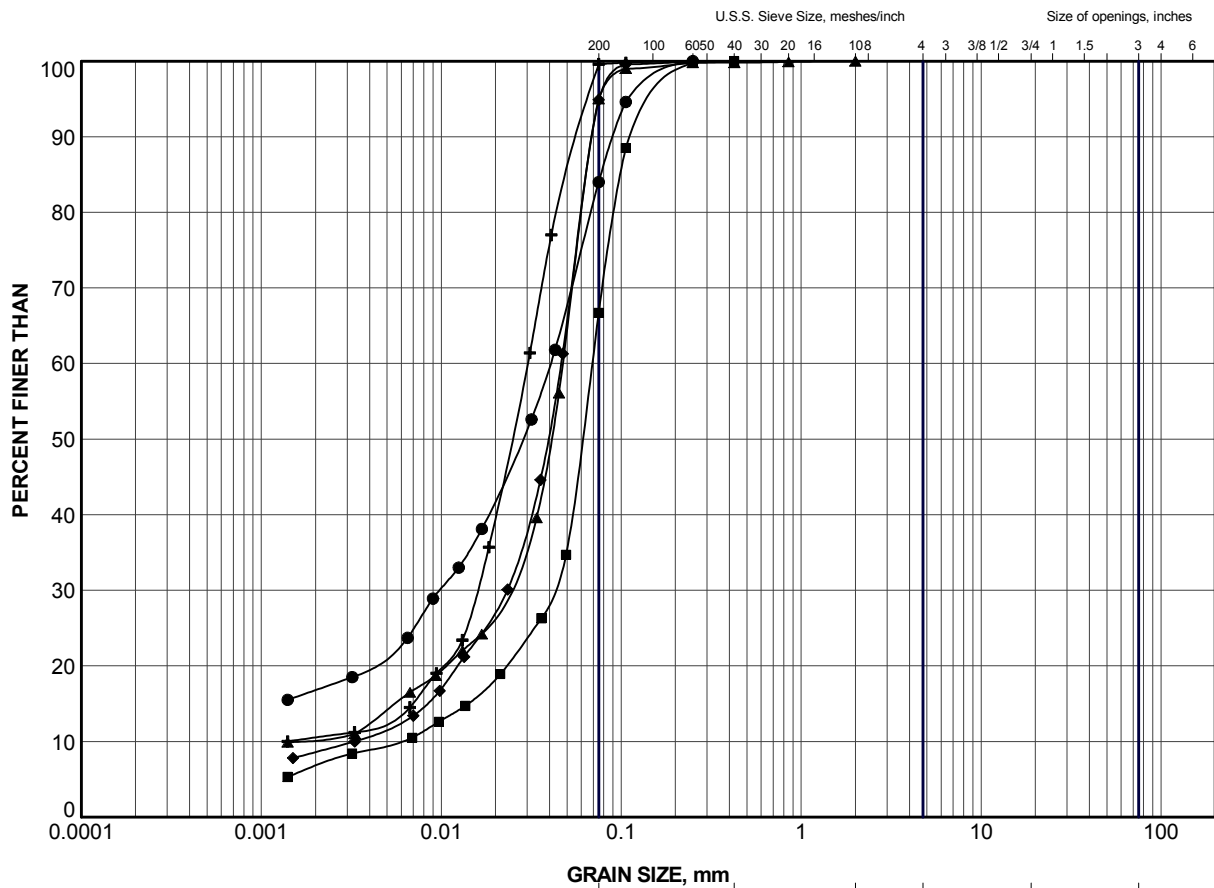
SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	DE-1	11	39.5	21.2	18.3
■	DE-1	12A	33.8	18.8	15.0
▲	DE-2	11	41.9	21.3	20.6
+	DE-2	12	36.0	19.5	16.5
◆	DE-3	8B	37.7	19.7	18.0
◇	DE-3	12	34.8	20.3	14.5
○	DE-4	10	39.9	19.1	20.8
△	DE-4	13	32.2	19.5	12.7
⊗	DE-5	10	28.9	16.3	12.6
⊕	DE-5	12	34.1	19.5	14.6
□	DE-6	11	38.7	20.2	18.5
⊗	DE-6	13	39.0	20.1	18.9

PROJECT					
HIGHWAY 17 DEER CREEK CULVERT STA 11+815					
TITLE					
PLASTICITY CHART CLAYEY SILT to SILTY CLAY					
PROJECT No.		13-1184-0074		FILE No.	
DRAWN		TB		May 2014	
CHECK		AB		May 2014	
APPR		JMAC		May 2014	
 Golder Associates SUDBURY, ONTARIO				SCALE N/A REV.	
FIGURE B2					



GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	DE-1	13	188.1
■	DE-3	15	186.9
▲	DE-4	15	186.5
+	DE-5	14	187.4
◆	DE-6	12	191.7

PROJECT					
HIGHWAY 17 DEER CREEK CULVERT STA 11+815					
TITLE					
GRAIN SIZE DISTRIBUTION SILT to SILT and SAND					
PROJECT No.		13-1184-0074		FILE No. 13-1184-0074.GPJ	
DRAWN	TB	May 2014	SCALE	N/A	REV.
CHECK	AB	May 2014	FIGURE B3		
APPR	JMAC	May 2014			





APPENDIX C

Non-Standard Special Provisions

WORKING SLAB – Item No.

Non-Standard Special Provision

Scope of Work

The subgrade soils for the box culvert foundations may be susceptible to disturbance and loosening from construction traffic and ponded water.

Where precast box culverts are used, if all of the box segments are not placed on the prepared subgrade within four hours of its inspection and approval, a concrete working slab of 20 MPa compressive strength at 28 days with minimum thickness of 100 mm, shall be placed on the foundation subgrade. A minimum 75 mm thick uncompacted levelling pad consisting of Granular 'A' material (OPPS.PROV 1010) or concrete fine aggregate (meeting the grading requirements specified in OPSS.PROV 1002) shall be provided on top of the concrete working slab.

Basis of Payment

Payment at the lump sum contract price for the above tender item includes full compensation for all labour, equipment and material for completion of the work.

END OF SECTION

UNWATERING OF STRUCTURE EXCAVATION - Item No.

Non-Standard Special Provision

Construction of both sections of the culvert will require excavations to extend below the groundwater level. The cohesionless soils that are present below the groundwater table will slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate excavation protection and unwatering system to enable construction in dry conditions, to prevent disturbance to the founding soils.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

OBSTRUCTIONS

Non-Standard Special Provision

The Contactor shall be alerted to the presence of cobbles and boulders within the embankment fill and in the native soil. Considerations of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for sub-excavation and installation of the temporary shoring and roadway protection system, if required.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
1010 Lorne Street
Sudbury, Ontario, P3C 4R9
Canada
T: +1 (705) 524 6861

