



REPORT

FOUNDATION INVESTIGATION AND DESIGN REPORT

Gully Creek, Site 12-297, Highway 21

GWP 3101-15-00, WP 3140-15-01, Contract 12

Ministry of Transportation, Ontario - West Region

Submitted to:

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Maxxam Certificate of Analysis

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Maxxam Certificate of Analysis

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PART A

FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Stantec Consulting Ltd. (Stantec) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out an investigation of the subsurface conditions at the Gully Creek Site (Site No. 12-297/C) north of Bayfield, Ontario on Highway 21 as part of detail design for GWP 3101-15-00, Contract 12.

The purpose of the work is to provide recommendations based on a review of the available geotechnical and geological data from the MTO Geocres Library and the results of a supplementary subsurface exploration program. The current exploration program consisted of drilling six boreholes for the proposed bridge abutments and approach embankments, carrying out in situ testing in the boreholes and carrying out laboratory testing on selected samples. The terms of reference for the scope of work are provided in the MTO's Request for Proposal, Golder's proposal P1534424 dated September 2, 2015 and Golder Change Order 7 (REV5) dated July 23, 2018. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated October 26, 2015.

2.0 SITE DESCRIPTION

Gully Creek crosses Highway 21 approximately 6.8 kilometres (kms) north of County Road 3 (Mill Road) in Bayfield, Ontario. The approximate location of the Gully Creek site is shown on the Key Plan, Drawing 1.

The existing structure is a 7.2 metre (m) span, 3.7 m high and 29.6 m long open footing concrete arch culvert with approximately 7 to 8 m of fill on the existing culvert. The existing highway grade at the centreline of the culvert is 194.5 m, with the ground surface at the inlet at approximately 184 m and outlet at 183 m, corresponding to an approximately 10 to 12 m embankment height at the culvert location. The existing highway embankments in the vicinity of the existing Gully Creek structure have RSS walls on the east and west sides, extending north and south. The existing side slopes are heavily vegetated and oversteepened in the areas without RSS walls. The topography of the surrounding lands is generally flat to gently undulating leading up to the Gully Creek site with the ground dipping steeply toward Gully Creek. Select site photographs are attached in Appendix D.

3.0 INVESTIGATION PROCEDURES

3.1 Previous Investigation (AMEC - 2013)

A review of the available information from the MTO Geocres Library was carried out in conjunction with the preparation of this report. The information was provided in:

- Geocres Report 40P12-21 titled "Foundation Investigation and Design Report, Rehabilitation of Highway 21 from Bayfield to Goderich, Ontario, G.W.P. 834-93-00" dated May 2013, by AMEC Environment & Infrastructure, a Division of AMEC Americas Limited.

One borehole, G30, was advanced at the Gully Creek site and the Record of Borehole and related laboratory test data are attached to this report in Appendix A.

3.2 Current Investigation

The boreholes for the current investigation were drilled using a truck mounted drilling rig supplied and operated by a specialist subcontractor under the direction of a member of our engineering staff. Standard penetration testing (SPT) and sampling was carried out in each of the current boreholes using conventional split spoon sampling equipment (ASTM D1586). All of the samples obtained during the investigation were brought to our laboratory in London, Ontario for further examination and routine laboratory testing. The results of the field and laboratory testing are shown on the Records of Boreholes in Appendix B, on Drawings 1 and 2 and on Figures 1 to 9. The encountered groundwater conditions are shown on the Records of Boreholes. Following completion of drilling and sampling, the boreholes were backfilled in accordance with current regulations and MTO recommendations.

The borehole locations and ground surface elevations at the borehole locations are shown on the Record of Borehole sheets in Appendices A and B and on Drawing 1. The as-drilled borehole locations and ground surface elevations were measured by a member of our technical staff, referenced to the highway centerline and existing bridge structure, and converted into northing/easting coordinates on the plan drawing. The table below summarizes the coordinates, ground surface elevations and depths of the current and previous boreholes.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
Current Investigation				
BH-101	4 830 716.6	368 924.9	195.0	9.8
BH-102	4 830 731.3	368 920.6	194.8	26.4
BH-103	4 830 732.7	368 911.0	194.7	24.5
BH-104	4 830 772.0	368 911.0	194.5	24.1
BH-105	4 830 784.8	368 925.5	194.1	22.7
BH-106	4 830 797.5	368 910.9	194.9	10.1
Previous Investigation - GEOCRE 40P12-21				
G30	4 830 745.9 *	368 912.7 *	194.4	18.5

*Location of Borehole G30 inferred from AMEC - Borehole Location Plan as the co-ordinates on the Record of Borehole differ from the Borehole Location Plan.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Site Geology

The project area is located within the physiographic region known as the Huron Slope, bordered closely by the Huron Fringe toward Lake Huron as indicated in “The Physiography of Southern Ontario”¹. This region is located within a sub region described as bevelled till plains (also known as the St. Joseph Till² deposits). The overburden soils are reported to consist of silt/clay tills with minor deposits of sand and gravel derived from glaciolacustrine deposits.

The geological mapping indicates that the underlying bedrock consists of limestone, dolostone and shale of the Detroit River Group of the Onondaga Formation of Middle Devonian age³. Based on the available bedrock mapping the bedrock surface at the site is at about elevation 175 m or about 20 m below the ground surface⁴.

4.2 Subsurface Conditions

The subsurface conditions encountered in the boreholes previously drilled at the site (Geocres Report No. 40P12-21) are shown in detail on the Record of Borehole sheets in Appendix A. The Records of Boreholes and related laboratory data for the current investigation are provided in Appendix B. The following discussion has been simplified in terms of major strata for the purposes of geotechnical design. The soil boundaries discussed in this report and shown on the Records of Boreholes have been inferred from non-continuous samples and observations of drilling and sampling resistance. These boundaries typically represent a transition from one soil type to another and should not necessarily be interpreted to represent exact planes of geological change. The subsurface conditions should be expected to vary between and beyond the borehole locations. Further, post-investigation construction activities at the site may have altered the subsurface conditions from those shown on previous Record of Borehole G30.

The soil descriptions on the previous Records of Boreholes have been interpreted to correspond to standard MTO soil descriptions, using the original laboratory data, where available. The standard MTO soil descriptions are used in the discussion below and on Drawings 1 and 2. The subsurface conditions encountered in the previous boreholes generally consisted of granular and cohesive fill overlying a deposit of clayey silt to silty clay till which are underlain by limestone bedrock.

4.3 Previous Investigation

A single borehole (G30) was advanced as part of Geocres Report No. 40P12-21. G30 encountered sand and gravel, silty sand and silty clay fill which extended to about Elevation 185.7 m, approximately 8.7 m below the existing highway grade. Trace amounts of topsoil and organics were noted throughout the fill deposit. The loose to compact granular fill had N values of 4 to 11 blows per 0.3 m and the firm to stiff cohesive fill had N values of 4 and 15 blows per 0.3 m.

¹ Ontario Geological Survey 2010, Surficial Geology of Southern Ontario; Ontario Geological Survey, Miscellaneous Release Data, 128-REV, accessed October 2018

² Quaternary Geology of the Goderich Area, Southern Ontario; Ontario Dept. Mines and Northern Affairs, Prelim. Map P1232, Geol. Ser., scale 1:50,000. 1977.

³ Ontario Geological Survey, 1991, Bedrock Geology of Ontario, Southern Sheet, Ontario Geological Survey, Map 2544, Scale 1:1 000 000.

⁴ Bedrock Topography Series, Goderich-Seaforth Sheet; Ontario Dept. Mines and Northern Affairs, Prelim. Map P297, Geol. Ser., scale 1:50,000. 1964.

Underlying the fill, native clayey silt to silty clay was encountered at about Elevation 185.7 m. Borehole G30 was terminated in the clayey silt to silty clay, approximately 18.4 m below the existing highway grade after exploring it for about 9.7 m. Cobbles and boulders were noted in this deposit.

The clayey silt to silty clay had SPT N values ranging from 14 to 79 blows per 0.3 m, indicating a stiff to hard consistency. Samples of the clayey silt to silty clay had water contents ranging from about 12 to 17 per cent. The clayey silt to silty clay had plastic limits of about 13 and 15 per cent, liquid limits of about 26 and 27 per cent and corresponding plasticity indices of 12 and 13 per cent. The relevant data corresponding to borehole G30 are provided on the Records of Borehole and associated figures in Appendix A.

4.3.1 Groundwater Conditions

Borehole G30 was reported to be dry during and upon completion of drilling on March 14, 2012.

4.3.2 Analytical Testing of Soil Samples

The results of previous analytical testing for a suite of inorganic parameters are provided in Appendix A.

4.4 Current Investigation

4.4.1 Embankment Fill

Fill was encountered in all of the boreholes with an overall thickness ranging from about 1.4 to 6.7 m. A layer of topsoil was encountered at the ground surface in borehole 105 and was about 0.4 m thick. Boreholes 102, 103, 104 and 106 were advanced through the roadway or shoulder on the existing Highway 21 platform and boreholes 101 and 105 were advanced just off the existing platform. The asphalt was 50 to 175 millimetres (mm) thick at the borehole locations and was underlain by layers of gravelly sand and sand fill about 1.2 to 2.1 m thick. Beneath the pavement structure, the fill varied between the boreholes and consisted of silty sand to sandy silt and clayey silt including trace amounts of topsoil/organics. In Borehole 103, a 0.6 m thick layer of topsoil was encountered within the fill at approximately elevation 191.7 m. Pieces of wood were encountered in borehole 104 at about Elevation 192.5 m depth.

Grain size distribution curves for samples of the fill are shown on Figures B-1 and B-2 in Appendix B.

The fill had SPT N values of 2 to 36 blows per 0.3 m. Water contents of samples of the granular portions of the fill were about 2 to 15 per cent and the samples of the cohesive portions of the fill had water contents of about 12 to 22 per cent. A sample of the cohesive fill had plastic and liquid limits of about 17 and 36 per cent, respectively, based on a single Atterberg limits determination, the results of which are shown on Figure B-3 in Appendix B.

4.4.2 Clayey Silt

Beneath the fill in all of the boreholes an extensive layer of clayey silt was encountered between elevation 193.6 and 188.0 m. Boreholes 101, 103, 104 and 106 were terminated in the clayey silt after exploring it for about 6.3 to 20.6 m. Where fully penetrated in borehole 102, the clayey silt was about 19.8 m. Cobbles and boulders were encountered within Borehole 102 and should be expected throughout the clayey silt.

Grain size distribution curves for samples of the clayey silt are provided on Figures B-4 and B-5 in Appendix B.

The clayey silt had N values ranging from 9 to greater than 100 blows per 0.3 m indicating a stiff to hard consistency. Samples of the clayey silt had water contents that ranged from about 11 to 26 per cent. Samples of the clayey silt had plastic limits ranging from about 12 to 17 per cent and liquid limits ranging from about 22 to 31 per cent based on eighteen Atterberg limits determinations, the results of which are provided on Figures B-6 and B-7 in Appendix B.

4.4.3 Silt to Silt and Sand

Silt and silt and sand layers were encountered in boreholes 102 and 104, respectively. The silt was encountered in Borehole 102 at elevation 171.3 and was about 1.6 m thick. The silt and sand was encountered in Borehole 104 at elevation 173.8 m within the clayey silt and was about 2.1 m thick.

The very dense silt to silt and sand layers had SPT N values of 57 and 106 blows per 0.3 m, respectively. Samples of the silt to silt and sand had water contents of about 11 and 16 per cent.

A grain size distribution curve for a sample of the silt and sand is shown on Figure B-8 in Appendix B.

4.4.4 Sandy Gravel

Underlying the silt in borehole 102, a 0.9 m thick layer of sandy gravel was encountered at Elevation 169.72 m.

The very dense sandy gravel had an SPT N value of 60 blows for 152 mm of penetration with a water content of about 11 per cent.

A grain size distribution curve for a sample of the sandy gravel is shown on Figure B-9 in Appendix B. Cobbles and boulders should be expected in the sandy gravel.

4.4.5 Bedrock/Refusal

Bedrock was encountered beneath the sandy gravel in borehole 102 and inferred beneath the clayey silt in borehole 105 at elevation 168.8 and 170.4 m, respectively. In borehole 102, the limestone bedrock was explored for about 0.4 m by augering.

4.4.6 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling. Boreholes 101, 103, 104, 105 and 106 were dry during drilling. Groundwater was encountered during drilling below the clayey silt in borehole 102 at elevation 170.2 m. The above-noted encountered water level is not necessarily considered to be representative of the long-term, stabilized groundwater conditions. The colour change from brown to grey in the clayey silt at about Elevation 185 to 190 metres may represent the lowest groundwater in the clayey silt. The groundwater levels should be expected to fluctuate seasonally and be higher during periods of sustained precipitation or during spring snow melt conditions.

Based on the General Arrangement drawing provided by Stantec, we understand that the Gully Creek water level was at elevation 184.01 m in June 2016.

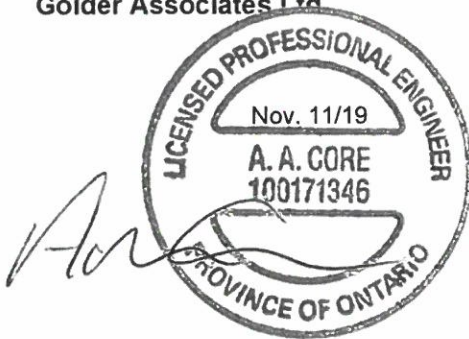
4.4.7 Analytical Testing of Soil Samples

Select soil samples from Boreholes 102 and 105 were obtained during the field investigation using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of inorganic parameters, the results of which are provided in Appendix B. It should be noted that the samples were submitted beyond the standard hold times.

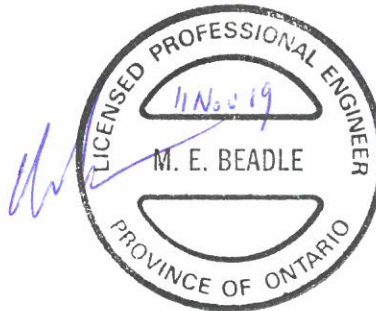
5.0 MISCELLANEOUS

The investigation was carried out using drilling equipment supplied and operated by Aardvark Drilling, under the direction of Messrs. Adam Core and Mike Arthur. This report was prepared by Mr. Adam Core, P.Eng. and the technical aspects were reviewed by Mr. Michael E. Beadle, P.Eng., an Associate with Golder. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment, conducted an independent quality review of this report.

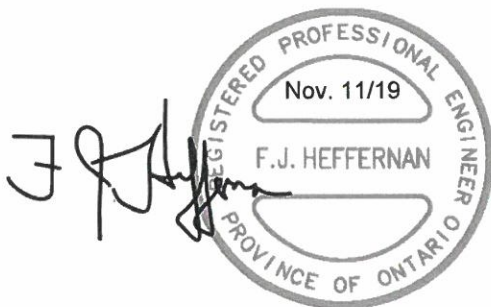
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PART B

FOUNDATION INVESTIGATION REPORT
Gully Creek, Site No. 12-297, Highway 21
GWP 3101-15-00, WP 3140-15-01, Contract 12
Ministry of Transportation, Ontario – West Region

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed replacement of the Gully Creek culvert (Site No. 12-297) with a new bridge structure. The recommendations are based on our interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at this site. The interpretation of the subsurface information and recommendations presented in this Foundation Design Report (Part B) are intended to provide MTO's designers with sufficient information to assess the feasible foundation alternatives and to design the proposed bridge structure foundations and approach embankments.

The discussion and recommendations contained in this Foundation Design Report (Part B) shall not be used or relied upon for any other purpose or by any other parties, including the construction contractor. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. The contractor must make their own interpretation based on the factual data in the Foundation Investigation Report (Part A), as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

The existing structure is a 7.2 m span, by 3.7 m high and 29.6 m long open footing concrete arch culvert supporting approximately 7 to 8 m of fill. The existing highway grade at the centreline of the culvert is about 194.5 m. The ground surface elevation at the inlet is approximately 184 m and at the outlet is 183 m. The existing highway embankments in the vicinity of the existing Gully Creek culvert have RSS walls on the east and west sides.

Based on the General Arrangement drawing provided by Stantec on September 24, 2018 and subsequent discussions with Stantec and MTO, we understand that a single span bridge structure on the existing alignment is the preferred alternative. The existing culvert will be removed. We understand that the work will be completed using a full road closure and detour of Highway 21 which eliminates the need for staged construction and temporary roadway protection systems.

The proposed structure is an approximately 43 m long, single span bridge that will be constructed on the existing alignment. The proposed highway grade at the north and south abutments will be about 0.6 m to 0.7 m higher than the existing grade, respectively, to improve overall road geometrics. Further we understand that MTO would like to avoid retaining walls, favouring a traditionally graded embankment and acquiring property to accommodate embankment side slopes which will extend beyond the existing right-of-way.

6.2 Consequence and Site Understanding Classification

The replacement bridge is being designed in accordance with the current Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC 2014). In accordance with Section 6.5 of CHBDC (2014) and its Commentary, the proposed bridge and its foundation system are considered to have a "typical consequence level" associated with exceeding limits states design. The degree of understanding, based on the scope of the current foundation investigation and design, is considered 'typical' as described in Clause 6.5.3.2 of CHBDC (2014). The appropriate corresponding Ultimate Limit States (ULS) and Serviceability Limit States (SLS) consequence factor, Ψ , and

geotechnical resistance factors at ULS (ϕ_{gu}) and SLS (ϕ_{gs}), respectively, from Tables 6.1 and 6.2 of the CHBDC have been used for design in this report.

6.3 Foundations

Based on the proposed bridge geometry and the subsurface conditions at this site, deep foundation options are being considered for support of the bridge abutments. Shallow foundations are not considered to be feasible due to the lower geotechnical axial resistances that would be available, the potential for differential settlements and since shallow footings cannot support a fully integral abutment design which we understand to be preferable from a structural perspective. A summary of the advantages and disadvantages associated with each foundation option is provided below and a comparison of the foundation options based on advantages, disadvantages, risks/consequences and relative costs is provided in Table 1 following the text of this report.

- **Driven Steel H-piles:** Driven steel H-piles are feasible for the support of the abutments and would permit integral abutment design. The abutments would be supported on end-bearing piles driven into the very dense sandy gravel, hard clayey silt or onto limestone bedrock.
- **Steel Pipe Piles:** Deep foundations comprised of driven steel pipe piles are not considered appropriate for this site due to the higher risk of pile damage associated with potential obstructions such as cobbles and boulders. Further, pipe piles are typically not suitable for integral abutment design.
- **Drilled steel casings (small diameter):** Drilled steel casings involve installation of a 305 mm to 750 mm diameter permanent steel casing socketed into the hard clayey silt using wash boring methods and/or rotary percussive drilling, with the casing then filled with concrete. Small diameter drilled casings are more advantageous when obstructions may be present. There is typically a cost premium for this type of foundation and, given their rigidity, are generally not suitable for integral abutments.

Regardless of the deep (pile) foundation option selected, additional mitigation measures will have to be incorporated into the design, including potential for the piles encountering obstructions such as cobbles and boulders.

The following sections provide detailed foundation recommendations for the replacement bridge. Steel H-piles driven to refusal in the very dense sandy gravel, hard clayey silt or on the limestone bedrock have been identified as the preferred foundation alternative for this site and as such, the other foundation options described above are not addressed further in this report.

6.3.1 Deep Foundations – Steel H-Piles

The replacement bridge could be supported on steel HP310X110 piles driven to practical refusal in the sandy gravel or on the limestone bedrock. To reduce the potential for damage to the piles during driving to the required tip elevation, the piles should be fitted with a Titus Standard driving shoe or equivalent.

The following sections provide details regarding the tip elevation, geotechnical axial resistances, set criteria and pile driving notes, resistance to lateral loads and frost protection for driven steel H-piles.

6.3.2 Geotechnical Axial Resistance – Driven Piles

For design, the factored geotechnical axial resistances at ULS and geotechnical reactions at SLS for a HP 310x110 pile is provided in the following table. The SLS values correspond to an estimated total settlement of 25 mm.

Pile Location (Boreholes)	Founding Strata	Proposed Underside of Pile Cap (m)	Estimated Pile Tip Elevation (m)	Pile Type	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Reaction at SLS (kN)
North Abutment (104, 105)	Hard Clayey Silt	190.2	171.5 to 170.4 ²	HP 310x110	1,800	1,500
South Abutment (102, 103)	Very Dense sandy gravel or Limestone bedrock	190.5 ¹	168.8 ³		2,000	1,600

NOTES:

- 1) Based on Borehole 103, fill materials were encountered to Elevation 188.0 m which will require removal prior to pile cap construction. As such, lowering the pile cap elevation or removing and replacing the fill with compacted granular fill is discussed further in Section 6.6.1.
- 2) Terminated a minimum of 2 m into hard portion of deposit with SPT N values of 100 blows/0.3m. Provision should be included in the contract documents for varying pile lengths.
- 3) Elevation 168.8 m is based on the encountered bedrock at 102. It should be noted that a zone of N values greater than 100 blows and obstructions were encountered between Elevation 178 m and 173.5 m in Borehole 103.

The actual pile penetration and pile set characteristics will be dependent, to some extent, upon the driving equipment selected by the contractor. The pile driving hammer should be selected such that the energy delivered to the piles is sufficient to achieve the termination criteria (ultimate geotechnical resistances and tip elevations). It is recommended that, following the selection of the driving equipment, the piling contractor submit for review the proposed pile driving criteria based on the characteristics of the hammer and equipment intended for use.

The pile capacity must be verified in the field by the use of the Hiley formula in accordance with MTO Standard Drawing SS103-11 (MTO, 2008) "Pile Driving Control" during the final stages of driving, starting at about 1 to 2 m higher than the tip elevations provided above. The ultimate geotechnical axial resistance obtained from the Hiley formula should then be multiplied by a geotechnical resistance factor equal to 0.5 in accordance with current MTO practice to verify that the factored ULS design value has been achieved. Given that the piles will be driven to refusal in hard materials (N values greater than 100 blows per 0.3 m or limestone bedrock), PDA testing is not considered to be warranted. Given the potentially variable materials in which refusal will occur, Hiley verification is considered appropriate to assess the pile capacity; however, since some piles may be driven to bedrock, the Foundation Specialist should ensure that the piles are not overdriven which could result in damage to the piles.

If the piles do not reach the pile tip elevation, then it is likely that the piles have “hung-up” on an obstruction. If this occurs, the pile should be tested in the field using Hiley formula as noted above, and the designers should be contacted to assess whether the pile capacity achieved is sufficient for support of the replacement structure.

6.3.3 Frost Protection

The pile caps should be provided with a minimum of 1.2 m of soil cover or thermal equivalent for frost protection as per OPSD 3090.101 (Frost Penetration Depths for Southern Ontario).

6.3.4 Downdrag Load (Negative Skin Friction)

The replacement structure will be constructed on the existing alignment, and a nominal 0.6 m to 0.7 m grade raise (increase in loading of 13 to 15 kilopascals (kPa)) will be required at the approach embankments. As discussed further in Section 6.4.3, the settlements of the approach embankment are anticipated to be negligible given the overconsolidated nature of the stiff to hard clayey silt. Given that the settlements are expected to be negligible, the negative skin friction or down drag loads can be neglected.

6.3.5 Resistance to Lateral Loads

The design of pile foundations subjected to lateral loads should take into account such factors as the batter of the pile (if any), the relative rigidity of the pile to the surrounding soil, the fixity condition at the head of the pile (pile cap level), the structural capacity of the pile to withstand bending moments, the soil resistance that can be mobilized, the tolerable lateral deflections at the head of the pile and pile group effects. For a longer, more flexible pile, the maximum yield moment of the pile may be reached prior to mobilization of the lateral geotechnical resistance. For design purposes, both the structural and geotechnical resistances should be evaluated to establish the governing case. Lateral loading could be resisted fully or partially by the use of battered piles.

It is understood that an integral abutment foundation design is being considered for the replacement bridge. The integral abutment design should include the installation of 3 m long corrugated steel pipe (CSP) liners with the annular space between the pile and the liner backfilled with uniformly graded, loose sand (in accordance with the NSSP in Appendix C), so that the upper portion of the H-piles will be free to flex and move laterally within the limits of the CSP. With this design, the passive lateral resistance over the length of the pile within the CSP liner should be based on the resistance provided by the loose sand.

Where ground conditions are generally competent and the lateral loads on piles are relatively small such that the maximum lateral pile deflections will be relatively small, the resistance to lateral loading in front of a single pile can be estimated using subgrade reaction theory as outlined below. However, it should be noted that the response of a pile to lateral loads is highly nonlinear and methods that assume linear behavior (such as subgrade reaction theory) are only appropriate where the maximum pile deflections are less than 1 percent of the pile diameter, where the loading is static (no cycling) and where the pile material is linear (CFEM, 2006). Where these conditions are not met, the non-linear lateral behavior of the soil should be assessed using p-y curves.

The factored serviceability geotechnical response of the soil in front of the piles under lateral loading at this site may be calculated using subgrade reaction theory suggested in the 2014 CHBDC Commentary (Section C6.11.2.2), where the coefficient of horizontal subgrade reaction, k_h , (kilopascals per metre (kPa/m)) is based on the equation given below, as described by Terzaghi (1955) and the Canadian Foundation Engineering Manual (CFEM 2006).

For cohesionless soils:

$$k_h = \frac{n_h z}{B}$$

where:

- n_h = constant of horizontal subgrade reaction (kPa/m), as given below;
- z = depth below underside of pile cap for loose sand in CSP (m)
- z = depth below ground surface for all other soils (m)
- B = pile diameter or width (m)

For cohesive soils:

$$k_h = \frac{67s_u}{B}$$

where:

- s_u = undrained shear strength of the soil (kPa), as given below.

The following values of n_h may be incorporated into the calculations of the coefficient of horizontal subgrade reaction (k_h) for structural analysis for a single vertical HP pile. The ranges in values reflect the variability in the subsurface conditions, the soil properties and the approximate nature of the analysis and the non-linear nature of the soil behaviour (such that k_h is a function of deflection).

Foundation Element (Boreholes)	Soil Type	Elevation (m)	n_h (MPa/m)	s_u (kPa)
North Abutment (104 and 105)	CSP Liner – Sand, loose	190.2 – 187.2	2-4	
	Clayey Silt, stiff to hard	187.2 – 170.4		250-300
South Abutment (102 and 103)	CSP Liner – Sand, loose	190.5 – 187.5	2-4	
	Clayey Silt, stiff to hard	187.5 – 171.3		250-300
	Silt, very dense	171.3 – 169.7	11- 25	
	Sandy Gravel, very dense	169.7 – 168.8	11 - 25	

The lateral resistances for the various foundation options are summarized in the following table.

Pile Type	Lateral Resistance ¹	
	Factored ULS ² (kN)	SLS ³ (kN)
Driven Integral Abutment		
HP 310 x 110	125 (S) / 55 (W)	20 (S) / 15 (W)
HP 310 x 132	140 (S) / 60 (W)	25 (S) / 20 (W)
HP 360 x 132	155 (S) / 70 (W)	30 (S) / 20 (W)

Notes:

1) Resistances are for 10 mm of deflection unless otherwise noted.

2, 3) S – strong axis bending for integral abutment; W - weak axis bending for integral abutment.

The lateral resistances above are based on Brom's Method from "Design and Construction of Driven Pile Foundations Workshop Manual – Volume 1, FHWA, Pub. No. FHWA H1 97-013, Revised November 1998". Fixed-head conditions were assumed for the H-pile. In cases where the applied loads approach those in the above table, or if the design is sensitive to lateral loads and displacements, horizontal subgrade reaction theory should be used. For integral abutments, the horizontal load was assumed to be applied at the underside of the abutment stem or about at elevation 190.2 m for the north abutment and about elevation 190.5 m for the south abutment.

Group action for lateral loading should be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor, R, as follows:

Pile Spacing in Direction of Loading, d = Pile Diameter	Subgrade Reaction Reduction Factor, R
8d	1.00
6d	0.70
4d	0.40
3d	0.25

6.3.6 Seismic Considerations

Subsurface ground conditions for seismic site characterization were established based on the results of the investigation. Based on the anticipated foundation levels on/within the bedrock, the site may be classified as Site Class C in accordance with Table 4.1 of the CHBDC (2014).

In accordance with Table 4.10 of the CHBDC 2014, this site should be considered to be located in Seismic Performance Zone 1. In accordance with Section 4.4.5.1 of the CHBDC, no seismic analysis is required for structures located in Seismic Performance Zone 1.

6.4 Approach Embankment Design and Construction

Based on the GA drawing provided by Stantec, the proposed highway grade at the north and south approach embankments for the replacement structure will be at about elevation 195.2 m and 195.5 m, respectively, approximately 0.6 to 0.7 m above the existing highway grade.

The following sections address subgrade preparation and embankment construction, stability and settlement analysis for the raised approach embankments on Highway 21 and the new/widened approach embankments. It is assumed that all of the existing fill and any organic soil (peat and topsoil) will be removed from within the footprints of the pile caps and within the new footprint (along the existing slope and beyond the toe of the existing embankment). The geometry of the proposed embankments and the existing ground surface included in the stability and settlement analyses are based on the cross-sections provided by Stantec. The piezometric conditions used in the analyses are based on the groundwater level as encountered during the subsurface investigation.

6.4.1 Subgrade Preparation and Embankment Construction

Fill for construction and widening of the embankments at and behind the new abutments, and for construction of the new or widened detour embankments, should consist of Select Subgrade Material (SSM) meeting the specifications of OPSS.PROV 1010 (Aggregates). The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting) and OPSS.PROV 206 (Grading). Embankment side slopes should be constructed no steeper than 2 Horizontal to 1 Vertical (2H:1V) fill. New fill should be keyed/benched into the existing fill in accordance with Ontario Provincial Standard Drawing (OPSD) 208.010 (Benching of Earth Slopes). Where embankment widening is required, the lower 1 m of the widening should consist of compacted Granular B Type II to provide a “drainage layer” to reduce the potential for built-up of hydrostatic pressures behind the widening.

In accordance with MTO's standard practice, a minimum 2 m wide bench should be provided where embankment slopes are greater than 8 m in height, such that the uninterrupted slope height does not exceed 8 m, consistent with OPSD 202.010 (Slope Flattening).

The abutment foreslopes and side slopes adjacent to Gully Creek will require erosion protection in accordance with OPSS 511 (Rip Rap, Rock Protection and Granular Sheeting). Erosion protection should be placed on the slopes to at least 0.5 m above the design high water level. Subject to confirmation and modifications as necessary based on the hydrology reports (by others), erosion protection could consist of a minimum 0.6 m thick layer of R-10 Rip Rap (180 mm size as per OPSS.PROV 1004 (Aggregates - Miscellaneous)), rock protection or concrete slope paving. The designer should address the potential for hydraulic scour below the pile caps in the design of the bridge foundations.

To reduce surface water erosion on the granular embankment side slopes, topsoil and seeding as per OPSS 802 (Topsoil) and OPSS.PROV 804 (Seed and Cover) should be carried out as soon as possible after construction of the embankments. If this slope protection is not in place before winter, then alternate protection measures, such

as covering the slope with straw, or gravel sheeting as per OPSS 511 (Rip Rap, Rock Protection and Granular Sheeting) and OPSS.PROV 1004 (Aggregates – Miscellaneous) will be required to reduce the potential for erosion.

6.4.2 Embankment Stability

Slope stability analyses were carried out for drained and undrained conditions for both the north and south approaches and foreslopes, however the drained condition for the north foreslope and north approach embankment represent the “worst case” scenarios. Figures S1 and S2 show the embankment/wall geometry in the context of the interpreted stratigraphic profiles and cross-sections on Drawings 1 and 2 for the drained condition at the north foreslope and approach.

The Factor of Safety (FoS) is defined as the ratio of forces tending to resist failure to the driving forces tending to cause the 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. $FoS = 1/(\psi * \phi_{gu})$). Accordingly, a target minimum FoS of 1.3 has been used for design of the temporary embankment side slopes, and FoS of 1.5 for the design of the final embankment configuration and vertical walls as per Table 6.2 of CHBDC (2014) for the total stress (short-term undrained) and effective stress (long-term drained) condition, as applicable.

Limit equilibrium slope stability analyses were performed using the commercially available program GeoStudio 2018 (Version 9.0), 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 to establish the minimum FoS. The stability analyses were performed to check that the target minimum FoS was achieved for the design embankment heights and geometries. In general, circular slip surfaces were analysed in the design.

For the new granular fill, the existing granular fill and the non-cohesive native soil deposits, effective stress parameters were used in the analyses assuming drained conditions. The parameters were estimated from empirical correlations using the in-situ SPT ‘N’-values and our knowledge of the mechanical behaviour of these types of soils. The correlations proposed by Terzaghi and Peck (1967) were employed and the results were tempered by engineering judgment based on our experience in similar soils.

The total stress parameters (i.e., average mobilized undrained shear strength - s_u) for the cohesive soils were estimated from correlations with the SPT results and other laboratory test data (i.e., natural water content), where appropriate. Effective friction angles have also been estimated for these cohesive deposits for analysis of the factor of safety in long-term conditions.

Summarized below are the simplified stratigraphy and the associated strengths and unit weights employed for the different soil types in the proposed works areas.

Soil Deposit	Bulk Unit Weight (kN/m ³)	Short-Term Analysis		Long-Term Analysis
		Effective Friction Angle (°)	Undrained Shear Strength (kPa)	Effective Friction Angle (°)
New Granular Fill (SSM)	20	32	-	32
Clayey Silt	18	-	75	30

6.4.2.1 Results of Analysis

The stability analysis indicates that the foreslopes and side slopes will have FoS greater than 1.5 against global instability in long-term, drained conditions, as shown on Figures 1 and 2. The FoS for the short-term, drained conditions, is greater than 1.3. This is based on sub-excavation of the any organic or deleterious materials encountered at the toe of the embankment are removed.

6.4.3 Embankment Settlement

Given the 0.6 m to 0.7 m grade raise at the north and south approach embankments and the overconsolidated clayey silt deposit corresponding to an increase in loading of 12 to 15 kPa, the settlements are anticipated to be negligible (i.e. less than about 20 mm).

6.5 Lateral Earth Pressures

The lateral earth pressures acting on the abutment walls and any associated wing walls will depend on the type and method of placement of the backfill material, the nature of the soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structures, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of walls for this site. It should be noted that 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 accordingly.

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II, should be used as backfill behind the walls. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting). Other aspects of the granular backfill requirements with respect to sub-drains and frost taper should be in accordance with OPSD 3101.150 (Walls, Abutment, Backfill, Minimum Granular Requirement), OPSD 3121.150 (Walls, Retaining, Backfill, Minimum Granular Requirement) and OPSD 3190.100 (Walls, Retaining and Abutment, Wall Drain).

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls in accordance with CHBDC (2014) Section 6.12.3 and Figure 6.6. Care must be taken during the compaction operation not to overstress the wall. Heavy construction equipment should be maintained at a distance of at least 1 m away from the walls while the backfill soils are being placed. Hand-operated compaction equipment should be used to compact the backfill soils immediately behind the walls as per OPSS.PROV 501. Other surcharge loadings should be accounted for in the design as required.
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.2 m behind the back of the wall (in accordance with Figure C6.20 (a) of the Commentary to the CHBDC). For unrestrained walls, granular fill should be placed within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing in accordance with Figure C6.20(b) 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	Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Granular A or Granular B Type II	22 kN/m ³	0.43	0.27
SSM	20 kN/m ³	0.47	0.31

- If the wall support and superstructure allow lateral yielding of the stem, active earth pressures may be used in the foundation design of the structure. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as:
 - Rotation of approximately 0.002 about the base of a vertical wall (where the rotation is calculated as the horizontal displacement divided by the height of the wall).
 - Horizontal translation of 0.001 times the height of the wall.
 - A combination of both.
- If the wall does not allow lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition), at-rest earth pressures (plus any compaction surcharge) should be assumed for geotechnical design.

6.6 Construction Considerations

6.6.1 Excavations and Control of Groundwater and Surface Water

Prior to the construction of the new embankments, it is recommended that the existing fill and any organic soils be removed from within the footprint of the pile caps and proposed embankment widening within 20 m of the proposed replacement bridge abutments. For the pile cap construction, excavations will extend to approximately elevation 190.2 m (4.3 m depth relative to the existing Highway 21 grade) at the north abutment/approach and to elevation 190.5 m (4.3 m depth relative to the existing Highway 21 grade) at the south abutment/approach to the underside of the proposed pile cap. Sub-excavation is required to remove the existing embankment fill at the south abutment, ranging from elevation 188.0 to 191.0 m, based on Boreholes 102 and 103, respectively. As such, consideration could be given to sub-excavating and replacing these with granular fill as described above in Section 6.4; we understand that lowering of the pile caps is not practical. If a granular pad is constructed, the edge of the pad must be at least 1 m from the outer edge of the footing prior to sloping downwards and outwards at 1 horizontal to 1 vertical (1H:1V).

All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects (as amended). Above the groundwater level, the fill materials can be considered Type 3 soils and any organic soils encountered should be considered Type 4 soils. The native clayey silt can be classified as a Type 2 soil. All soils below the groundwater level should be considered Type 3 or Type 4 soils. Temporary open-cut excavations in Type 3 soils should be formed no steeper than 1H:1V. In Type 4 soils, the side slopes should be formed no steeper than 3H:1V.

Excavations for the pile caps are anticipated to be above the groundwater and the Gully Creek water level. As such proactive dewatering is not expected to be required. Surface water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. All surface water should be directed away from the excavations. Seepage from the granular fills should be expected, particularly after precipitation events. It is anticipated that minor surface water seepage and seepage from the granular fills can be controlled by using properly filtered sumps within the excavation.

The clayey silt that will be exposed within the excavation at the abutments may be susceptible to disturbance from construction traffic and/or ponded water. A concrete working slab should be placed below the pile cap, above the subgrade (unless the soils are protected by a granular pad as noted above). We anticipate that the CSPs will be installed after the installation of the working slab in cored holes or alternatively the contractor can form the working slab with holes to accommodate the CSPs.

6.6.2 Obstructions

The native soils at this site are glacially derived and, as such, are generally hard and very dense and contain coarse gravel, cobbles and boulders as noted on the borehole records, which could affect the installation of deep foundations and excavations for foundations. Further, in Borehole 104, pieces of wood were encountered at 2.0 m depth. An NSSP should be included in the Contract Documents to identify to the contractor the potential presence of cobbles and/or boulders within the overburden soils along with the potential for wood or other debris in the embankment fill; an example NSSP is included in Appendix C.

6.6.3 Analytical Testing for Construction Materials

The results of analytical testing carried out on soil samples from Boreholes 102 and 105 from the current investigation and Borehole G30 from GEOCRESS 40P12-21 for the replacement structure are summarized below:

Parameter	Units	Current Investigation ¹		GEOCRESS 40P12-21
		Borehole 102, Sample 6	Borehole 105, Sample 6	Borehole G30, SS2
Resistivity	ohm-cm	1100	2200	800
Conductivity	µmho/cm	905	456	1250
pH	pH	7.96	7.89	7.82
Sulphate	µg/g	27 (or 0.0027%)	230 (or 0.023%)	< 20 (Detectable limit = 20)
Chloride	µg/g	430	52	640

Notes:

1. Samples tested past standard hold time.
2. Analytical testing carried out by Maxxam Analytics Inc.

The above suite of parameters tested is intended to allow the design engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection of steel reinforcing elements.

For potential sulphate attack on concrete, the results of the soil analysis were compared to Table 3 in CSA A23-1, and indicate that the relative degree of sulphate attack is low (less than the moderate range of 0.1 to 0.2%). However, given that the bridge is located on Highway 21 and will be exposed to de-icing salts, it is recommended that C-1 or C-2 exposure class concrete be considered. Further, the resistivity results indicate in the three samples tested range from 800 to 2200 ohm-cm indicating that the soil has a “moderate to severe” corrosiveness (Moderate 4500>R>2000, Severe 2000>R) potential based on the Transportation Research Board Guidelines (Transportation Research Board, National Research Council, 1998 as referenced in the MTO Gravity Pipe Design Guidelines, 2014).

The creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events and the water and/or soil chemistry could also be variable. These recommendations are provided as guidance only; the structural designer should take the results of the laboratory testing and the potential for corrosion into consideration when selecting materials for bridge construction.

The samples obtained from the current investigation were tested beyond the suggested hold time; however when compared with the previously tested samples, the results are generally consistent and are considered to be appropriate for the intended purposes. The Certificate of Analysis for the testing carried out as part of the current investigation has been included in Appendix B.

7.0 MISCELLANEOUS

This report was prepared by Mr. Adam Core, P.Eng. and the technical aspects were reviewed by Mr. Michael E. Beadle, P.Eng., an Associate and Senior Geotechnical Engineer with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment, conducted an independent quality review of this report.

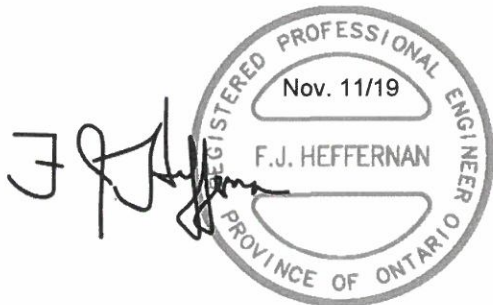
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- Ontario Provincial Standard Drawings
- | | |
|---------------|---|
| OPSD 202.010 | Slope Flatening |
| OPSD 208.010 | Benching of Earth Slopes |
| OPSD 3090.101 | Foundation, Frost Penetration Depths for Southern Ontario |
| OPSD 3101.150 | Walls Abutment, Backfill Minimum Granular Requirement |
| OPSD 3121.150 | Walls Retaining, Backfill Minimum Granular Requirement |
| OPSD 3190.100 | Walls, Retaining and Abutment, Wall Drain |
- Ontario Provincial Standard Specifications
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| OPSS.PROV 206 | Construction Specifications for Grading. |
| OPSS.PROV 501 | Construction Specification for Compacting |
| OPSS 511 | Construction Specification for Rip Rap, Rock Protection and Granular Sheetting |
| OPSS 802 | Construction Specification for Topsoil |

OPSS 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling - Structures
OPSS 903	Construction Specification for Deep Foundations
OPSS.PROV 1004	Material Specification for Aggregates – Miscellaneous
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Water Resources Act

Ontario Regulation 903 Wells (as amended)

Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91 Construction Projects (as amended)

Table 1: Evaluation of Foundation Alternatives

Foundation Type	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Driven Steel H-piles	1	<ul style="list-style-type: none"> ■ Straightforward construction. ■ Higher axial resistance compared to spread footings. ■ Allows for integral abutment design. 	<ul style="list-style-type: none"> ■ Low potential for “hanging up” on cobbles and boulders within cohesive deposit. 	<ul style="list-style-type: none"> ■ Relative costs higher than shallow foundations. ■ Mobilization of piling equipment relatively expensive. 	<ul style="list-style-type: none"> ■ Low potential for not achieving design resistance at design pile tip elevation.
Driven Steel Pipe Piles	2	<ul style="list-style-type: none"> ■ Relatively straightforward construction. ■ Higher axial resistance compared to spread footings. ■ May be suitable for integral abutment design depending on pile diameter. 	<ul style="list-style-type: none"> ■ Potential for “hanging up” on cobbles and boulders within cohesive deposit. 	<ul style="list-style-type: none"> ■ Relative costs higher than shallow foundations. ■ Mobilization of piling equipment relatively expensive. 	<ul style="list-style-type: none"> ■ Potential for not achieving design resistance at design pile tip elevation and therefore have to drive additional piles.
Small Diameter Drilled Steel Casings	3	<ul style="list-style-type: none"> ■ Highly suited to penetrate through hard soils, including cobbles and boulders, to bedrock. ■ Higher axial resistance compared to steel H-piles and spread footings. ■ Reduced vibrations on TMB bridge compared with pile driving. 	<ul style="list-style-type: none"> ■ Requires specialized drilling equipment. ■ Likely not suitable for integral abutment design. ■ Requires more onerous management of cuttings/drilling fluid to prevent discharge of these materials into the river. 	<ul style="list-style-type: none"> ■ Mobilization of specialized equipment relatively expensive. ■ Higher cost than steel H-piles due to requirement for casings to remain in place as permanent liners. ■ Higher cost due to need to dispose of 	<ul style="list-style-type: none"> ■ Potential impact on river water quality due to cuttings/drilling fluid release. ■ Requires off-site disposal area for disposal of drilling fluid and cutting.

Foundation Type	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
			<ul style="list-style-type: none"> Requires similar shoring system and excavations as steel H-piles. 	drilling fluid/cuttings off site.	
Shallow Foundations	NP	<ul style="list-style-type: none"> Conventional construction. 	<ul style="list-style-type: none"> Lower geotechnical axial resistance at ULS and SLS Not suitable for integral abutment design. Variable clayey silt conditions at abutments potentially results in differential settlement. 	<ul style="list-style-type: none"> Typically lower relative cost than deep foundations. Cost would rise substantially due to difficulties associated with relatively deep shoring and unwatering system installation/ operation. 	<ul style="list-style-type: none"> Potential for differential settlement between foundation units.

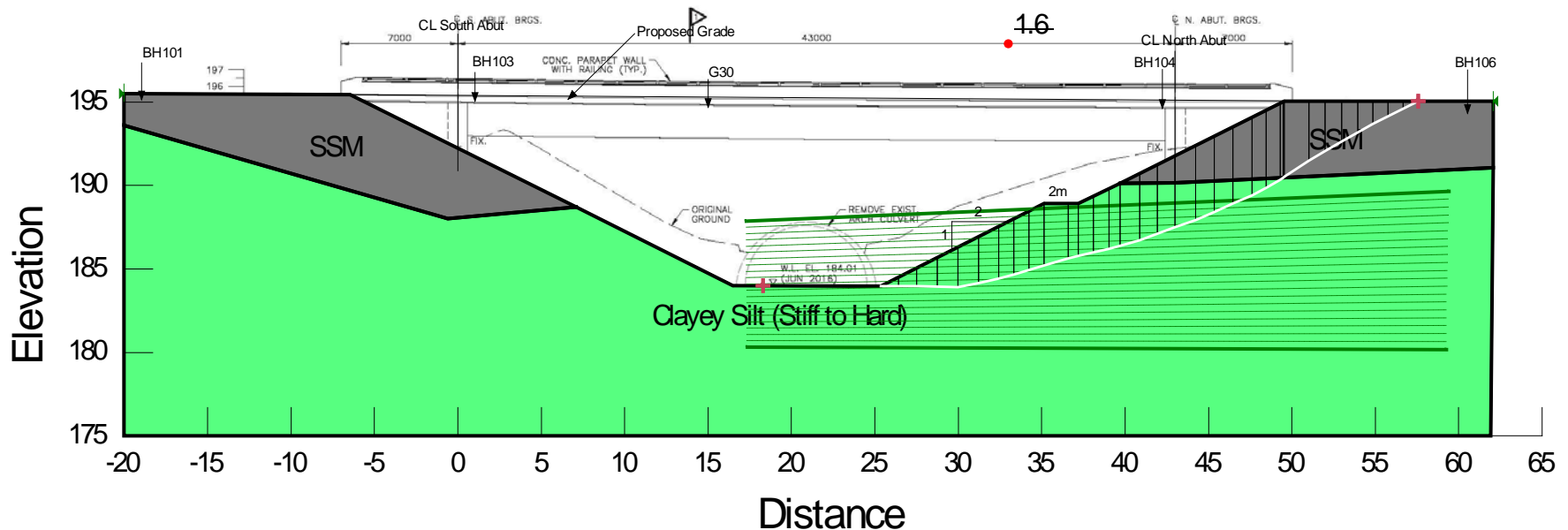
NP = Not Practical

Global Stability Analysis

Proposed North Front Slope Long-Term (Drained) Analysis

Figure S1

Material Name	Unit Weight (kN/m ³)	Undrained Shear Strength (kPa)	Friction Angle (degrees)
Select Subgrade Material (SSM)	20	-	32
Clayey Silt	19	-	30

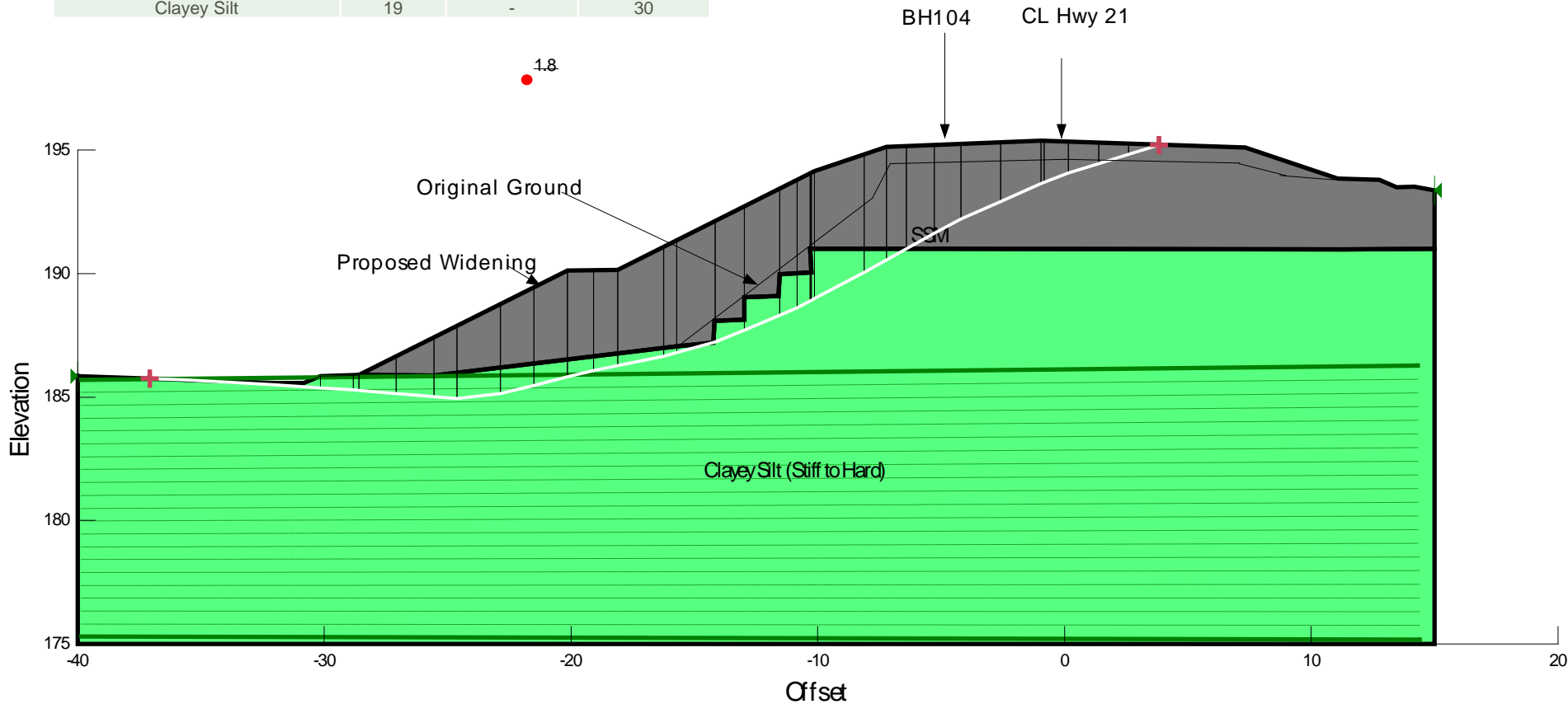


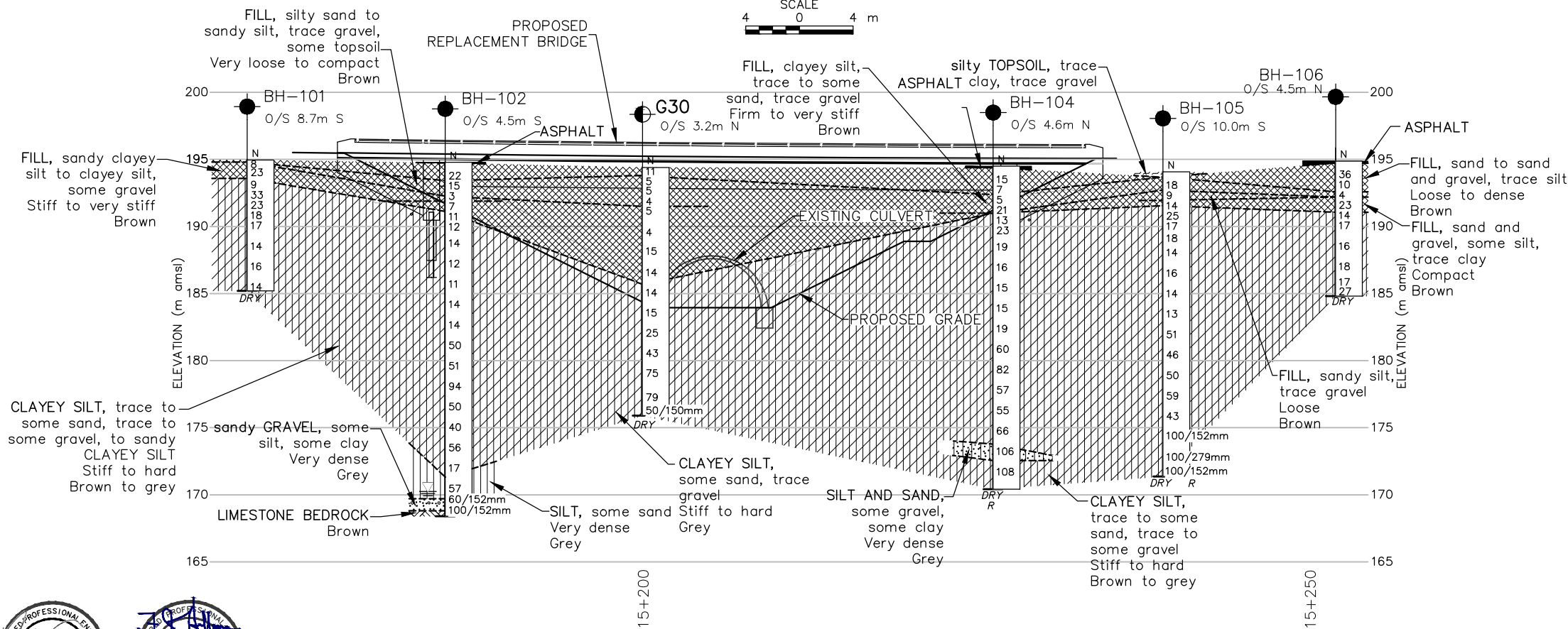
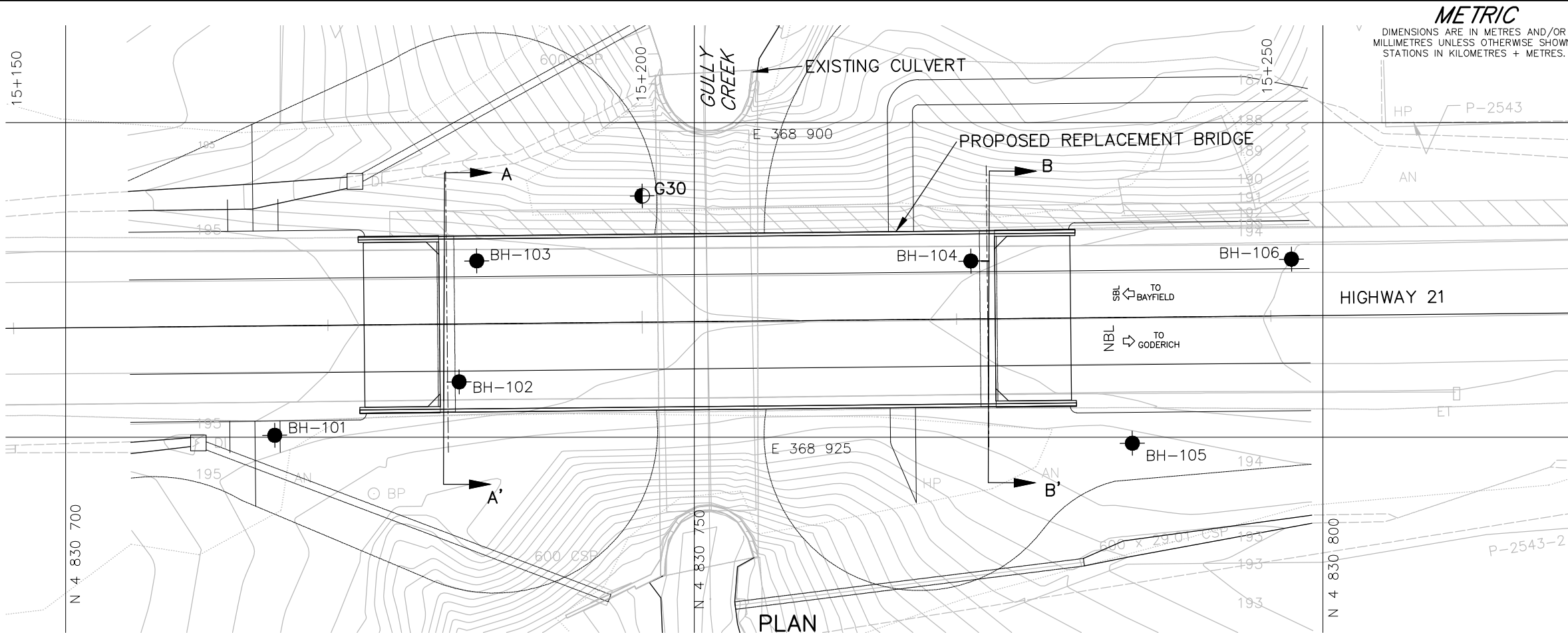
Global Stability Analysis

Figure S2

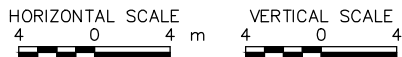
Proposed North Approach, West Side Slope Long-Term (Drained) Analysis

Material Name	Unit Weight (kN/m ³)	Undrained Shear Strength (kPa)	Friction Angle (degrees)
Select Subgrade Material (SSM)	20	-	32
Clayey Silt	19	-	30





PROFILE ALONG E HIGHWAY 21



METRIC

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

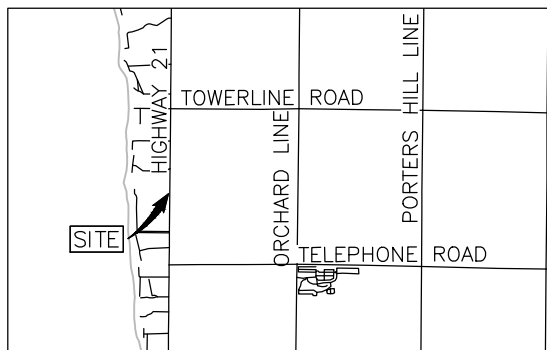
CONT No.
WP No. 3140-15-01

HIGHWAY 21
GULLY CREEK BRIDGE
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET

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KEY PLAN

SCALE IN KILOMETRES
0 1 2

LEGEND

- Borehole - Current Investigation
- Borehole (Geocres 40P12-21)
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ≡ WL encountered during drilling
- DRY Borehole dry during drilling
- R Refusal

No.	ELEVATION	CO-ORDINATES (MTM ZONE 11)	
		NORTHING	EASTING
BH-101	195.0	4 830 716.6	368 924.9
BH-102	194.8	4 830 731.3	368 920.6
BH-103	194.7	4 830 732.7	368 911.0
BH-104	194.5	4 830 772.0	368 911.0
BH-105	194.1	4 830 784.8	368 925.5
BH-106	194.9	4 830 797.5	368 910.9
Geocres 40P12-21			
G30	194.4	4 830 745.9	368 912.7

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 contract documents.

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

REFERENCE

Drawing files 165000980-12-297-plb.dwg, provided in digital format by Stantec on September 24, 2018.

NO.	DATE	BY	REVISION
Geocres No. 40P12-38			
HWY. 21			PROJECT NO. 1534424-12000 DIST.
SUBM'D. AC	CHKD. AC	DATE: Sept 30/19	SITE: 12-297
DRAWN: ZB/DH/AS	CHKD. AC	APPD: FJH	DWG. 1





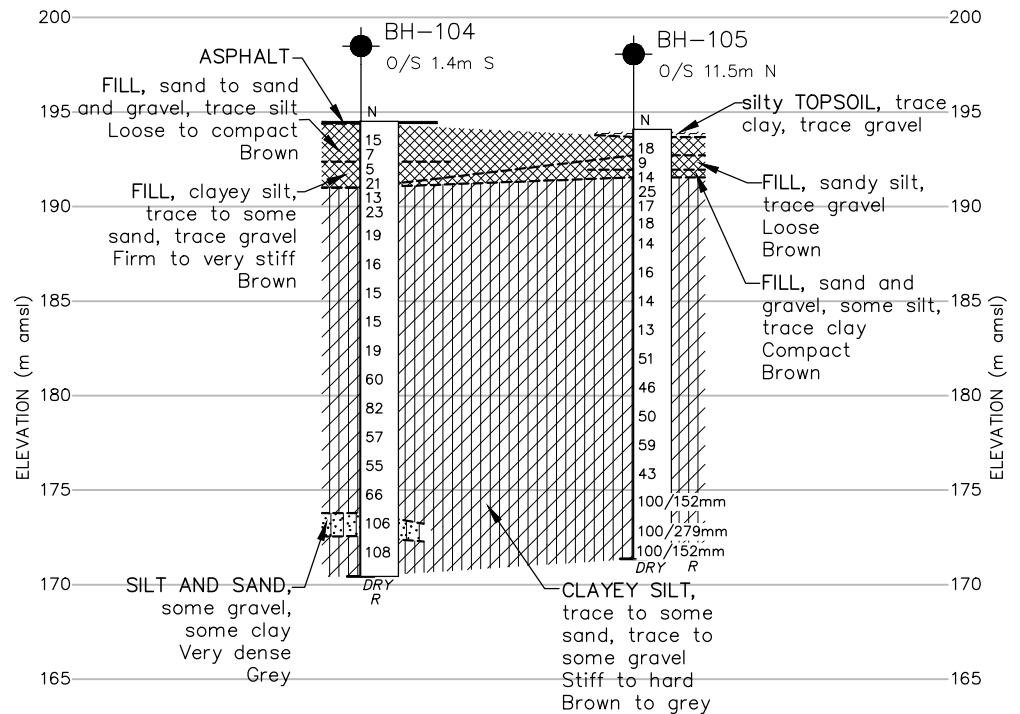
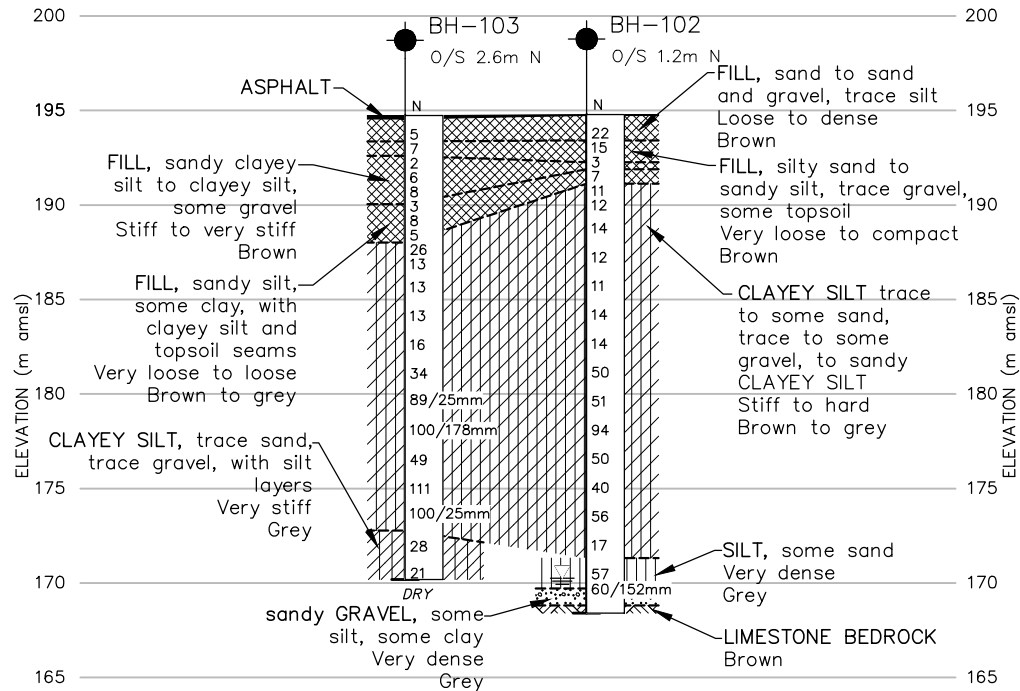
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 3140-15-01

HIGHWAY 21
GULLY CREEK BRIDGE
SOIL STRATA

SHEET

C:\0_Golder_Logs\Horizontal_Logs\GreyScale.jpg



LEGEND

- Borehole - Current Investigation
- Standard Penetration Test Value
- Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL encountered during drilling
- Borehole dry during drilling
- Refusal

No.	ELEVATION	CO-ORDINATES (MTM ZONE 11)	
		NORTHING	EASTING
BH-102	194.8	4 830 731.3	368 920.6
BH-103	194.7	4 830 732.7	368 911.0
BH-104	194.5	4 830 772.0	368 911.0
BH-105	194.1	4 830 784.8	368 925.5

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 contract documents.

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

REFERENCE

Drawing files 165000980-12-297-plb.dwg, provided in digital format by Stantec on September 24, 2018.

NO.	DATE	BY	REVISION
Geocres No. 40P12-38			
HWY. 21	PROJECT NO. 1534424-12000		DIST.
SUBM'D. AC	CHKD. AC	DATE: Sept 30/19	SITE: 12-297
DRAWN: ZB/DH/AS	CHKD. AC	APPD. FJH	DWG. 2

APPENDIX A

**Record of Borehole and Laboratory Test –
GEOCRES 40P21-21**

G.W.P. 834-93-00	LOCATION Sta.15+205, SBL, 5.0m W of Rd C/L, 2.8m S of Culv C/L, E443055 N4829232	ORIGINATED BY JF
DIST Goderich HWY 21	BOREHOLE TYPE 200 mm diameter borehole (Hollow Stem)	COMPILED BY SC
DATUM Geodetic	DATE March 14, 2012 - March 14, 2012	CHECKED BY SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO. TP110076

[illegible]

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

2 OF 2

G.W.P. 834-93-00	LOCATION Sta.15+205, SBL, 5.0m W of Rd C/L, 2.8m S of Culv C/L, E443055 N4829232	ORIGINATED BY JF
DIST Goderich HWY 21	BOREHOLE TYPE 200 mm diameter borehole (Hollow Stem)	COMPILED BY SC
DATUM Geodetic	DATE March 14, 2012 - March 14, 2012	CHECKED BY SM
PROJECT Rehabilitation of Highway 21, from Bayfield to Goderich, Ontario		JOB NO. TP110076

[illegible]

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

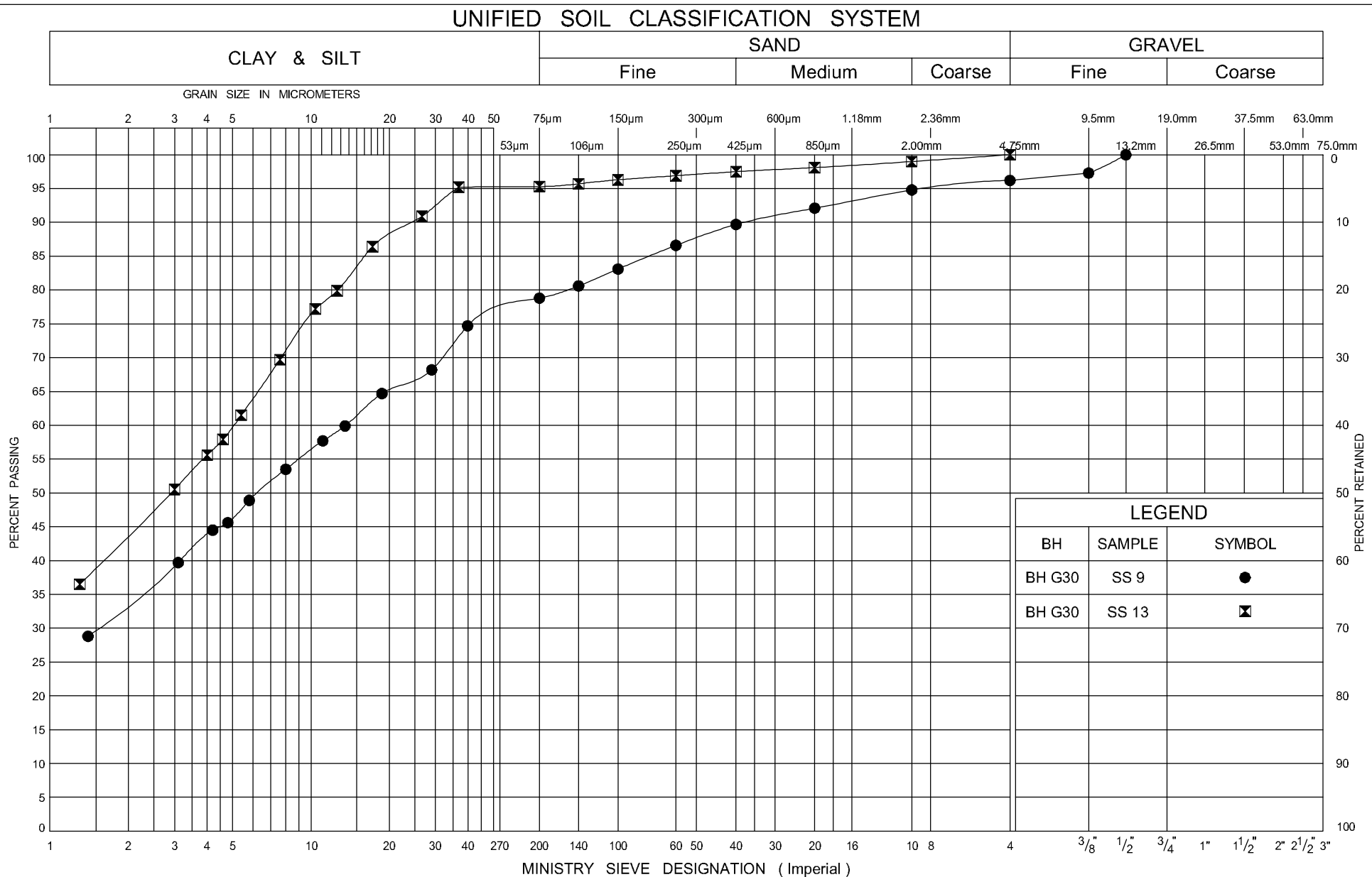


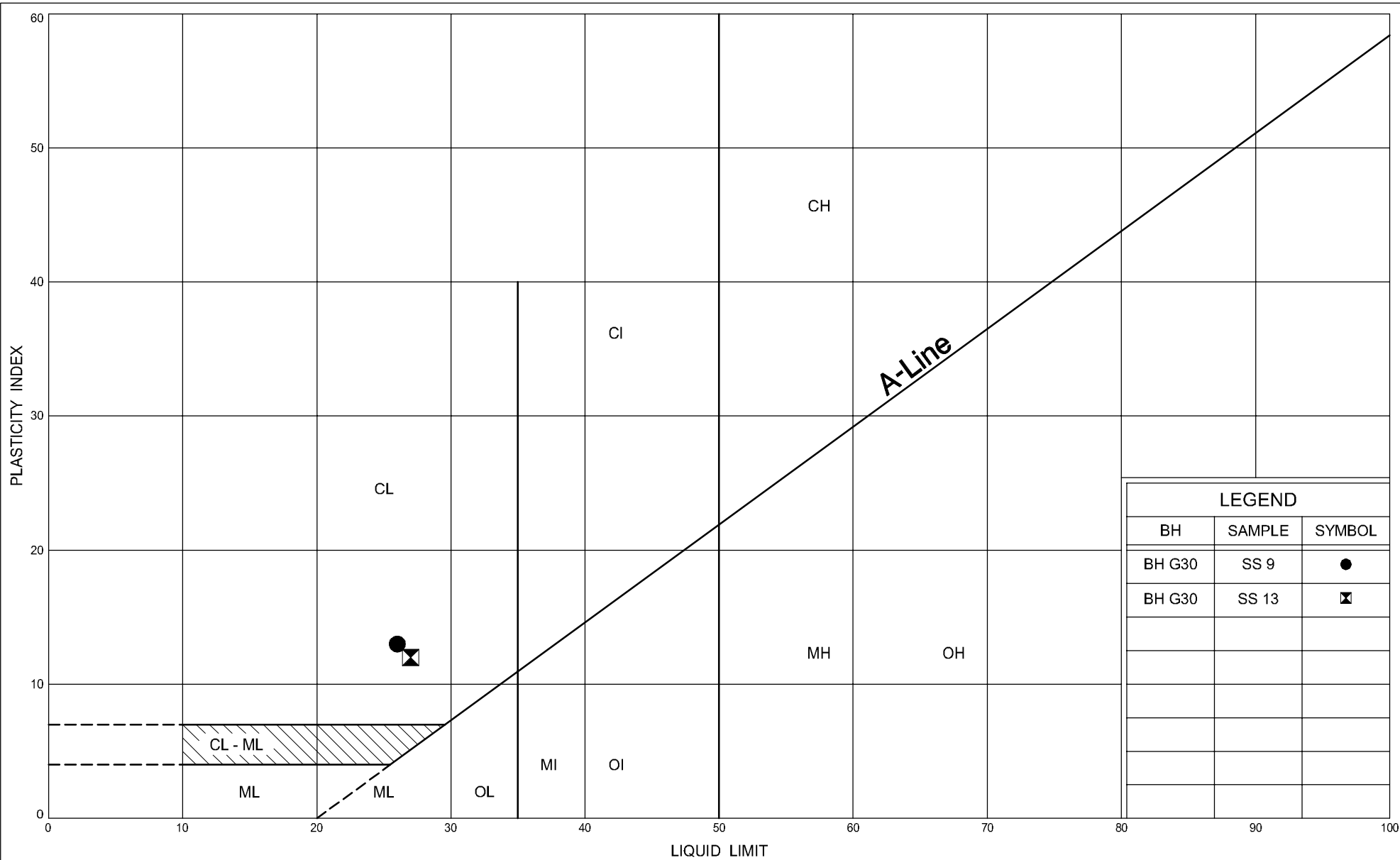
Figure No. B 1

G.W.P. 834-93-00

Convert to Standard Time 10/20/2021 Based to order

GRAIN SIZE DISTRIBUTION

CLAYEY SILT / SILTY CLAY



Your Project #: TP110076.05
Your C.O.C. #: 27188503, 271885-03-01

Attention: Shami Mala
AMEC Environment & Infrastructure
Scarborough
104 Crockford Blvd
Scarborough, ON
CANADA M1R3C3

Report Date: 2012/03/23

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B238403
Received: 2012/03/19, 12:10

Sample Matrix: Soil
Samples Received: 9

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
Chloride (20:1 extract)	9	N/A	2012/03/23	CAM SOP-00463	EPA 325.2
Conductivity	9	N/A	2012/03/23	CAM SOP-00414	APHA 2510
pH CaCl ₂ EXTRACT	8	2012/03/22	2012/03/22	CAM SOP-00413	SM 4500H+ B
pH CaCl ₂ EXTRACT	1	2012/03/22	2012/03/23	CAM SOP-00413	SM 4500H+ B
Resistivity of Soil	9	2012/03/19	2012/03/23	CAM SOP-00414	APHA 2510
Sulphate (20:1 Extract)	9	N/A	2012/03/23	CAM SOP-00464	EPA 375.4

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. Reporting results to two significant figures at the RDL is to permit statistical evaluation and is not intended to be an indication of analytical precision.

The CWS PHC methods employed by Maxxam conform to all prescribed elements of the reference method and performance based elements have been validated. All modifications have been validated and proven equivalent following the 'Alberta Environment Draft Addenda to the CWS-PHC, Appendix 6, Validation of Alternate Methods'. Documentation is available upon request. Maxxam has made the following improvements to the CWS-PHC reference benchmark method: (i) Headspace for F1; and, (ii) Mechanical extraction for F2-F4. Note: F4G cannot be added to the C6 to C50 hydrocarbons. The extraction date for samples field preserved with methanol for F1 and Volatile Organic Compounds is considered to be the date sampled.

Maxxam Analytics is accredited by SCC (Lab ID 97) 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.

- * RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
- * Results relate only to the items tested.

../2

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

-2-

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

GINA BAYBAYAN,
Email: GBAYBAYAN@maxxam.ca
Phone# (905) 817-5766

=====
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: 2

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

RESULTS OF ANALYSES OF SOIL

Maxxam ID		MV6494	MV6495	MV6496	MV6497	MV6498		
Sampling Date		2012/03/13 10:00	2012/03/13 10:00	2012/03/13 10:10	2012/03/13 10:10	2012/03/13 09:50		
	Units	G22-SS6	G26-SS4	G28-SS2	G31-SS2	G35-SS1B	RDL	QC Batch
Calculated Parameters								
Resistivity	ohm-cm	3400	1400	970	1700	3400		2793995
Inorganics								
Soluble (20:1) Chloride (Cl)	ug/g	90	350	550	290	90	20	2799578
Conductivity	umho/cm	292	734	1030	598	290	2	2799683
Available (CaCl2) pH	pH	7.64	7.41	7.71	7.72	7.71		2798076
Soluble (20:1) Sulphate (SO4)	ug/g	25	54	<20	<20	20	20	2799579

Maxxam ID		MV6499	MV6500		MV6501		MV6502		
Sampling Date		2012/03/16 14:30	2012/03/16 14:40		2012/03/16 15:50		2012/03/16 14:50		
	Units	G24-SS4	G30-SS2	QC Batch	G37-SS2	QC Batch	G38-SS2	RDL	QC Batch
Calculated Parameters									
Resistivity	ohm-cm	1300	800	2793995	1300	2793995	1100		2793995
Inorganics									
Soluble (20:1) Chloride (Cl)	ug/g	380	640	2799578	350	2799578	450	20	2799578
Conductivity	umho/cm	771	1250	2799683	785	2799683	949	2	2799683
Available (CaCl2) pH	pH	7.47	7.82	2798076	8.05	2799276	7.35		2798048
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	2799579	<20	2799579	<20	20	2799579

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

Test Summary

Maxxam ID MV6494
Sample ID G22-SS6
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6495
Sample ID G26-SS4
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6496
Sample ID G28-SS2
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

Test Summary

Maxxam ID MV6497
Sample ID G31-SS2
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6498
Sample ID G35-SS1B
Matrix Soil

Collected 2012/03/13
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6499
Sample ID G24-SS4
Matrix Soil

Collected 2012/03/16
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

Test Summary

Maxxam ID MV6500
Sample ID G30-SS2
Matrix Soil

Collected 2012/03/16
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798076	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6501
Sample ID G37-SS2
Matrix Soil

Collected 2012/03/16
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2799276	2012/03/22	2012/03/23	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam ID MV6502
Sample ID G38-SS2
Matrix Soil

Collected 2012/03/16
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Chloride (20:1 extract)	AC/EC	2799578	N/A	2012/03/23	DEONARINE RAMNARINE
Conductivity	COND	2799683	N/A	2012/03/23	NEIL DASSANAYAKE
pH CaCl2 EXTRACT		2798048	2012/03/22	2012/03/22	XUANHONG QIU
Resistivity of Soil		2793995	2012/03/23	2012/03/23	CRISTINA CARRIERE
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

Test Summary

Maxxam ID MV6502 Dup
Sample ID G38-SS2
Matrix Soil

Collected 2012/03/16
Shipped
Received 2012/03/19

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
Sulphate (20:1 Extract)	AC/EC	2799579	N/A	2012/03/23	DEONARINE RAMNARINE

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

Package 1	10.7°C
-----------	--------

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

GENERAL COMMENTS

Maxxam Job #: B238403
Report Date: 2012/03/23

AMEC Environment & Infrastructure
Client Project #: TP110076.05

QUALITY ASSURANCE REPORT

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	Units	Value (%)	QC Limits	% Recovery	QC Limits
2799578	Soluble (20:1) Chloride (Cl)	2012/03/23	107	75 - 125	106	75 - 125	<20	ug/g	NC	35		
2799579	Soluble (20:1) Sulphate (SO ₄)	2012/03/23	114 ⁽¹⁾	75 - 125	104	85 - 115	<20	ug/g	NC ⁽²⁾	35		
2799683	Conductivity	2012/03/23					<2	umho/cm	0.1	35	99	75 - 125

N/A = Not Applicable

RPD = Relative Percent Difference

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 blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.

Spiked Blank: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.

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

NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

(1) - Matrix Spike Parent ID [MV6502-01]

(2) - Duplicate Parent ID [MV6502-01]

Validation Signature Page

Maxxam Job #: B238403

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

A handwritten signature in black ink, appearing to read "Cristina Carriere", is written over a horizontal line.

CRISTINA CARRIERE, Scientific Services

=====

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.

APPENDIX B

**Record of Boreholes and
Laboratory Data – Current Investigation**

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (<i>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (*q_t*), porewater pressure (*u*) and sleeve friction (*f_s*) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL, w _p	plastic limit
LL, w _L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
Y	unit weight

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

COARSE-GRAINED SOILS

Compactness¹

Term	SPT 'N' (blows/0.3m) ²
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	➤ 50

3. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ^{1,2} (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

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

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength


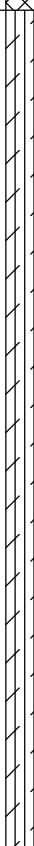
τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress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

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


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

PROJECT <u>1534424 - 12001</u>		RECORD OF BOREHOLE No BH-101		1 OF 1		METRIC	
W.P. <u>3140-15-01</u>		LOCATION <u>MTM: N 4830716.6, E 368924.9 LAT/LONG: LAT 43.613627, LONG -81.705559</u>		ORIGINATED BY <u>AC</u>			
DIST <u> </u> HWY <u>21</u>		BOREHOLE TYPE <u>108mm I.D. HOLLOW STEM AUGERS</u>		COMPILED BY <u>ZJB/AMS</u>			
DATUM <u>GEODETIC</u>		DATE <u>2018 August 21</u>		CHECKED BY <u> </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/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W _p	W	W _L					
195.0	GROUND SURFACE						195													
0.0	FILL, sand and gravel, some silt, trace organics Brown		1	SS	8															
0.2	FILL, sandy clayey silt, some gravel Stiff to very stiff Brown		2	SS	23															
193.6							194													
1.4	CLAYEY SILT, trace to some sand, trace gravel Stiff to hard Brown to grey at about elev. 191.3m		3	SS	9															
			4	SS	33															
			5	SS	23															
			6	SS	18															
			7	SS	17															
			8	SS	14															
			9	SS	16															
			10	SS	14															
185.2	END OF BOREHOLE							186												
9.8	Borehole dry upon completion of drilling on August 21, 2018																			

LDN_MTO_06 1534424-12001.GPJ LDN_MTO.GDT 27-11-18

PROJECT 1534424 - 12001		RECORD OF BOREHOLE No BH-102		1 OF 2	METRIC
W.P. 3140-15-01		LOCATION MTM: N 4830731.3 E 368920.6 LAT/LONG: LAT 43.613759 LONG -81.705609		ORIGINATED BY MA	
DIST _____ HWY 21		BOREHOLE TYPE 108mm I.D. HOLLOW STEM AUGERS, 100mm O.D. MUD ROTARY REAMER		COMPILED BY ZJB/AMS	
DATUM GEODETIC		DATE 2018 August 28		CHECKED BY _____	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
						20	40	60	80	100	W _p	W	W _L							
194.8	PAVEMENT SURFACE					195														
0.1	ASPHALT (50mm)					194														
	FILL, sand to sand and gravel		1	SS	22															
193.4	Compact																			
1.4	Brown		2	SS	15	193														
	FILL, silty sand to sandy silt, some topsoil																			
192.3	Very loose to compact		3	SS	3															
2.5	Brown					192														
191.9	FILL, clayey silt, trace sand, trace topsoil																			
2.9	Soft		4	SS	7															
	Brown					191														
191.1	FILL, silt and sand, some clay																			
3.7	Loose	5	SS	11																
	Brown				190															
	CLAYEY SILT, trace to some sand, trace to some gravel to sandy CLAYEY SILT	6	SS	12																
	Stiff to hard				189															
	Brown to grey at about elevation 189.5m				188															
		7	SS	14																
					187															
		8	SS	12																
					186															
		9	SS	11																
					185															
		10	SS	14																
					184															
		11	SS	14																
					183															
		12	SS	50																
					182															
					181															

Continued Next Page

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

LDN_MTO_06 1534424-12001.GPJ LDN_MTO.GDT 27-11-18

PROJECT <u>1534424 - 12001</u>		RECORD OF BOREHOLE No BH-102		2 OF 2	METRIC
W.P. <u>3140-15-01</u>	LOCATION <u>MTM: N 4830731.3 E 368920.6 LAT/LONG: LAT 43.613759 LONG -81.705609</u>	ORIGINATED BY <u>MA</u>			
DIST <u></u> HWY <u>21</u>	BOREHOLE TYPE <u>108mm I.D. HOLLOW STEM AUGERS, 100mm O.D. MUD ROTARY REAMER</u>	COMPILED BY <u>ZJB/AMS</u>			
DATUM <u>GEODETIC</u>	DATE <u>2018 August 28</u>	CHECKED BY <u></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/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)									
								○ UNCONFINED + FIELD VANE					W _p	W	W _L		GR	SA	SI	CL		
						20	40	60	80	100												
	CLAYEY SILT, trace to some sand, trace to some gravel to sandy CLAYEY SILT Stiff to hard Brown to grey at about elevation 189.5m																					
			13	SS	51									○								
			14	SS	94									○								
	One large piece of gravel at approximately elev. 176.6m		15	SS	50									⊞	—	⊞		24	11	39	26	
			16	SS	40									○								
			17	SS	56										○							
			18	SS	17											○						
171.3																						
23.5	SILT, some sand Very dense Grey		19	SS	57										○							
169.7																						
25.1	sandy GRAVEL, some silt, some clay Very dense Grey																					
168.8			20	SS	60/ 152mm										○				41	30	19	10
26.0	LIMESTONE BEDROCK Brown		21	SS	100/ 152mm																	
168.4																						
26.4	END OF BOREHOLE																					
	Groundwater encountered at about elev. 170.2m during drilling on August 28, 2018																					

LDN_MTO_06 1534424-12001.GPJ LDN_MTO.GDT 27-11-18

PROJECT 1534424 - 12001		RECORD OF BOREHOLE No BH-104		1 OF 2	METRIC
W.P. 3140-15-01	LOCATION MTM: N 4830772.0 , E 368911.0 LAT/LONG: LAT 43.614127 , LONG -81.705724		ORIGINATED BY MA		
DIST _____ HWY 21	BOREHOLE TYPE 108mm I.D. HOLLOW STEM AUGERS, 100mm MUD ROTARY TRICONE		COMPILED BY ZJB/AMS		
DATUM GEODETIC	DATE 2018 August 22		CHECKED BY _____		

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	W _p	W	W _L						
194.5	PAVEMENT SURFACE																				
0.0	ASPHALT (125mm)																				
0.1	FILL, sand to sand and gravel, trace silt Loose to compact Brown																				
	Geogrid encountered at about elev. 194.1m																				
	A 60mm piece of wood encountered at about elev. 192.5																				
192.4	FILL, clayey silt, trace sand, trace gravel, with silt seams Firm to very stiff Brown																				
2.1																					
191.0	CLAYEY SILT, trace to some sand, trace to some gravel Stiff to hard Brown to grey at about elev. 189.0m																				
3.5																					
													</								

Continued Next Page

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

PROJECT 1534424 - 12001		RECORD OF BOREHOLE No BH-104		2 OF 2	METRIC
W.P. 3140-15-01		LOCATION MTM: N 4830772.0 , E 368911.0 LAT/LONG: LAT 43.614127 , LONG -81.705724		ORIGINATED BY MA	
DIST _____ HWY 21		BOREHOLE TYPE 108mm I.D. HOLLOW STEM AUGERS, 100mm MUD ROTARY TRICONE		COMPILED BY ZJB/AMS	
DATUM GEODETIC		DATE 2018 August 22		CHECKED BY _____	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _p W W _L				GR	SA	SI	CL
								20	40	60	80	100	20	40	60					
		CLAYEY SILT, trace to some sand, trace to some gravel Stiff to hard Brown to grey at about elev. 189.0m																		
			13	SS	82										○	├──┤				10 18 46 26
			14	SS	57										○					
			15	SS	55											○				
			16	SS	66											○				
173.8																				
20.7		SILT and SAND, some gravel, some clay Very dense Grey																		
			17	SS	106											○				13 34 40 13
172.6																				
22.0		CLAYEY SILT, trace sand Hard Grey																		
			18	SS	108											○				
170.4																				
24.1		END OF BOREHOLE, SPLIT SPOON REFUSAL (100 Blows for 0mm) Borehole dry during drilling on August 22, 2018																		

LDN_MTO_06 1534424-12001.GPJ LDN_MTO.GDT 27-11-18

PROJECT 1534424 - 12001		RECORD OF BOREHOLE No BH-105		1 OF 2	METRIC
W.P. 3140-15-01	LOCATION MTM: N 4830784.8 , E 368925.5 LAT/LONG: LAT 43.614241 , LONG -81.705543			ORIGINATED BY MA	
DIST _____ HWY 21	BOREHOLE TYPE 108mm I.D. HOLLOW STEM AUGERS, 100mm OD MUD ROTARY TRICONE			COMPILED BY ZJB/AMS	
DATUM GEODETIC	DATE 2018 August 29 - 30			CHECKED BY _____	

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					W _P	W	W _L		GR	SA	SI	CL	
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE													
							20	40	60	80	100										
194.1	GROUND SURFACE																				
0.0	silty TOPSOIL, trace clay, trace gravel																				
193.7																					
0.4	FILL, clayey silt, trace silt Very stiff Brown		1	SS	18																
192.7																					
1.4	FILL, sandy silt, trace gravel Loose Brown		2	SS	9																
192.0																					
2.1	FILL, sand and gravel, some silt, trace clay		3	SS	14																
191.6	Compact Brown																				
2.5	CLAYEY SILT, trace to some sand trace gravel Stiff to hard Brown to grey at about elev. 182.1m		4	SS	25													3	13	55	29
			5	SS	17																
			6	SS	18																
			7	SS	14													6	13	52	29
			8	SS	16																
			9	SS	14																
			10	SS	13																
			11	SS	51																
			12	SS	46													8	9	45	38

Continued Next Page

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

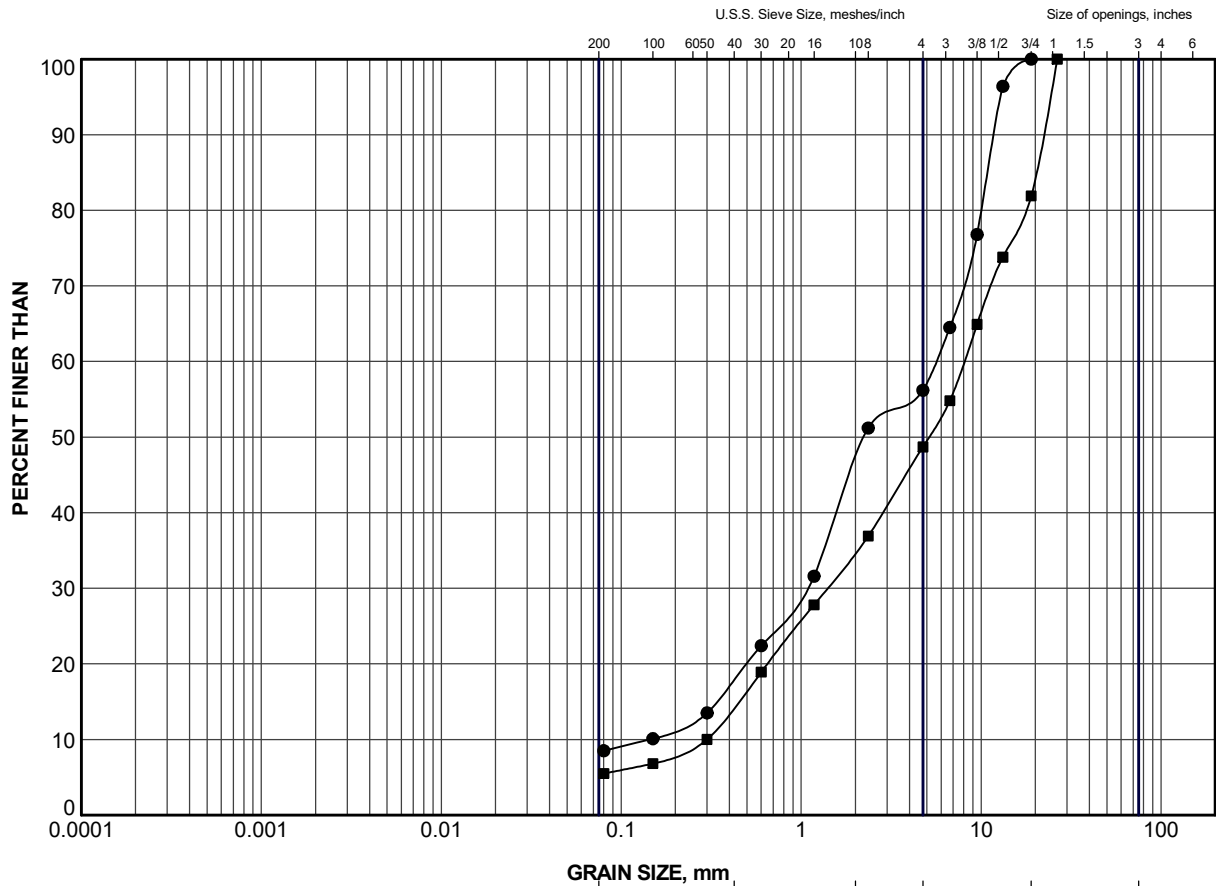
PROJECT <u>1534424 - 12001</u>		RECORD OF BOREHOLE No BH-105		2 OF 2	METRIC
W.P. <u>3140-15-01</u>	LOCATION <u>MTM: N 4830784.8 , E 368925.5 LAT/LONG: LAT 43.614241 , LONG -81.705543</u>	ORIGINATED BY <u>MA</u>			
DIST <u></u> HWY <u>21</u>	BOREHOLE TYPE <u>108mm I.D. HOLLOW STEM AUGERS, 100mm OD MUD ROTARY TRICONE</u>	COMPILED BY <u>ZJB/AMS</u>			
DATUM <u>GEODETIC</u>	DATE <u>2018 August 29 - 30</u>	CHECKED BY <u></u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × LAB VANE	20	40	60	80	100	w _p		w	w _L		
	CLAYEY SILT, trace to some sand trace gravel Stiff to hard Brown to grey at about elev. 182.1m																			
			13	SS	50									○						
			14	SS	59									○						
			15	SS	43									○						
			16	SS	100/ 152mm									○	10	15	20		5 5 48 42	
			17	SS	100/ 279mm									○						
171.4	Limestone fragment in split spoon		18	SS	100/ 152mm									○						
22.7	END OF BOREHOLE																			
	Borehole dry during drilling on August 29 & 30, 2018																			

PROJECT 1534424 - 12001		RECORD OF BOREHOLE No BH-106		1 OF 1	METRIC
W.P. 3140-15-01		LOCATION MTM: N 4830797.5 , E 368910.9 LAT/LONG: LAT 43.614356 , LONG -81.705722		ORIGINATED BY MA	
DIST _____ HWY 21		BOREHOLE TYPE 108mm I.D. HOLLOW STEM AUGERS		COMPILED BY ZJB/AMS	
DATUM GEODETIC		DATE 2018 August 27		CHECKED BY _____	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60 80 100	20 40 60 80 100	10 20 30						
194.9	GROUND SURFACE						195										
0.0	ASPHALT (150mm)																
0.2	FILL, sand and gravel, trace silt Dense to compact Brown		1	SS	36												
			2	SS	10												
192.6							193									52 43 5	
2.3	FILL, clayey silt, some sand Firm Brown		3	SS	4												
192.2																	
2.7	FILL, sand and gravel, some silt Compact Brown		4	SS	23												
191.1							191										
3.8	CLAYEY SILT, trace to some sand, trace gravel Stiff to very stiff Brown to grey at about elev. 190.5m		5	SS	14											1 14 52 33	
			6	SS	17												
							190										
			7	SS	16		189										
							188										
			8	SS	18		187										
			9	SS	17		186										
			10	SS	27		185									2 17 47 34	
184.8																	
10.1	END OF BOREHOLE Borehole dry during drilling on August 27, 2018																

LDN_MTO_06 1534424-12001.GPJ LDN_MTO.GDT 27-11-18

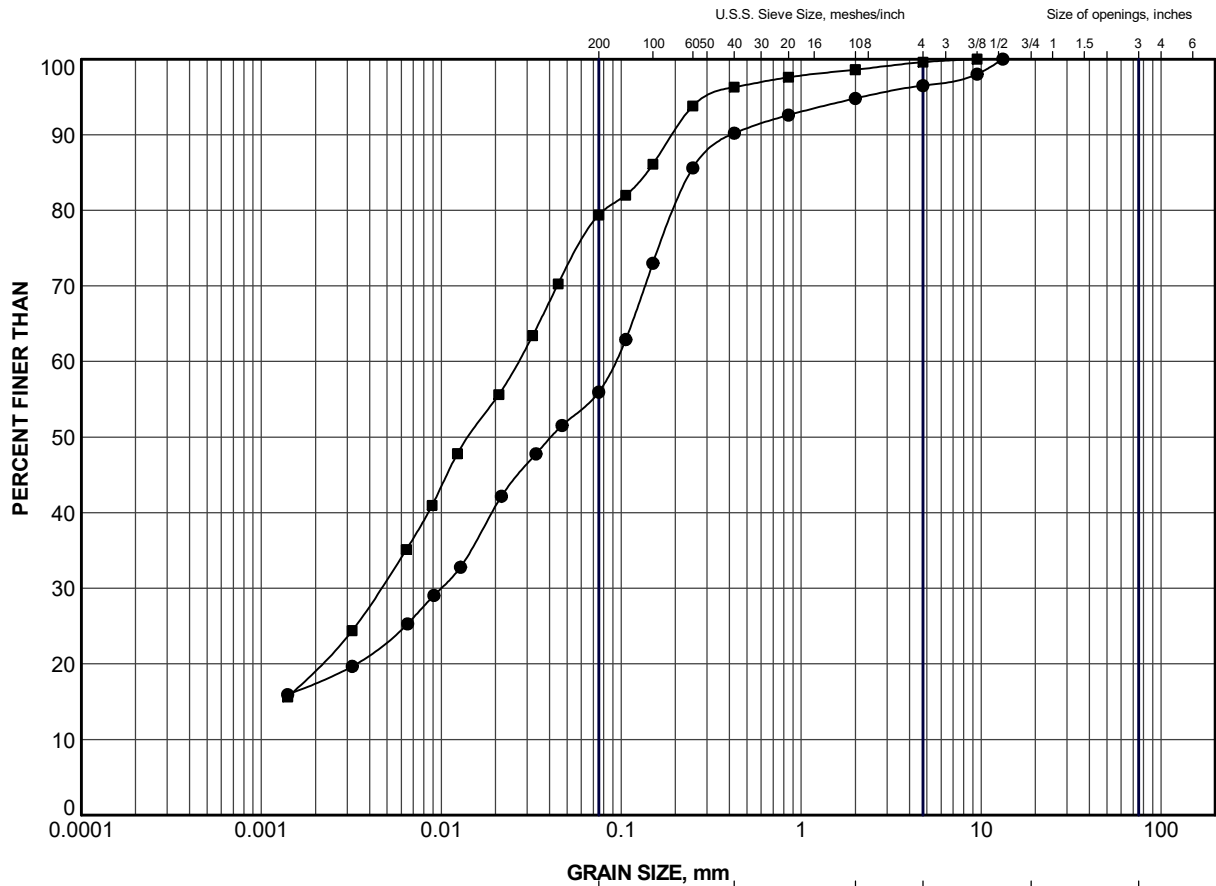


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-104	2	192.8
■	BH-106	2	193.1

PROJECT		HIGHWAY 21 GULLY CREEK - SITE NO. 12-297/C GWP 3101-15-00 (CONTRACT 12)	
TITLE		GRAIN SIZE DISTRIBUTION FILL, SAND and GRAVEL	
	PROJECT No.	1534424 - 12001	FILE No. 1534424-12001-R01001
	DRAWN	AMS	Nov. 26/18
	CHECK	Ac	
	SCALE	N/A	REV.
		FIGURE 1	

LDN_MTO_GSD_GLDR_LDN.GDT 23-10-18 15:01



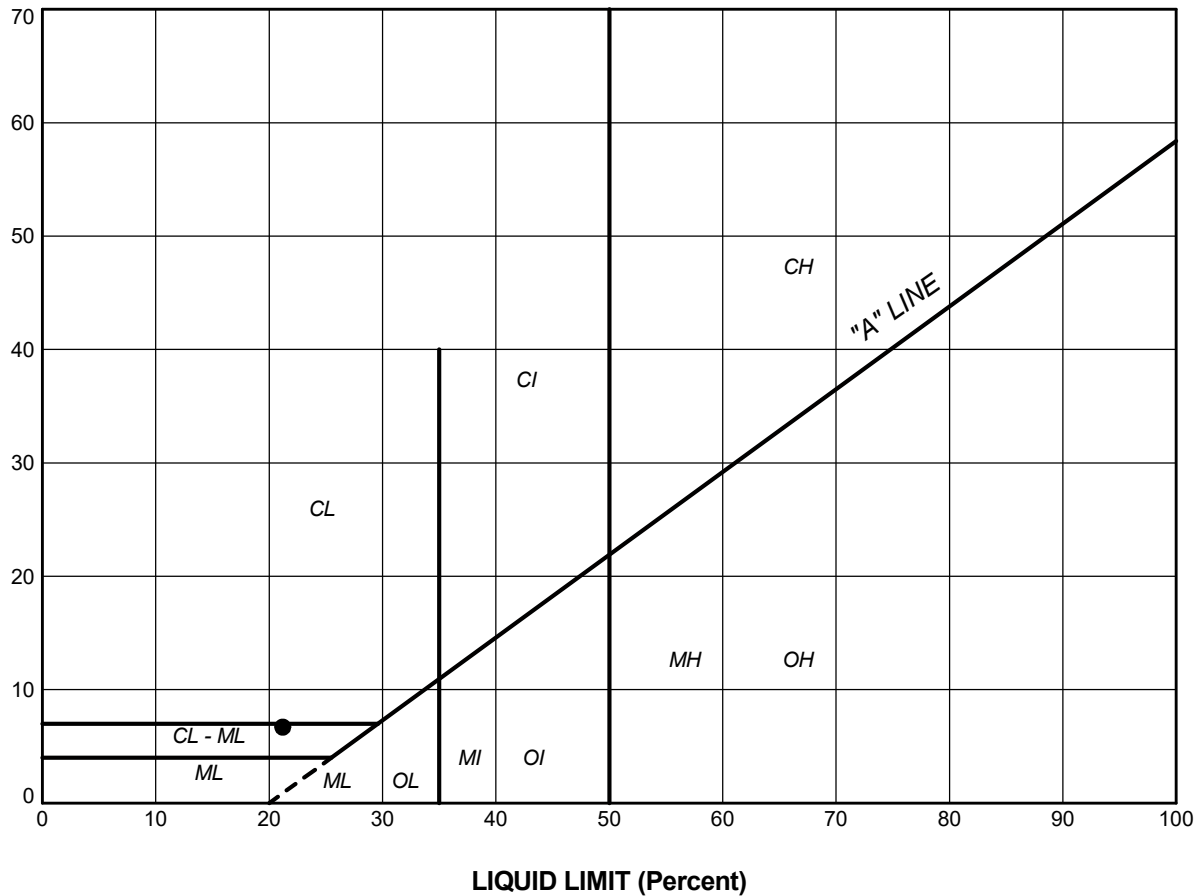
CLAY AND SILT	GRAVEL SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-102	4	191.5
■	BH-103	5	190.7

PROJECT		HIGHWAY 21 GULLY CREEK - SITE NO. 12-297/C GWP 3101-15-00 (CONTRACT 12)				
TITLE		GRAIN SIZE DISTRIBUTION FILL, silt and sand to sandy clayey silt				
		PROJECT No. 1534424 - 12001		FILE No. 1534424-12001-R01002		
		SCALE N/A		REV.		
		DRAWN AMS	Nov. 26/18			
		CHECK HC				
		FIGURE 2				

PLASTICITY INDEX (Percent)



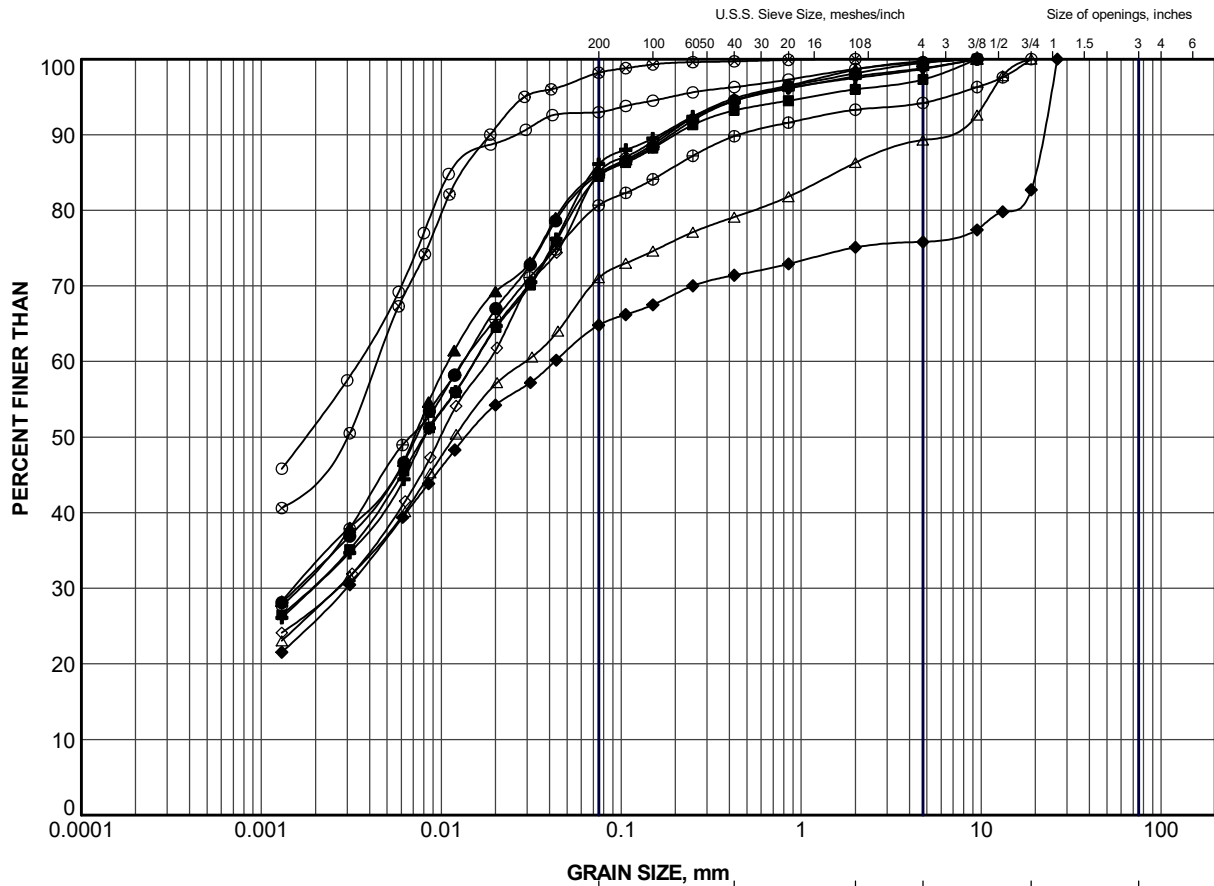
SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH-103	5	21.2	14.5	6.7

PROJECT		HIGHWAY 21 GULLY CREEK - SITE NO. 12-297/C GWP 3101-15-00 (CONTRACT 12)	
TITLE		PLASTICITY CHART FILL, sandy clayey silt	
PROJECT No. 1534424 - 12001		FILE No. 1534424-12001-R01003	
DRAWN	AMS	Nov. 26/18	SCALE N/A
CHECK	AMS		REV.
GOLDER		FIGURE 3	

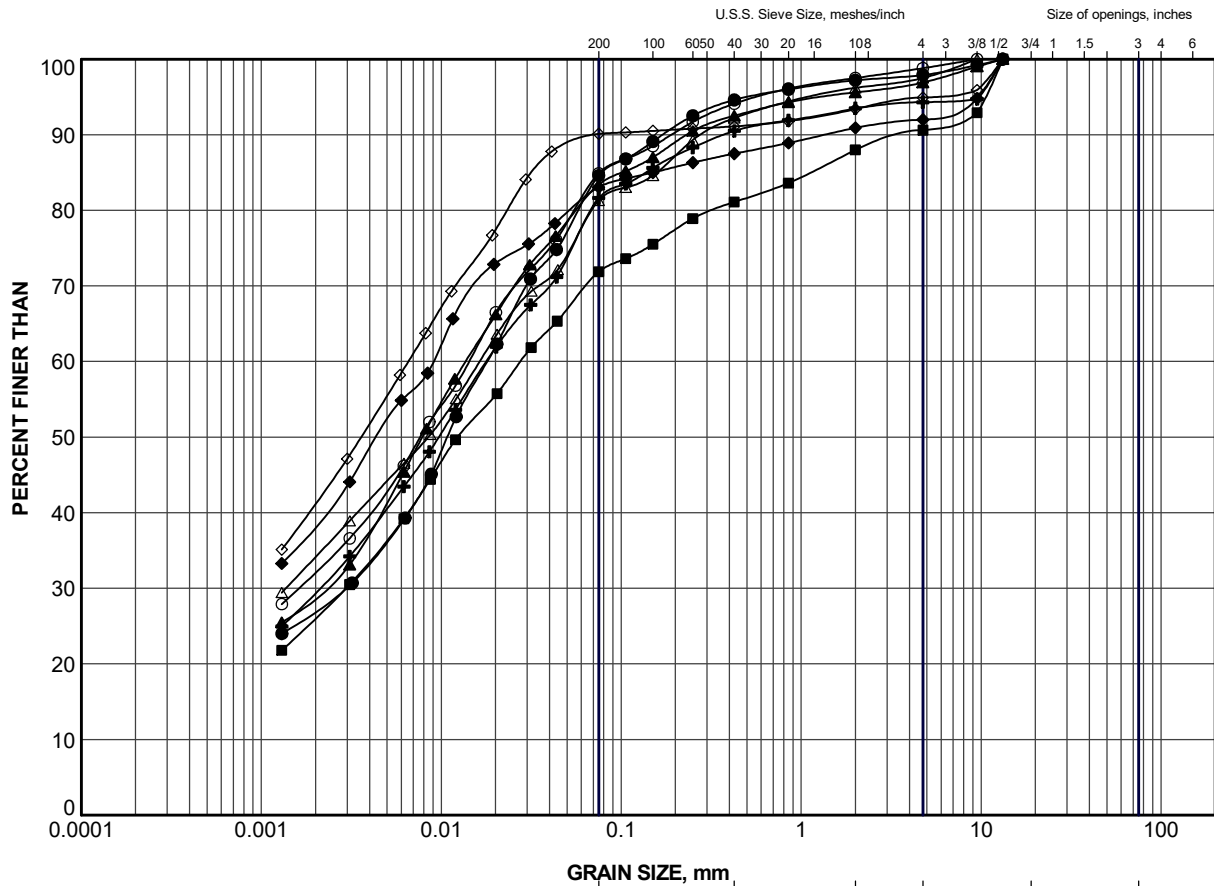


CLAY AND SILT						Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-101	5	191.6
■	BH-101	8	188.5
▲	BH-102	5	190.7
+	BH-102	7	188.8
◆	BH-102	15	176.6
◇	BH-103	10	186.9
○	BH-103	14	181.1
△	BH-103	18	175.0
⊗	BH-103	20	171.9
⊕	BH-104	5	190.5

PROJECT		HIGHWAY 21 GULLY CREEK - SITE NO. 12-297/C GWP 3101-15-00 (CONTRACT 12)			
TITLE		GRAIN SIZE DISTRIBUTION CLAYEY SILT			
PROJECT No. 1534424 - 12001		FILE No. 1534424-12001-R01004			
DRAWN AMS		Nov. 26/18		SCALE N/A	REV.
CHECK <i>Ac</i>				FIGURE 4	



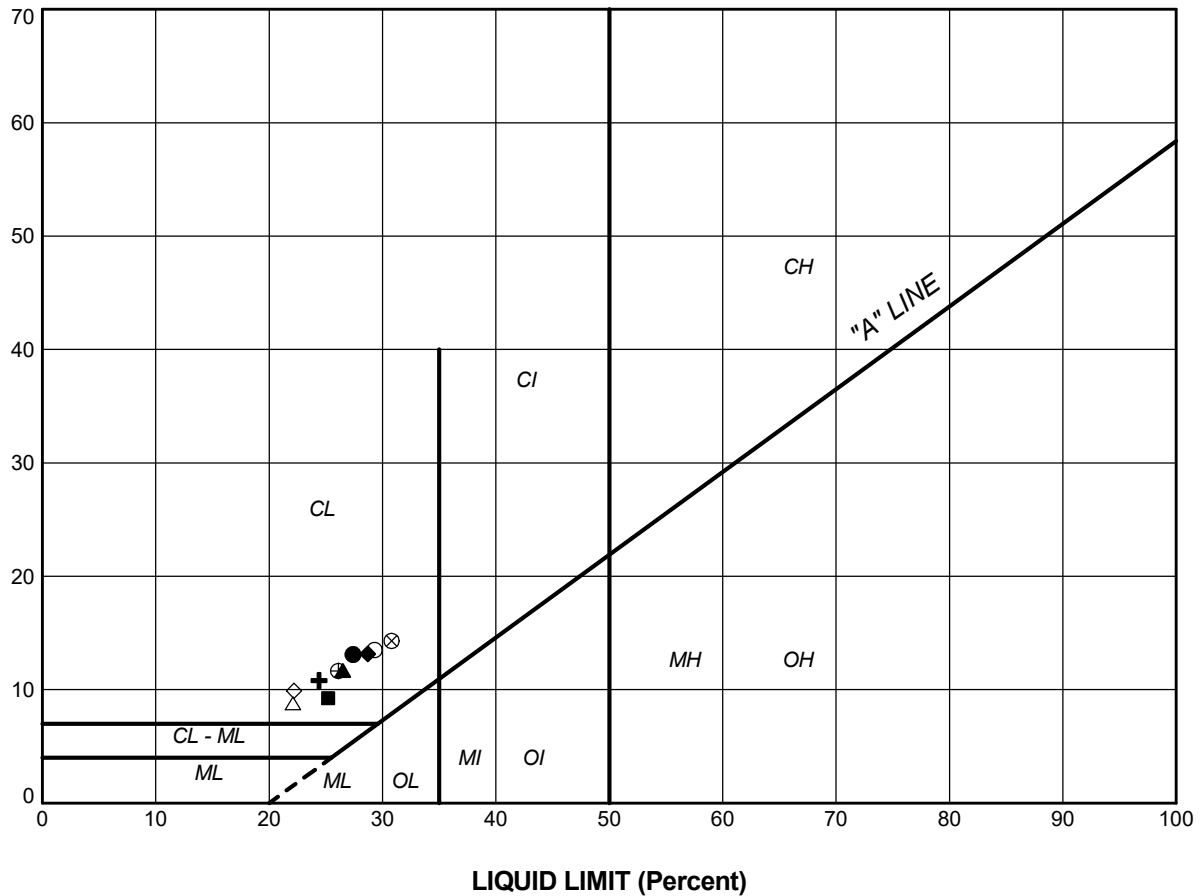
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-104	9	185.4
■	BH-104	13	179.3
▲	BH-105	4	190.8
+	BH-105	7	188.1
◆	BH-105	12	180.4
◇	BH-105	16	174.4
○	BH-106	5	190.8
△	BH-106	9	185.5

PROJECT		HIGHWAY 21 GULLY CREEK - SITE NO. 12-297/C GWP 3101-15-00 (CONTRACT 12)				
TITLE		GRAIN SIZE DISTRIBUTION CLAYEY SILT				
		PROJECT No. 1534424 - 12001		FILE No. 1534424-12001-R01005		
		SCALE N/A		REV.		
		DRAWN AMS	Nov. 26/18			
		CHECK <i>Ac</i>				
		FIGURE 5				

PLASTICITY INDEX (Percent)



SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

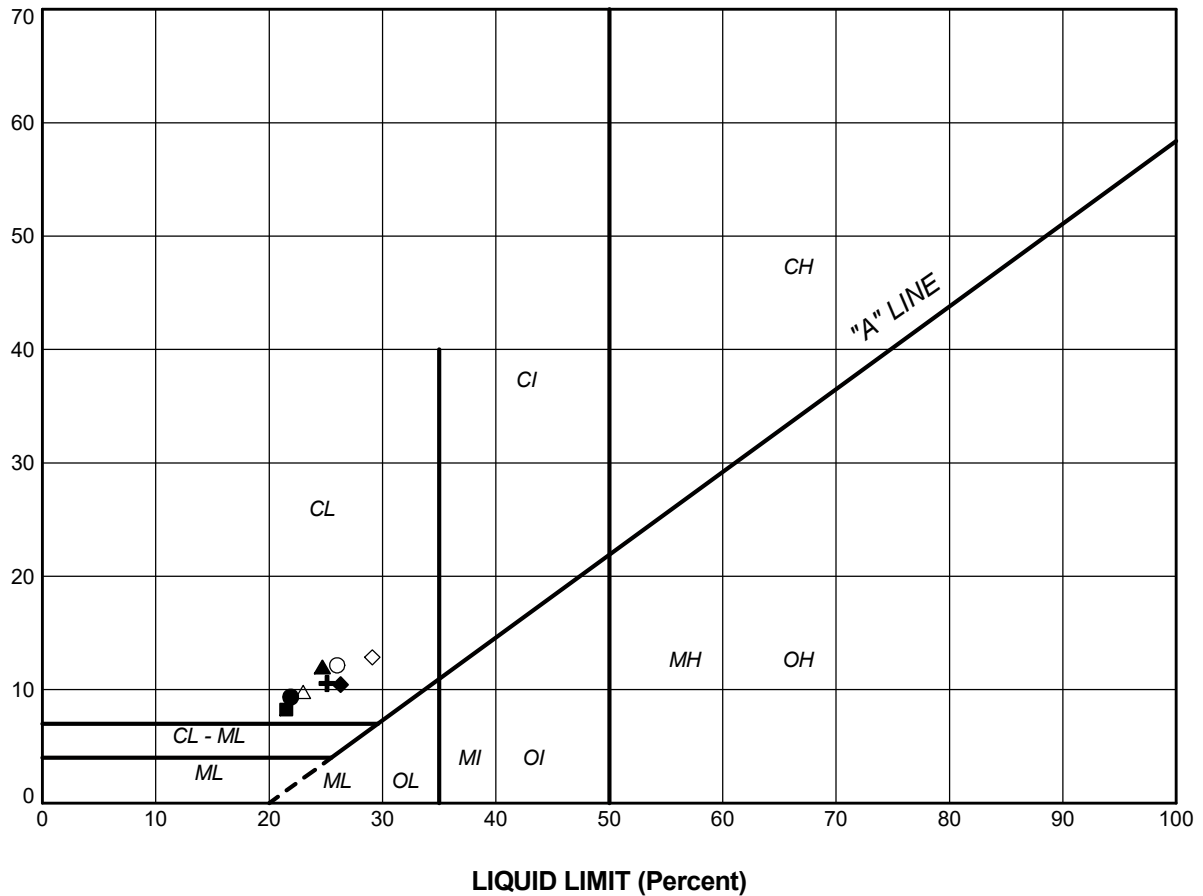
PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH-101	5	27.4	14.3	13.1
■	BH-101	8	25.2	16.0	9.3
▲	BH-102	5	26.5	14.8	11.7
+	BH-102	7	24.4	13.6	10.8
◆	BH-102	15	28.7	15.6	13.2
◇	BH-103	10	22.2	12.3	9.9
○	BH-103	14	29.3	15.8	13.5
△	BH-103	18	22.1	13.3	8.8
⊗	BH-103	20	30.8	16.5	14.3
⊕	BH-104	5	26.1	14.5	11.7

PROJECT		HIGHWAY 21 GULLY CREEK - SITE NO. 12-297/C GWP 3101-15-00 (CONTRACT 12)	
TITLE		PLASTICITY CHART CLAYEY SILT	
PROJECT No. 1534424 - 12001		FILE No. 1534424-12001-R01006	
DRAWN	AMS	Nov. 26/18	SCALE N/A
CHECK	Ac		REV.
GOLDER			FIGURE 6

PLASTICITY INDEX (Percent)



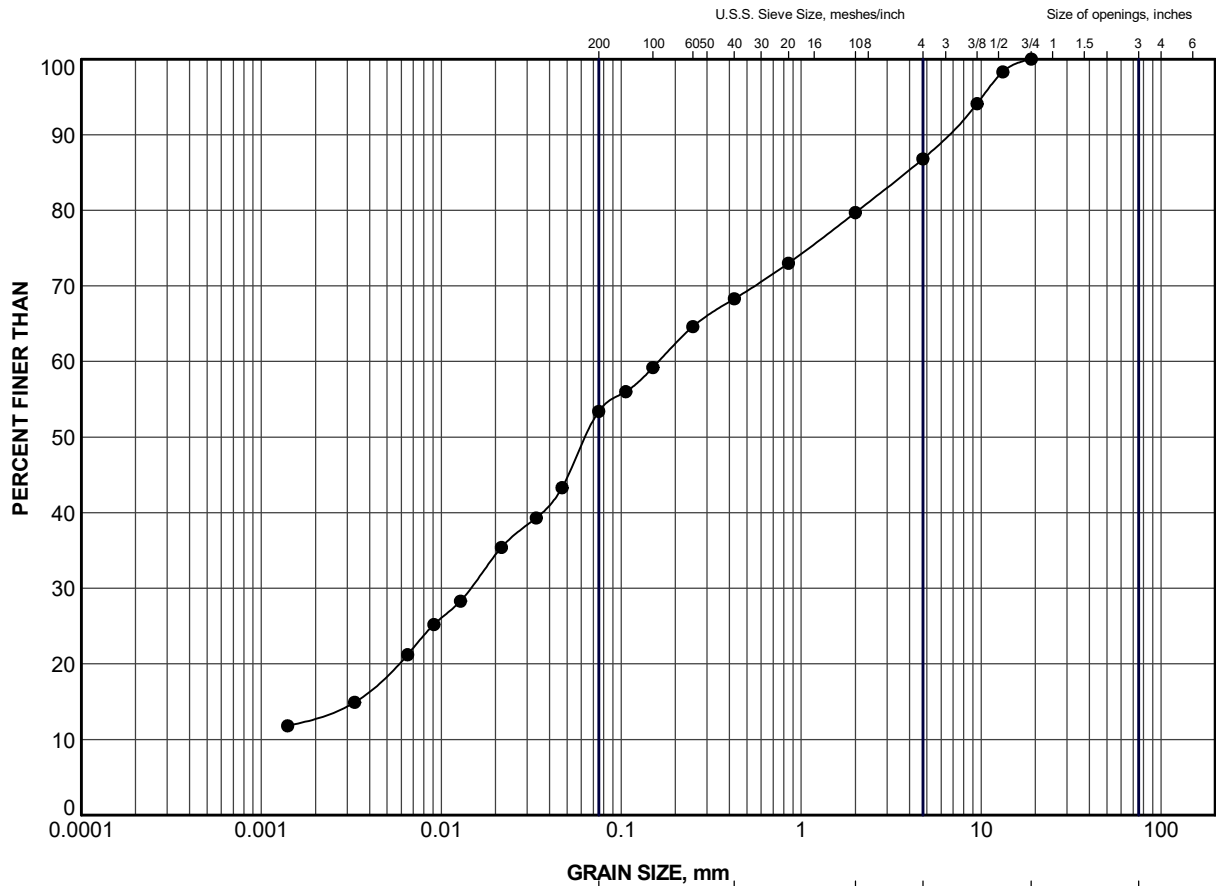
SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH-104	9	21.9	12.6	9.4
■	BH-104	13	21.5	13.3	8.3
▲	BH-105	4	24.7	12.7	12.0
+	BH-105	7	25.1	14.6	10.6
◆	BH-105	12	26.3	15.9	10.5
◇	BH-105	16	29.1	16.3	12.9
○	BH-106	5	26.0	13.9	12.2
△	BH-106	9	23.0	13.2	9.8

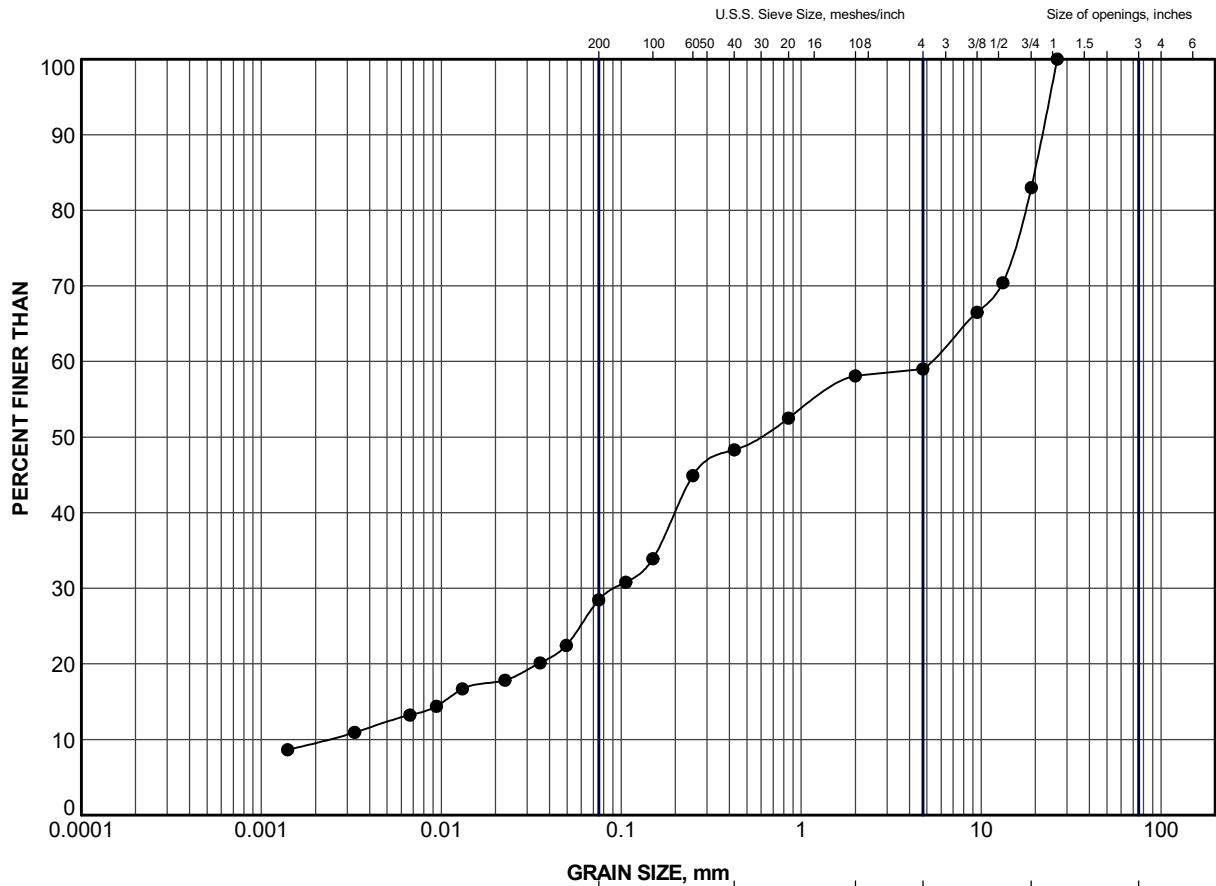
PROJECT		HIGHWAY 21 GULLY CREEK - SITE NO. 12-297/C GWP 3101-15-00 (CONTRACT 12)	
TITLE		PLASTICITY CHART CLAYEY SILT	
PROJECT No. 1534424 - 12001		FILE No. 1534424-12001-R01007	
DRAWN	AMS	Nov. 26/18	SCALE N/A
CHECK	AC		REV.
GOLDER			FIGURE 7



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-104	17	173.2

PROJECT		HIGHWAY 21 GULLY CREEK - SITE NO. 12-297/C GWP 3101-15-00 (CONTRACT 12)				
TITLE		GRAIN SIZE DISTRIBUTION SILT and SAND				
		PROJECT No. 1534424 - 12001		FILE No. 1534424-12001-R01008		
		SCALE N/A		REV.		
		DRAWN AMS	Nov. 26/18			
		CHECK AC				
		FIGURE 8				



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

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-102	20	169.0

PROJECT		HIGHWAY 21 GULLY CREEK - SITE NO. 12-297/C GWP 3101-15-00 (CONTRACT 12)				
TITLE		GRAIN SIZE DISTRIBUTION sandy GRAVEL				
		PROJECT No. 1534424 - 12001		FILE No. 1534424-12001-R01009		
		SCALE N/A		REV.		
		DRAWN AMS	Nov. 26/18			
		CHECK <i>HC</i>				
		FIGURE 9				

LDN_MTO_GSD_GLDR_LDN.GDT 23-10-18 15:56

Your P.O. #: 1534424-12001
Your Project #: 1534424-1221
Site Location: GULLY CREEK
Your C.O.C. #: 104313

Attention: Adam Core

Golder Associates Ltd
309 Exeter Rd
Unit 1
London, ON
CANADA N6L 1C1

Report Date: 2018/10/23
Report #: R5452620
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B8Q8904

Received: 2018/10/11, 09:05

Sample Matrix: Soil
Samples Received: 2

Analyses	Date		Date Analyzed	Laboratory Method	Reference
	Quantity	Extracted			
Chloride (20:1 extract)	2	N/A	2018/10/17	CAM SOP-00463	EPA 325.2 m
Conductivity	2	N/A	2018/10/15	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl ₂ EXTRACT	2	2018/10/12	2018/10/12	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	2	2018/10/12	2018/10/15	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	2	N/A	2018/10/17	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

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

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

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

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

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

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

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Attention: Adam Core

Golder Associates Ltd
309 Exeter Rd
Unit 1
London, ON
CANADA N6L 1C1

Your P.O. #: 1534424-12001
Your Project #: 1534424-1221
Site Location: GULLY CREEK
Your C.O.C. #: 104313

Report Date: 2018/10/23
Report #: R5452620
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B8Q8904

Received: 2018/10/11, 09:05

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Christine Gripton, Senior Project Manager
Email: CGripton@maxxam.ca
Phone# (800)268-7396 Ext:250

=====

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.

SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		HZO548			HZO548		
Sampling Date		2018/08/28 05:00			2018/08/28 05:00		
COC Number		104313			104313		
	UNITS	BH 102 SA#6 15-16.5'	RDL	QC Batch	BH 102 SA#6 15-16.5' Lab-Dup	RDL	QC Batch
Calculated Parameters							
Resistivity	ohm-cm	1100		5779875			
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g	430	20	5785363			
Conductivity	umho/cm	905	2	5782981			
Available (CaCl2) pH	pH	7.96		5779977			
Soluble (20:1) Sulphate (SO4)	ug/g	27	20	5785372	26	20	5785372
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate							

Maxxam ID		HZO549		
Sampling Date		2018/08/29 04:00		
COC Number		104313		
	UNITS	BH 105 SA#5 12.5-14.0'	RDL	QC Batch
Calculated Parameters				
Resistivity	ohm-cm	2200		5779875
Inorganics				
Soluble (20:1) Chloride (Cl-)	ug/g	52	20	5785363
Conductivity	umho/cm	456	2	5782981
Available (CaCl2) pH	pH	7.89		5779977
Soluble (20:1) Sulphate (SO4)	ug/g	230	20	5785372
RDL = Reportable Detection Limit QC Batch = Quality Control Batch				

Maxxam Job #: B8Q8904
Report Date: 2018/10/23

Golder Associates Ltd
Client Project #: 1534424-1221
Site Location: GULLY CREEK
Your P.O. #: 1534424-12001
Sampler Initials: MA

TEST SUMMARY

Maxxam ID: HZO548
Sample ID: BH 102 SA#6 15-16.5'
Matrix: Soil

Collected: 2018/08/28
Shipped:
Received: 2018/10/11

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5785363	N/A	2018/10/17	Deonarine Ramnarine
Conductivity	AT	5782981	N/A	2018/10/15	Barbara Kalbasi Esfahani
pH CaCl2 EXTRACT	AT	5779977	2018/10/12	2018/10/12	Gnana Thomas
Resistivity of Soil		5779875	2018/10/15	2018/10/15	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5785372	N/A	2018/10/17	Alina Dobreanu

Maxxam ID: HZO548 Dup
Sample ID: BH 102 SA#6 15-16.5'
Matrix: Soil

Collected: 2018/08/28
Shipped:
Received: 2018/10/11

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphate (20:1 Extract)	KONE/EC	5785372	N/A	2018/10/17	Alina Dobreanu

Maxxam ID: HZO549
Sample ID: BH 105 SA#5 12.5-14.0'
Matrix: Soil

Collected: 2018/08/29
Shipped:
Received: 2018/10/11

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5785363	N/A	2018/10/17	Deonarine Ramnarine
Conductivity	AT	5782981	N/A	2018/10/15	Barbara Kalbasi Esfahani
pH CaCl2 EXTRACT	AT	5779977	2018/10/12	2018/10/12	Gnana Thomas
Resistivity of Soil		5779875	2018/10/15	2018/10/15	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5785372	N/A	2018/10/17	Alina Dobreanu

GENERAL COMMENTS

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

Package 1	9.0°C
-----------	-------

Sample HZO548 [BH 102 SA#6 15-16.5'] : PHCACL-S: Analysis was performed past sample holding time. This may increase the variability associated with these results.

Sample HZO549 [BH 105 SA#5 12.5-14.0'] : PHCACL-S: Analysis was performed past sample holding time. This may increase the variability associated with these results.

Results relate only to the items tested.

Maxxam Job #: B8Q8904
Report Date: 2018/10/23

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1534424-1221
Site Location: GULLY CREEK
Your P.O. #: 1534424-12001
Sampler Initials: MA

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5779977	Available (CaCl ₂) pH	2018/10/12			99	97 - 103			0.14	N/A
5782981	Conductivity	2018/10/15			106	90 - 110	<2	umho/cm	1.4	10
5785363	Soluble (20:1) Chloride (Cl ⁻)	2018/10/17	NC	70 - 130	107	70 - 130	<20	ug/g	4.4	35
5785372	Soluble (20:1) Sulphate (SO ₄)	2018/10/17	NC	70 - 130	103	70 - 130	<20	ug/g	4.7	35

N/A = Not Applicable

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

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

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

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

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

VALIDATION SIGNATURE PAGE

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

Cristina Carriere

Cristina Carriere, Scientific Service Specialist

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

APPENDIX C

Non-Standard Special Provisions

CSP FOR INTEGRAL ABUTMENTS – Item No.

Non-Standard Special Provision

Scope

This specification covers the requirements for the installation of the corrugated steel pipes (CSPs) at the integral abutments.

SUBMISSION AND DESIGN REQUIREMENTS

All submissions shall bear the seal and signature of an Engineer.

At least two weeks prior to commencement of installation of the abutment piles, the Contractor shall submit to the Contract Administrator, for information purposes only, three (3) sets of the working drawings.

The Contractor shall have a copy of the submitted working drawings on site at all times. Working drawings shall include at least the following:

1. Layout and elevations of the CSPs;
2. Location of reference points, and location of the centroid of each pile with respect to the reference points;
3. Construction sequence and details;
4. Source of the sand fill, and description of placing methods and equipment;
5. Location and details of all temporary bracing and spacers for the piles and CSPs;
6. Method for preventing water and debris from entering the CSP prior to placing sand; and
7. Method for preventing concrete from abutment pours from entering the CSPs during placement.

The Contractor shall be responsible for the complete detailed design of all temporary bracing, including spacers required to maintain the piles, CSP spacing and abutment stems in their specified positions through all stages of construction until the CSPs have been backfilled. All temporary bracing shall be removed.

MATERIAL

Corrugated Steel Pipe

CSP shall be in accordance with OPSS 1801 and shall be from a supplier listed under DSM#4.60.80. The CSP shall be of the diameter and wall thickness specified on the Contract Drawings, and shall be galvanized in accordance with CSA G164-M.

CSPs shall be supplied in the lengths and with the end treatments, either square or skew, as specified on the Contract Drawings; field cutting and splicing of CSPs will not be permitted. Cut ends shall be neat and free of burrs. The planes defined by the end treatments of each CSP shall be parallel to each other.

Handling and storage of CSPs shall be in accordance with the manufacturer's recommendations. Damaged CSPs shall be rejected. Localized areas of damaged galvanizing on otherwise acceptable CSPs shall be repaired with two coats of zinc-rich paint.

Sand Fill

The sand fill for backfilling the CSP shall meet the gradation requirements of Table 1 below:

Table 1 – Sand Fill Gradation Requirements

MTO Sieve Designation		Percentage Passing by Weight
2 mm	#10	100%
600 µm	#30	80% to 100%
425 µm	#40	40% to 80%
250 µm	#60	5% to 25%
150 µm	#100	0% to 6%

CONSTRUCTION

The sequence of construction shall be in accordance with the working drawings and as follows, unless otherwise approved:

1. Form concrete levelling pad and place CSPs and spacers.
2. Construct concrete levelling pads.
3. Install piles by driving to the design tip elevation or bedrock if end-bearing piles are selected.
4. Place loose sand into the CSP.
5. Remove temporary spacers.

The CSP shall be positioned such that the piles are centrally positioned within the CSP. Temporary blocking and bracing shall be used to hold the CSP in position.

The Contractor shall ensure the full perimeters of the top of all CSPs at each abutment are at the elevation and orientation shown on the working drawings.

The CSP at each pile shall be constructed to the following tolerances:

<u>Criteria</u>	<u>Tolerance</u>
Maximum deviation of CSP from pile centroid	+/- 50 mm
Maximum deviation of any point on the top perimeter of the CSP from the specified elevation	+/- 10 mm

The sand fill shall be placed dry of optimum and free-flowing, completely filling the volume between the CSP and pile. No additional compaction effort other than the action of placing the sand itself shall be applied to the sand fill.

The placing of the sand fill shall be carried out in a manner such as to not damage and displace the CSP.

Basis of Payment

Payment at the contract price for the above tender item shall include all labour, equipment and material required to do the work.

OBSTRUCTIONS

Non-Standard Special Provision

The Contactor is hereby notified that cobbles and boulders are were encountered in the current investigation as noted on Borehole 103 and in G30 from the previous investigation (GEOCRES 40P12-21) were present within the clayey silt deposit at the site. A 60 millimetre thick piece of wood was encountered within the fill in Borehole 104. Further, the native soils at the site are glacially derived and as such are very dense and should be expected to contain cobbles and boulders, which could affect excavations and the installation of deep foundations. Consideration of the presence of these obstructions must be made in selection of appropriate equipment and procedures for sub-excavation and installation of the foundation systems.

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

APPENDIX D

Photographs 1 to 4



Photograph 1: South approach facing north (August 2018).



Photograph 2: Northwest side of culvert facing north (August 2018).



Photo 3: Outlet, facing east toward embankment (August 2018).



Photo 4: Outlet, facing east, upstream (August 2017).



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