



November 12, 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

**PROPOSED HIGHWAY 11 WESTBOUND PASSING LANE
STATION 21+150 to 21+700
TOWNSHIP OF DEVITT, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5166-12-00**

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REPORT





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PART A

**FOUNDATION INVESTIGATION REPORT
HIGHWAY 11 – PROPOSED WESTBOUND PASSING LANE
TOWNSHIP OF DEVITT, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5166-12-00**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Ltd. (MMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed westbound passing lane from STA 21+150 to STA 21+700 along Highway 11 in the Township of Devitt, Ontario. The Key Plan showing the general location of this section of Highway 11 and the location of the investigated area is shown on Drawings 1 and 2. The purpose of this investigation is to establish the subsurface conditions at the location of the proposed passing lane by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The proposed westbound passing lane is located to the east of Val Côté, Ontario, approximately 25 km east of the east junction of Highway 583. In general, the topography in the area of the overall project limits consists of relatively flat terrain utilized as farmland or with moderate tree cover. Based on our observations at the site and the fill material encountered at the borehole locations, it appears as though the footprint of the former highway is located on the north side of the existing highway within the area of the proposed passing lane. The existing embankment is up to about 2 m high and the ground surface at the borehole locations advanced within the limits of the study area, including the existing Highway 11 embankment, varies between about Elevation 234 m and 236 m.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between July 25 and July 28, 2013, and between August 22 and August 25, 2013, during which time a total of twelve (12) boreholes (P1-1 to P1-11, P1-2a) were advanced for the proposed passing lane, as shown on Drawings 1 and 2. The boreholes were advanced using a track mounted CME 55 supplied and operated by Landcore Drilling of Sudbury, Ontario. The Record of Borehole sheets are provided in Appendix A.

The boreholes were advanced to depths ranging between 9.8 m and 18.9 m below existing ground using 108 mm inside diameter continuous flight hollow stem augers. A Dynamic Cone Penetration Test (DCPT) was driven from the bottom of Borehole P1-9 from 18.9 m to 23.5 m depth and terminated upon refusal to further penetration.

Soil samples were generally obtained at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Samples of the cohesive soils were obtained using 76 mm O.D. thin-walled Shelby tubes (ASTM D1587) for relatively undisturbed samples. Field vane shear tests were carried out in cohesive soils (strata) for assessment of undrained shear strengths (ASTM D2573) using an MTO Standard 'N' size vane. The boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903-Wells (as amended).

The fieldwork was supervised throughout by a member of our technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes and examined and cared for the soil samples. The samples were identified in



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the field, placed in appropriate containers, labelled and transported to our Sudbury Geotechnical Laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are included in Appendix B.

The as-drilled borehole locations for the current investigation were measured in the field relative to stakes installed by MMM. Golder referenced as-drilled borehole ground surface elevations to the stakes. The ground surface elevations at the borehole locations are referenced to Geodetic datum. The as-drilled borehole locations for the investigation, the ground elevations and borehole depths at the drilled locations are shown in the table below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
P1-1	5 499 099.1	353 001.3	234.5	9.8
P1-2	5 499 095.1	353 026.0	234.7	18.9
P1-2a	5 499 095.6	353 024.1	234.7	8.8
P1-3	5 499 089.2	353 050.3	234.8	9.8
P1-4	5 499 065.0	353 147.4	235.5	9.8
P1-5	5 499 033.7	353 268.4	235.5	12.8
P1-6	5 499 005.5	353 390.2	235.4	12.8
P1-7	5 498 990.2	353 437.9	235.4	12.8
P1-8	5 498 982.7	353 487.6	235.3	12.8
P1-9	5 498 966.0	353 534.9	235.2	18.9
P1-10	5 499 079.5	353 048.0	235.8	9.8
P1-11	5 498 972.5	353 485.1	235.7	9.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on terrain mapping by the Ontario Geological Survey¹, the subsurface soils in the vicinity of the site consist of ground moraine deposits of clayey till. Approximately 500 m south of the proposed passing lane area, an approximately 1 km wide area of peat/organic deposit is noted on the terrain map.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions, as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the Record of Boreholes sheets attached in Appendix A. The results of the in situ tests (i.e., SPT "N"-values and

¹ Northern Ontario Engineering Geology Terrain Study, OGS Electronic Map, printed February 2014



undrained shear strengths from the field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. Detailed results of the laboratory testing of the soil samples are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations of drilling progress and cuttings. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations. The inferred soil stratigraphy based on the results of the boreholes along the passing lane is shown on Drawings 1 to 3.

In general, the subsoils along the proposed passing lane consist of embankment fill underlain by organic soil (outside of the existing roadway), underlain in turn by a cohesive deposit consisting of silty clay, clay and/or clayey silt, and underlain by cohesionless soils, where encountered, consisting of silt, sand and silt and/or sand. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

Various fill materials were encountered from ground surface at each of the boreholes advanced at the site. For each borehole, the following provides a summary of the fill types and thicknesses.

- Boreholes P1-1 to P1-9 were advanced at or beyond the toe of the existing embankment and encountered 0.7 m to 3.0 m thick sand/silty sand fill and/or peat from ground surface between Elevation 235.5 m and 234.5 m. Borehole P1-1 encountered a 1.2 m thick layer of clayey silt fill interlayered with the sand fill.
- Boreholes P1-10 and P1-11 were advanced through the existing embankment and encountered 8.0 m and 3.2 m thick sand and gravel to sand fill, respectively, from ground surface at Elevation 235.8 m and 235.7 m, respectively.

SPT 'N'-values measured within the sand/silty sand fill range between 0 blows (i.e., weight of hammer) and 15 blows per 0.3 m of penetration, indicating a very loose to compact relative density. Two SPT 'N'-values measured within the clayey silt fill in Borehole P1-1 are 1 blow and 4 blows per 0.3 m of penetration, suggesting a very soft to soft consistency. SPT 'N'-values measured within the peat fill range between 0 blows (i.e., weight of hammer) and 9 blows per 0.3 m of penetration, suggesting a very soft to firm consistency.

A grain size distribution test was carried out on two samples of the sand fill and the results are shown on Figure B1 in Appendix B.

The natural water content measured on samples of the sand/silty sand fill range between about 12 per cent and 27 per cent.

4.2.2 Peat

A 0.2 m to 1.9 m thick deposit of black fibrous and/or amorphous peat was encountered beneath the fill in Boreholes P1-1 to P1-9 between Elevation 234.7 m and Elevation 231.7 m.

SPT 'N'-values measured within the peat range between 0 blows (i.e., weight of hammer) and 11 blows per 0.3 m of penetration, suggesting a very soft to stiff consistency.



The natural water content measured on samples of the peat range between about 71 per cent and 356 per cent.

4.2.3 Organic Silty Clay

A deposit of black to brown organic silty clay, trace to some sand was encountered below the peat in Boreholes P1-1 to P1-3 and P1-8 between Elevation 233.1 m and Elevation 230.8 m with thicknesses ranging between 0.9 m and 1.6 m.

SPT 'N'-values recorded within the organic silty clay were 0 blows (i.e., weight of hammer) per 0.3 m of penetration, suggesting the cohesive deposit has a very soft consistency.

The natural water content measured on one sample of the organic silty clay is about 134 per cent.

4.2.4 Sandy Silt (Upper)

A 0.8 m thick deposit of brown sandy silt, trace organics was encountered below the peat in Borehole P1-4 at Elevation 234.1 m.

One SPT 'N'-value measured within the sandy silt was 6 blows per 0.3 m of penetration, indicating a loose relative density.

4.2.5 Clay to Clayey Silt

A deposit of grey clay to clayey silt, trace sand was encountered below the organic silty clay in Boreholes P1-1 to P1-3 and P1-8, below the sandy silt in Borehole P1-4, below the peat in Boreholes P1-5 to P1-7 and P1-9, and beneath the fill in Boreholes P1-10 and P1-11. The surface of the deposit was encountered between Elevation 233.3 m and 227.8 m and the deposit is between 3.4 m to 9.4 m thick in Boreholes P1-2, P1-4, P1-9 and P1-11. Boreholes P1-1, P1-3, P1-5 to P1-8 and P1-10 were terminated after penetrating between 1.8 m and 10.2 m into the deposit. In Borehole P1-5, an approximately 1.6 m thick layer of sand and silt, trace to some clay was encountered at Elevation 226.9 m, within the clay to clayey silt deposit.

SPT 'N'-values measured within the clay to clayey silt range between 0 blows (i.e., weight of hammer) and 10 blows per 0.3 m of penetration. In situ field vane tests carried out within this deposit measured undrained shear strengths ranging from 12 kPa to greater than 75 kPa, and the sensitivity is calculated to range between 1 and 4. The field vane tests results, together with the SPT 'N'-values, indicate that the clay to clayey silt deposit has a very soft to stiff consistency. One SPT 'N'-value measured within the sand and silt layer in Borehole P1-5 is 14 blows per 0.3 m of penetration, indicating a compact relative density.

A grain size distribution for fifteen samples of the clay to clayey silt deposit and one sample of the sand and silt interlayer in Borehole P1-5 is shown on Figure B2.1 and B2.2 in Appendix B.

Atterberg limits testing carried out on twenty-four samples of the clay to clayey silt deposit yielded liquid limits ranging from about 18 per cent to 82 per cent, plastic limits ranging from about 12 per cent to 25 per cent and plasticity indices ranging from about 6 per cent to 57 per cent. The results of the Atterberg limits testing are shown on the plasticity chart on Figure B3 in Appendix B and indicate that the deposit is classified as a clayey



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silt of low plasticity to a clay of high plasticity. Atterberg limits testing carried out on one sample of the sand and silt interlayer in Borehole P1-5 yielded a liquid limit of about 14 per cent, a plastic limit of about 12 per cent and a plasticity index of about 2 per cent, indicating the sample is a silt of slight plasticity.

The natural water content measured on samples of the clayey silt to clay range between about 13 per cent and 74 per cent.

A laboratory consolidation test was carried out on one specimen of the silty clay deposit obtained from a Shelby tube sample in Borehole P1-2a. The preconsolidation stress was estimated from the void ratio versus logarithmic pressure plot using the Casagrande method as well as from the total work versus pressure plot. A bulk unit weight of 17.3 kN/m^3 and a specific gravity of about 2.75 was measured on the consolidation test specimen. Details of the test results are shown on Figure B4 in Appendix B, and the test results are summarized below.

Borehole, Sample No.	Sample Depth, Elevation	σ_{vo}' (kPa)	σ_p' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	OCR	C_c	C_r	e_o	c_v^* (cm^2/s)
P1-2a, 1	5.5 m, 229.2 m	30	30	0	1.0	0.22	0.03	1.24	5.0×10^{-4}

*For approximate stress range of $31 \text{ kPa} \leq \sigma_v' \leq 66 \text{ kPa}$ based on a 2 m grade raise within the footprint of the 4 m embankment widening.

where: σ_{vo}' is the in situ vertical effective overburden stress in kPa
 σ_p' is the preconsolidation stress in kPa
OCR is overconsolidation ratio
 e_o is initial void ratio
 C_c is the compression index
 C_r is the recompression index
 c_v is the coefficient of consolidation in cm^2/s

4.2.6 Silt

A deposit of grey silt, some clay, trace to some sand was encountered below the clay to clayey silt in Boreholes P1-2 and P1-9. The surface of the deposit was encountered at Elevation 224.2 m and 223.3 m with thicknesses of 1.2 m and 4.4 m in Boreholes P1-2 and P1-9, respectively.

SPT 'N'-values measured within the silt range between 10 blows and 20 blows per 0.3 m of penetration, indicating a compact relative density.

A grain size distribution for one sample of the silt deposit is shown on Figure B5, in Appendix B.

Atterberg limits testing carried out on one sample of the silt classified the deposit as non-plastic.

The natural water content measured on one sample of the silt is about 24 per cent.

4.2.7 Sand to Sandy Silt (Lower)

A deposit of grey sand to silty sand, some clay, trace to some gravel was encountered below the silt in Boreholes P1-2 and P1-9, and below the clay to clayey silt in Boreholes P1-4 and P1-11. The surface of the



deposit was encountered between Elevation 229.9 m and 223.0 m and the deposit was not penetrated after exploring the deposit between 1.1 m and 7.2 m.

SPT 'N'-values measured within the sand to sandy silt range between 0 blows (i.e., weight of hammer) and 21 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

A grain size distribution for six samples of the sand to sandy silt deposit is shown on Figure B6, in Appendix B.

Atterberg limits testing carried out on one sample of the sandy silt in Borehole P1-4 yielded a liquid limit of about 19 per cent, a plastic limit of about 13 per cent and a plasticity index of about 6 per cent. The results of the Atterberg limits testing are shown on the plasticity chart on Figure B7 in Appendix B and indicate that the deposit is classified as a silt of slight plasticity. Atterberg limits testing carried out on a sample of the sandy silt in Borehole P1-2 determined the sample to be non-plastic.

The natural water content measured on samples of the sand to sandy silt are between about 14 per cent and 22 per cent.

4.2.8 Refusal

Refusal to further DCPT penetration was encountered in Borehole P1-9 at a depth of 23.5 m below ground surface, corresponding to Elevation 211.7 m.

4.2.9 Groundwater Conditions

The water levels measured in the surface fill upon the completion of drilling were at depths of 1.7 m to 2.5 m, between Elevation 234.1 m to 232.3 m. Water levels measured below the fill within the clay to clayey silt, sand and sandy silt at depths of 5.3 m to 11.1 m (Elevation 229.8 m to Elevation 222.5 m) were not considered to be stabilized. Groundwater and creek water levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The drilling program was supervised by Mr. Shane Albert. This report was prepared by Mr. Matthew Thibeault, EIT, and was reviewed by Mr. Andre Bom, P.Eng. A quality control review of the report was provided by Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project.



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PART B

FOUNDATION DESIGN REPORT

HIGHWAY 11 – PROPOSED WESTBOUND PASSING LANE

TOWNSHIP OF DEVITT, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5166-12-00



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides design recommendations on the foundation aspects for the proposed Highway 11 westbound passing lane extension. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigations at the site.

The interpretation and recommendations presented are intended only to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the embankment widening at this site. As such, where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

Golder was retained by MMM to provide recommendations on foundation aspects for the detail design of the new westbound passing lane along the north side of the existing Highway 11 alignment in Devitt Township, Ontario. The foundation investigation was completed for approximately 550 m of the proposed 2.6 km long passing lane, between STA 21+150 to STA 21+700. The foundation investigation was carried out after the pavement investigation was completed, which encountered up to about 5.4 m of fill/organic material underlain by soft cohesive soil. The existing Highway 11 embankment in the investigated area is up to about 2.0 m in height.

This report presents the results of embankment stability and settlement analyses and provides recommendations on embankment geometry, embankment fill materials and implementation of mitigation alternatives that may be required as a means to reduce settlement and to improve stability. The report also addresses potential construction concerns and geotechnical problems associated with embankment construction, sub excavation of soft/organic materials and placement of new fill materials.

The subsoils encountered in the various areas investigated are composed of deposits of organic and/or fill material, underlain by soft to stiff cohesive deposits (clay, silty clay and/or clayey silt) and underlain by very loose to compact cohesionless soils (silt, sand), where encountered.

6.2 Embankment Stability and Settlement

The new westbound passing lane will result in a widening to the north of the existing embankment by about 4 m. Based on the profiles provided by MMM, the existing embankment grade will be maintained and a grade raise of up to about 2.0 m will be required beyond the toe of the existing embankment to accommodate the passing lane between about STA 21+150 and STA 21+200. From about STA 21+200 to STA 21+700, the existing grade on the north side of the embankment will generally remain the same due to the presence of the former highway platform; however, infilling of the existing ditches and regrading of the former roadway (i.e., cut) to accommodate new ditching at the toe of the new passing lane will be required.

Sections 6.2.2 and 6.2.3 of this report present the results of stability and settlement analysis, respectively, for the widened embankment. Due to the presence of the fill and/or organic material, up to 5.3 m thick at the foundation investigation boreholes, sub-excavation of the existing fill and organic material beyond the toe of the existing



embankment and below the proposed embankment will be required prior to passing lane construction, as discussed further in Section 6.3. For design purposes, the groundwater level is based on the observed conditions within the surface fills during drilling.

Stability and settlement analysis were carried out for the critical section of the proposed embankment widening at STA 21+175. The critical section corresponds to the greatest new embankment height and/or the maximum thickness of soft, compressible cohesive soils. East of STA 21+200, embankment stability and settlement are not required due to the relatively minor grade changes with respect to the original highway platform.

6.2.1 Embankment Fill Types

Different embankment fill alternatives (i.e., rock fill and granular fill) provide relative advantages and disadvantages in terms of availability, weight (i.e., driving force and applied load to the founding stratum), construction cost and time, ease of construction and post-construction performance.

In order to be consistent with the existing embankment fill, as found in Boreholes P1-10 and P1-11, and due to the relatively low embankment height of 2 m, granular fill is recommended for construction of the passing lane instead of rock fill. In this regard, the stability and settlement analyses discussed below have been carried out on the basis that the embankment widening will be constructed of granular fill.

The main advantage of using granular fill for embankment construction is the ease of construction and negligible post-construction settlement within the embankment fill itself. However, this option will require a larger volume of fill relative to rock fill and wider right-of-way because the side slopes of granular fill embankments (2H:1V) are flatter than those of rock fill (1.25H:1V). For this project, acceptable granular fill is considered to be well-graded, locally available and/or imported sand and gravel material.

The magnitude of settlement of granular fill placed for the widened embankment will be nominal (up to 25 mm) and will occur during construction provided:

- all the organic material is sub-excavated;
- the granular material is end dumped below the groundwater level as the excavation of the existing fill and organic material advances; and
- the granular material is properly placed and compacted above the groundwater level.

6.2.2 Stability

6.2.2.1 Methodology

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



design requirements and the field data available and is based on deep-seated, global failure surfaces that would affect the operation of the roadway.

6.2.2.2 Parameter Selection

The simplified stratigraphy together with the associated strength and unit weight employed for the existing fills and the different native soil types for the critical sections in each lane extension are summarized below.

New granular fill modelled in the analysis is assumed to have a unit weight of 21 kN/m^3 and an effective friction angle of 35° . Backfill placed at the toe of a new embankment side slope where the fill and organic soil was sub-excavated is assumed to have a unit weight of 15 kN/m^3 , an effective friction angle of 27° and a cohesion of 1 kPa .

For the native granular soils, effective stress parameters were employed in the analyses assuming drained conditions. The effective stress parameters (effective friction angle and effective cohesion) for the granular (and peat) soils were estimated from empirical correlations using the results of in situ SPT, in conjunction with engineering judgement based on experience in similar soil conditions.

For cohesive deposits, total stress parameters were employed in the analysis assuming undrained conditions. The total stress parameters (i.e., average mobilized undrained shear strength – s_u) for the cohesive soils were developed based on the results of in situ field vane shear tests, inferred from the laboratory consolidation tests results, and estimated from correlations with the SPT results and other laboratory test data (natural water content). From the consolidation tests, the following correlation proposed by Mesri (1975) was employed to estimate the undrained shear strength:

$$s_u = 0.22 \sigma_p'$$

where:

s_u	=	average mobilized undrained shear strength (kPa)
σ_p'	=	preconsolidation pressure (kPa)

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

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

where:

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

The profile of the undrained shear strength versus elevation, together with the selected design line in the vicinity of the critical section, i.e., between STA 21+150 and STA 21+200, is presented on Figure 1.

The simplified stratigraphy together with the associated strengths and unit weight values assigned to the different native soil types at the critical section are summarized below.



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Critical Section, Borehole Numbers	Soil Type ¹	Unit Weight (kN/m ³)	Undrained Shear Strength (kPa)	Angle of Internal Friction (°)
STA 21+175, Borehole P1-2 and P1-10	Existing Granular Fill (Within Existing Embankment)	20	-	30
	Existing Granular Fill (Beyond New Toe)	19	-	28
	Peat/Organic Silt Clay (Beyond New Toe)	12	1	27
	Clay to Clayey Silt	17	10 to 20, (increasing linearly with depth)	-
	Silt	18	-	28
	Sand to Sandy Silt (Lower)	19	-	29

6.2.2.3 Results of Analysis

The stability analysis carried out for the 2.0 m grade raise associated with the 4 m embankment widening at STA 21+175 indicates that after completion of construction, including removal and replacement of the fill and organic material, the embankment will have a Factor of Safety (FoS) greater than 1.3 for a deep-seated, global failure surface that would impact the operation of the highway, as shown on Figure 2. Therefore, stability mitigation is not required for the embankment along the proposed extents of the passing lane.

6.2.3 Settlement

The following sections outline the methods used to conduct the settlement analyses and the results of the analyses.

6.2.3.1 Methodology

To estimate the magnitude of the expected settlements, analyses were carried out along the alignment using hand calculations. The rate of settlement/consolidation of the cohesive foundation soils was assessed using Terzaghi's one-dimensional consolidation theory.

The sources of settlement at this site are:

- primary time-dependent consolidation of the cohesive deposits;
- secondary time-dependent (creep) consolidation of the cohesive deposits (long-term);
- immediate settlement of the native granular soils; and
- self-weight compression of the embankment fill materials (where applicable).



The thickness of the compressible foundation soils and the height of the embankment vary along the proposed passing lane and as such the settlements along the length of a given area section will similarly vary. Given that the analysis was carried out in the critical section, the settlements estimated will represent the maximum value along the proposed passing lane.

6.2.3.2 Settlement Performance Requirements

The settlement performance criterion for design of embankments crossing over swamps is in accordance with Section 1.3 of MTO's Guideline, Embankment Settlement Criteria for Design, dated March 2010. In general, for widening of an existing embankment where the embankment is not approaching a structural element, the embankment design criteria for post-construction settlement is as follows:

- Total settlements and differential settlement rates are to be less than 75 mm and 100:1, respectively, over a 20-year period following completion of construction for a non-freeway.

6.2.3.3 Parameter Selection

For the native granular soils, effective stress parameters were employed in the analyses assuming drained conditions. The effective stress parameters (effective friction angle and effective cohesion) for the granular soils were estimated from empirical correlations using the results of in situ SPT and/or DCPTs (Kulhawy and Mayne, 1990), in conjunction with engineering judgment based on experience in similar soil conditions.

The consolidation settlement of the cohesive deposits was assessed using the results of the laboratory index tests and in situ field vane tests in the boreholes and nearby consolidation testing in the area of the proposed passing lane to estimate the stress history and deformation parameters for the cohesive deposits along the passing lane. Estimates of deformation parameters (i.e., compression and recompression indices) were obtained using empirical correlations proposed in literature by Terzaghi and Peck (1967), which was found to be the most consistent with the results of laboratory consolidation test for the clayey soil along the alignment of the proposed passing lane.

The following correlation relating in situ undrained shear strength to preconsolidation stress proposed by Mesri (1975) was employed:

$$\sigma'_p = \frac{S_{u(mob)}}{0.22}$$

where:

$$S_{u(mob)} = \mu S_{u(FV)}$$

$$\sigma'_p = \text{preconsolidation stress (kPa)}$$

$$S_{u(mob)} = \text{average mobilized undrained shear strength (kPa)}$$

$$S_{u(FV)} = \text{undrained shear strength from field vane test (kPa)}$$

$$\mu = \text{Bjerrum's (1973) correction factor based on Plasticity Index}$$

The coefficient of consolidation, c_v (cm²/s), required in the settlement time-rate analysis was estimated from the consolidation test and the U.S. Navy (1986) correlation with liquid limits assuming normally-consolidated soils.



FOUNDATION REPORT - HIGHWAY 11 PROPOSED WESTBOUND PASSING LANE, GWP 5166-12-00

In addition to primary consolidation within cohesive deposits, secondary compression will also occur. Secondary compression is referred to as creep settlement and occurs over a long period of time, after full dissipation of excess pore pressure under a constant stress. The following relationship has been employed for estimating the magnitude of creep settlement over the life of the embankment following the completion of primary settlement at each location.

$$S_c = HC_{\alpha\epsilon} \log\left(\frac{t}{t_{EoP}}\right)$$

where:

- S_c = secondary consolidation (creep) settlement (mm)
- $C_{\alpha\epsilon}$ = modified secondary compression index as estimated from laboratory consolidation tests and/or from the empirical correlation by Mesri (1973)
- H = initial thickness of normally consolidated portion of compressible clay deposit (mm)
- t = post-construction period of interest (20 years)
- t_{EoP} = time to reach end of primary consolidation (years)

The values of modified secondary compression index ($C_{\alpha\epsilon}$) estimated from the empirical correlation were compared with the values of $C_{\alpha\epsilon}$ calculated from the results of the laboratory consolidation tests.

The profile of the pertinent engineering parameters of the cohesive deposit versus elevation, together with the selected design line in the vicinity of the critical section, i.e., between STA 21+150 and STA 21+200, is presented on Figure 1.

The simplified stratigraphy together with the associated strength and unit weight values assigned to the different native soil types at the critical section are presented below.

Critical Section, Borehole Number	Stratigraphic Unit	Approximate Thickness (m)	Unit Weight (kN/m ³)	Estimated Deformation Properties
STA 21+175, Borehole P1-2	Existing Fill*	3.0	19	-
	Peat/ Organic Silty Clay*	1.6	12	-
	Clay to Clayey Silt	5.9	17	See Figure 1
	Silt	1.2	18	E' = 10 MPa
	Sand to Sandy Silt	> 7.2	19	E' = 10 MPa

Note: * The existing fill and organic soils are to be removed prior to embankment construction.

6.2.3.4 Results of Analysis

As granular fill is the preferred material placed for the widened embankment, assuming the fill is placed as discussed in Section 6.2.1 and 6.3, up to 25 mm of settlement is expected to occur within the fill during and following of embankment construction.



It is estimated that the settlement of the foundation soils within the vicinity of the critical section will be up to about 190 mm of primary consolidation of the cohesive deposit. Based the laboratory consolidation testing and NAVFAC correlation with Liquid Limit in conjunction with engineering judgment based on our experience with similar cohesive soils in Northern Ontario, assuming a coefficient of consolidation (c_v) of $2 \times 10^{-3} \text{ cm}^2/\text{s}$ and assuming two-way drainage for the cohesive deposit, it is estimated that about 90 per cent of the primary consolidation of the cohesive deposit will occur within about 1.2 years after completion of embankment construction to its final grade.

The magnitude of total secondary (creep) settlement for the cohesive deposit is estimated to be about 20 mm per log-cycle of time for this area corresponding to about 25 mm over a 20-year period following the completion of a one (1) year preload period discussed below.

Based on the above settlement estimates and the settlement criteria discussed in Section 6.2.3.2, we recommend that the widened embankment be preloaded for a period of one (1) year to reduce the post-construction settlement to within MTO's criteria.

6.3 Subgrade Preparation and Embankment Construction

The following sections discuss general aspects of subgrade preparation and embankment widening for the proposed passing lane including: removal of the existing fill and organic material, groundwater control, backfilling and embankment fill placement and platform widening.

6.3.1 Removal of Existing Fill and Organics

Based on the subsurface information from the boreholes advanced during the foundation investigation, the thickness of the fill and organic material within the footprint of the lane extension is up to 5.3 m. After clearing and grubbing of the lane extension areas and prior to the placement of any fill for the new construction, the fill and organic material within the lane footprint should be stripped from the plan limits of the proposed works. The existing fill and organic materials should be sub-excavated and backfilled simultaneously in accordance with OPSS 209 (Embankments Over Swamps and Compressible Soils), in staged excavation in strips of limited width to maintain stability and to protect the existing roadway during sub-excavation and replacement operations. As the proposed passing lane will be constructed immediately adjacent to the existing roadway embankment, the excavation should be carried out as per OPSD 203.030 (Embankments Over Swamp). The sub-excavation and backfilling operations should be incorporated into a Non-Standard Special Provision (NSSP) in the Contract (an example is included in Appendix C). Given that granular fill material was placed below grade for the existing embankment, sloughing of the existing granular fill into the excavation should be expected leading to the steepening of the existing embankment side slopes. If this occurs, consideration will have to be given to removing existing fill from the existing embankment side slopes to minimize sloughing.

All excavations must be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. In addition, provisions for traffic control measures should be included in the Contract to maintain the safe operation of Highway 11 and any associated side roads during excavation operations.



6.3.2 Groundwater and Surface Water Control

Excavation within the plan limits of the proposed works will be required to remove organic and/or soft deposits prior to embankment fill placement, which will extend below the water table. Groundwater flow into the excavations will occur due to the relatively permeable subsoils and high groundwater levels observed at all of the lane extensions crossing low-lying areas. Dewatering is not required for the excavation and backfilling below water, as per OPSS 209. Surface water should be directed away from the excavations at all times.

6.3.3 Backfilling and Embankment Fill Placement

As the backfilling following sub-excavation will be below the water table, we recommend that granular fill such as OPSS PROV. 1010 (Aggregates) Granular 'B' Type II be placed at the site. Granular fill placed below the water table should be end dumped as the excavation advances.

Above the water table, the new fill should be keyed into the existing embankment side slopes per the requirements of OPSD 208.010 (Benching of Earth Slopes). Granular fill should be placed and compacted in accordance with OPSS 501 (Compacting), recognizing that the material will be placed to form a wedge-shaped embankment profile and it will be difficult to compact the material along the outer portion of the slope. Granular material should be compacted to at least 95 per cent of its Standard Proctor Maximum Dry Density. Side slopes for granular fill embankments should be no steeper than 2H:1V.

6.3.4 Platform Widening

In accordance with the requirements of MTO Northern Region Engineering Directive NRE 98-200 policy on the widening of embankment platforms, the construction of the embankments should include an allowance for platform widening (in 500 mm increments) to accommodate post-construction settlements so that the minimum standard shoulder widths are maintained if future grade raises on the embankments are required. According to NRE 98-200, the need for future raises in road grade could occur due to settlement of the embankment fill, settlement of the foundation soils and to accommodate future pavement overlays up to 200 mm thick. It is understood that this policy applies to all granular fill embankments where widening restrictions are present (i.e., due to space/property issues, presence of a sensitive body of water and so on). It is further understood that the minimum platform widening on major highways (i.e., including Highway 11) is 2 m, unless the preferred mitigation option eliminates uncertainty regarding embankment settlement/ performance (i.e., full sub-excavation to bedrock and backfill with granular material). At this site, platform widening of 2 m is considered appropriate.

7.0 CLOSURE

This report was prepared by Mr. Matthew Thibeault and Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.



Report Signature Page

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Fintan J. Heffernan, P.Eng.
Designated MTO Contact

MT/AB/FJH/kp

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- | | |
|------------|---|
| ASTM D1586 | Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils |
| ASTM D1587 | Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes |
| ASTM D2573 | Standard Test Method for Field Vane Shear Test in Cohesive Soil |
- Commercial Software
- GeoStudio (Version 7.23) by Geo-Slope International Ltd.
- Ministry of Transportation Ontario, Embankment Settlement Criteria for Design, Final Draft, March 2010.
- Northern Region Engineering Directive: Embankment Design Guidelines NRE 98-200, October 1998.
- Ontario Occupational Health and Safety Act:
- Ontario Regulation 213/91 Construction Projects as amended by O. Reg. 443/09
- Ontario Provincial Standard Drawings:
- | | |
|--------------|--|
| OPSD 203.030 | Embankments Over Swamp, Existing Slopes Maintained |
| OPSD 208.010 | Benching of Earth Slopes |
- Ontario Provincial Standard Specification:
- | | |
|----------|---|
| OPSS 209 | Construction Specification for Embankments Over Swamps and Compressible Soils |
| OPSS 501 | Construction Specification for Compacting |
- Ontario Water Resources Act:
- Ontario Regulation 903, Wells (as amended)

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

CONT No.
GWP No. 5166-12-00

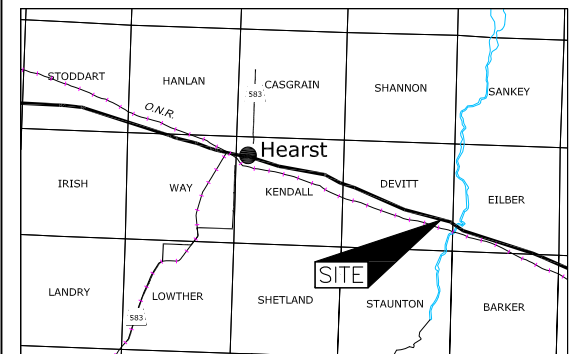


HIGHWAY 11
STA 21+150 to 21+700 WESTBOUND PASSING LANE
BOREHOLE LOCATIONS AND
SOIL STRATA

SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



KEY PLAN
SCALE
10 0 10 km

LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
P1-1	234.5	5499099.1	353001.3
P1-2	234.7	5499095.1	353026.0
P1-2A	234.7	5499095.6	353024.1
P1-3	234.8	5499089.2	353050.3
P1-4	235.5	5499065.0	353147.4
P1-5	235.5	5499033.7	353268.4
P1-10	235.8	5499079.5	353048.0

NOTES

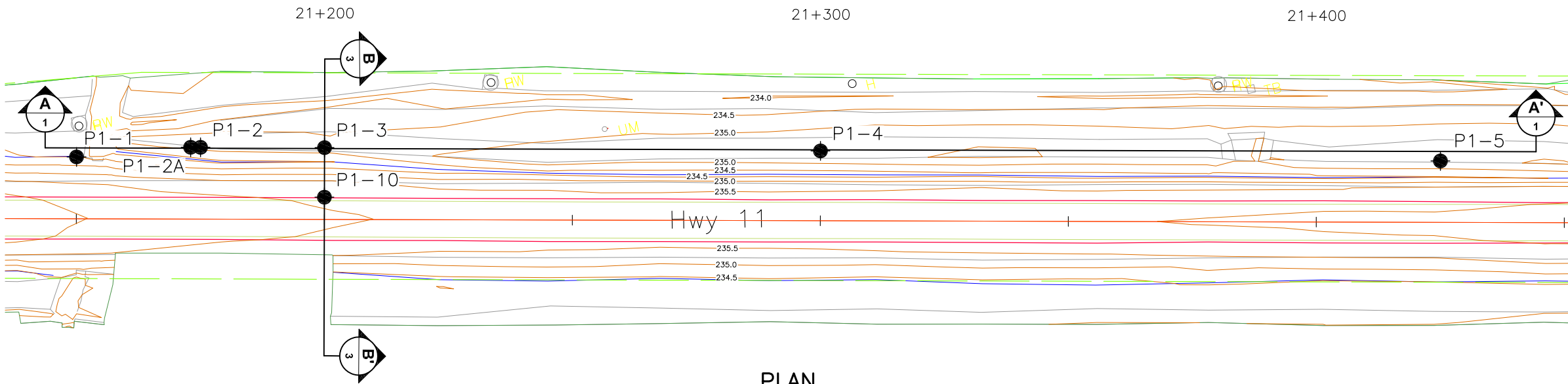
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

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

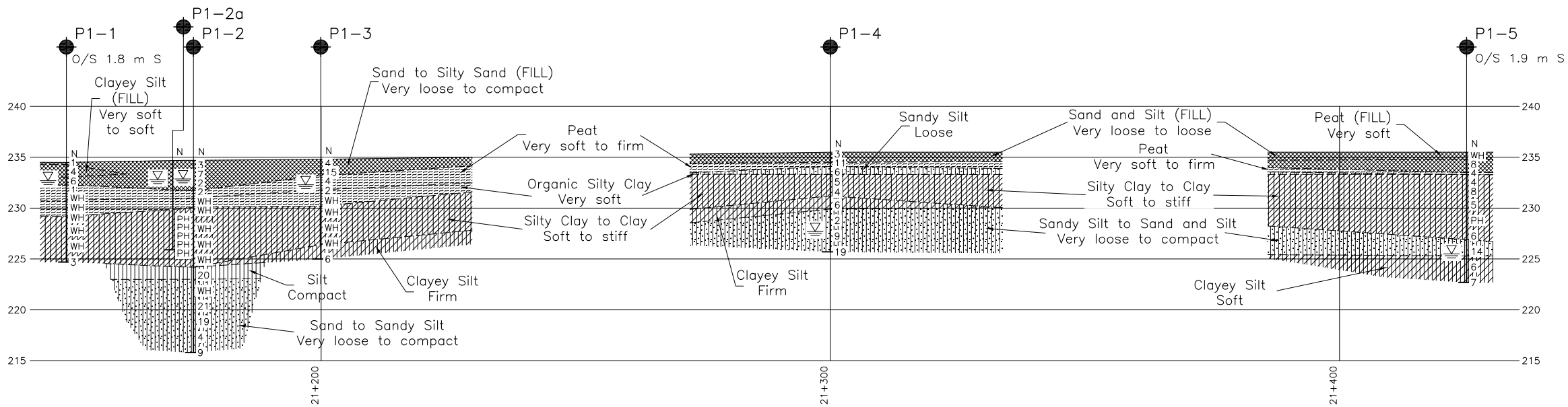
REFERENCE

Base plans provided in digital format by MMM, drawing file no. prelim-DEVITT.dwg, received MAR 14, 2012.



PLAN

SCALE
10 0 10 20 m



A-A'
1

PROFILE
HIGHWAY 11

HORIZONTAL SCALE
10 0 10 20 m
5 0 5 10 m



NO.	DATE	BY	REVISION
Geocres No. 42G-52			
HWY. 11	PROJECT NO. 10-1191-0038		DIST.
SUBM'D. MT	CHKD.	DATE: FEB 2014	SITE:
DRAWN: TB	CHKD. AB	APPD. FJH	DWG. 1

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

CONT No.
GWP No. 5166-12-00

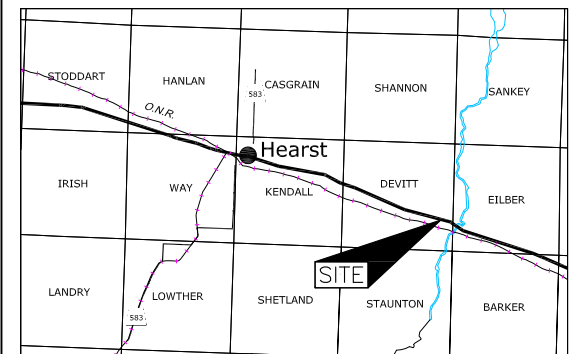


HIGHWAY 11
STA 21+150 to 21+700 WESTBOUND PASSING LANE
BOREHOLE LOCATIONS AND
SOIL STRATA

SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



KEY PLAN
SCALE
10 0 10 km

LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
P1-6	235.4	5499005.5	353390.2
P1-7	235.4	5498990.2	353437.9
P1-8	235.3	5498982.7	353487.6
P1-9	235.2	5498966.0	353534.9
P1-11	235.7	5498972.5	353485.1

NOTES

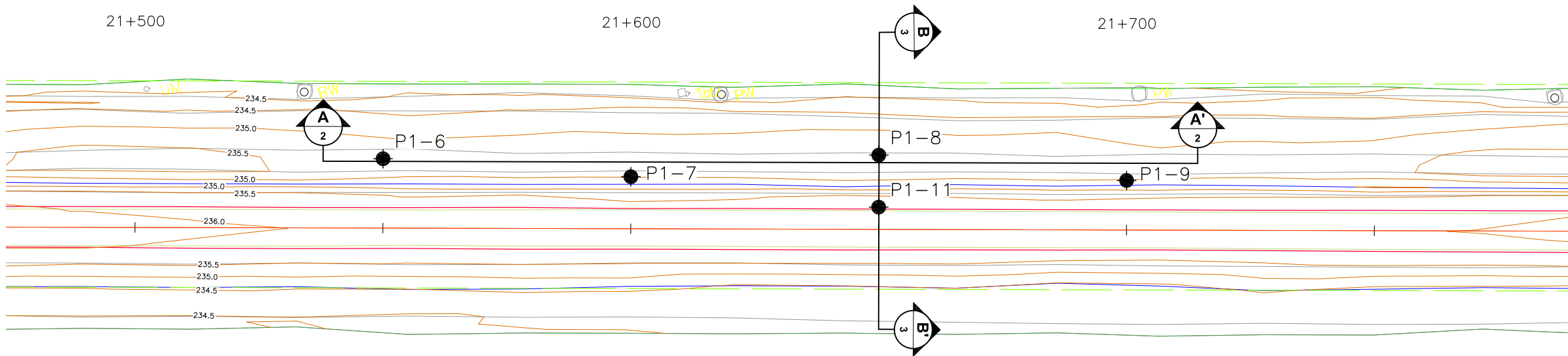
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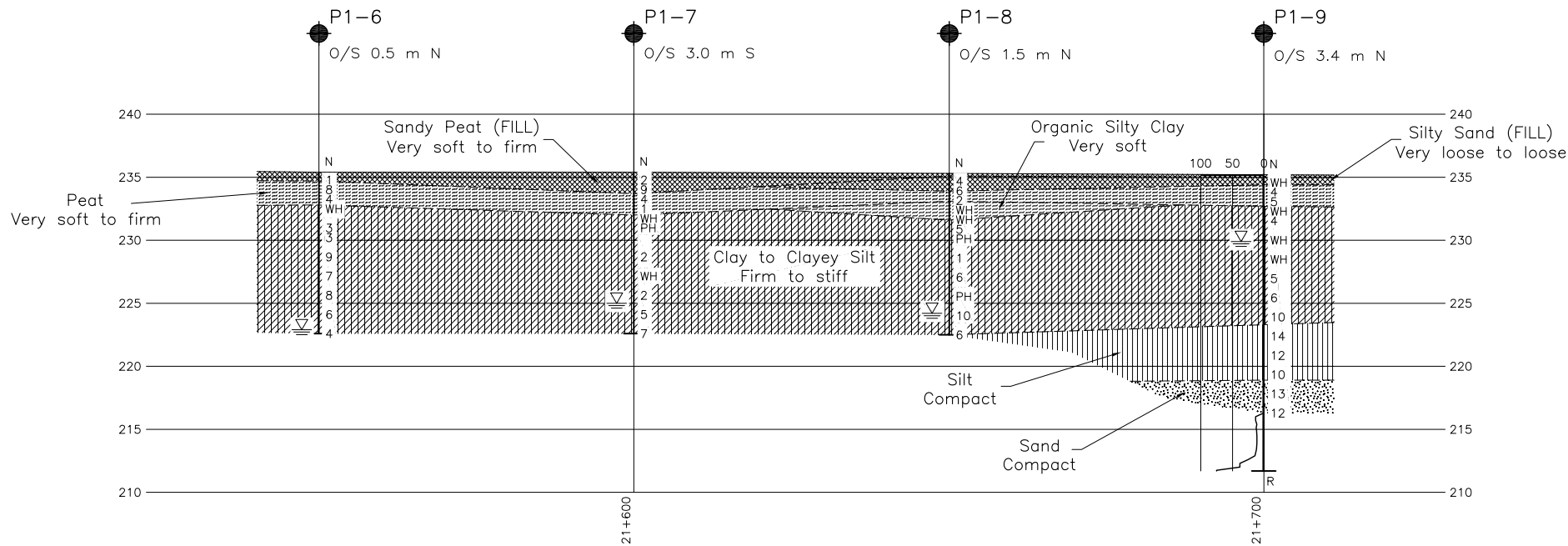
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Base plans provided in digital format by MMM, drawing file no. prelim-DEVITT.dwg, received MAR 14, 2012.



PLAN

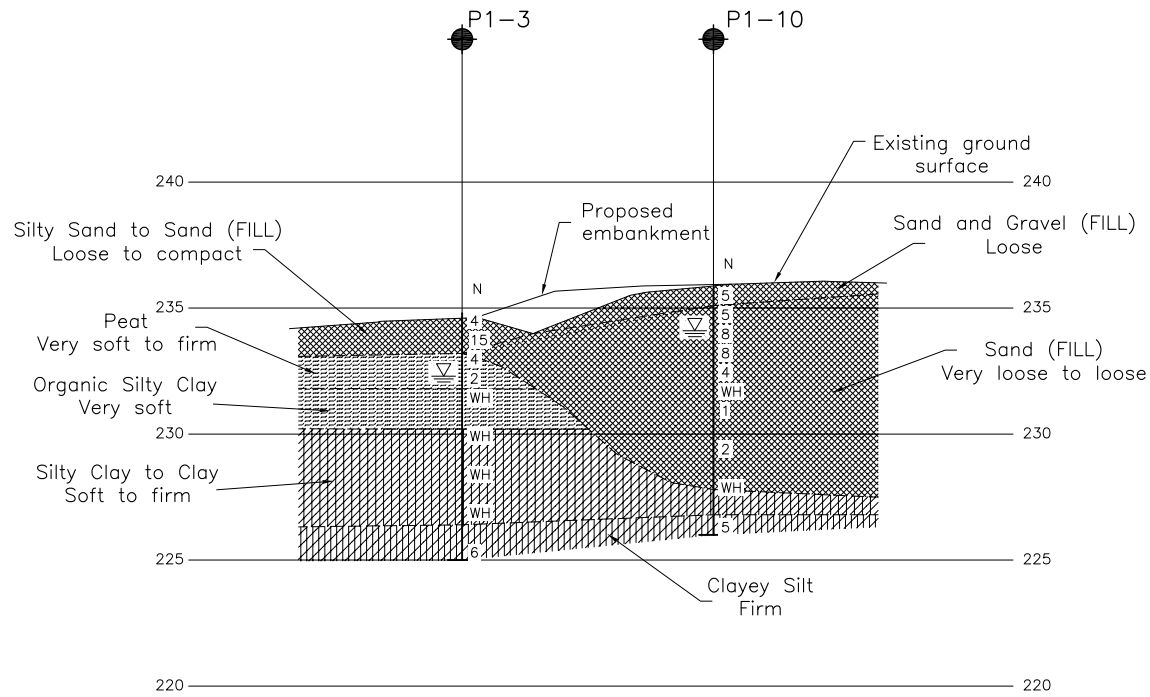
SCALE
10 0 10 20 m



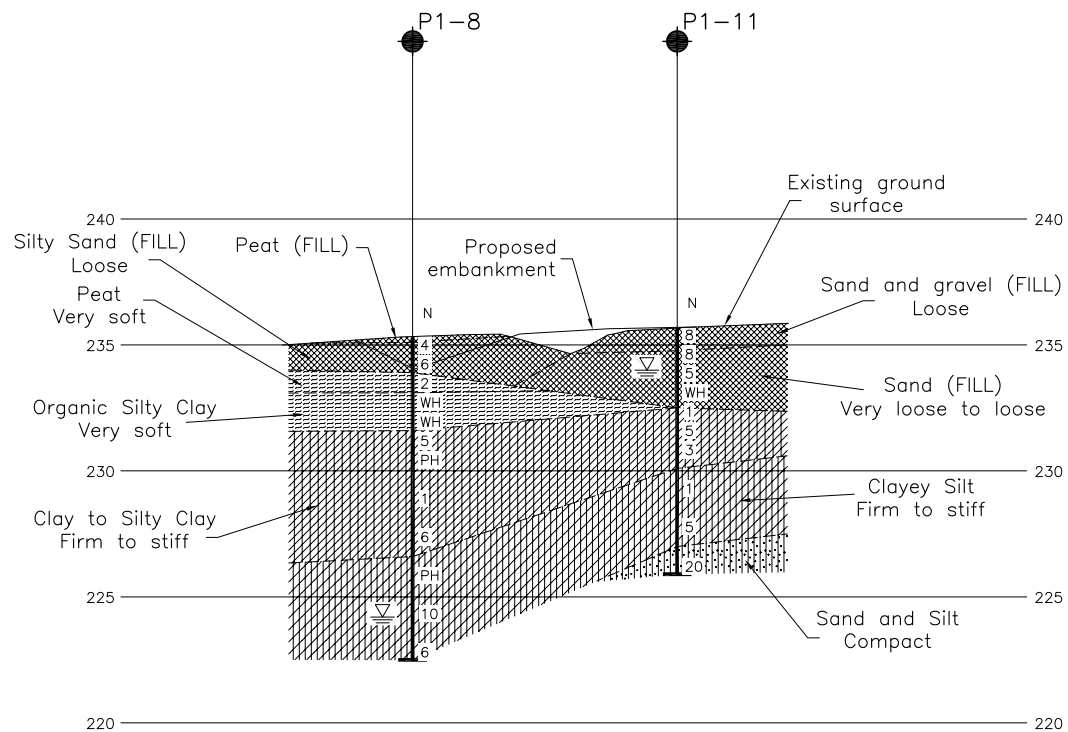
A-A'
2
PROFILE
HIGHWAY 11
HORIZONTAL SCALE
10 0 10 20 m
5 0 5 10 m



NO.	DATE	BY	REVISION
Geocres No.			
HWY. 11		PROJECT NO. 10-1191-0038	DIST.
SUBM'D. MT	CHKD.	DATE: FEB 2014	SITE:
DRAWN: TB	CHKD. AB	APPD. FJH	DWG. 2



B-B' SECTION AT STA 21+200
1
HIGHWAY 11
HORIZONTAL SCALE
3 0 3 6 m
3 0 3 6 m



B-B' SECTION AT STA 21+650
2
HIGHWAY 11
HORIZONTAL SCALE
3 0 3 6 m
3 0 3 6 m

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CONT No.
GWP No. 5166-12-00

HIGHWAY 11
STA 21+150 to 21+700 WESTBOUND PASSING LANE
SOIL STRATA

SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA

LEGEND

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

NOTES

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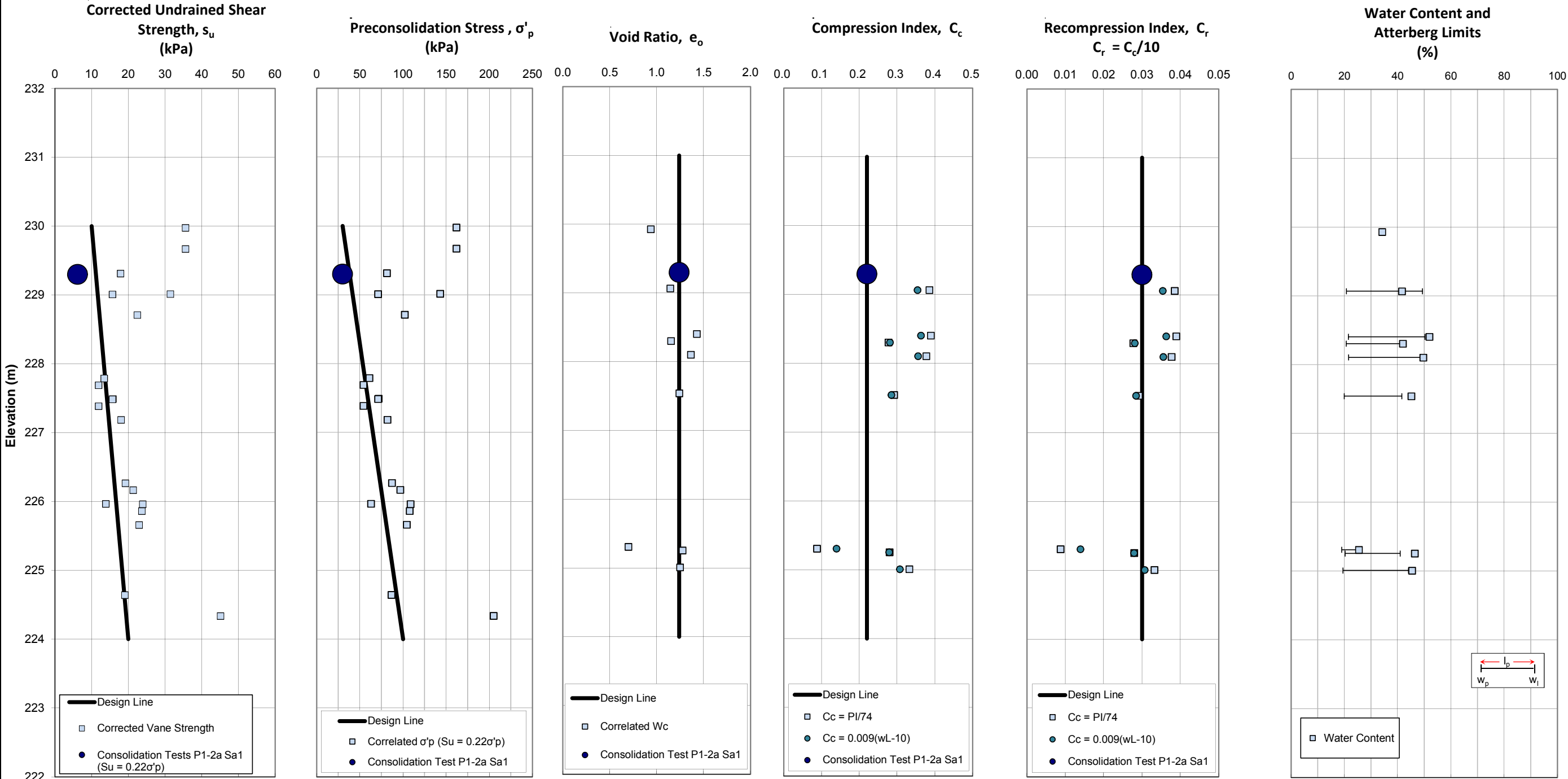


NO.	DATE	BY	REVISION
Geocres No.			
HWY. 11	PROJECT NO. 10-1191-0038		DIST.
SUBM'D. MT	CHKD.	DATE: FEB 2014	SITE:
DRAWN: TB	CHKD. AB	APPD. FJH	DWG. 3

N:\Active\2010\1190 Sudbury\1191\10-1191-0038 MMM Hwy 11 Mattawishkvia River\Analyses\WBPL\10-1191-0038 -Param Sum - WBPL Hearst.xlsm\Figure 1

SUMMARY OF ENGINEERING PARAMETERS
FOR COHESIVE DEPOSITS
Highway 11 WESTBOUND PASSING LANE
STA 21+150 to 21+200 (Boreholes P1-1 to P1-3)

FIGURE 1



Golder Associates Ltd.

Date: November 2014
Project No: 10-1191-0038

Prepared By: TB/MT
Checked By: AB



New Granular Fill
Unit Weight: 21kN/m³
Phi: 35°

Backfill
Unit Weight: 15kN/m³
Cohesion: 1 kPa
Phi: 27°

Existing Granular Fill
Unit Weight: 20 kN/m³
Phi: 30 °

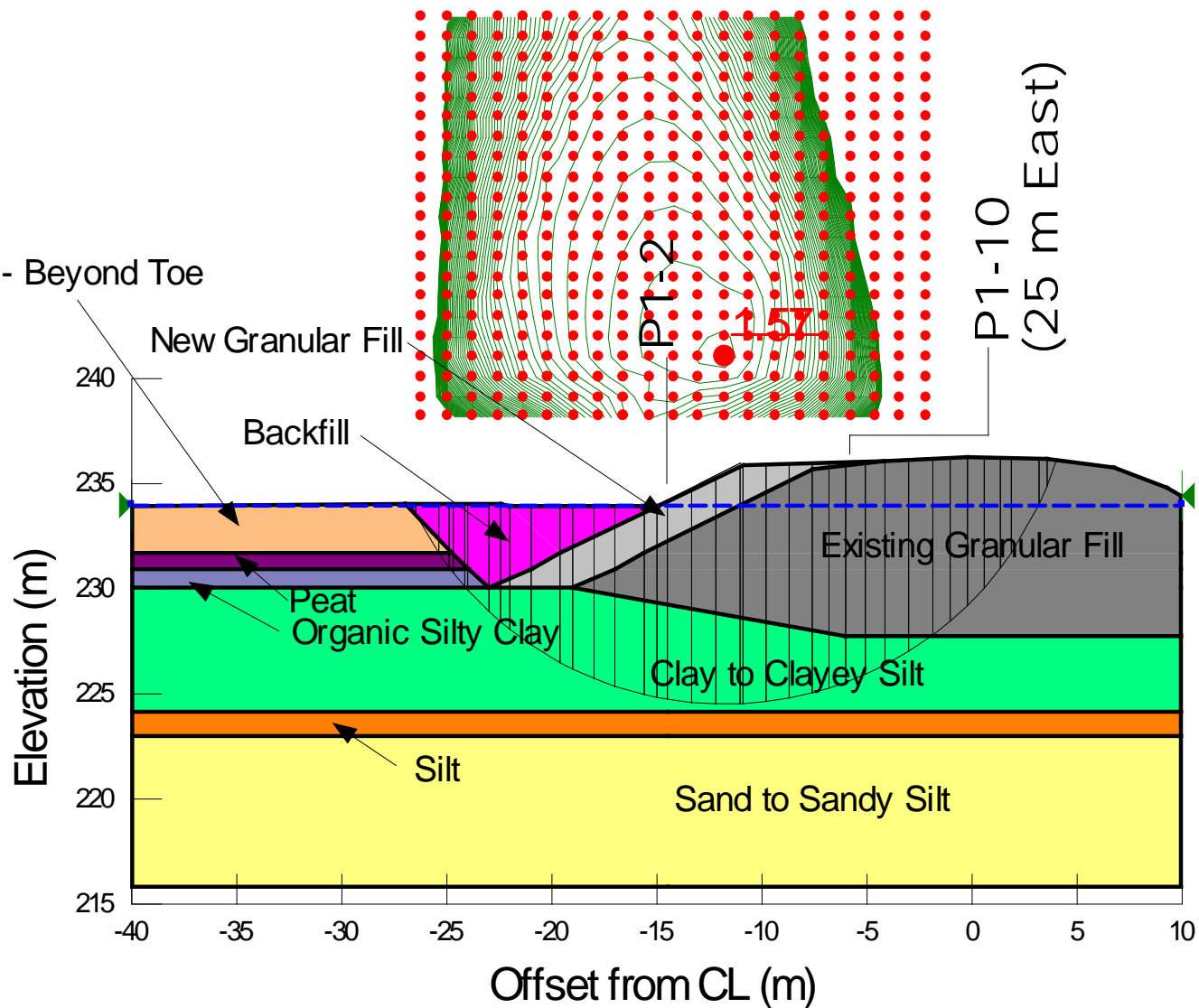
Existing Fill - Beyond Toe
Unit Weight: 19 kN/m³
Phi: 28 °


Peat / Organic Silty Clay
Unit Weight: 12kN/m³
Cohesion: 1 kPa
Phi: 27°

Clay to Clayey Silt
Unit Weight: 17 kN/m³
Upper Cohesion: 10 kPa
Rate of Change: 0.6 kPa/m

Silt
Unit Weight: 18 kN/m³
Phi: 28 °

Sand to Sandy Silt
Unit Weight: 19 kN/m³
Phi: 29 °



PROJECT		HIGHWAY 11 WESTBOUND PASSING LANE					
TITLE		STABILITY ANALYSIS NORTH SIDE SLOPE AT STA 21+175					
		PROJECT No. 10-1191-0038		FILE No. ----			
		DESIGN	MT	FEB 2014	SCALE	AS SHOWN	REV.
		CADD	--				
		CHECK	AB	FEB 2014	FIGURE 2		
		REVIEW					





APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

Notes: 1
2

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

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



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

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



IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

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

PROJECT		10-1191-0038		RECORD OF BOREHOLE No P1-1				1 OF 1 METRIC						
G.W.P.		5166-12-00		LOCATION		N 5499099.1; E 353001.3		ORIGINATED BY SA						
DIST		HWY 11		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers		COMPILED BY MT						
DATUM		Geodetic		DATE		August 23, 2013		CHECKED BY AB						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
234.5	GROUND SURFACE													
0.0	Sand, trace gravel, trace organics (FILL)		1	SS	1		234							
0.2	Brown Moist		2	SS	4		233							
233.1	Clayey silt, trace gravel, trace sand, trace organics (FILL)				232									
1.4	Very soft to soft Grey Wet	3	SS	6	231									
232.3	Sand, trace gravel, trace organics (FILL)				230									
2.2	Loose Brown Wet	4	SS	1	229									
	PEAT (Fibrous), trace sand				228									
	Very soft Black Wet	5	SS	WH	227									
230.8	ORGANIC SILTY CLAY, trace sand				226									
3.7	Very soft Black to brown Wet	6	SS	WH	225									
		7	SS	WH										
229.2	SILTY CLAY, trace sand													
5.3	Soft to firm Grey Wet													
		8	SS	WH										
		9	SS	WH										
		10	SS	3										
224.7	END OF BOREHOLE													
9.8	Note: 1. Water level at a depth of 1.8 m below ground surface (Elev. 232.7 m) upon completion of drilling.													

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 27/02/14 DATA INPUT:

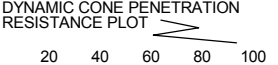
+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE



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

PROJECT <u>10-1191-0038</u>		RECORD OF BOREHOLE No P1-2a				1 OF 1 METRIC											
G.W.P. <u>5166-12-00</u>		LOCATION <u>N 5499095.6; E 353024.1</u>				ORIGINATED BY <u>SA</u>											
DIST <u> </u> HWY <u>11</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>				COMPILED BY <u>MT</u>											
DATUM <u>Geodetic</u>		DATE <u>August 24, 2013</u>				CHECKED BY <u>AB</u>											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
234.7 0.0	GROUND SURFACE																
229.4 5.3	SILTY CLAY Sample 1 to 3: Small voids (1 mm or less) noted throughout samples. Sample 3: Sand pockets noted.		1	TO	PH											17.3	
225.9 8.8	END OF BOREHOLE Note: 1. Water level at a depth of 1.9 m below ground surface (Elev. 232.8 m) upon completion of drilling. 2. Borehole P1-2a is located 2 m west of Borehole P1-2.																

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 27/02/14 DATA INPUT:

PROJECT 10-1191-0038			RECORD OF BOREHOLE No P1-3			1 OF 1 METRIC							
G.W.P. 5166-12-00			LOCATION N 5499089.2; E 353050.3			ORIGINATED BY SA							
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers			COMPILED BY MT							
DATUM Geodetic			DATE August 24, 2013			CHECKED BY AB							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT <div style="text-align: center;">  </div>	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								
234.8	GROUND SURFACE												
0.0	Silty sand to sand, trace gravel, trace organics (FILL) Loose to compact Brown Moist		1	SS	4		234						
			2	SS	15								
233.2	PEAT (Fibrous) Very soft to firm Black Moist to wet		3	SS	4		233						
1.6			4	SS	2								
231.8	ORGANIC SILTY CLAY Very soft Black Wet		5	SS	WH		232						
3.0							231						
230.2	SILTY CLAY to CLAY Soft Grey Wet		6	SS	WH		230						
4.6	Silt seams encountered from 6.1 m to 8.4 m depth.						229						
			7	SS	WH		228						
							227						
226.4	CLAYEY SILT Firm Grey Wet		8	SS	WH		226						
8.4													
225.0	END OF BOREHOLE		9	SS	6		225						
9.8	Note: 1. Water level at a depth of 2.5 m below ground surface (Elev. 232.3 m) upon completion of drilling.												

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 27/02/14 DATA INPUT:

PROJECT 10-1191-0038			RECORD OF BOREHOLE No P1-4				1 OF 1 METRIC							
G.W.P. 5166-12-00			LOCATION N 5499065.0; E 353147.4				ORIGINATED BY SA							
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY MT							
DATUM Geodetic			DATE August 25, 2013				CHECKED BY AB							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
235.5	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	Silty peat, trace to some sand (FILL) Soft Brown Moist		1	SS	3		235							
234.5			2A	SS	11									
234.1	PEAT (Fibrous) Firm Black Moist		2B				234							
1.4	Sandy SILT, trace organics Loose Brown Wet		3	SS	6									
233.3														
2.2	SILTY CLAY, trace sand, trace gravel Stiff Grey Wet		4	SS	5		233							1 3 43 53
			5	SS	4		232							
231.2														
4.3	CLAYEY SILT Firm Grey Wet		6	SS	6		231							
229.9							230							
5.6	Sandy SILT, trace to some clay, trace to some gravel Very loose to compact Grey Wet		7	SS	2		229							7 28 48 17
							228							
			8	SS	9		227							
			9	SS	19		226							2 26 62 10
225.7	END OF BOREHOLE													
9.8	Note: 1. Water level at a depth of 7.8 m below ground surface (Elev. 227.7 m) upon completion of drilling.													

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 27/02/14 DATA INPUT:

PROJECT		10-1191-0038		RECORD OF BOREHOLE No P1-5				1 OF 1 METRIC					
G.W.P.		5166-12-00		LOCATION		N 5499033.7; E 353268.4		ORIGINATED BY SA					
DIST		HWY 11		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers		COMPILED BY MT					
DATUM		Geodetic		DATE		July 28, 2013		CHECKED BY AB					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
235.5	GROUND SURFACE							20 40 60 80 100	20 40 60				
0.0	Peat (FILL) Very soft Black Moist		1	SS	WH								
234.8													
0.7	Sand and silt, trace organics (FILL) Very loose to loose Brown Moist		2	SS	8								
233.5			3	SS	4								
	PEAT (Amorphous) Black Moist												
2.2	SILTY CLAY to CLAY Firm to stiff Grey Wet		4	SS	4								
	Silt seams encountered from 4.6 m to 6.7 m depth.		5	SS	8								
			6	SS	5								
			7	TO	PH								
			8	SS	6								
226.9													
8.6	SAND and SILT, trace to some clay, trace gravel Compact Grey Wet		9	SS	14								
225.3													
10.2	CLAYEY SILT, trace sand Soft Grey Wet		10	SS	6								
			11	SS	7								
222.7													
12.8	END OF BOREHOLE												
	Note: 1. Water level at a depth of 10.0 m below ground surface (Elev. 225.5 m) upon completion of drilling.												

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 27/02/14 DATA INPUT:

PROJECT		10-1191-0038		RECORD OF BOREHOLE No P1-6		1 OF 1		METRIC							
G.W.P.		5166-12-00		LOCATION		N 5499005.5; E 353390.2		ORIGINATED BY							
DIST		HWY 11		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers		COMPILED BY							
DATUM		Geodetic		DATE		July 28, 2013		CHECKED BY							
AB															
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS		ELEVATION SCALE		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
235.4	GROUND SURFACE														
0.0	Sandy peat (FILL) Very soft Brown Moist		1	SS	1		235								
234.7	PEAT (Amorphous) Very soft to firm Brown Moist to wet		2	SS	8		234								
0.7			3	SS	4		233								
232.8	CLAYEY SILT, trace sand Firm to stiff Grey Wet		4	SS	WH		232								
2.6			5	SS	3		231								
	Silt seams encountered from 4.0 m to 9.1 m depth.		6	SS	3		230								
			7	SS	9		229								
			8	SS	7		228								
			9	SS	8		227								
			10	SS	6		226								
			11	SS	4		225								
222.6	END OF BOREHOLE						224								
12.8	Note: 1. Water level at a depth of 12.5 m below ground surface (Elev. 222.9 m) upon completion of drilling.						223								

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

PROJECT 10-1191-0038			RECORD OF BOREHOLE No P1-7			1 OF 1 METRIC								
G.W.P. 5166-12-00			LOCATION N 5498990.2; E 353437.9			ORIGINATED BY SA								
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers			COMPILED BY MT								
DATUM Geodetic			DATE July 27, 2013			CHECKED BY AB								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
235.4	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	Peat, some sand, some silt (FILL) Soft to firm Brown Moist		1	SS	2		235							
			2	SS	9		234							
233.7	PEAT (Amorphous) Very soft to soft Black Wet		3	SS	4		233							
			4	SS	1									
232.0	CLAYEY SILT Firm to stiff Grey Wet		5A	SS	WH		232							
			5B	SS	WH									
			6	TO	PH		231							
							230							
			7	SS	2		229							1 5 64 30
							228							
			8	SS	WH		227							
							226							
			9	SS	2		225							
							224							
			10	SS	5		223							3 22 52 23
			11	SS	7									
222.6	END OF BOREHOLE													
12.8	Note: 1. Water level at a depth of 10.4 m below ground surface (Elev. 225.0 m) upon completion of drilling.													

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 27/02/14 DATA INPUT:

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

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

PROJECT 10-1191-0038			RECORD OF BOREHOLE No P1-9			1 OF 2 METRIC								
G.W.P. 5166-12-00			LOCATION N 5498966.0; E 353534.9			ORIGINATED BY SA								
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers			COMPILED BY MT								
DATUM Geodetic			DATE July 25 and 26, 2013			CHECKED BY AB								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
235.2	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	Peat (FILL)		1	SS	WH		235							
0.2	Silty sand, some gravel (FILL)													
234.4	Very loose Grey to brown Moist		2	SS	4		234							
0.8	PEAT (Amorphous) Soft Black Wet		3	SS	5		233							
232.7	CLAY, trace sand Firm to stiff Grey Wet		4	SS	WH		232							
2.5			5	SS	4		231							
			6	SS	WH		230							
			7	SS	WH		229							
	Silt seams encountered from 6.1 m to 8.2 m depth.		8	SS	5		228							
228.1	CLAYEY SILT Firm to stiff Grey Wet		9	SS	6		227							
7.1			10	SS	10		226							
			11	SS	14		225							
223.3	SILT, trace to some sand, trace to some clay Compact Grey Wet		12	SS	12		224							
11.9							223							
							222							
							221							

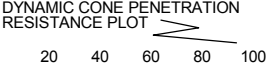


Continued Next Page

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

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 27/02/14 DATA INPUT:

PROJECT 10-1191-0038				RECORD OF BOREHOLE No P1-9				2 OF 2 METRIC									
G.W.P. 5166-12-00				LOCATION N 5498966.0; E 353534.9				ORIGINATED BY SA									
DIST _____ HWY 11				BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY MT									
DATUM Geodetic				DATE July 25 and 26, 2013				CHECKED BY AB									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
218.9	SILT, trace to some sand, trace to some clay Compact Grey Wet		13	SS	10		220										
16.3	SAND, trace to some gravel, trace silt Compact Grey Wet		14	SS	13		219										
							218										11 83 (6)
							217										
216.3			15	SS	12		216										
18.9	END OF BOREHOLE START OF DCPT						215										
							214										
							213										
211.7							212										
23.5	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)																
	Note: 1. Water level at a depth of 5.3 m below ground surface (Elev. 229.9 m) upon completion of drilling.																

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 27/02/14 DATA INPUT:

PROJECT 10-1191-0038			RECORD OF BOREHOLE No P1-10				1 OF 1 METRIC				
G.W.P. 5166-12-00			LOCATION N 5499079.5; E 353048.0				ORIGINATED BY SA				
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY MT				
DATUM Geodetic			DATE August 22, 2013				CHECKED BY AB				
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p — W — W _L WATER CONTENT (%)	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
235.8	GROUND SURFACE										
0.0	Sand and gravel, trace silt (FILL) Loose Brown Moist to wet		1	SS	5						3 92 (5)
235.1			2	SS	5						
0.7	Sand, trace gravel, trace silt (FILL) Very loose to loose Brown Moist to wet		3	SS	8						
			4	SS	8						
			5	SS	4						
			6	SS	WH						
			7	SS	1						
			8	SS	2						
227.8			9a	SS	WH						
8.0	SILTY CLAY Firm Grey Wet		9b								
226.8											
9.0	CLAYEY SILT, trace to some sand, trace gravel Firm Grey Wet		10	SS	5						5 9 64 22
226.0											
9.8	END OF BOREHOLE										
Note: 1. Water level at a depth of 1.7 m below ground surface (Elev. 234.1 m) upon completion of drilling.											

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 06/03/14 DATA INPUT:

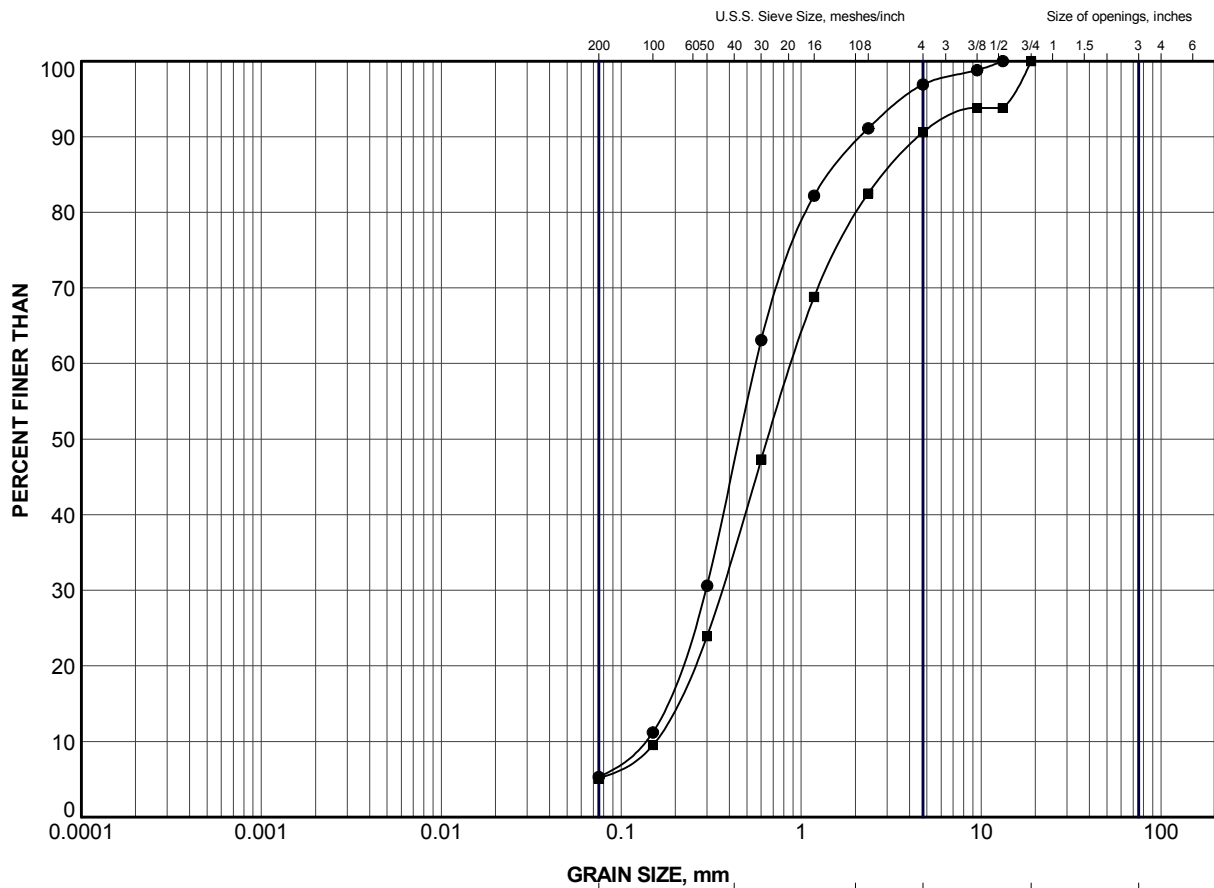
PROJECT		10-1191-0038		RECORD OF BOREHOLE No P1-11		1 OF 1 METRIC											
G.W.P.		5166-12-00		LOCATION		N 5498972.5; E 353485.1											
DIST		HWY 11		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers											
DATUM		Geodetic		DATE		August 22, 2013											
						ORIGINATED BY SA											
						COMPILED BY MT											
						CHECKED BY AB											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	W _p	W	W _L	γ	GR	SA	SI	CL	
235.7	GROUND SURFACE																
0.0	Sand and gravel (FILL) Loose Brown Moist		1	SS	8		235										
235.0																	
0.7	Sand, trace silt, trace gravel (FILL) Very loose to loose Brown to grey Wet		2	SS	8		234										
			3	SS	5												
	Peat pockets in Sample 4.		4	SS	WH		233										
232.5																	
3.2	CLAY, silt seams Firm to stiff Grey Wet		5	SS	1		232										
			6	SS	5												
			7	SS	3		231										
230.1																	
5.6	CLAYEY SILT Firm to stiff Grey Wet		8	SS	1		230										
							229										
			9	SS	5		228										
227.0																	
8.7	SAND and SILT, trace clay Compact Grey Wet		10	SS	20		227										
225.9																	
9.8	END OF BOREHOLE						226										
Note: 1. Water level at a depth of 1.7 m below ground surface (Elev. 234.0 m) upon completion of drilling.																	

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



APPENDIX B


Laboratory Test Results

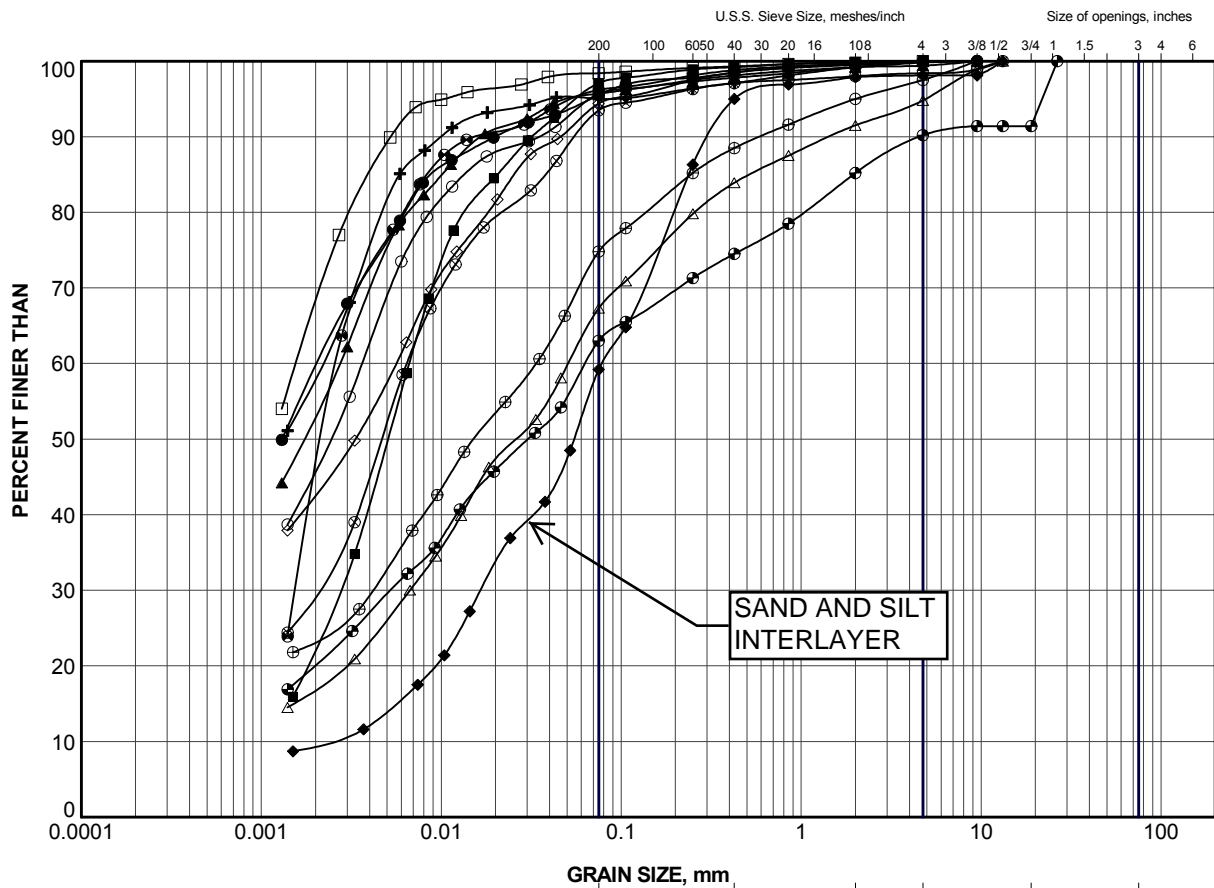


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	P1-10	6	231.7
■	P1-11	3	233.9

PROJECT					
HIGHWAY 11 WESTBOUND PASSING LANE					
TITLE					
GRAIN SIZE DISTRIBUTION SAND (FILL)					
PROJECT No.		10-1191-0038		FILE No. 1910038 BH LOGS.GPJ	
DRAWN	TB	Feb 2014	SCALE	N/A	REV.
CHECK	MT	Feb 2014			
APPR	AB	Feb 2014			
 Golder Associates SUDBURY, ONTARIO			FIGURE B1		



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	P1-1	8	228.1
■	P1-3	9	225.3
▲	P1-4	4	232.9
+	P1-5	5	232.2
◆	P1-5	9	226.1
◇	P1-5	11	223.0
○	P1-6	6	230.5
△	P1-6	9	226.0
⊗	P1-7	7	229.0
⊕	P1-7	10	224.4
□	P1-8	6	231.2
⊗	P1-8	8	228.9
⊕	P1-8	11	224.3

PROJECT

HIGHWAY 11
WESTBOUND PASSING LANE

TITLE

GRAIN SIZE DISTRIBUTION

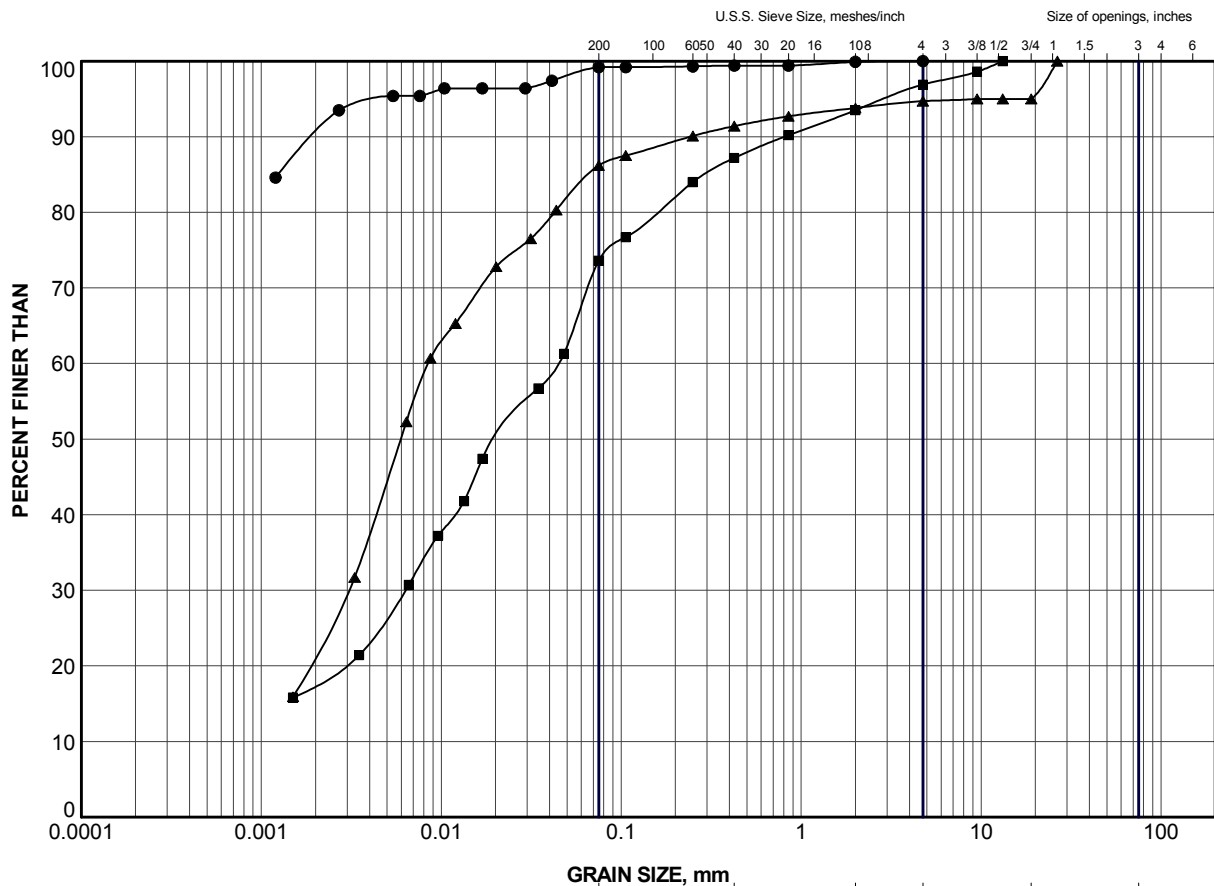
CLAY to CLAYEY SILT

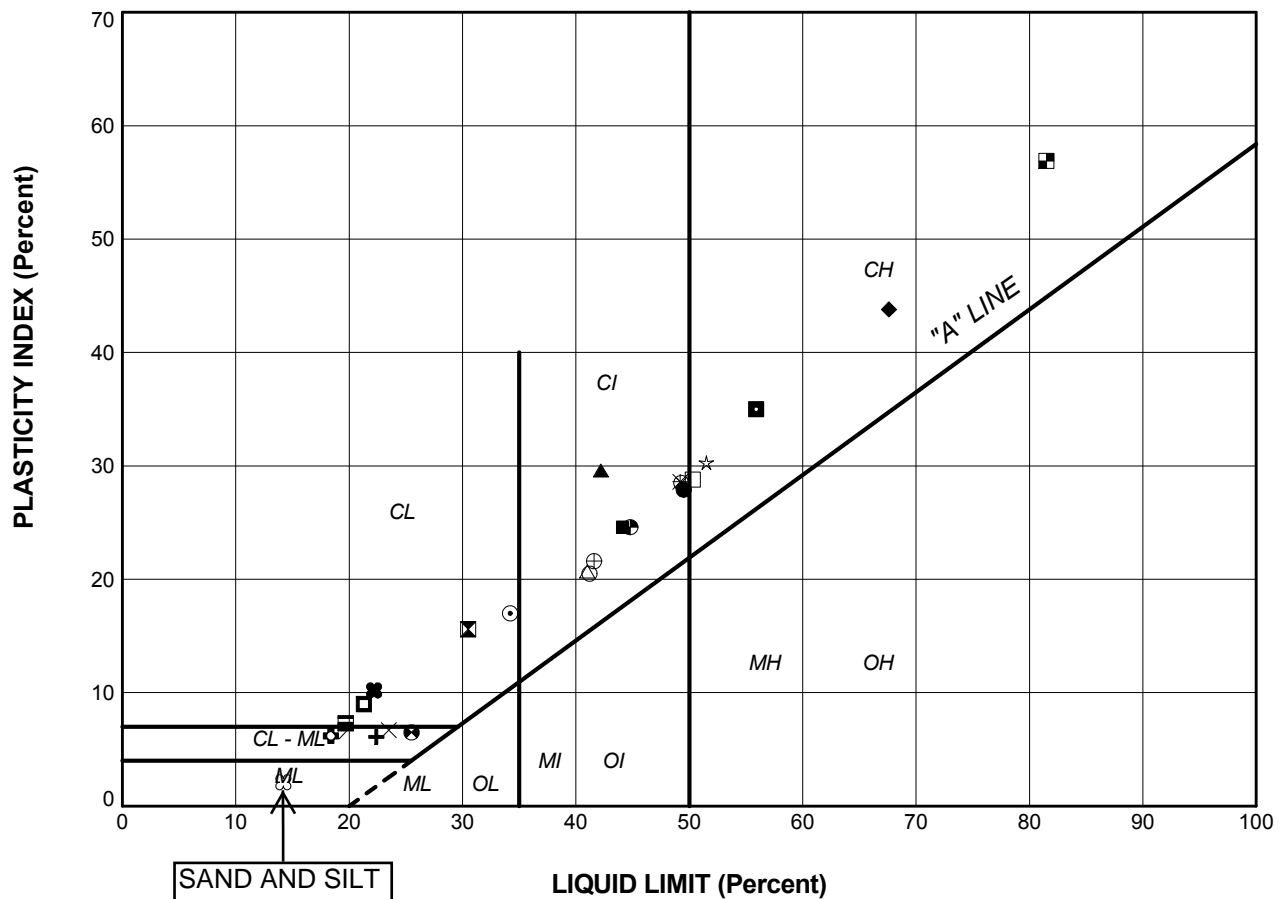


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PROJECT No. 10-1191-0038		FILE No. 1910038 BH LOGS.GPJ	
DRAWN	TB	Feb 2014	SCALE N/A
CHECK	MT	Feb 2014	REV.
APPR	AB	Feb 2014	


FIGURE B2.1





LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	P1-1	8	49.5	21.6	27.9
■	P1-1	10	44.1	19.5	24.6
▲	P1-10	9b	42.2	12.6	29.6
+	P1-10	10	22.4	16.3	6.1
◆	P1-11	6	67.6	23.8	43.8
◇	P1-11	8	19.1	12.5	6.6
○	P1-2	7	41.2	20.7	20.5
△	P1-2	9	41.0	20.3	20.7
⊗	P1-2a	1	49.3	20.8	28.5
⊕	P1-2a	3	41.6	20.0	21.6
□	P1-3	7	50.3	21.5	28.8
⊗	P1-3	9	25.5	19.0	6.5
⊕	P1-4	4	44.8	20.2	24.6
☆	P1-5	5	51.5	21.2	30.3
⊗	P1-5	9	14.2	12.1	2.1
⊕	P1-5	11	30.5	14.9	15.6
⊗	P1-6	6	34.2	17.2	17.0
⊕	P1-6	9	18.4	12.2	6.2
×	P1-7	7	23.5	16.8	6.7
⊗	P1-7	10	22.2	12.0	10.2
■	P1-8	6	55.9	20.9	35.0
*	P1-8	8	49.2	20.6	28.6
□	P1-8	11	21.3	12.3	9.0
■	P1-9	6	81.5	24.6	56.9
■	P1-9	8	19.7	12.4	7.3

PROJECT				
HIGHWAY 11 WESTBOUND PASSING LANE				
TITLE				
PLASTICITY CHART CLAY to CLAYEY SILT				
PROJECT No.		10-1191-0038		FILE No.1011910038 BH LOGS.GPJ
DRAWN	TB	Feb 2014	SCALE	N/A
CHECK	MT	Feb 2014	REV.	
APPR	AB	Feb 2014		
 Golder Associates SUDBURY, ONTARIO			FIGURE B3	

CONSOLIDATION TEST SUMMARY**FIGURE B4****Pg. 1 of 4****SAMPLE IDENTIFICATION**

Project Number: 10-1191-0038
Borehole Number: P1-2a

Sample Number: 1
Sample Depth, m: 5.4

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	2		
Date Started	3-Sep-13		
Date Completed	18-Sep-13		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.526	Unit Weight, kN/m ³	17.32
Sample Diameter, cm	6.351	Dry Unit Weight, kN/m ³	12.05
Area, cm ²	31.68	Specific Gravity, Measured	2.75
Volume, cm ³	80.02	Solids Height, cm	1.129
Water Content, %	43.76	Volume of Solids, cm ³	35.76
Wet Mass, g	141.37	Volume of Voids, cm ³	44.26
Dry Mass, g	98.34		

TEST COMPUTATIONS

Pressure kPa	Primary Consolidation	Corr. Height cm	Void Ratio	Average Height cm	t ₉₀ sec	cv. cm ² /s	mv m ² /kN	k cm/s	Total Work kJ/m ³
0	0	2.526	1.238	2.526					
4	0.11	2.515	1.228	2.520	866	0.0016	1.05E-03	1.60E-07	0.009
13	0.09	2.506	1.220	2.510	778	0.0017	4.08E-04	6.87E-08	0.041
31	0.43	2.463	1.182	2.484	3375	0.0004	9.54E-04	3.62E-08	0.417
66	0.87	2.376	1.105	2.419	2381	0.0005	9.73E-04	4.97E-08	2.131
137	0.84	2.292	1.031	2.334	2160	0.0005	4.70E-04	2.46E-08	5.700
277	0.74	2.219	0.965	2.255	1009	0.0011	2.08E-04	2.18E-08	12.351
558	0.64	2.155	0.909	2.187	694	0.0015	9.00E-05	1.29E-08	24.358
1117	0.56	2.099	0.859	2.127	375	0.0026	3.97E-05	9.95E-09	46.166
558	-0.06	2.105	0.864	2.102					
137	-0.19	2.123	0.881	2.114					
31	-0.26	2.149	0.904	2.136					
4	-0.24	2.173	0.925	2.161					

Note:

k calculated using α based on t₉₀ values.**SAMPLE DIMENSIONS AND PROPERTIES - FINAL**

Sample Height, cm	2.173	Unit Weight, kN/m ³	17.74
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	14.01
Area, cm ²	31.68	Specific Gravity, Measured	2.75
Volume, cm ³	68.85	Solids Height, cm	1.129
Water Content, %	26.64	Volume of Solids, cm ³	35.76
Wet Mass, g	124.54	Volume of Voids, cm ³	33.09
Dry Mass, g	98.34		

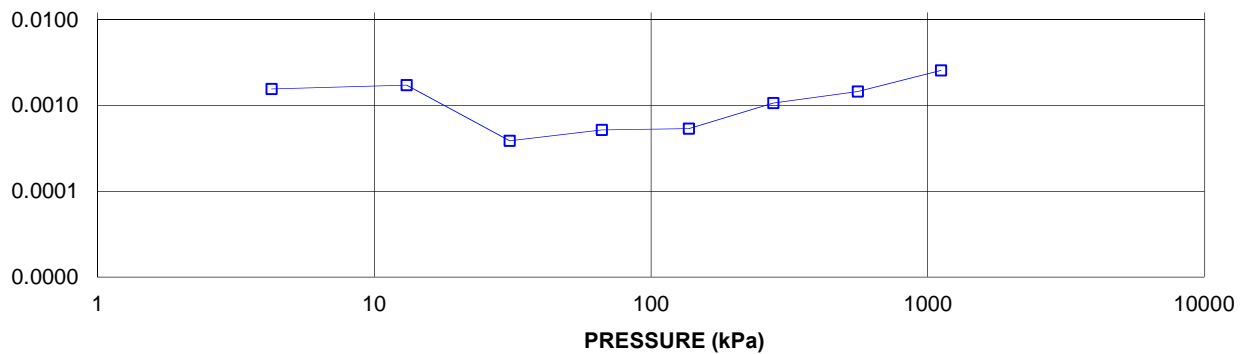
CONSOLIDATION TEST SUMMARY

FIGURE B4

Pg. 2 of 4

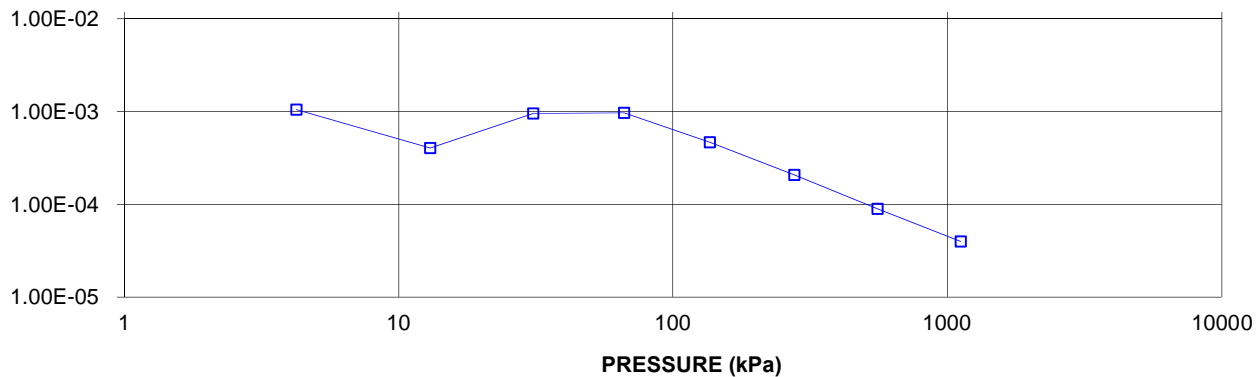
COEFFICIENT OF CONSOLIDATION,
cm²/s

CONSOLIDATION TEST
CV cm²/s VS PRESSURE (kPa)
BH P1-2a Sa 1



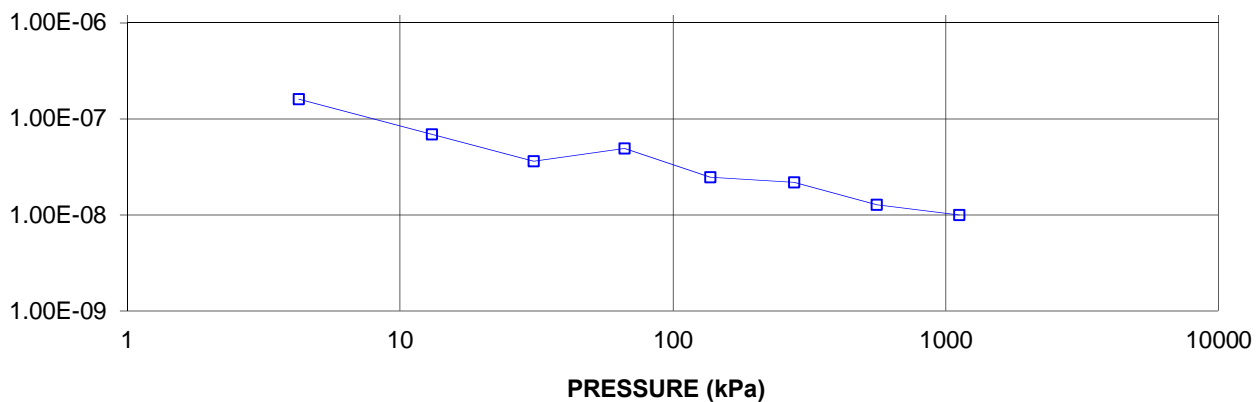
VOLUME COMPRESSIBILITY, m²/kN

CONSOLIDATION TEST
MV m²/kN vs PRESSURE (kPa)
BH P1-2a Sa 1



HYDRAULIC CONDUCTIVITY,
cm/s

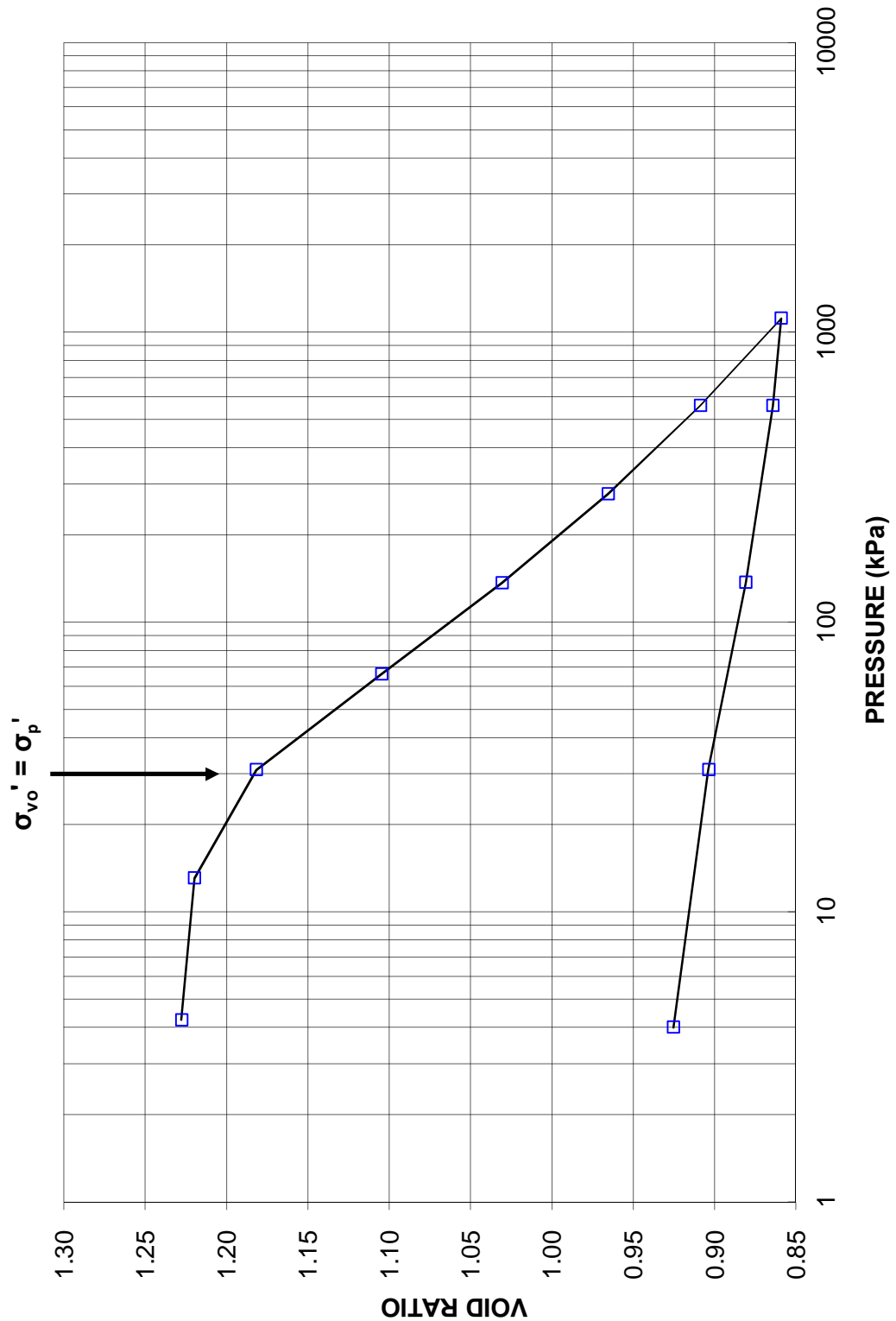
CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs PRESSURE
BH P1-2a Sa 1



**CONSOLIDATION TEST
VOID RATIO VS LOG PRESSURE**

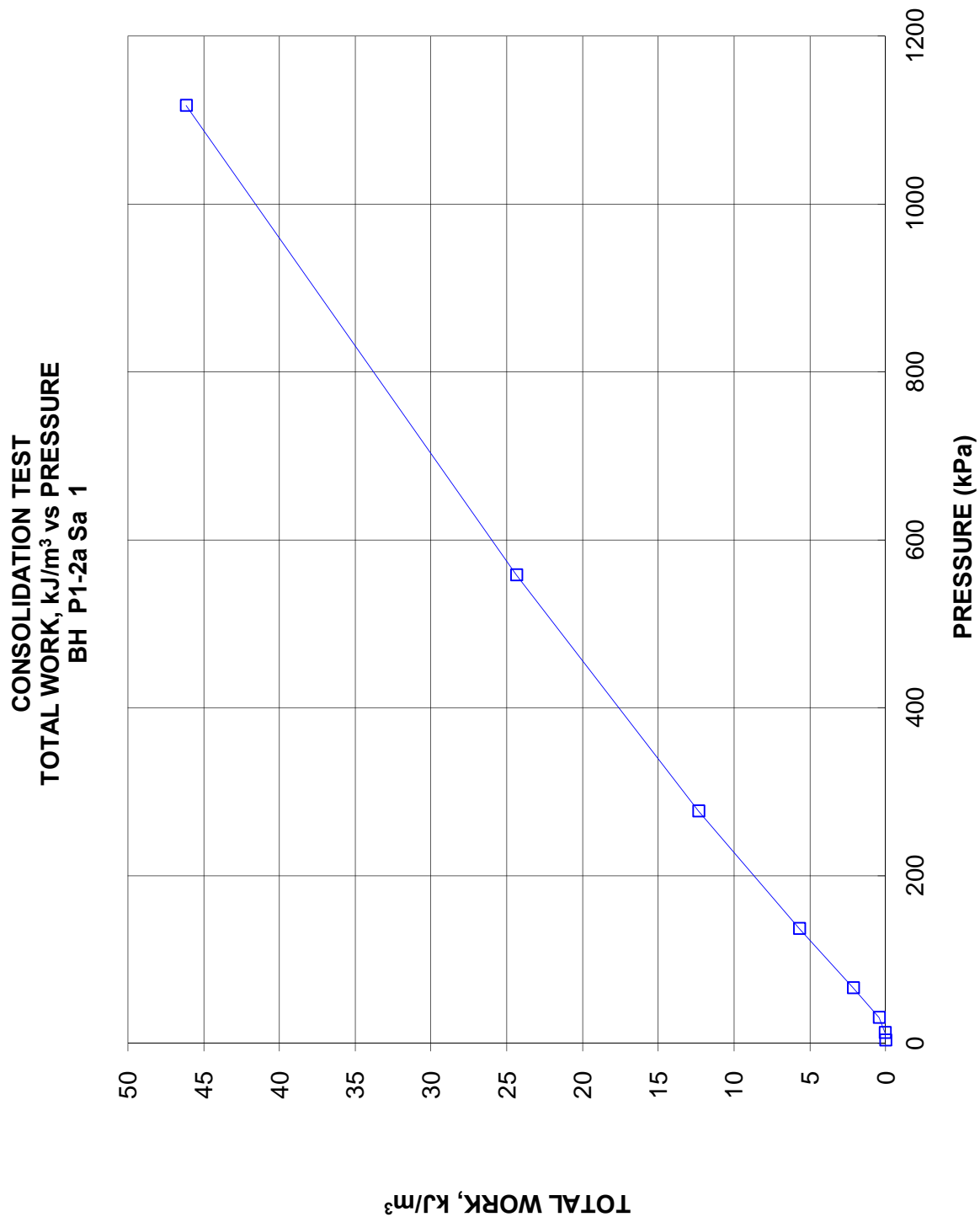
FIGURE B4
Pg. 3 of 4

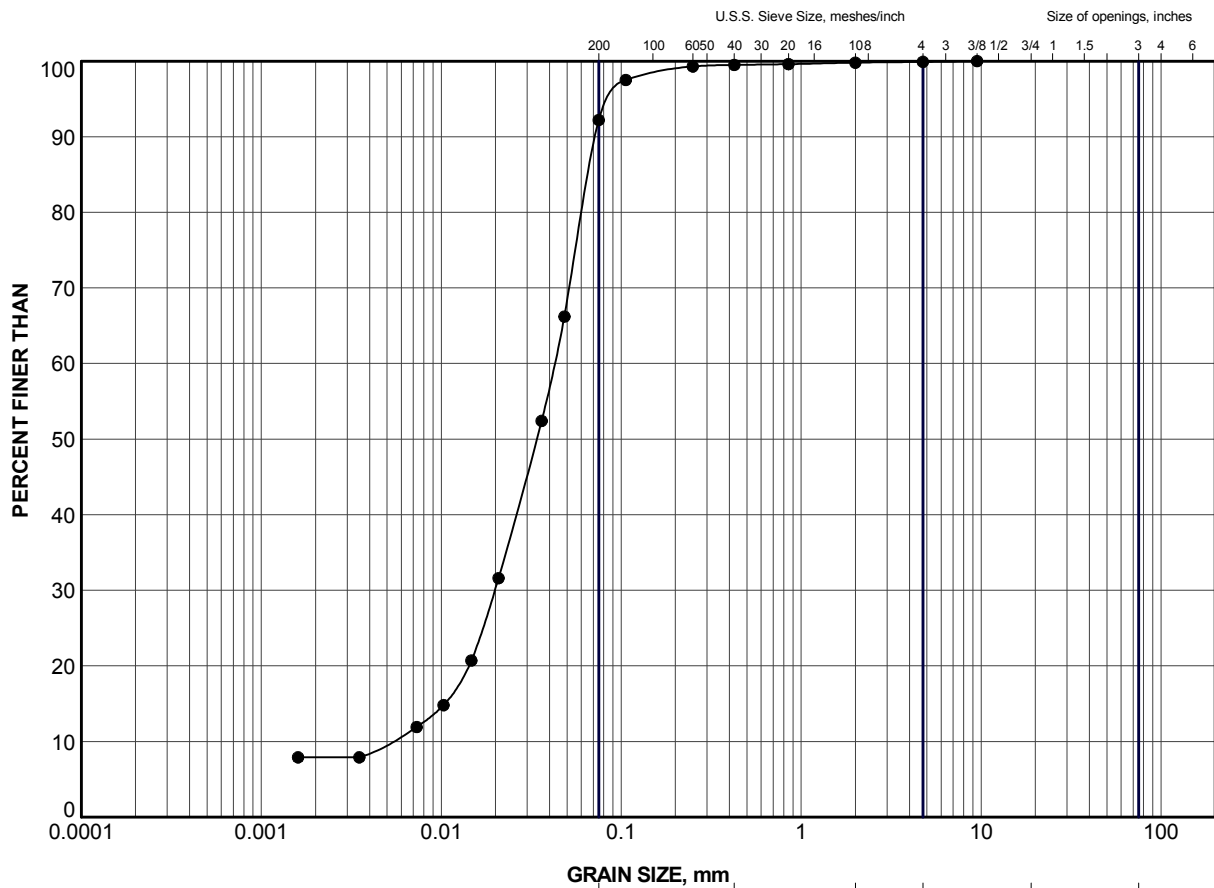
**CONSOLIDATION TEST
VOID RATIO vs. PRESSURE
BH P1-2a Sa 1**



CONSOLIDATION TEST
TOTAL WORK VS PRESSURE

FIGURE B4
Pg. 4 of 4




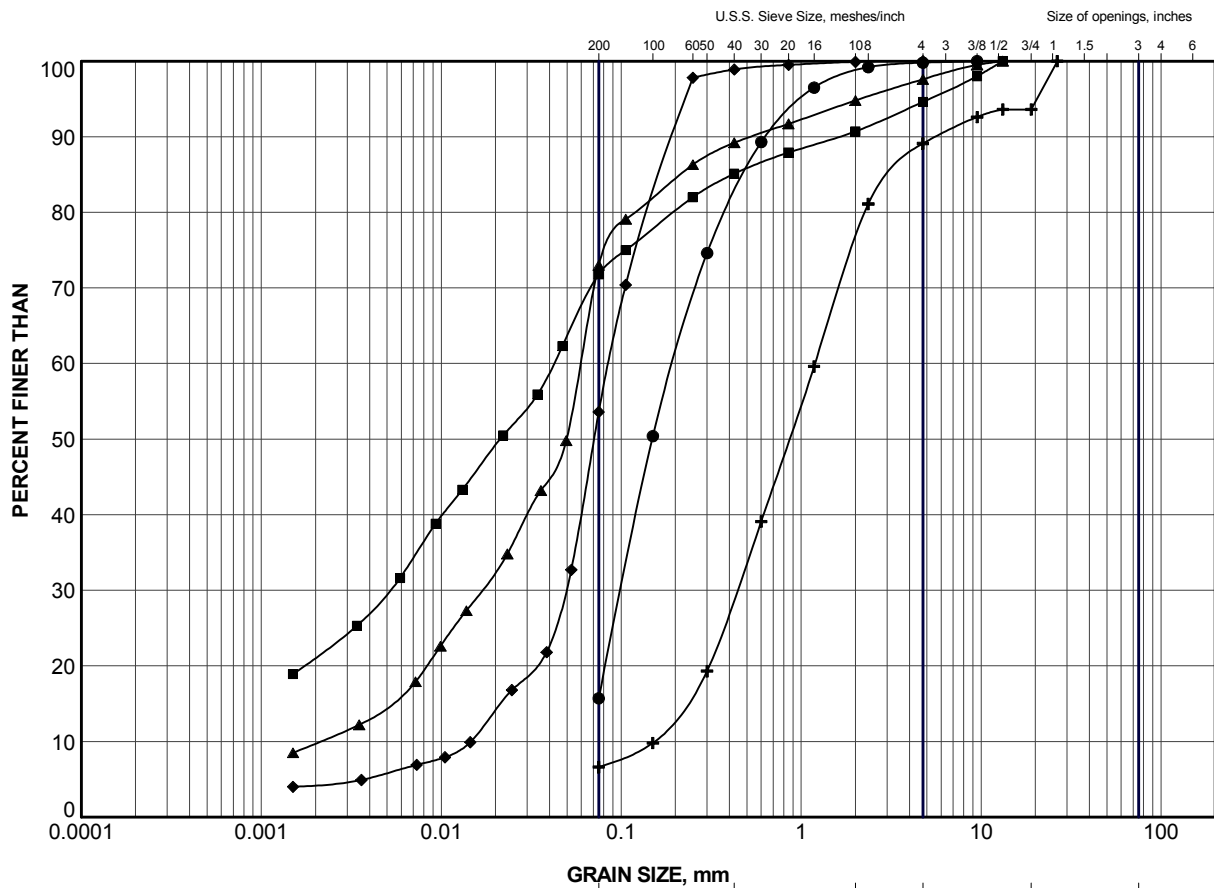


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	P1-9	11	222.7


PROJECT						HIGHWAY 11 WESTBOUND PASSING LANE					
TITLE						GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.			10-1191-0038			FILE No			1910038 BH LOGS.GPJ		
DRAWN	TB	Feb 2014		SCALE	N/A	REV.					
CHECK	MT	Feb 2014									
APPR	AB	Feb 2014									
 Golder Associates SUDBURY, ONTARIO						FIGURE B5					

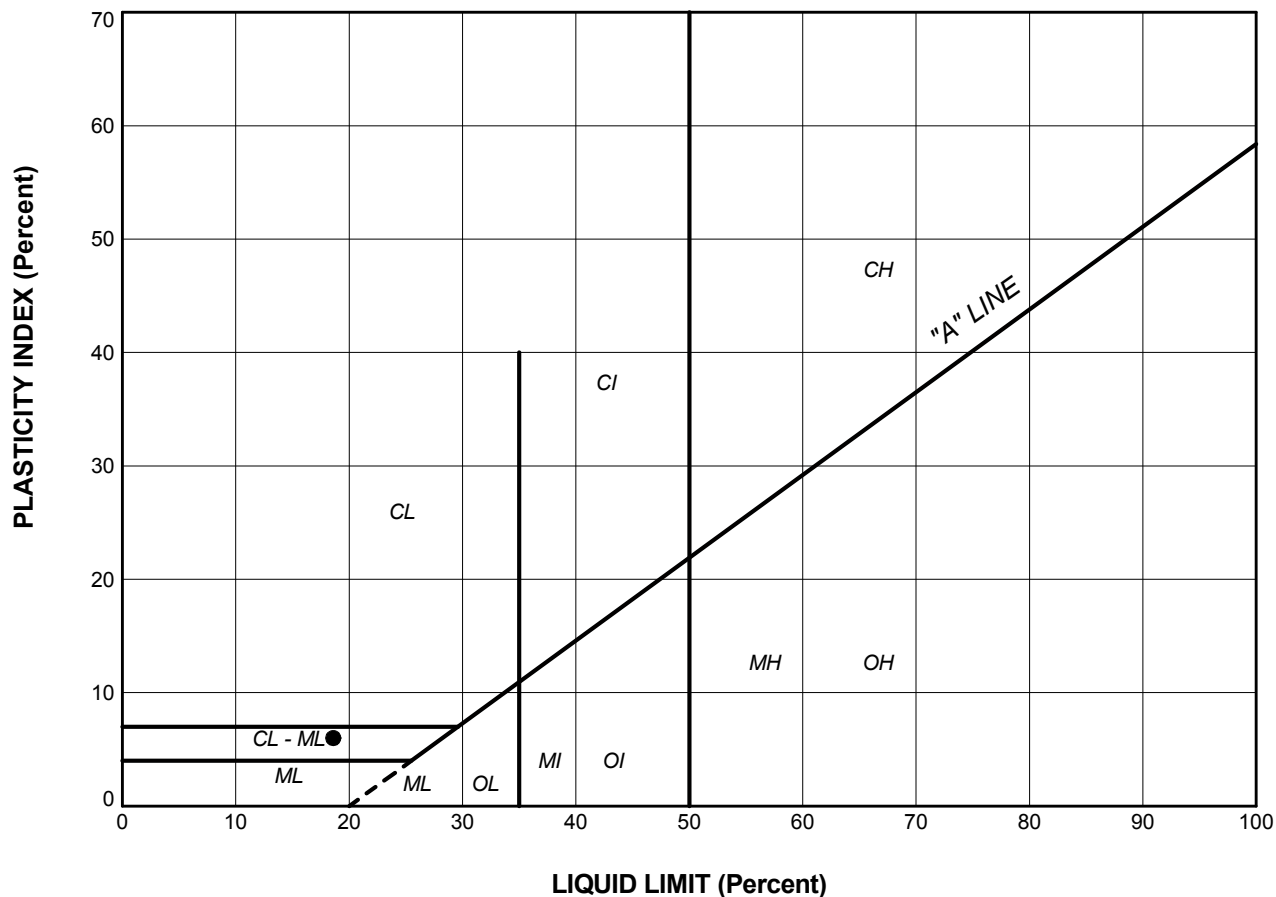


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	P1-2	11	222.2
■	P1-2	14	217.6
▲	P1-4	9	226.0
✚	P1-9	14	218.1
◆	P1-11	10	226.2

PROJECT					HIGHWAY 11 WESTBOUND PASSING LANE				
TITLE					GRAIN SIZE DISTRIBUTION SAND to SANDY SILT				
PROJECT No.		10-1191-0038		FILE No		1910038 BH LOGS.GPJ			
DRAWN	TB	Feb 2014		SCALE	N/A	REV.			
CHECK	MT	Feb 2014		FIGURE B6					
APPR	AB	Feb 2014							
 Golder Associates SUDBURY, ONTARIO									




SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	P1-4	7	18.6	12.6	6.0

PROJECT					
HIGHWAY 11 WESTBOUND PASSING LANE					
TITLE					
PLASTICITY CHART SANDY SILT					
PROJECT No.		10-1191-0038		FILE No.1011910038 BH LOGS.GPJ	
DRAWN	TB	Feb 2014	SCALE	N/A	REV.
CHECK	MT	Feb 2014			
APPR	AB	Feb 2014			
 Golder Associates SUDBURY, ONTARIO			FIGURE B7		



APPENDIX C

Non-Standard Special Provisions

SWAMP EXCAVATION – Item No.

Non-Standard Special Provision

This Non-Standard Special Provision outlines the procedure for sub-excavation of the peat/organic fill deposits for the Highway 11 widening of embankment in Devitt Township at the following locations:

- Westbound Passing Lane Extension:
 - Station 21+150 to 21+700

Staged excavation of limited extent shall be employed to maintain stability of and to protect the existing Highway 11 embankment during sub-excavation and replacement operations. The staged excavation procedures to be followed are:

- Removal of peat/organic deposits to the depth specified within the proposed embankment widened footprint and simultaneously backfill of the excavation in accordance with OPSS 209 Section 209.07.03.
- Excavation of organic material beyond the existing toe of the embankment in accordance with OPSD 203.030.
- Provisions for traffic control measures shall be available on site to maintain the safe operations and traffic flow of Highway 11.

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