



Foundation Investigation and Design Report

*Highway 11 – 2+1 Roadway Model Project: **Site SW8***

Assignment No. 5021-E-0038

GWP 5033-22-00

Geocres No. 31L13-002

(Latitude: 46.798949; Longitude: -79.801547)

Type of Document:

Final Report

EXP Project Number:

ADM-23010055-A0

Prepared For:

AECOM

189 Wyld Street

North Bay, Ontario, P1B 1Z2

Attn: Jason Wright, P.Eng.

Cc: Kyle Hampton, P.Eng.

Prepared By:

EXP Services Inc.

1595 Clark Boulevard

Brampton, ON L6T 4V1

Canada

Date Submitted:

October 24, 2024

Foundation Investigation and Design Report

Project Name:

*Highway 11 – 2+1 Roadway Model Project: **Site SW8***

Assignment No. 5021-E-0038

GWP 5033-22-00

Geocres No. 31L13-002

(Latitude: 46.798949; Longitude: -79.801547)

Type of Document:

Final Report

EXP Project Number:

ADM-23010055-A0

Issue and Revised Record

Rev.	Date	Format	Prepared by	Reviewed by	Approved by	Description
A	July 12, 2024	pdf	D. Mroz S. Micic	T.C. Kim	S. Gonsalves	Draft Report for Review by AECOM
B	July 25, 2024	pdf	D. Mroz S. Micic	T.C. Kim	S. Gonsalves	Draft Report for Review by MTO
B	October 24, 2024	pdf	D. Mroz S. Micic	T.C. Kim	S. Gonsalves	Final Report

Table of Contents

1	FOUNDATION INVESTIGATION REPORT.....	1
1.1	Introduction.....	1
1.2	Site Description and Geological Setting	1
1.2.1	Site Description	1
1.2.2	Geological Setting.....	2
1.3	Previous Investigations.....	2
1.4	Investigation Procedures.....	2
1.4.1	Site Investigation and Field Testing.....	2
1.4.2	Laboratory Testing	5
1.5	Subsurface Conditions.....	5
1.5.1	Subsoils.....	6
1.5.1.1	Asphalt Treatment	6
1.5.1.2	Topsoil	6
1.5.1.3	Peat.....	6
1.5.1.4	Organic Silt.....	7
1.5.1.5	Cohesionless Fill: Sandy Gravel/Sand and Gravel/Gravelly Sand	9
1.5.1.6	Rockfill	10
1.5.1.7	Clayey Silt.....	10
1.5.1.8	Gravelly Sand / Sand and Gravel / Sandy Gravel	12
1.5.1.9	Glacial Till: Cobbles and Boulders.....	13
1.5.2	Bedrock	15
1.6	Groundwater and Surface Water Conditions.....	16
2	ENGINEERING DISCUSSION & RECOMMENDATIONS	18
2.1	General	18
2.2	Expected Ground Conditions.....	18
2.3	Site Considerations.....	19
2.3.1	Construction/Mitigation Options	19
2.3.2	Frost Depth.....	22
2.3.3	Seismic Hazard Site Classification and Values	22
2.3.4	Liquefaction Potential	23
2.4	Embankment	23
2.4.1	General	23
2.4.2	Stability Considerations.....	24
2.4.3	Settlement Considerations.....	25
2.4.3.1	General	25
2.4.3.2	Settlement of Foundation Soils	25
2.4.3.3	Settlement of Embankment Fill	27

2.4.3.4 Discussion of Settlement Results.....28

2.5 Construction Considerations 29

2.5.1 Excavation 29

2.5.2 Subgrade Preparation 29

2.5.3 Embankment Construction 30

2.5.4 Platform Widening 31

2.5.5 Site Dewatering 31

3 CLOSURE 32

REFERENCES..... 33

LIMITATIONS AND USE OF REPORT 34

Appendices

- APPENDIX A: SITE PHOTOGRAPHS
- APPENDIX B: DRAWINGS
- APPENDIX C: BOREHOLE LOGS
- APPENDIX D: LABORATORY DATA
- APPENDIX E: BEDROCK CORE PHOTOGRAPHS
- APPENDIX F: SLOPE STABILITY ANALYSES
- APPENDIX G: SETTLEMENT ANALYSES
- APPENDIX H: SEISMIC HAZARD CALCULATION
- APPENDIX I: OPSDs
- APPENDIX J: NSSPs

1 FOUNDATION INVESTIGATION REPORT

1.1 Introduction

This report presents the results of the geotechnical investigation completed by EXP Services Inc. (EXP) for the proposed widening of Highway 11 and the corresponding embankment/roadway construction at site SW8. The site is located approximately 5.5 km north of the intersection of Highway 64 and Highway 11 from approximately Station 19+950 to 20+235 in the Townships of Sisk and Station 10+000 to 10+015 in the township of Olive in the District of Nipissing, Ontario (Latitude: 46.798949; Longitude: -79.801547). The work was undertaken under Agreement No. 5021-E-0038 and the terms of reference (TOR) provided by AECOM. The AutoCAD drawings for Highway 11 were also provided by AECOM.

The purpose of the investigation was to evaluate the subsurface condition along the proposed widening of Highway 11, and based on this investigation, to provide a borehole location plan, cross section subsurface profile, record of boreholes, laboratory test results, and a written description of the subsurface conditions to permit detailed design and recommendations for the construction of the new proposed embankment/roadway associated with the widening of the highway. The site specific geotechnical investigation consisted of a field investigation program including visual inspections, drilling, soil sampling, and laboratory testing.

This foundation investigation report has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing completed for this project.

1.2 Site Description and Geological Setting

1.2.1 Site Description

The site is located approximately 5.5 km north of the intersection of Highway 64 and Highway 11 from approximately Station 19+950 to 20+235 in the Townships of Sisk and Station 10+000 to 10+015 in the township of Olive in the District of Nipissing, Ontario. At the site, Highway 11 generally runs in the north-south direction, with a speed limit of 90 km/h (unless otherwise posted). At the site, Highway 11 is approximately 8.5 m wide with a 3.2 m wide gravel shoulder on the east side (northbound lane) and a 4.3 m wide gravel shoulder on the west side (southbound lane). In total, the existing roadway with both shoulders included is about 16.0 m wide. The elevation of the highway pavement centerline at the site ranges approximately from Elev. 292.0 m to 291.2 m from south to north as per the AutoCAD drawings provided by AECOM. The roadway embankment at SW8 is estimated to be up to 3.5 m high on the west side and 2.8 m on the east side of the highway.

The general site conditions were assessed during a site visit September 13, 2023 as well as during the field investigation works between October 30, 2023, and April 25, 2024. Select photographs of the site are presented in Appendix A. The site plan and cross-section profiles along the existing highway are shown on the drawings attached in Appendix B.

Both sides of the embankment were observed to be mostly comprised of gravel and/or grass with boulder-sized rockfill. Marshland was observed on both sides of the embankment with vegetation consisting primarily of large conifers and wild bushes. In general, the highway is founded on top of a built-up embankment while the natural terrain in the surrounding area is relatively flat. No signs of sinkholes/instabilities were observed on the SW8 section of Highway 11. Bedrock outcrops were observed on the north and south end of the site beyond the extent of the drilled boreholes.

Photographs 1 to 6 in Appendix A shows the site and activities during drilling photographed between March and April 2024 by EXP. Photograph 1 shows the general existing roadway surface and the shoulder, embankment side slope, and ground conditions/vegetation beyond embankment toe along the NBL side. Photographs 2 and 3 show the existing embankment side slope and ground conditions/vegetation along the SBL side as well as the overhead power lines running adjacent to the SBL. Photograph 4 shows rockfill which is visible along the WBL side approximately between borehole BH8-12 and BH8-13. Photograph 5 shows the drilling of borehole BH8-4 which required the use of mat for access, while Photograph 6 shows the drilling of borehole BH8-9 with the rig placed directly on the ground surface.

1.2.2 Geological Setting

According to the Ministry of Northern Development and Mines, Map 2555 (Quaternary Geology of Ontario, East-Central Sheet, 1991) the surface conditions in the vicinity of the project area are expected to consist of glaciofluvial outwash deposits comprised of gravel and sand, including proglacial river and deltaic deposits, and Precambrian bedrock: undifferentiated igneous and metamorphic rock. The bedrock could be exposed at the surface or covered by a discontinuous, thin layer of drift. According to Map 2543 (Bedrock Geology of Ontario, East-Central Sheet, 1991), the bedrock geology of the site is of migmatitic rocks and gneisses of undetermined protolith: commonly layered biotite gneisses and migmatites; locally includes quartzofeldspathic gneisses, orthogneisses, and paragneisses.

1.3 Previous Investigations

There are no available previous geotechnical reports at the location of the site in the MTO GEOCRETS library; the nearest available reports on Highway 11 are approximately 5.9 km south and 4.4 km north, respectively, from the site:

- Geocres No. 31L-062: "Foundation Investigation Report for Marian Creek Culvert Extension, Proposed Widening of Highway 11, W.P. 60-87-00, Site 43-360, District 17, Sudbury", Ministry of Transportation Ontario, Engineering Materials Office, Foundation Design Section, dated August 10, 1993.
- Geocres No. 31L-140: "Supplementary Preliminary Foundation Investigation Report for Re-Alignment of Highway 11 at Robin Creek, Sudbury Area, Agreement 5004-E-0058 (Assignment #7)", Project: SPT1151G, Prepared by Shaheen & Peaker Ltd., dated April 26, 2006.
- Geocres No. 31L-141: "Foundation Investigation Report, Preliminary Field Investigation for Re-Alignment of Highway 11 at Three Locations Between Hwy 64 and Town of Latchford, Agreement 5004-E-0058 (Assignment #3)", Project: SPT1151C, Prepared by Shaheen & Peaker Ltd., dated December 12, 2005.

1.4 Investigation Procedures

1.4.1 Site Investigation and Field Testing

A site reconnaissance was conducted by an EXP representative on September 13, 2023 to evaluate the general site conditions for the proposed borehole locations.

The site investigation for the three (3) roadway boreholes was performed on between October 30 to November 1, 2023 while the investigation of the eleven (11) off-road boreholes was performed between March 4 and 12, 2024 along the east side and April 16 to 25 2024 along the west side of Highway 11. In total, the entire field program consisted of drilling fourteen (14) sampled boreholes, numbered BH1-1 to BH1-14. The boreholes were strategically located along the highway and slightly beyond the footprint of the proposed expansion to provide subsurface information for the widening of the highway.

Roadway boreholes BH8-2 and BH8-6 were advanced on the east side (northbound lane) of the highway while BH8-11 was advanced on the west side (southbound lane). Boreholes BH8-1, BH8-3 to BH8-5, and BH8-7 were advanced off-road beyond the toe of the existing embankment on the east side of the highway while boreholes BH8-8 to BH8-10 and BH8-12 to BH8-14 were advanced off-road beyond the toe of the existing embankment on the west side of the highway.

The locations of the boreholes drilled during this investigation are shown on Drawing 1 in Appendix B. Roadway boreholes BH8-2, BH8-6 and BH8-11 were advanced to depths of between 8.0 m and 10.4 m below ground surface. East side off-road boreholes BH8-1, BH8-3 to BH8-5, and BH8-7 were advanced to depths between 6.2 m and 14.9 m below ground surface and west side off-road boreholes BH8-8 to BH8-10 and BH8-12 to BH8-14 were advanced to depths between 5.4 m and 13.1 m below ground surface.

The roadway boreholes drilled during this fieldwork were advanced using a truck mounted CME 75 drill rig, while the off-road boreholes were advanced using a track mounted CME55 drill rig, both operated by specialist drilling contractor, Marathon Drilling Ltd. All drill rigs were equipped with hollow stem augers, NW casing/NQ coring or HW casing/HQ coring, and standard soil sampling equipment. Due to the relatively steep highway embankments with limited access for the drill rig and swamp conditions, access (swamp) mats were used to create access to and a stable working surface for off-road boreholes and were provided and installed by Northern Mat & Bridge. Traffic control was provided by Demora Construction Services Inc.

The borehole locations (referenced to the MTM NAD83 Zone 10) and their ground surface elevations were surveyed by EXP personnel using a Trimble DA2 GNSS receiver with Trimble Catalyst GNSS positioning, having an accuracy of ± 0.1 m in the horizontal and vertical directions. Elevations for each borehole were referenced from the benchmark "HCP 305", which was a stake located on the northbound lane shoulder at Elev. 291.027 m by the surveyor. Ground surface elevations of the boreholes are summarized in Table 1.1 below.

During the drilling of the boreholes, a combination of Standard Penetration Tests (SPT), thin-walled (Shelby) tubes, and rock coring was attempted to obtain soil and rock samples. Soil samples were obtained using a 51 mm outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) at intervals ranging from 0.75 m to 1.5 m in depth, as shown on the attached borehole logs (Appendix C). The original field (uncorrected) SPT "N" values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual (CFEM, pg. 103) and used to provide an assessment of in-situ consistency of cohesive soils or compactness of non-cohesive soils. The SPT "N" values taken within the particles larger than diameter of split spoon sampler may not be reliable and collected samples are possibly not representative of the layer. Field vane shear tests (FVST) were conducted using a standard MTO vane at regular intervals where very soft to stiff cohesive materials were encountered. The original field (uncorrected) undrained shear strengths measured with the vane are presented on the borehole logs. Where very soft to firm soils were encountered, thin-walled (Shelby) tube samples were taken. When a hard stratum was reached (refusal of split spoon), sampling of hard material was performed by diamond core drilling using a 1.5 m long NQ double tube wireline core barrel.

Where possible, groundwater level measurements were carried out in the boreholes before coring and at the completion of the boreholes, in accordance with MTO guidelines. However, all boreholes at this site were advanced using diamond coring procedures. Water was used during advancement of cores from the ground surface, therefore groundwater was not measured in boreholes due to the drilling method. A standpipe piezometer was installed in BH8-4 and BH8-10 to permit monitoring of the groundwater level on the east and west side of Hwy 11, respectively. The recorded groundwater levels are presented in the borehole log sheets in Appendix C. All other drilled boreholes were decommissioned by bentonite/cement mixtures in accordance with the Ministry of the Environment

Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act) upon completion of drilling.

The fieldwork was supervised by an EXP geotechnical representative who directed the drilling and sampling operations, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification and retrieved soil samples for subsequent laboratory testing and identification.

All recovered soil samples were placed in labelled moisture-proof bags and returned to EXP's laboratory for additional visual, textual, and olfactory examination, and selective testing. The rock cores were placed in wooden core boxes and photographed as shown in Appendix E.

Table 1.1. Summary of boreholes completed

Borehole No.	Location	Location (MTM NAD 83 Zone 10)		Latitude	Longitude	Ground Surface Elevation ¹ (m)	Borehole Depth ² (m)
		Northing	Easting				
BH8-1	Off-road beyond toe of existing slope: east side of highway	5184571.2	281810.4	46.800292	-79.801181	289.3	6.9
BH8-2	East shoulder of Highway 11	5184509.6	281786.9	46.799736	-79.801487	291.4	10.4
BH8-3	Off-road beyond toe of existing slope: east side of highway	5184477.3	281799.8	46.799447	-79.801316	290.3	10.4
BH8-4	Off-road beyond toe of existing slope: east side of highway	5184425.3	281798.4	46.798979	-79.801331	289.9	13.4
BH8-5	Off-road beyond toe of existing slope: east side of highway	5184376.4	281797.6	46.798539	-79.801340	289.2	14.9
BH8-6	East shoulder of Highway 11	5184324.4	281776.8	46.798070	-79.801610	291.9	8.0
BH8-7	Off-road beyond toe of existing slope: east side of highway	5184297.4	281794.2	46.797828	-79.801381	289.3	6.2
BH8-8	Off-road beyond toe of existing slope: west side of highway	5184557.5	281763.9	46.800167	-79.801790	289.6	5.4
BH8-9	Off-road beyond toe of existing slope: west side of highway	5184511.6	281765.0	46.799754	-79.801774	289.5	7.2
BH8-10	Off-road beyond toe of existing slope: west side of highway	5184470.2	281763.6	46.799382	-79.801790	289.7	13.1
BH8-11	West shoulder of Highway 11	5184422.8	281775.6	46.798955	-79.801631	291.2	10.1

Borehole No.	Location	Location (MTM NAD 83 Zone 10)		Latitude	Longitude	Ground Surface Elevation ¹ (m)	Borehole Depth ² (m)
		Northing	Easting				
BH8-12	Off-road beyond toe of existing slope: west side of highway	5184374.3	281755.1	46.798518	-79.801896	289.0	13.0
BH8-13	Off-road beyond toe of existing slope: west side of highway	5184328.2	281747.1	46.798104	-79.801999	288.8	5.4
BH1-14	Off-road beyond toe of existing slope: west side of highway	5184276.5	281740.9	46.797638	-79.802077	288.5	7.7

Notes:

1. The ground surface elevations are referenced from HCP 305.
2. Depths are relative to ground surface.

1.4.2 Laboratory Testing

All soil and rock samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content on all soil samples and particle size distribution for approximately 25% of the collected soil samples. Atterberg limits testing was done in conjunction with grain size distribution tests on select samples. All laboratory tests were carried out in accordance with MTO and/or ASTM standards as appropriate.

The laboratory test results are provided on the attached borehole log sheets in Appendix C. The results of the grain size analyses and Atterberg limits are presented graphically in Appendix D.

1.5 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix C. The "Explanation of Terms Used in Report" preceding the borehole logs in Appendix C forms an integral part of and should be read in conjunction with this report.

A borehole location plan and cross section subsurface profiles are provided in Appendix B. It should be noted that the stratigraphic boundaries indicated on the borehole log and cross section stratigraphic profiles are inferred from semi-continuous sampling, observations of drilling progress and results of Standard Penetration Tests (SPT). These boundaries typically represent transitions from one soil type to another and should not be regarded as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

Below the roadway, the subsurface conditions encountered within the investigated depths of the geotechnical investigation indicate the following subsurface sequence: cohesionless fill consisting of varying amounts of predominantly sand and gravel followed by rockfill, underlain by native clayey silt or sand and gravel over glacial till comprised of cobbles and boulders in a silt, sand, and gravel soil matrix followed by bedrock.

At the toe of the embankment along the east and west side of the highway, the encountered subsurface conditions were observed to generally consist of organic materials (topsoil, peat, organic silt) over clayey silt followed by glacial till comprised of cobbles and boulders in a silt, sand, and gravel soil matrix underlain by bedrock. The bedrock was

relatively shallow at the north and south extents of the site, while the organic layers (particularly peat) layers and clayey silt were significantly deeper towards the center of the site.

A detailed description of the subsurface conditions encountered is discussed further in subsequent sections.

1.5.1 Subsoils

1.5.1.1 Asphalt Treatment

Asphalt treatment, approximately 100 mm to 175 mm thick, was encountered at the ground surface of borehole BH8-2 and BH8-6. Asphalt thicknesses may further vary beyond the borehole location.

1.5.1.2 Topsoil

Topsoil, approximately 75 mm to 760 mm thick, was encountered at the ground surface of boreholes BH8-1, BH8-3, BH8-4, BH8-8 to BH8-10, BH8-13, and BH8-14.

Laboratory testing performed on selected samples consisted of four (4) moisture content tests. The test results are as follows:

Moisture Content:

- 50% to 396%

The results of the moisture content tests are provided on the record of borehole sheets in Appendix C.

1.5.1.3 Peat

Peat was encountered at the ground surface of boreholes BH8-5, BH8-7, and BH8-12, below topsoil in boreholes BH8-4 and BH8-10, and below the sand and gravel fill in borehole BH8-3. The depths and elevations of this layer encountered are listed in Table 1.2.

Table 1.2. Summary of peat

Borehole No.	Elevation ¹ (m)		Layer Surface Depth ² (m)	Layer Thickness (m)
	Top	Bottom		
BH8-3	289.5	286.9	0.8	2.6
BH8-4	289.1	284.6	0.8	4.5
BH8-5	289.2	284.2	0.0	5.0
BH8-7	289.3	289.1	0.0	0.2

Borehole No.	Elevation ¹ (m)		Layer Surface Depth ² (m)	Layer Thickness (m)
	Top	Bottom		
BH8-10	289.6	286.9	0.1	2.7
BH8-12	289.0	284.6	0.0	4.4

Notes:

1. The elevations are referenced from HCP 305.
2. Depths are relative to ground surface.

The peat encountered at the site ranged from fibrous to amorphous. The material was generally brown to black in colour and wet to saturated. The SPT “N” values obtained within this material ranged from WH (weight of hammer) to 5 blows per 0.3 m penetration suggesting that this layer was very soft to firm in consistency, but generally very soft to soft in consistency.

Laboratory testing performed on selected samples consisted of twenty-two (22) moisture content tests and five (5) organic content tests. The test results are as follows:

Moisture Content:

- 115% to 772%
- 24% (silty sand fill layer interbedded in peat)

Organic Content:

- 18.5% to 86.8%

The results of the moisture content and organic content tests are provided on the record of borehole sheets in Appendix C.

1.5.1.4 Organic Silt

A layer of organic silt was encountered below the peat in boreholes BH8-5 and BH8-10. The depths and elevations of this layer encountered are listed in Table 1.3.

Table 1.3. Summary of organic silt

Borehole No.	Elevation ¹ (m)		Layer Surface Depth ² (m)	Layer Thickness (m)
	Top	Bottom		
BH8-5	284.2	283.7	5.0	0.5
BH8-10	286.9	286.0	2.8	0.9

Notes:

1. The elevations are referenced from HCP 305.
2. Depths are relative to ground surface.

The composition of this material generally consisted of a mixture of organics with silt, trace sandy to being sandy, trace clay to being clayey. The organic silt was generally brown to dark brown in colour and wet. The SPT “N” values in this layer were WH indicating that this layer was very loose in compactness.

Laboratory testing performed on selected samples consisted of two (2) moisture content tests, two (2) organic content tests, two (2) grain size distribution tests, and two (2) Atterberg limit tests. The test results are as follows:

Moisture Content:

- 70% to 147%

Organic Content:

- 16.1% to 42.1%

Grain Size Distribution (organic silt layer):

- 0% gravel to 13%
- 1% sand to 38%
- 45% to 79% silt
- 4% to 20% clay

Atterberg Limits (organic silt layer):

- Liquid Limit: 29% to 260%
- Plastic Limit: 20% to 195%
- Plasticity Index: 8% to 65%

The results of the moisture content, organic content, grain size distribution, and Atterberg limit tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution test and Atterberg limit test are also provided on Figure 1 and Figure 2, respectively, in Appendix D.

1.5.1.5 Cohesionless Fill: Sandy Gravel/Sand and Gravel/Gravelly Sand

Cohesionless fill material consisting of varying distributions of predominantly sand and gravel was encountered below the asphalt in boreholes BH8-2 and BH8-6 at the ground surface of borehole BH8-11. The depths and elevations of this layer encountered are listed in Table 1.4.

Table 1.4. Summary of cohesionless fill: sandy gravel/sand and gravel/gravelly sand

Borehole No.	Elevation ¹ (m)		Layer Surface Depth ² (m)	Layer Thickness (m)
	Top	Bottom		
BH8-2	291.2	289.9	0.2	1.3
BH8-3	290.1	289.5	0.2	0.6
BH8-6	291.8	288.5	0.1	3.3
BH8-11	291.2	289.7	0.0	1.5

Notes:

3. The elevations are referenced from HCP 305.
4. Depths are relative to ground surface.

The composition of this fill material generally consisted of sand and gravel in varying amounts with trace to some silt. A silt layer with some sand, some silt, and trace gravel was encountered in sample SS2 in borehole BH2-6 at a depth of approximately 0.8 m. The fill was generally brown to grey in colour with pink/grey gravel (BH8-6) and ranging from damp to wet. The SPT “N” values obtained within this material ranged from 7 blows per 0.3 m penetration to 104 blows per 200 mm suggesting that this layer was loose to very dense, but generally compact to very dense in compactness.

Laboratory testing performed on selected samples consisted of seven (7) moisture content tests, and four (4) grain size distribution tests. The test results are as follows:

Moisture Content:

- 3% to 15%

Grain Size Distribution:

- 8% to 51% gravel
- 15% to 55% sand
- 67% silt
- 10% clay
- 12% to 24% silt and clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution test are also provided on Figure 3 in Appendix D.

1.5.1.6 Rockfill

Rockfill consisting of various sized fragments of rock in a soil matrix (gravel, sand and silt sized particles) was encountered in boreholes BH8-2 and BH8-11 below the cohesionless fill layer. The depths and elevations of this layer encountered are listed in Table 1.5.

Table 1.5. Summary of rockfill

Borehole No.	Elevation ¹ (m)		Layer Surface Depth ² (m)	Layer Thickness (m)
	Top	Bottom		
BH8-2	289.9	287.4	1.5	2.5
BH8-11	289.7	288.2	1.5	1.5

Notes:

1. The elevations are referenced from HCP 305.
2. Depths are relative to ground surface.

The composition of this rockfill layer generally consisted of cobble to boulder sized rockfill with silt, sand and gravel sized particles within the in-fill soil matrix. The particle size within the rockfill varies from silt to boulder size (i.e. from 0.002 mm to greater than 300 mm).

A combination of SPT and coring was carried out during the exploration of this layer. Where possible, split spoon sampling was attempted to obtain samples from this layer. However, it should be noted that in most cases, obtained samples from this layer were either not adequate or did not accurately represent the particle size distribution of this material. The SPT “N” values obtained within this layer ranged from 10 to 31 blows per 0.3 m penetration, suggesting that this layer was compact to dense in relative density.

Laboratory testing was not performed on soil samples from this layer due to minimal sample recovery during the investigation.

1.5.1.7 Clayey Silt

Native clayey silt was encountered below topsoil/peat in boreholes BH8-1, BH8-3 to BH8-5, BH8-7 to BH8-9, and BH8-12 to BH8-14, below the organic silt in borehole BH8-10, below the rockfill in borehole BH8-2, and below the gravelly sand to sandy gravel fill in borehole BH8-6. The depth and elevations of this layer encountered at this borehole location are listed in Table 1.6.

Table 1.6. Summary of clayey silt layer

Borehole No.	Elevation ¹ (m)		Layer Surface Depth ² (m)	Layer Thickness (m)
	Top	Bottom		
BH8-1	289.1	288.5	0.2	0.6
BH8-2	287.4	285.4	4.0	2.0
BH8-3	286.9	283.0	3.4	3.9
BH8-4	284.6	277.1	5.3	7.5
BH8-5	283.7	275.8	5.5	7.9
BH8-6	288.5	287.1	3.4	1.4
BH8-7	289.1	286.7	0.2	2.4
BH8-8	289.4	287.5	0.2	1.9
BH8-9	289.4	285.7	0.1	3.7
BH8-10	286.0	281.4	3.7	4.6
BH8-12	284.6	278.8	4.4	5.8
BH8-13	288.7	286.4	0.1	2.3
BH8-14	288.4	286.1	0.1	2.3

Notes:

1. The elevations are referenced from HCP 305.
2. Depths are relative to ground surface.

The composition of this material generally consisted of clay and silt with generally trace gravel, trace sand, and trace organics. This layer was generally brown to grey in colour and moist to saturated. The SPT “N” values obtained within this layer ranged from WR (weight of rods) to 17 blows per 0.3 m penetration, suggesting that this layer was very soft to very stiff in consistency. In-situ vane testing with this layer measured an undrained shear strength ranging

from approximately 25 kPa to over 120 kPa indicating this material is firm to very stiff in consistency. The clayey silt layer typically increases in consistency from very soft/soft to stiff/very stiff with depth.

Laboratory testing performed on selected samples consisted of thirty-six (36) moisture content tests, five (5) organic content tests, fourteen (14) grain size distribution tests, thirteen (13) Atterberg limit tests, and three (3) unit weight tests. The test results are as follows:

Moisture Content:

- 17% to 67%

Organic Content:

- 0.5% to 7.1%

Grain Size Distribution:

- 0% to 1% gravel
- 1% to 4% sand
- 64% to 82% silt
- 15% to 35% clay

Atterberg Limits:

- Liquid Limit: 27% to 35%
- Plastic Limit: 18% to 26%
- Plasticity Index: 5% to 9%

Unit Weight:

- 19.3 kN/m³ to 19.9 kN/m³

The results of the moisture content, organic content, grain size distribution, Atterberg limit and unit weight tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution test and Atterberg limit test are also provided on Figures 4 and 5 and Figures 6 and 7, respectively, in Appendix D.

1.5.1.8 Gravelly Sand / Sand and Gravel / Sandy Gravel

Native gravelly sand / sand and gravel / sandy gravel was encountered below the clayey silt in borehole BH8-1 and BH8-7 and below the rockfill in borehole BH8-11. The depth and elevations of this layer encountered at these borehole locations are listed in Table 1.7.

Table 1.7. Summary of gravelly sand / sand and gravel / sandy gravel layer

Borehole No.	Elevation ¹ (m)		Layer Surface Depth ² (m)	Layer Thickness (m)
	Top	Bottom		
BH8-1	288.5	286.6	0.8	1.9
BH8-7	286.7	285.8	2.6	0.9
BH8-11	288.2	285.9	3.0	2.3

Notes:

1. The elevations are referenced from HCP 305.
2. Depths are relative to ground surface.

The composition of this material generally consisted of sand and gravel in varying amounts with some silt. The material was generally brown to grey in colour and wet to saturated. The SPT “N” values obtained within this material ranged from 6 blows per 0.3 m penetration to 100 blows per 0.1 m penetration, suggesting that this layer was loose to very dense, but generally compact to very dense in compactness.

Laboratory testing performed on selected samples consisted of three (3) moisture content tests. The test results are as follows:

Moisture Content:

- 10% to 13%

The results of the moisture content are provided on the record of borehole sheets in Appendix C.

1.5.1.9 Glacial Till: Cobbles and Boulders

Glacial till comprised of cobbles and boulders in a silt, sand, and gravel soil matrix were encountered below the clayey silt layer in boreholes BH8-2 to BH8-5, BH8-8 to BH8-10, and BH8-14, and below the native sand and gravel in borehole BH8-11. The depths and elevations of this layer encountered at these borehole locations are listed in Table 1.8.

Table 1.8. Summary of glacial till (cobbles and boulders) layer

Borehole	Elevation ¹ (m)		Layer Surface Depth ² (m)	Layer Thickness (m)
	Top	Bottom		
BH8-2	285.4	282.3	6.0	3.1
BH8-3	283.0	279.9	7.3	3.1

Borehole	Elevation ¹ (m)		Layer Surface Depth ² (m)	Layer Thickness (m)
	Top	Bottom		
BH8-4	277.1	276.5	12.8	0.6
BH8-5	275.8	274.3	13.4	1.5
BH8-8	287.5	286.6	2.1	0.9
BH8-9	285.7	284.9	3.8	0.8
BH8-10	281.4	280.0	8.3	1.4
BH8-11	285.9	281.1	5.3	4.8
BH8-14	286.1	284.1	2.4	2.0

Notes:

1. The elevations are referenced from HCP 305.
2. Depths are relative to ground surface.

The composition of this layer was generally comprised of cobbles and boulders with layers of silt, sand and gravel within the soil matrix. The particle size within the layer varied from clay to boulder size (i.e., from less 0.002 mm to greater than 300 mm).

A combination of SPT and coring was carried out during the exploration of this layer. Where possible, split spoon sampling was attempted to obtain samples from this layer. However, it should be noted that in most cases, obtained samples from this layer were either not adequate or did not accurately represent the particle size distribution of this material as particles larger than 35 mm (inside diameter of SPT sampler) could not be obtained.

The SPT “N” values obtained within the layers of silt/sand/gravel ranged from 24 blows per 0.3 m penetration to 100 blows per 0.08 m penetration, suggesting that these layers within the cobbles and boulders are compact to very dense. In addition, refusal due to a cobble or boulder was likely encountered when the split spoon could not penetrate 0.3 m. It is also important to note that the use of water for coring through the cobbles and boulders layer may have affected some SPT ‘N’ values measured.

Laboratory testing performed on selected samples consisted of two (2) moisture content tests, one (1) organic content test, and one (1) grain size distribution test. The test results are as follows:

Moisture Content:

- 5% to 8%

Organic Content:

- 4.8%

Grain Size Distribution:

- 49% gravel;
- 41% sand;
- 10% silt and clay;

The results of the moisture content and grain size distribution tests performed by EXP are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests performed by EXP are also provided on Figure 8 in Appendix D.

1.5.2 Bedrock

Bedrock was encountered beneath the clayey silt in borehole BH8-6, BH8-12, and BH8-13, below the native granular soil in boreholes BH8-1 and BH8-7, and below the cobbles and boulders in boreholes BH8-2, BH8-8 to BH8-10, and BH8-14. Elevations at the top of bedrock were between 287.1 m to 278.8 m. The bedrock was investigated by coring about 1.3 m to 4.2 m into the stratum. The bedrock surface depths and elevations encountered at these borehole locations are listed in Table 1.9. Photographs of the rock cores are included in Appendix E.

Table 1.9. Summary of bedrock

Borehole No.	Elevation ¹ (m)		Layer Surface Depth ² (m)
	Top	Bottom	
BH8-1	286.6	282.4	2.7
BH8-2	282.3	281.0	9.1
BH8-6	287.1	283.9	4.8
BH8-7	285.8	283.1	3.5
BH8-8	286.6	284.2	3.0
BH8-9	284.9	282.3	4.6
BH8-10	280.0	276.6	9.7
BH8-12	278.8	276.0	10.2

Borehole No.	Elevation ¹ (m)		Layer Surface Depth ² (m)
	Top	Bottom	
BH8-13	286.4	283.4	2.4
BH8-14	284.1	280.8	4.4

Notes:

1. The elevations are referenced from HCP 305.
2. Depths are relative to ground surface.

Based on the bedrock NQ cores (~ core diameter 47 mm) recovered, the bedrock at the site consisted of gneiss. In general, the rock samples are described as dark grey with pink/white in colour and moderately weathered to fresh. The Rock Quality Designation (RQD) measured on the core samples typically ranged from approximately 31% to 100%, indicating a rock mass of poor to excellent quality, but generally fair to excellent quality (as per CFEM). The total core recovery (TCR) of bedrock cores ranged from 77% to 100%.

1.6 Groundwater and Surface Water Conditions

All boreholes at this site were advanced using diamond coring procedures. Water was used during advancement of HQ casing and NQ cores from ground surface. Therefore, groundwater was not measured in open boreholes upon completion due to the drilling method.

The groundwater levels in the boreholes were observed in piezometers. The groundwater levels measured in piezometers installed in boreholes BH8-4 and BH8-10 are shown on the borehole logs and are presented below in Table 1.10.

Table 1.10. Groundwater levels measured in piezometers encountered at SW8

Borehole No.	Date Measured	Ground Surface Elevation ¹ (m)	Groundwater Depth ² /Elevation ¹ (m)
East Side of Embankment			
BH8-4	March 27, 2024	289.9	0.1/289.8
	April 2, 2024		0.1/289.8
	April 24, 2024		0.2/289.7
	May 15, 2024		0.2/289.7
	May 29, 2024		0.2/289.7
	June 18, 2024		0.2/289.7
West Side of Embankment			
BH8-10	April 24, 2024	289.7	1.1/288.6
	May 15, 2024		1.2/288.5
	May 29, 2024		1.2/288.5
	June 18, 2024		1.2/288.5

*Foundation Investigation and Design Report
Highway 11, 2+1 Roadway Model Project: **Site SW8**
Assignment No. 5021-E-0038
Date: October 24, 2024*

Notes:

- 1. The elevations are referenced from HCP 305.*
- 2. Depths are relative to ground surface.*

It should be noted that fluctuations in the level of the groundwater may occur due to seasonal variations, (precipitation, snowmelt, rainfall), local soil permeability, construction remediation activities, and other related factors.

2 ENGINEERING DISCUSSION & RECOMMENDATIONS

2.1 General

This section of the report provides geotechnical design recommendations for the design and construction of the proposed widening of Highway 11 at site SW8. Site SW8 is located approximately 5.5 km north of the intersection of Highway 64 and Highway 11 from approximately Station 19+950 to 20+235 in the Townships of Sisk and Station 10+000 to 10+015 in the township of Olive in the District of Nipissing, Ontario (Latitude: 46.798949; Longitude: -79.801547) in the Ministry of Transportation (MTO) Northeastern Region. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site performed by EXP between October 30, 2023, and April 25, 2024. The compiled factual data is presented in **Part I- Foundation Investigation Report** of this report. The interpretation and recommendations provided are intended solely for the design of the proposed embankment widening. Comments on construction are only provided to highlight issues that could affect the design. Contractors should make their own assessments of the factual data and how it might affect construction means and methods, scheduling and the like.

General Arrangement drawings for the embankment widening was not available at the time of preparing this report. It is unknown whether the highway will be widened on one side or both sides, but it is expected that the highway will be widened by up to approximately 7 m as per the TOR. Highway 11 at SW8 is sloped with an elevation ranging between approximately Elev. 292.0 m to 291.2 m from south to north at the centerline, as per the AutoCAD drawings provided by AECOM. The roadway embankment at SW8 could be up to 3.5 m above the existing ground on the west side and 2.8 m on the east side of the highway. It is also understood that the existing highway grade is planned to remain unchanged with respect to the original ground level.

This part of the report addresses the geotechnical design of the foundation for the proposed embankment widening by providing geotechnical design parameters at the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) as well as other geotechnical parameters that may be required in accordance with the latest edition of the *Canadian Highway Bridge Design Code (CHBDC) (CAN/CSA-S6-19)*, the *Canadian Foundation Engineering Manual (CFEM) (2023)*, *Guideline for MTO Foundation Engineering Services, Version 02 (October 2020) and Version 03 (April 2022)*, and generally accepted good practice. Pertinent construction issues from a geotechnical standpoint were examined in general accordance with the Terms of Reference. This section provides discussion and recommendations for the widening of the Highway 11 on the east and west side and construction considerations such as an assessment of slope stability and settlement of the widened embankments, site preparation, excavation, and frost depth.

2.2 Expected Ground Conditions

The following ground conditions along the proposed highway widening are evident from the current investigation:

- a) Highway 11 is a two-lane road (~ 8.5 m wide) with extended gravel shoulders (~3.2 m wide on the NBL/east side and 4.3 m on the SBL/west side). In total, the existing roadway with both shoulders included is about 16.0 m. Highway 11 is generally oriented in the north-south direction. The elevation of the centreline of the roadway is about Elev. 292.0 m to 291.2 m along SW8, sloping downwards from south to north. Both sides of the embankment were observed to be mostly comprised of gravel and/or grass with boulder-sized rockfill. Marshland was observed on both sides of the embankment with vegetation consisting primarily of large conifers and wild bushes. In general, the highway is founded on top of a built-up embankment while the natural terrain in the surrounding area is relatively flat.

- b) Below the pavement structure (borehole BH8-2, BH8-6, BH8-11), the highway embankment consists of cohesionless fill material comprising varying distributions of predominantly sand and gravel (~1.3 to 3.3 m thick) followed by rockfill consisting of cobble and boulder sized rock fragments in a silt, sand, and gravel soil matrix (BH8-2 and BH8-11, ~1.5 m to 2.5 m thick). The fill layers are underlain by native clayey silt (BH8-2 and BH8-6, ~1.4 m to 2.0 m thick) or native sand and gravel (BH8-11, ~2.3 m thick) followed by glacial till comprised of cobbles and boulders in a silt, sand, and gravel soil matrix (BH8-2 and BH8-11, ~3.1 m to 4.8 m thick) over bedrock.
- c) Along the west side of the highway beyond the toe of the existing embankment slope (boreholes BH8-8 to 10, and BH8-12 to 14) the subsurface conditions encountered consisted of topsoil (~0.075 to 0.225 m thick), followed by native clayey silt (~ 1.8 to 5.8 m thick) followed by a layer of glacial till comprised of cobbles and boulders in a silt, sand, and gravel soil matrix (~0.8 m to 2 m thick), underlain by bedrock encountered at about Elev. 278.8 m to 286.4 m. In BH8-12 and BH8-10 a layer of peat (~2.7 to 4.4 m thick) was encountered between topsoil and clayey silt.
- d) Along the east side of the highway beyond the toe of the existing embankment slope (boreholes BH8-1, BH8-3 to 5 and BH8-7), the subsurface conditions encountered consisted of topsoil (~0.15 m to 0.760 m thick), followed by peat (~ 2.6 to 5.5 m thick), followed by clayey silt (~3.9 m to 7.9 m thick) underlain by bedrock at about Elev. 274.3 m to 279.9 m. The layer of peat was not encountered below the topsoil in BH8-7 and BH8-1. In these boreholes the topsoil is followed with native clayey silt (~0.6 m to 2.4 m thick) and gravelly sand to sandy gravel (~ 0.9 m to 1.9 m thick) underlain by bedrock at about Elev. 285.8 m to 286.6 m.
- e) At the site, the bedrock surface is unevenly slopping in different directions. Bedrock outcrops were observed on the north and south end of the site beyond the extent of the boreholes.
- f) Water was used during advancement of cores from the ground surface; therefore, groundwater was not measured in boreholes due to the drilling method. The groundwater level on the east side of the embankment observed in the piezometer installed in borehole BH8-4 was 0.1 m below ground surface (~Elev. 289.8 m) on April 2, 2024, while the groundwater level on the west side measured in the piezometer installed in borehole BH8-10 was 1.1 m below ground surface (~Elev. 288.6 m) on April 24, 2024.

2.3 Site Considerations

2.3.1 Construction/Mitigation Options

Considering the soil conditions encountered at the site (i.e. peat layer up to 5.5 m thick) it is assessed that the new embankment widening material cannot be supported by the existing foundation soil unless the conditions are improved. Table 2.1 summarizes construction/mitigation options which have been considered for soil improvement within the footprint of the widening fill necessary to be done to proceed with construction of the new fill. The table shows advantages, disadvantages, risk, relative cost and ranking for each option.

Among these options, the option of excavation of peat and other weak/soft soils within the footprint of the widening fill and its replacement with more competent soils (i.e. rockfill) is recommended as the most practical and economical at this site. Soil improvement using stone columns is also feasible at the site, but that option is assessed as more costly. The other options listed in Table 2.1 were assessed as impractical at the site and/or very expensive.

Table 2.1. Considered construction/mitigation measures

Mitigation Technique		Advantages	Disadvantages	Risk	Relative Cost	Ranking
Sub-excavation and replacement of peat/organic material	Excavate peat/organic material up to 5.5 m within the widening footprint and place rock fill	<ul style="list-style-type: none"> • Strengthening the soil within the footprint • Steeper side slope (1.25H:1V) is possible, smaller footprint, less material • Ability to place under water • Increase stability for appropriately defined process and sequence. • Straightforward construction • Use of available fill material • More control of construction 	<ul style="list-style-type: none"> • During excavation the stability of existing embankment could be jeopardized. Special Provisions required defining staged construction and sequence to be followed. • Requires deep excavation. • Need more material. Assume rock fill; need to define placement approach. • Later settlement of Fill itself 	Moderate with appropriate approach	Low to Moderate	1
	Stone columns	<ul style="list-style-type: none"> • Possible one single stage construction • Less settlement 	<ul style="list-style-type: none"> • Require specialty construction methodology 	Moderate	High	2
	Vacuum Consolidation	<ul style="list-style-type: none"> • Speed up the consolidation 	<ul style="list-style-type: none"> • Requires specialty construction methodology • Very difficult to install in swampy area • Difficult to maintain vacuum 	High	Very High	N/A
Ground Improvement	Electroosmotic Treatment	<ul style="list-style-type: none"> • Speed up the consolidation 	<ul style="list-style-type: none"> • Require specialty construction methodology • Very difficult to install electrodes through rock fill • Limited application 	High	Very High	N/A

Mitigation Technique	Advantages	Disadvantages	Risk	Relative Cost	Ranking
Chemical Grouting/Deep Mixing	<ul style="list-style-type: none"> • Increase soil strength 	<ul style="list-style-type: none"> • Soil type • Expensive • Can cause ground heave 	High	High	N/A
Vibro Compaction	<ul style="list-style-type: none"> • An effective treatment for soft/weak soils at depths of 2m > 20m. • Optimised and localised treatment solution for different soils • Highly economical and often results in greater time savings • Reduces the risk of seismically induced liquefaction • Minimal noise and vibration • Allows high production rates being quicker to complete than piling 	<ul style="list-style-type: none"> • Vibro-compaction is only effective on granular and non-cohesive soils • Densification generally cannot be achieved when the granular soil contains more than 12-15% silt or more than 2% clay • A comprehensive analysis of the soil profile is needed with continuous sampling or in-situ testing • Not suitable for sites with contaminated land if vibratory techniques use water jetting 	High	Moderate to High	N/A

2.3.2 Frost Depth

The frost depth within the SW8 site area is estimated to be approximately 2.1 m in accordance with OPSD 3090.100.

2.3.3 Seismic Hazard Site Classification and Values

Seismic characterization of the site should be compliant with the CHBDC. The potential for seismic loading must be considered for design in accordance with Section 6.14.7 of the CHBDC with respect to the soil conditions encountered at the site. Table 4.1 of the CHBDC shows site classification for seismic site response based on average soil properties in the top 30 m.

At this site, the subsoil conditions below the roadway generally consists of gravelly sand to sandy gravel fill, followed by native clayey silt and/or sand and gravel, followed by glacial till comprised of cobbles and boulders in a silt, sand, and gravel soil matrix underlain by bedrock encountered between Elev. 287.1 m to 282.3 m. The subsoil conditions at the bottom of the embankment generally consists of topsoil underlain by peat and/organic silt, followed by clayey silt and then by gravelly sand to sandy gravel and/or glacial till comprised of cobbles and boulders in a silt, sand, and gravel soil matrix. During the fieldwork, the groundwater level was measured at about Elev. 289.8 m in the piezometer on the east side of the embankment (BH8-4) and Elev. 288.6 m on the west side of the embankment (BH8-10). Based on the soil characteristics, the site class for this site is estimated to be Class “D” according to Table 4.1 of the CHBDC.

From the Natural Resources Canada website, 2020 NBC seismic hazard values are obtained using the site location coordinates and the site-adjusted damped reference spectral accelerations for the project site are shown in Table 2.2 below:

Table 2.2. Seismic design values

Probability of Exceedance in 50 Years (Return Period)	Sa(0.2) (g) ¹	Sa(0.5) (g)	Sa(1.0) (g)	Sa(2.0) (g)	PGA (g)
Latitude: 46.798949; Longitude: -79.801547					
2% (1 in 2475-year)	0.418	0.363	0.21	0.0982	0.256

Note:

1. g = acceleration due to gravity (9.81 m/s^2)

These values are associated with an earthquake having a 2% probability of exceedance in a 50-year period (1 in 2475-year) for Site Class D and is also shown on the seismic hazard calculation data sheet for this site attached in Appendix H.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the reference peak ground acceleration (PGA_{ref}). Since $Sa(0.2)/PGA$ is less than 2.0 at this site, PGA_{ref} is equal to $0.8 \cdot PGA = 0.205 \text{ g}$, as per section 4.4.3.3. of the CHBDC (CAN/CSA-S6-19). The site coefficient $F(PGA)$, for this site (Seismic Site Class D and $PGA_{ref} = 0.205 \text{ g}$) is 1.1.

2.3.4 Liquefaction Potential

Liquefaction of cohesionless soils below the groundwater table, including the native clayey silt, gravelly sand to sandy gravel and glacial till layers at the project site was evaluated through the SPT-based liquefaction triggering procedures described in Boulanger and Idriss (2014) using the site's $PGA = 0.256g$ (1 in 2475-year event).

SPT 'N' values within the native clayey silt were measured to be between the weight of the SPT hammer and/or weight of the drilling rods to 18 blows per 0.3 m penetration beyond the toe of the west side of the existing embankment (at depths ranging between about 0.1 m to 4.4 m below ground), between 4 and 7 blows per 0.3 m penetration beneath the existing embankment (at depths ranging between about 3.4 m to 4.0 m below ground), and between the weight of the SPT hammer to 17 blows per 0.3 m penetration beyond the toe of the east side of the existing embankment (at depths ranging between about 0.2 m to 5.5 m below ground).

SPT 'N' values of the native gravelly sand to sandy gravel were measured to be between 6 and 49 blows per 0.3 m penetration below the existing embankment (at a depth of 3.0 m below ground) and between 18 to over 100 blows per 0.3 m penetration beyond the toe of the east side of the existing embankment (at depths ranging between about 0.8 m to 2.6 m below ground).

Susceptibility to seismically induced liquefaction is not expected to significantly impact the overall project design due to the presence of shallow bedrock and low seismic risk.

2.4 Embankment

2.4.1 General

Based on the information provided to EXP by AECOM, the existing highway grade is planned to remain unchanged with respect to the original ground level. Widening will be completed on both sides of the highway with a total widening of up to approximately 7 m as per the TOR.

The geometry analyzed in this report is defined based on EXP's geotechnical investigation and observations at the site. Based on the existing surrounding ground level and Highway 11 surface profile, it appears the construction of the widened embankment could require placement of approximately 1.7 m to 3.5 m of fill above existing ground on the west side and 1.1 m to 2.8 m on the east side of the highway, assuming the natural terrain at the toe is flat along SW8. However, the geometry of the embankment and surrounding terrain (bottom of embankment) will be confirmed once the cross-sections of the highway embankment at SW8 are available.

Design analyses and recommendations for the embankment widening have been carried out using rockfill in accordance with OPSD 202.010, OPSD 203.010, and OPSD 203.030, since the existing embankment materials consist primarily of rockfill. The side slopes of rockfill should not be steeper than 1.25H:1V.

The design of embankment widening through the swampy area should allow for sub-excavation of peat/organic soils. Based on the results of the current investigation the thickness of peat/organic soils at the west side was encountered to be up to 5.5 m. However, the thickness of peat/organic soils below the new embankment footprint could vary between these locations.

2.4.2 Stability Considerations

Preliminary slope stability analyses were performed to assess the global stability of the new embankment to check if a minimum Factor of Safety of 1.5 for static and 1.1 for seismic conditions is achieved as per MTO criteria for typical degree of understanding. The static and seismic slope stability analyses were performed using the Morgenstern-Price method developed on the basis of limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

The stratigraphy and groundwater conditions at the site were developed based on the results of the geotechnical investigation presented in Part I – Foundation Investigation Report. The parameters were selected based on the empirical correlations with SPT and engineering judgement for the effective stress assessments. For cohesive deposits, in situ vane testing and empirical correlations with SPT results and other pertinent laboratory testing results were employed to select parameters. Corrections developed by Bjerrum for in situ vane tests were considered. Peat friction angle and undrained shear strength (including recommended strength reductions) were employed based on correlations from Mesri & Ajlouni (2007). The seismic properties given in Appendix H (Section 2.3.3) were obtained from the Natural Resources Canada website, 2020 NBC, using the site location coordinates. Tabulated below in Table 2.3 are the soil parameters used for the slope stability analyses. Station 19+950 on the west side, where the embankment is approximately the highest, and Station 20+050 on the west, where the thickest layer of peat and very soft to soft clayey silt was encountered in boreholes were selected as the critical cases for slope modelling.

Table 2.3. Soil properties used in slope stability analyses

Material Type	Effective Stress Parameters ϕ' (degrees)	c' (kpa)	Undrained Shear Strength, C_u (kPa)	γ (kN/m ³)
Existing Sand and Gravel Fill (Compact to Very Dense)	34	-	-	21
Existing Rockfill	40	-	-	18
New Rockfill	42	-	-	18
Peat	23	-	7	14
Clayey Silt (Soft) ¹	25	-	15	19
Clayey Silt (Firm to Very Stiff) ¹	30	-	50	20
Clayey Silt (Soft to Very Soft) ²	25	-	15	19
Clayey Silt (Firm to Stiff) ²	29	-	40	20
Cobbles and Boulders	36	-	-	18
Bedrock	Impenetrable			

Notes:

1. Material at Station 19+950, west side of existing embankment
2. Material at Station 20+050, west side of existing embankment

Based on the borehole information, the subsoils encountered at the work area consist of cohesionless fill and native cohesive and cohesionless soils above the bedrock. Therefore, total stress (undrained conditions) analyses for a short-term assessment and effective stress (drained conditions) analyses for a long-term assessment of the slopes were performed taking into consideration the subsoil conditions encountered at the site. The analyses assume that all peat/organic material will be removed prior to construction. In addition, a traffic surcharge pressure of 16 kPa was adopted in the slope stability assessments. Table 2.4 summarizes the results of performed slope stability analyses. The SLOPE/W graphical printouts for the analyses are included in Appendix F (Figures F1 – F6).

Table 2.4. Summary of results of embankment slope stability analyses

Location	Max Height (m)	Conditions	Min FOS
West Side, Station 19+950 (1.25H:1V)	~3.5	Undrained short-term conditions, static condition	2.0 (Figure F1)
		Drained long-term conditions, static condition	1.7 (Figure F2)
		Drained long-term conditions, seismic condition	1.4 (Figure F3)
West Side, Station 20+050 (1.25H:1V)	~3 m	Undrained short-term conditions, static condition	1.5 (Figure F4)
		Drained long-term conditions, static condition	1.7 (Figure F5)
		Drained long-term conditions, seismic condition	1.2 (Figure F6)

As seen in Table 2.4, embankment widening of Highway 11 using rockfill with 1.25H:1V side slopes can be considered stable for static and seismic conditions (i.e., calculated FOS > 1.5 for static and FOS > 1.1 for seismic with $k_h = 0.5 \cdot F(PGA) \cdot PGA = 0.128 \text{ g}$), assuming that all loose soils and any organic material are excavated and replaced with properly compacted rockfill. Additionally slope stability analyses and design commentary may be required for the embankment once cross-sections at SW8 are available.

2.4.3 Settlement Considerations

2.4.3.1 General

Based on the post-construction settlement criteria for embankment widening stipulated in MTO's "Embankment Settlement Criteria for Design", the maximum settlement limits during the pavement design life of the widened embankment are 75 mm for the total settlement and 100:1 for the differential settlement rate for non-freeways (i.e. including this segment of Highway 11). The differential settlement rate is applicable to both the new widened embankment and the differential settlement rate between the existing and the new embankment. The settlement across the widened embankment shall transition uniformly from the widening point (existing highway embankment rounding) to the new embankment rounding such that surface drainage is not impeded. Although a portion of the total estimated settlement is expected to occur post-construction, the differential movements should be able to be accommodated during the paving process and an appropriate delay between embankment construction and final paving.

To assess if the new constructed embankment at the site will meet the above criteria, the settlement of foundation soil below the new embankment footing and the settlement of widened embankment itself were estimated for comparison. The following sections include the method and results of these settlement analyses, as well as discussion about the total predicted settlement relative to the MTO criteria.

2.4.3.2 Settlement of Foundation Soils

Fill to be placed on native soils for the new embankment widening will induce some settlement of the foundation soils (clayey silt). Therefore, settlement analyses were carried out to calculate the predicted settlement considering the construction of the rockfill embankment at the site.

Station 20+050 on the west and east side of the existing Highway 11 embankment was considered the critical section at the site in terms of settlement magnitude considering the height of the existing embankment and the largest thickness of organics (peat/organic silt) and very soft to soft clayey silt underneath. The settlement analyses were performed with an approximate 2.7 m and 2.5 m high embankment above the existing ground at the west side and east side at that station, respectively, assuming the peat/organics and loose/deleterious material are entirely removed below the widened embankment footprint. It is estimated that roughly 4.4 m and 5.5 m of excavation is required to remove all the organic material resulting in the total of 7.1 m and 8.0 m thickness of new fill on the west and east side, respectively.

A computer program, Settle3D (Rocscience) was employed for settlement calculation of foundation soils due to construction of new embankment/widening at the site. Settle3D is a 3-dimensional program for the analysis of immediate and consolidation settlement (if any) under foundations, embankments and surface loads. The program combines the simplicity of one-dimensional analysis with the power and visualization capabilities of more sophisticated three-dimensional programs.

A representative site stratigraphy was developed based on the Record of Borehole logs with material properties based on the results of in-situ field testing and laboratory testing. The magnitudes of total (consolidation) settlement for the new embankment/widening fill have been assessed based on Standard Penetration Test (SPT) and field vane shear test results. The parameters used in the settlement analyses are summarized in Table 2.5 below. These parameters were estimated using empirical relationships with measured soil properties at the site and the available data in EXP and MTO libraries obtained in the area.

Table 2.5. Soil strength parameters used in settlement analyses

Material Type	γ (kN/m ³)	C_c	C_r	P_c (kPa)	e_0	C_v (cm ² /s)
West Side of the Existing Embankment						
Clayey Silt (Very Soft to Soft)	19	0.25	0.05	80	0.60	0.03
Clayey Silt (Firm to Stiff)	20	0.19	0.038	120	0.55	0.03
East Side of the Existing Embankment						
Clayey Silt (Very Soft to Soft)	19	0.24	0.048	80	0.60	0.03
Clayey Silt (Firm to Stiff)	20	0.17	0.034	120	0.55	0.03

The summary of results of settlement analyses is given in Table 2.6. The Settle 3D results of these cases can be seen in Figures 1 and 2 in Appendix G. The estimated total settlement under the widened portion of the embankment could range from 5 mm to 58 mm from the center to the edge of the widened embankment at the west side, and 8 mm to 45 mm from the center to the edge of the widened embankment at the east side assuming that the peat/organic silt is completely removed. Considering the type of foundation soils, the estimated settlements are expected to be mostly consolidation settlement; the immediate settlement is estimated to be negligible.

Table 2.6. Results of settlement analyses

Location	Embankment Type	Calculated Total Settlement of Foundation Soils at Widened Portion (mm) ¹			Differential Settlement between Edges of Existing and New Embankment (mm)
		At Hwy 11 Centerline	At Edge of Existing Embankment	At Edge of Widened Embankment	
West Side of Existing Embankment (Sta. 20+050)	Rockfill ²	5	37	58	21
East Side of Existing Embankment (Sta. 20+050)		8	34	45	11

Notes:

1. Total settlement at 2 years after construction. Due to the nature of cohesive foundation soils below the water table the immediate settlement is considered negligible.
2. Unit weight of rockfill above the existing ground is assumed to be 18 kN/m^3 , while below the existing ground level within the peat subexcavation the unit weight of rockfill was reduced by the unit weight of peat ($18 \text{ kN/m}^3 - 14 \text{ kN/m}^3 = 4 \text{ kN/m}^3$)

As noted in Table 2.6, the differential settlement between edges of existing and new widened portion of embankment is estimated to be about 21 mm and 11 mm. It is expected that this difference will be even less at the time of paving (i.e., the time of paving is not known at this stage of writing the report, but it is reasonable to assume that it will be occurred 4 to 6 months after the construction of widened embankment). This settlement will be accompanied by settlement of the embankment itself. These magnitudes were estimated in the section below.

2.4.3.3 Settlement of Embankment Fill

The fill is also expected to experience some settlement. It is estimated that the embankment itself will compress by about 0.5 to 1 percent of the embankment height under its self-weight, depending on material type and assuming placement as per MTO practices. More granular material fills would compress less and over a shorter time, typically within the period of embankment construction.

Settlement in rockfill embankments is associated with the crushing of points of contact and rearrangement of rock fragments under the load or a change in moisture content. If groundwater rises, poorly compacted, unsaturated rockfill is likely to be susceptible to more settlement. The magnitude of settlement manifested in this form depends on the type and nature of the rockfill, the thickness of the rockfill, gradation, the method of construction (i.e. below the water level – dumped rockfill and above the water level- compacted rockfill) and subgrade conditions.

Generally, for rockfill embankments constructed on compressible soils and non-compressible soils, the MTO Guideline Rock Fill Settlement and Rock Fill Quantity Estimates Dated September 14, 2010 should be followed. Table 2.7 presents the short-term settlements (i.e., within about 1 year following completion of construction to full height) and long-term settlements (i.e., after 1 year, over the life of the embankment) provided in this guideline in terms of the relative embankment height for compacted and dumped rockfills. For rock fill embankments built on a

compressible subgrade, the estimated settlement must account for both the compression of the rock fill (short-term and long-term, as described above) in addition to the settlement of the compressible foundation soils.

At the site the rockfill is assumed to be predominantly placed on a compressible clayey silt layer after the peat/organics is removed. However, it is anticipated that a portion of the widened embankment may be placed over non-compressible gravelly sand/sand and gravel/sandy gravel. Therefore, where the embankment is placed on non-compressible soil, the occurrence of settlement because of rock particles in the short or long term will be negligible or would not exceed the amounts in Table 2.7. Where the embankment is placed on compressible soil, the settlement of the soil should be added to the total anticipated settlement. Table 2.7 provides estimates for compacted rockfill. However, it is expected that the rockfill placed below the water table (i.e., not compacted) will settle more, and likely twice the values for compacted rock fill.

Table 2.7. Short and long term rockfill settlement as per MTO Guideline Rock Fill Settlement and Rock Fill Quantity Estimates

Height of Rock Fill, H (m)	Compacted Rock Fill	
	Short-term Settlement ¹ (m)	Long-term Settlement (m)
Up to 5	0.5% H	-
>5 to 10 ²	0.75% H	-
>10 to 15	1.0% H	-
>15	-	0.1% H

Notes:

1. Approximately 90% of the short-term settlement may be expected to be complete within 6 months following construction to full height.
2. This case is applicable to SW8.

For removal of peat/organics below the embankment widening footprint, it is estimated that 7.1 m and 8.0 m of new fill on the west and east side, respectively, will be required. The settlement of the rockfill itself based on Table 2.7 is estimated to be approximately 53 mm on the west side and 60 mm on the east side.

The surcharge load from the weight of the new fill is about 70 kN/m² where the thick layer of very soft to clayey silt is present. The ultimate bearing capacity of the clayey silt layer (i.e., assuming that peat/organics will be completely excavated) is higher than the estimated surcharge load, and no failure against bearing capacity is anticipated because of embankment widening.

2.4.3.4 Discussion of Settlement Results

As per Section 2.4.3.2, widening along the west side is estimated to cause 37 mm at the edge of the existing embankment and 58 mm at the edge of the widened embankment indicating a post-construction differential settlement of 21 mm of the foundation soils. Widening along the east side is estimated to cause 34 mm at the edge of the existing embankment and 45 mm at the edge of the widened embankment indicating a post-construction differential settlement of 11 mm of the foundation soils. Given the nature of these soils (cohesive soils below the

groundwater table), this magnitude of settlement will primarily be consolidation occurring after construction of the embankment widening. The total differential post-construction settlement between the edge of existing and widened embankment, including settlement of the rockfill itself, could be up to ~75 mm on the west side and ~70 mm on the east side which meets the MTO Embankment Settlement Criteria for Design maximum limit of 75 mm for embankment widening.

2.5 Construction Considerations

2.5.1 Excavation

All excavations must be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety (OHSA) and good construction practice.

Temporary excavation side slopes through peat/organic soil shall be in accordance with the OHSA, OPSD 203.010 (Embankments Over Swamp; New Construction) and/or OPSD 203.030 (Embankments Over Swamp; Existing Slope Maintained). The peat/organic soil encountered in the lower area can be classified as Type 4 soil using OHSA classification, as it is usually deposited below the groundwater table. Type 4 soils must be sloped 3H:1V or flatter. The existing fill and native soils are considered as Type 3 soils above the groundwater table and Type 4 soils below the groundwater table. Temporary excavations in those soils (i.e., those that are open only for a short period) above the groundwater table may be made with side slopes not steeper than about 1H:1V, while the temporary slopes below the groundwater table must be formed at 3H:1V.

Excavation of the soils at the project site may be carried out using conventional excavation equipment. During excavation, no excavated material should be piled close to the top of excavated slope. All excavated surfaces should be kept free from frost. In addition, runoff and surface flow shall be directed away from open excavations.

It is recommended that a NSSP be included in the Contract Documents to warn the Contractor of the presence of peat/organic deposits along the lower area as well as about its excavation and backfilling with new fill. The NSSP is attached in Appendix J to 'red flag' this issue.

2.5.2 Subgrade Preparation

Prior to construction of the embankment widening, the site will need to be cleared and grubbed of any existing bushes, trees, and vegetation. All surficial topsoil, peat, organics, existing fill, and softened or loosened soils should be sub-excavated from below the proposed widening footprint. Considering the findings at the site, the anticipated sub-excavation depths/elevations at the borehole locations are presented in Table 2.8.

Table 2.8. Anticipated sub-excavation depths/elevations at borehole locations

Location	Borehole No.	Existing Ground Elevation at Borehole Location (m)	Recommended Stripping Depth/Excavation (m)
East Side	BH8-1	289.3	0.8/288.5

Location	Borehole No.	Existing Ground Elevation at Borehole Location (m)	Recommended Stripping Depth/Excavation (m)
	BH8-3	290.3	3.4/286.9
	BH8-4	289.9	5.3/284.6
	BH8-5	289.2	5.5/283.7
	BH8-6	289.3	0.8/288.5
West Side	BH8-8	289.6	0.8/288.8
	BH8-9	289.5	1.5/288.0
	BH8-10	289.7	2.8/286.9
	BH8-12	289.0	4.4/284.6
	BH8-13	288.8	0.8/288.0
	BH8-14	288.5	0.8/287.3

The top layer of peat/organics shall be excavated along the whole footprint of the new embankment widening in accordance with OPSP 203.030 (i.e., widening of existing embankment) which is attached in Appendix I.

The stabilized groundwater is expected to be near the ground surface based on the readings in the piezometers and the observed surface water.

2.5.3 Embankment Construction

The removal of peat/organic deposits within the proposed footprint and backfilling of the excavation shall be carried out simultaneously in accordance with OPSS.PROV 209. Rockfill can be used as a backfill for embankments 1.2 m or higher given that the largest dimension should be limited to 0.5 m (NSSP should be included in the Contract Document; an example is provided in Appendix J). If the embankment is lower than 1.2 m, the embankment should be constructed from engineered fill consisting of Granular A or Granular B Type II. As mentioned before, the example of NSSP for excavation of peat/organic material and backfilling is also attached in Appendix J. Excavations should be carried out in accordance with Ontario Regulation 213 with appropriate traffic control as applicable.

Based on the boreholes advanced in the area, it is recommended to sub-excavate up to 5.5 m below grade to remove the soft/loose soils 1 m beyond the toe of the footprint of new widened embankment. The Contractor should not over excavate beyond the depth required to remove the peat/organic material (i.e., if only 1 m of peat/organic material is present, the sub-excavation can stop at that depth). It is recommended to sub-excavate and backfill with rockfill simultaneously up to water level near the toe and be carried out as a continuous operation in limited strip lengths up to 10 m (perpendicular to highway), dividing each strip in half and excavating/backfilling from outside to inside as shown in Appendix J. As per OPSS.PROV 209, compaction of the rockfill is not a requirement until at least 600 mm above water level. Thus, water entering the sub-excavation is not anticipated to be a major concern.

Grading and embankment construction with material placed after the backfill material should be conducted in accordance with OPSS.PROV 206 and OPSS.PROV 501. Except for the top 1.0 m, where a pavement structure should be placed, the embankment fills should consist of an approved rockfill. Rock embankments shall be constructed by placing embankment materials full width in successive uniform layers. As per OPSS.PROV 206, layers of rock embankment should not exceed 1.5 m thickness prior to construction. Material in each layer should be fully compacted prior to the succeeding layer is placed. Each rockfill layer should be compacted with a tractor bulldozer with a minimum number of complete passes of 6 and the maximum passes of 8. A complete pass should be defined as 100% coverage of layer surface. Quality assurance should be provided as per MTO standard 501.08 (OPSS.PROV 501). Inspection and field density should be carried out by qualified personnel during placement operations to ensure that appropriate materials are used and that adequate levels of compaction have been achieved.

In accordance with OPSD 202.010, embankment fill materials used for highway widening should be properly benched into the existing embankment and compacted where the existing embankment is comprised of earth fill. However, if the benching is impractical at this site, then the surface of the existing rockfill side slopes to be widened should be scratched to remove any soil/vegetation to provide a good bond between the existing rockfill and the rockfill placed for the widening.

Adequate chinking at the top of the rockfill should be provided before the placement of Granular B Type II for the pavement. The objective of chinking of rockfill exposed to the subgrade level is to form a dense, compact mass which reduces the potential migration of surrounding soils into the existing rockfill which could cause future settlement/soil movements/sinkholes. Alternatively, a suitably robust geotextile can be placed for separation purposes. Transitions between earth fill and rockfill or granular fill, if any, should be constructed in accordance with OPSD 205.040.

2.5.4 Platform Widening

Northern Region Engineering Directive NRE98-200, indicates that there may be need for future road grade raise to restore design alignment, due to compression/settlement of the embankment fill, and the foundation soils, and to address future pavement overlays up to 200 mm thick. Platform width if unaltered, may then result in substandard shoulders. Practical and economic considerations indicate that overbuild at original construction is the preferred approach.

The requirement for widening on each side is based on compression/settlement of the embankment fill, the estimated consolidation settlement of founding soils including long term creep and the 200 mm pavement overlay allowance, multiplied by the horizontal component of the side slope of the pavement structure and the minimum set by NRE-98-200 in swamp environments, (2 m per side, for Highway 11). The minimum requirements noted can be waived for cases of full excavation to bedrock and backfill with granular. For the embankments proposed the minimum requirements under NRE-98-200 of 2 m would apply.

2.5.5 Site Dewatering

Since excavation of peat/organics within the footprint will be executed in sections parallel to the existing highway approximately 3 m to 5 m wide sections and then immediately backfilled with rockfill (see attached NSSP – Excavation of Peat/Organics and Backfilling in Appendix J). Placement of rockfill should be extend to about 0.6 m above the water level and compacted. Therefore, it is anticipated that dewatering will not be required. During construction, all surface water must be directed away from the excavations.

3 CLOSURE

The recommendations made in this report are in accordance with our present understanding of the project and are provided solely for the team responsible for the design of the works described herein.

We recommend that we be retained to review our recommendations as the design nears completion to ensure that the final design is in agreement with the assumptions on which our recommendations are based and that our recommendations have been interpreted as intended. If not accorded this review, EXP will assume no responsibility for the interpretation and use of the recommendations in this report.

A subsurface investigation is a limited sampling of a site; the subsurface conditions have been established only at the test hole locations. Should conditions at the site be encountered which differ from those reported at the test locations, we require that we be notified immediately in order to assess this additional information and our recommendations, as appropriate. It may then be necessary to perform additional investigations and analyses.

Contractors bidding on or undertaking any proposed work at this site should, relative to the subsurface conditions, decide on their own investigations, if deemed necessary, as well as their own interpretations of the factual results provided herein, so they may draw their own conclusions as to how the subsurface conditions may affect them.

This Foundation Investigation and Design Report has been prepared by Daniel Mroz, M.E.Sc., EIT, and Silvana Micic, Ph.D., P.Eng. It was reviewed by TaeChul Kim, M.E.Sc., P.Eng. and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was supervised by Daniel Mroz, M.E.Sc., EIT, Elvis Lu, M.Eng., Stephen Fredericks, M.Eng, P.Eng., and Amirhossein Medghalchi, M.Sc., M.Eng., EIT.

EXP Services Inc.



Daniel Mroz, M.E.Sc., EIT
 Technical Specialist



Silvana Micic, Ph.D., P.Eng.
 Senior Geotechnical Engineer
 Project Manager




TaeChul Kim, M.E.Sc., P.Eng.
 Senior Geotechnical/Foundation Specialist



Stan E. Gonsalves, M.Eng., P.Eng.
 Principal Engineer
 Designated MTO Foundation Contact



REFERENCES

- Boulanger, R. W. and Idriss, I. M., 2014. CPT and SPT based liquefaction triggering procedures. Department of Civil and Environmental Engineering, College of Engineering, University of California at Davis.
- Canadian Geotechnical Society, 2023. Canadian Foundation Engineering Manual, 5th Edition. The Canadian Geotechnical Society, British Columbia.
- Canadian Standards Association (CSA), 2019. Canadian Highway Bridge Design Code and Commentary on CAN/CSA-S6-19. CSA Special Publication.
- Mesri, G. and Ajlouni, M., 2007. Engineering Properties of Fibrous Peats. Journal of Geotechnical and Geo-environmental Engineering Volume 133, Issue 7.
- Ministry of Northern Development and Mines, Map 2555. Quaternary Geology of Ontario, East-Central Sheet, 1991
- Ministry of Northern Development and Mines Map 2543. Bedrock Geology of Ontario, East-Central Sheet, 1991
- Ministry of Transportation, July 2, 2010. Embankment Settlement Criteria for Design
- Ministry of Transportation, April 2022. Guideline for MTO Foundation Engineering Services, Version 03

ASTM International:

ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Ontario Provincial Standard Specifications (OPSS):

OPSS.PROV 206 Construction Specification for Grading

OPSS.PROV 209 Construction Specification for Embankments Over Swamps and Compressible Soils

OPSS.PROV 501 Construction Specification for Compacting

Ontario Provincial Standard Drawings (OPSD):

OPSD 202.010 Slope Flattening Using Excess Material on Earth or Rock Embankment

OPSD 203.010 Embankment Over Swamp; New Construction

OPSD 203.030 Embankments Over Swamp; Existing Slope Maintained

OPSD 205.040 Transition Treatment, Earth Fill to Rock Fill, and Earth Fill to Granular Fill

OPSD 3090.100 Foundation Frost Penetration Depths for Northern Ontario

Ontario Water Resources Act:

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

Ontario Occupational Health and Safety Act (OHSA):

Ontario Regulation 213/91 Construction Projects

LIMITATIONS AND USE OF REPORT

BASIS OF REPORT

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of EXP may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by EXP. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and EXP's recommendations. Any reduction in the level of services recommended will result in EXP providing qualified opinions regarding the adequacy of the work. EXP can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the borehole results contained in the Report. The number of boreholes necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to EXP to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

RELIANCE ON INFORMATION PROVIDED

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to EXP by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. EXP has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions,

misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to EXP.

STANDARD OF CARE

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment form part of the Report. This material includes, but is not limited to, the terms of reference given to EXP by its client ("Client"), communications between EXP and the Client, other reports, proposals or documents prepared by EXP for the Client in connection with the site described in the Report. In order to properly understand the suggestions, recommendations and opinions expressed in the Report, reference must be made to the Report in its entirety. EXP is not responsible for use by any party of portions of the Report.

USE OF REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. No other party may use or rely upon the Report in whole or in part without the written consent of EXP. Any use of the Report, or any portion of the Report, by a third party are the sole responsibility of such third party. EXP is not responsible for damages suffered by any third party resulting from unauthorised use of the Report.

REPORT FORMAT

Where EXP has submitted both electronic file and a hard copy of the Report, or any document forming part of the Report, only the signed and sealed hard copy shall be the original documents for record and working purposes. In the event of a dispute or discrepancy, the hard copy shall govern. Electronic files transmitted by EXP have utilized specific software and hardware systems. EXP makes no representation about the compatibility of these files with the Client's current or future software and hardware systems. Regardless of format, the documents described herein are EXP's instruments of professional service and shall not be altered without the written consent of EXP.

Appendix A – Site Photographs



Photograph 1. Roadway surface and shoulder, embankment side slope, and ground conditions beyond embankment toe along NBL (east) side, looking north (April 22, 2024)



Photograph 2. Embankment side slope and ground conditions beyond embankment toe along SBL (west) side for north half of SW8, looking north (March 27, 2024)



Photograph 3. Embankment side slope and ground conditions beyond embankment toe along SBL (west) side for south half of SW8, looking south (March 27, 2024)



Photograph 4. Rockfill along west (SBL) side of embankment approximately between BH8-12 and BH8-13, looking southwest (March 27, 2024)



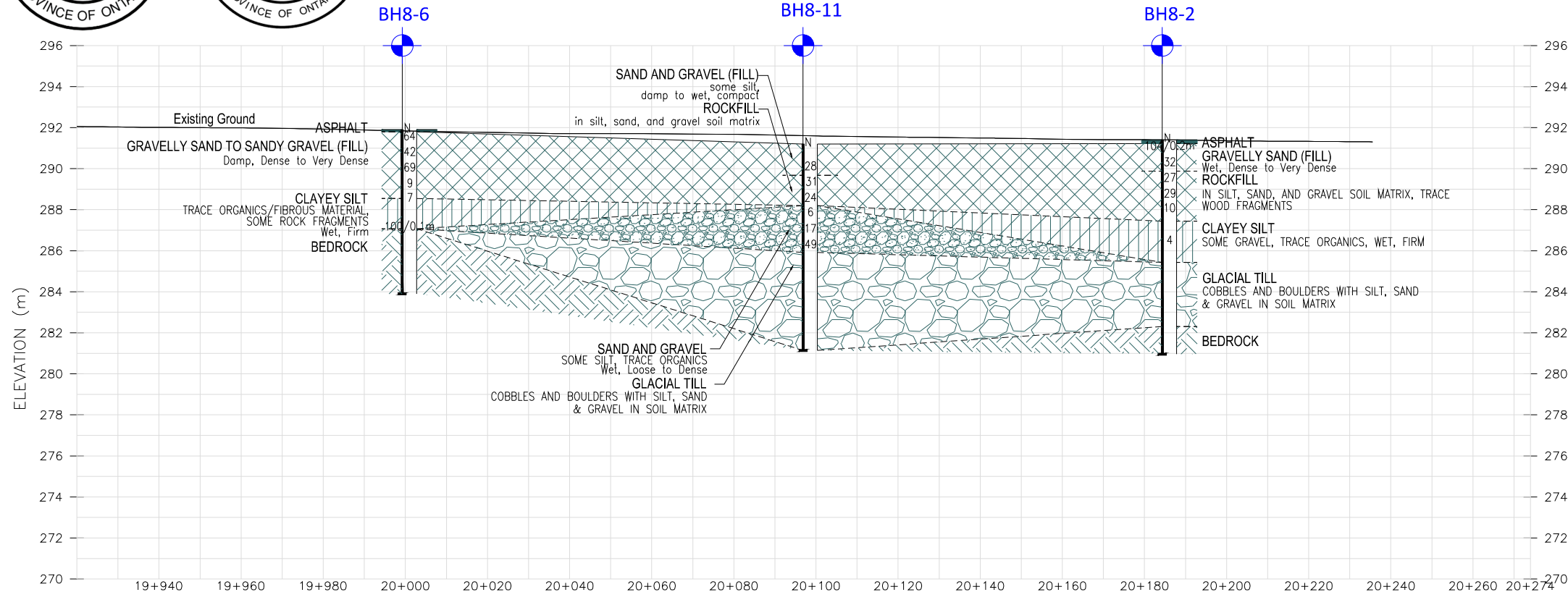
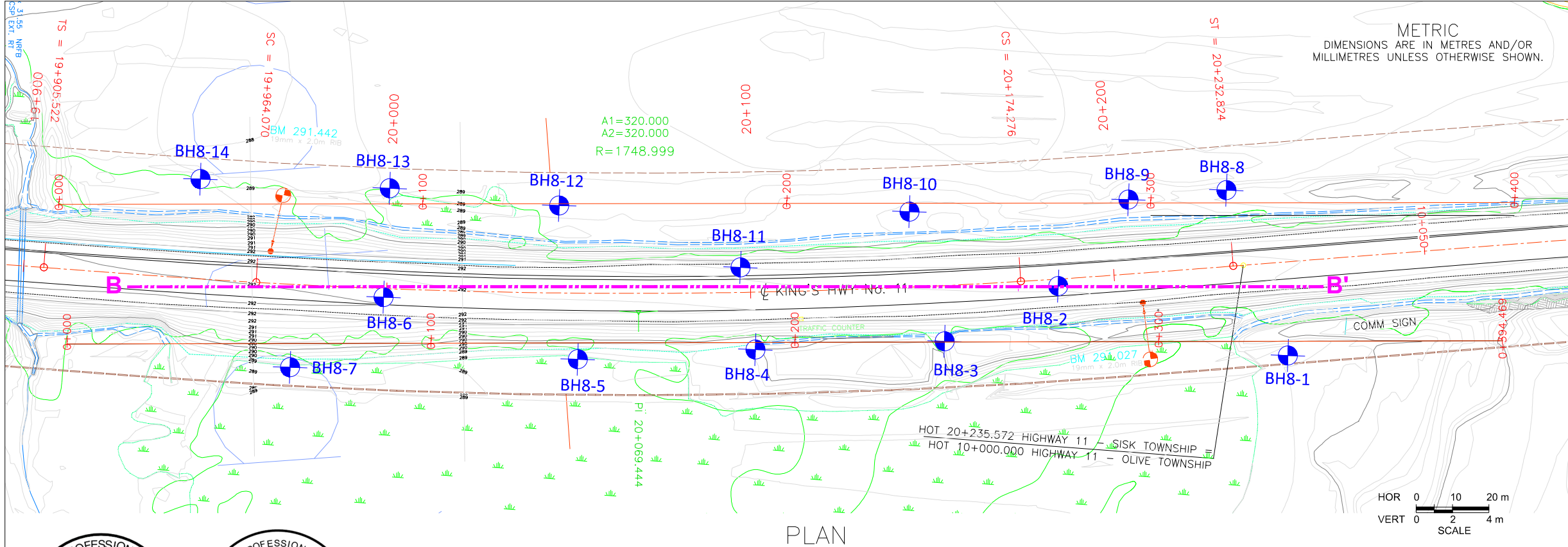
Photograph 5. Drilling of BH8-4 on mats, looking northwest (March 7, 2024)



Photograph 6. Drilling of borehole BH8-9, looking southwest (April 25, 2024)

Appendix B – Drawings

FILE NAME: \\PBR\F50001\Drawings\2024\2024-07-23 09:14 - SW8 & SW11\05790011001\05790011001_SW8_plan & profile - V2.dwg
MODIFIED: 2024-07-23 09:14



CONT No. 5021-E-0038

ASSIG No.

GWP No. 5033-22-00

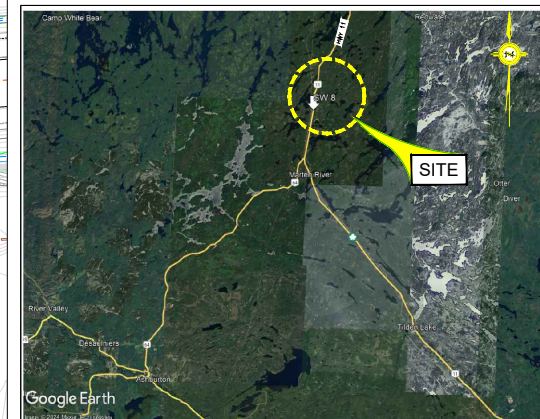
Highway 11 from Sand Dam Road Northerly 13.8 Km
to Ellesmere Road (SW8)

Latitude: 46.798949°; Longitude: -79.801547°

BOREHOLE LOCATION PLAN & SOIL STRATA



EXP SERVICES INC.



KEY PLAN
N.T.S.

LEGEND

- Borehole Location (EXP)
- Water Level Upon Completion of Drilling
(W. L. NOT STABILIZED)
- Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent)
(W. L. STABILIZED)
- Piezometer
- HCP 305 (Benchmark)

SOIL STRATA SYMBOLS

TOPSOIL	CLAYEY SILT	SAND
WATER	SANDY SILT	SILT
ASPHALT	SANDY GRAVEL	COBBLES AND BOULDERS
FILL	SILTY SAND	BEDROCK
PEAT		

BOREHOLE COORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
BH8-1	289.3	5184571.2	281810.4
BH8-2	291.4	5184509.6	281786.9
BH8-3	290.3	5184477.3	281799.8
BH8-4	289.9	5184425.3	281798.4
BH8-5	289.2	5184376.4	281797.6
BH8-6	291.9	5184324.4	281776.8
BH8-7	289.3	5184297.4	281794.2
BH8-8	289.6	5184567.5	281763.9
BH8-9	289.5	5184511.6	281765.0
BH8-10	289.7	5184470.2	281763.6
BH8-11	291.2	5184422.8	281775.6
BH8-12	289.0	5184374.3	281755.1
BH8-13	288.8	5184328.2	281747.1
BH8-14	288.5	5184276.5	281740.9

NOTES

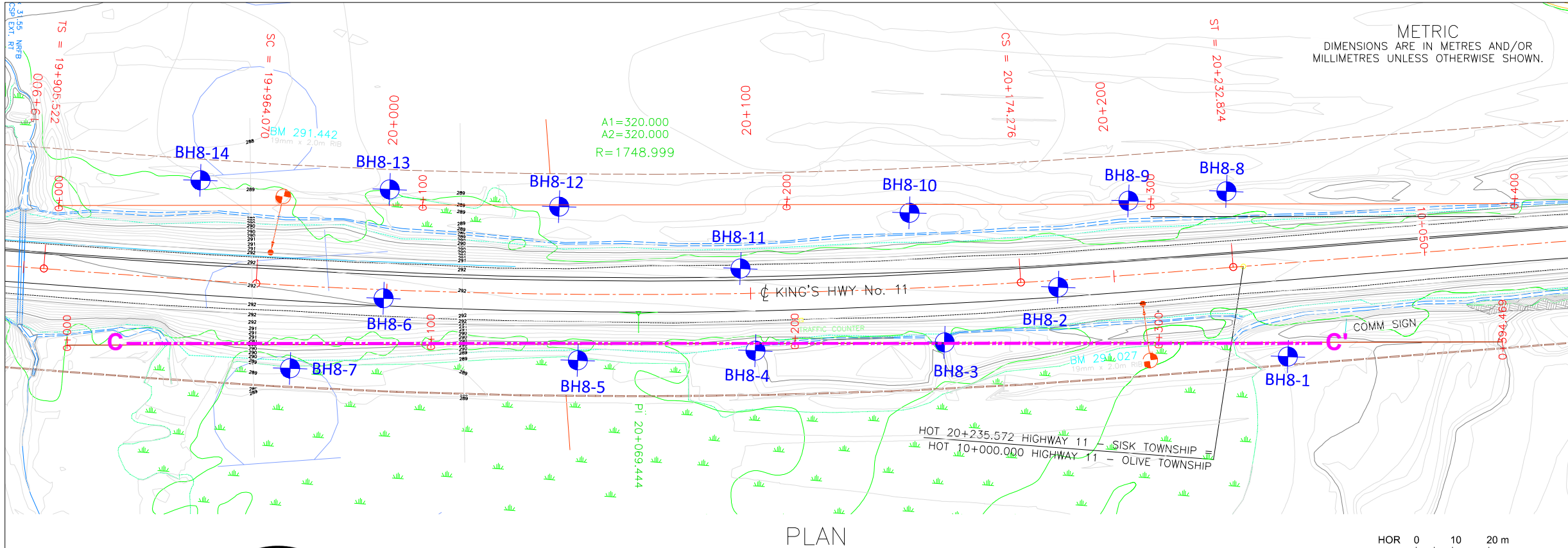
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

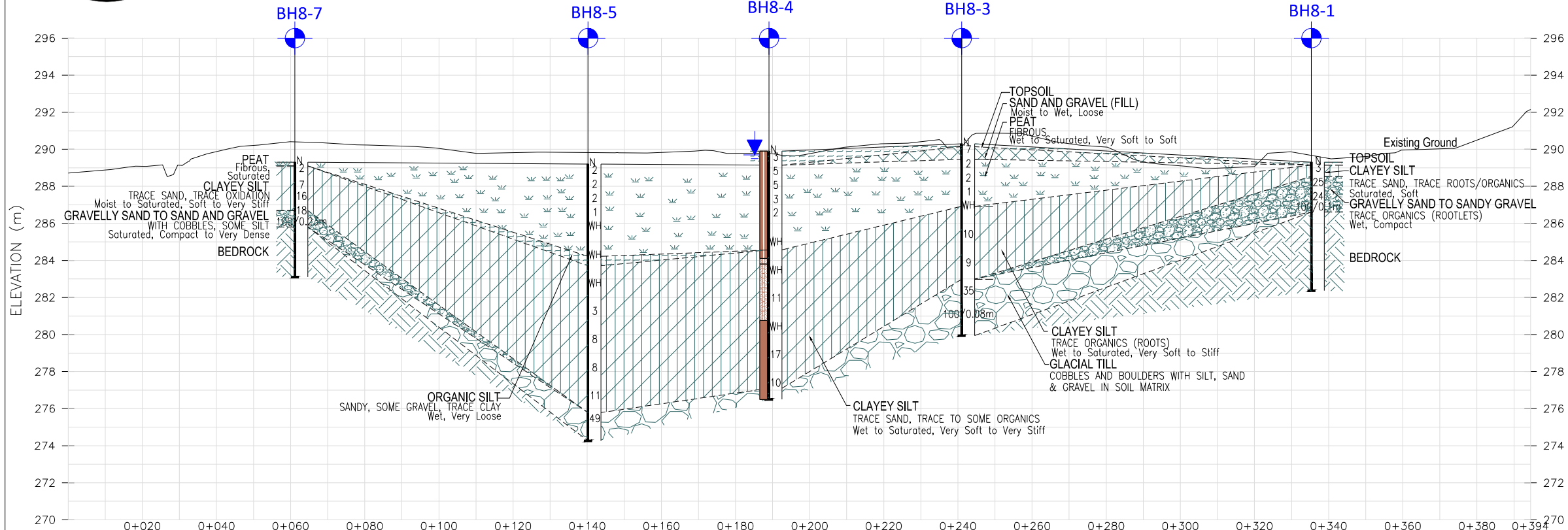
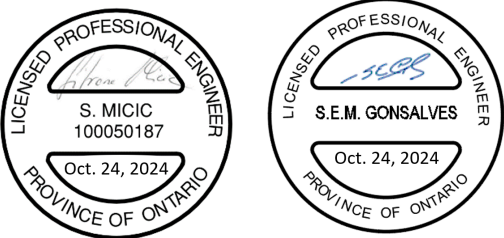
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of the OPS Gen. Cond.

SUBMISSION FOR MTO REVIEW			
NO	DATE	BY	DESCRIPTION
PROJECT No.	ADM-23010055-A0	GEOCRES No.	31L13-002
SUBM'D SH	CHKD. TL	DATE	JULY 19, 2024 SITE SW8
DRAWN SH	CHKD. TL	APPRD SG	DWG 02

FILE NAME: \\PBRMFS001\Data_Zeus\2003-Brampton\Proposals\Projects\International\WFO Projects\WFO 5021-E-0038 - Hwy 11 with AECOM\60 Execution\SW8 - SW8 & SW11\605790011001\6005690011001_SW8_plan & profile - V2.dwg
MODIFIED: 2024-07-23 09:14



PLAN



SECTION C-C'

CONT No. 5021-E-0038
ASSIG No.
GWP No. 5033-22-00

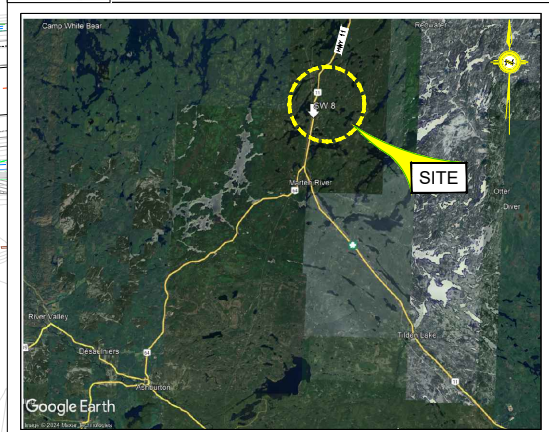
Highway 11 from Sand Dam Road Northerly 13.8 Km
to Ellesmere Road (SW8)
Latitude: 46.798949°; Longitude: -79.801547°

BOREHOLE LOCATION PLAN & SOIL STRATA

SHEET 3

exp.

EXP SERVICES INC.



KEY PLAN
N.T.S.

LEGEND

- Borehole Location (EXP)
- Water Level Upon Completion of Drilling (W. L. NOT STABILIZED)
- Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent) (W. L. STABILIZED)
- Piezometer
- HCP 305 (Benchmark)

SOIL STRATA SYMBOLS

TOPSOIL	CLAYEY SILT	SAND
WATER	SANDY SILT	SILT
ASPHALT	SANDY GRAVEL	COBBLES AND BOULDERS
FILL	SILTY SAND	BEDROCK
PEAT		

BOREHOLE COORDINATES/ NAD 83/ MTM ON-10			
BH No.	ELEV.	NORTHING	EASTING
BH8-1	289.3	5184571.2	281810.4
BH8-2	291.4	5184509.6	281786.9
BH8-3	290.3	5184477.3	281799.8
BH8-4	289.9	5184425.3	281798.4
BH8-5	289.2	5184376.4	281797.6
BH8-6	291.9	5184324.4	281776.8
BH8-7	289.3	5184297.4	281794.2
BH8-8	289.6	5184567.5	281763.9
BH8-9	289.5	5184511.6	281765.0
BH8-10	289.7	5184470.2	281763.6
BH8-11	291.2	5184422.8	281775.6
BH8-12	289.0	5184374.3	281755.1
BH8-13	288.8	5184328.2	281747.1
BH8-14	288.5	5184276.5	281740.9

NOTES

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

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

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 the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of the OPS Gen. Cond.

SUBMISSION FOR MTO REVIEW			
NO	DATE	BY	DESCRIPTION
PROJECT No.	ADM-23010055-A0	GEOCREs No.	31L13-002
SUBM'D SH	CHKD. TL	DATE	JULY 19, 2024 SITE SW8
DRAWN SH	CHKD. TL	APPRD SG	DWG 03

Appendix C – Borehole Logs

Explanation of Terms Used on Borehole Records

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil: mixture of soil and humus capable of supporting good vegetative growth.

Peat: fibrous fragments of visible and invisible decayed organic matter.

Fill: where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc.; none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

Till: the term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Terminology describing soil structure:

Desiccated: having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.

Stratified: alternating layers of varying material or color with the layers greater than 6 mm thick.

Laminated: alternating layers of varying material or color with the layers less than 6 mm thick.

Fissured: material breaks along plane of fracture.

Varved: composed of regular alternating layers of silt and clay.

Slickensided: fracture planes appear polished or glossy, sometimes striated.

Blocky: cohesive soil that can be broken down into small angular lumps which resist further breakdown.

Lensed: inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; not thickness.

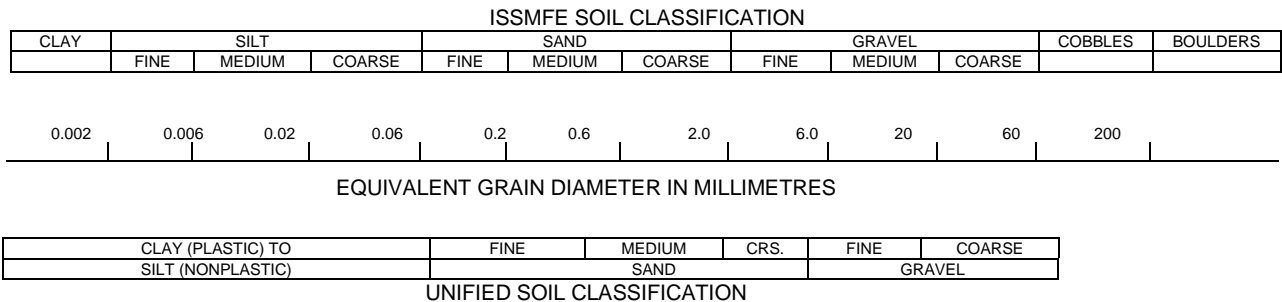
Seam: a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

Homogeneous: same color and appearance throughout.

Well Graded: having wide range in grain sized and substantial amounts of all predominantly on grain size.

Uniformly Graded: predominantly on grain size.

All soil sample descriptions included in this report follow generally the ASTM D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) with some modification to reflect current MTO practices. The system divides soils into three major categories: (1) coarse grained, (2) fine-grained, and (3) highly organic. The soil is then subdivided based on either gradation or plasticity characteristics. The system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification. The classification excludes particles larger than 76 mm. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually in accordance with ASTM D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems. Others may use different classification systems; one such system is the ISSMFE Soil Classification.



Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Canadian Foundation Engineering Manual (CFEM):

Table a: Percent or Proportion of Soil

Term	Description	Criteria
"trace"	trace gravel, trace sand, etc.	1% - 10%
"some"	some gravel, some sand, etc.	10% - 20%
Adjective	gravelly, sandy, silty and clayey	20% - 35%
"and"	and gravel, and sand, etc.	>35%
Noun	gravel, sand, silt, clay	>35% and main fraction

The standard terminology to describe cohesionless soils includes the compactness as determined by the Standard Penetration Test 'N' value:

Table b: Apparent Density of Cohesionless Soil

	'N' Value (blows/0.3 m)
Very Loose	N<5
Loose	5≤N<10
Compact	10≤N<30
Dense	30≤N<50
Very Dense	50≤N

The standard terminology to describe cohesive soils includes consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests or similar field and laboratory analysis, Standard Penetration Test 'N' values can also be used to provide an approximate indication of the consistency and shear strength of fine grained, cohesive soils:

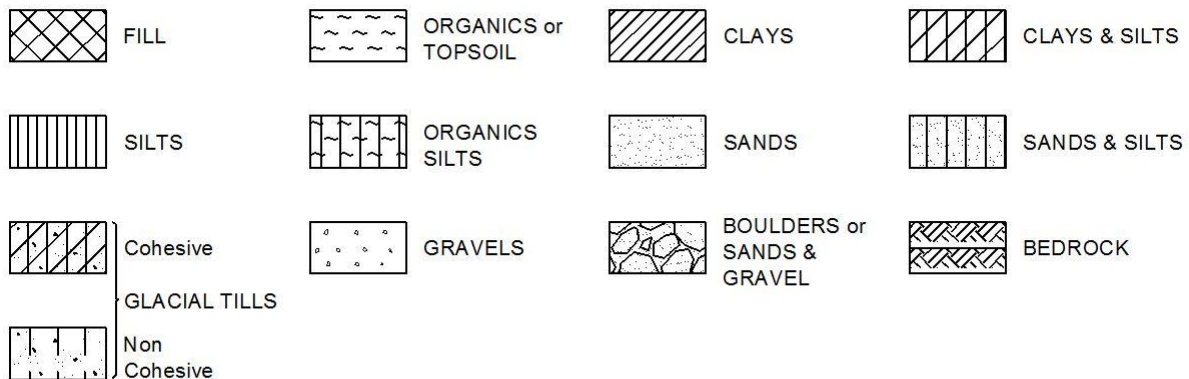
Table c: Consistency of Cohesive Soil

Consistency	Vane Shear Measurement (kPa)	'N' Value
Very Soft	<12.5	<2
Soft	12.5-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Note: 'N' Value - The Standard Penetration Test records the number of blows of a 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler 1 foot (305mm). For split spoon samples where full penetration is not achieved, the number of blows is reported over the sampler penetration in meters (e.g. 50/0.15).

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



WATER LEVEL MEASUREMENT



Open Borehole or Test Pit



Monitoring Well, Piezometer or Standpipe

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	Split spoon sample (obtained from the Standard Penetration Test)
WS	Wash sample
BS	Bulk sample
TW	Thin wall sample or Shelby tube
PS	Piston sample
AS	Auger sample
VT	Vane test
GS	Grab sample
HQ, NQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits

STRESS AND STRAIN

u_w	kPa	Pore water pressure
r_u	1	Pore pressure ratio
σ	kPa	Total normal stress
σ'	kPa	Effective normal stress
τ	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
ε	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
μ	1	Coefficient of friction

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	Coefficient of volume change
c_c	1	Compression index
c_s	1	Swelling index
c_r	1	Recompression index
c_v	m ² /s	Coefficient of consolidation
H	m	Drainage path
T_v	1	Time factor
U	%	Degree of consolidation
σ'_{v0}	kPa	Effective overburden pressure
σ'_p	kPa	Preconsolidation pressure
τ_f	kPa	Shear strength
c'	kPa	Effective cohesion intercept
ϕ'	—°	Effective angle of internal friction
c_u	kPa	Apparent cohesion intercept
ϕ_u	—°	Apparent angle of internal friction
τ_R	kPa	Residual shear strength
τ_r	kPa	Remoulded shear strength
S_t	1	Sensitivity = c_u/τ_r

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m ³	Density of solid particles
γ_s	kN/m ³	Unit weight of solid particles
ρ_w	kg/m ³	Density of water
γ_w	kN/m ³	Unit weight of water
ρ	kg/m ³	Density of soil
γ	kN/m ³	Unit weight of soil
ρ_d	kg/m ³	Density of dry soil
γ_d	kN/m ³	Unit weight of dry soil
ρ_{sat}	kg/m ³	Density of saturated soil
γ_{sat}	kN/m ³	Unit weight of saturated soil
ρ'	kg/m ³	Density of submerged soil
γ'	kN/m ³	Unit weight of submerged soil
e	1, %	Void ratio
n	1, %	Porosity
w	1, %	Water content
S_r	%	Degree of saturation
W_L	%	Liquid limit
W_P	%	Plastic limit
W_s	%	Shrinkage limit
I_p	%	Plasticity index = $(W_L - W_P)$
I_L	%	Liquidity index = $(W - W_P)/I_p$
I_C	%	Consistency index = $(W_L - W)/I_p$
e_{max}	1, %	Void ratio in loosest state
e_{min}	1, %	Void ratio in densest state
I_D	1	Density index = $(e_{max} - e)/(e_{max} - e_{min})$
D	mm	Grain diameter
D_n	mm	N percent - diameter
C_u	1	Uniformity coefficient
h	m	Hydraulic head or potential
q	m ³ /s	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	kN/m ³	Seepage force

Brampton, Ontario

RECORD OF BOREHOLE No BH8-1

1 OF 1

METRIC

W.P. ADM-23010055-A0 LOCATION 5184571.2N, 281810.4E, NAD83 MTM Zone 10 ORIGINATED BY SF
DIST NER HWY 11 BOREHOLE TYPE Track Mounted CME 55 COMPILED BY DM
DATUM Geodetic DATE 2024.03.12 - 2024.03.12 LATITUDE 46.800292 LONGITUDE -79.801181 CHECKED BY TL

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										WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE								● QUICK TRIAXIAL		
289.3	GROUND SURFACE						20	40	60	80	100									
289.0	TOPSOIL ~150 mm thick																			
0.2	CLAYEY SILT, trace sand, trace roots/organics, brown, saturated, soft		SS1	SS	3											0 4 78 18				
288.5																				
0.8	GRAVELLY SAND TO SANDY GRAVEL, trace organics (rootlets), brown to grey, wet, compact		SS2	SS	25															
			SS3	SS	24															
			SS4	SS	100/0.1m															
286.6	- spoon bouncing on cobble, cobbles below ~2.5 m depth			NQ																
2.7	BEDROCK, Run 1: Start/End: 2.7 to 4.1 m Recovery: 100% RQD: 74% Run 2: Start/End: 4.1 to 5.7 m Recovery: 100% RQD: 61% Run 3: Start/End: 5.7 to 6.9 m Recovery: 100% RQD: 66%		RUN 1	NQ																
			RUN 2	NQ																
			RUN 3	NQ																
282.4	BOREHOLE TERMINATED AT ~ 6.9 m DEPTH																			
6.9	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process.																			

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

Brampton, Ontario

RECORD OF BOREHOLE No BH8-2

1 OF 1

METRIC

W.P. ADM-23010055-A0 LOCATION 5184509.6N, 281786.9E, NAD83 MTM Zone 10 ORIGINATED BY EL
DIST NER HWY 11 BOREHOLE TYPE Truck Mounted CME 75 COMPILED BY IL
DATUM Geodetic DATE 2023.10.30 - 2023.10.31 LATITUDE 46.799736 LONGITUDE -79.801487 CHECKED BY TL

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											
								<div><div></div><div>20406080100</div></div>											
								<div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>					<div>WATER CONTENT (%)</div> <div><div></div><div>204060</div></div>						
291.4	GROUND SURFACE																		
290.0	ASPHALT ~175mm thick																		
0.2	GRAVELLY SAND (FILL), trace asphalt fragments, brown, wet, dense to very dense		SS1	SS	104/0.2m		291												
			SS2	SS	32														
							290												
289.9																			
1.5	ROCKFILL, in silt, sand, and gravel soil matrix, trace wood fragments		SS3	SS	27														
			SS4	SS	29		289												
			SS5	SS	10		288												
287.4																			
4.0	CLAYEY SILT, some gravel, trace organics, wet, firm						287												
			SS6	SS	4														
							286												
285.4																			
6.0	GLACIAL TILL, cobbles and boulders with silt, sand, and gravel in soil matrix			NQ			285												
				NQ															
				NQ			284												
				NQ															
				NQ			283												
282.3							282												
9.1	BEDROCK																		
	Run 1: Start/End: 9.1 to 10.4 m Recovery: 100% RQD: 55%		RUN 1	NQ															
281.0																			
10.4	BOREHOLE TERMINATED AT ~ 10.4 m DEPTH						281												
	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process.																		

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

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

Brampton, Ontario

RECORD OF BOREHOLE No BH8-3

1 OF 1

METRIC

W.P. ADM-23010055-A0 LOCATION 5184477.3N, 281799.8E, NAD83 MTM Zone 10 ORIGINATED BY DM
DIST NER HWY 11 BOREHOLE TYPE Track Mounted CME 55 COMPILED BY IL
DATUM Geodetic DATE 2024.03.04 - 2024.03.06 LATITUDE 46.799447 LONGITUDE -79.801316 CHECKED BY TL

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									
290.3	GROUND SURFACE							20	40	60	80	100					
290.0	TOPSOIL ~150 mm thick																
0.2	SAND AND GRAVEL (FILL), brown to grey, moist to wet, loose		SS1	SS	7		290										
289.5																	
0.8	PEAT, fibrous, black to brown, wet to saturated, very soft to soft		SS2	SS	2		289									211	
	- becoming amorphous with fibrous layers at ~1.5 m depth		SS3	SS	2											486	
	- mixture of amorphous and fibrous at ~2.3 m depth		SS4	SS	1		288									384	
286.9			SS5	SS	WH		287									177	Organic Content = 18.5%
3.4	CLAYEY SILT, trace organics (roots), grey, wet to saturated, very soft to soft							2.9									
				VANE			286										
	- becoming stiff at ~4.6 m depth		SS6	SS	10		285										0 1 64 35
				VANE				12.4									
	- silty clay inclusions at ~6.1 m depth		SS7	SS	9		284										
283.0				VANE				14.5									
7.3	GLACIAL TILL, cobbles and boulders with silt, sand, and gravel in soil matrix - sand and gravel, trace silt			NQ			283										
			SS8	SS	35		282										49 41 (10)
				NQ													
			SS9	SS	100/ 0.08m		281										
				NQ													
279.9	BOREHOLE TERMINATED AT ~ 10.4 m DEPTH						280										
10.4	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process. 2. Borehole terminated after three attempts: - First borehole attempt: core bit damaged and lost in hole at 8.1 m. - Second borehole attempt: moved 1 m east, tri-cone assembly stuck in hole at 10.4 m. - Third borehole attempt: moved 1 m north, casing shoe destroyed at 9.8 m. 3. WH = weight of hammer																

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

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

Brampton, Ontario

RECORD OF BOREHOLE No BH8-4

1 OF 2

METRIC

W.P. ADM-23010055-A0 LOCATION 5184425.3N, 281798.4E, NAD83 MTM Zone 10 ORIGINATED BY DM
DIST NER HWY 11 BOREHOLE TYPE Track Mounted CME 55 COMPILED BY IL
DATUM Geodetic DATE 2024.03.07 - 2024.03.07 LATITUDE 46.798979 LONGITUDE -79.801331 CHECKED BY TL

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		W _P	W	W _L					
								○ UNCONFINED + FIELD VANE	WATER CONTENT (%)								
							● QUICK TRIAXIAL × LAB VANE										
289.9	GROUND SURFACE							20	40	60	80	100					
0.0	TOPSOIL ~760 mm thick		SS1	SS	3											99	
289.1							289									115	
0.8	PEAT, amorphous with fibers, brown to black, saturated, soft to firm		SS2	SS	5												
			SS3	SS	5		288									383	
			SS4	SS	3		287										
			SS5	SS	2		286									731	
							285									772	
284.6			SS6	SS	WH											131	
5.3	CLAYEY SILT, trace sand, trace to some organics, wet to saturated, grey, very soft to very stiff								2.8								
				VANE			284										
				TW													
	- no organics below 6.1 m depth		SS7	SS	WH		283			2.9							0 2 77 21
				VANE													
							282										
			SS8	SS	11				1								
				VANE			281										
			SS9	SS	WH		280										
				VANE													
							279										0 2 80 18
							278										
			SS10	SS	17												
			SS11	SS	10												
277.1																	
12.8	GLACIAL TILL, cobbles and boulders with silt, sand, and gravel in soil matrix						277										
276.5																	
13.4	BOREHOLE TERMINATED AT ~ 13.4 m DEPTH																
	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process 2. Casing shoe destroyed during advancement through cobbles and																

Continued Next Page

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

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

Brampton, Ontario

2 OF 2

METRIC

W.P.	ADM-23010055-A0		LOCATION	5184425.3N, 281798.4E, NAD83 MTM Zone 10			ORIGINATED BY	DM		
DIST	NER	HWY 11	BOREHOLE TYPE	Track Mounted CME 55			COMPILED BY	IL		
DATUM	Geodetic		DATE	2024.03.07 - 2024.03.07	LATITUDE	46.798979	LONGITUDE	-79.801331	CHECKED BY	TL

[illegible]

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

ONTARIO MTO HWY 11 -SW8 .GPJ ONTARIO MTO.GDT 7/19/24

Brampton, Ontario

RECORD OF BOREHOLE No BH8-5

1 OF 2

METRIC

W.P. ADM-23010055-A0 LOCATION 5184376.4N, 281797.6E, NAD83 MTM Zone 10 ORIGINATED BY DM/SF
DIST NER HWY 11 BOREHOLE TYPE Track Mounted CME 55 COMPILED BY IL
DATUM Geodetic DATE 2024.03.07 - 2024.03.11 LATITUDE 46.798539 LONGITUDE -79.80134 CHECKED BY TL

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									
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE						
289.2	GROUND SURFACE						20	40	60	80	100						
0.0	PEAT , fibrous, brown to black, wet to saturated, very soft to soft - thin layer of (~115 mm) silty sand fill at ~0.3 m depth		SS1	SS	2										195		
															290		
			SS2	SS	2												
			SS3	SS	2										182		
			SS4	SS	1												
			SS5	SS	WH												
284.2	- becoming amorphous at ~4.6 m depth		SS6	SS	WH									323			
5.0	ORGANIC SILT , sandy, some gravel, trace clay, dark brown, wet, very loose													147			
283.7																	
5.5		CLAYEY SILT , trace sand, grey, wet to saturated, very soft to firm			TW												
				SS7	SS	WH											
					VANE												
				SS8	SS	3											
					VANE												
				SS9	SS	8											
			VANE														
			SS10	SS	8												
				VANE													
			SS11	SS	11												
275.8																	
13.4	GLACIAL TILL , cobbles and boulders with silt, sand, and gravel in soil matrix		SS12	SS	49												
274.3																	

Continued Next Page

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

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

Brampton, Ontario

RECORD OF BOREHOLE No BH8-52 OF 2METRIC

W.P. ADM-23010055-A0LOCATION 5184376.4N, 281797.6E, NAD83 MTM Zone 10ORIGINATED BY DM/SF

DIST NER HWY 11BOREHOLE TYPE Track Mounted CME 55COMPILED BY IL

DATUM GeodeticDATE 2024.03.07 - 2024.03.11LATITUDE 46.798539LONGITUDE -79.80134CHECKED BY TL

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMITNATURAL MOISTURE CONTENTLIQUID LIMIT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					Wp	W			Wl		
							20	40	60	80	100								
14.9	BOREHOLE TERMINATED AT ~ 14.9 m DEPTH DUE TO REFUSAL Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process. 2. Borehole terminated due to inability to core into layer. 3. WH = weight of hammer																		

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

Brampton, Ontario

RECORD OF BOREHOLE No BH8-6

1 OF 1

METRIC

W.P. ADM-23010055-A0 LOCATION 5184324.4N, 281776.8E, NAD83 MTM Zone 10 ORIGINATED BY EL
 DIST NER HWY 11 BOREHOLE TYPE Truck Mounted CME 75 COMPILED BY IL
 DATUM Geodetic DATE 2023.10.30 - 2023.10.30 LATITUDE 46.79807 LONGITUDE -79.80161 CHECKED BY TL

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									WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE		● QUICK TRIAXIAL × LAB VANE									
291.9	GROUND SURFACE					20	40	60	80	100	20	40	60		GR	SA	SI	CL	
290.4	ASPHALT ~100mm thick		SS1	SS	64														
290.1	GRAVELLY SAND TO SANDY GRAVEL (FILL), brown to grey sand with pink and grey gravel, damp, dense to very dense - silt, some sand, trace gravel, trace clay at ~0.8 m depth		SS2	SS	42														
			SS3	SS	69														
			SS4	SS	9														
			SS5	SS	7														
288.5	CLAYEY SILT, trace organics/fibrous material, some rock fragments, grey, wet, firm																		
287.1	-spoon refusal on bedrock		SS6	SS	100/ 0.1m														
283.9	BEDROCK		RUN 1	NQ															
			RUN 2	NQ															
283.9	BOREHOLE TERMINATED AT ~ 8.0 m DEPTH																		
8.0	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process.																		

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

Brampton, Ontario

RECORD OF BOREHOLE No BH8-71 OF 1METRIC

W.P. ADM-23010055-A0LOCATION 5184297.4N, 281794.2E, NAD83 MTM Zone 10ORIGINATED BY DM

DIST NER HWY 11BOREHOLE TYPE Track Mounted CME 55COMPILED BY IL

DATUM GeodeticDATE 2024.03.04 - 2024.03.04LATITUDE 46.797828LONGITUDE -79.801381CHECKED BY TL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMITNATURAL MOISTURE CONTENTLIQUID LIMIT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20406080100	20406080100	Wp	W	WL	WATER CONTENT (%)				
289.3	GROUND SURFACE																
289.0	PEAT, fibrous, black, saturated																
0.2	CLAYEY SILT, trace sand, trace oxidation, grey, moist to saturated, soft to very stiff		SS1	SS	2		289										
	- Measured vane shear strength greater than 120 kPa at 0.8 m			VANE													
	- becoming wet, increase in oxidation at ~1.5 m depth		SS2	SS	7		288								0 2 70 28		
			SS3	SS	16												
286.7			SS4	SS	18		287										
2.6	GRAVELLY SAND TO SAND AND GRAVEL, with cobbles, some silt, grey, saturated, compact to very dense		SS5	SS	100/0.23m		286										
285.8	BEDROCK		RUN 1	NQ			285										
3.5	Run 1: Start/End: 3.5 to 4.1 m Recovery: 100% RQD: 100%		RUN 2	NQ			284										
	Run 2: Start/End: 4.1 to 5.6 m Recovery: 100% RQD: 100%		RUN 3	NQ													
	Run 3: Start/End: 5.6 to 6.2 m Recovery: 100% RQD: 100%																
283.1	BOREHOLE TERMINATED AT ~6.2 m DEPTH																
6.2	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process																

Brampton, Ontario

RECORD OF BOREHOLE No BH8-8

1 OF 1

METRIC

W.P. ADM-23010055-A0

LOCATION 5184557.5N, 281763.9E, NAD83 MTM Zone 10

ORIGINATED BY AM

DIST NER HWY 11

BOREHOLE TYPE Track Mounted CME 55

COMPILED BY EL

DATUM Geodetic

DATE 2024.04.25 - 2024.04.25

LATITUDE 46.800167

LONGITUDE -79.80179

CHECKED BY TL

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			20	40	60	80	100	Wp	W	WL		
289.6	GROUND SURFACE																
289.4	TOPSOIL, ~225 mm thick																
0.2	CLAYEY SILT, trace sand, trace organics, brown to grey, saturated, firm to very stiff		SS1	SS	5											Organic Content = 7.1%	
			SS2	SS	14											Organic Content = 2.3%	
	-Measured vane shear strength greater than 120 kPa at 1.5 m			VANE												0 1 82 17	
287.5	GLACIAL TILL, cobbles and boulders with silt, sand, and gravel in soil matrix																
2.1				NQ													
286.6	BEDROCK		RUN 1	NQ													
3.0	Run 1: Start/End: 3.0 to 3.5 m Recovery: 100% RQD: 90%																
	Run 2: Start/End: 3.5 to 4.9 m Recovery: 100% RQD: 100%		RUN 2	NQ													
	Run 3: Start/End: 4.9 to 5.4 m Recovery: 100% RQD: 88%		RUN 3	NQ													
284.2	BOREHOLE TERMINATED AT ~ 5.4 m DEPTH																
5.4	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process																

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

+ 3, X 3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

Brampton, Ontario

RECORD OF BOREHOLE No BH8-91 OF 1METRIC

W.P. ADM-23010055-A0LOCATION 5184511.6N, 281765.0E, NAD83 MTM Zone 10ORIGINATED BY AM

DIST NER HWY 11BOREHOLE TYPE Track Mounted CME 55COMPILED BY EL

DATUM GeodeticDATE 2024.04.22 - 2024.04.22LATITUDE 46.799754LONGITUDE -79.801774CHECKED BY TL

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			20	40	60	80	100	Wp	W	Wl		
289.5	GROUND SURFACE																
289.4	TOPSOIL, ~75 mm thick		SS1	SS	7											1 2 82 15	
	CLAYEY SILT, trace sand, trace organics/topsoil, grey, moist to saturated, soft to firm		SS2	SS	3												
	- becoming stiff to hard at ~1.5 m depth		SS3	SS	18											0 1 79 20	
			VANE														
	- some sand and trace gravel		SS4	SS	34												
285.7	GLACIAL TILL, cobbles and boulders with silt, sand, and gravel in soil matrix																
284.9	BEDROCK		RUN 1	NQ													
	Run 1: Start/End: 4.6 to 5.7 m Recovery: 100% RQD: 74%																
	Run 2: Start/End: 5.7 to 7.2 m Recovery: 100% RQD: 93%		RUN 2	NQ													
282.3	BOREHOLE TERMINATED AT ~7.2 m DEPTH																
	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process																

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

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

Brampton, Ontario

RECORD OF BOREHOLE No BH8-10

1 OF 2

METRIC

W.P. ADM-23010055-A0 LOCATION 5184470.2N, 281763.6E, NAD83 MTM Zone 10 ORIGINATED BY AM
DIST NER HWY 11 BOREHOLE TYPE Track Mounted CME 55 COMPILED BY DM
DATUM Geodetic DATE 2024.04.16 - 2024.04.17 LATITUDE 46.799382 LONGITUDE -79.80179 CHECKED BY TL

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 (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)				
								○ UNCONFINED	+ FIELD VANE						● QUICK TRIAXIAL	× LAB VANE			
289.7	GROUND SURFACE																		
289.0	TOPSOIL ~100 mm thick		SS1	SS	2								132	Organic Content = 86.8%					
	PEAT, fibrous, black to brown, wet to saturated, very soft to soft		SS2	SS	2								520						
			SS3	SS	WH								419						
			SS4	SS	WH								165						
286.9	ORGANIC SILT, clayey, trace sand, brown, wet, very loose		SS5	SS	WH									Organic Content = 42.1% 0 1 79 20					
286.0																			
3.7	CLAYEY SILT, trace to some organics, brown, saturated, very soft to firm			VANE															
	- becoming grey at ~4.6 m depth		SS6	SS	WH														
				TW										19.3 0 1 79 20					
	- becoming stiff at ~6.1 m depth		SS7	SS	10														
				VANE															
281.4																			
8.3	GLACIAL TILL, cobbles and boulders with silt, sand, and gravel in soil matrix			NQ															
280.0	- no sample recovery		SS8	SS	100/0.13m														
9.7	BEDROCK		Run1	NQ															
	Run 1: Start/End: 9.7 to 10.1 m Recovery: 100% RQD: 63%		Run2	NQ															
	Run 2: Start/End: 10.1 to 11.6 m Recovery: 100% RQD: 31%																		
	Run 3: Start/End: 11.6 to 13.1 m Recovery: 100% RQD: 70%		Run3	NQ															
276.6	BOREHOLE TERMINATED AT ~ 13.1 m DEPTH																		
13.1	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process. 2. WH - weight of hammer 3. Monitoring Well Readings: Date Depth Elev. Apr 24/24 1.1 288.6 m May 15/24 1.2 288.5 m																		

Continued Next Page

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

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

Brampton, Ontario

2 OF 2

METRIC

W.P.	ADM-23010055-A0	LOCATION	5184470.2N, 281763.6E, NAD83 MTM Zone 10			ORIGINATED BY	AM
DIST	NER	HWY	11	BOREHOLE TYPE	Track Mounted CME 55	COMPILED BY	DM
DATUM	Geodetic	DATE	2024.04.16 - 2024.04.17	LATITUDE	46.799382	LONGITUDE	-79.80179
						CHECKED BY	TL

[illegible]

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

ONTARIO MTO HWY 11 -SW8 .GPJ ONTARIO MTO.GDT 7/19/24



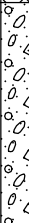

Brampton, Ontario

RECORD OF BOREHOLE No BH8-11

1 OF 1

METRIC

W.P. ADM-23010055-A0 LOCATION 5184422.8N, 281775.6E, NAD83 MTM Zone 10 ORIGINATED BY EL
 DIST NER HWY 11 BOREHOLE TYPE Truck Mounted CME 75 COMPILED BY IL
 DATUM Geodetic DATE 2023.11.01 - 2023.11.01 LATITUDE 46.798955 LONGITUDE -79.801631 CHECKED BY TL

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								WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL							× LAB VANE	
291.2	GROUND SURFACE						20	40	60	80	100	20	40	60	kN/m ³	GR SA SI CL		
0.0	SAND AND GRAVEL (FILL) , some silt, dark grey to brown, damp, compact						291									51 37 (12)		
	- becoming wet at ~0.9 m depth		SS1	SS	28		290											
289.7																		
1.5	ROCKFILL , in silt, sand, and gravel soil matrix		SS2	SS	31		289											
	- no sample recovery, rock obstructed sample entry																	
			SS3	SS	24													
288.2																		
3.0	SAND AND GRAVEL , some silt, trace organics, grey, wet, loose to dense		SS4	SS	6		288											
	- no sample recovery																	
			SS5	SS	17		287											
			SS6	SS	49													
285.9							286											
5.3	GLACIAL TILL , cobbles and boulders with silt, sand, and gravel in soil matrix			NQ		285												
							284											
							283											
							282											
	- gravel with trace organic/fibrous infilling encountered below ~9.1 m depth			NQ											Organic Content = 4.8%			
281.1																		
10.1	BOREHOLE TERMINATED AT ~ 10.1 m DEPTH																	
	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process.																	

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

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

1 OF 1

METRIC

DATUM	Geodetic	DATE	2024.04.22 - 2024.04.22	LATITUDE	46.798518	LONGITUDE	-79.801896	CHECKED BY	TL
-------	----------	------	-------------------------	----------	-----------	-----------	------------	------------	----

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

Brampton, Ontario

RECORD OF BOREHOLE No BH8-131 OF 1METRIC

W.P. ADM-23010055-A0LOCATION 5184328.2N, 281747.1E, NAD83 MTM Zone 10ORIGINATED BY AM

DIST NER HWY 11BOREHOLE TYPE Track Mounted CME 55COMPILED BY DM

DATUM GeodeticDATE 2024.04.17 - 2024.04.17LATITUDE 46.798104LONGITUDE -79.801999CHECKED BY TL

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								
288.8	GROUND SURFACE												
288.8	TOPSOIL ~75 mm thick		SS1	SS	2		288					19.5	Organic Content = 1.9% 0 1 71 28
288.8	CLAYEY SILT, trace organics, brown to grey, saturated, soft to stiff		SS2	SS	7								
				VANE			287						
286.4	- cobble/boulder encountered		SS3	SS	100/0.10m		286						
286.4	BEDROCK												
	Run 1: Start/End: 2.4 to 3.9 m Recovery: 77% RQD: 40%		RUN 1	NQ			285						
	Run 2: Start/End: 3.9 to 5.4 m Recovery: 100% RQD: 65%		RUN 2	NQ			284						
283.4	BOREHOLE TERMINATED AT ~ 5.4 m DEPTH												
5.4	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process.												

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

Brampton, Ontario

RECORD OF BOREHOLE No BH8-141 OF 1METRIC

W.P. ADM-23010055-A0LOCATION 5184276.5N, 281740.9E, NAD83 MTM Zone 10ORIGINATED BY AM

DIST NER HWY 11BOREHOLE TYPE Track Mounted CME 55COMPILED BY DM

DATUM GeodeticDATE 2024.04.17 - 2024.04.17LATITUDE 46.797638LONGITUDE -79.802077CHECKED BY TL

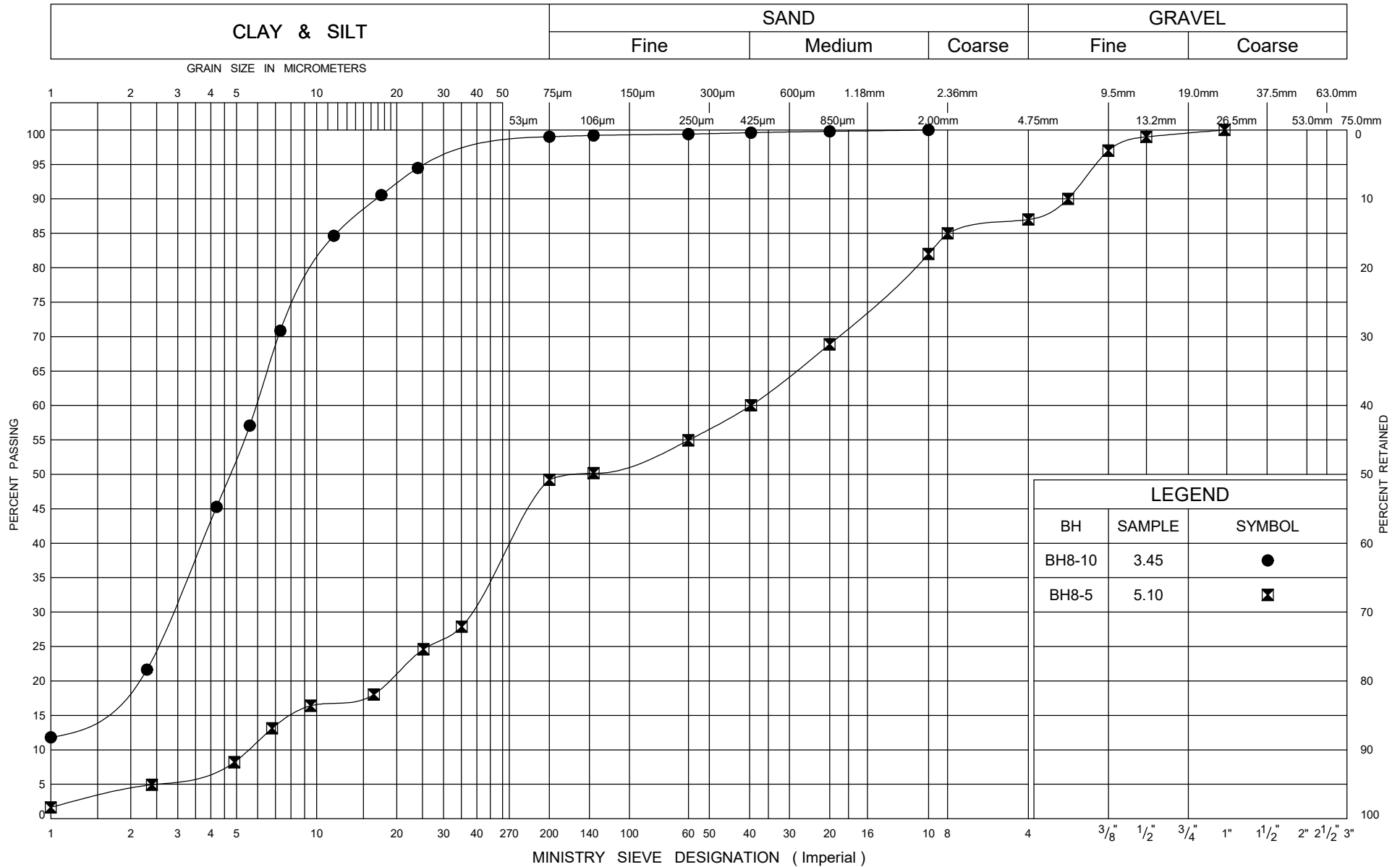
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMITNATURAL MOISTURE CONTENTLIQUID LIMIT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _p	W	W _L		
							20	40	60	80	100						
288.5	GROUND SURFACE																
288.4	TOPSOIL ~100 mm thick		SS1	SS	3												
	CLAYEY SILT, trace organics, brownish grey, saturated, soft																
	- stiff to very stiff below ~0.8 m depth		SS2	SS	14												
	- Measured vane shear strength greater than 120 kPa at 1.7 m			VANE													
286.1																	
286.1	GLACIAL TILL, cobbles and boulders with silt, sand, and gravel in soil matrix		SS3	SS	24												
			SS4	SS	53												
				NQ													
284.1																	
284.1	BEDROCK		RUN 1	NQ													
	Run 1: Start/End: 4.4 to 4.7 m Recovery: 100% RQD: 100%																
	Run 2: Start/End: 4.7 to 6.2 m Recovery: 100% RQD: 90%		RUN 2	NQ													
	Run 3: Start/End: 6.2 to 7.7 m Recovery: 100% RQD: 100%		RUN 3	NQ													
280.8																	
280.8	BOREHOLE TERMINATED AT ~7.7 m DEPTH																
	Notes: 1. Groundwater level not measured in open hole due to water being introduced in drilling/coring process.																

ONTARIO MTO HWY 11-SW8.GPJ ONTARIO MTO.GDT 7/19/24

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

Appendix D – Laboratory Data

UNIFIED SOIL CLASSIFICATION SYSTEM

Ministry of
Transportation

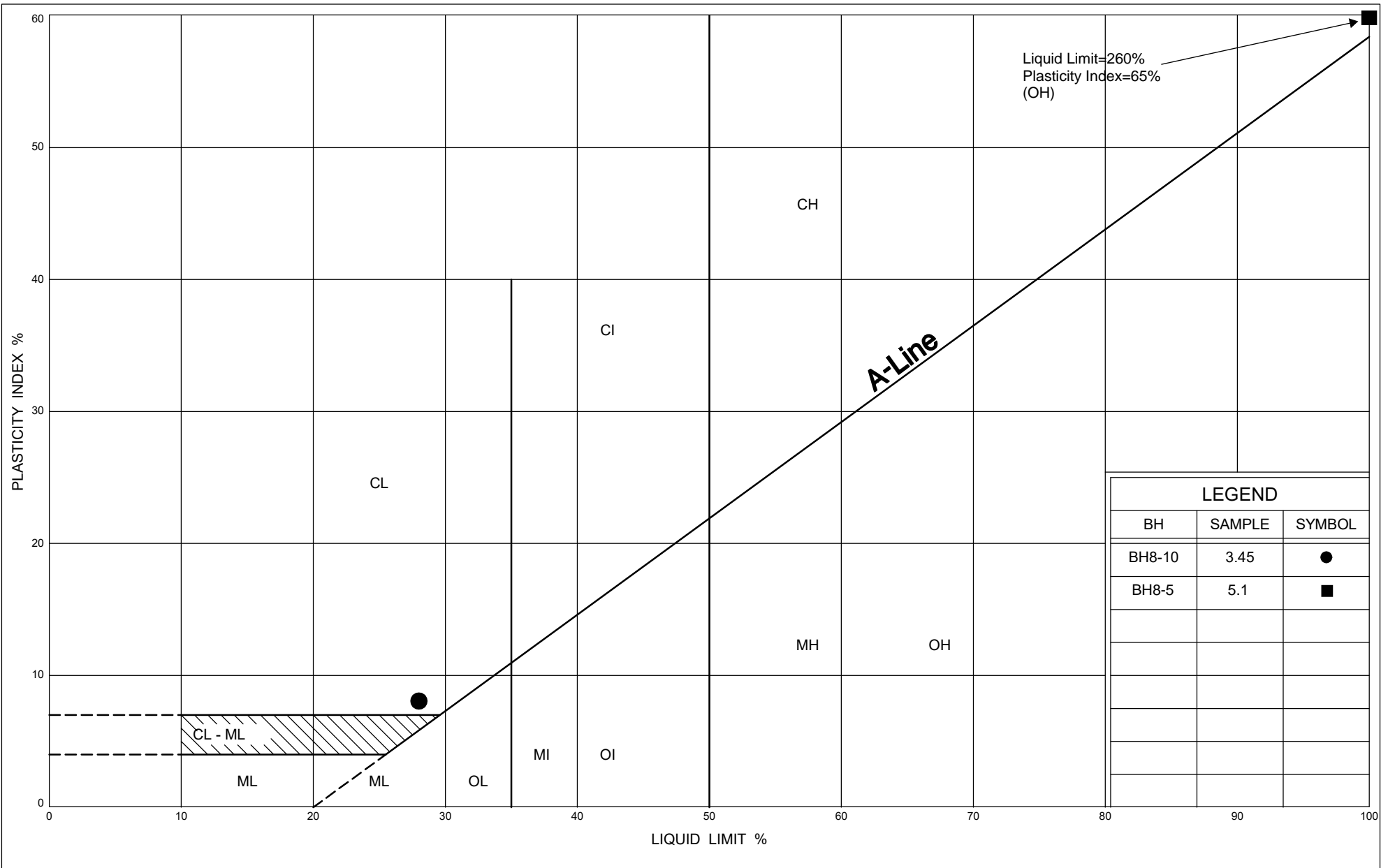
GRAIN SIZE DISTRIBUTION

Organic Silt

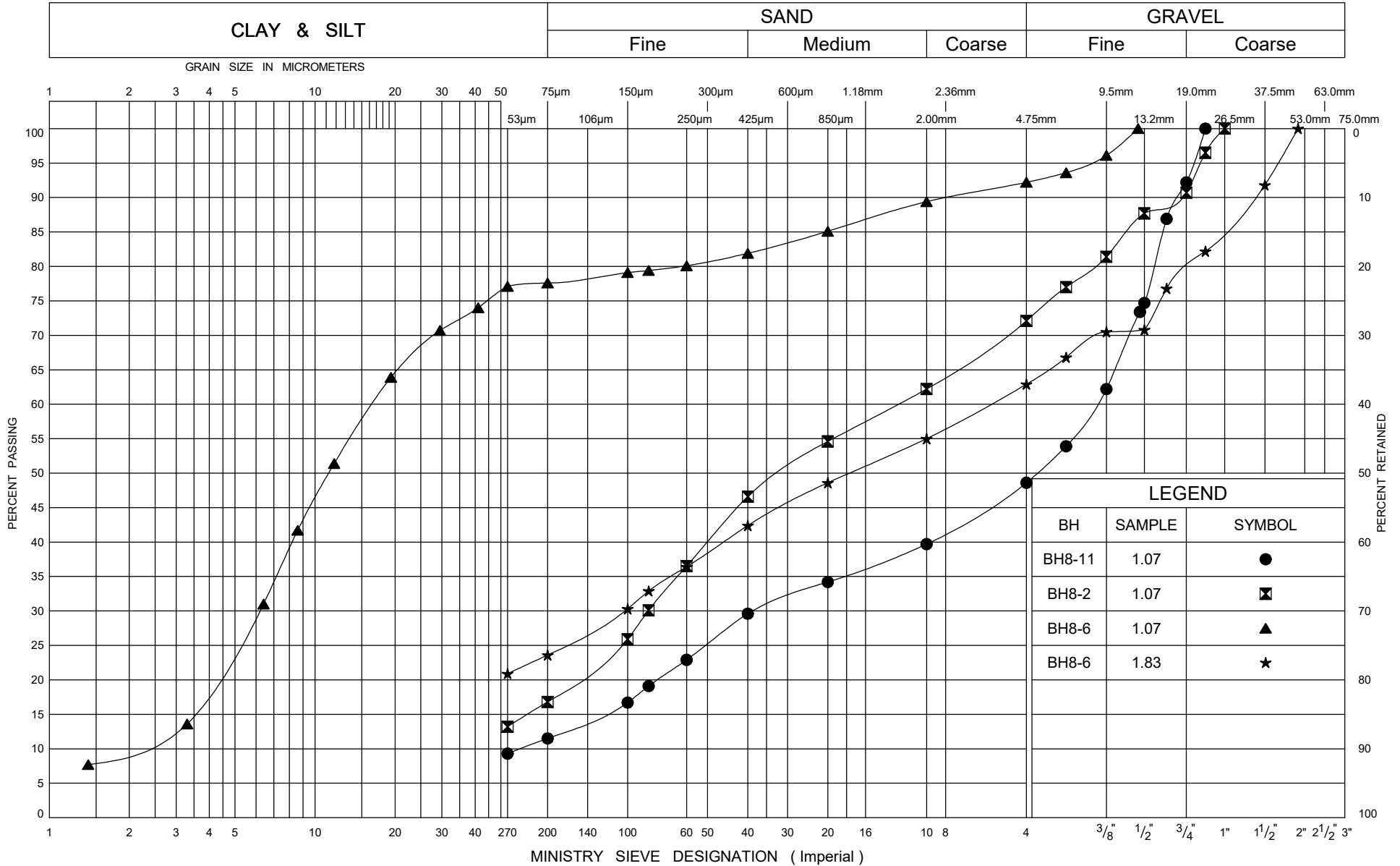
FIG No 1

GWP 5033-22-00

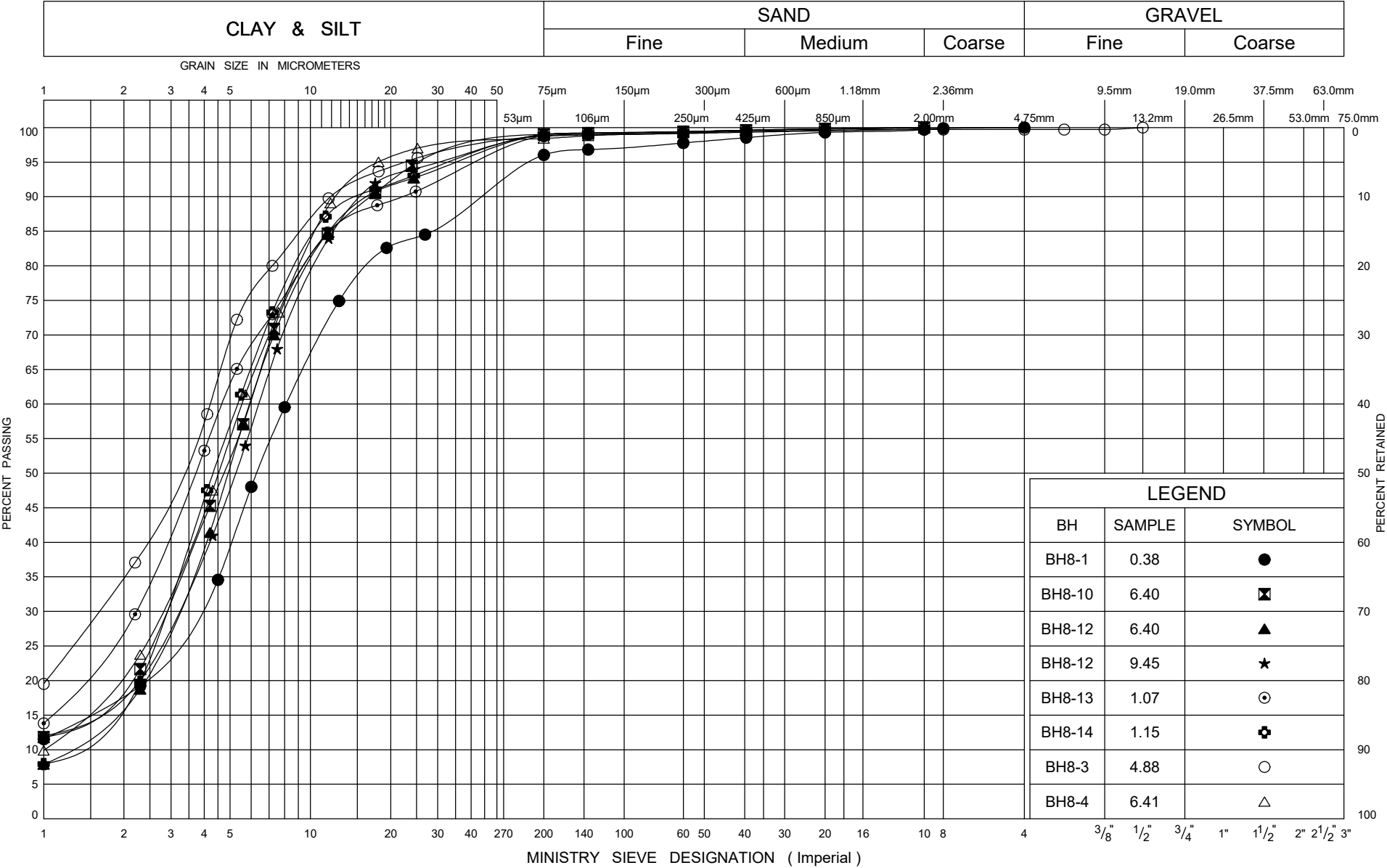
Highway 11 2+1, SW8



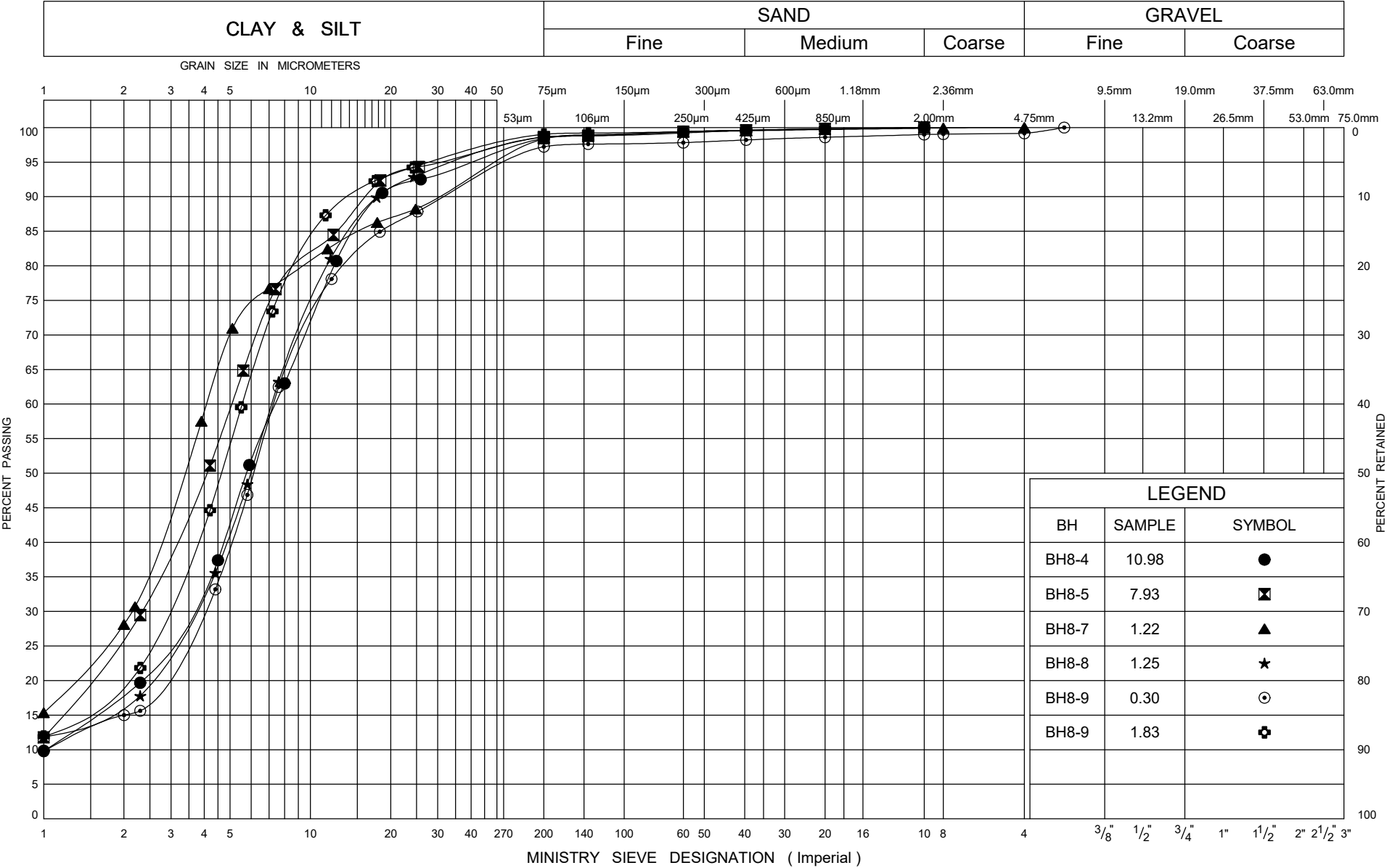
UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

Ontario

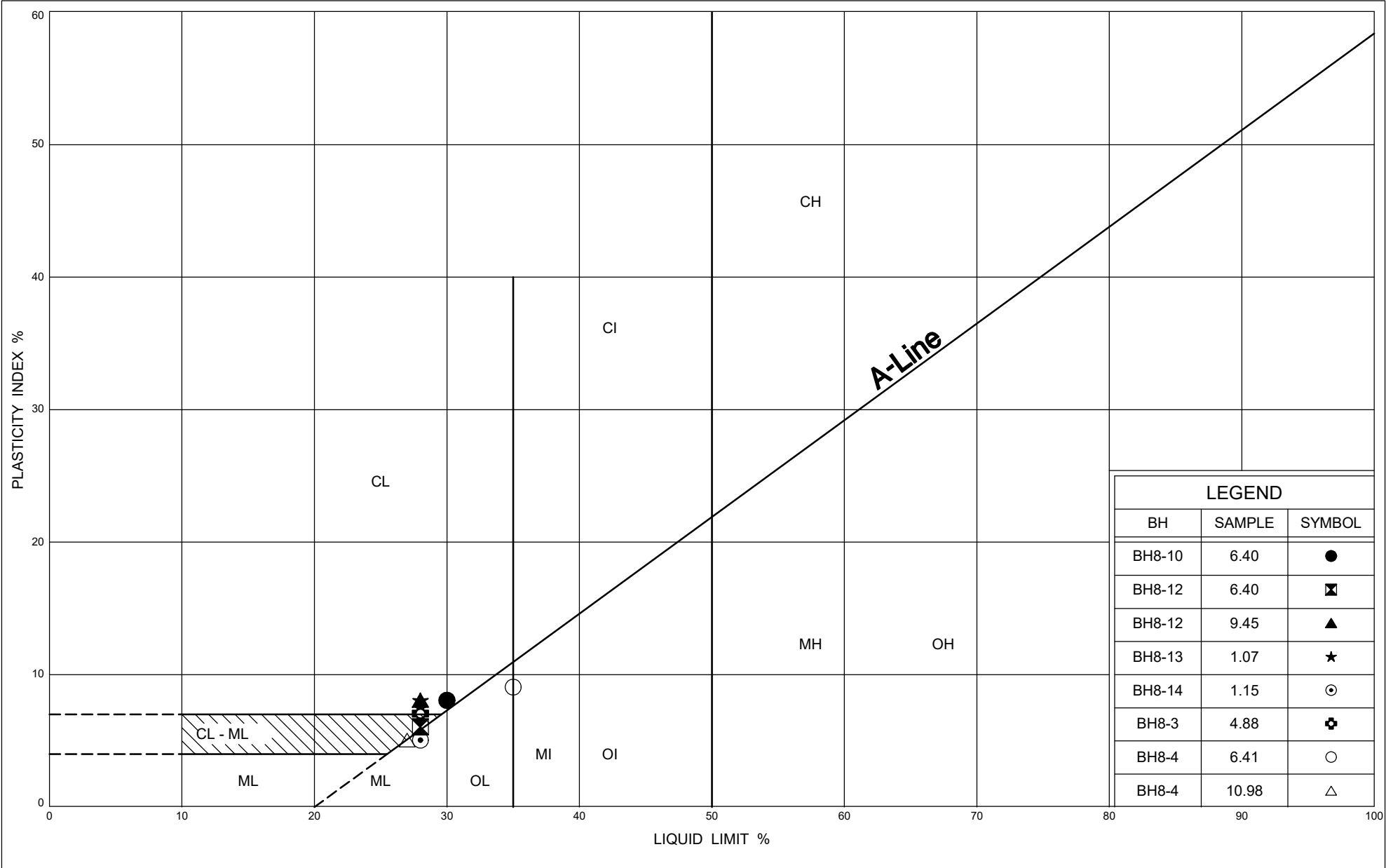
GRAIN SIZE DISTRIBUTION

Clayey Silt

FIG No 5

GWP 5033-22-00

Highway 11 2+1, SW8



Ministry of
Transportation

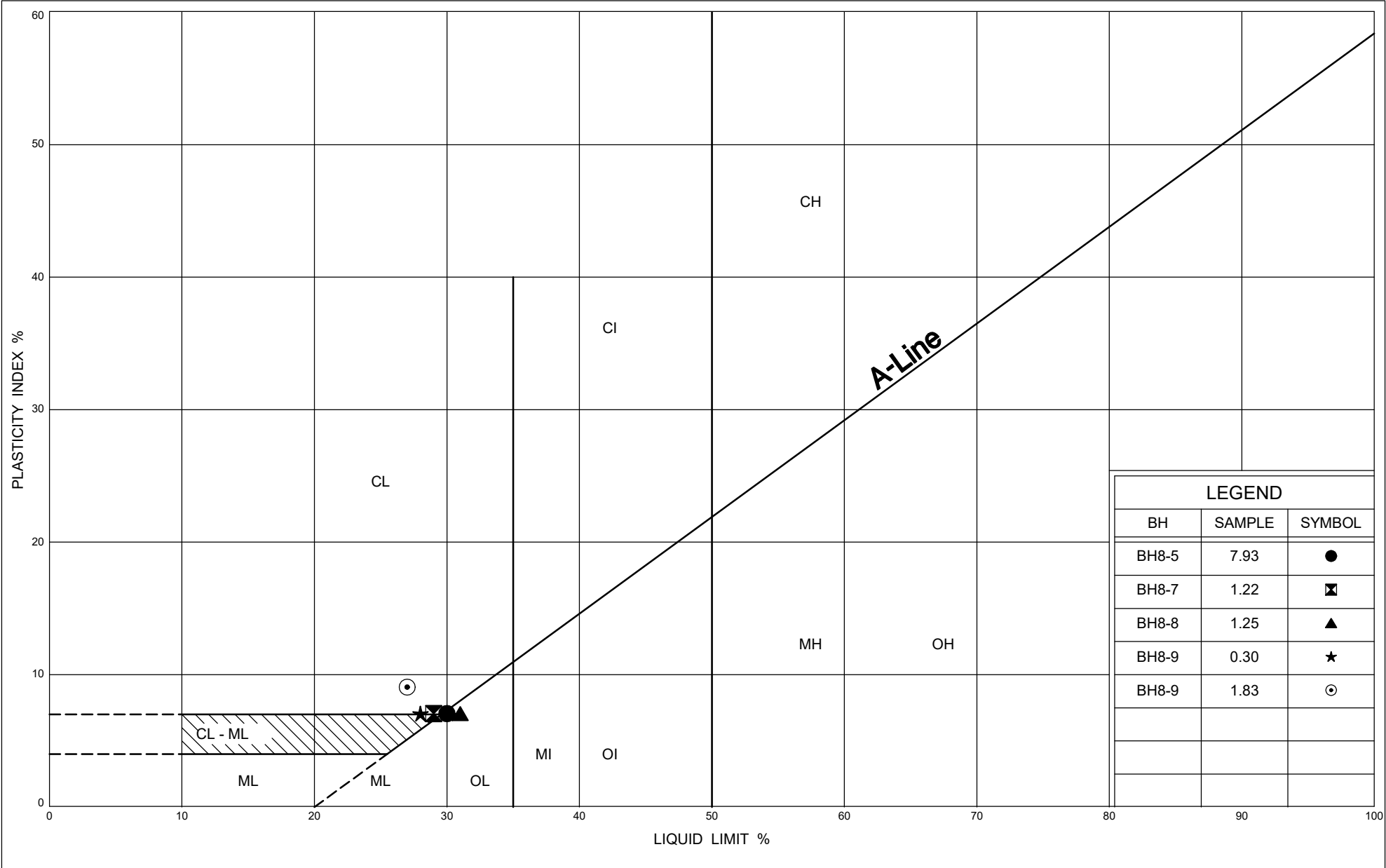
PLASTICITY CHART

Clayey Silt

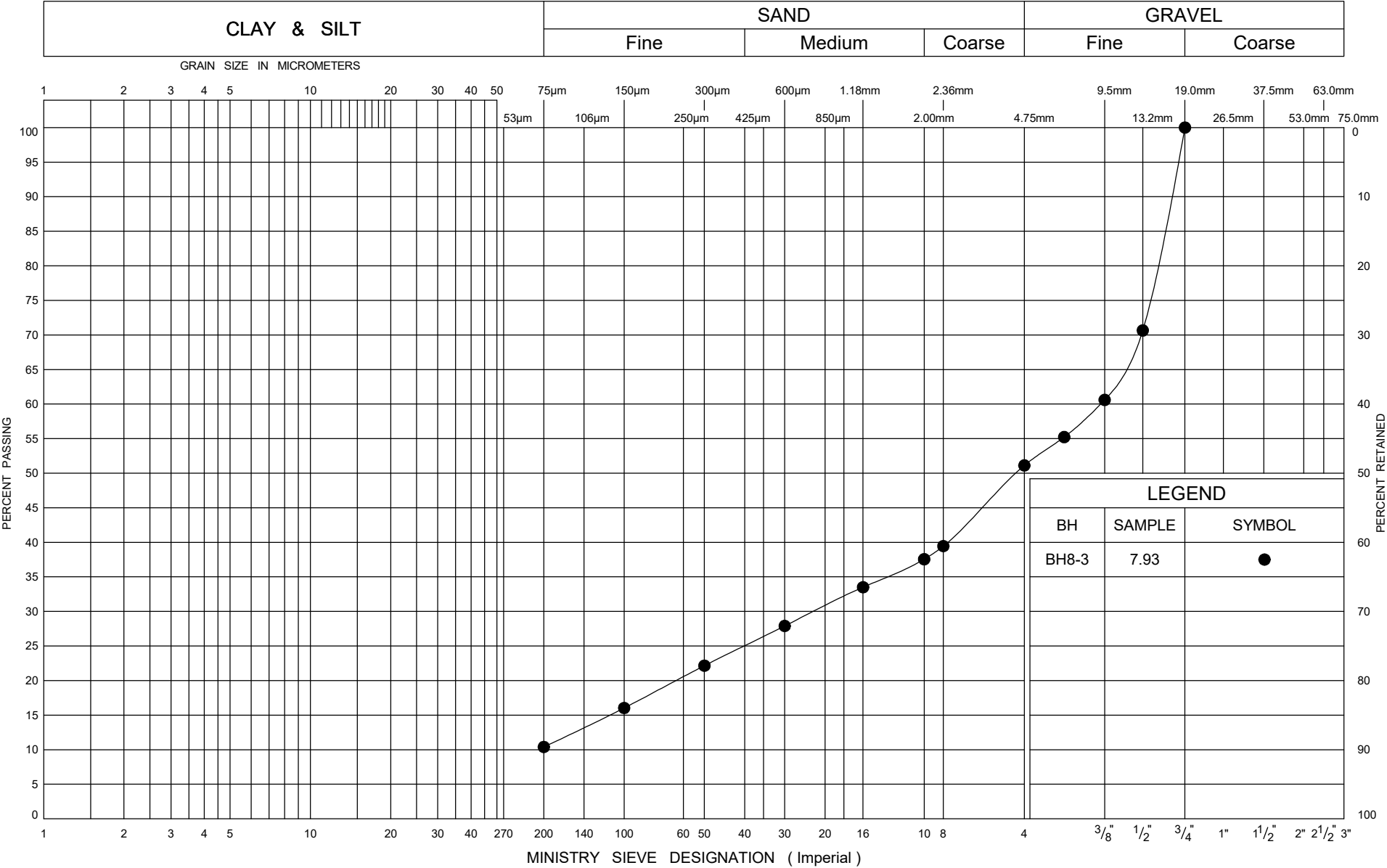
FIG No 6

GWP 5033-22-00

Highway 11 2+1, SW8



UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

Cobbles and Boulders (Soil Matrix)

FIG No 8

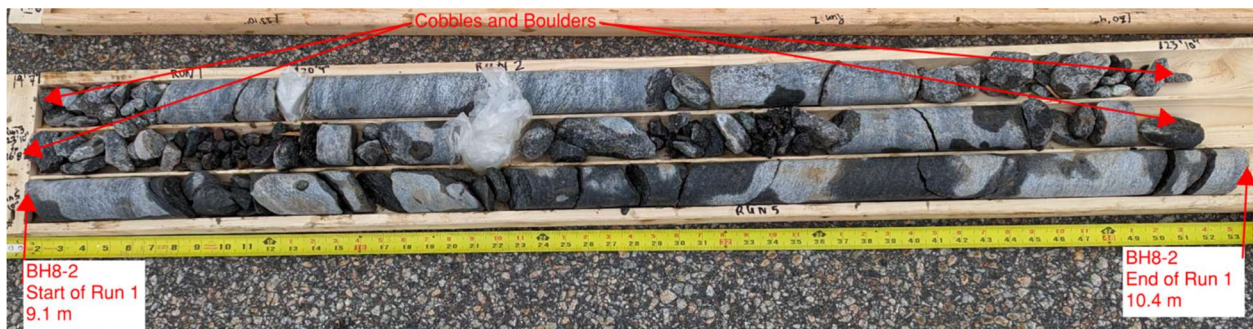
GWP 5033-22-00

Highway 11 2+1, SW8

Appendix E – Bedrock Core Photographs



Photograph E1. Rock cores from BH8-1. Top: Run 1, Middle/Bottom: Run 2, Bottom: Run 3.



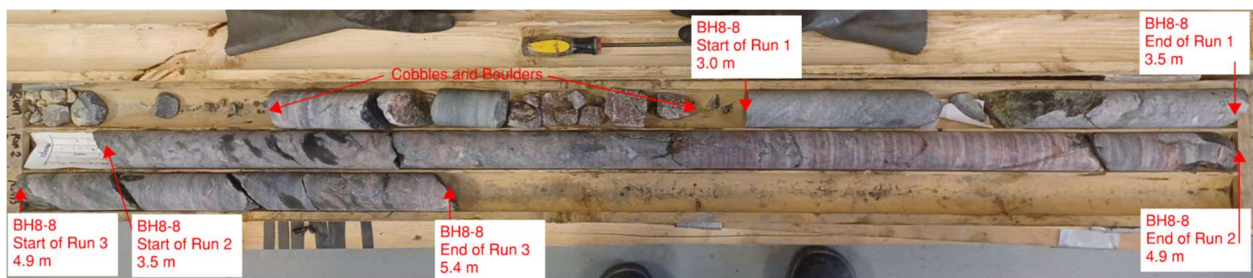
Photograph E2. Rock cores from BH8-2. Top: Cobbles and Boulders, Middle: Cobbles and Boulders, Bottom: Run 1.



Photograph E3. Rock cores from BH8-6. Top: Run 1, Middle/Bottom: Run 2.



Photograph E4. Rock cores from BH8-7. Top: Run 1, Middle: Run 2, Bottom: Run 3.



Photograph E5. Rock cores from BH8-8. Top: Run 1, Middle: Run 2, Bottom: Run 3.



Photograph E6. Rock cores from BH8-9. Top: Cobbles and Boulders, Middle: Run 1, Bottom: Run 2.



Photograph E7. Rock cores from BH8-10. Top: Run 1, Middle: Run 2, Bottom: Run 3.



Photograph E8. Rock cores from BH8-12. Top: Run 1, Middle/Bottom: Run 2.



Photograph E9. Rock cores from BH8-13. Top: Run 1, Middle/Bottom: Run 2.



Photograph E10. Rock cores from BH8-14. Top: Run 1, Middle/Bottom: Run 2.

Appendix F – Slope Stability Analyses

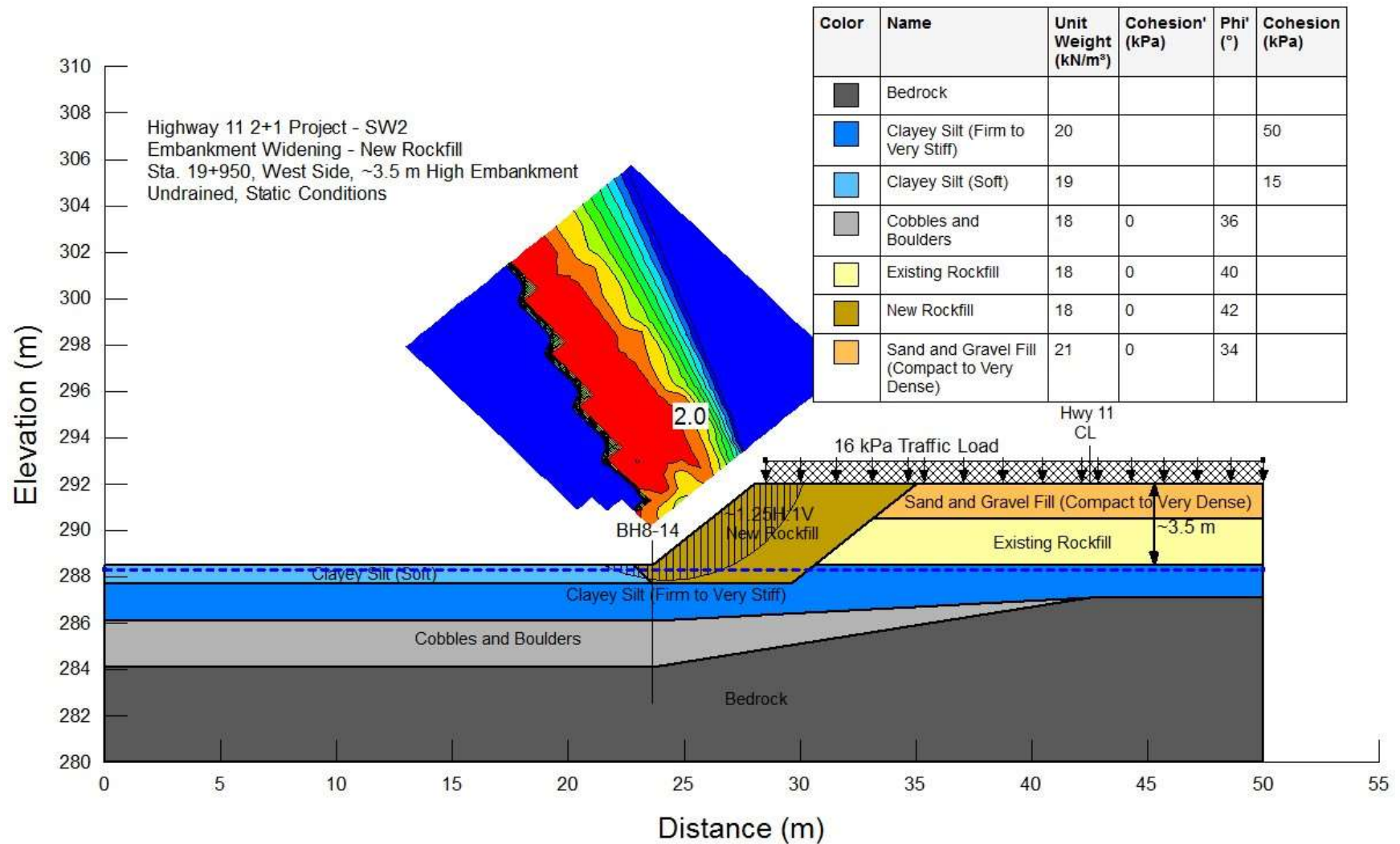


Figure F1: Slope stability analysis for embankment widening at Sta. 19+950, west side (~3.5 m high) – Rockfill (1.25H:1V) – undrained, static condition

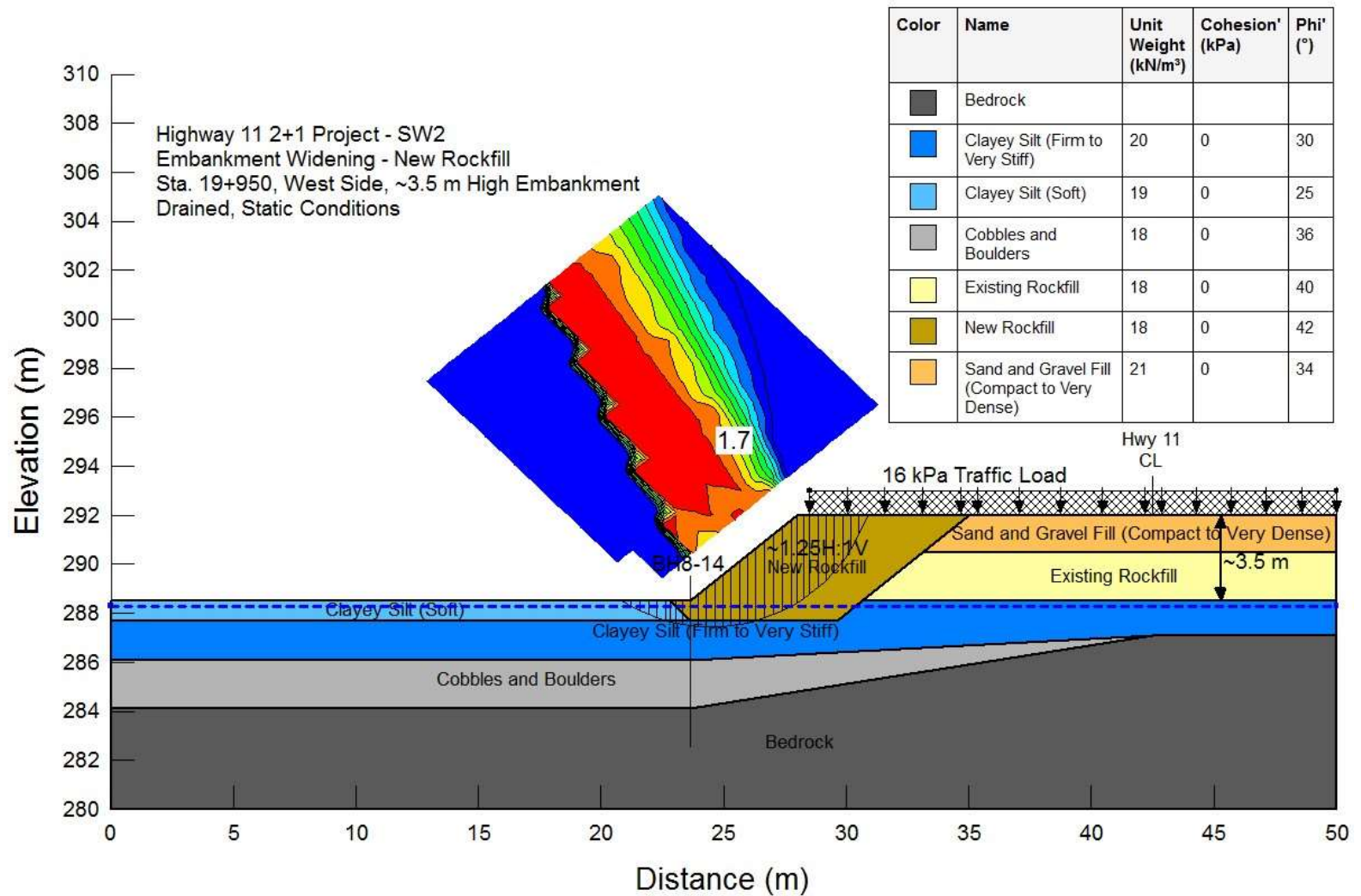


Figure F2: Slope stability analysis for embankment widening at Sta. 19+950, west side (~3.5 m high) – Rockfill (1.25H:1V) – drained, static condition

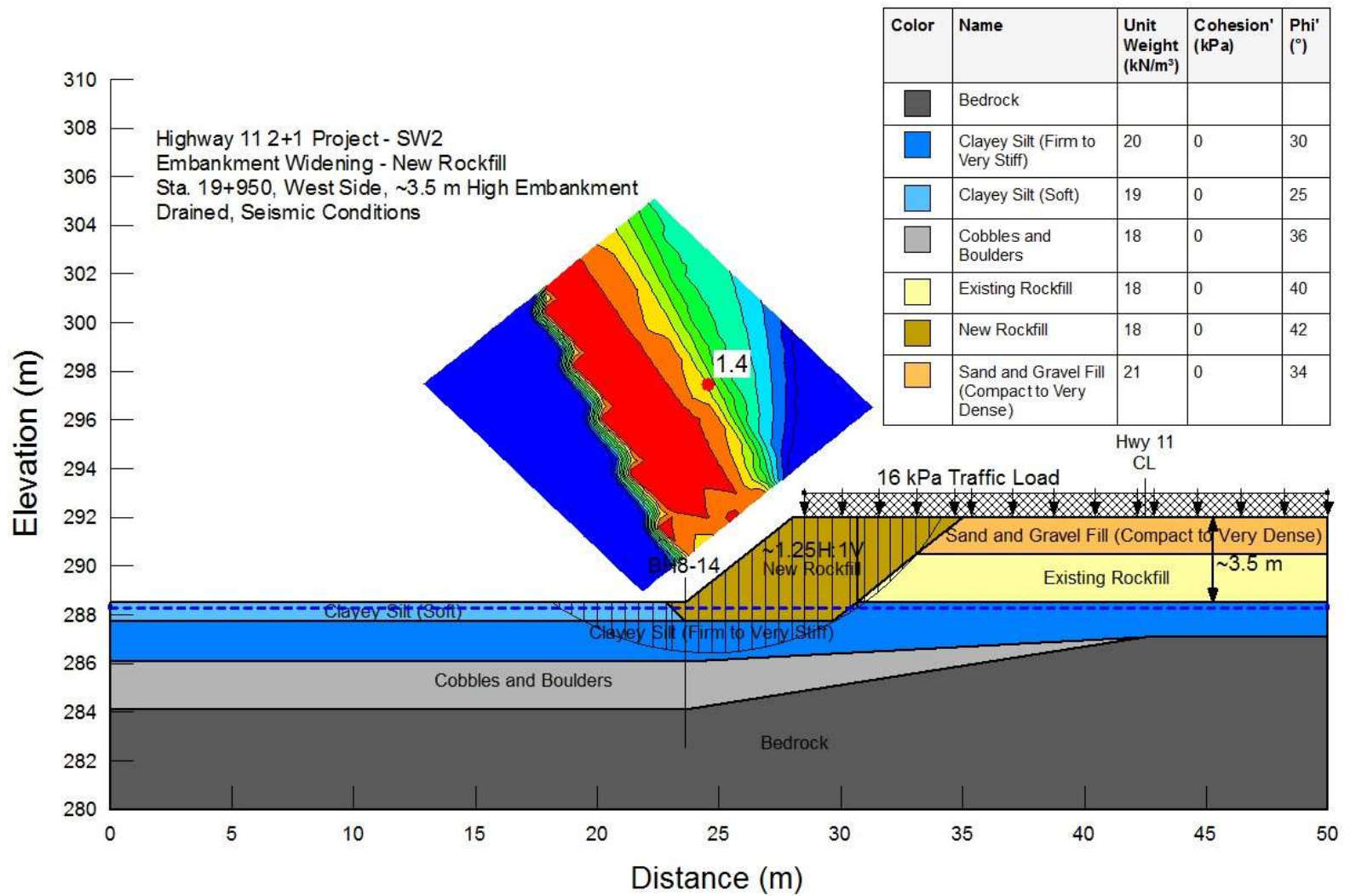


Figure F3: Slope stability analysis for embankment widening at Sta. 19+950, west side (~3.5 m high) – Rockfill (1.25H:1V) – drained, seismic condition

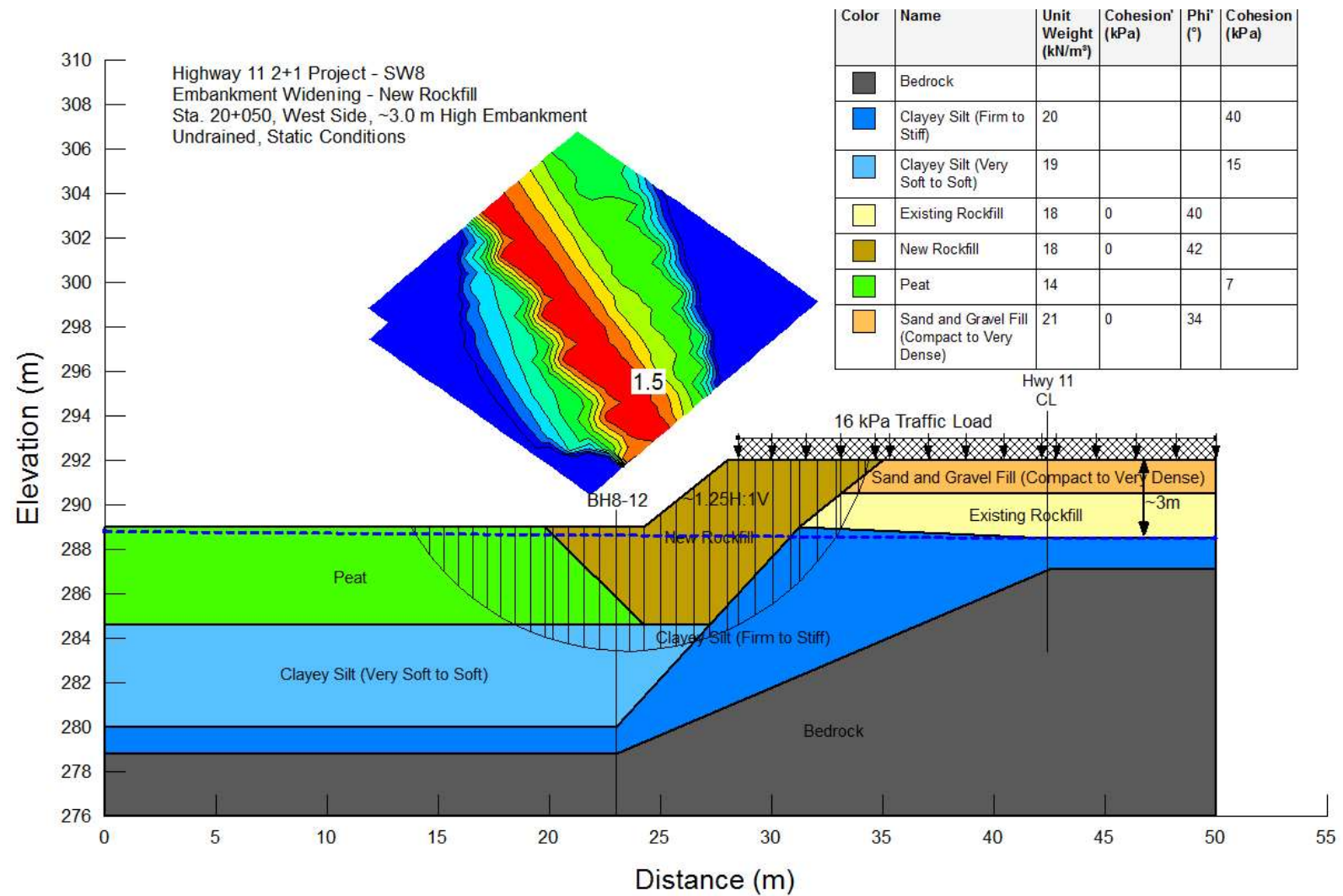


Figure F4: Slope stability analysis for embankment widening at Sta. 20+050, west side (~3 m high) – Rockfill (1.25H:1V) – undrained, static condition

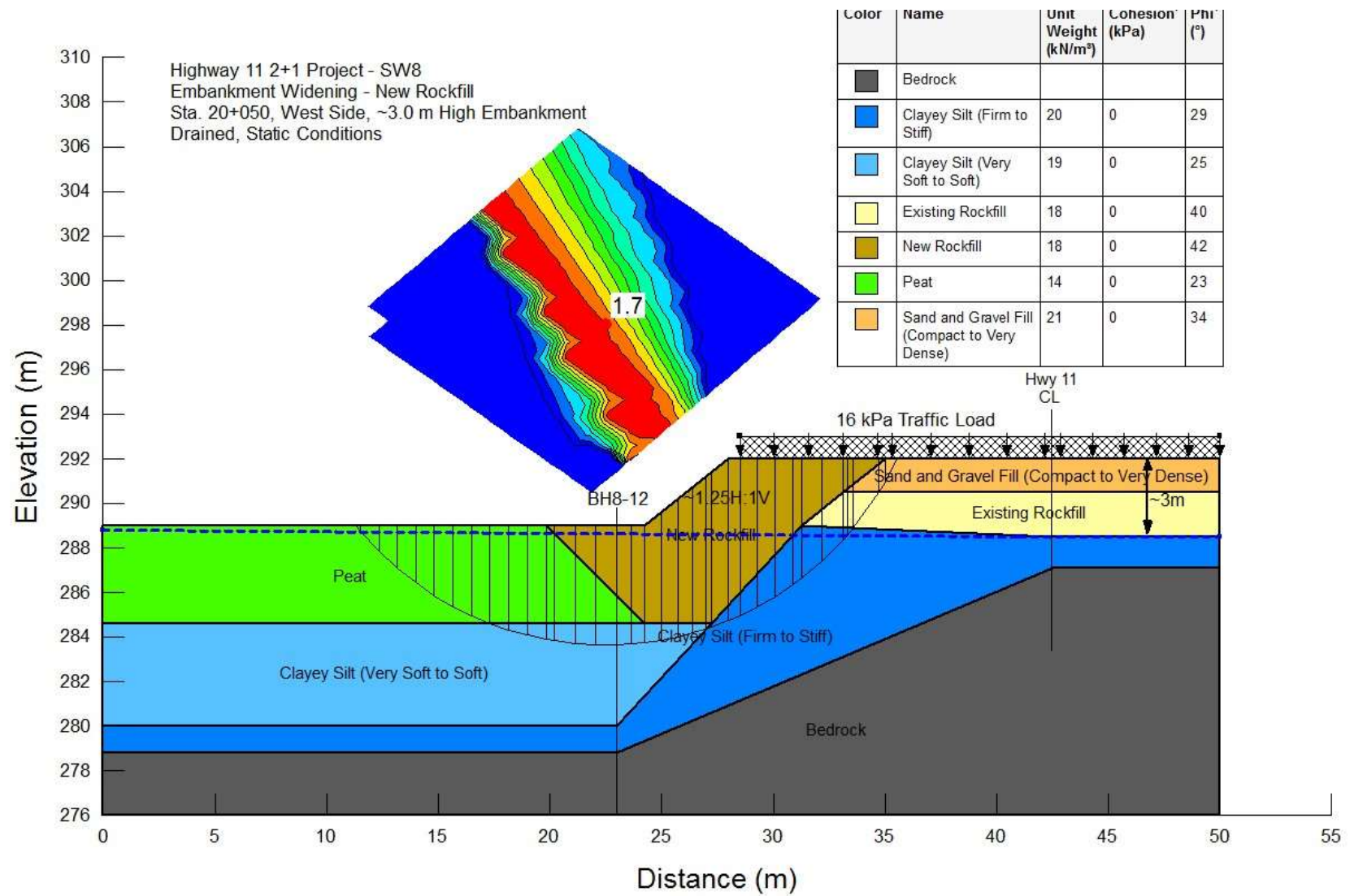


Figure F5: Slope stability analysis for embankment widening at Sta. 20+050, west side (~3 m high) – Rockfill (1.25H:1V) – drained, static condition

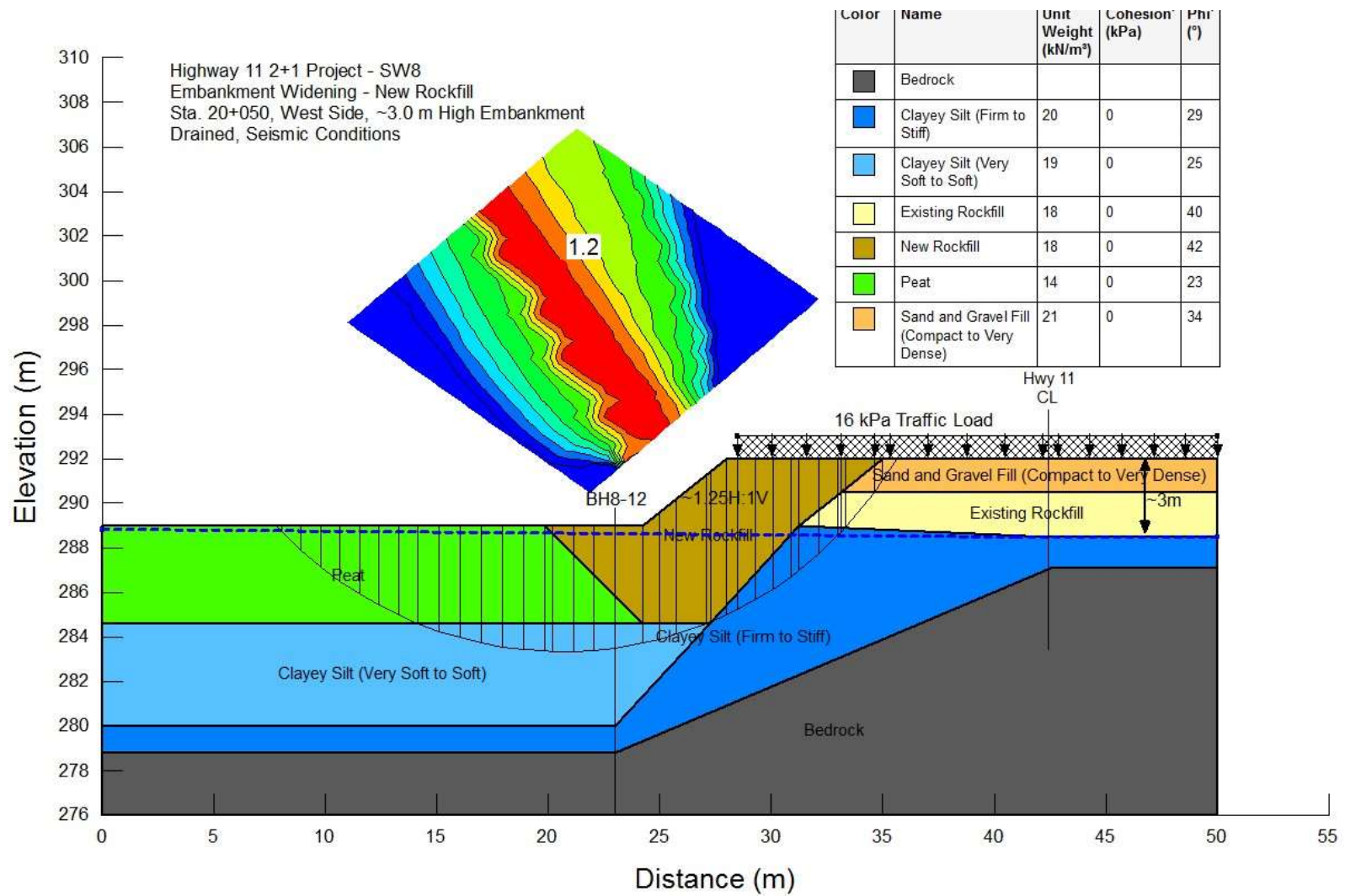
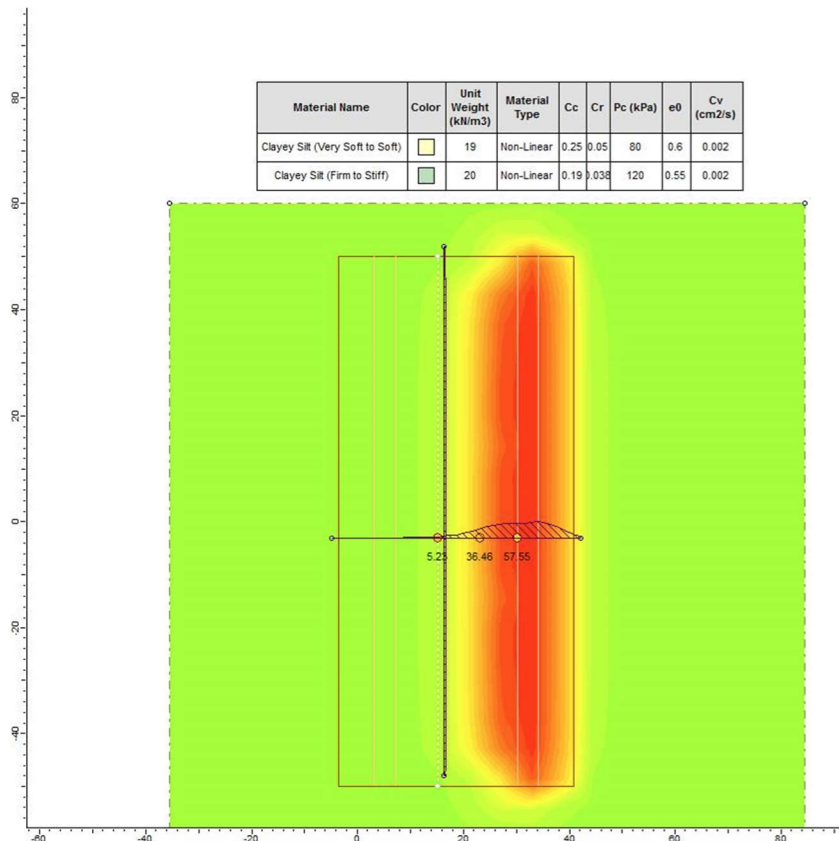
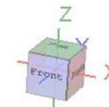
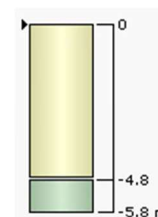
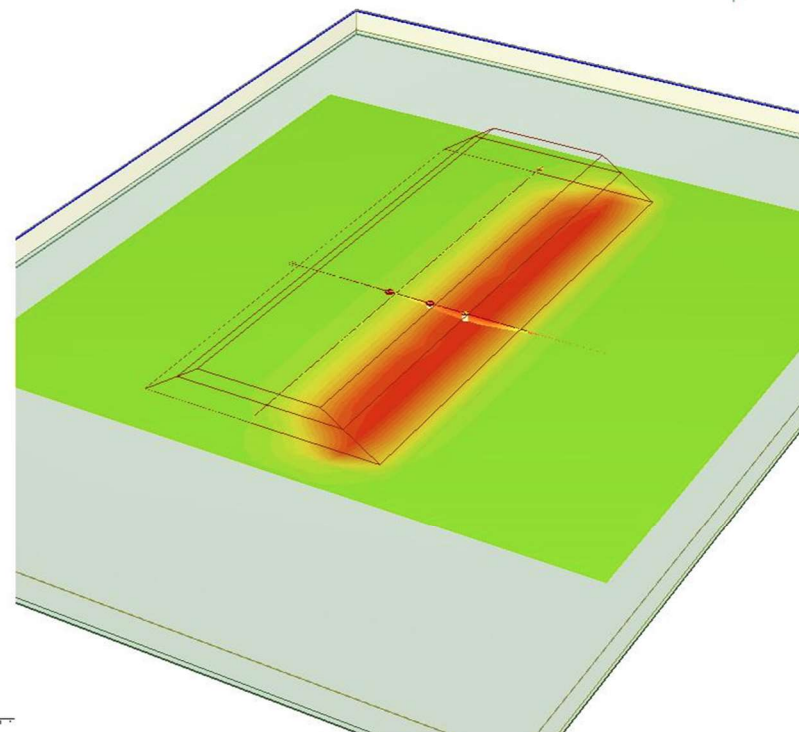


Figure F6: Slope stability analysis for embankment widening at Sta. 20+050, west side (~3 m high) – Rockfill (1.25H:1V) – drained, seismic condition

Appendix G – Settlement Analyses



Material Name	Color	Unit Weight (kN/m ³)	Material Type	Cc	Cr	Pc (kPa)	e0	Cv (cm ² /s)
Clayey Silt (Very Soft to Soft)		19	Non-Linear	0.25	0.05	80	0.6	0.002
Clayey Silt (Firm to Stiff)		20	Non-Linear	0.19	0.038	120	0.55	0.002



Project: Hwy 11: 2 + 1 – SW8

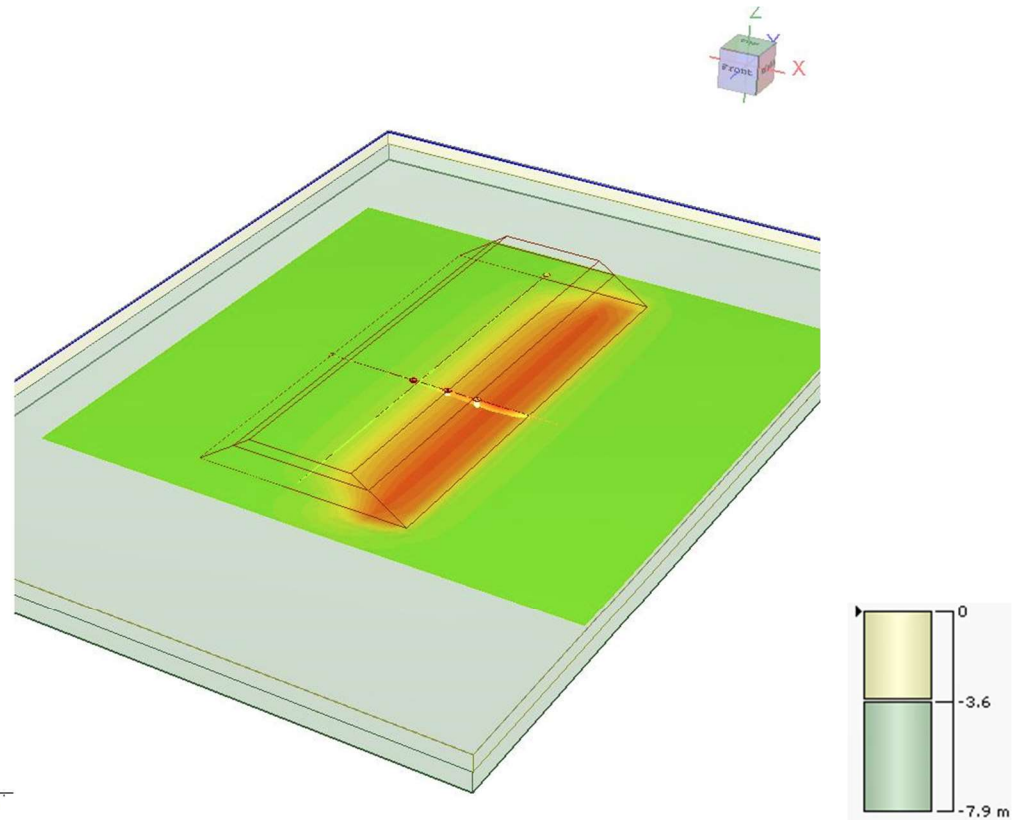
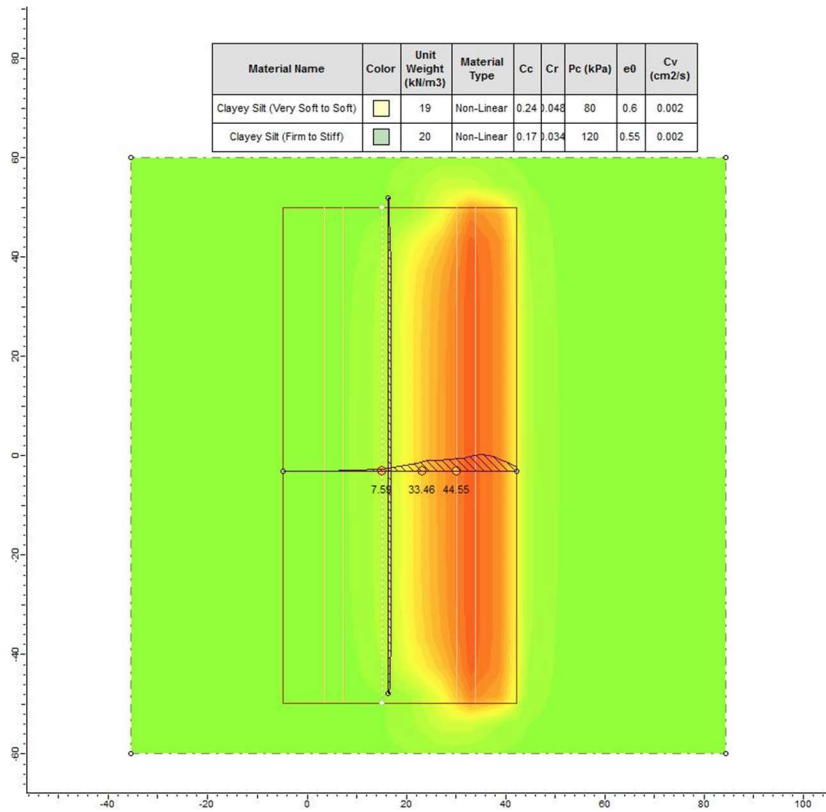
Analysis Description: Embankment Widening with Rockfill (West side) – **Total Settlement**

Figure No: G1

Company: EXP Services Inc.

Date: July 10, 2024

File Name: Hwy 11: 2+1 – SW8, Settlement Analysis



Project: Hwy 11: 2 + 1 – SW8

Analysis Description: Embankment Widening with Rockfill (East side) – **Total Settlement**

Figure No: G2

Company: EXP Services Inc.

Date: July 10, 2024

File Name: Hwy 11: 2+1 – SW8, Settlement Analysis

Appendix H – Seismic Hazard Calculation



Government
of Canada

Gouvernement
du Canada

Canada.ca › [Natural Resources Canada](#) › [Earthquakes Canada](#)

2020 National Building Code of Canada Seismic Hazard Tool

i This application provides seismic values for the design of buildings in Canada under Part 4 of the National Building Code of Canada (NBC) 2020 as prescribed in Article 1.1.3.1. of Division B of the NBC 2020.

Seismic Hazard Values

User requested values

Code edition	NBC 2020
Site designation X_S	X_D
Latitude (°)	46.799
Longitude (°)	-79.802

Please select one of the tabs below.

NBC 2020

Additional Values

Plots

API

Background Information

The 5%-damped spectral acceleration ($S_a(T, X)$, where T is the period, in s, and X is the site designation) and peak ground acceleration ($PGA(X)$) values are given in units of acceleration due to gravity (g , 9.81 m/s^2). Peak

ground velocity. (PGV(X)) values are given in m/s. Probability is expressed in terms of percent exceedance in 50 years. Further information on the calculation of seismic hazard is provided under the *Background Information* tab.

The 2%-in-50-year seismic hazard values are provided in accordance with Article 4.1.8.4. of the NBC 2020. The 5%- and 10%-in-50-year values are provided for additional performance checks in accordance with Article 4.1.8.23. of the NBC 2020.

See the *Additional Values* tab for additional seismic hazard values, including values for other site designations, periods, and probabilities not defined in the NBC 2020.

NBC 2020 - 2%/50 years (0.000404 per annum) probability

$S_a(0.2, X_D)$	$S_a(0.5, X_D)$	$S_a(1.0, X_D)$	$S_a(2.0, X_D)$	$S_a(5.0, X_D)$	$S_a(10.0, X_D)$	PGA(X_D)	PGV(X_D)
0.418	0.363	0.21	0.0982	0.0259	0.00806	0.256	0.24

The log-log interpolated 2%/50 year $S_a(4.0, X_D)$ value is : **0.0358**

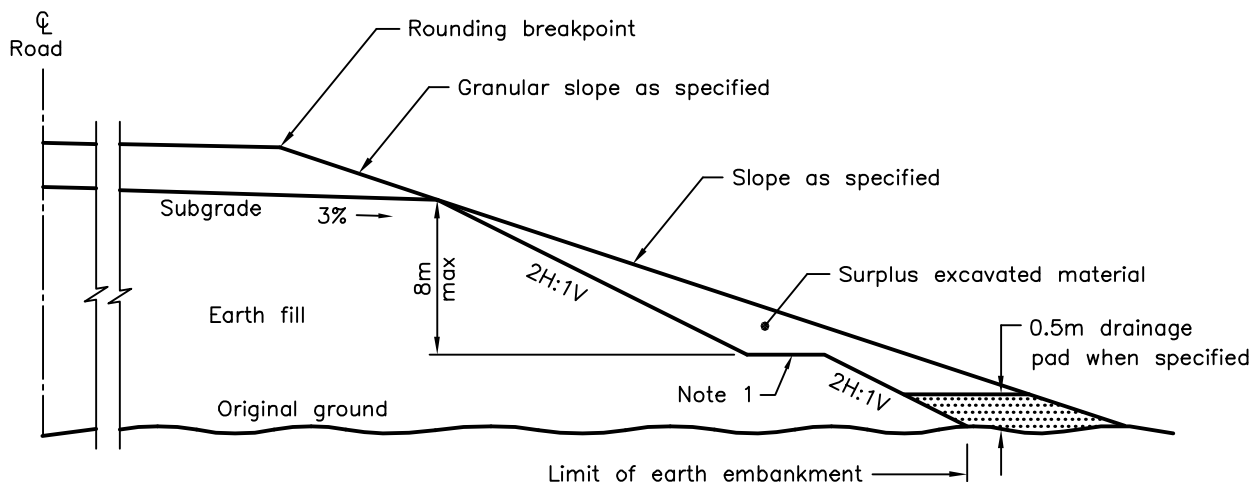
► Tables for 5% and 10% in 50 year values

Download CSV

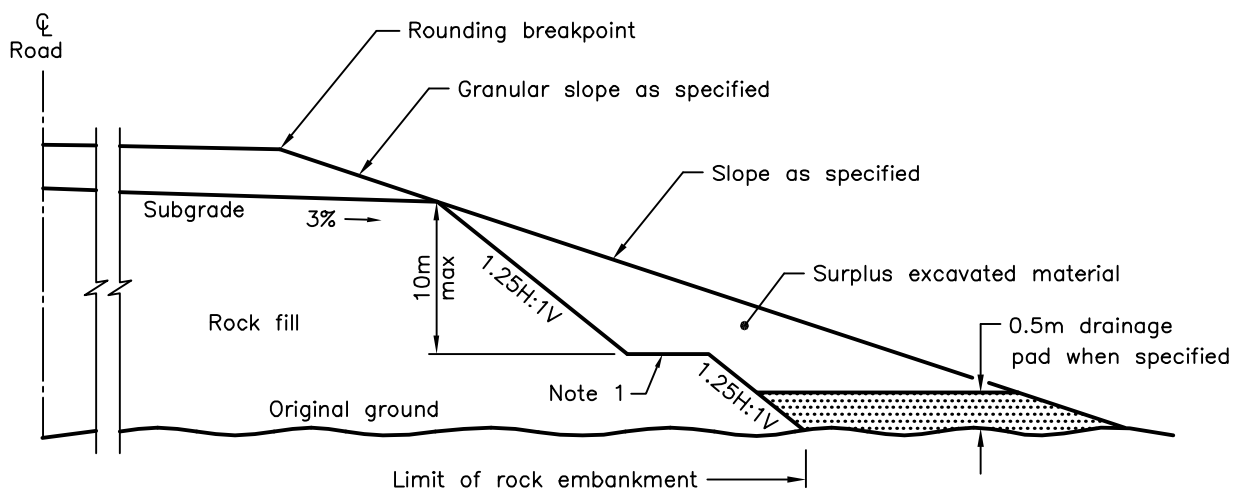
← Go back to the [seismic hazard calculator form](#)

Date modified: 2021-04-06

Appendix I – OPSDs



EARTH EMBANKMENT



ROCK EMBANKMENT

NOTES:

1 Benches 2m minimum in width are required along slopes at maximum vertical intervals as shown.

A Height of fill is the vertical difference between top of subgrade and top of original ground measured at new road centreline.

B Surplus excavated material placed shall not extend beyond the right-of-way.

C All dimensions are in metres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2016

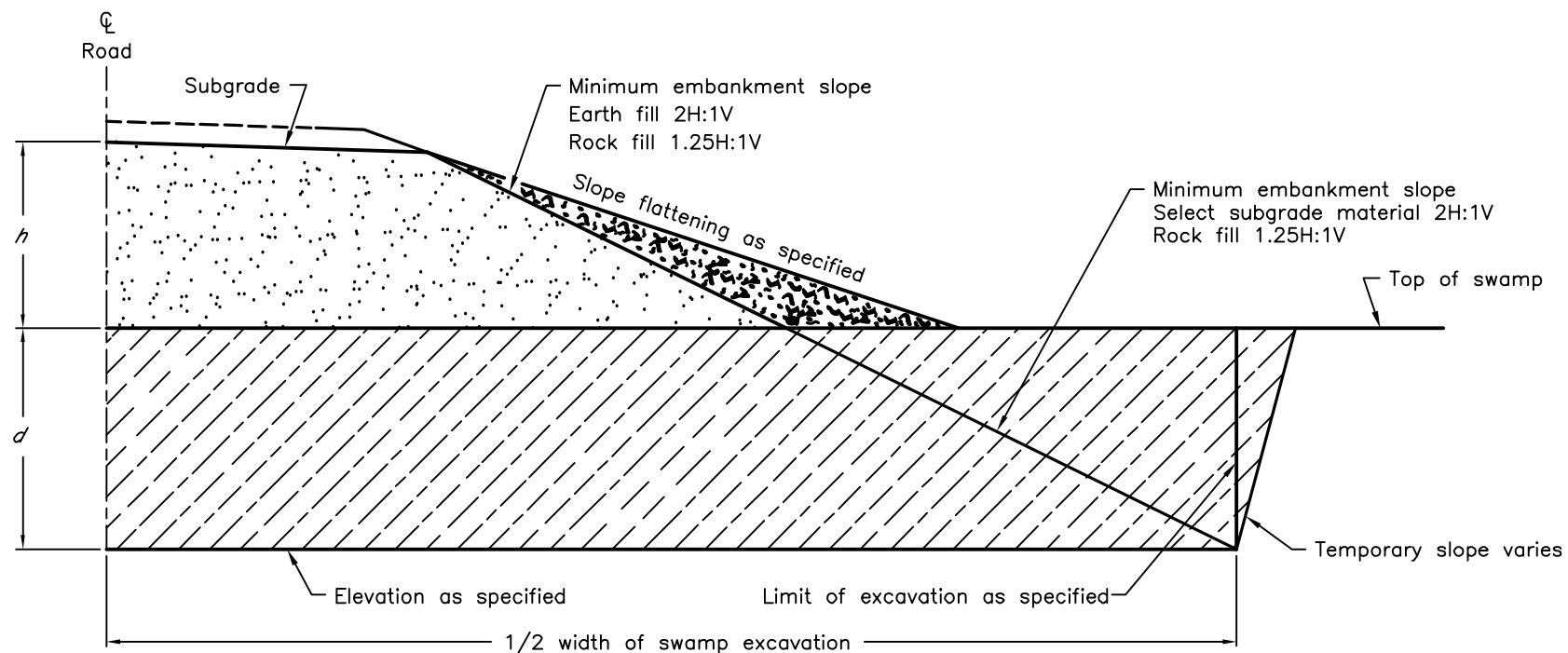
Rev

3



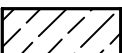
**SLOPE FLATTENING
USING SURPLUS EXCAVATED MATERIAL
ON EARTH OR ROCK EMBANKMENT**

OPSD 202.010





LEGEND:

-  Embankment materials as specified
-  Excavated swamp material
-  Excavate and backfill as specified

h – Height of fill
 d – Depth of sub-excavation

NOTE:

A Height of fill is the vertical difference between subgrade and top of swamp measured at new road centreline.

ONTARIO PROVINCIAL STANDARD DRAWING

EMBANKMENTS OVER SWAMP

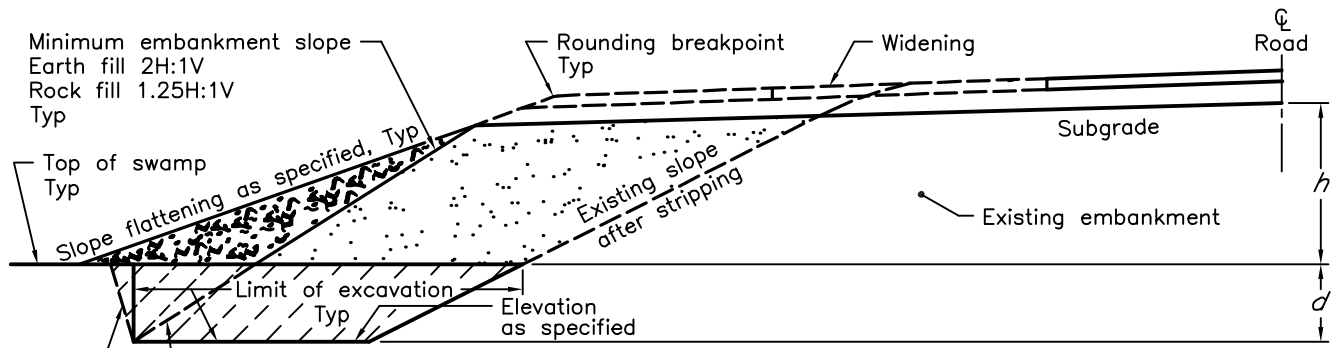
NEW CONSTRUCTION

Nov 2017

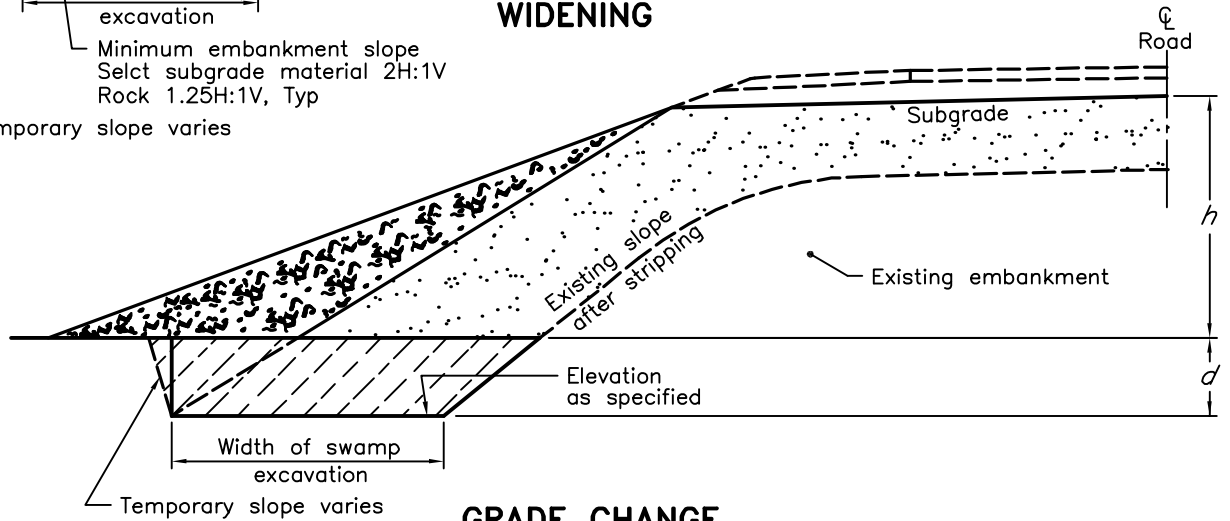
Rev 4



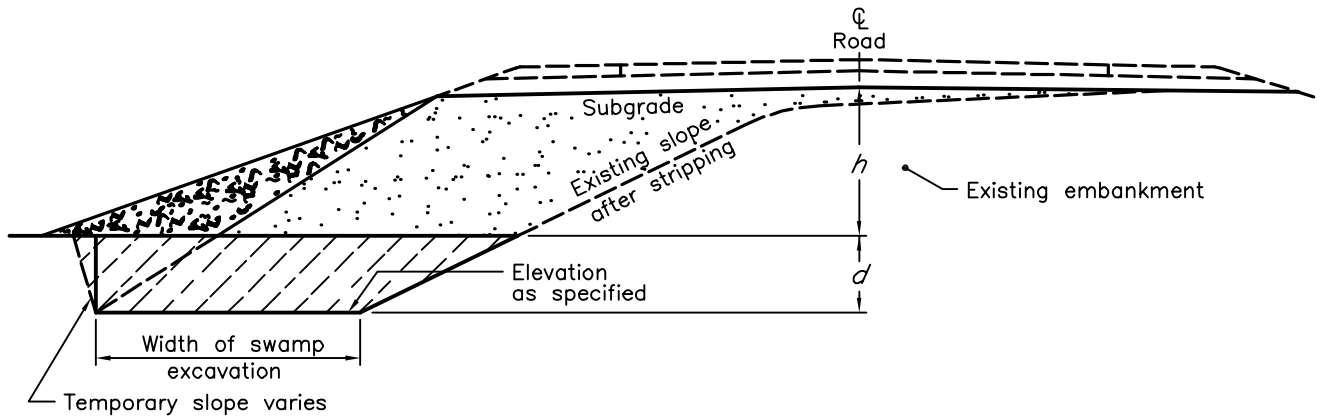
OPSD 203.010



WIDENING



GRADE CHANGE



RE-ALIGNMENT AND GRADE CHANGE

NOTES:

- A Topsoil shall be stripped from existing slopes.
- B Height of fill is the vertical difference between subgrade and top of swamp measured at new road centreline.
- C Widening of existing earth embankments shall be benched according to OPSD 208.010.

LEGEND:

- h - Height of fill
 d - Depth of sub-excitation
- Embankment materials as specified
 - Excavated swamp material
 - Excavate and backfill as specified

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2017

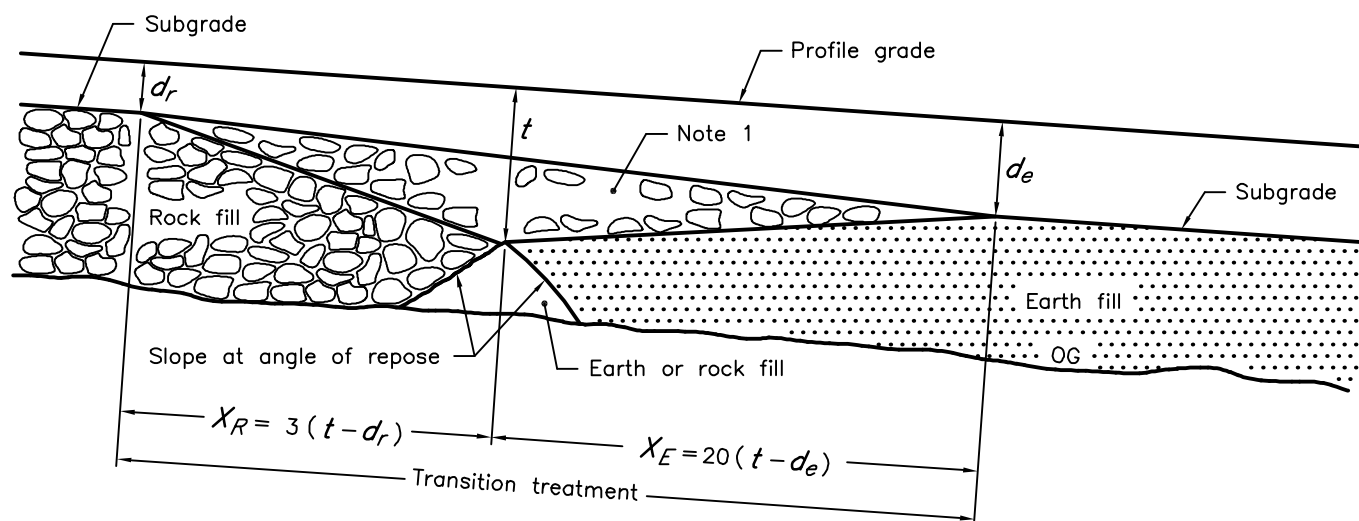
Rev 4

EMBANKMENTS OVER SWAMP

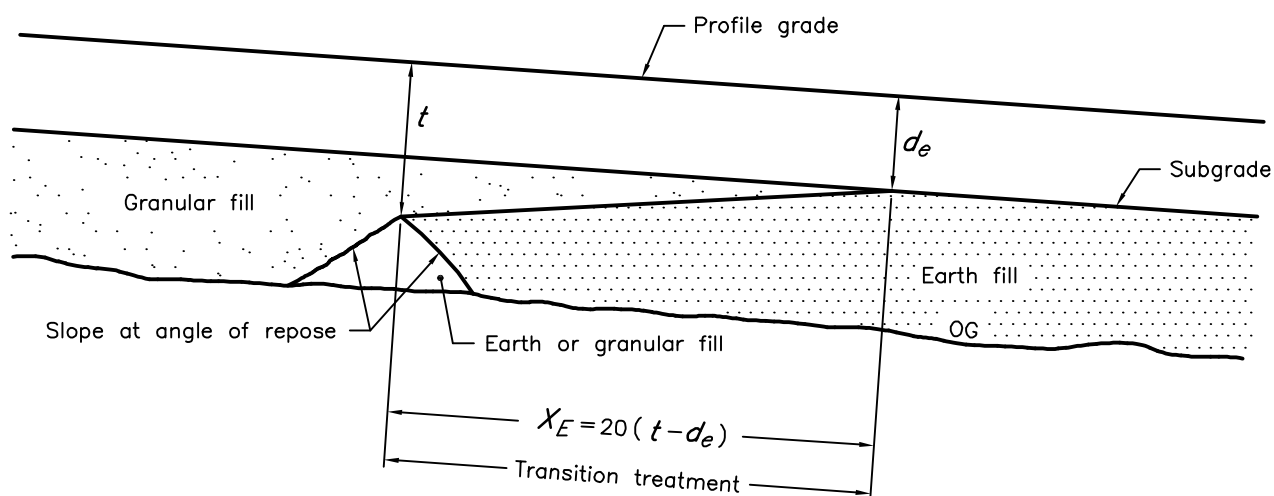
EXISTING SLOPES MAINTAINED



OPSD 203.030



EARTH FILL TO ROCK FILL



EARTH FILL TO GRANULAR FILL

NOTES:

- 1 Rock or granular fill.
- A Embankment slopes to transition uniformly over distance X_R and X_E .
- B Profile grade and subgrade lines apply across the transverse section.

LEGEND:

- d_e – Depth of granular base and subbase over earth
 d_r – Depth of granular base and subbase over rock fill
 t – Transition treatment depth, as specified
 X_E – Length of transition for earth fill, 15m maximum
 X_R – Length of transition in rock fill

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2016

Rev 3

TRANSITION TREATMENT
 EARTH FILL TO ROCK FILL AND
 EARTH FILL TO GRANULAR FILL



OPSD 205.040

Appendix J – NSSPs

EXCAVATION OF PEAT/ORGANIC DEPOSITS AT THE TOE OF HWY 11 EMBANKMENT AND BACKFILLING WITH ROCKFILL

Non-Standard Special Provision

Scope of Work

Excavation of top layers of peat/organic material within the footprint of new embankment fill for widening of Hwy 11, and backfill of excavation with rockfill.

Construction

The top peat/organic material shall be excavated along the whole footprint of the new embankment fill for widening. The excavation shall be in accordance with OPSD 203.030 following the slope of the existing rockfill embankment, and then, backfilled with rockfill immediately after excavation. Do not keep the excavation opened under any circumstances.

These simultaneous excavation and backfilling operations shall be done from outside to inside in sections parallel to the existing highway as shown below. The sections shall be approximately 3 m to 5 m wide.

