

**REPORT**

# Foundation Investigation and Design Report

*Mile Hill Widening - High Fill and Deep Cut Areas*

*Highway 17 Rehabilitation from Sault Ste. Marie North Limits Northerly 14.5 km to the Goulais River Bridge*

*Algoma District, Ontario*

*GWP 5181-13-00*

Submitted to:

**AECOM**

189 Wyld Street, Suite 103  
North Bay, Ontario  
P1B 1Z2

Submitted by:

**Golder, member of WSP**

6925 Century Avenue, Suite #100, Mississauga, Ontario, L5N 7K2, Canada

+1 905 567 4444

19122433 Rev.0

December 3, 2021

GEOCRES NO. 41K-119

LAT. 46.680050°

LONG. -84.343235°



## Distribution List

1 e-copy: MTO Northeastern Region (North Bay)

1 e-copy: MTO Foundations Section (Downsview)

1 e-copy: AECOM (North Bay)

1 e-copy: Golder, a member of WSP (Mississauga)

# Table of Contents

## PART A – FOUNDATION INVESTIGATION REPORT

<b>1.0 INTRODUCTION .....</b>	<b>1</b>
<b>2.0 PROJECT AND SITE DESCRIPTION .....</b>	<b>1</b>
2.1 Project Description .....	1
2.2 Site Description .....	2
<b>3.0 FIELD INVESTIGATION PROCEDURES.....</b>	<b>2</b>
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS.....</b>	<b>5</b>
4.1 Regional Geology.....	5
4.2 Overview of Local Subsurface Conditions .....	5
4.2.1 Highway 17 NBL – STA 11+440 to STA 11+620 (High Fill Area No. 1) .....	6
4.2.1.1 Asphalt.....	6
4.2.1.2 SAND (SP) and Gravel to SAND (SP) to SILTY SAND (SM) (FILL) .....	6
4.2.1.3 Gravelly SAND (SP) to SILTY SAND (SM) to SILT (ML) .....	7
4.2.1.4 CLAYEY SILT-SILT (CL-ML).....	8
4.2.1.5 SAND (SP).....	8
4.2.2 Highway 17 NBL – STA 12+150 to STA 12+220 (Deep Cut Area No. 1).....	8
4.2.2.1 ASPHALT.....	8
4.2.2.2 SAND (SP) and Gravel (FILL) .....	8
4.2.2.3 Gravelly SILTY SAND (SM/GM) .....	8
4.2.2.4 CLAYEY SILT-SILT (CL-ML).....	9
4.2.2.5 SILT (ML).....	10
4.2.3 Highway 17 NBL – STA 13+240 to STA 13+400 (High Fill Area No. 2).....	10
4.2.3.1 ASPHALT.....	10
4.2.3.2 Gravelly SAND (SP) to SILTY SAND (SM) (FILL).....	10
4.2.3.3 Cobbles.....	11
4.2.3.4 Gravelly SAND (SP) to SILTY GRAVEL (GM) to Sandy SILT (ML) .....	11
4.3 Groundwater Conditions .....	11
<b>5.0 CLOSURE .....</b>	<b>12</b>

## PART B – FOUNDATION DESIGN REPORT

<b>6.0</b>	<b>DISCUSSION AND ENGINEERING RECOMMENDATIONS .....</b>	<b>15</b>
6.1	General.....	15
6.2	Consequence and Site Understanding .....	15
6.3	High Fill Embankment and Deep Cut Platform Widening Areas .....	16
6.3.1	Embankment Fill Types .....	16
6.3.2	Stability .....	17
6.3.2.1	Method of Analyses .....	17
6.3.2.2	Parameter Selection .....	18
6.3.3	Settlement.....	19
6.3.3.1	Method of Analyses .....	19
6.3.3.2	Parameter Selection .....	20
6.3.3.3	Settlement of Embankment Fill.....	20
6.4	Settlement Performance Requirements.....	21
6.5	Results of Stability and Settlement Analyses.....	22
6.5.1	Stability - Highway 17 NBL – STA 11+440 to STA 11+620 (High Fill Area No. 1).....	22
6.5.2	Stability - Highway 17 NBL – STA 12+150 to STA 12+220 (Deep Cut Area No. 1).....	23
6.5.3	Stability - Highway 17 NBL – STA 13+240 to STA 13+400 (High Fill Area No. 2).....	23
6.5.4	Settlement – Highway 17 NBL STA 11+440 to STA 11+620 (High Fill Area No. 1) .....	23
6.5.5	Settlement – Highway 17 NBL STA 13+240 to STA 13+400 (High Fill Area No. 2) .....	24
6.6	Subgrade Preparation and Embankment Construction .....	25
6.6.1	Temporary Excavations and Removal of Organic Soils .....	25
6.6.2	Groundwater and Surface Water Control .....	25
6.6.3	Backfilling.....	26
6.6.4	Embankment Fill Placement .....	26
6.6.5	Erosion Protection.....	26
6.7	Cut Slope Construction .....	27
<b>7.0</b>	<b>CLOSURE .....</b>	<b>27</b>

## REFERENCES

## Abbreviations and Terms Used on Records of Boreholes and Test Pits

## List of Symbols

**DRAWINGS**

Drawing 1	Key Plan
Drawing 2	Index Plan

**FIGURES**

Figure 1	Site Photographs – High Fill Area No. 1 (STA 11+440 to STA 11+620)
Figure 2	Site Photographs – Deep Cut Area No. 1 (STA 12+150 to STA 12+220)
Figure 3	Site Photographs – High Fill Area No. 2 (STA 13+240 to STA 13+400)
Figure 4A	Highway 17 NBL Widening – High Fill Area No. 1, STA 11+540 (Aweres Township) – Global Slope Stability (Long-Term/Permanent Condition) – Widening – 7.5 m High Embankment; New Granular Fill; 2H:1V
Figure 4B	Highway 17 NBL Widening – High Fill Area No. 1, STA 11+540 (Aweres Township) – Global Slope Stability (Long-Term/Permanent Condition) – Widening – 7.5 m High Embankment; New Rock Fill; 1.25H:1V
Figure 5	STA 12+170 (Deep Cut Area No. 1) – Global Slope Stability (Long-Term/Permanent Condition) – Widening – 9 m High Deep Cut; 2H:1V Slope
Figure 6A	STA 13+390 (High Fill Area No. 2) – Global Slope Stability (Long-Term/Permanent Condition) – Widening – 10 m High Embankment; New Granular Fill; 2H:1V
Figure 6B	STA 13+390 (High Fill Area No. 2) – Global Slope Stability (Long-Term/Permanent Condition) – Widening – 10 m High Embankment; New Rock Fill; 1.25H:1V
Figure 6C	STA 13+390 (High Fill Area No. 2) – Global Slope Stability (Long-Term/Permanent Condition) – Widening – 10 m High Embankment; New Rock Fill; 1.75H:1V

**LIST OF APPENDICES****APPENDIX A Highway 17 NBL - STA 11+440 to STA 11+620 (High Fill Area No. 1)**

Drawing A1	High Fill Area 1 (STA 11+440 - 11+620) Boreholes Location and Soil Strata
Borehole Records	HF1-01, HF1-02, HF1-03
Figure A1	Grain Size Distribution – Gravelly SILTY SAND (SM) to SILTY SAND (SM) (FILL)
Figure A2	Grain Size Distribution – Gravelly SILTY SAND (SM) to SILT (ML) and Sand to SILT (ML)
Figure A3	Plasticity Chart – SILTY SAND (SM) of slight plasticity
Figure A4	Consolidated, Drained Direct Shear (Borehole HF1-02, Sample Nos. 5 and 6)

**APPENDIX B Highway 17 NBL - STA 12+150 to STA 12+220 (Deep Cut Area No. 1)**

Drawing B1	Deep Cut Area 1 (STA 12+150 – 12+220) Boreholes Location and Soil Strata
Borehole Records	DC1-01, DC1-02
Figure B1	Grain Size Distribution – Gravelly SILTY SAND (SM/GM)
Figure B2	Grain Size Distribution – CLAYEY SILT-SILT (CL-ML)
Figure B3	Plasticity Chart – CLAYEY SILT-SILT (CL-ML)
Figure B4	Grain Size Distribution – SILT (ML)
Figure B5	Consolidated, Drained Direct Shear (Borehole DC1-02, Sample Nos. 1 and 2A)
Figure B6	Consolidated, Drained Direct Shear (Borehole DC1-02, Sample Nos. 4, 5 and 6)

**APPENDIX C Highway 17 NBL - STA 13+240 to STA 13+400 (High Fill No. 2)**

Drawing C1	High Fill Area 2 (STA 13+240 – 13+400) Boreholes Location and Soil Strata
Borehole Records	HF2-01, HF2-02
DCPT Records	HF2-03, HF2-04
Figure C1	Grain Size Distribution – SILTY SAND (SM) (FILL)
Figure C2	Grain Size Distribution – SILTY GRAVEL (GM) and Sand to Sandy SILT (ML)

**APPENDIX D Special Provisions**

Special Provision	Excavating for Widening
Special Provision	Rock Fill Embankment

# PART A

**FOUNDATION INVESTIGATION REPORT  
MILE HILL WIDENING – HIGH FILL AND DEEP CUT AREAS  
HIGHWAY 17 REHABILITATION FROM SAULT STE. MARIE NORTH LIMITS  
NORTHERLY 14.5 KM TO THE GOULAIS RIVER BRIDGE  
ALGOMA DISTRICT, ONTARIO  
GWP 5181-13-00**



## 1.0 INTRODUCTION

Golder, a member of WSP (“Golder”) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the detail design of high fill embankment and deep cut slope areas associated with the platform widening along Highway 17 north of Sault Ste. Marie, Ontario. The general location and extent of the Highway 17 widening project is shown on the Key Plan in Drawing 1.

The purpose of this foundation investigation is to establish the subsurface conditions at the locations of the proposed high fill and deep cut platform widening areas by methods of borehole drilling, in-situ testing, and laboratory testing on selected soil samples. The preferred widened alignment was provided by AECOM and indicates two high fill and one deep cut investigation areas as shown on the Index Plan in Drawing 2.

This report summarizes the factual results of field and laboratory work (including field investigation procedures, borehole stratigraphy, and geotechnical laboratory test results) and provides a description of the interpreted soil and groundwater conditions at the proposed high fill and deep cut platform widening areas.

## 2.0 PROJECT AND SITE DESCRIPTION

### 2.1 Project Description

The overall project involves the rehabilitation of Highway 17 from Sault Ste. Marie north limits northerly 14.5 km to the Goulais River Bridge. The project also includes the rehabilitations of the Root River Culverts #3 and #4 on Highway 17, and the replacement of the Robertson Creek culvert on Highway 17 (Foundation Investigation and Design Report prepared by Golder under separate cover; Geocres No. 41K-118).

As the detailed design of the project progressed, the scope of work was expanded to included widening of Highway 17 between approximately Station 11+300 and Station 14+500 in the Township of Aweres, Algoma District. This section of Highway 17 is located south of the Goulais River and north of Heyden. The platform widening is proposed on the east side of the highway to accommodate a second northbound lane, while ditch improvements and rock cuts are proposed on the west side of the highway.

Following AECOM's confirmation of the new widened alignment of Highway 17, a total of two high fill embankments and one deep cut slope (defined as fills and cuts greater than 4.5 m in height) were identified within the proposed platform widening areas within the project limits.

The approximate locations, lengths, and heights of the high fill embankments and the deep cut slope explored as part of this foundation investigation are summarized below.

High Fill / Deep Cut Area	Limits of High Fill and Deep Cut Areas (Project Chainage)	Length (m)	Approximate Height (m)	Reference Drawings
High Fill	STA 11+440 to STA 11+620	180	4.5 to 8.0	Drawings 2 and A1
Deep Cut	STA 12+150 to STA 12+220	70	5.0 to 9.0	Drawings 2 and B1
High Fill	STA 13+240 to STA 13+400	160	5.0 to 10.0	Drawings 2 and C1



## 2.2 Site Description

The proposed widening will extend along a section of Highway 17 known as Mile Hill. As the name suggests, Mile Hill is a high relief area in the terrain that overlooks the Goulais River valley/lowlands to the north of the proposed widening section.

The stretch of Highway 17 along Mile Hill carries one northbound lane and two southbound lanes. The travelled portion of the highway consists of an asphalt surface and varies significantly in elevation. The surface of the highway within the project limits is between about Elevation 204 m (Station 11+300 – northern terminus of the project) and Elevation 344 m (between approximately Station 13+980 and Station 14+130 – about 400 m north of the southern terminus of the project).

The existing highway embankment and cut slope within the proposed high fill and deep cut platform widening areas varies between about 4.5 m and 10.0 m in height. The existing side slopes are generally constructed at an inclination of two horizontal to one vertical (2H:1V). Site photographs taken during the investigation at the proposed high fill and deep cut platform widening areas are shown in Figures 1 to 3. A summary of the site observations at each investigated area is provided below.

Reference Figure	Limits of High Fill and Deep Cut Areas (Project Chainage)	Site Observations
1	STA 11+440 to STA 11+620 (High Fill)	The eastern slope of the highway embankment appears stable and is comprised of granular fill. The majority of the slope is covered with grasses and weeds, except for the upper 1 m to 2 m of the slope which is barren and comprised of granular fill. Standing water was observed in places at the toe of the embankment, particularly near the northern limit of the high fill area where a marsh is present. The marsh extends northerly towards the Goulais River valley/lowlands.
2	STA 12+150 to STA 12+220 (Deep Cut)	The eastern cut slope appears stable and is covered with granular fill. The upper half of the slope is heavily vegetated with coniferous trees. There are no signs of distress/bulging at the toe of the cut slope. No seepage of water was noted along the face or toe of the slope. A rock outcrop is present adjacent to the east shoulder of the highway immediately north of the high fill area (i.e., between about Station 12+115 and Station 12+140).
3	STA 13+240 to STA 13+400 (High Fill)	The eastern slope of the highway embankment appears stable and is comprised of granular fill and is covered with grasses and weeds. An approximately 1.5 m to 2 m wide bench extends across the slope about 2 m below the highway grade. The narrow bench is part of a trail for snowmobiles and ATVs. A CSP culvert extends below Highway 17 immediately south of the high fill area at about Station 13+410. It is noted that the watercourse banks east/northeast of the outlet of the culvert appear over steepened and eroding. The watercourse channel and the banks in the immediate vicinity of the outlet are protected with rip-rap.

## 3.0 FIELD INVESTIGATION PROCEDURES

The field work at the proposed high fill and deep cut platform widening areas was carried out between July 13 and 22, 2021 during which time seven boreholes (designated as Boreholes HF1-01 to HF1-03, DC1-01, DC1-02, HF2-01

and HF2-02) and two Dynamic Cone Penetration Tests (DCPTs HF2-03 and HF2-04) were advanced along the Highway 17 corridor north of Sault Ste. Marie, Ontario. The approximate borehole locations are described below.

Borehole / DCPT Designation	Approximate Borehole Location
HF1-01	East shoulder of Highway 17 at approximately STA. 11+440
HF1-02	East toe of highway embankment at approximately STA. 11+540
HF1-03	East shoulder of Highway 17 at approximately STA. 11+620
DC1-01	East shoulder of Highway 17 at approximately STA. 12+165
DC1-02	East of Highway 17, at top of cut slope at approximately STA. 12+150
HF2-01	East shoulder of Highway 17 at approximately STA. 13+390
HF2-02 and DCPTs HF2-03 and HF2-04	East toe of highway embankment at approximately STA. 13+380

The subsurface soil conditions encountered in the boreholes are shown in detail on the Records of Boreholes and provided in Appendices A to C. Each appendix is associated with an individual high fill or deep cut platform widening area. Abbreviations and terms used on the Records of Boreholes and a list of symbols are provided following the references section to assist in the interpretation of the borehole records. The locations of the as-drilled boreholes are shown in plan in Drawings A1 to C1.

The boreholes were advanced using portable drilling equipment or a track-mounted drilling rig. Boreholes HF1-02, HF2-02, and DC1-02 were advanced using portable drilling equipment comprised of a tripod and a manual (i.e., rope-and-cathead) hammer and pulley system. The portable equipment was supplied and operated by Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario. These boreholes were advanced through the overburden using 'BW' casing and wash boring techniques. A portable and manually operated Hilti drill was also used to core through cobbles and rock fragments encountered within the overburden in Borehole HF2-02. Boreholes HF1-01, HF1-03, HF2-01, and DC1-01 were advanced using a CME-55 track-mounted drilling rig supplied and operated by Landcore Drilling Inc. of Chelmsford, Ontario. These boreholes were advanced using 108 mm inner diameter, continuous flight, hollow-stem augers, but 'NW' casing with wash boring techniques and rock coring using an 'NQ' double-tube rock core barrel was required at the locations of Boreholes HF1-01, HF1-03, and HF2-01 to penetrate boulders, cobbles, rock fragments, and gravel layers encountered within the embankment fill and in the underlying granular overburden soils. Drilling at these sites was challenging due to presence of these obstructions. The soil samples were generally obtained at intervals of depth of about 0.75 m and 1.5 m below the ground surface (although in places soil samples were obtained continuously) until termination of the boreholes. All soil samples were collected using a 50 mm outer diameter split-spoon sampler driven generally by a standard weight (i.e., 140 lb) hammer; more specifically, a manually-dropped hammer when using portable equipment and an auto-drop hammer when using the drilling rig, in general accordance with Standard Penetration Test (SPT) procedures (ASTM D1586, *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*).

Two Dynamic Cone Penetration Tests (DCPTs) were also carried out adjacent to Borehole HF2-02 and cone refusal was encountered at depths of about 1.4 m and 1.7 m below existing ground surface.

The boreholes were advanced to depths ranging between about 3.2 m and 16.8 m below existing ground surface, corresponding to termination elevations ranging between approximately 312.7 m and 192.1 m.

All boreholes were backfilled upon completion of drilling in general accordance with Ontario Regulation 903 (*Wells*), as amended.

Prior to commencement of field work, Golder arranged for the clearance of underground utilities and services. The field work was observed on a full-time basis by members of Golder's technical and engineering staff who monitored the borehole drilling/coring, in-situ testing, and soil sampling operations, and logged the boreholes in the field. The soil samples were transported to Golder's Mississauga and Sudbury geotechnical laboratories where the soil samples underwent further visual and tactile examination and geotechnical laboratory testing.

Geotechnical index testing (i.e., water content, organic content, Atterberg limits, and grain size distribution) was carried out on selected soil samples. Consolidated drained direct shear tests were also carried out in accordance with ASTM D3080 (*Standard Test Method for Direct Shear Test of Soil Soils Under Consolidated Drained Conditions*) on select soil samples. The results of the geotechnical index testing are summarized on the borehole records, but details of all test results, including the direct shear tests are provided in Appendices A to C. All of the laboratory testing was carried out in general accordance with MTO Laboratory and/or ASTM Standards, as appropriate.

The as-drilled borehole locations (in plan) were established by members of Golder's technical staff by measuring distances between the as-drilled borehole locations and the Highway 17 chainage (that was marked on-site by others) and other notable features such as, hydro poles. Given the relatively short distances between the as-drilled borehole locations and the highway chainage markers and other notable features, where applicable, the on-site measurements are considered accurate to within 0.5 m in the horizontal direction. It is noted that the field measurements were then used to plot the boreholes on the respective borehole location plans to determine the northing/easting coordinates of the as-drilled boreholes. The corresponding ground surface elevations at the locations of the as-drilled boreholes were obtained from the Digital Terrain Model (DTM) of the project sites provided by AECOM. The contour elevations presented in the DTM are accurate to within 0.1 m. The northing/easting coordinates (referenced to the NAD83 Canadian Spatial Reference System (CSRS) V6:2010 MTM Zone 13 coordinate system), latitude/longitude coordinates, and corresponding ground surface elevations (referenced to the Canadian Geodetic Vertical Datum (CGVD) 1928:1978), are provided on the borehole records in Appendices A to C, presented on Drawings A1 to C1, and summarized below.

Borehole / DCPT Designation	Coordinates (MTM NAD83 Zone 13)		Ground Surface Elevation	Borehole Depth <sup>1</sup>
	Northing (Latitude)	Easting (Longitude)		
HF1-01	5171967.0 m (46.686788°)	278525.0 m (-84.343507°)	208.9 m	16.8 m
HF1-02	5171867.8 m (46.685897°)	278551.9 m (-84.343149°)	208.4 m	9.8 m
HF1-03	5171787.1 m (46.685170°)	278530.4 m (-84.343426°)	221.5 m	11.7 m
DC1-01	5171239.9 m (46.680248°)	278547.3 m (-84.343174°)	260.0 m	7.7 m

Borehole / DCPT Designation	Coordinates (MTM NAD83 Zone 13)		Ground Surface Elevation	Borehole Depth <sup>1</sup>
	Northing (Latitude)	Easting (Longitude)		
DC1-02	5171257.8 m (46.680409°)	278561.5 m (-84.342990°)	262.3 m	7.3 m
HF2-01	5170308.3 m (46.671893°)	279245.0 m (-84.334003°)	323.5 m	14.3 m
HF2-02	5170332.1 m (46.672107°)	279250.3 m (-84.333935°)	315.8 m	3.2 m
HF2-03 (DCPT)	5170332.3 m (46.672110°)	279250.4 m (-84.333933°)	315.7 m	1.7 m
HF2-04 (DCPT)	5170332.1 m (46.672108°)	279250.7 m (-84.333929°)	315.7 m	1.4 m

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on the Northern Ontario Engineering Terrain (NOEGTS)<sup>1</sup> mapping, the proposed high fill and deep cut platform widening areas are located within the following areas:

- High Fill Area No. 1 – Station 11+440 to Station 11+620: border between bedrock knobs/near surface deposits underlain by shallow bedrock and organic terrain comprised of peat and organic soils (north of the proposed high fill area).
- Deep Cut Area No. 1 – Station 12+150 to Station 12+220: bedrock knobs/near surface deposits underlain by shallow bedrock.
- High Fill Area No. 2 – Station 13+240 to Station 13+400: border between an outwash plain/valley train (east/southeast of the proposed high fill area) comprised predominantly of sandy/gravelly soils and bedrock knobs/near surface deposits underlain by shallow bedrock.

Based on geological mapping developed by the Ontario Ministry of Northern Development and Mines (MNDM)<sup>2</sup>, the site is underlain by bedrock from the Neoarchean to Mesoarchean geologic era. The bedrock is comprised of a gneissic tonalite suite of intrusive rocks, particularly tonalite to granodiorite (foliated to gneissic) with minor supracrustal inclusions.

### 4.2 Overview of Local Subsurface Conditions

The subsurface soil and groundwater conditions encountered in the boreholes advanced at the site, together with the results of the in-situ and geotechnical laboratory testing, are presented on the borehole records, where applicable, and on the laboratory figures/sheets (provided in Appendices A to C). The results of the in-situ field tests

<sup>1</sup> Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41KNE, Study Number 91.

<sup>2</sup> Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario – East-Central Sheet, Ontario Geological Survey – Map 2544.

(i.e., SPT 'N'-values) as presented on the borehole records are uncorrected. The 'N'-values are based on SPT sampling procedures carried out with a standard weight (i.e., 140 lb) hammer; more specifically, a manually-dropped hammer when using portable equipment and an auto-drop hammer when using the drilling rig

The stratigraphic boundaries shown on the borehole records and on the interpreted soil strata profiles (i.e., in Drawings A1 to C1) are inferred from observations of drilling/coring progress, soil sampling, and in-situ testing, and therefore represent transitions between soil types rather than exact planes of geologic change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions encountered at High Fill Area No. 1 consist of granular fill underlain by a native granular deposit. At Deep Cut Area No. 1, the subsurface conditions consist of silty sand and gravel underlain by a deposit of clayey silt-silt which in turn is underlain by a deposit of non-plastic silt. At High Fill Area No. 2, the subsurface conditions consist of granular fill underlain by a native granular deposit. In some areas, boulders, cobbles, and rock fragments were encountered within the embankment fill and/or within the underlying native soils.

More detailed descriptions of the subsurface conditions encountered in the boreholes at each high fill platform widening area and deep cut location are provided in the following sections.

#### **4.2.1 Highway 17 NBL – STA 11+440 to STA 11+620 (High Fill Area No. 1)**

The plan and profile along the toe and through the existing highway embankment at the proposed highway widening (i.e., on the east side of Highway 17) showing the borehole locations and interpreted stratigraphy between about Station 11+440 and Station 11+620 in the Aweres Township are presented in Drawing A1. The proposed widened high fill embankment within this section of the highway ranges between about 4.5 m and 8.0 m high relative to the existing ground surface.

A total of three boreholes (Boreholes HF1-01 to HF1-03), were advanced to investigate the subsurface conditions within this high fill area.

In general, the subsurface conditions encountered along the proposed high fill platform widening consist of a granular embankment fill underlain by a granular deposit ranging from gravelly sand to silt. In places, the granular deposit is interlayered with clayey silt-silt. In some areas, boulders, cobbles, and rock fragments were encountered within the embankment fill and/or within the underlying native soils.

##### **4.2.1.1 Asphalt**

An approximately 100 mm and 110 mm thick layer of asphalt was encountered at ground surface in Boreholes HF1-01 and HF1-03, respectively, which were advanced on the east shoulder of Highway 17.

##### **4.2.1.2 SAND (SP) and Gravel to SAND (SP) to SILTY SAND (SM) (FILL)**

An approximately 3.6 m and 5.2 m thick layer of granular fill was encountered below the asphalt in Boreholes HF1-01 and HF1-03, respectively. The granular fill is comprised of sand and gravel to gravelly sand to sand to gravelly silty sand to silty sand. Boulders (340 mm and 610 mm in size) and rock fragments were encountered within the fill in both boreholes as noted on the borehole records. Wood fragments were also recovered from the lower portion of the granular fill.

The SPT 'N'-values measured within the granular fill generally range between 20 blows and 90 blows per 0.3 m of penetration, indicating a compact to very dense state of compactness. A SPT 'N'-value of 4 blows per 0.3 m of penetration was measured in Borehole HF1-03, indicating a loose state of compactness. A SPT 'N'-value of 50 blows per 0.15 m of penetration was also measured at a depth of about 0.9 m in Borehole HF1-03; however, the split-spoon was bouncing on an obstruction which required rock coring, as shown on the respective borehole record.

The water content measured on six samples of the granular fill ranges between about 4% and 25%.

The results of grain size distribution tests carried out on two samples recovered from the granular fill are shown in Figure A1 in Appendix A.

#### 4.2.1.3 Gravelly SAND (SP) to SILTY SAND (SM) to SILT (ML)

A native granular deposit varying in composition from gravelly sand to gravelly silty sand to silty sand to silt and sand to sandy silt to silt was encountered below the granular fill in Boreholes HF1-01 and HF1-03, and at the ground surface in Borehole HF1-02. Interlayers of clayey silt-silt were encountered within this deposit in Borehole HF1-02 and are addressed in Section 4.2.1.4. Boulders (up to 820 mm in size), cobbles, gravel and rock fragments were encountered within this deposit in Borehole HF1-03, as noted on the respective borehole record. The top of this deposit was encountered at elevations between approximately 216.2 m and 205.2 m. Boreholes HF1-02 and HF1-03 were terminated within this deposit at depths of about 9.8 m (Elevation 198.6 m) and 11.7 m (Elevation 209.8 m), respectively.

The SPT 'N'-values measured within the granular deposit generally range between 10 blows and 104 blows per 0.3 m of penetration, indicating a compact to very dense state of compactness. A SPT 'N'-value of 7 blows per 0.3 m of penetration was measured in Borehole HF1-03, indicating a loose state of compactness. A SPT 'N'-value of 32 blows per 0.15 m of penetration was also measured at a depth of about 0.9 m in Borehole HF1-03; however, the split-spoon was bouncing on an obstruction which required rock coring, as shown on the respective borehole record.

Laboratory consolidated, drained direct shear (DS) tests were carried out on a combined sample of the sandy silt from Borehole HF1-02. The sample was prepared at an average density of 19.8 kN/m<sup>3</sup> and a water content of about 20% and tested in a submerged condition. The details of the test results are shown in Figure A4 in Appendix A and the results of the direct shear test are summarized below.

Borehole/Sample Nos.	Depth (m)	Effective Cohesion Intercept, $c'$ (kPa)	Effective Angle of Internal Friction, $\phi'$ (degrees)
HF1-02 Sample Nos. 5 and 6 (combined)	3.05 to 4.42	0	36

The water content measured on eleven samples recovered from this deposit ranges between about 12% and 21%.

The results of grain size distribution test carried out on seven samples of this deposit are shown in Figure A2 in Appendix A.

Atterberg limits tests were also carried out on the fines portion of three samples recovered from this deposit in Boreholes HF1-01 and HF1-02. The results of the Atterberg limits tests carried out on the fines portion of the silt and sand indicate that the material is classified as non-plastic. The Atterberg limits test carried out on the fines portion of the near-surface silty sand deposit encountered in Borehole HF1-02 measured a liquid limit of 25%, a plastic limit of 22%, and a corresponding plasticity index of about 3%. The results of the of the Atterberg limits test are shown on the plasticity chart in Figure A3 in Appendix A, and indicate that the fines portion of the material is classified as silt of slight plasticity.



#### 4.2.1.4 CLAYEY SILT-SILT (CL-ML)

Approximately 0.3 m and 1.6 m thick layers of clayey silt-silt, trace sand were encountered interlayered within the native granular deposit at Elevation 205.7 m and Elevation 202.8 m, respectively, in Borehole HF1-02 which was advanced at the eastern toe of the highway embankment.

The SPT 'N'-values measured within the upper and lower clayey silt-silt layers were 31 blows and 19 blows per 0.3 m of penetration, respectively, suggesting a hard and very stiff consistency.

#### 4.2.1.5 SAND (SP)

A granular deposit comprised of sand, trace to some gravel, some fines was encountered below the silt and sand to silt deposit in Borehole HF1-01. The top of the deposit was encountered at approximately Elevation 195.6 m. Cobbles, gravel, and rock fragments were encountered between depths of about 15.3 m and 16.5 m below existing ground surface. Borehole HF1-01 was terminated within the sand deposit at a depth of about 16.8 m below existing ground surface, corresponding to Elevation 192.1 m, upon casing refusal.

The SPT 'N'-values measured within the sand deposit were 30 blows and 42 blows per 0.3 m of penetration, indicating a dense state of compactness.

### 4.2.2 Highway 17 NBL – STA 12+150 to STA 12+220 (Deep Cut Area No. 1)

The plan and cross-section of the proposed highway widening in cut (i.e., on the east side of Highway 17) showing the borehole locations and interpreted stratigraphy between about Station 12+150 and Station 12+220 in the Township of Aweres are presented in Drawing B1. The proposed deep cut widening within this section of the highway ranges between about 5.0 m and 9.0 m high relative to the existing ground surface.

A total of two boreholes (Boreholes DC1-01 and DC1-02) were advanced to investigate the subsurface conditions within this deep cut area. It was not possible to advance a borehole at the crest of the highest section of the existing slope due to low overhead power lines running on top of the slope and due to the limited MTO right-of-way. As a result, Borehole DC1-02 was advanced at the northern limit of the deep cut area where the slope is about 4.5 m high as opposed to the area where the slope is about 9 m high.

In general, the subsurface conditions consist of silty sand and gravel underlain by a deposit of clayey silt-silt which in turn is underlain by a deposit of non-plastic silt.

#### 4.2.2.1 ASPHALT

An approximately 100 mm thick layer of asphalt was encountered at ground surface in Borehole DC1-01 which was advanced at the east shoulder of Highway 17.

#### 4.2.2.2 SAND (SP) and Gravel (FILL)

An approximately 0.8 m thick layer of sand and gravel fill was encountered below the asphalt in Borehole DC1-01.

A SPT 'N'-value measured within the sand and gravel fill was 18 blows per 0.3 m of penetration, indicating a compact state of compactness.

#### 4.2.2.3 Gravelly SILTY SAND (SM/GM)

An approximately 0.9 m thick deposit of gravelly silty sand, trace organics and wood fragments was encountered at the ground surface in Borehole DC1-02 which was advanced on top of the existing cut slope. The top of this granular deposit was encountered at approximately Elevation 262.3 m.



A SPT 'N'-value measured within the gravelly silty sand deposit was 31 blows per 0.3 m of penetration, indicating a dense state of compactness.

Laboratory consolidated, drained direct shear (DS) tests were carried out on a combined sample of the gravelly silty sand from Borehole DC1-02. The sample was prepared at an average density of 20.6 kN/m<sup>3</sup> and a water content of about 15% and tested in both a dry and submerged conditions. The details of the test results are shown in Figure B5 in Appendix B and the results of the direct shear test are summarized below.

Borehole/Sample Nos.	Depth (m)	Effective Cohesion Intercept, $c'$ (kPa)	Effective Angle of Internal Friction, $\phi'$ (degrees)
DC1-02 Sample Nos. 1 and 2A (combined) [Dry Box]	0 to 0.94	0	61
DC1-02 Sample Nos. 1 and 2A (combined) [Submerged Box]	0 to 0.94	0	52

The water content measured on a sample of the silty sand and gravel deposit is about 21%.

A grain size distribution test carried out on a sample recovered from the granular deposit is shown in Figure B1 in Appendix B.

#### 4.2.2.4 CLAYEY SILT-SILT (CL-ML)

A deposit comprised of clayey silt-silt was encountered below the granular deposit in Boreholes DC1-01 and DC1-02, respectively. The top of this deposit was encountered at approximately Elevation 259.1 m and Elevation 261.4 m, and the thickness of the deposit is about 2.8 m to 4.3 m in the respective boreholes.

The SPT 'N'-values measured within the clayey silt-silt deposit range between 15 blows and 43 blows per 0.3 m of penetration, suggesting a stiff to hard consistency.

Laboratory consolidated, drained direct shear (DS) tests were carried out on a combined sample of the clayey silt-silt from Borehole DC1-02. The samples were prepared at an average density of 19.6 kN/m<sup>3</sup> and a water content of about 25% and tested in a submerged condition. The details of the test results are shown in Figure B6 in Appendix B and the results of the direct shear test are summarized below.

Borehole/Sample Nos.	Depth (m)	Effective Cohesion Intercept, $c'$ (kPa)	Effective Angle of Internal Friction, $\phi'$ (degrees)
DC1-02 Sample Nos. 4, 5 and 6	2.29 to 5.79	0	35

The water content measured on five samples of the clayey silt-silt deposit ranges between about 15% and 26%.

The results of grain size distribution tests carried out on two samples of the clayey silt-silt deposit are shown in Figure B2 in Appendix B.

The results of Atterberg limits tests carried out on two samples of the cohesive deposit measured liquid limits of 23% and 29%, plastic limits of 18% and 22%, and corresponding plasticity indices of 5% and 7%, indicating the material is classified as a clayey silt-silt, as shown on the plasticity chart in Figure B3 in Appendix B.

#### 4.2.2.5 SILT (ML)

A deposit comprised of silt, trace sand was encountered below the deposit of clayey silt-silt in Boreholes DC1-01 and DC1-02. The top of this deposit was encountered at approximately Elevations 256.3 m and 257.1 m in the respective boreholes. Both boreholes were terminated within the silt deposit at depths of about 7.7 m (Elevation 252.3 m) and 7.3 m (Elevation 255.0 m), respectively.

The SPT 'N'-values measured within the silt deposit generally range between 10 blows and 70 blows per 0.3 m of penetration, indicating a compact to very dense state of compactness. A SPT 'N'-value of 0 blows (i.e., weight of hammer) was measured in Borehole DC1-01. A SPT 'N'-value of 100 blows for 0.05 m of penetration was also measured at the termination depth of Borehole DC1-01, but the high 'N'-value can be attributed to the split-spoon refusal.

The water content measured on four samples of the silt deposit ranges between approximately 22% and 25%.

A grain size distribution test carried out on a sample of the silt recovered from Borehole DC1-01 is shown in Figure B4 in Appendix B.

An Atterberg limits test was also carried out on the fines portion of a sample of the silt recovered from Borehole DC1-01. The results of the Atterberg limits test indicate that the fines portion of this material is classified as non-plastic silt.

### 4.2.3 Highway 17 NBL – STA 13+240 to STA 13+400 (High Fill Area No. 2)

The plan and cross-section of the proposed highway embankment widening (i.e., on the east side of Highway 17) showing the borehole and DCPT locations and interpreted stratigraphy between about Station 13+240 and Station 13+400 in the Aweres Township are presented in Drawing C1. The height of the proposed embankment within this section of the highway ranges between about 5.0 m and 10.0 m high relative to the existing ground surface.

A total of two boreholes (Boreholes HF2-01 and HF2-02) and two DCPTs carried out near Borehole HF2-02 (DCPT HF2-03 and HF2-04), were advanced to investigate the subsurface conditions within this high fill area.

In general, the subsurface conditions encountered along the proposed high fill platform widening consist of a granular embankment fill underlain by a granular deposit ranging from silty gravel to sandy silt. Cobbles and rock fragments were encountered within the granular native soils.

#### 4.2.3.1 ASPHALT

An approximately 120 mm thick layer of asphalt was encountered at ground surface in Borehole HF2-01 which was advanced at the east shoulder of Highway 17.

#### 4.2.3.2 Gravelly SAND (SP) to SILTY SAND (SM) (FILL)

An approximately 4.5 m thick layer of granular fill was encountered below the asphalt in Borehole HF2-01 at approximately Elevation 323.4 m. The fill varies in composition from gravelly sand to silty sand to sand.

The SPT 'N'-values measured with the granular fill range between 22 blows and 56 blows per 0.3 m of penetration, indicating a compact to very dense state of compactness.

The water contents measured on two samples of the silty sand fill are about 8% and 10%. The water content measured on a sample of the sand fill is about 27%. The higher water content can be attributed to the presence of organics. A laboratory organic content measured on a sample of the sand fill is approximately 4.5% as indicated on the borehole record.

The results of a grain size distribution test carried out on one sample of the silty sand fill is shown in Figure C1 in Appendix C.

#### **4.2.3.3 Cobbles**

A deposit of cobbles with gravel and rock fragments was encountered below the sand fill in Borehole HF2-01. The top of this deposit was encountered at a depth of about 4.6 m below existing ground surface, corresponding to Elevation 318.9 m. The deposit of cobbles was fully penetrated using rock coring methods and is approximately 1.5 m thick. It is expected that any coarse-grained and fine-grained soil particles making up the soil matrix would have been washed away during advancement of the drill casing using flush water. The recovered cobbles were measured to be up to about 130 mm in size.

#### **4.2.3.4 Gravelly SAND (SP) to SILTY GRAVEL (GM) to Sandy SILT (ML)**

A granular deposit comprised of gravelly sand to silty gravel to sandy silt was encountered below the deposit of cobbles in Borehole HF2-01 and immediately at the ground surface in Borehole HF2-02. Boreholes HF2-01 and HF2-02 were terminated within this deposit at depths of about 14.3 m (Elevation 309.2 m) and 3.2 m (Elevation 312.7 m), respectively.

The SPT 'N'-values measured within the granular deposit generally range between 48 blows to 80 blows per 0.3 m of penetration, indicating a dense to very dense state of compactness. A SPT 'N'-value of 4 blows per 0.3 m of penetration was measured at the ground surface in Borehole HF2-02. Several 'N'-values of 50 blows and 100 blows for less than 0.3 m of penetration were measured in Borehole HF2-02 and can be attributed to inferred cobbles and rock fragments.

The water content measured on seven samples of the granular deposit ranges between approximately 9% and 21%. Laboratory organic content testing performed on a sample of the sandy silt deposit recovered from Borehole HF2-02 measured approximately 0.3% as indicated on the borehole record.

The results of grain size distribution tests carried out on four samples of the granular deposit are shown in Figure C2 in Appendix C.

### **4.3 Groundwater Conditions**

The soil samples recovered from the boreholes advanced within the limits of the proposed high fill and deep cut widening areas were generally moist to wet. It is noted that in most boreholes, wash boring techniques and/or rock coring with water was utilized to advance the boreholes. Consequently, the water level measurements taken inside the boreholes may not be representative of stabilized groundwater levels.

The estimated groundwater level at each high fill and deep cut embankment widening area is summarized below based on observations of standing water near the boreholes, depths at which wet soil samples were collected, water level measurements inside the boreholes, and/or other observations on site.

High Fill and Deep Cut Areas (Project Chainage)	Observations	Estimated Depth to Groundwater/ Groundwater Elev.
High Fill Area No. 1 (STA 11+440 to STA 11+620)	<ul style="list-style-type: none"> <li>- Existing ground surface slopes down from south to north.</li> <li>- In Borehole HF1-01, wet soil samples below a depth of 3.7 m (Elevation 205.2 m), and water level measured in open borehole at a depth of about 3.7 m (Elevation 205.2 m) upon removal of casing.</li> <li>- In Borehole HF1-02, wet soil samples below a depth of 0.7 m (Elevation 207.7 m), and water level measured in open borehole at a depth of about 1.6 m (Elevation 206.8 m) upon completion of drilling.</li> <li>- In Borehole HF1-03, wet soil samples below a depth of 0.9 m (Elevation 220.6 m), and water level measured in open borehole at a depth of about 4.0 m (Elevation 217.5 m) upon completion of drilling.</li> <li>- Standing water at the ground surface near Boreholes HF1-01 and HF1-02 and a marshy area noted near the east slope of the highway embankment near the northern segment of the high fill area (refer to site photographs on Figure 1).</li> </ul>	At ground surface at the eastern toe of the highway embankment
Deep Cut Area No. 1 (STA 12+150 to 12+220)	<ul style="list-style-type: none"> <li>- Existing ground surface slopes down from south to north.</li> <li>- Drainage ditch at the toe of the cut slope was dry during the subsurface investigation.</li> <li>- No water seepage noted along the face of the cut slope.</li> <li>- In Borehole DC1-01, wet soil samples below a depth of 3.7 m (Elevation 258.3) and water level measured in hollow stem augers at a depth of about 4.6 m below ground surface (Elevation 255.4 m) upon completion of drilling.</li> <li>- In Borehole DC1-02 (advanced near the crest of the cut slope), wet soil samples below a depth of about 1.5 m below ground surface (Elevation 260.8 m) and water level measured in open borehole at a depth of about 1.5 m below ground surface (Elevation 255.4 m) upon completion of drilling.</li> </ul>	At about Elevation 260.8 m along the cut slope and below the drainage ditch at the toe of the cut slope
High Fill Area No. 2 (STA 13+240 to 13+400)	<ul style="list-style-type: none"> <li>- Existing ground surface slopes down from south to north.</li> <li>- In Borehole HF2-01, only moist soil samples noted, and borehole dry upon completion of drilling and removal of casing.</li> <li>- In Borehole HF2-02, only moist soil samples noted, and open borehole dry upon completion of drilling.</li> <li>- A CSP culvert extends below the highway embankment at about Sta. 13+410. The watercourse flows in a northeast direction.</li> </ul>	At about Elevation 314 m based on watercourse water level

The groundwater level observations at this site will be subject to seasonal fluctuations and precipitation events; therefore, the water levels should be expected to be higher during the spring season or during any period of heavy and/or sustained precipitation.

## 5.0 CLOSURE

The field work for this investigation was supervised by Mr. Ankaren Maheswaran, a junior geotechnical analyst, Ms. Harmandeep Kaur, a field technician, and Mr. Tibor Berecz, E.I.T, a junior geotechnical engineer-in-training at Golder.

This Foundation Investigation Report was prepared by Ms. Alysha Kobylinski, P.Eng. and Mr. Tomasz Zalucki, P.Eng., geotechnical engineers at Golder. Mr. Paul Dittrich, Ph.D., P.Eng., an MTO Foundations Designated Contact and Principal of Golder, conducted an independent technical and quality control review of the report.

## Signature Page

Golder Associates Ltd.



Alysha Kobylinski, P.Eng.  
*Geotechnical Engineer*



Tomasz Zalucki, P.Eng.  
*Geotechnical Engineer*



Paul Dittrich, Ph.D., P.Eng.  
MTO Foundations Designated Contact, Principal

AK/TZ/JPD/tz/ak/ml

Golder and the G logo are trademarks of Golder Associates Corporation

[https://golderassociates.sharepoint.com/sites/108558/project files/6 deliverables/foundations/mile hill-final fidr/19122433-rpt-rev0-highway 17-mile hill widening-final fidr-20211203.docx](https://golderassociates.sharepoint.com/sites/108558/project%20files/6%20deliverables/foundations/mile%20hill-final%20fidr/19122433-rpt-rev0-highway%2017-mile%20hill%20widening-final%20fidr-20211203.docx)

# PART B

**FOUNDATION DESIGN REPORT  
MILE HILL WIDENING – HIGH FILL AND DEEP CUT AREAS  
HIGHWAY 17 REHABILITATION FROM SAULT STE. MARIE NORTH LIMITS  
NORTHERLY 14.5 KM TO THE GOULAIS RIVER BRIDGE  
ALGOMA DISTRICT, ONTARIO  
GWP 5181-13-00**



## 6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the detail design of two high fill embankment areas and one deep cut area associated with the platform widening along Highway 17 north of Sault Ste. Marie, Ontario. These recommendations are based on interpretation of factual data obtained from the boreholes advanced during the field investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess feasible embankment design and construction alternatives/strategies that may be required as part of the proposed highway widening works. This foundation design report, discussion and recommendations are intended for the use of MTO and its designers and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor.

Contractors must make their own interpretation based on the factual data presented in the Foundation Investigation Report (Part A of this report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

### 6.1 General

Based on the Highway 17 alignment and cross-section drawings provided by AECOM, the highway will be widened between approximately Station 11+300 and Station 14+500 in the Township of Aweres, Algoma District. This section of Highway 17 is located south of the Goulais River and north of Heyden. The platform widening is proposed on the east side of the highway to accommodate a second northbound lane, while ditch improvements and rock cuts are proposed on the west side of the highway. A total of two high fill embankments and one deep cut slope (identified as fills and cuts greater than 4.5 m in height) were identified within the proposed platform widening areas within the project limits. The following table summarizes the extent and proposed heights of the high fill embankments and deep cut slope investigated as part of the foundation investigation.

High Fill / Deep Cut Area	Limits of High Fill and Deep Cut Areas (Project Chainage, Aweres Township)	Approximate Height (m)
High Fill	STA 11+440 to STA 11+620	4.5 to 8.0
Deep Cut	STA 12+150 to STA 12+220	5.0 to 9.0
High Fill	STA 13+240 to STA 13+400	5.0 to 10.0

This report presents the results of stability analyses of the proposed high fill embankments and the deep cut slope as well as settlement analyses at the high fill widening areas and provides recommendations for stable embankment/cut slope geometry, placement of new embankment fill materials, and implementation of foundation mitigation alternatives that may be required as a means to improve stability, where necessary. The report also addresses potential construction concerns and geotechnical challenges associated with embankment construction, sub-excavation of any organic soils, and placement of new fill materials.

### 6.2 Consequence and Site Understanding

Highway 17 carries medium to high traffic volumes and its performance is expected to have potential impacts on other transportation corridors, consequently, in accordance with Section 6.5 of the *Canadian Highway Bridge*

*Design Code* (CHBDC, 2019) and its *Commentary*, the geotechnical systems (i.e., the high fill embankments and the deep cut slope) are considered to have a “typical consequence level” associated with exceeding limits states design.

In addition, a typical to high level of project-specific foundation investigation was carried out at this site (as presented in Foundation Investigation Report (Part A) of this overall report); it is noted that direct shear tests were carried out on select soil samples to obtain a better estimate of soil strength parameters). As such, in comparison to the degree of site understanding specified in Section 6.5 of the *CHBDC* (2019), the level of confidence for design is considered to range from a “typical understanding” to a “high understanding”. Accordingly, the appropriate corresponding ULS and SLS consequence factor,  $\Psi$ , and geotechnical resistance factors,  $\phi_{gu}$  and  $\phi_{gs}$ , from Tables 6.1 and 6.2 of the *CHBDC* (2019) have been used for design and are summarized below:

- $\Psi = 1.0$
- $\phi_{gu} = 0.65$  to  $0.70$ : global stability – permanent condition for embankments (fill); the geotechnical resistance factors translate to Factors of Safety (FoS) of 1.43 and 1.54 (i.e.,  $FoS = 1/(\Psi \cdot \phi_{gu})$ ).

Furthermore, based on Table 8.3 of the *Canadian Foundation Engineering Manual – 4<sup>th</sup> Edition* (CFEM, 2006), the range of global factors of safety commonly used for earthworks (i.e., embankments and cuts not associated with or adjacent to a highway structure) and assuming a shearing mode of failure is between 1.3 and 1.5. These ranges of FoS are considered appropriate for this site.

## 6.3 High Fill Embankment and Deep Cut Platform Widening Areas

Based on the vertical profiles of the widened Highway 17 alignment provided to Golder by AECOM, the high fill and deep cut platform widening areas within the project limits are proposed to range from about 4.5 m to about 10.0 m in height.

Section 6.3.1 of this report address various embankment fill types that can be considered for the platform widenings at the high fill areas. Sections 6.3.2 and 6.3.3 summarize the methods used to analyze the stability and settlement (at the high fill areas only) at critical sections of the high fill and deep cut areas. The aforementioned sections also provide foundation engineering parameters used in the analyses. Section 6.4 outlines the settlement performance requirements for each high fill area based on MTO's embankment settlement criteria. The settlement criteria do not apply to the deep cut area as this segment of the widening will involve an unloading of the foundation soils. Section 6.5 provides a summary of stability and settlement analyses and recommendations regarding possible design and construction alternatives to mitigate stability issues and/or post-construction settlement, where applicable. General aspects of subgrade preparation and embankment construction are presented in Section 6.6, while general aspects pertaining to the cut slope are presented in Section 6.7.

At all high fill areas, the analyses assume that any near surface organic soils will be removed prior to placement of new embankment fill (as discussed in Section 6.6.1).

### 6.3.1 Embankment Fill Types

Different embankment fill alternatives (i.e., rock fill and granular fill) provide relative advantages and disadvantages in terms of availability, weight (i.e., driving force and applied load to the foundation deposits), construction cost and time, ease of construction and post-construction performance. The following sub-sections address the use of rock fill and granular fill to construct the platform widenings at the two high fill areas.

## Rock Fill

The main advantage of widening embankments using rock fill is the ability to typically achieve steeper side slopes (1.25 horizontal to 1 vertical (1.25H:1V) – although in some cases the slopes may need to be flatter), which is preferred in areas with limited right-of-way, thus reducing the overall quantity of fill material required for the project and for placement of material in sub-excavated areas. Rock fill is also expected to be available locally – either from excavations in cuts through bedrock outcrops within the limits of the project or from rock borrow areas close to the project limits. The disadvantage of using rock fill for the widening of embankments is that some post-construction settlement of the embankment fill (rock fill) itself will occur. Settlement of the rock fill is discussed further in Section 6.3.3.3. Furthermore, considering that the proposed platform widening(s) at the site are relatively narrow, it may not be possible to effectively spread / compact / grade the rock fill – that is, the rock fill may need to be placed with a hydraulic excavator resulting in slower construction and potentially long-term performance issues of the widened highway platform (i.e., reflective cracking in the asphalt at the interface between the new and existing fills). The size of the rock fill would also need to be restricted since it may not be possible to construct a narrow platform with large rock fill fragments (refer to Section 6.6.4). Such restrictions could result in higher material costs due to tighter gradation specifications.

## Granular Fill

The main advantage of using granular fill for widening embankments is the ease of construction and negligible post-construction settlement of the embankment fill itself following compaction. However, the compaction may need to be carried with smaller construction equipment (e.g., a walk-behind tandem smooth-drum compaction roller) where the proposed platform widening is too narrow to accommodate standard construction equipment (e.g., a smooth-drum vibratory roller). Furthermore, this option will require a larger volume of fill and potentially a wider right-of-way because the side slopes of granular fill embankments (generally constructed at 2H:1V) are flatter than those of rock fill.

For this project, acceptable granular fill is considered to consist of well-graded, locally sourced and/or imported granular material and should satisfy the requirements of OPSS.PROV 1010 Granular 'B' Type I or Type II material.

### 6.3.2 Stability

The following sections outline the method used to evaluate embankment stability at the high fill embankment platform widening areas and at the deep cut area and present the soil/fill engineering parameters used in the analyses for each critical section. The results of the stability analyses are presented in Section 6.5 where they are discussed together with the results of the settlement analyses and recommendations regarding possible design and construction alternatives to mitigate stability issues and/or post-construction settlement, where applicable.

#### 6.3.2.1 Method of Analyses

Stability analyses were carried out for the critical sections of the proposed high fill embankment and deep cut platform widening areas. Critical sections correspond to the greatest embankment height or greatest cut height and/or maximum thickness of weak deposits. The stability of the proposed high fill and deep cut sections were analyzed using limit equilibrium methods. The stability analyses assume that all organic soils encountered at/below ground surface within the footprint of the proposed high fill platform widening areas will be removed and replaced in accordance with Ontario Provincial Standard Drawing (OPSD) 203.030 (*Embankments Over Swamp – Existing Slopes Maintained – Widening*) prior to the proposed platform widening.

All limit equilibrium slope stability analyses were carried out using the commercially available program Slide2, developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. Morgenstern-Price is a

general method of slices which is based on equilibrium of forces and moments acting on each slice of the soil mass above the potential failure surface. For all analyses, the Factor of Safety of numerous potential failure surfaces was computed in order to establish the minimum Factor of Safety. The Factor of Safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. For the purpose of the stability analysis, the target minimum Factor of Safety for design is equal to the inverse of the product of the consequence factor,  $\Psi$ , and the geotechnical resistance factor,  $\phi_{gu}$  (i.e.,  $Factor\ of\ Safety = 1/(\Psi \cdot \phi_{gu})$ ).

### 6.3.2.2 Parameter Selection

The simplified stratigraphy together with the associated unit weight(s) and foundation engineering parameters employed for the different fill and native soil types at the critical sections are summarized below as well as on the individual slope stability figures.

High Fill / Deep Cut Area (Critical Section)	Soil Type	Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	Effective Friction Angle, $\phi'$ (°)	Effective Cohesion, $c'$ (kPa)
High Fill Area No. 1 (STA 11+540)	Generally Compact to Very Dense Sand and Gravel to Sand to Silty Sand (Fill) – Highway 17 Embankment	20	34	--
	Compact to Very Dense Gravelly Sand to Sand to Silty Sand to Silt	20	35 <sup>1</sup>	--
Deep Cut Area No. 1 (STA 12+170)	Compact Sand and Gravel (Fill) – Highway 17 platform fill	21	35	--
	Dense Gravelly Silty Sand	20	40 <sup>1</sup>	--
	Stiff to Hard Clayey Silt-Silt	18.5	35 <sup>1</sup>	--
	Compact to Very Dense Silt	18	35	--
High Fill Area No. 2 (STA 13+390)	Compact to Very Dense Gravelly Sand to Silty Sand (Fill) – Highway 17 Embankment	20	35	--
	Generally Dense to Very Dense Gravelly Sand to Silty Gravel to Sandy Silt	20	36	--

Note:

1. Effective friction angles utilized in stability analyses based on results of laboratory consolidated drained direct shear (DS) tests carried out on select soil samples from the respective soil deposits, tempered with engineering judgement based on precedent experience.

The fill and overburden soils encountered at the high fill and deep cut platform widening areas is generally comprised of granular materials. For granular soils/fills, effective stress parameters were employed in the analyses assuming drained conditions. The effective stress parameters (effective friction angle and effective cohesion, where applicable) for granular soils/fills were estimated from: 1) laboratory consolidated drained direct shear (DS) tests carried out on select soil samples; 1) empirical correlations using the results of in-situ SPT's; and, 3) experience with similar stratigraphic units in Northern Ontario. Where applicable, the correlations proposed by Peck et al. (1974) and U.S. Navy (1986) as well as correlations provided in the CHBDC (2019) were employed and the results were adjusted using engineering judgment based on precedent experience in similar soil conditions.

The following is a summary of embankment slope geometries, unit weights, and effective friction angles for the various fill types modelled in the analyses.

Fill Type	Typical Slope Profile <sup>1</sup>	Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	Effective Friction Angle, $\phi'$ (°)
Rock Fill	1.25H:1V	19	40
Granular Fill (Granular 'B' Type I or Type II) <sup>2</sup>	2H:1V	21	36

Notes:

1. The recommended embankment fill slope profiles are based on results of stability analyses, as discussed in Section 6.5.

2. Granular 'B' Type II fill recommended for placement below groundwater table and/or ponded water level in swamp(s).

### 6.3.3 Settlement

The following sections outline the methods used to carry out the settlement analyses at the high fill embankment platform widening areas and present the soil/fill foundation engineering parameters used in the analyses for the critical sections. The results of the settlement analyses are presented in Section 6.5 where they are discussed together with the results of the stability analyses and recommendations regarding possible design and construction alternatives to mitigate stability issues and/or post-construction settlement, where applicable.

#### 6.3.3.1 Method of Analyses

In order to estimate the magnitude of the expected settlements, analyses were carried out at critical sections of the proposed fill embankments using the commercially available program Settle3, developed by Rocscience Inc. Critical sections correspond to the greatest embankment height and/or maximum thickness of compressible soil deposits. The settlement analyses assume that all organic soils encountered at/below ground surface within the footprint of the proposed high fill platform widening areas will be removed and replaced in accordance with OPSD 203.030 (*Embankments Over Swamp – Existing Slopes Maintained – Widening*) and OPSS.PROV 206 (*Grading*), prior to the proposed platform widening. If organic soils are not fully excavated from within the footprint of the proposed highway platform widening areas, the proposed platform widenings will result in additional loading of the organic soils which in turn will experience settlement and may lead to poor long-term performance in the embankment widening areas.

The sources of settlement are considered to include:

- Elastic (i.e., immediate) settlement of the native granular soils and very stiff to hard cohesive soil layers (short-term settlement encountered at the high fill areas); and,
- Self-weight compression of the embankment fill materials (short-term and long-term settlement).

The thickness of the foundation soils and the height of the embankments vary along the proposed highway alignment within each high fill embankment platform widening area, and as such the settlements along the length of a given alignment will similarly vary. Given that the analyses were carried out at critical sections, the settlements estimated will generally represent the maximum estimated value along a given section of the alignment.

### 6.3.3.2 Parameter Selection

The simplified stratigraphy together with the associated deformation parameters employed for the different native soil types for the critical sections are summarized below.

High Fill / Deep Cut Area (Critical Section)	Soil Type	Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	Elastic Modulus, $E'$ (MPa)
High Fill Area No. 1 (STA 11+540)	Compact to Very Dense Gravelly Sand to Sand to Silty Sand to Silt	20	25
	Very Stiff to Hard Clayey Silt-Silt	20	20
High Fill Area No. 2 (STA 13+390)	Generally Dense to Very Dense Gravelly Sand to Silty Gravel to Sandy Silt	20	60

The immediate compression of the granular deposits was modelled by estimating an elastic modulus of deformation ( $E'$ ) based on the results of in-situ SPT 'N'-values and using correlations proposed by Bowles (1984) and Kulhawy and Mayne (1990). These estimated values were compared with the typical range of expected values for similar soil types, as outlined in *CHBDC* (2019) and adjusted, as appropriate, using engineering judgment based on precedent experience in similar soil conditions.

### 6.3.3.3 Settlement of Embankment Fill

If rock fill is used for the construction of the proposed widenings at the high fill areas, there will be settlement due to compression of the rock fill itself under self weight, in addition to the settlement of the underlying foundation soils as described above. The magnitude of settlement of the rock fill depends on the following factors:

- Type of rock/strength of rock particles
- Size and shape of rock particles
- Gradation of rock fill
- Total height/thickness of rock fill (i.e., stress level)
- Method of construction and sequence of placement (including lift thickness, compactive effort and state of packing)

The settlement of rock fill occurs as a result of re-arrangement of rock particles under load and wetting and as a result of localized crushing of rock particles at point contacts. The magnitude of both the short-term and long-term post-construction settlement of the rock fill is a function of the height of fill as well as the method of fill placement (i.e., compacted versus dumped rock fill) as outlined in "*MTO Guideline for Rock Fill Settlement and Rock Fill Quantity Estimates*", dated September 2010.

Rock fill should be placed, whenever possible, in a controlled manner (i.e., not end-dumped) in accordance with OPSS.PROV 206 (*Grading*). Blading, dozing and 'chinking' the rock fill to form a dense, compact mass is required to minimize voids and bridging and reduce settlements, and should be used to construct rock fill embankments above the existing ground surface. Where rock fill cannot be placed in a controlled manner (e.g., below the groundwater table), the post-construction settlement of the rock fill is expected to be greater. Furthermore, considering that the highway platform widening is proposed to be relatively narrow in some areas, resulting in the placement of a relatively small wedge of rock fill on top of the existing embankment side slopes, it may not be practical to place and "chink" the rock fill in a controlled manner using a conventional tractor bulldozer. In these

areas, consideration can be given to using a hydraulic excavator to place and “chink” the rock fill in accordance with Special Provision 102S05 (amendment to OPSS. PROV 206).

### Short-Term Rock Fill Settlement

The magnitude of short-term post-construction settlement associated with compacted and end-dumped rock fill may be estimated in accordance with the MTO Guideline (September 2010), as follows:

Total Height of Rock Fill, H	Short-Term Rock Fill Settlement	
	Compacted Rock Fill	Dumped Rock Fill
Up to 5 m	0.5%·H	1.0%·H
> 5 m to 10 m	0.75%·H	1.5%·H
>10 m to 15 m	1.0%·H	2.0%·H

Approximately 90% of the short-term settlement may be expected to occur within the first six months following construction of the embankment to full height. The short-term settlement is expected to be fully completed within one year following the completion of embankment construction to full height.

### Long-Term Rock Fill Settlement

The magnitude of long-term post-construction settlement for compacted and end-dumped rock fill may be estimated in accordance with the MTO Guideline (September 2010), as follows:

Total Height of Rock Fill, H	Long-Term Rock Fill Settlement	
	Compacted Rock Fill	Dumped Rock Fill
Up to 15 m	0.1%·H	0.2%·H

The long-term rock fill settlement is expected to occur from one year following the completion of construction over the life of the embankment.

## 6.4 Settlement Performance Requirements

The settlement performance criterion of design for embankment widening is in accordance with Section 1.3 of MTO's March 2010 guideline titled, “*Embankment Settlement Criteria for Design*.” In general, embankment widenings not approaching a structural element are to be designed as follows:

- Total settlement and differential settlement rate are to be less than 50 mm and 200:1, respectively, over a 20-year period following construction of the pavement structure for a King's highway.

However, where embankments approach structural elements (such as culverts or bridge abutments) or where areas of non-compressible/compressible soils are located adjacent to exposed bedrock, more stringent settlement criterion associated with these transition points will apply in accordance with Section 1.2 of the MTO Guideline. The summary of post-construction settlement criterion at each high fill platform widening area based on the guidelines summarized above is provided below.



Limits of High Fill Area (Project Chainage)	Length (m)	Post-Construction Settlement Criterion Over 20-year Period Following Completion of Construction
High Fill Area No. 1 (STA 11+440 to STA 11+620)	180	50 mm
High Fill Area No. 2 (STA 13+240 to STA 13+400)	160	

Furthermore, the guideline indicates that 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.*”

These performance criteria form part of the overall design performance for each high fill platform widening area.

## 6.5 Results of Stability and Settlement Analyses

Based on the results of the subsurface investigation and review of the highway profile and cross-section drawings provided by AECOM, the critical sections for stability (i.e., the greatest embankment height and/or maximum height of cut) were identified at the following locations:

- Highway 17 NBL – Approximately STA 11+540 (Aweres Township)
  - Approximately 7.5 m high embankment with existing side slopes constructed at an inclination of approximately 2.5H:1V.
- Highway 17 NBL – Approximately STA 12+170 (Aweres Township)
  - Approximately 9 m deep cut with existing side slopes constructed at an inclination of approximately 2H:1V.
- Highway 17 NBL – Approximately STA 13+390 (Aweres Township)
  - Approximately 10.0 m high embankment with existing side slopes constructed at an inclination of approximately 2.2H:1V.

Sections 6.5.1 to 6.5.3 provide a summary of the results of the global slope stability analyses for each critical high fill section (assuming a 3.5 m to 5.5 m widening of the existing highway embankment) and for the critical deep cut section (assuming a 2.5 m widening and a 9 m deep cut). In areas where the minimum Factor of Safety against a deep-seated, global failure surface that would impact the operation of the highway is less than the design Factor of Safety described in Section 6.2, a discussion regarding stability mitigation measures is provided, and the preferred alternative from a foundation perspective is identified.

Sections 6.5.4 and 6.5.5 provide a summary of estimated magnitudes of settlement along the proposed high fill embankment widening areas. Due to the primarily granular nature of the foundation soils and the fact that the cohesive foundation soils (where present) are thin, very stiff and over-consolidated, it is anticipated that the settlement of the foundation soils will occur during or shortly after construction.

### 6.5.1 Stability - Highway 17 NBL – STA 11+440 to STA 11+620 (High Fill Area No. 1)

The results of stability analyses for the approximately 7.5 m high widened highway embankment carried out at the critical section (Station 11+540) are presented below.

Fill Type of Proposed Widening	Scenario (Long-Term/Permanent Condition)	Min. Factor of Safety	Reference Figure
Granular Fill	5.5 m widening with 2H:1V side slope	1.5	4A

Fill Type of Proposed Widening	Scenario (Long-Term/Permanent Condition)	Min. Factor of Safety	Reference Figure
Rock Fill	5.5 m widening with 1.25H:1V side slope	1.6	4B

If the proposed platform widening is constructed with granular fill with the side slope inclined at 2H:1V, the calculated minimum Factor of Safety is 1.5. Similarly, if the proposed platform widening is constructed with rock fill with the side slope inclined at 1.25H:1V, the calculated minimum Factor of Safety is 1.6. Both Factors of Safety are greater than the target Factors of Safety specified in Section 6.2 – that is, between about 1.4 and 1.5.

### 6.5.2 Stability - Highway 17 NBL – STA 12+150 to STA 12+220 (Deep Cut Area No. 1)

The results of stability analyses for the approximately 9 m high deep cut carried out at the critical section (Station 12+170) are presented below.

Scenario (Long-Term/Permanent Condition)	Min. Factor of Safety	Reference Figure
2.5 m widening (cut) with 2H:1V side slope	1.5	5

If the new slope is cut at an inclination of 2H:1V, the calculated minimum Factor of Safety is 1.5. However, considering that the slope may be saturated during periods of heavy and/or sustained precipitation or during the snow melt period, the face of the slope should be protected with a minimum 0.5 m thick (measured perpendicular to the face of the slope) granular sheeting. The granular sheeting will provide erosion protection and resistance against surficial instability.

### 6.5.3 Stability - Highway 17 NBL – STA 13+240 to STA 13+400 (High Fill Area No. 2)

The results of stability analyses for the approximately 10 m high widened highway embankment carried out at the critical section (Station 13+390) are presented below.

Fill Type of Proposed Widening	Scenario (Long-Term/Permanent Condition)	Min. Factor of Safety	Reference Figure
Granular Fill	5.5 m widening with 2H:1V side slope	1.7	6A
Rock Fill	5.5 m widening with 1.25H:1V side slope	1.3	6B
Rock Fill	5.5 m widening with 1.75H:1V side slope	1.4	6C

If the proposed platform widening of Highway 17 is constructed with granular fill with a side slope inclined at 2H:1V, the calculated minimum Factor of Safety is 1.7. Alternatively, if the proposed platform widening is constructed with rock fill with the side slope inclined at 1.25H:1V, the minimum Factor of Safety is 1.3. In order to achieve a minimum Factor of Safety between 1.4 and 1.5 (as described in Section 6.2), the rock fill side slope has to be constructed at an inclination of 1.75H:1V. The latter strategy will result in a calculated minimum Factor of Safety of 1.4.

### 6.5.4 Settlement – Highway 17 NBL STA 11+440 to STA 11+620 (High Fill Area No. 1)

The results of settlement analyses for the approximately 7.5 m high widened highway embankment carried out at the critical section (Station 11+540) are presented below.

Fill Type / Widening Scenario	Settlement ( $\delta$ ) of Foundation Soils	Settlement ( $\delta$ ) of New Fill
Granular Fill – 2H:1V side slope	5 mm to 10 mm	Negligible (assuming compacted granular fill)
Rock Fill – 1.25H:1V side slope	5 mm to 10 mm	$\delta_{\text{short-term}} < 25 \text{ mm}$ $\delta_{\text{long-term}} \approx 5 \text{ mm}$ (assuming up to 2.3 m of rock fill placed above existing embankment side slope using a hydraulic excavator)

For the granular fill widening option, the total settlement of the foundation soils is estimated to be up to about 10 mm. The settlement is estimated to be comprised of elastic settlement that will occur during or shortly following completion of construction.

For the rock fill widening option, the total settlement of the foundation soils is estimated to be up to about 10 mm. Similarly, the settlement is estimated to be comprised of elastic settlement that will occur during or shortly following completion of construction. In addition, the total settlement of the rock fill itself (assuming it is placed and chinked with a hydraulic excavator and has a maximum thickness of 2.3 m placed above the existing embankment slope) is estimated to be less than 30 mm, with 25 mm expected to occur within the first year after construction, and about 5 mm expected to occur over the remaining design life of the embankment.

Considering that the estimated post-construction settlement for both fill options is less than 50 mm over a 20-year design life, settlement mitigation measures are not required along this proposed high fill embankment platform widening.

### 6.5.5 Settlement – Highway 17 NBL STA 13+240 to STA 13+400 (High Fill Area No. 2)

The results of settlement analyses for the approximately 10.0 m high widened highway embankment carried out at the critical section (Station 12+170) are presented below.

Fill Type / Widening Scenario	Settlement ( $\delta$ ) of Foundation Soils	Settlement ( $\delta$ ) of New Fill
Granular Fill – 2H:1V side slope	5 mm	Negligible (assuming compacted granular fill)
Rock Fill – 1.75H:1V side slope	5 mm	$\delta_{\text{short-term}} \approx 25 \text{ mm}$ $\delta_{\text{long-term}} \approx 5 \text{ mm}$ (assuming up to 2.6 m of rock fill placed above existing embankment side slope using a hydraulic excavator)

For the granular fill widening option, the total settlement of the foundation soils is estimated to be less than about 5 mm. The settlement is estimated to be comprised of immediate settlement due to compression of the granular deposits and is expected to occur during construction.

For the rock fill widening option, the total settlement of the foundation soils is estimated to be less than about 5 mm. Similarly, the settlement is estimated to be comprised of immediate settlement due to compression of the granular deposits and is expected to occur during construction. In addition, the total settlement of the rock fill itself (assuming

it is placed and chinked with a hydraulic excavator and has a maximum thickness of 2.6 m placed above the existing embankment slope) is estimated to be about 30 mm, with about 25 mm expected to occur within the first year after construction, and about 5 mm expected to occur over the remaining design life of the embankment.

Considering that the estimated post-construction settlement for both fill options is less than 50 mm over a 20-year design life, settlement mitigation measures are not required along this proposed high fill embankment platform widening.

## 6.6 Subgrade Preparation and Embankment Construction

The following sections discuss general aspects of subgrade preparation and embankment construction for the high fill embankment platform widening areas, including: removal of surficial and near surface organic materials; groundwater control; and placement of embankment fills.

### 6.6.1 Temporary Excavations and Removal of Organic Soils

Based on the subsurface information encountered in the boreholes advanced during the field investigation, organic deposits were not encountered. However, a marsh was observed to be present along the northern segment of High Fill Area No. 1 – that is, at the toe of the existing highway embankment. These types of low-lying/swampy environments are generally indicators of the presence of organic deposits (e.g., peat, loam, organic silts). A pavement investigation was also carried out by Golder along the Highway 17 corridor as part of Mile Hill widening project. Two probeholes were advanced at the toe of existing highway embankment in the vicinity of the marsh – one probehole at Station 11+400 and one probehole at Station 11+500. Approximately 0.5 m of fibrous/organic silt was encountered in the two probeholes. Consequently, all surficial and near surface organic deposits within the proposed high fill embankment platform widening areas should be fully sub-excavated from the plan limits of the proposed works.

All organic materials within the footprint of the widenings shall be removed using construction procedures in accordance with OPSS.PROV 209 (*Embankments Over Swamps and Compressible Soils*). Furthermore, all excavation operations carried out adjacent to the existing highway embankment should be carried out in accordance with OPSS.PROV 206 (*Grading*), and in particular, Clause 206.07.03.03 (*Excavation for Widening*). The clause stipulates that the excavation operation shall at no time be in advance of the backfilling operation by a distance greater than the limits as specified in the Contract Documents. A Non-Standard Special Provision (NSSP) has been prepared to address this restriction and is provided in Appendix D. Furthermore, the clause stipulates that excavation shall be backfilled prior to closing down operations each day.

All excavations must be carried out in accordance with Ontario Regulation 213, *Ontario Occupational Health and Safety Act for Construction Projects* (as amended). If workers are required to enter temporary excavations, the organic deposits are classified as Type 4 soils, and any temporary excavations must be sloped at 3H:1V or flatter.

In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of Highway 17.

### 6.6.2 Groundwater and Surface Water Control

Excavation within the plan limits of the proposed works will be required to sub-excavate surficial organics prior to embankment fill placement, which will likely extend below the groundwater level. Groundwater flow / seepage into the excavations will occur due to the presence of generally permeable deposits and relatively high groundwater levels observed at the high fill areas. Dewatering is not required for the excavation and backfilling in the proposed

high fill embankment platform widening areas provided rock fill or granular (i.e., Granular B Type II) soils are used for the backfill material, however, surface water should be directed away from the excavations at all times.

### 6.6.3 Backfilling

In general, it is recommended that rock fill or Granular 'B' Type II (not Granular 'B' Type I) fill be used for replacement of the sub-excavated material (where organic deposits are encountered) given the anticipated saturated / submerged conditions. For placement of fill below the water level, rock fills and granular fills are anticipated to be end-dumped and nominally spread and compacted as the excavation advances as per OPSS.PROV 209 (*Embankments Over Swamps and Compressible Soils*) and OPSS.PROV 206 (*Grading*) (refer to Section 6.6.1 for details).

### 6.6.4 Embankment Fill Placement

Placement of rock fill and granular fill (satisfying OPSS.PROV 1010 Granular 'B' Type I or Type II requirements) above the water table for construction of high fill embankment platform widening areas should be carried out in accordance with the requirements as outlined in OPSS.PROV 206 (*Grading*). If the proposed platform is wide enough to accommodate a tractor bulldozer, the rock fill should not be end-dumped into final position, but should be placed and pushed forward over the end of the layer being constructed. Otherwise, a hydraulic excavator will need to be used to place and "chink" the rock fill in accordance with Special Provision 102S05 (amendment to OPSS. PROV 206). Voids and bridging should be minimized by blading and dozing the rock fill to form a dense, compacted mass. Similarly, if a hydraulic excavator is utilized, the voids and bridging should be minimized by raking and 'chinking'.

Side slopes for rock fill embankments should be no steeper than 1.25H:1V or flatter based on the stability results provided in Section 6.5. Side slopes for granular fill embankments should be no steeper than 2H:1V. Granular 'B' Type II or rock fill fore slopes do not require erosion protection. Furthermore, as noted in Section 6.3.1, given the relatively narrow width of the proposed platform widening, it may not be possible to construct the widened highway platform with large rock fragments. Consequently, the maximum particle size of rock fill (if used for filling) shall not be greater than 500 mm in any dimension. Additional details are provided in a Non-Standard Special Provision (NSSP) provided in Appendix D.

New fill placed on the side slopes of the existing embankment shall be keyed into the existing embankment fill by benching in accordance with OPSD 208.010 (*Benching of Earth Slopes*). Considering the presence of boulders and cobbles encountered within the existing highway embankment fill, it is noted that it may be challenging to carry out the benching requirements, but the contractor must make all efforts to bench the slopes in accordance with OPSD 208.010. Further, any vegetation / organics and loose soils/fills present along the face of the existing embankment side slopes should be stripped and all attempts should be made to carry out the required benching; at a minimum, the face of the existing embankment side slopes should be scarified and "roughened" to reduce the potential of creating a weak zone/interface between the new fill and existing embankment fill.

Furthermore, all earth fill and rock fill embankment side slopes along the high fill platform widening areas should include a minimum 2 m wide bench for embankment heights in excess of 8 m and 10 m, respectively, in general accordance with OPSD 202.010 (*Slope Flattening*).

### 6.6.5 Erosion Protection

If Granular 'B' Type I material is used along the high fill platform widening areas, the slopes should be vegetated as soon as practicable after construction to minimize the potential for erosion due to surface water run-off/ snow melt, either by placement of topsoil in accordance with OPSS.PROV 802 (*Topsoil*) and seeding in accordance with

OPSS.PROV 804 (*Temporary Erosion Control*) or pegged sod in accordance with OPSS.PROV 803 (*Vegetative Cover*).

If vegetation protection is not in place before the winter season, an alternate protection, such as covering the slopes with granular sheeting or temporary erosion control blankets, is recommended to reduce the potential for remedial works required on the side slopes in the spring season prior to topsoil and seeding.

## 6.7 Cut Slope Construction

As noted in Section 6.5.2, the deep cut between Station 12+150 and Station 12+220 should be inclined at 2H:1V to ensure the target Factor of Safety against instability is satisfied.

Furthermore, considering that the existing cut slope appears to be covered with granular fill (at least the lower portion of the slope – refer to Photograph 2 in Figure 2), the face of the proposed cut slope should also be protected with a permanent granular cover – that is, with a minimum 0.5 m thick granular sheeting (measured perpendicular to the face of the slope). If the slope becomes saturated during periods of heavy and/or sustained precipitation or during the snow melt period, the granular sheeting will provide surficial erosion protection and resistance against surficial instability.

## 7.0 CLOSURE

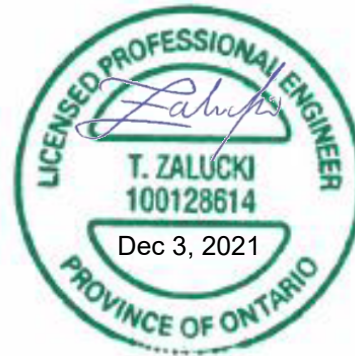
This Foundation Design Report was prepared by Ms. Alysha Kobylinski, P.Eng. and Mr. Tomasz Zalucki, P.Eng., geotechnical engineers at Golder. Mr. Paul Dittrich, Ph.D., P.Eng., an MTO Foundations Designated Contact and Principal of Golder, conducted an independent technical and quality control review of the report.

## Signature Page

Golder Associates Ltd.

Alysha Kobylinski

Alysha Kobylinski, P.Eng.  
*Geotechnical Engineer*



Tomasz Zalucki, P.Eng.  
*Geotechnical Engineer*



Paul Dittrich, Ph.D., P.Eng.  
MTO Foundations Designated Contact, Principal

AK/TZ/JPD/tz/ak/ml

Golder and the G logo are trademarks of Golder Associates Corporation

[https://golderassociates.sharepoint.com/sites/108558/project files/6 deliverables/foundations/mile hill-final fidr/19122433-rpt-rev0-highway 17-mile hill widening-final fidr-20211203.docx](https://golderassociates.sharepoint.com/sites/108558/project%20files/6%20deliverables/foundations/mile%20hill-final%20fidr/19122433-rpt-rev0-highway%2017-mile%20hill%20widening-final%20fidr-20211203.docx)



## REFERENCES

Bowles, J.E. 1984. Physical and Geotechnical Properties of Soils, Second Edition. McGraw Hill Book Company, New York.

Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual – 4<sup>th</sup> Edition.

Canadian Standards Association (CSA). 2019. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-19. CSA Special Publication, S6.1-19.

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

Ministry of Transportation, Ontario. March 2, 2010. Embankment Settlement Criteria for Design.

Ministry of Transportation, Ontario. April 12, 2010. Post-Construction Rock Fill Settlement and Guidelines for Estimating Rock Fill Quantity.

Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41KNE, Study Number 91.

Ontario Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East-Central Sheet, Ontario Geological Survey – Map 2544.

Peck, R.B., Hanson, W.E., and Thornburn, T.H. 1974. Foundation Engineering, 2<sup>nd</sup> Edition, John Wiley & Sons, New York.

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

### **ASTM International:**

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

ASTM D3080 Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions

### **Commercial Software:**

Settle3 by Rocscience Inc.

Slide2 by Rocscience Inc.

### **Ontario Occupational Health and Safety Act:**

Ontario Regulation 213 Construction Projects (as amended)

### **Ontario Provincial Standard Specifications (OPSS), Construction:**

OPSS.PROV 206 Construction Specification for Grading

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

OPSS.PROV 802 Construction Specification for Topsoil

OPSS.PROV 803 Construction Specification for Vegetative Cover

OPSS.PROV 804 Construction Specification for Temporary Erosion Control

### **Ontario Provincial Standard Specifications (OPSS), Materials:**

OPSS.PROV 206 Grading

OPSS.PROV 209 Embankments Over Swamps and Compressible Soils

OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material

**Ontario Provincial Standard Drawings (OPSD):**

OPSD 202.010            Slope Flattening Using Surplus Excavated Material on Earth or Rock Embankment  
OPSD 203.030            Embankments Over Swamp – Existing Slopes Maintained - Widening  
OPSD 208.010            Benching of Earth Slopes

**Ontario Regulations:**

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

**Special Provisions (SP):**

SP102S05            Amendment to OPSS.PROV 206, November 2014

# ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

## MINISTRY OF TRANSPORTATION, ONTARIO

### PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse	19 to 75	0.75 to 3
	Fine	4.75 to 19	(4) to 0.75
SAND	Coarse	2.00 to 4.75	(10) to (4)
	Medium	0.425 to 2.00	(40) to (10)
	Fine	0.075 to 0.425	(200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

### MODIFIERS FOR SECONDARY COMPONENTS<sup>1,2</sup>

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

- Only applicable to components not described by Primary Group Name.
- Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

### PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

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

#### Cone Penetration Test (CPT)

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

#### Dynamic Cone Penetration Resistance (DCPT); $N_d$ :

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

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

### SAMPLES

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

### SOIL TESTS

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

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

### COARSE-GRAINED SOILS

#### Compactness<sup>1</sup>

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

- Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.
- SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

### FINE-GRAINED SOILS

#### Consistency

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

- SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
- SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

### Field Moisture Condition

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

# LIST OF SYMBOLS

## MINISTRY OF TRANSPORTATION, ONTARIO

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

### I. GENERAL

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

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta\sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

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

### III. SOIL PROPERTIES

#### (a) Index Properties

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

#### (a) Index Properties (continued)

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

#### (b) Hydraulic Properties

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

#### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_{a(e)}$	secondary compression index
$C_a$	rate of secondary compression
$C_{a(e)}$	modified secondary compression index
$m_v$	coefficient of volume change
$c_v$	coefficient of consolidation (vertical direction)
$c_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

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

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

Notes: 1  
2

$\tau = c' + \sigma' \tan \phi'$   
shear strength = (compressive strength)/2

## Drawings

CONT No.  
GWP No. 5181-13-00

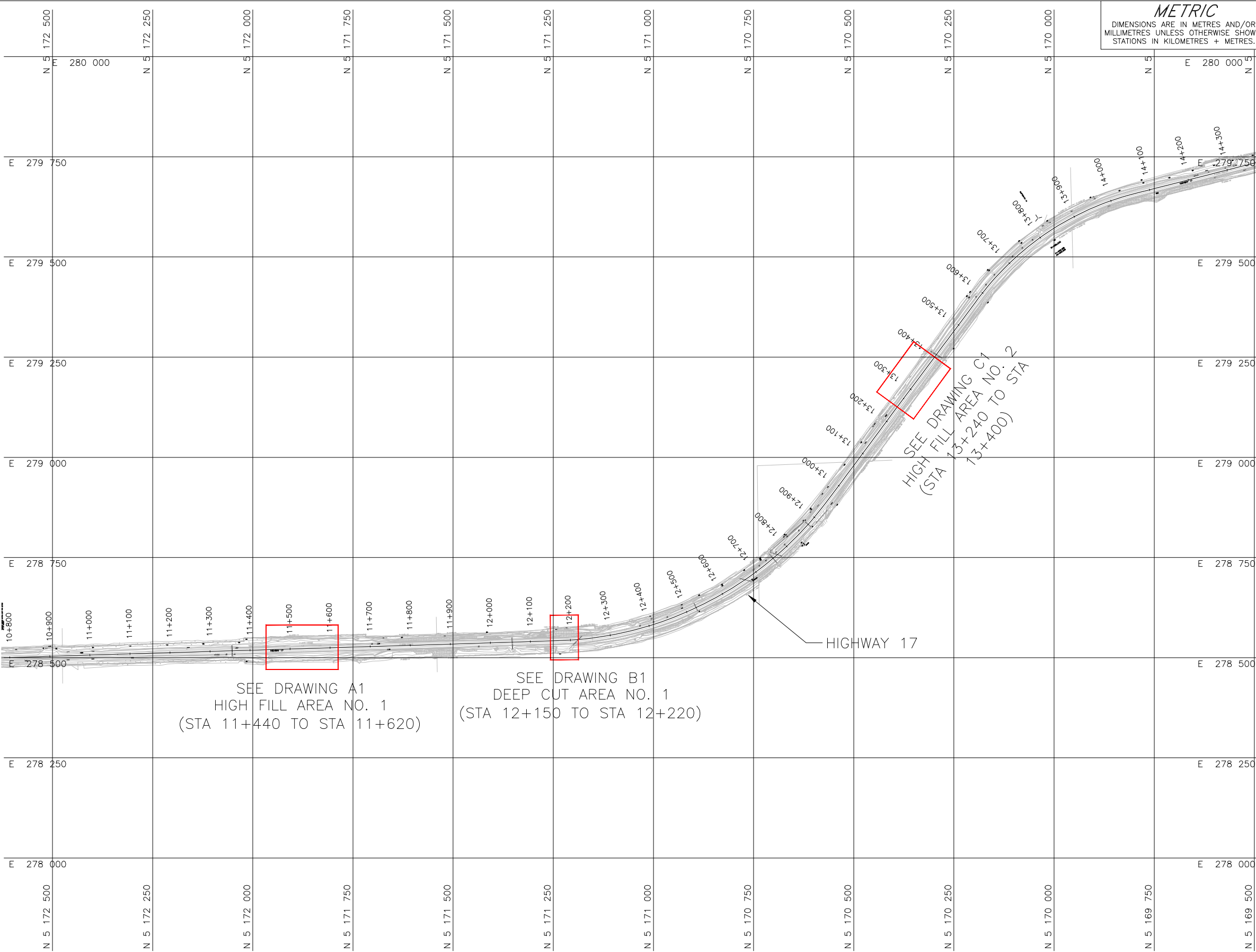


KEY PLAN



Location plans provided in digital format by Ministry of Transportation, Ontario, drawing file nos. 5181-13-00-Location Map\_18E32.pdf, dated April 16, 2019.

[illegible]




PLAN




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

CONT No.  
GWP No. 5181-13-00

HIGHWAY 17  
MILE HILL WIDENING  
INDEX PLAN

 **GOLDER**  
MEMBER OF WSP

  
SHEET



**REFERENCE**  
Base plans provided in digital format by AECOM, drawing file nos.  
5181-13-00 - Base plan.dwg and 5181-13-00 - DTM and  
Contours.dwg, received September 09, 2021.

NO.	DATE	BY	REVISION
Geocres No. 41K-119			
HWY. HWY 17	PROJECT NO. 19122433		DIST. .
SUBM'D. TZ	CHKD. TZ	DATE: 12/1/2021	SITE: .
DRAWN: SA	CHKD. .	APPD. JPD	DWG. 2



## Figures




**Photograph 1 (Northern segment of high fill area; Borehole HF1-01 as-drilled location):** Standing water and a marsh noted near the northern limit of the high fill area (looking north towards the Goulais River valley)



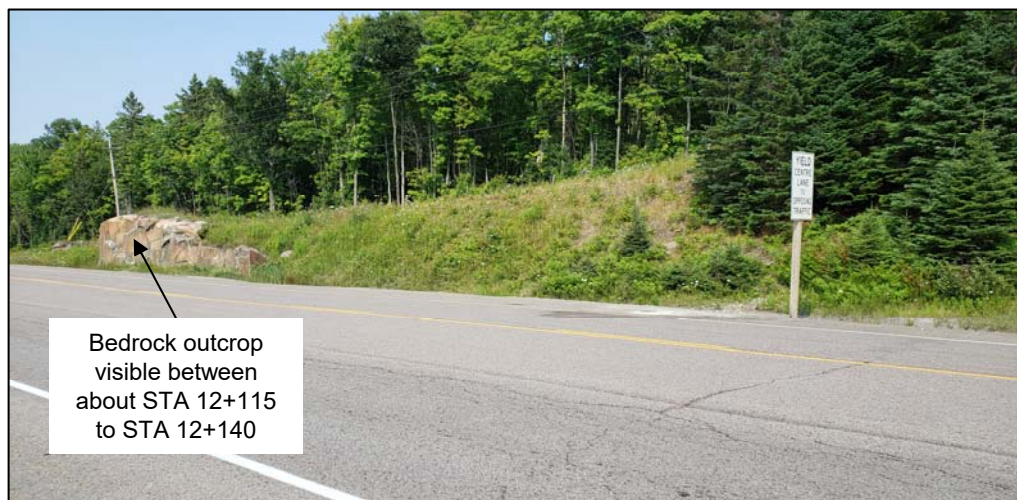
**Photograph 3 (Borehole HF1-02 as-drilled location):** The eastern slope of the highway embankment is vegetated with grasses and weeds; standing water and a marsh are visible near the toe of the slope (looking south, parallel to Highway 17)



**Photograph 2 (Borehole HF1-03 as-drilled location):** The eastern slope of the highway embankment is vegetated with grasses and weeds (looking north towards Goulais River valley)

PROJECT		Mile Hill Widening – High Fill and Deep Cut Areas Highway 17 Rehabilitation Algoma District, Ontario				
TITLE		SITE PHOTOGRAPHS HIGH FILL AREA No. 1 (STA 11+440 TO STA 11+620)				
 <b>GOLDER</b> MEMBER OF WSP		PROJECT No. 19122433			FILE No. ----	
		DESIGN	ACK	20211014	SCALE	NTS
		CADD	--		<b>FIGURE 1</b>	
		CHECK	TZ	20211014		
		REVIEW	JPD	20211015		






**Photograph 1 (Northern segment of deep cut area):** The northern segment of the cut slope is vegetated with grasses (looking northeast from Highway 17)



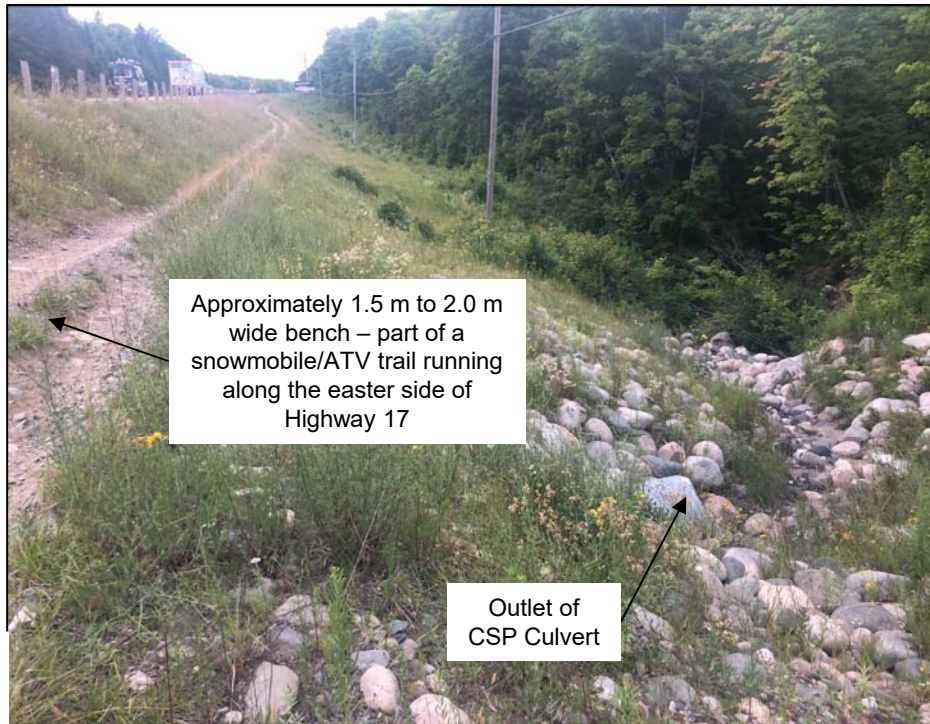
**Photograph 2 (Southern segment of deep cut area):** The lower portion of the cut slope is covered with granular material and the upper portion of the cut slope is heavily vegetated with coniferous trees (looking southeast from Highway 17)



**Photograph 3 (Borehole DC1-02 as-drilled location):** Crest of cut slope east of Highway 17 (looking north towards the Goulais River valley)

PROJECT		Mile Hill Widening – High Fill and Deep Cut Areas Highway 17 Rehabilitation Algoma District, Ontario				
TITLE		SITE PHOTOGRAPHS DEEP CUT AREA No. 1 (STA 12+150 TO STA 12+220)				
 <b>GOLDER</b> MEMBER OF WSP		PROJECT No. 19122433			FILE No. ----	
		DESIGN	ACK	20211014	SCALE	NTS
		CADD	--		<b>FIGURE 2</b>	
		CHECK	TZ	20211014		
		REVIEW	JPD	20211015		






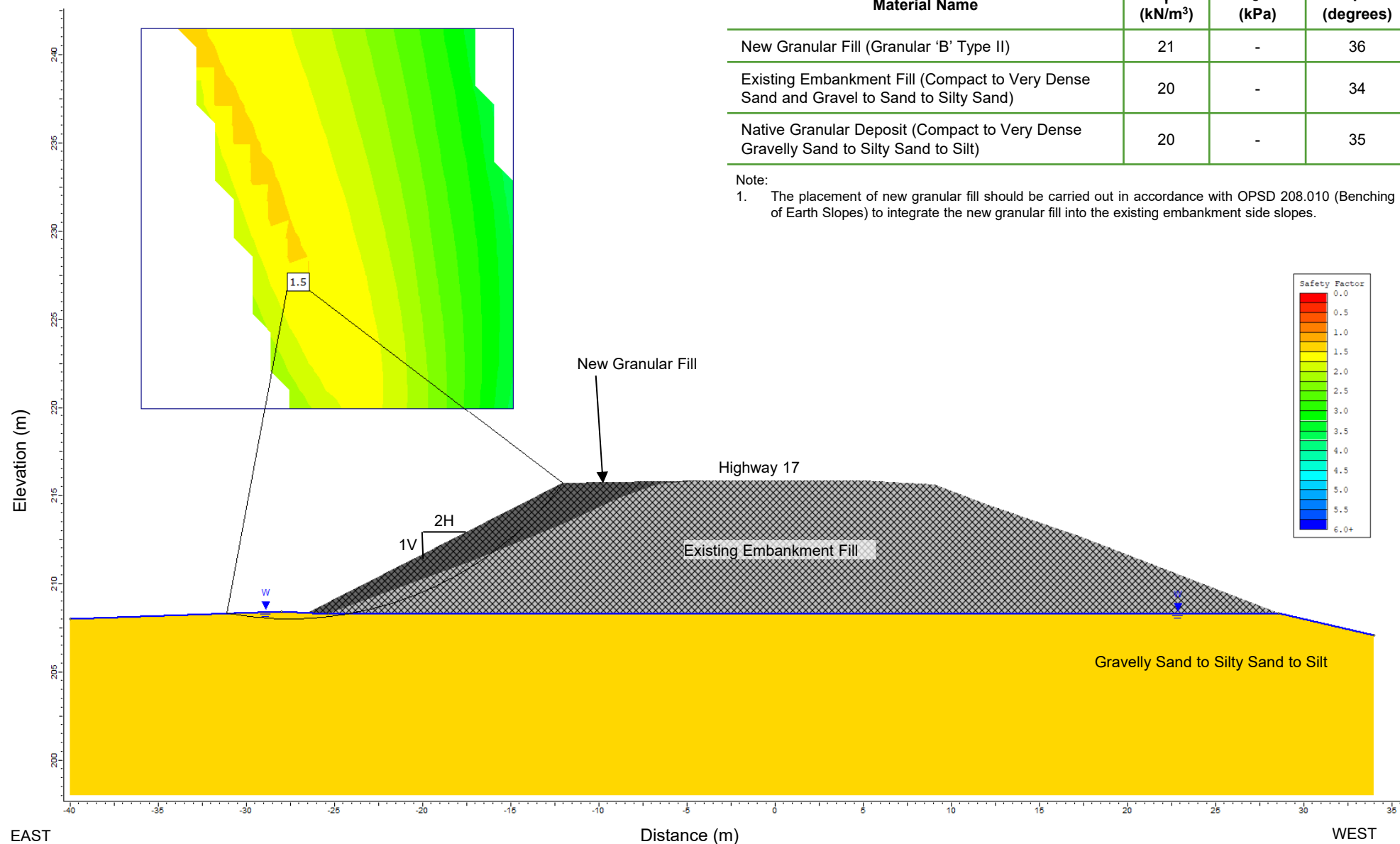
**Photograph 1 (High fill area):** The eastern slope of the highway embankment is vegetated with grasses and weeds; rip-rap is visible near the outlet of a CSP culvert and along the watercourse (looking north, parallel to Highway 17)

**Photograph 2 (Watercourse channel at the toe of high fill area):** Watercourse banks appear over steepened and eroding (looking east from Highway 17)

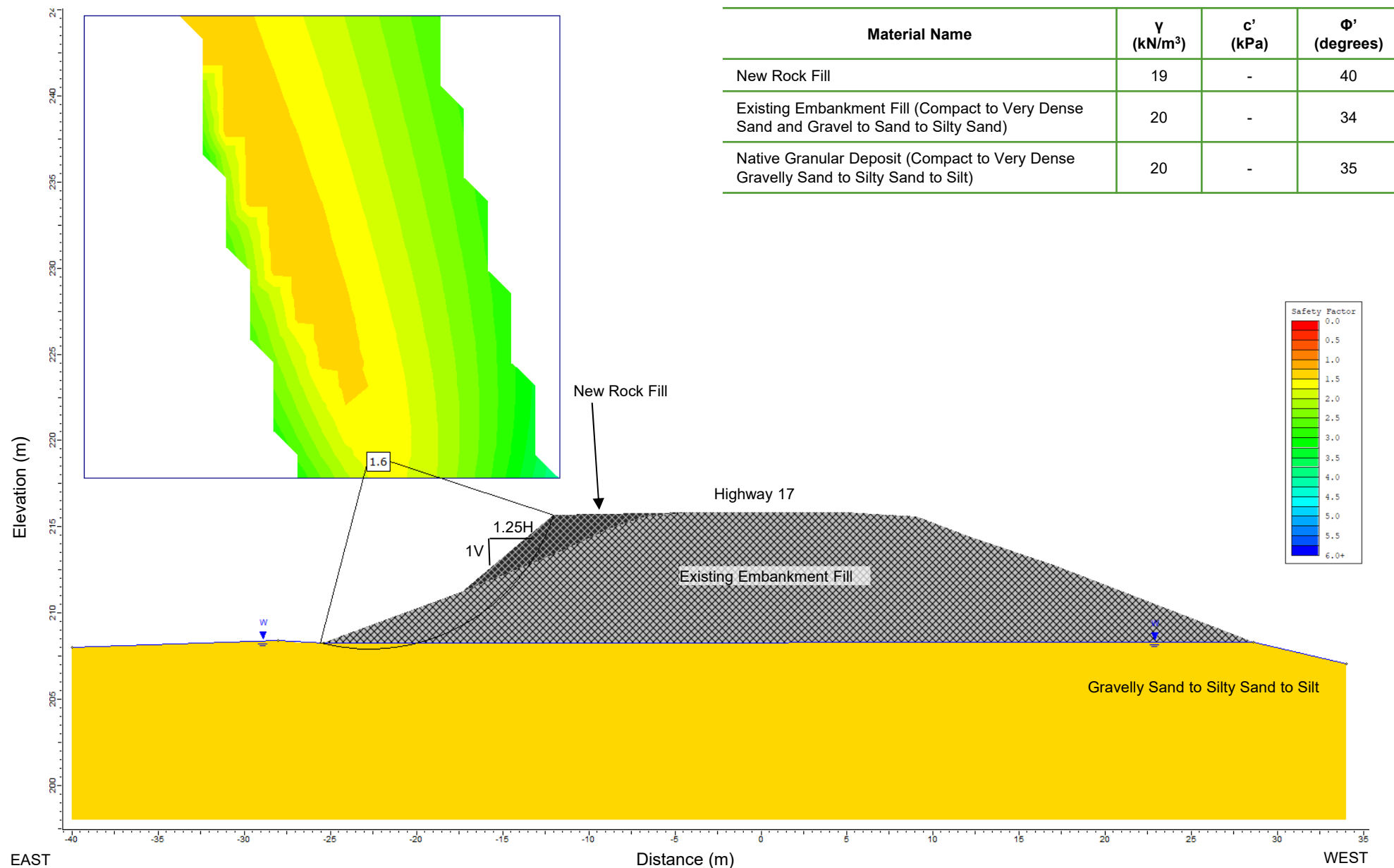


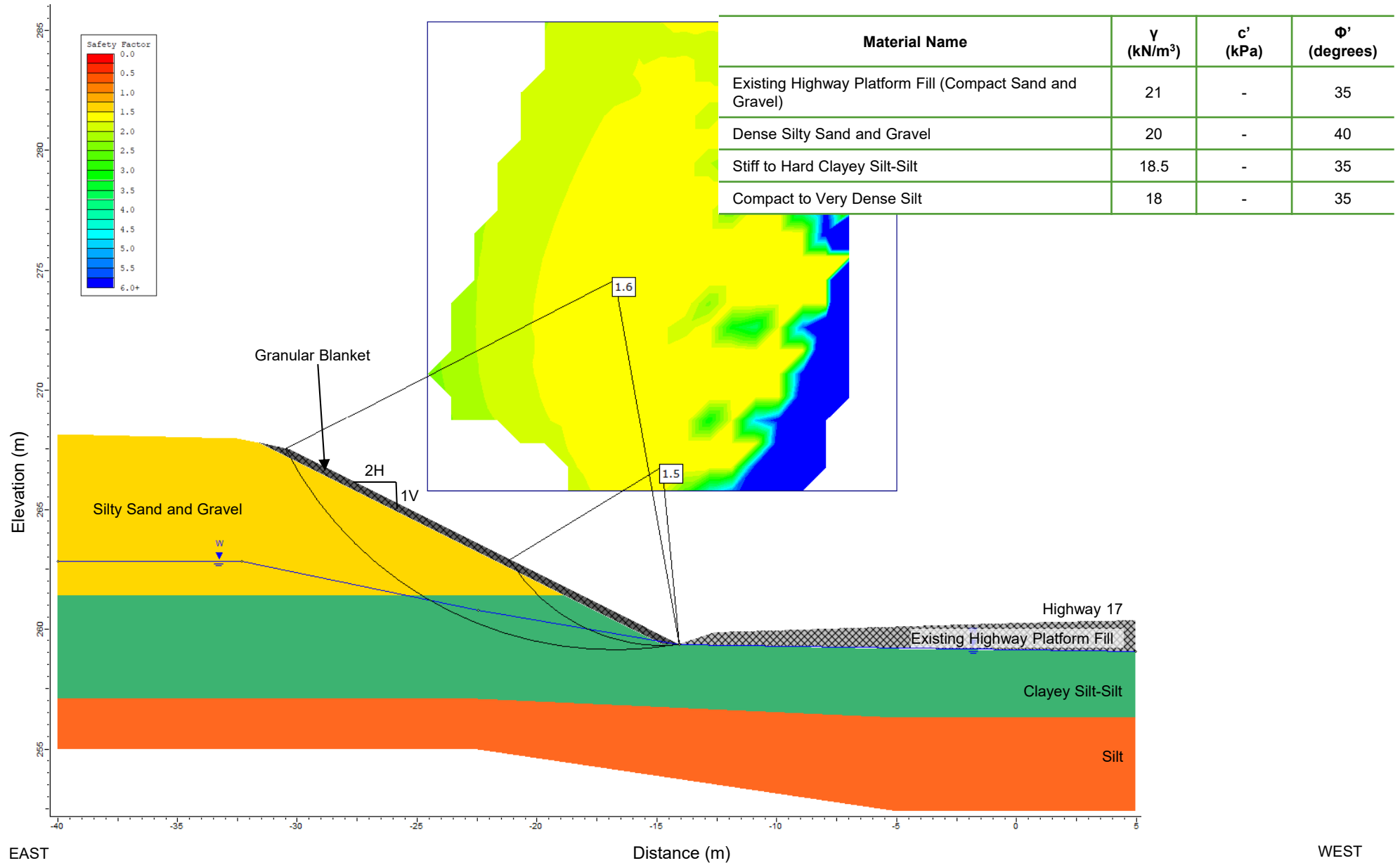
**Photograph 3 (Outlet of CSP Culvert at STA 13+410 ):** The slope of the highway embankment near the culvert outlet is covered with rip-rap (looking north and parallel to Highway 17)

PROJECT		Mile Hill Widening – High Fill and Deep Cut Areas Highway 17 Rehabilitation Algoma District, Ontario			
TITLE		SITE PHOTOGRAPHS HIGH FILL AREA No. 2 (STA 13+240 TO STA 13+400)			
 <b>GOLDER</b> MEMBER OF WSP		PROJECT No. 19122433		FILE No. ----	
		DESIGN	ACK	20211014	SCALE NTS
		CADD	--		VER. 1.
		CHECK	TZ	20211014	<b>FIGURE 3</b>
		REVIEW	JPD	20211015	

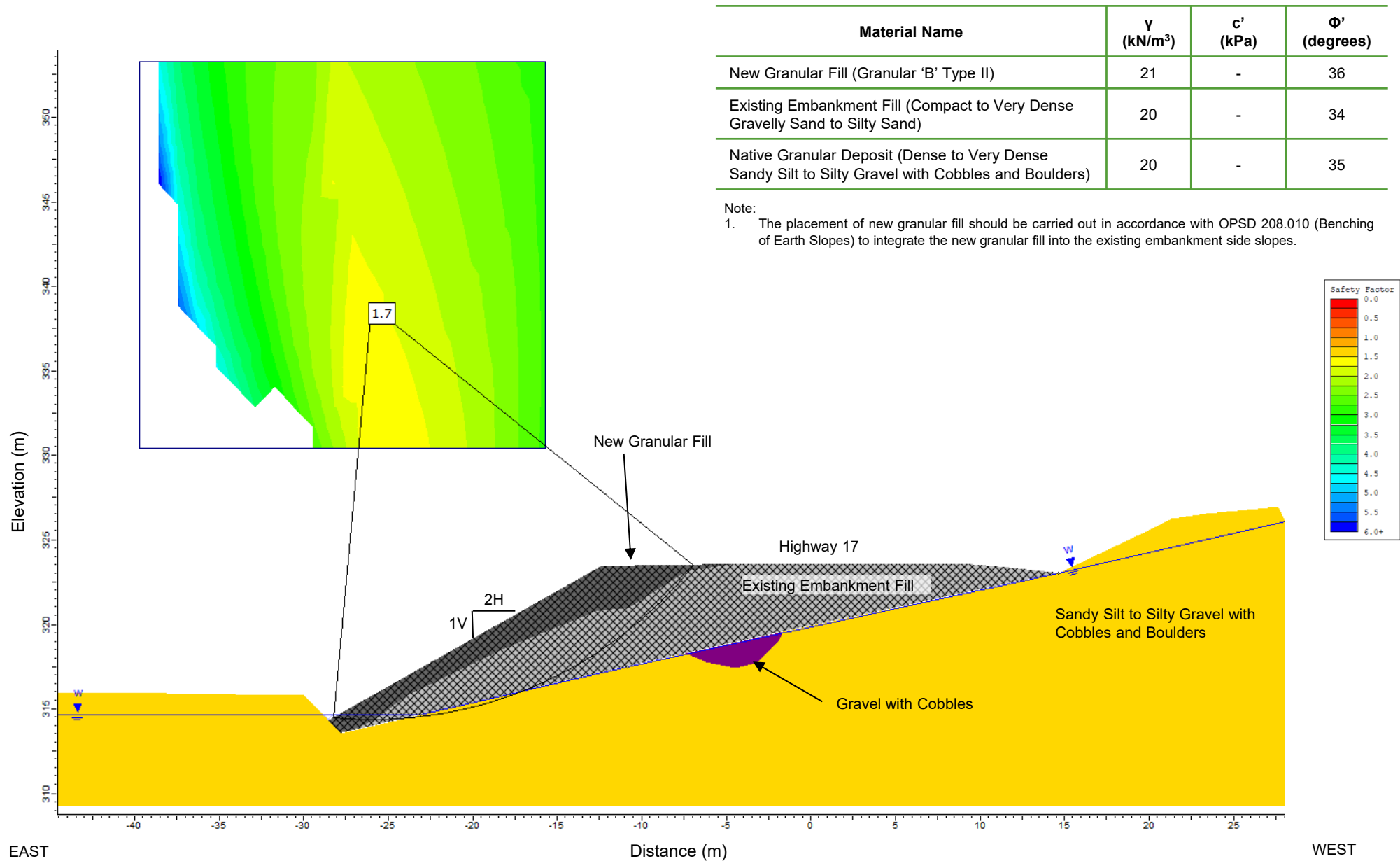


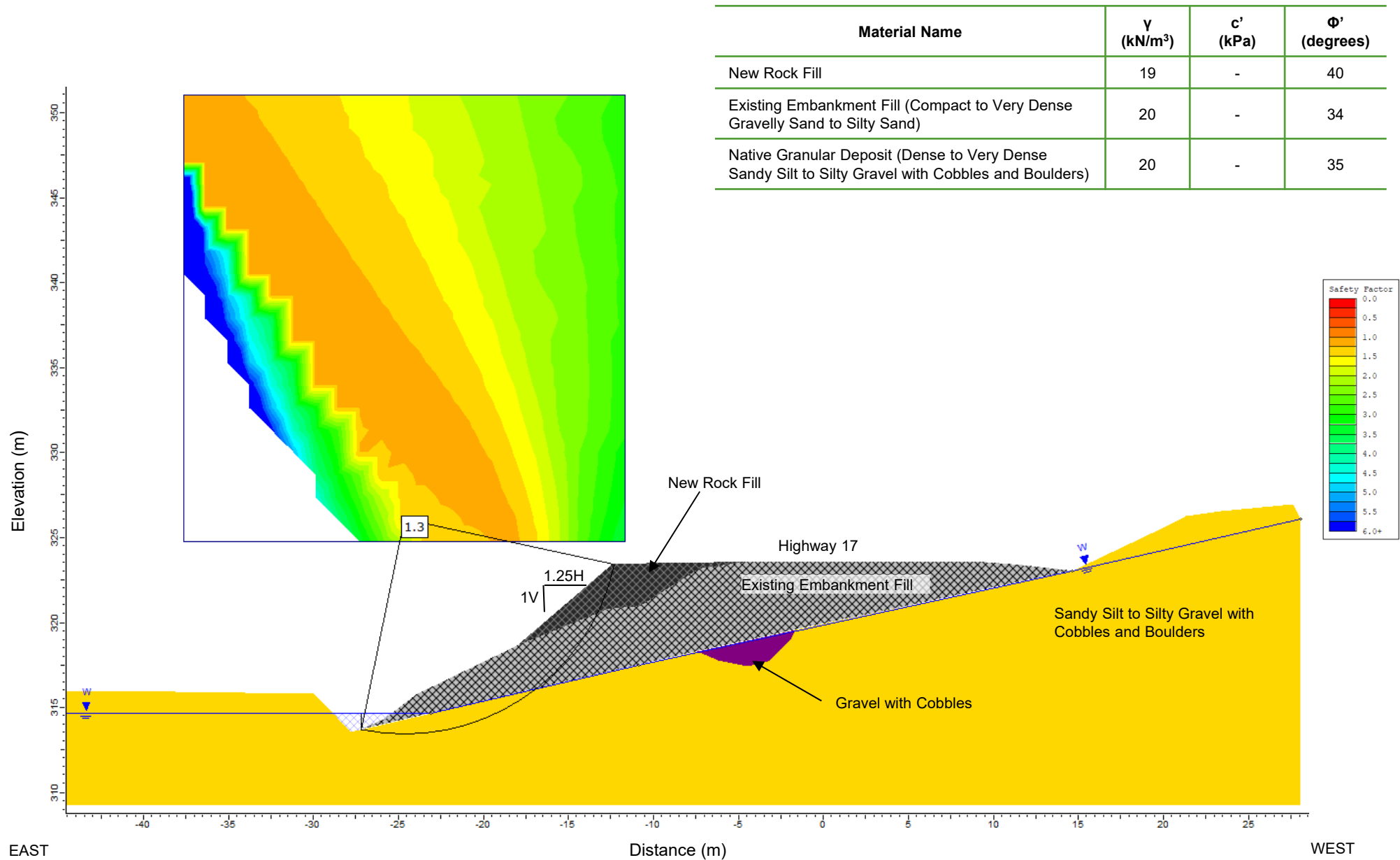


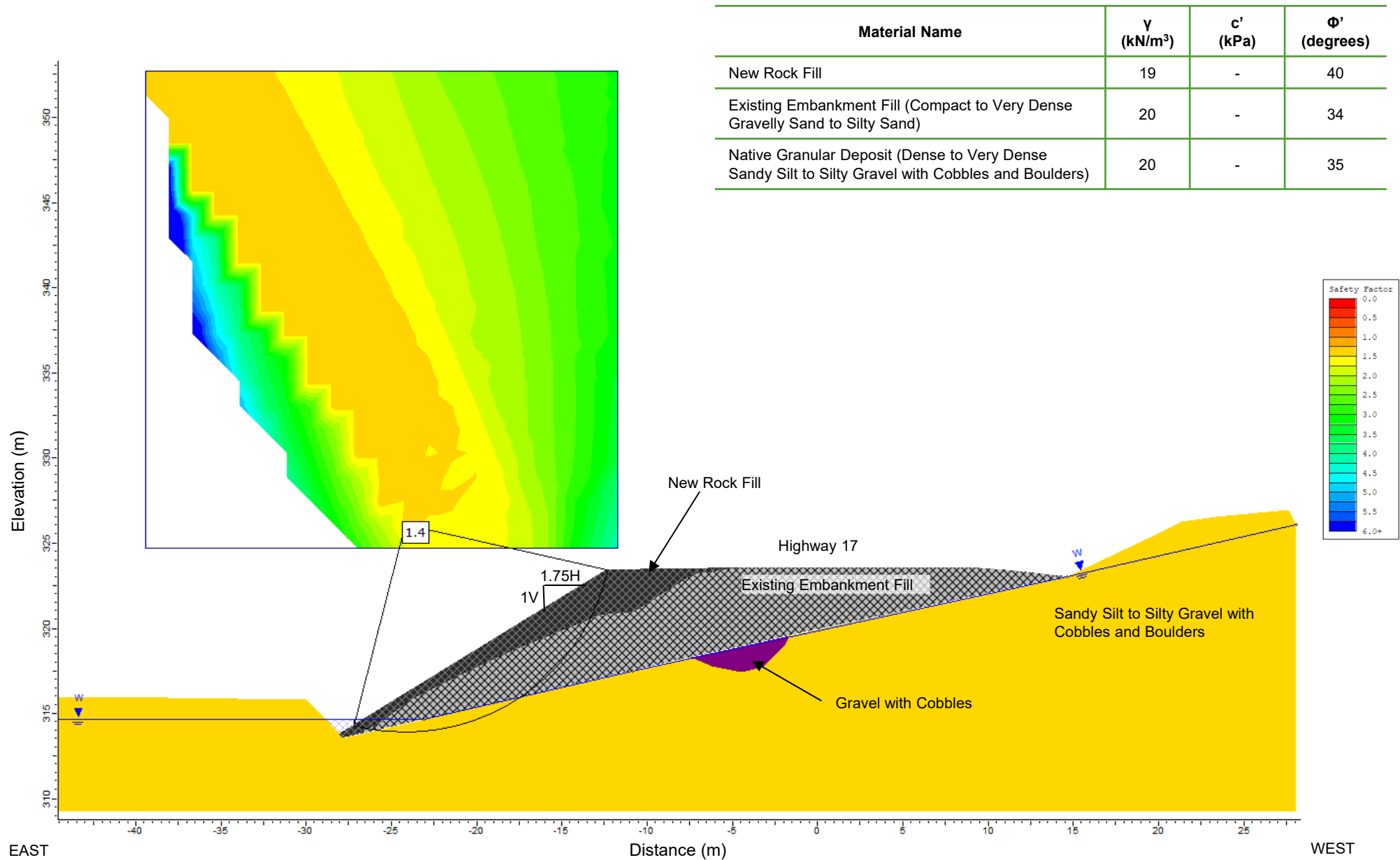






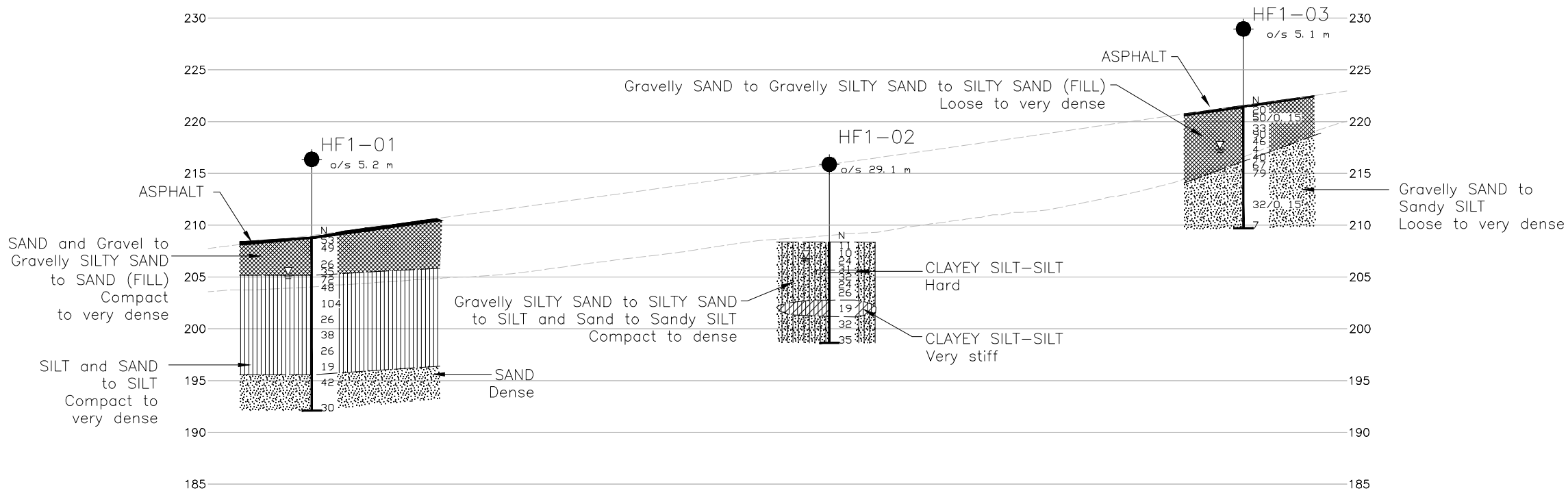
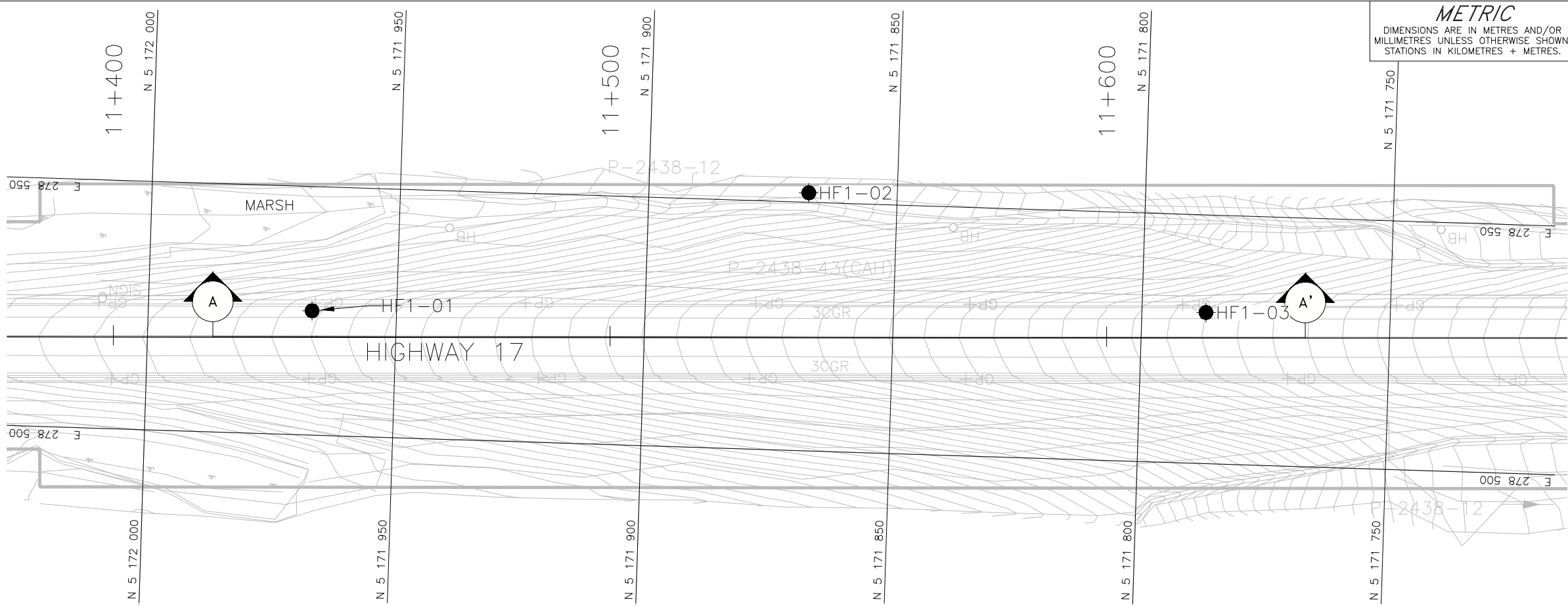




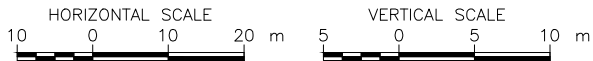


**APPENDIX A**

Highway 17 NBL - STA 11+440 to  
STA 11+620 (High Fill Area No. 1)



PROFILE A-A'



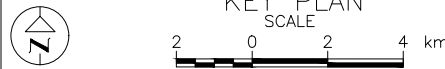
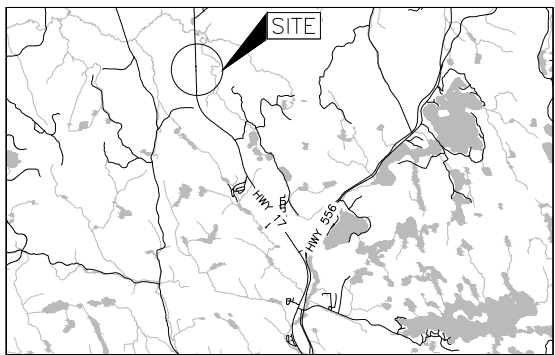
**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No. 5181-13-00  
GWP No. 5181-13-00



HWY 17-MILE HILL WIDENING  
HIGH FILL AREA 1 (STA 11+440 - 11+620)  
BOREHOLES LOCATION AND SOIL  
STRATA

SHEET



LEGEND

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

BOREHOLE CO-ORDINATES (MTM NAD83 ZONE 13)

No.	ELEVATION	NORTHING	EASTING
HF1-01	208.9	5171967.0	278525.0
HF1-02	208.4	5171867.8	278551.9
HF1-03	221.5	5171787.1	278530.4

SITE COORDINATES: Lon. -84.343149, Lat. 46.685897



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.

REFERENCE

Base plans provided in digital format by AECOM, drawing file nos. 5181-13-00 - Base plan.dwg and 5181-13-00 - DTM and Contours.dwg, received September 09, 2021.

NO.	DATE	BY	REVISION
Geocres No. 41K-119			
HWY.	HWY 17	PROJECT NO.	19122433
SUBM'D. ACK	CHKD. TZ	DATE:	12/1/2021
DRAWN: SA	CHKD. ACK	APPD. JPD	DWG. A1

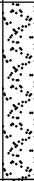
<b>PROJECT</b> 19122433		<b>RECORD OF BOREHOLE No HF1-01</b>		SHEET 1 OF 2		<b>METRIC</b>	
G.W.P. 5181-13-00		LOCATION N 5171967.0; E 278525.0 MTM NAD 83 ZONE 13 (LAT. 46.686788; LONG. -84.343507)		ORIGINATED BY TB			
DIST Algoma HWY 17		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers; NW Casing; Wash Boring; Rock Coring		COMPILED BY ACK			
DATUM Geodetic		DATE July 22, 2021		CHECKED BY TZ			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20 40 60 80 100	20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>		
208.9	GROUND SURFACE													
0.0	ASPHALT (100 mm)		1	SS	53									
208.2	SAND (SP) and gravel, trace fines (FILL) Very dense Brown Moist		2	SS	49									
0.7	Gravelly SILTY SAND (SM) to SAND (SP), trace gravel, trace fines (FILL) Compact to dense Brown Moist - Split-spoon refusal at a depth of about 1.2 m - 610 mm boulder and rock fragments encountered between depths of about 1.2 m and 2.3 m - 50 mm wood fragment encountered at a depth of about 2.3 m		-	RC	-									
				RC	-									
205.2	- Wood fragments encountered between depths of about 3.0 m and 3.2 m		3	SS	26									
			4	SS	35									
3.7	SILT (ML) and sand, trace gravel to SILT (ML) some sand, trace gravel Compact to very dense Grey Wet		5	SS	72									
			6	SS	48									
			7	SS	104									
			8	SS	26									
			9	SS	38									
			10	SS	26									
			11	SS	19									
195.6	SAND (SP), some silt, trace to some gravel, some fines Dense Grey Wet		12	SS	42									
13.3														

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

GTA-MTO 001 S:\CLIENTS\MTOWHY\_17\_MILE\_HILL\02\_DATA\GINTHWY\_17\_MILE\_HILL.GPJ GAL-GTA.GDT 12/2/21

PROJECT		RECORD OF BOREHOLE				No HF1-01		SHEET 2 OF 2		METRIC																
G.W.P. 19122433		LOCATION N 5171967.0; E 278525.0 MTM NAD 83 ZONE 13 (LAT. 46.686788; LONG. -84.343507)				ORIGINATED BY TB																				
DIST Algoma HWY 17		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers; NW Casing; Wash Boring; Rock Coring				COMPILED BY ACK																				
DATUM Geodetic		DATE July 22, 2021				CHECKED BY TZ																				
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)										
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)									
	--- CONTINUED FROM PREVIOUS PAGE ---																									
192.1	SAND (SP), some silt, trace to some gravel, some fines		-	RC	-	193																				
16.8	Dense Grey Wet - Cobbles, gravel, and rock fragments encountered between depths of about 15.2 m and 16.5 m - NW casing refusal at a depth of about 15.3 m END OF BOREHOLE		13	SS	30																					
NOTES: 1. The cored depth intervals and particle sizes of recovered boulders, cobbles, gravel, and rock fragments are summarized as follows: <table border="1" style="width: 100%; margin-top: 10px;"> <thead> <tr> <th>Depth (m)</th> <th>Recovered</th> </tr> </thead> <tbody> <tr> <td>1.2 - 2.3</td> <td>610 mm</td> </tr> <tr> <td>15.3 - 16.2</td> <td>180 mm</td> </tr> <tr> <td></td> <td>80 mm</td> </tr> <tr> <td></td> <td>several 20 mm to 40 mm sized pieces</td> </tr> </tbody> </table> 2. NW casing advanced below a depth of about 1.2 m to facilitate wash boring operations. 3. Water level measured in NW casing at a depth of about 4.0 m below ground surface (Elev. 204.9 m) upon completion of drilling. 4. Open borehole caved to a depth of about 12.5 m below ground surface (Elev. 196.4 m) upon removal of casing. 5. Water level measured in open borehole at a depth of about 3.7 m below ground surface (Elev. 205.2 m) upon removal of casing.																	Depth (m)	Recovered	1.2 - 2.3	610 mm	15.3 - 16.2	180 mm		80 mm		several 20 mm to 40 mm sized pieces
Depth (m)	Recovered																									
1.2 - 2.3	610 mm																									
15.3 - 16.2	180 mm																									
	80 mm																									
	several 20 mm to 40 mm sized pieces																									

GTA-MTO 001 S:\CLIENTS\MTOWHY\_17\_MILE\_HILL\02\_DATA\GINT\HWY\_17\_MILE\_HILL.GPJ GAL-GTA.GDT 12/2/21



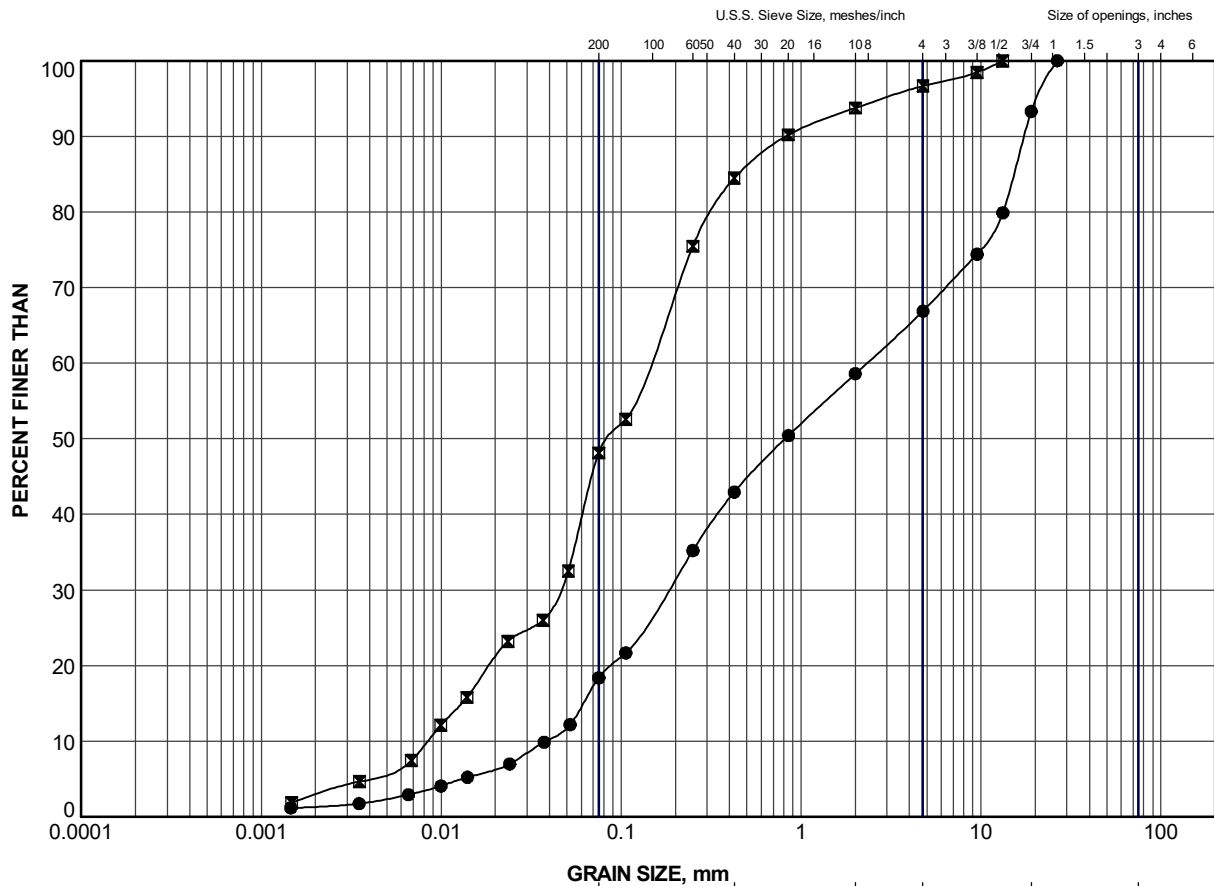
PROJECT 19122433		RECORD OF BOREHOLE No HF1-02				SHEET 1 OF 1		METRIC								
G.W.P. 5181-13-00		LOCATION N 5171867.8; E 278551.9 MTM NAD 83 ZONE 13 (LAT. 46.685897; LONG. -84.343149)				ORIGINATED BY AM										
DIST Algoma HWY 17		BOREHOLE TYPE Portable Equipment - Wash Boring; BW Casing				COMPILED BY ACK										
DATUM Geodetic		DATE July 13 and 14, 2021				CHECKED BY TZ										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
208.4	GROUND SURFACE							20	40	60	80	100				
0.0	SILTY SAND (SM) of slight plasticity, trace gravel, trace organics Compact Brown Moist		1	SS	11	▽	208									5 49 38 8
207.7	Gravelly SILTY SAND (SM) to SILTY SAND (SM), some gravel Compact to dense Brown Wet		2	SS	10		207									31 54 12 3
0.7			3	SS	24		206									
	- No recovery in split-spoon Sample No. 2		4A	SS	31		205									
205.7			4B	SS	32		204									
205.4	CLAYEY SILT-SILT (CL-ML), trace sand Hard Brown Wet		5	SS	32		203									
3.0	SILT (ML) and Sand to Sandy SILT (ML), trace sand Compact to dense Brown to grey Wet - Approximately 150 mm thick layer of sandy clayey silt-silt encountered at a depth of about 4.0 m		6	SS	24		202									
			7	SS	26		201									
202.8			8	SS	19		200									
5.6	CLAYEY SILT-SILT (CL-ML), trace sand Very stiff Grey Wet		9	SS	32		199									
201.2	Sandy SILT (ML), trace sand Dense Grey Wet		10A	SS	35											
7.2			10B	SS	35											
198.9	SILTY SAND (SM) Dense Grey Wet															
9.8	END OF BOREHOLE															
NOTES: 1. Open borehole caved to a depth of about 3.0 m below ground surface (Elev. 205.4 m) upon removal of casing. 2. Water level measured in open borehole at a depth of about 1.6 m below ground surface (Elev. 206.8 m) upon completion of drilling. 3. Direct shear box tests carried out on Samples Nos. 5 and 6.																

GTA-MTO 001 S:\CLIENTS\MTOWHY\_17\_MILE\_HILL\GPJ GAL-GTA.GDT 12/2/21

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

PROJECT 19122433		RECORD OF BOREHOLE No HF1-03				SHEET 2 OF 2		METRIC																		
G.W.P. 5181-13-00		LOCATION N 5171787.1; E 278530.4 MTM NAD 83 ZONE 13 (LAT. 46.685170; LONG. -84.343426)				ORIGINATED BY TB																				
DIST Algoma HWY 17		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers; NW Casing; Wash Boring; Rock Coring				COMPILED BY ACK																				
DATUM Geodetic		DATE July 20 and 21, 2021				CHECKED BY TZ																				
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa																		
--- CONTINUED FROM PREVIOUS PAGE ---							<div style="display: flex; justify-content: space-around;"> <span>20</span><span>40</span><span>60</span><span>80</span><span>100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>○ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>					<div style="display: flex; justify-content: space-around;"> <span>20</span><span>40</span><span>60</span><span>80</span><span>100</span> </div>					<div style="display: flex; justify-content: space-around;"> <span>10</span><span>20</span><span>30</span> </div>									
<p>NOTES:</p> <ol style="list-style-type: none"> <li>The cored depth intervals and particle sizes of recovered boulders, cobbles, gravel, and rock fragments are summarized as follows:</li> <li>NW casing advanced below a depth of about 0.9 m to facilitate wash boring operations.</li> <li>Water level measured in NW casing at a depth of about 7.2 m below ground surface (Elev. 214.3 m) upon completion of drilling.</li> <li>Open borehole caved to a depth of about 4.0 m below ground surface (Elev. 217.5 m) upon removal of casing.</li> </ol>																										


GTA-MTO 001 S:\CLIENTS\MTOWHY\_17\_MILE\_HILL\02\_DATA\GINTHWY\_17\_MILE\_HILL\_GPJ GAL-GTA.GDT 12/2/21

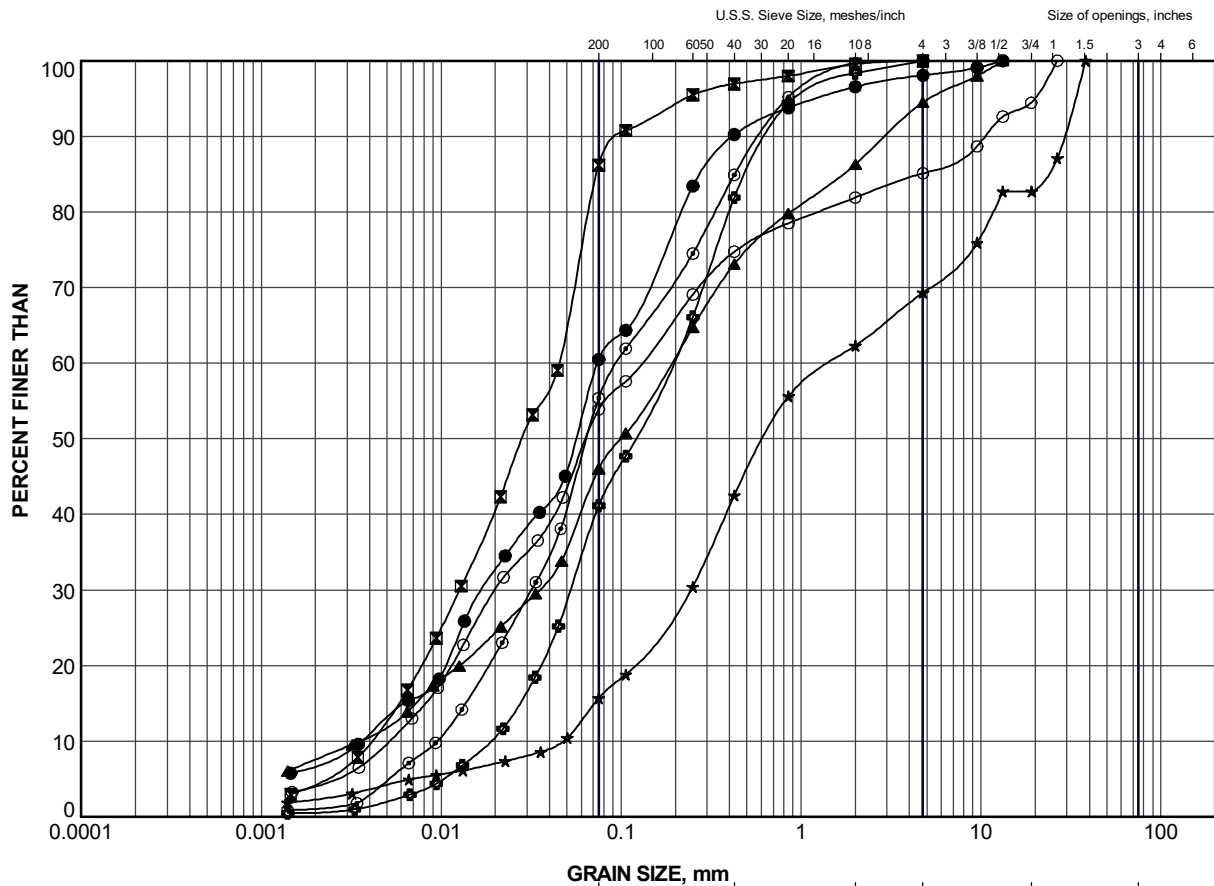


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	HF1-01	2	207.9
×	HF1-03	5	218.1

PROJECT					
HIGHWAY 17 MILL HILL WIDENING					
TITLE					
GRAIN SIZE DISTRIBUTION Gravelly SILTY SAND (SM) to SILTY SAND (SM) (FILL)					
PROJECT No.		19122433		FILE No. 19122433.GPJ	
DRAWN	TR	Oct 2021	SCALE	N/A	REV.
CHECK	AK	Oct 2021	FIGURE A1		
APPR	TZ	Oct 2021			
 <b>GOLDER</b> MEMBER OF WSP SUDBURY, ONTARIO					

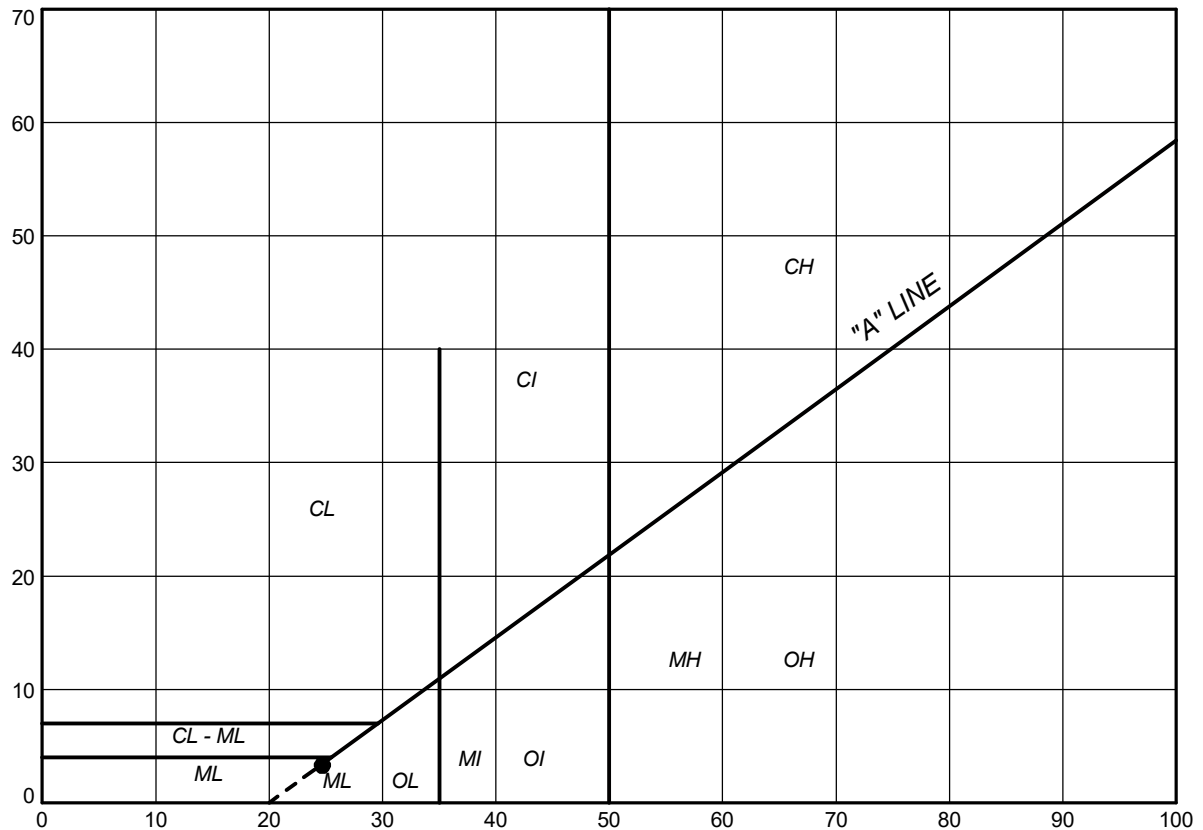


### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	HF1-01	6	204.0
⊠	HF1-01	11	196.4
▲	HF1-02	1	208.1
★	HF1-02	3	206.5
⊙	HF1-02	5	205.0
⊗	HF1-02	10B	198.7
○	HF1-03	8	215.8

PROJECT					HIGHWAY 17 MILL HILL WIDENING				
TITLE					<b>GRAIN SIZE DISTRIBUTION</b> Gravelly SILTY SAND (SM) to SILT (ML) and Sand to SILT (ML)				
PROJECT No.			19122433		FILE No.			19122433.GPJ	
DRAWN	TR	Oct 2021	SCALE	N/A	REV.				
CHECK	AK	Oct 2021							
APPR	TZ	Oct 2021							
 <b>GOLDER</b> MEMBER OF WSP SUDBURY, ONTARIO					<b>FIGURE A2</b>				

PLASTICITY INDEX (Percent)



LIQUID LIMIT (Percent)

**SOIL TYPE**  
C = Clay  
M = Silt  
O = Organic

**PLASTICITY**  
L = Low  
I = Intermediate  
H = High

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	HF1-02	1	24.7	21.4	3.3

PROJECT					
HIGHWAY 17 MILL HILL WIDENING					
TITLE					
PLASTICITY CHART SILTY SAND (SM) of slight plasticity					
PROJECT No. 19122433			FILE No. 19122433.GPJ		
DRAWN	TR	Oct 2021	SCALE	N/A	REV.
CHECK	AK	Oct 2021	FIGURE A3		
APPR	TZ	Oct 2021			
SUDBURY, ONTARIO					

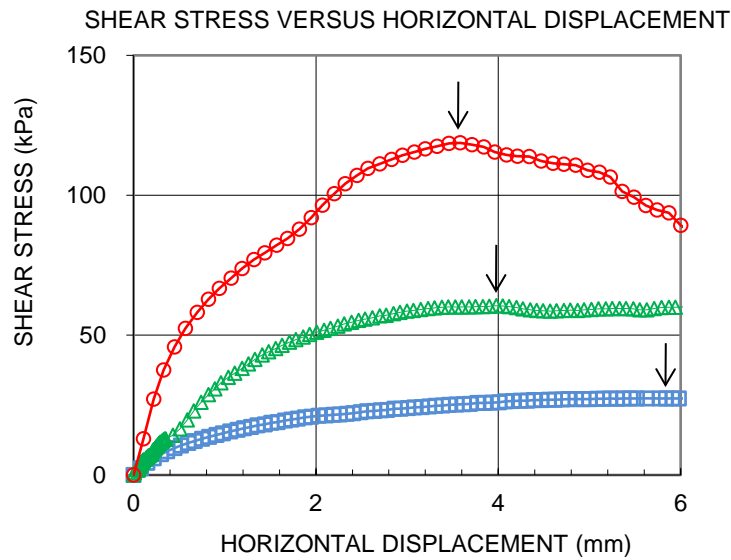
<b>CONSOLIDATED DRAINED DIRECT SHEAR TEST</b> <b>ASTM D3080</b> <b>SHEET 1 OF 3</b>		<b>FIGURE A4</b>		
TEST STAGE	A	B	C	
BOREHOLE NUMBER		HF1-02		
SAMPLE		Combined Samples 5 and 6A		
SAMPLE DEPTH, (m)		3.05-4.42		
SAMPLE HEIGHT, (mm)	28.10	27.10	25.19	
SAMPLE LENGTH, (mm)	60.00	60.00	60.00	
WATER CONTENT, BEFORE TEST, (%)	19.9	19.9	19.9	
NORMAL (CONSOLIDATION) STRESS, (kPa)	40	80	160	
WATER CONTENT, AFTER TEST, (%)	16.0	16.1	17.5	
DISPLACEMENT RATE, mm/min	0.024	0.024	0.024	
TIME TO FAILURE, hours	3.9	2.8	2.5	
PEAK SHEAR STRESS <sup>1</sup> , (kPa)	27.4	60.5	118.7	
HORIZONTAL DISPLACEMENT AT PEAK, (mm)	5.6	4.0	3.6	
DRY DENSITY, initial, Mg/m <sup>3</sup>	1.67	1.68	1.70	
WET DENSITY, initial, Mg/m <sup>3</sup>	2.00	2.02	2.04	
<b>TEST NOTES:</b> <sup>1</sup> In the absence of a peak, the shear stress reported is at 10 percent relative horizontal displacement (ASTM D3080). <sup>2</sup> Normal stresses assigned by the client <sup>3</sup> Specimens compacted to a target density 1.988 g/cm <sup>3</sup> at 20% moisture content; achieved 100 % compaction <sup>4</sup> Direct Shear Tests carried out submerged, per clients instruction. <sup>5</sup> Test was performed following ASTM D3080 which is currently withdrawn with no replacement.				
Date:	9/27/2021	Prepared By:	LH	
Project No.	19122433(1100)	Checked By:	MM	
<b>Golder Associates Ltd.</b>				



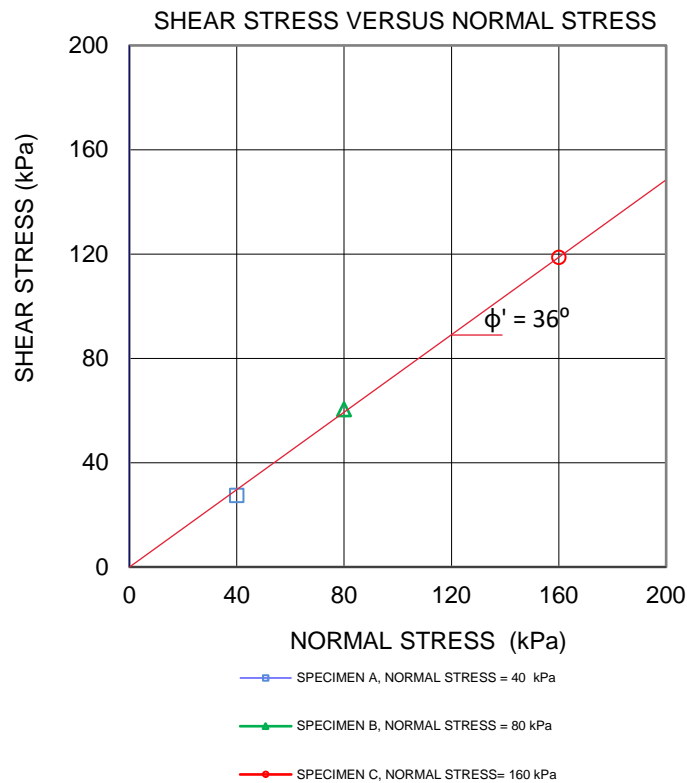
**CONSOLIDATED DRAINED DIRECT SHEAR TEST**  
**ASTM D3080**  
**SHEET 2 OF 3**

**FIGURE A4**

BH HF1-02 SA 5-6A



BH HF1-02 SA 5-6A



Date: 9/27/2021  
 Project No. 19122433(1100)

**Golder Associates Ltd.**

Prepared By LH  
 Checked By: MM

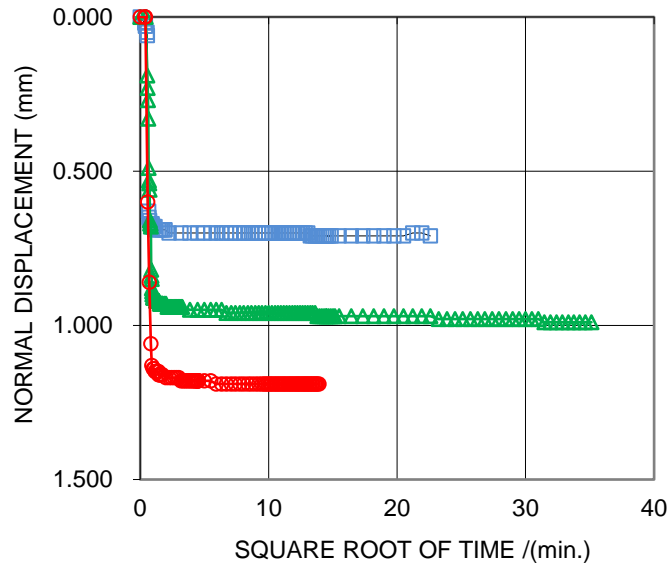
# CONSOLIDATED DRAINED DIRECT SHEAR TEST

ASTM D3080  
SHEET 3 OF 3

FIGURE A4

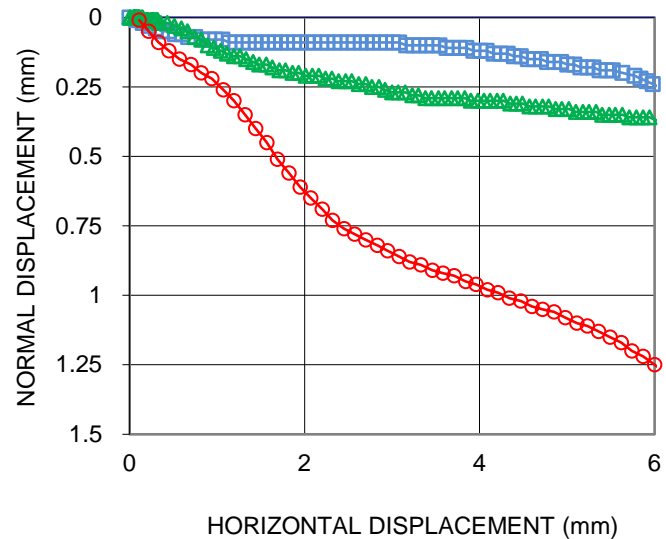
BH HF1-02 SA 5-6A

NORMAL DISPLACEMENT VERSUS SQUARE ROOT OF TIME



BH HF1-02 SA 5-6A

NORMAL DISPLACEMENT VERSUS HORIZONTAL DISPLACEMENT



HORIZONTAL DISPLACEMENT (mm)

- SPECIMEN A, NORMAL STRESS = 40 kPa
- SPECIMEN B, NORMAL STRESS = 80 kPa
- SPECIMEN C, NORMAL STRESS = 160 kPa

Date: 9/27/2021

Project No. 19122433(1100)

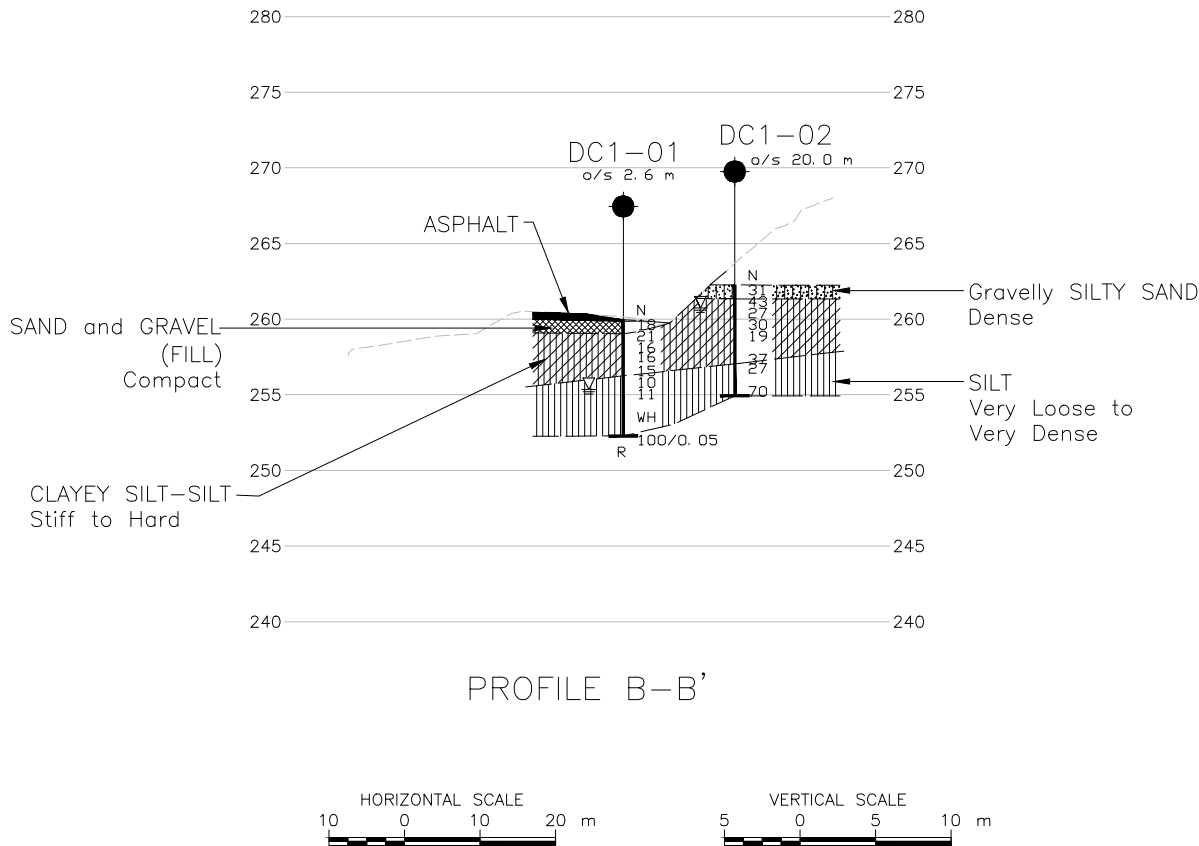
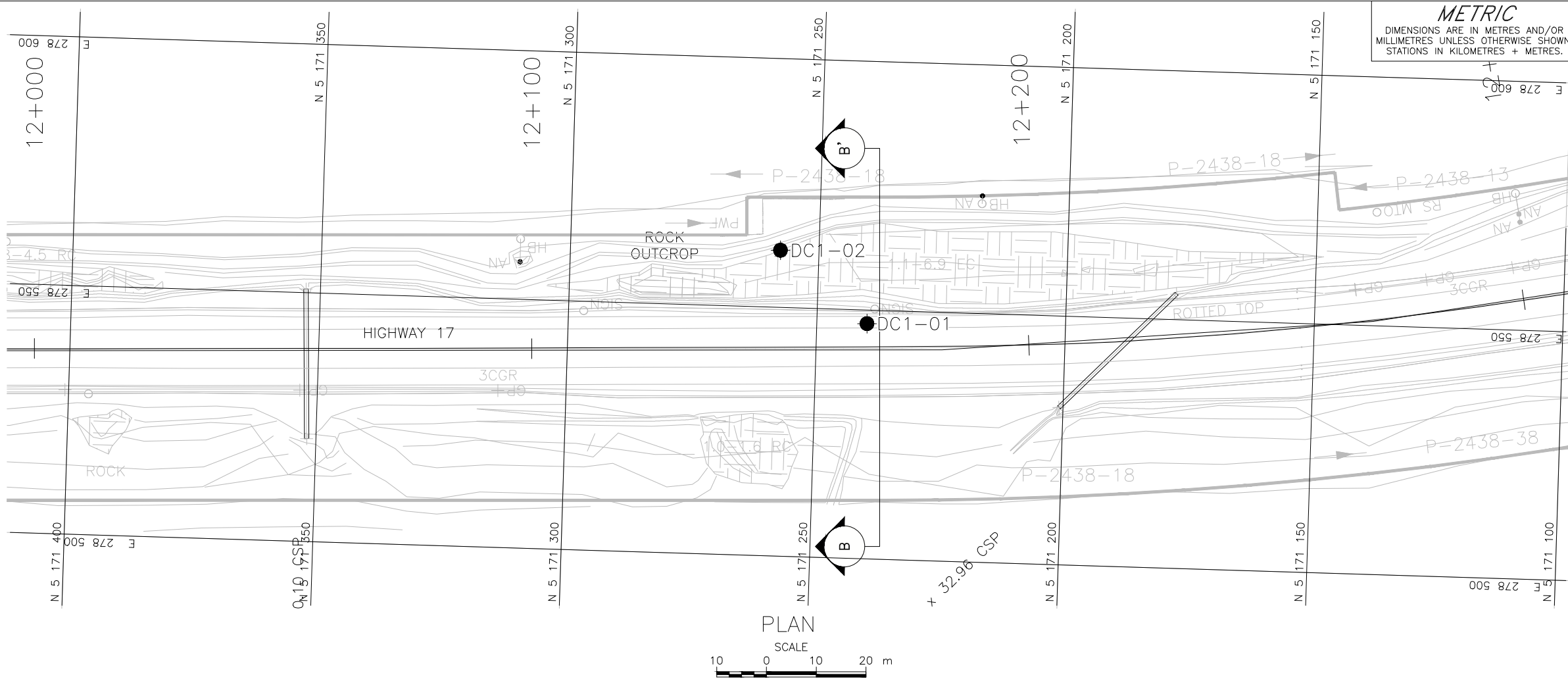
**Golder Associates Ltd.**

Prepared By LH

Checked By: MM

**APPENDIX B**

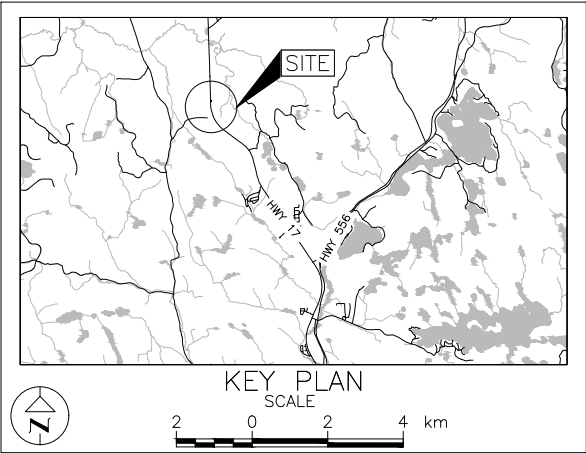
Highway 17 NBL – STA 12+150 to  
STA 12+220 (Deep Cut Area No. 1)



CONT No. GWP No. 5181-13-00

HWY 17-MILE HILL WIDENING  
DEEP CUT AREA 1 (STA 12+150 - 12+220)  
BOREHOLES LOCATION AND SOIL STRATA

SHEET



**LEGEND**

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

BOREHOLE CO-ORDINATES (MTM NAD83 ZONE 13)			
No.	ELEVATION	NORTHING	EASTING
DC1-01	260.0	5171239.9	278547.3
DC1-02	262.3	5171257.8	278561.5

SITE COORDINATES: Lon. -84.343174, Lat. 46.680248



**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.

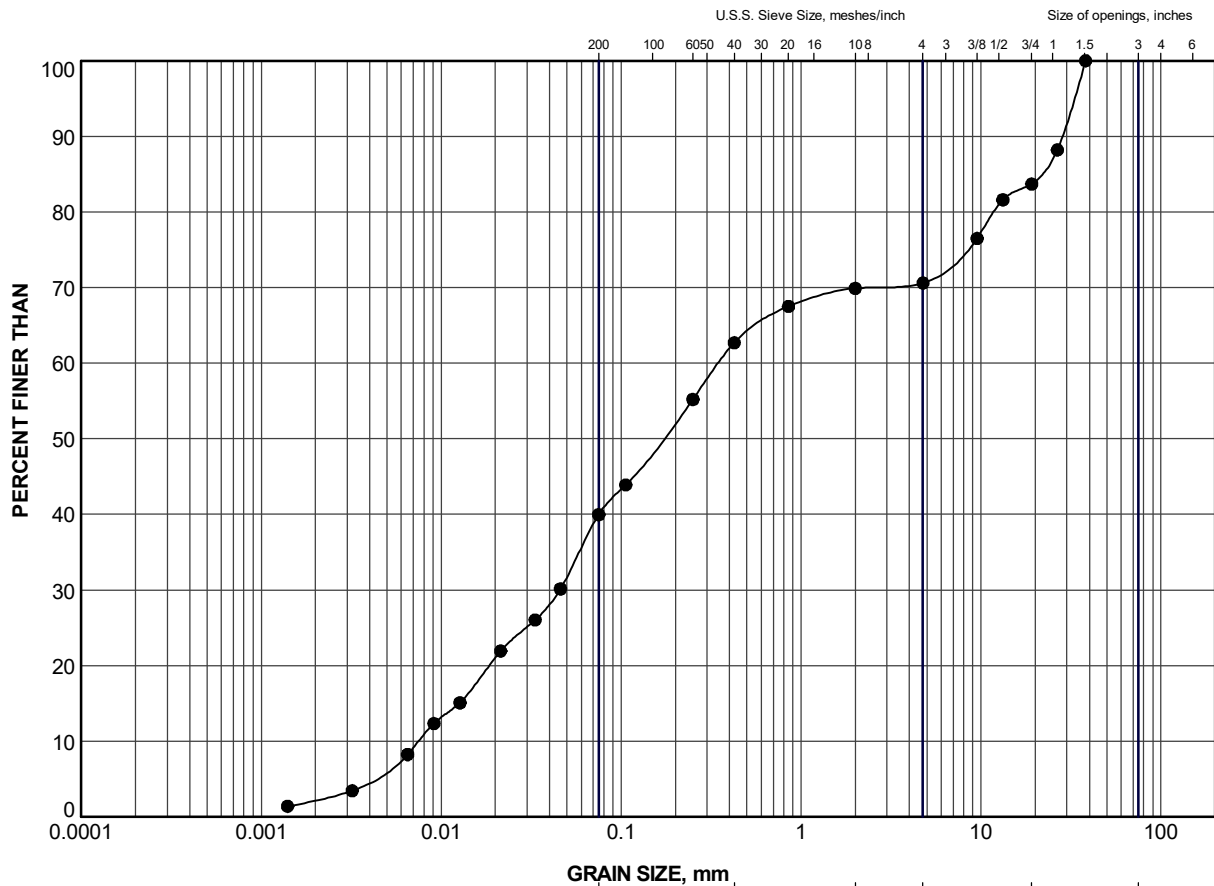
**REFERENCE**

Base plans provided in digital format by AECOM, drawing file nos. 5181-13-00 - Base plan.dwg and 5181-13-00 - DTM and Contours.dwg, received September 09, 2021.

NO.	DATE	BY	REVISION
Geocres No. 41K-119			
HWY. HWY 17	PROJECT NO. 19122433	DIST. ALGOMA	
SUBM'D. ACK	CHKD. TZ	DATE: 12/1/2021	SITE:
DRAWN: SA	CHKD. ACK	APPD. JPD	DWG. B1

PROJECT 19122433		RECORD OF BOREHOLE No DC1-01				SHEET 1 OF 1		METRIC								
G.W.P. 5181-13-00		LOCATION N 5171239.9; E 278547.3 MTM NAD 83 ZONE 13 (LAT. 46.680248; LONG. -84.343174)				ORIGINATED BY TB										
DIST Algoma HWY 17		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY ACK										
DATUM Geodetic		DATE July 20, 2021				CHECKED BY TZ										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
260.0	GROUND SURFACE															
0.0	ASPHALT (100 mm)		1	SS	18											
259.1	SAND (SP) and gravel (FILL) Compact Brown Moist		2A	SS	21											
0.9	CLAYEY SILT-SILT (CL-ML) Stiff to very stiff Grey Moist		2B													
			3	SS	16											
			4	SS	16											
			5	SS	15											
256.3	SILT (ML), trace sand Very loose to compact Grey Wet		6	SS	10											
3.7			7	SS	11											
			8	SS	WH											
252.3	SPLIT SPOON REFUSAL END OF BOREHOLE		9	SS	00/0.05											
7.7	NOTE:  1. Water level measured in hollow stem augers at a depth of about 4.6 m below ground surface (Elev. 255.4 m) upon completion of drilling.															


PROJECT 19122433		RECORD OF BOREHOLE No DC1-02				SHEET 1 OF 1		METRIC						
G.W.P. 5181-13-00		LOCATION N 5171257.8; E 278561.5 MTM NAD 83 ZONE 13 (LAT. 46.680409; LONG. -84.342990)				ORIGINATED BY AM								
DIST Algoma HWY 17		BOREHOLE TYPE Portable Equipment - Wash Boring; BW Casing				COMPILED BY ACK								
DATUM Geodetic		DATE July 15, 2021				CHECKED BY TZ								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
262.3	GROUND SURFACE							20 40 60 80 100	10 20 30					
0.0	Gravelly SILTY SAND (SM/GM), trace organics and wood fragments		1	SS	31		262							30 30 38 2
261.4	Dense Brown Moist		2A	SS	43		261							
0.9	CLAYEY SILT-SILT (CL-ML), trace sand, trace gravel		2B											
	Very stiff to hard													
	Brown to grey		3	SS	27		260							
	Moist to wet													
	- Wet below a depth of about 1.5 m below ground surface (Elev. 260.8 m)		4	SS	30									4 2 82 12
							259							
	- Grey below a depth of about 3.1 m below ground surface (Elev. 259.2 m)		5	SS	19									
							258							
257.1			6	SS	37		257							
5.2	SILT (ML), trace sand		7	SS	27									
	Compact to very dense													
	Grey						256							
	Wet													
			8	SS	70		255							
255.0														
7.3	END OF BOREHOLE													
	NOTES:													
	1. Water level measured in open borehole at a depth of about 1.5 m below ground surface (Elev. 260.8 m) upon completion of drilling.													
	2. Direct shear box tests carried out on Samples Nos. 1A/2 and 4/5/6.													

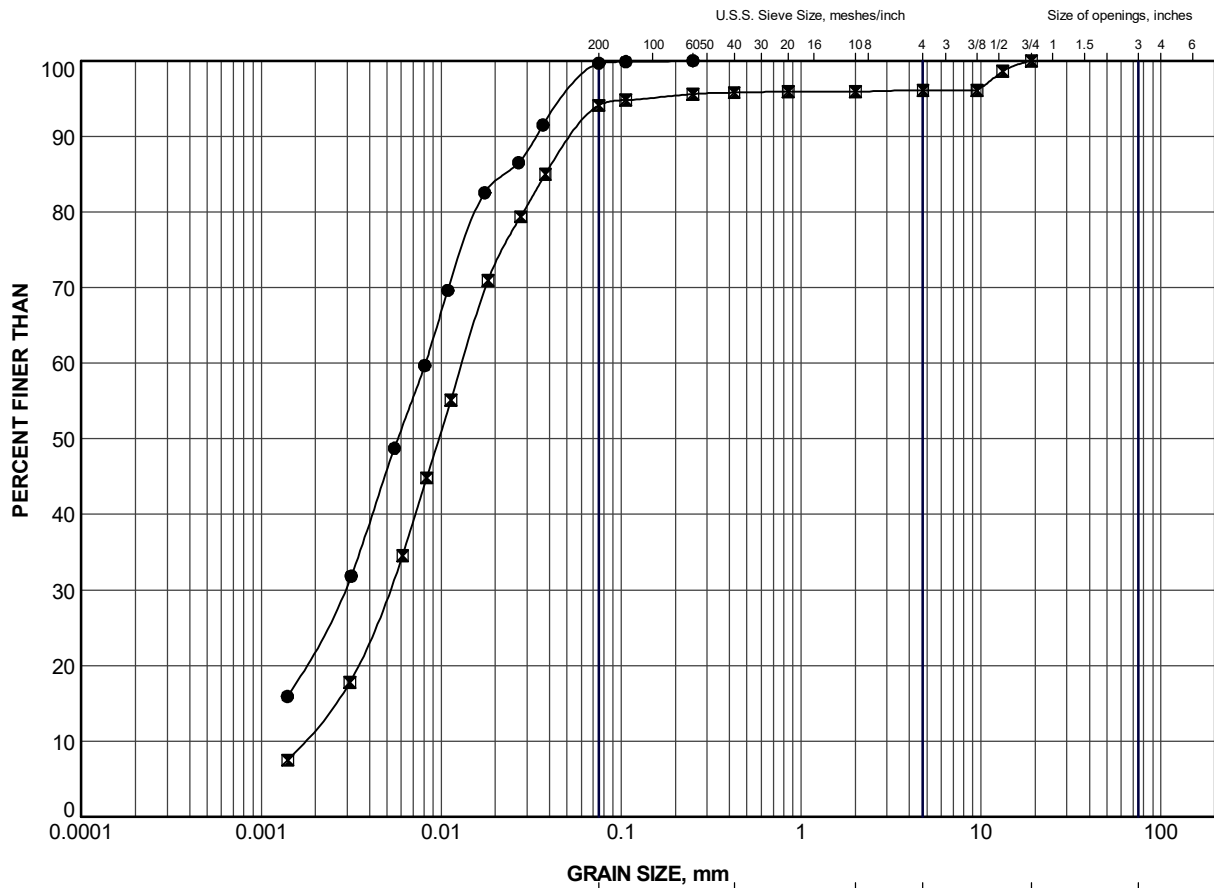


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	DC1-02	1	262.0


PROJECT					
HIGHWAY 17 MILL HILL WIDENING					
TITLE					
GRAIN SIZE DISTRIBUTION Gravelly SILTY SAND (SM/GM)					
PROJECT No. 19122433			FILE No. 19122433.GPJ		
DRAWN	TR	Oct 2021	SCALE	N/A	REV.
CHECK	AK	Oct 2021	<b>FIGURE B1</b>		
APPR	TZ	Oct 2021			
 <b>GOLDER</b> MEMBER OF WSP SUDBURY, ONTARIO					



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

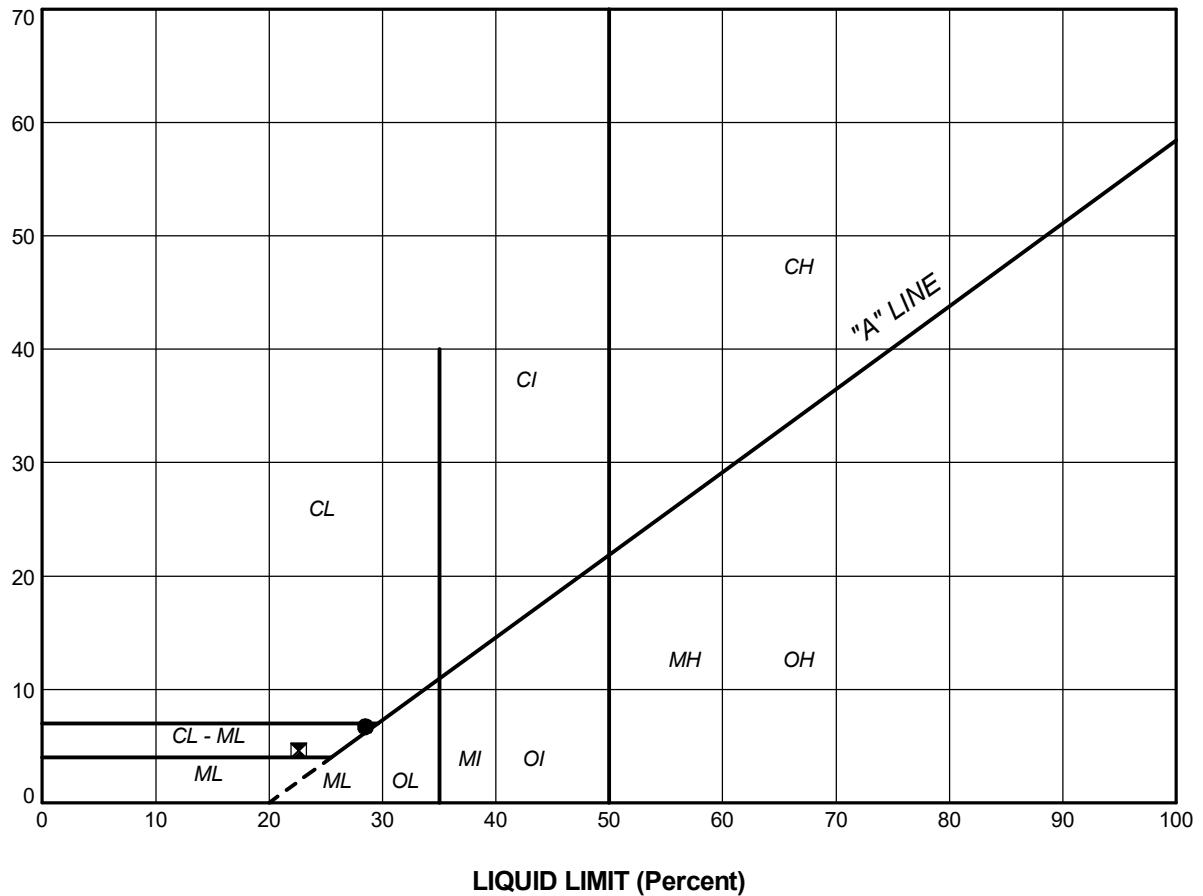
### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	DC1-01	4	257.4
×	DC1-02	4	259.7

PROJECT					
HIGHWAY 17 MILL HILL WIDENING					
TITLE					
GRAIN SIZE DISTRIBUTION CLAYEY SILT-SILT (CL-ML)					
PROJECT No.		19122433		FILE No. 19122433.GPJ	
DRAWN	TR	Oct 2021	SCALE	N/A	REV.
CHECK	AK	Oct 2021			
APPR	TZ	Oct 2021			
 <b>GOLDER</b> MEMBER OF WSP			<b>FIGURE B2</b>		
SUDBURY, ONTARIO					



PLASTICITY INDEX (Percent)



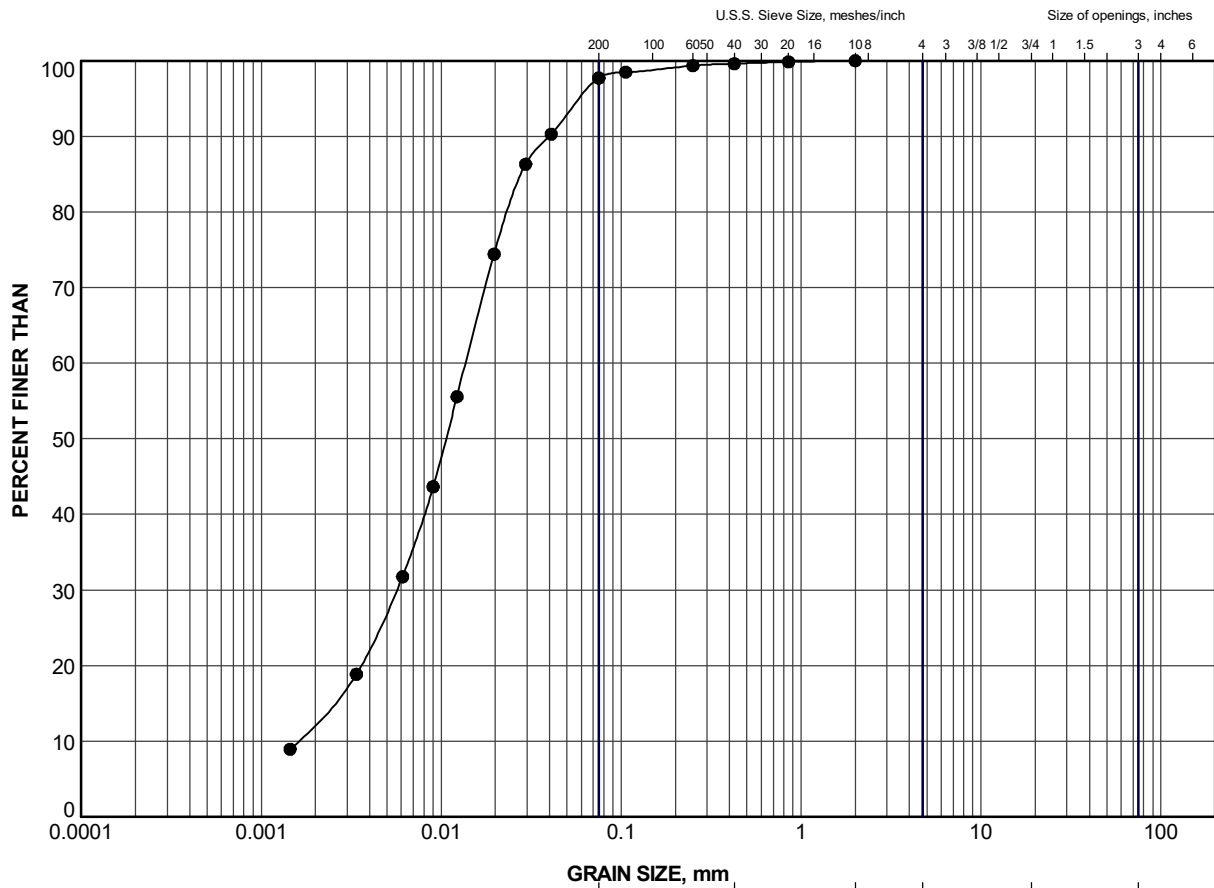
**SOIL TYPE**  
C = Clay  
M = Silt  
O = Organic

**PLASTICITY**  
L = Low  
I = Intermediate  
H = High

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	DC1-01	4	28.5	21.8	6.7
⊠	DC1-02	4	22.6	18.0	4.6


PROJECT					
HIGHWAY 17 MILL HILL WIDENING					
TITLE					
PLASTICITY CHART CLAYEY SILT-SILT (CL-ML)					
PROJECT No. 19122433			FILE No. 19122433.GPJ		
DRAWN	TR	Oct 2021	SCALE	N/A	REV.
CHECK	AK	Oct 2021	FIGURE B3		
APPR	TZ	Oct 2021			
SUDBURY, ONTARIO					



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

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	DC1-01	7	255.1

PROJECT						HIGHWAY 17 MILL HILL WIDENING					
TITLE						GRAIN SIZE DISTRIBUTION SILT (ML)					
PROJECT No.				19122433		FILE No.				19122433.GPJ	
DRAWN	TR	Oct 2021		SCALE	N/A	REV.					
CHECK	AK	Oct 2021									
APPR	TZ	Oct 2021									
 <b>GOLDER</b> <small>MEMBER OF WSP</small>						<b>FIGURE B4</b>					
SUDBURY, ONTARIO											

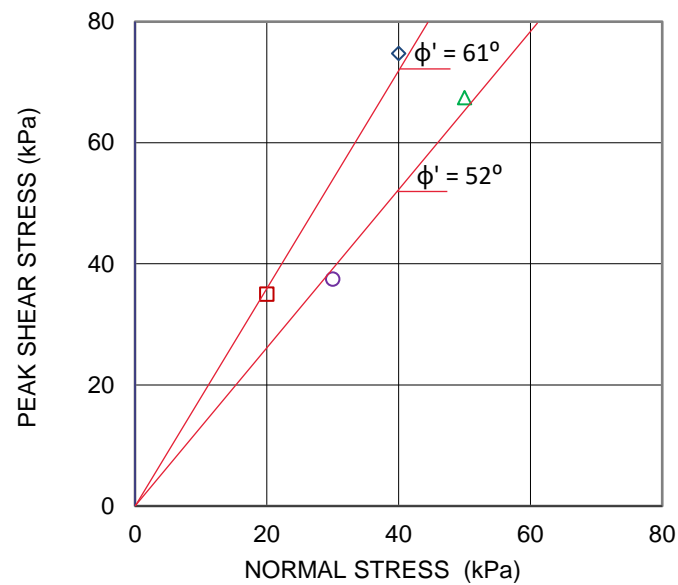
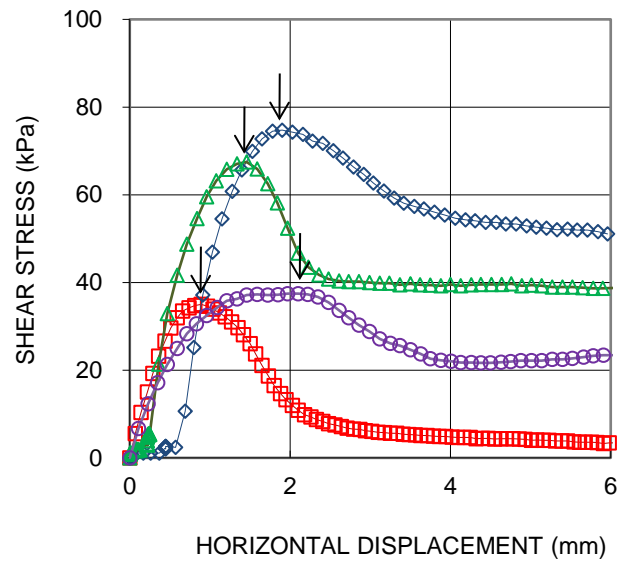
<b>CONSOLIDATED DRAINED DIRECT SHEAR TEST</b> <b>ASTM D3080</b> <b>SHEET 1 OF 3</b>			<b>FIGURE B5</b>	
TEST STAGE	A	B	C	D
BOREHOLE NUMBER	DC1-02			
SAMPLE NUMBER	Combined Samples 1, 2A			
SAMPLE DEPTH, (m)	0-0.94			
SAMPLE HEIGHT, (mm)	26.60	26.04	26.10	26.19
SAMPLE LENGTH, (mm)	60.00	60.00	60.00	60.00
WATER CONTENT, BEFORE TEST, (%)	14.7	15.4	14.9	15.7
NORMAL (CONSOLIDATION) STRESS, (kPa)	20	40	50	30
WATER CONTENT, AFTER TEST, (%)	13.5	14.6	17.9	18.7
DISPLACEMENT RATE, mm/min	0.024	0.024	0.024	0.024
TIME TO FAILURE, hours	0.6	1.3	1.0	1.5
PEAK SHEAR STRESS, (kPa)	35.0	74.7	67.5	37.5
HORIZONTAL DISPLACEMENT AT PEAK, (mm)	0.9	1.9	1.5	2.1
DRY DENSITY, initial, Mg/m <sup>3</sup>	1.82	1.82	1.83	1.82
WET DENSITY, initial, Mg/m <sup>3</sup>	2.09	2.1	2.1	2.10
<b>TEST NOTES:</b> <sup>1</sup> In the absence of a peak, the shear stress reported is at 10 percent relative horizontal displacement (ASTM D3080). <sup>2</sup> Normal stresses assigned by the client <sup>3</sup> Specimens compacted to a target density 2.09 g/cm <sup>3</sup> at 15% moisture content; achieved 100 % compaction <sup>4</sup> Direct Shear Tests A,B carried out within a dry shear box (not flooded), per clients instruction. <sup>5</sup> Specimen C, D carried out submerged as per clients instruction. <sup>6</sup> Test was performed following ASTM D3080 which is currently withdrawn with no replacement.				
Date: 10/05/2021 Project No. 19122433(1100)		<b>Golder Associates Ltd.</b> Prepared By: LH Checked By: MM		

# CONSOLIDATED DRAINED DIRECT SHEAR TEST

ASTM D3080

SHEET 2 OF 3

FIGURE B5



- A NORMAL STRESS =20 kPa
- ◇— B NORMAL STRESS= 40kPa
- △— C NORMAL STRESS =50 kPa
- D NORMAL STRESS =30 kPa

Date: 10/05/2021

Project No. 19122433(1100)

**Golder Associates Ltd.**

Prepared By LH

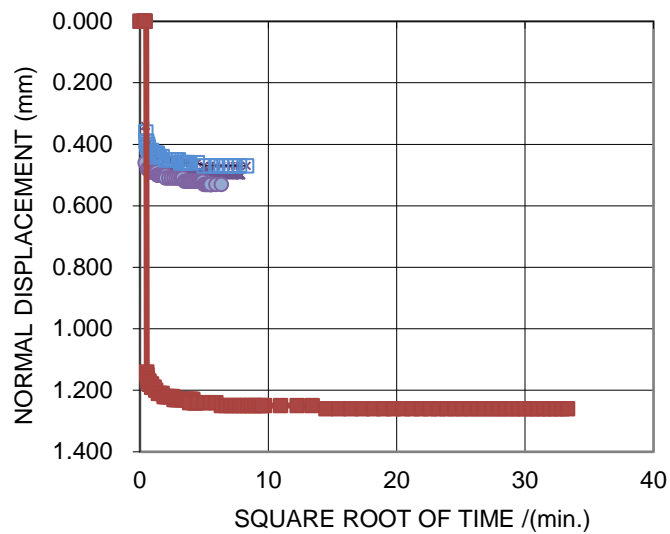
Checked By: MM

# CONSOLIDATED DRAINED DIRECT SHEAR TEST

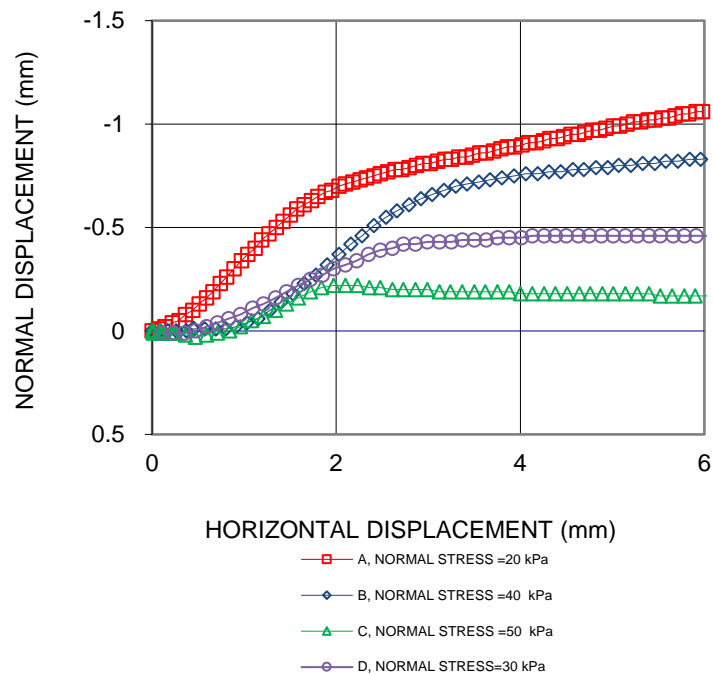
ASTM D3080  
SHEET 3 OF 3

FIGURE B5

BHDC1-02 SA 1-2A



BHDC1-02 SA 1-2A



Date: 10/05/2021

Project No. 19122433(1100)

**Golder Associates Ltd.**

Prepared By LH

Checked By: MM

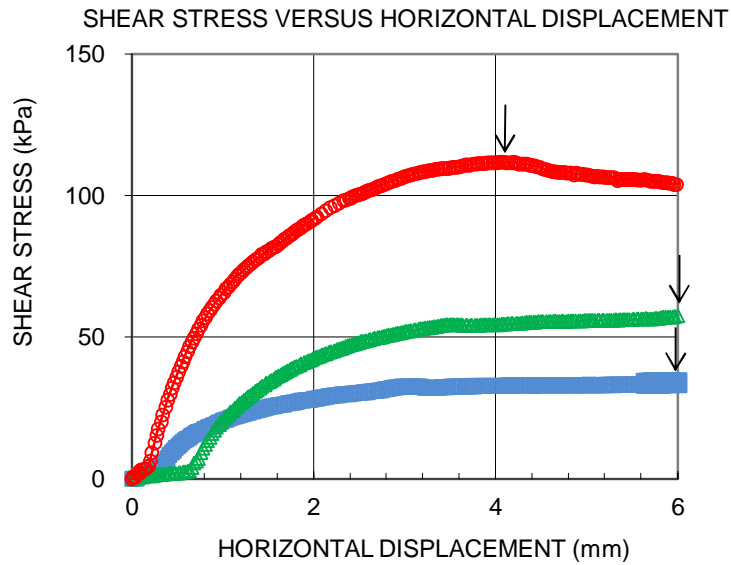
<b>CONSOLIDATED DRAINED DIRECT SHEAR TEST</b> <b>ASTM D3080</b> <b>SHEET 1 OF 3</b>		<b>FIGURE B6</b>		
TEST STAGE	A	B	C	
BOREHOLE NUMBER	DC1-02			
SAMPLE	Combined Samples 4,5,6			
SAMPLE DEPTH, (m)	2.29-5.79			
SAMPLE HEIGHT, (mm)	26.26	26.05	26.43	
SAMPLE LENGTH, (mm)	60.00	60.00	60.00	
WATER CONTENT, BEFORE TEST, (%)	24.9	24.9	24.9	
NORMAL (CONSOLIDATION) STRESS, (kPa)	40	80	160	
WATER CONTENT, AFTER TEST, (%)	20.8	19.9	20.2	
DISPLACEMENT RATE, mm/min	0.0048	0.0048	0.0048	
TIME TO FAILURE, hours	21	21	14	
PEAK SHEAR STRESS <sup>1</sup> , (kPa)	33.7	57.5	111.9	
HORIZONTAL DISPLACEMENT AT PEAK, (mm)	6.0	6.0	4.1	
DRY DENSITY, initial, Mg/m <sup>3</sup>	1.59	1.59	1.61	
WET DENSITY, initial, Mg/m <sup>3</sup>	1.99	1.99	2.01	
<b>TEST NOTES:</b> <sup>1</sup> In the absence of a peak, the shear stress reported is at 10 percent relative horizontal displacement (ASTM D3080). <sup>2</sup> Normal stresses assigned by the client <sup>3</sup> Specimens compacted to a target density 1.988 g/cm <sup>3</sup> at 25% moisture content; achieved 100 % compaction <sup>4</sup> Direct Shear Tests carried out submerged, per clients instruction. <sup>5</sup> Test was performed following ASTM D3080 which is currently withdrawn with no replacement.				
Date: 9/22/2021 Project No. 19122433(1100)		<b>Golder Associates Ltd.</b> Prepared By: LH Checked By: AH		



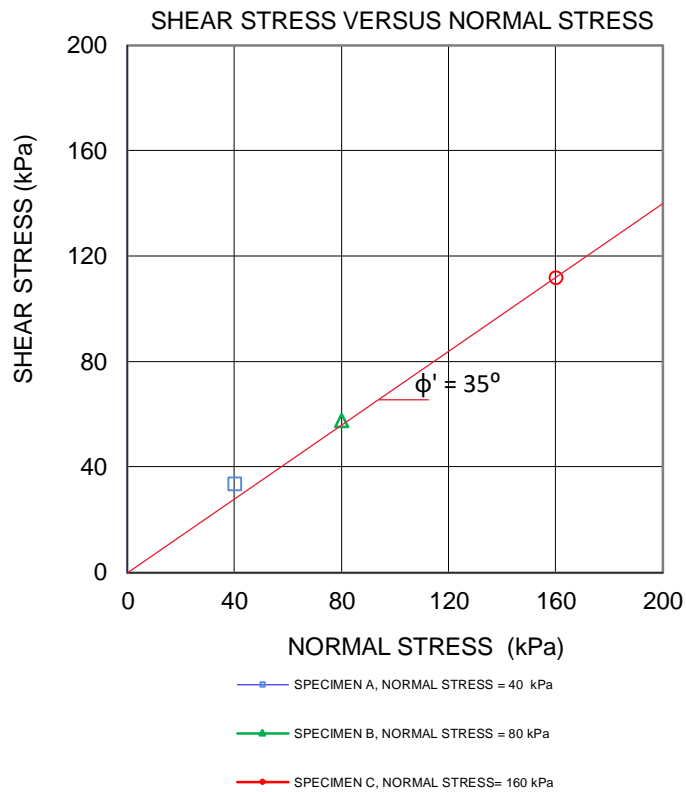
**CONSOLIDATED DRAINED DIRECT SHEAR TEST**  
**ASTM D3080**  
**SHEET 2 OF 3**

**FIGURE B6**

BHDC1-02 SA 4-6



BHDC1-02 SA 4-6



Date: 9/22/2021

Project No. 19122433(1100)

**Golder Associates Ltd.**

Prepared By: LH

Checked By: AH

# CONSOLIDATED DRAINED DIRECT SHEAR TEST

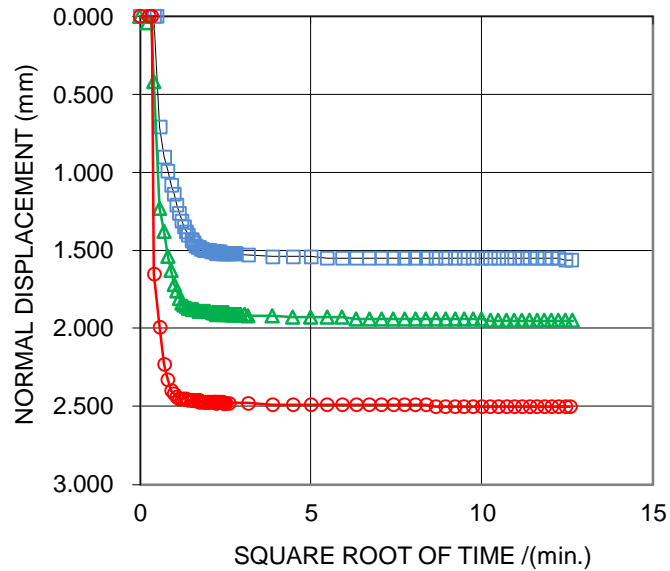
ASTM D3080

SHEET 3 OF 3

FIGURE B6

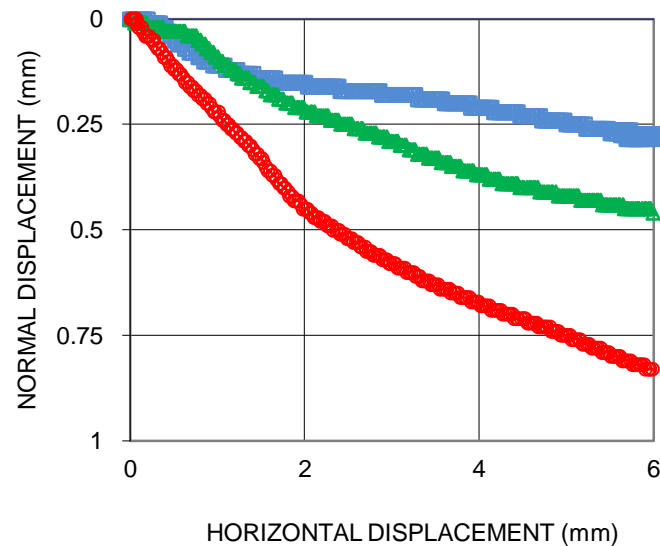
BHDC1-02 SA 4-6

NORMAL DISPLACEMENT VERSUS SQUARE ROOT OF TIME



BHDC1-02 SA 4-6

NORMAL DISPLACEMENT VERSUS HORIZONTAL DISPLACEMENT



HORIZONTAL DISPLACEMENT (mm)

- SPECIMEN A, NORMAL STRESS = 40 kPa
- ▲— SPECIMEN B, NORMAL STRESS = 80 kPa
- SPECIMEN C, NORMAL STRESS = 160 kPa

Date: 9/22/2021

Project No. 19122433(1100)

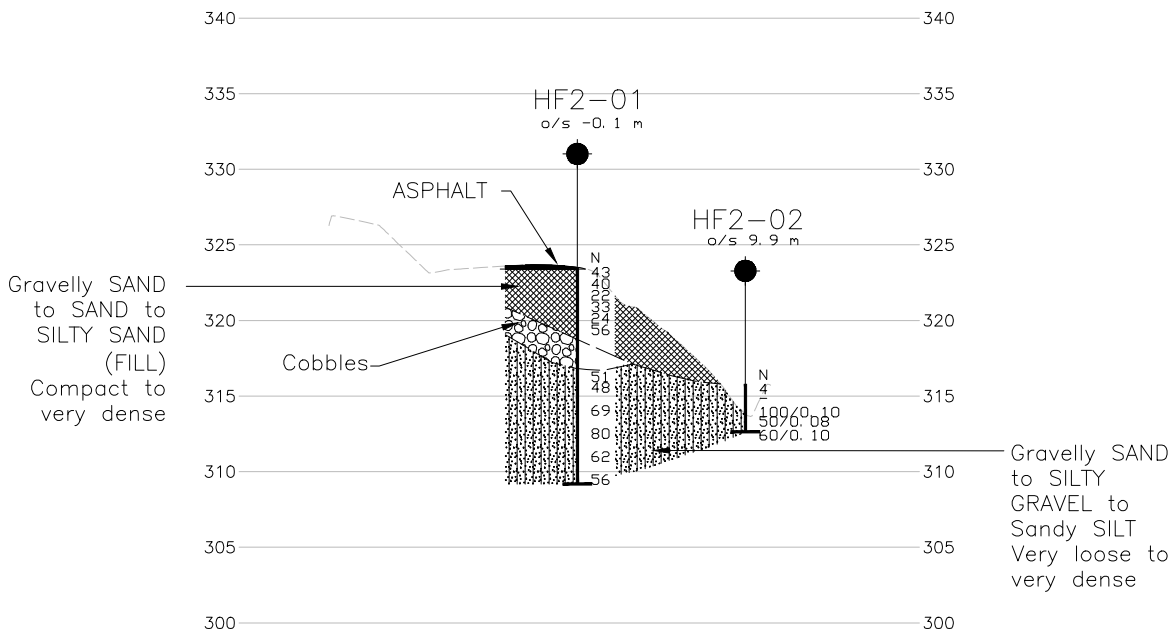
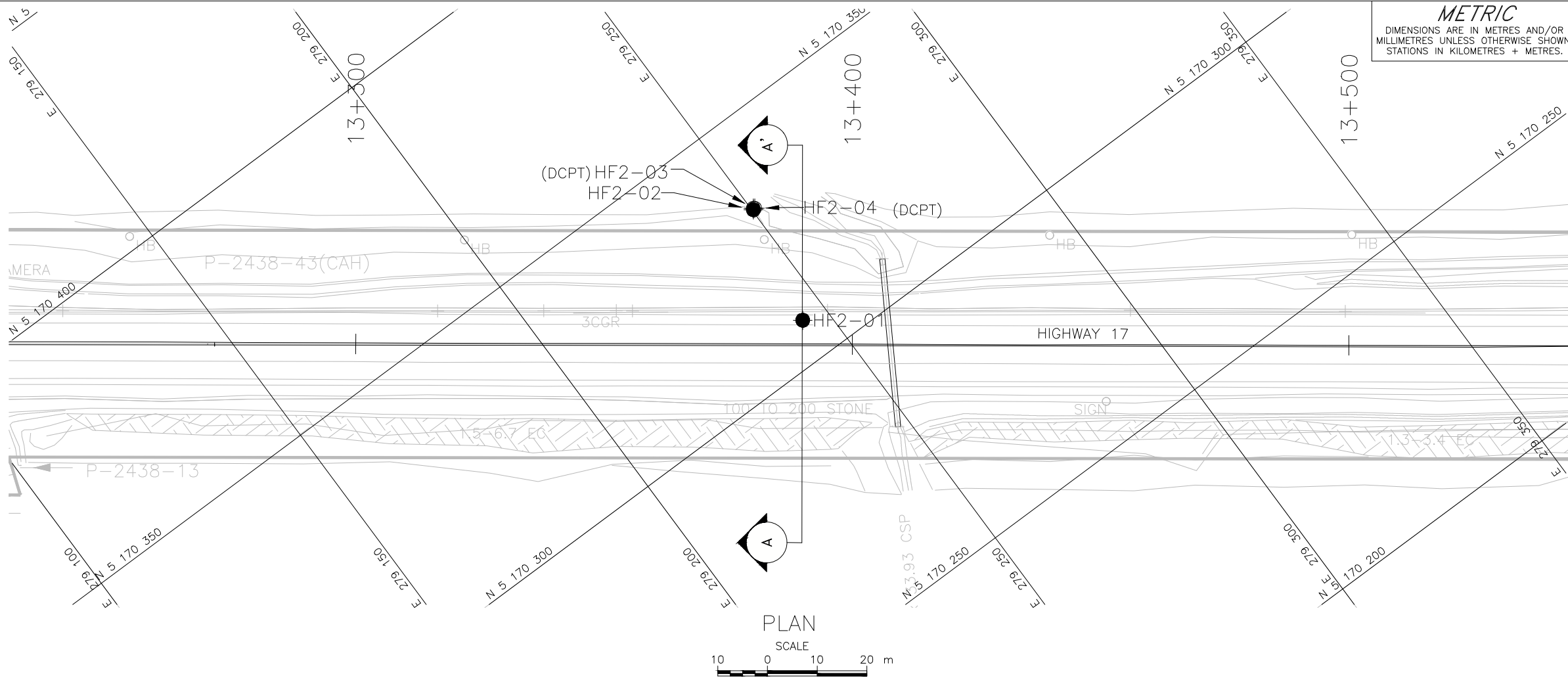
**Golder Associates Ltd.**

Prepared By: LH

Checked By: AH

**APPENDIX C**

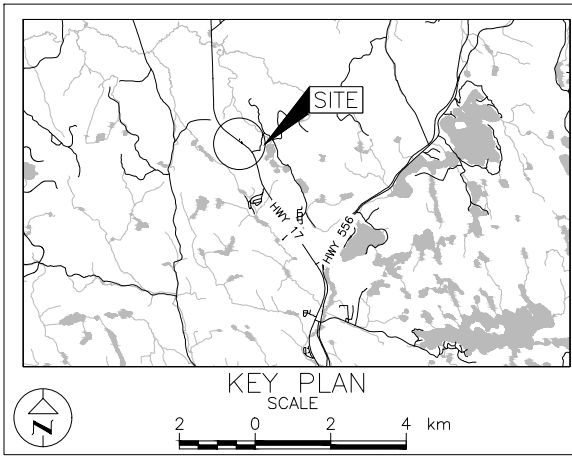
Highway 17 NBL - STA 13+240 to  
STA 13+400 (High Fill Area No. 2)



CONT No.  
GWP No. 5181-13-00

HWY 17-MILE HILL WIDENING  
HIGH FILL AREA 2 (STA 13+240 - 13+400)  
BOREHOLES LOCATION AND SOIL STRATA

SHEET



**LEGEND**

- Borehole - Current Investigation
- Dynamic Cone Penetration Test
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

BOREHOLE CO-ORDINATES (MTM NAD83 ZONE 13)			
No.	ELEVATION	NORTHING	EASTING
HF2-01	323.5	5170308.3	279245.0
HF2-02	315.8	5170332.1	279250.3
HF2-03	315.7	5170332.3	279250.4
HF2-04	315.7	5170332.1	279250.7

SITE COORDINATES: Lon. -84.334003, Lat. 46.671893



**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.

**REFERENCE**

Base plans provided in digital format by AECOM, drawing file nos. 5181-13-00 - Base plan.dwg and 5181-13-00 - DTM and Contours.dwg, received September 09, 2021.

NO.	DATE	BY	REVISION
Geocres No. 41K-119			
HWY. HWY 17	PROJECT NO. 19122433	DIST. ALGOMA	
SUBM'D. ACK	CHKD. TZ	DATE: 12/1/2021	SITE:
DRAWN: SA	CHKD. ACK	APPD. JPD	DWG. C1

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

PROJECT <u>19122433</u>		<b>RECORD OF BOREHOLE No HF2-01</b>				SHEET 2 OF 2		<b>METRIC</b>												
G.W.P. <u>5181-13-00</u>		LOCATION <u>N 5170308.3; E 279245.0 MTM NAD 83 ZONE 13 (LAT. 46.671893; LONG. -84.334003)</u>				ORIGINATED BY <u>TB</u>														
DIST <u>Algoma</u> HWY <u>17</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers; NW Casing; Wash Boring; Rock Coring</u>				COMPILED BY <u>ACK</u>														
DATUM <u>Geodetic</u>		DATE <u>July 19 and 20, 2021</u>				CHECKED BY <u>TZ</u>														
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa												
--- CONTINUED FROM PREVIOUS PAGE ---							<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>					<div style="display: flex; justify-content: space-between;"> <span>10 20 30</span> </div>								
NOTES:  1. The cored depth intervals and particle sizes of recovered cobbles, gravel, and rock fragments are summarized as follows:  Depth (m)    Recovered 4.6 - 6.1    20 mm to 130 mm  2. NW casing advanced below a depth of about 4.6 m to facilitate wash boring operations.  3. Borehole dry upon completion of drilling and prior to removal of casing.																				

GTA-MTO 001 S:\CLIENTS\MTOWHY\_17\_MILE\_HILL\02\_DATA\GINTHWY\_17\_MILE\_HILL.GPJ GAL-GTA.GDT 12/2/21

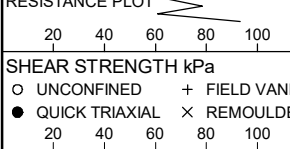


PROJECT 19122433		RECORD OF BOREHOLE No HF2-02				SHEET 1 OF 1		METRIC								
G.W.P. 5181-13-00		LOCATION N 5170332.1; E 279250.3 MTM NAD 83 ZONE 13 (LAT. 46.672107; LONG. -84.333935)				ORIGINATED BY HK										
DIST Algoma HWY 17		BOREHOLE TYPE Portable Equipment - Wash Boring; BW Casing; Rock Coring				COMPILED BY ACK										
DATUM Geodetic		DATE July 20, 2021				CHECKED BY TZ										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
315.8	GROUND SURFACE															
0.0	Sandy SILT (ML), some gravel to SILTY GRAVEL (GM) and sand, some silt Very loose to very dense Brown Moist  - Inferred cobbles and rock fragments encountered between depths of about 0.6 m and 1.5 m.		1	SS	4											
			-	RC	-											
			2	SS	100/0.10											45 39 16 0
			3	SS	50/0.08											17 31 47 5
312.7	SPLIT-SPOON REFUSAL END OF BOREHOLE		4	SS	80/0.10											
3.2	NOTES:  1. The cored depth intervals and particle sizes of recovered gravel and rock fragments are summarized as follows:  Depth (m)    Recovered 0.6 - 1.5    5 mm to 45 mm  2. Open borehole dry upon completion of drilling.															

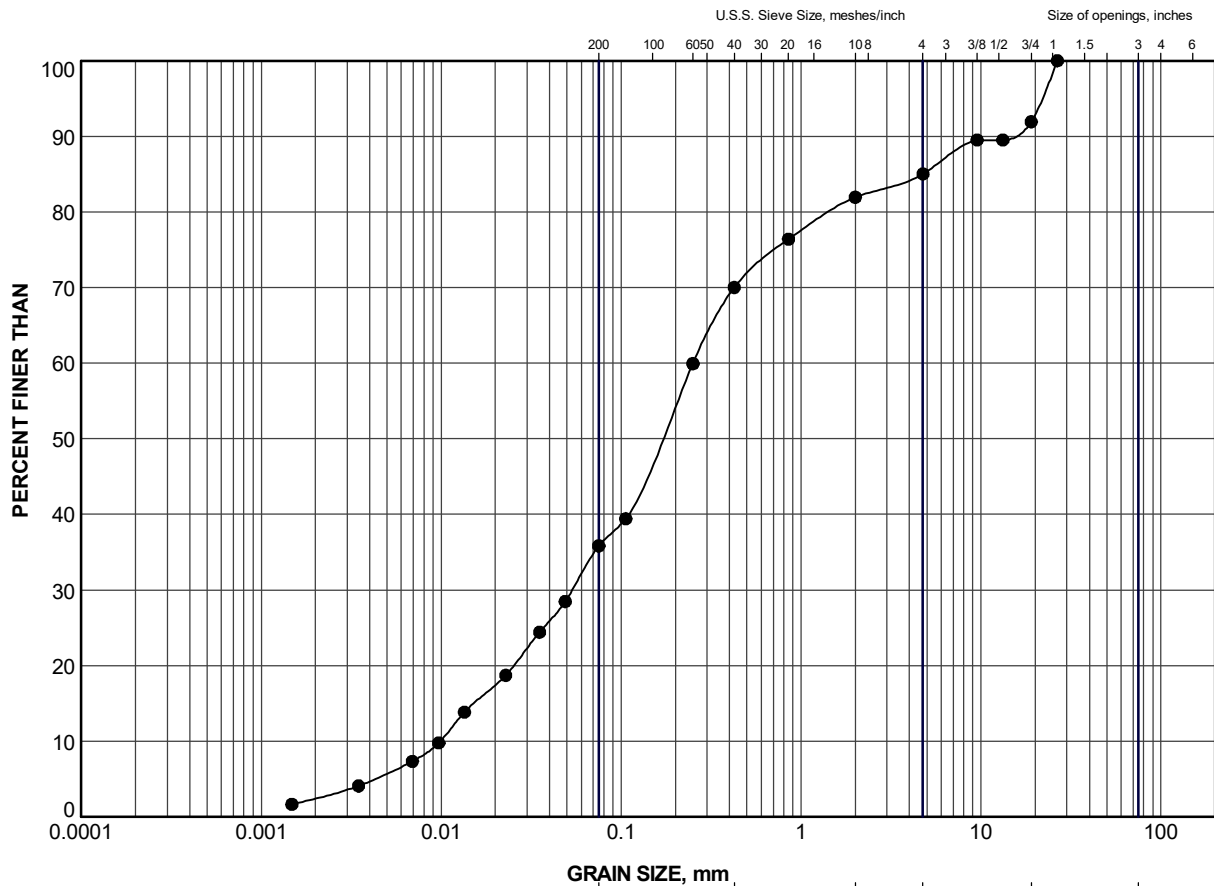
GTA-MTO 001 S:\CLIENTS\MTOWHY\_17\_MILE\_HILL\02\_DATA\GINT\HWY\_17\_MILE\_HILL\_GPJ\_GAL-GTA.GDT 12/2/21

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

S:\CLIENTS\MTO\001 S:\CLIENTS\MTO\HWY\_17\_MILE\_HILL\02\_DATA\GINT\HWY\_17\_MILE\_HILL.GPJ GAL-GTA.GDT 12/2/21

PROJECT <u>19122433</u>		<b>RECORD OF DCPT No HF2-04</b>		SHEET 1 OF 1		<b>METRIC</b>				
G.W.P. <u>5181-13-00</u>		LOCATION <u>N 5170332.1; E 279250.7 MTM NAD 83 ZONE 13 (LAT. 46.672108; LONG. -84.333929)</u>		ORIGINATED BY <u>HK</u>						
DIST <u>Algoma</u> HWY <u>17</u>		BOREHOLE TYPE <u>Portable Tripod Equipment</u>		COMPILED BY <u>TR</u>						
DATUM <u>Geodetic</u>		DATE <u>July 21, 2021</u>		CHECKED BY <u>TZ</u>						
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT W <sub>p</sub> NATURAL MOISTURE CONTENT W LIQUID LIMIT W <sub>L</sub> WATER CONTENT (%)	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE						
315.7 0.0	GROUND SURFACE START OF DCPT									
314.3 1.4	CONE REFUSAL END OF DCPT									


GTA-MTO 001 S:\CLIENTS\MTOWHY\_17\_MILE\_HILL\02\_DATA\GINTHWY\_17\_MILE\_HILL.GPJ GAL-GTA.GDT 12/2/21

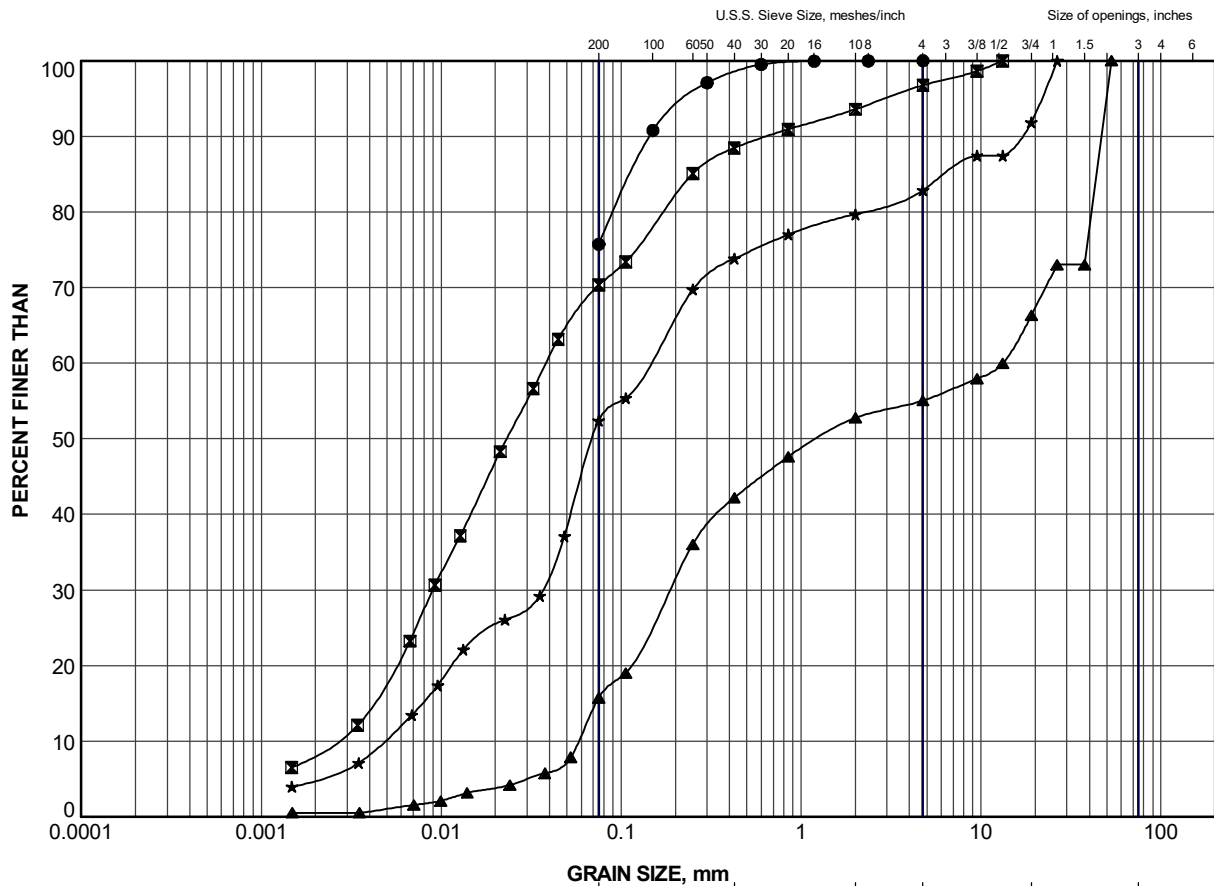


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	HF2-01	5	320.1


PROJECT					
HIGHWAY 17 MILL HILL WIDENING					
TITLE					
GRAIN SIZE DISTRIBUTION SILTY SAND (SM) (FILL)					
PROJECT No. 19122433			FILE No. 19122433.GPJ		
DRAWN	TR	Oct 2021	SCALE	N/A	REV.
CHECK	AK	Oct 2021	<b>FIGURE C1</b>		
APPR	TZ	Oct 2021			
 <b>GOLDER</b> MEMBER OF WSP SUDBURY, ONTARIO					



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

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	HF2-01	8	315.6
⊠	HF2-01	10	312.5
▲	HF2-02	2	314.3
★	HF2-02	3	313.5

PROJECT					
HIGHWAY 17 MILL HILL WIDENING					
TITLE					
GRAIN SIZE DISTRIBUTION SILTY GRAVEL (GM) and Sand to Sandy SILT (ML)					
PROJECT No.		19122433		FILE No. 19122433.GPJ	
DRAWN	TR	Oct 2021	SCALE	N/A	REV.
CHECK	AK	Oct 2021	FIGURE C2		
APPR	TZ	Oct 2021			
 <b>GOLDER</b> MEMBER OF WSP SUDBURY, ONTARIO					

**APPENDIX D**

# Special Provisions



**Section 206.07.03.03 of OPSS.PROV 206 is amended by being replaced with the following:**

---

Special Provision

---

Sub-excavation of existing organic materials along Highway 144 (as indicated in the Contract Drawings) shall be undertaken in such a way that the maximum length of open excavation in any area at any given time shall be 5 m in length. The Contractor shall backfill the sub-excavation with rock fill or Granular 'B' Type II material immediately behind the excavation operation so that the 5 m maximum open excavation requirement is maintained. At the end of each day's work, the Contractor shall ensure that all excavations are backfilled with rock fill.

**Section 206.07.05 of OPSS.PROV 206 is amended by replacing the first paragraph with the following:**

---

Special Provision

---

Rock fill for embankment construction shall be produced in a quarry from crushed or fractured bedrock fragments with 100% fractured faces. The rock fill particles shall be angular and not rounded or sub-rounded. The maximum particle size of the rock fill shall not be greater than 500 mm in any direction and the maximum percentage of particles passing the 75 µm sieve shall not be greater than 10%. The rock fill shall be well-graded with the gradation determined as provided in Note 2 of Table 8 within OPSS.PROV 1004 (November 2012). The rock fill particles shall have a minimum unconfined compressive strength (UCS) of 100 MPa and meet the physical property requirements of “Rock Protection” as provided in Table 7 within OPSS.PROV 1004 (November 2012).



**[golder.com](http://golder.com)**