



## **FINAL REPORT**

### **SUPPLEMENTARY FOUNDATION INVESTIGATION REPORT**

**Proposed Replacement of Culvert on Highway 118,  
Township of Stanhope, Ontario**

**Agreement No. 5015-E-0007**

**Assignment No. 5**

**Geocres No. 31E-382**

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# Ontario Ministry of Transportation

## Northeastern Region Geotechnical Section

### Foundation Investigation Report

Agreement No. 5013-E-0007

Assignment No. 5

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# 1 FOUNDATION INVESTIGATION REPORT

## 1.1 Introduction

This foundation investigation report presents the results of a geotechnical investigation completed by **exp** Services Inc. at a site proposed by the Ministry of Transportation of Ontario (MTO) for culvert replacement at Hwy 118 (i.e. Sta. 16+470), in the Township of Stanhope, Ontario, the Ministry of Transportation (MTO) Northeastern Region. The work was undertaken under Agreement # 5015-E-0007, Assignment No. 5. The terms of reference (TOR) were as presented in the MTO letter dated October 18, 2016.

The purpose of the investigation is to supplement a previous Foundation Investigation and Design Report at the same location performed by **exp** in 2016 (Geocres No. 31E-364, dated September 14 2016) with intent to improve understanding of the fill characteristics and to facilitate the selection of method for replacing the existing culvert. The site specific geotechnical investigation consisted of borings of vertical boreholes, excavation of test pits, soil sampling, borehole/test pit logging, and field and laboratory testing.

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

## 1.2 Site Description and Geological Setting

### 1.2.1 Site Description

The site for the proposed culvert replacement in by trenchless method as selected by a MTO representative is located at Hwy 118, approximately 1.3 km west of the junction of Hwy 118 and Hwy 35 in the Township of Stanhope. In the area of investigation, Hwy 118 is two-lane roadway with approximately 1.7 m wide partially paved shoulder. It is generally oriented in an east-west direction, but at site location it is oriented in a north-west direction with blind curve and sloping approximately 8% down towards westbound (north-west direction).

As noted in the TOR the existing structural plate corrugated steel pipe (SPCSP) culvert is situated beneath Hwy 118 at the site. The pipe is 50 m long having 1.2 m diameter. The existing culvert is intended to be replaced with a new culvert on a new alignment approximately 6 m offset to the north of the existing culvert. The invert of the new culvert will be approximately 0.7 m higher than existing and the length of the proposed culvert will be approximately 46 m. It is estimated that the highway embankment at the proposed culvert location varies from approximately 10.2 m high on inlet side to approximately 12.3 m high on outlet side having side slopes of approximately 1.5H:1V to 1.25H:1V on the inlet and outlet side, respectively. The site plan and cross-section profiles for the proposed culvert alignment are as shown on Drawings 1 and 2 in Appendix B. Photographs of the site/ existing culvert are presented in Appendix A.

During this site investigation carried out on December 2016 and May 2017, the general site conditions were assessed. At the site location water flows from east to west, towards Boshkung Lake, crossing Hwy 118 via a culvert. Note that at the time of site investigation on December, the site was covered with snow which limited our observations. However, during the site investigation on May, surficial flow of water through culvert was observed.

The vicinity of inlet and outlet of the culvert is heavily vegetated with trees. The slopes of the embankment were covered by rock fill. Bedrock outcrops were observed in the vicinity of site and the stream bed. The terrain generally slopes towards the lake (on the west side of the highway). At the site location, the bedrock slopes towards the inlet forming a valley, and further, also, slopes towards the lake (on west) at the outlet side. Selected photographs of the site are provided in Appendix A.

### 1.2.2 Geological Setting

In accordance with the Ministry of Northern Development and Mines Map 2556, Quarternary Geology of Ontario, Southern Sheet, the site is generally undifferentiated igneous and metamorphic rock, exposed at surface or covered by a discontinuous, thin layer of drift.

In accordance with the Ministry of Northern Development and Mines Map 2544, Bedrock Geology of Ontario, Southern Sheet, the bedrock at the site consists of tectonites, straight gneisses porphyroclastic gneisses, unsubdivided gneisses in major deformation zones, mylonites and protomylonites.

## 1.3 Investigation Procedures

### 1.3.1 Site Investigation and Field Testing

As indicated above, an initial foundation investigation at this site was performed by exp in March 2016 and the general sub surface investigation information was presented in the foundation investigation report (FIR) and foundation investigation and design report (FIDR) issued on September 2016 (Geocres No. 31E-364). The March 2016 investigation included drilling of four (4) boreholes numbered BH1 to BH4 to a maximum depth ranging from 1.8 m to 18.4 m (Elev. 332.2 m to Elev. 339.2 m). After this investigation, an additional field investigation was requested by MTO in order to obtain better understanding of the characteristics of the rock fill encountered at the site. Accordingly, additional filed investigation was performed on December 2 to 7, 2016 and May 3 to 11, 2017. The field program consisted of drilling two (2) sampled boreholes (BH101 and BH201) and excavation of four shallow test pits (TP1 to TP4). BH201 and test pits TP1 and TP2 were advanced in December 2016. However, due to bad weather and winter conditions, the completion of the field work was postponed for the spring time. The remaining filed work of drilling BH101 and excavation of test pits TP3 and TP4 was performed in May 2017.

The boreholes were strategically located along the proposed culvert alignment to provide subsurface information for the design of the proposed new culvert. BH101 and BH201 were advanced from the embankment crest within the travelled road. BH101 and BH201 were located along the proposed culvert centerline adjacent to the pavement edge line of EBL and WBL of the Hwy, respectively, and

opposite to previously drilled boreholes BH1 and BH2. BH101 and BH201 were advanced to depths of 15.1 m and 16.3 m, respectively.

Four shallow test pits were excavated between the existing and proposed culverts on either side of embankment to provide better information about the rock fill used for the construction of the embankment. Drawing 1 in Appendix B shows the locations of these test pits. Two test pits (i.e. TP1 and TP2) were excavated at the top of the embankment slope, about 1.6 m and 1.3 m south and north from the edge of embankment crest, while the other two (i.e. TP3 and TP4) were excavated at the bottom of the embankment slope, just above the embankment toes. TP1 and TP2 were located about 2.5 m west of the centerline of existing culvert alignment on the south and north side slope, respectively. Whereas, TP3 and TP4 were located about 4 m and 4.8 m west of the centerline of existing culvert alignment on the south and north side slope, respectively. The size of the test pits TP1 and TP2 were about 6.5 m long x 1.2 m wide and about 0.4 m deep. TP3 was about 7.5 m long x 1.2 m wide and about 1 m deep, while TP4 was about 4.8 m long x 1.4 m wide, and also about 1 m deep.

Boreholes drilled from the embankment crest (BH101 and BH201) were advanced using a truck mounted CME-85 drill rig and CME-75 drill rig respectively. The drill rig was equipped with a hollow stem auger, tri-cone and standard soil/ rock sampling equipment operated by a specialist drilling contractor, Landcore Drilling and Marathon Drilling Company Ltd. A wash boring technique with casing in conjunction with core barrel was used to advance the boreholes through the embankment. When the cobbles and boulders were encountered, the core barrel was used to advance the borehole and obtain core samples. Between the obstructions, a combination of conventional SPT sampling and/or tri-coning was attempted. Considering the size of a SPT sampler (i.e. 35 mm inside diameter), only particles smaller than 35 mm in diameter was able to be collected in the sampler. The larger particles could be possibly pushed aside during the driving of the sampler. The test pits excavated from the embankment crest (TP1 and TP2) were excavated using a Kobelco-210 track mounted excavator and the test pits excavated from the toe of embankment (TP3 and TP4) were excavated using a CAT-311 track mounted excavator.

The borehole/test pit locations (referenced to the MTM NAD83 coordinate system) and their ground surface elevations were temporary surveyed by **exp** personnel using the Temporary Benchmark (TBM) provided (BM 828023 mark on rock, see photographs, in Appendix A) north of the site and west of the highway. The TBM elevation is assumed as Elev. 343.962 m. The location of the boreholes and test pits are shown on Drawing 1, in Appendix B.

During the drilling of the boreholes, a combination of Standard Penetration Tests (SPT) and coring was attempted to obtain the soil and rock samples. Soil samples were obtained using a 51 mm outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) at intervals ranging from 0.75 m to 1.5 m in depth as shown on the attached borehole logs (Appendix C). The original field (uncorrected) SPT "N" values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual (CFEM, pg. 40) and used to provide an assessment of in-situ consistency or relative density of non-cohesive soils. The SPT "N" values taken within the particles larger than diameter of split spoon sampler may not be reliable and collected samples are possibly not representative of the layer. When a hard

stratum was reached (refusal of split spoon), sampling of hard material was performed by diamond core drilling using a 1.5 m long NQ double tube wireline core barrel.

Upon completion of the boreholes, ground water level measurements were carried out in the boreholes in accordance with the MTO guidelines. However, boreholes were advanced using a wash boring technique, so the stabilized ground water level could not be established by short term observations in boreholes. The drilled boreholes were decommissioned by bentonite/cement mixtures in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act). The test pits were backfilled and compacted properly. It has been reinstated to the original conditions.

The fieldwork was supervised by members of **exp's** engineering who directed the drilling and sampling operations, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification, and retrieved soil samples for subsequent laboratory testing and identification.

All of the recovered soil samples placed in labelled moisture-proof bags were returned to **exp's** Brampton laboratory for additional visual, textual, olfactory examination and selective testing.

### 1.3.2 Previous Investigation

The following previous investigation report from the 2016 investigation is available on the MTO GEOCRE Library:

- Foundation Investigation and Design Report, Culvert Installation Hwy 118, Township of Stanhope; G.W.P. 5140-13-00; Agreement # 5015-E-0008; Geocres No. 31E-364; exp Services Inc.; September, 2016.

Four borehole logs produced based on the investigation conducted by exp in March 2016 at location of this culvert (identified as BH1 to BH4) are attached in Appendix F of this report. The details of the borehole locations and elevations completed at the site location at the 2016 investigation are outlined in Table 1.1. The location details of each borehole should be considered an estimate only.

*Table 1.1. Summary of boreholes completed at the 2016 investigation*

BH No.	Borehole Locations (Station and Offset from the centreline) <sup>1</sup>	Ground Elevation (m)	Borehole Depth (m)	Borehole Bottom Elevation (m)	Piezometer/ Monitoring Well
BH1	2 m west of the proposed culvert centreline adjacent to the pavement edge line of EBL	350.6	18.4	332.2	None
BH2	2 m east of the proposed culvert centreline adjacent to the pavement edge line of WBL	351.2	15.7	335.5	None
BH3	Toe of the embankment at inlet of proposed culvert	341.0	1.8	339.2	None

BH No.	Borehole Locations (Station and Offset from the centreline) <sup>1</sup>	Ground Elevation (m)	Borehole Depth (m)	Borehole Bottom Elevation (m)	Piezometer/ Monitoring Well
BH4	Toe of the embankment at outlet of proposed culvert	338.3	2.2	336.1	None

Note: <sup>1</sup> Station and offset measurements are approximate.

### 1.3.3 Laboratory Testing

All soil and rock samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content and particle size distribution from the selected soil samples. Since most of split spoon samples collected from boreholes within the rock fill layer were not able of adequate size for testing, particle size distribution tests were not possible to perform for many collected samples at this site. All the laboratory tests were carried out in accordance with MTO and/or ASTM Standards as appropriate. Since wash boring technique were used to advance boreholes and generally cohesionless material was encountered, it should be noted that the moisture content values obtained from laboratory tests may not be accurate representation of the soil moisture condition.

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

## 1.4 Subsurface Conditions

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

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

The general stratigraphy encountered within the investigated depths of previous boreholes (exp 2016) and current investigation are inline. In general, the subsoil condition at the site consist of a layer of fill material composed of gravelly sand to various sized of fragments of blasted rock in a silty, sandy and gravelly soil matrix underlain by native peat, followed by a layer of gravelly sand and bedrock.

A detailed description of the subsurface conditions encountered in boreholes and test pits is discussed further in subsequent sections. It should be noted that the following sections are based on the geotechnical investigation conducted by **exp** for this assignment and previous assignment (exp 2016; Geocres 31E-364).

## 1.4.1 Boreholes

### 1.4.1.1 Asphalt

Asphalt was encountered at the surface of boreholes BH1, BH2, BH101 and BH201. Thickness of the asphalt layer was between 0.12 m and 0.15 m. Asphalt thicknesses may further vary beyond the borehole locations.

### 1.4.1.2 Fill: Sandy Gravel to Gravelly Sand/Silty Sand

Sandy gravel to gravelly sand/silty sand fill was encountered below the asphalt in all boreholes drilled at the top of the embankment (i.e. BH1, BH2, BH101 and BH201). The sandy gravel to gravelly sand fill extended to depths ranging between 1.5 m to 2.7 m below road surface with elevations ranging between Elev. 348.4 m and 349.7 m. The explored thickness of this layer was between 1.3 m to 2.6 m.

The composition of this fill layer is sand and gravel, with some cobbles and clay inclusions. The material is brown to grey in color, and moist. The SPT “N” values within this layer ranged from 13 to 77 blows per 300 mm penetration, suggesting compact to very dense, but generally compact, compactness condition.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture Content: (**exp 2016 and 2017**)

- 2.6% to 13.0%

Grain Size Distribution: (**exp 2016 and 2017**)

- 2% to 24 % gravel;
- 66% to 77% sand; and
- 8% to 25% silt and clay

The results of the moisture content and grain size distribution tests for this assignment are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests for this assignment are also provided on Figure 1 in Appendix D. The borehole logs and graphical results from the 2016 investigation are provided in Appendix F.

### 1.4.1.3 Fill: Various Sized Fragments of Blasted Rock in Soil Matrix

A layer of fill consisting of various sized fragments of blasted rock within soil matrix was encountered below the sandy gravel to gravelly sand fill in all boreholes drilled at the top of the embankment (i.e. BH1, BH2, BH101 and BH201). This fill layer extended to depths ranging between 8.2 m to 12.2 m



below road surface with elevations ranging between Elev. 342.9 m and 339.0 m. The explored thickness of this layer was between 5.5 m to 10.7 m.

The composition of this fill layer is a silty, sandy and gravelly soil matrix with blasted rock fragments having various particle sizes from sand to boulder size. As explained in Section 1.3.1 the combination of SPT and coring was attempted to obtain samples from this fill layer. Where it was possible a standard split spoon sampler attempted to collect samples at this layer. However, in the majority cases adequate samples could not be recovered. The SPT “N” values measured during these tests ranged from 3 blows per 300 mm penetration to 60 blows per 50 mm penetration. However, only for information purpose, the obtained SPT “N” values within the soil matrix are recorded in the borehole logs suggesting very loose to very dense compactness condition. For the other part of this layer where the split spoon/auger refusal was encountered, coring was performed recovering cored rock samples together with infill soils as recorded on the borehole logs. Some voids were also identified during the coring and are recorded on the borehole logs.

Soils and rock fragments collected in the split spoon sampler and during coring were subjected to laboratory testing. In particular, laboratory testing performed on selected soil samples recovered in the split spoon sampler consisted of moisture content and grain size distribution tests. The test results are as follows:

**Moisture Content: (exp 2016 and 2017)**

- 3.6% to 11.9%

**Grain Size Distribution: (exp 2016)**

- 49% gravel;
- 43% sand; and
- 8% silt and clay

The results of the moisture content tests are provided on the record of borehole sheets in Appendix C. The borehole logs and graphical results from the 2016 investigation are provided in Appendix F.

At the time of the 2016 investigation, uniaxial compressive strength and abrasivity tests were also performed on selected boulder-sized rock fragment core samples recovered from BH1. The results of these tests are summarized in Table 1.2 below.

*Table 1.2 Uniaxial compressive strength and CERCHAR abrasivity index of rock cores in the rock fill of various-sized blasted rock particles*

Borehole	Ground Surface Elevation (m)	Rock Core Sample Depth (m)	Uniaxial Compressive Strength (MPa)	CERCHAR Abrasivity Index (CAI)
BH1	350.6	5.33 – 6.1	-	4.32
		7.01 – 7.62	94.1	-

The test results indicate that rock fragments are strong to very strong as per Table 3.5 of CFEM (2006) and highly abrasive based on modified classification of rock abrasiveness (Restner, 2007).

The results of uniaxial compression tests and CERCHAR abrasivity tests are also provided in Appendix F.

#### 1.4.1.4 Rock Fill: Cobble and Boulder-Sized Blasted Rock

A layer of rock fill consisting of cobble and boulder-sized blasted rock fragments was encountered below the layer of fill of various sized fragments of blasted rock in the soil matrix found in BH1, BH101 and BH201. This rock fill layer extended to depths ranging between 12.7 m to 13.7 m below the road surface with elevations ranging between Elev. 336.9 m and 338.4 m. The explored thickness of this layer was between 1.9 m (BH101) and 5.5 m (BH201).

The composition of this rock fill layer is mainly of cobbles and boulders size grains. The coring was attempted to obtain their samples. As noted on the borehole logs, the size of cored rock samples was upto 1.0 m. Between the rock pieces some silty and sandy soil infills and/or voids were observed during the coring.

At the time of the 2016 investigation, uniaxial compressive strength and abrasivity tests were also performed on selected rock core samples from this rock fill recovered in BH1. The results of these tests are summarized in Table 1.3 below.

*Table 1.3 Uniaxial compressive strength and CERCHAR abrasivity index of boulder cores in the rock fill of cobble and boulder-sized blasted rock particles*

Borehole	Ground Surface Elevation (m)	Rock Core Sample Depth (m)	Uniaxial Compressive Strength (MPa)	CERCHAR Abrasivity Index (CAI)
BH1	350.6	9.76 – 10.67	-	4.56
		11.28	100.8	-
		11.58 – 12.19	55.7	4.49

The test results indicate that boulder-sized rock pieces are strong to very strong as per Table 3.5 of CFEM (2006) and highly abrasive based on modified classification of rock abrasiveness (Restner, 2007).

The results of uniaxial compression tests and CERCHAR abrasivity tests are provided in Appendix F.

#### 1.4.1.5 Gravely Sand to Sand and Gravel

Native gravely sand to sand and gravel layer was encountered below the rock fill layer in borehole BH1 and BH2 and below peat layer in BH101. The gravely sand to sand and gravel extended to depths ranging between 12.7 m to 14.6 m below road surface with elevations ranging between Elev. 336.0 m to 338.5 m. The explored thickness of this layer was between 0.5 m to 0.9 m.



The composition of this layer is mostly sand and gravel, few silt and clay size particles, some peat and occasional cobbles and boulders. The material is grey to reddish brown, moist to wet. The SPT “N” values within this layer ranged from 30 blows per 300 mm penetration to 50 blows per 100 mm penetration suggesting compact to very dense compactness condition.

Laboratory testing performed on selected samples consisted of moisture content test and grain size distribution test and the test results are as follows:

Moisture content: **(exp 2016 and 2017)**

- 18.2% to 25.9%

Grain Size Distribution: **(exp 2016)**

- 27% to 48 % gravel;
- 45% to 65% sand;
- 7% to 8% silt and clay

The result of moisture content tests are provided on the record of borehole sheets in Appendix C. The borehole logs and graphical results obtained at the 2016 investigation are provided in Appendix F.

#### **1.4.1.6 Peat**

A peat layer was encountered the beneath sand and gravel layer in BH2, beneath the rock fill in BH101 and BH201, and at the ground surface in BH3 and BH4. The peat was described as very soft to stiff, brown to black, wet and containing trace sand, trace gravel and trace roots and rootlets. The peat layer extended to depths ranging between 13.3 m to 13.7 m below the road surface with elevation ranging between Elev. 337.3 m and 337.9 m in boreholes advanced from the roadway. In off-road boreholes advanced at inlet and outlet locations, the peat layer was at the ground surface and extended to depths ranging between 0.2 m and 0.6 m below the ground surface with elevations ranging between 338.2 m and 340.4 m. The explored thickness of this layer was between 0.2 m to 0.8 m.

Laboratory testing performed on selected peat samples consisted of moisture content tests. The test results are as follows:

Moisture content: **(exp 2016 and 2017)**

- 40.3% to 86.9%

The results of the moisture content tests are provided on the record of borehole sheets in Appendix C. The borehole logs from the 2016 investigation are provided in Appendix F.

#### **1.4.1.7 Sandy Silt**

A native sandy silt layer was encountered below the peat layer in BH2. The sandy silt layer extended to depth of about 14.0 m below the road surface with elevation about 337.2 m. The explored thickness of this layer was about 0.7 m.

The composition of the layer is mostly sand and silt, trace clay, trace gravel and trace organics. The material is grey in color, and wet. One SPT “N” value obtained within this layer was 50 blows per 100 mm penetration suggesting very dense compactness condition.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture Content: (**exp 2016**)

- 32.6%

Grain Size Distribution: (**exp 2016**)

- 6 % gravel;
- 37% sand;
- 53% silt and;
- 4% clay

The borehole logs and graphical results from the 2016 investigation are provided in Appendix F.

#### **1.4.1.8 Cobbles and Boulders**

Cobbles and boulders were encountered underlying a peat layer in BH3. The cobbles and boulders layer extended to depths about 1.5 m below ground surface with elevation about 339.5 m. The explored thickness of this layer was about 0.9 m.

The composition of this layer is mostly cobbles and boulders, trace some sand, trace silt and trace organics. One SPT “N” value obtained within this layer was 50 blows per 127 mm penetration suggesting very dense compactness condition. The recovered cored sample obtained within this layer is about 150 mm.

Laboratory testing performed on one collected sample consisted of moisture content test and the test result is as follows:

Moisture Content: (**exp 2016**)

- 16.7%

#### **1.4.1.9 Bedrock**

Bedrock was encountered underlying the peat/ sandy peat layer in BH1, BH201 and BH4, cobbles and boulders in BH3, gravelly sand in BH101 and beneath the sandy silt layer in BH2. The bedrock was encountered at depths ranging between about 0.2 m and 1.5 m below ground surface at the inlet and outlet, and about 13.5 m to 14.6 m below the existing road surface. The bedrock was confirmed by coring of 0.5 m to 3.9 m long rock cores. The elevation of the bedrock surface below Hwy 118 ranges from Elev. 336.0 m to Elev. 339.5 m. The bedrock surface depth and elevation encountered at the drilled borehole locations are listed in Table 1.4. Photographs of rock cores are included in Appendix E. All the boreholes are terminated within bedrock.

*Table 1.4 Depth and elevation of bedrock surface*

<b>Borehole</b>	<b>Depth Below Ground Surface (m)</b>	<b>Elevation (m)</b>	<b>Comments</b>
BH1	14.6	336.0	Bedrock Cored
BH2	14.0	337.2	Bedrock Cored
BH3	1.5	339.5	Bedrock Cored
BH4	0.2	338.2	Bedrock Cored
BH101	14.6	336.4	Bedrock Cored
BH201	13.5	337.6	Bedrock Cored

Based on the rock cores recovered, the bedrock consists of granitic gneiss. In general, the rock samples are described as grey, with pink and white striations have a fine crystalline structure, slightly weathered. The Rock Quality Designation (RQD) measured on the rock core samples typically ranged from approximately 21% to 100%, indicating a rock mass of very poor to excellent, but generally fair to excellent quality.

#### 1.4.2 Test Pits

As noted before, four shallow test pits were excavated between the existing and proposed culverts on either side of embankment as shown on Drawing 1 in Appendix B. Test pits TP1 and TP2 were excavated at the top of the embankment slope, while test pits TP3 and TP4 were excavated above the toe of the embankment. TP1 and TP3 were excavated on the west (outlet) side, while TP2 and TP4 were excavated on the east (inlet) side. The size of the test pits TP1 and TP2 were about 6.5 m long x 1.2 m wide and about 0.4 m deep. TP3 was about 7.5 m long x 1.2 m wide and about 1 m deep, while TP4 was about 4.8 m long x 1.4 m wide, and also about 1 m deep.

Photographs taken during the excavation of the test pits (i.e. Photo15 to Photo 26) are included in Appendix A. The description of geotechnical findings during the excavation of the test pits is given in the attached records of test pit in Appendix C.

##### 1.4.2.1 Fill: Sandy Gravel to Gravelly Sand/Silty Sand

Sandy gravel to gravelly sand/silty sand fill was encountered on the surface of test pits TP1 and TP2 as shown in Photos 15, 16 and 17, Appendix A. Thickness of sandy gravel to gravelly sand fill in test pits was about 0.2 m.

#### **1.4.2.2 Fill: Various Sized Fragments of Blasted Rock in Soil Matrix**

Fill consisting of blasted rock fragments in silty, sandy and gravelly soil matrix was encountered below sandy and gravelly fill in the test pits excavated along the embankment slope from the top of the embankment (TP 1 and TP2) as shown in Photos 16 and 18, Appendix A. The size of rock fragments varied from gravel to boulder size. The rock fragments were round to angular.

#### **1.4.2.3 Rock Fill: Cobble and Boulder-Sized Blasted Rock**

Rock fill was encountered in the test pits excavated above toes of each side of the embankment slope (TP2 and TP4). These excavated test pits are shown through Photos 19 to 26 in Appendix A. The rock fill pieces had mostly cobble and boulder size and angular to round shape. Some rock fill pieces were 1.65 m in size as shown on Photo 24. An infill between rock grains was mostly silty, sandy, gravelly and organic soil, but voids were also observed. The shallow bedrock was encountered at the inlet side (Photo 26).

### **1.5 Ground Water Conditions**

Since the wash boring method was used for drilling boreholes, accurate groundwater levels at these holes could not be measured in the open holes at the time of drilling operations.

At the time of previous investigation (exp 2016) surficial flow of water through the culvert was observed to be at approximate Elev. 341.1 m and 338.0 m at the inlet and outlet sides, respectively.

Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods.

August 31, 2017

## 1.6 CLOSURE

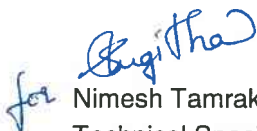
The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. could be greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

This Foundation Investigation Report has been prepared by Mr. Nimesh Tamrakar, M.Eng, EIT. and Dr. S. Micic, Ph.D., P. Eng. and reviewed by Mr. T.C. Kim, M.E.Sc., P.Eng. and Mr. S.E. Gonsalves, M.Eng., P.Eng. designated MTO foundation contact. The field investigation was conducted by Mr. Devendra Panchal.


We trust that these comments provide you with sufficient information to for your present requirements. Should you have any questions, please do not hesitate to contact this office

Yours truly,

**exp Services Inc.**

  
for Nimesh Tamrakar, M.Eng., EIT.  
Technical Specialist

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

  
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Senior Geotechnical Engineer  
Project Manager

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

Encl.



## **Appendix A – Photographs**





Photo 1: Hwy 118 looking south-east (upward) from existing culvert location



Photo 2: Hwy 118 looking north-west (downward) from existing culvert location





Photo 3: Looking east (inlet side) at existing culvert location



Photo 4: Looking west (outlet side) at existing culvert location





Photo 5: Looking South-East from north of existing culvert inlet



Photo 6: Looking west from inlet side of existing culvert





Photo 7: Looking east from outlet of existing embankment



Photo 8: Looking north and BH4 location from existing culvert outlet





Photo 9: East side (Inlet) slope at proposed culvert location. Looking west from BH3 location



Photo 10: West side (Outlet) slope at proposed culvert location. Looking east from BH4 location





Photo 11: Inlet side, bedrock outcrops



Photo 12: Outlet side, bedrock outcrops





Photo 13: Deterioration of culvert at inlet



Photo 14: TBM on rock outcrop north-west of proposed culvert



## TEST PITS



Photo 15: Test pit TP1 at the west embankment slope facing outlet side



Photo 16: Test pit TP1 at the west embankment slope, various sized rock fragments in soil matrix





Photo 17: Test pit TP2 at the east embankment slope facing west, inlet side



Photo 18: Test pit TP2 at the east embankment slope, various sized rock fragments in soil matrix





Photo 19: Test pit TP3 at the toe of west embankment slope facing west, outlet side



Photo 20: Test pit TP3 at the toe of west embankment slope, beginning of excavation





Photo 21: Test pit TP3 at the toe of the west embankment side, cobble and boulder sized rock fill





Photo 22: Test pit TP4 at the toe of the east embankment side, inlet side



Photo 23: Test pit TP4 at the toe of the east embankment side, beginning of excavation





Photo 24: Test pit TP4 at the toe of the east embankment side, cobbles and boulder sized rock fill





Photo 25: Test pit TP4 at the toe of the east embankment side, boulder sized rock fill





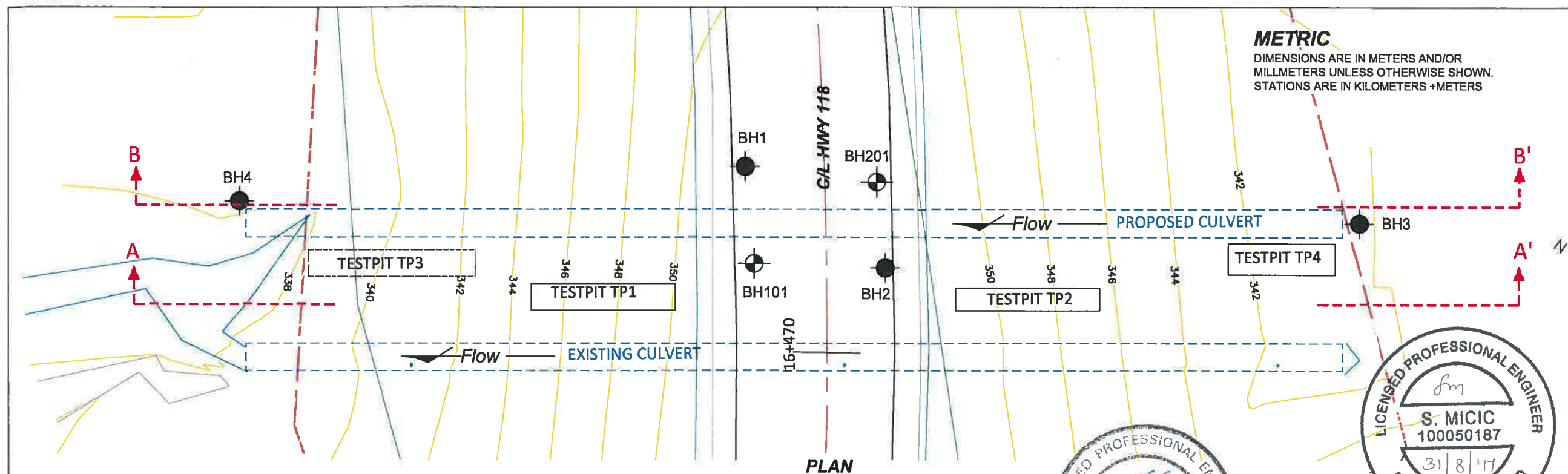
Photo 26: Test pit TP4 at the toe of the east embankment side, bedrock elevation

## **Appendix B – Drawings**

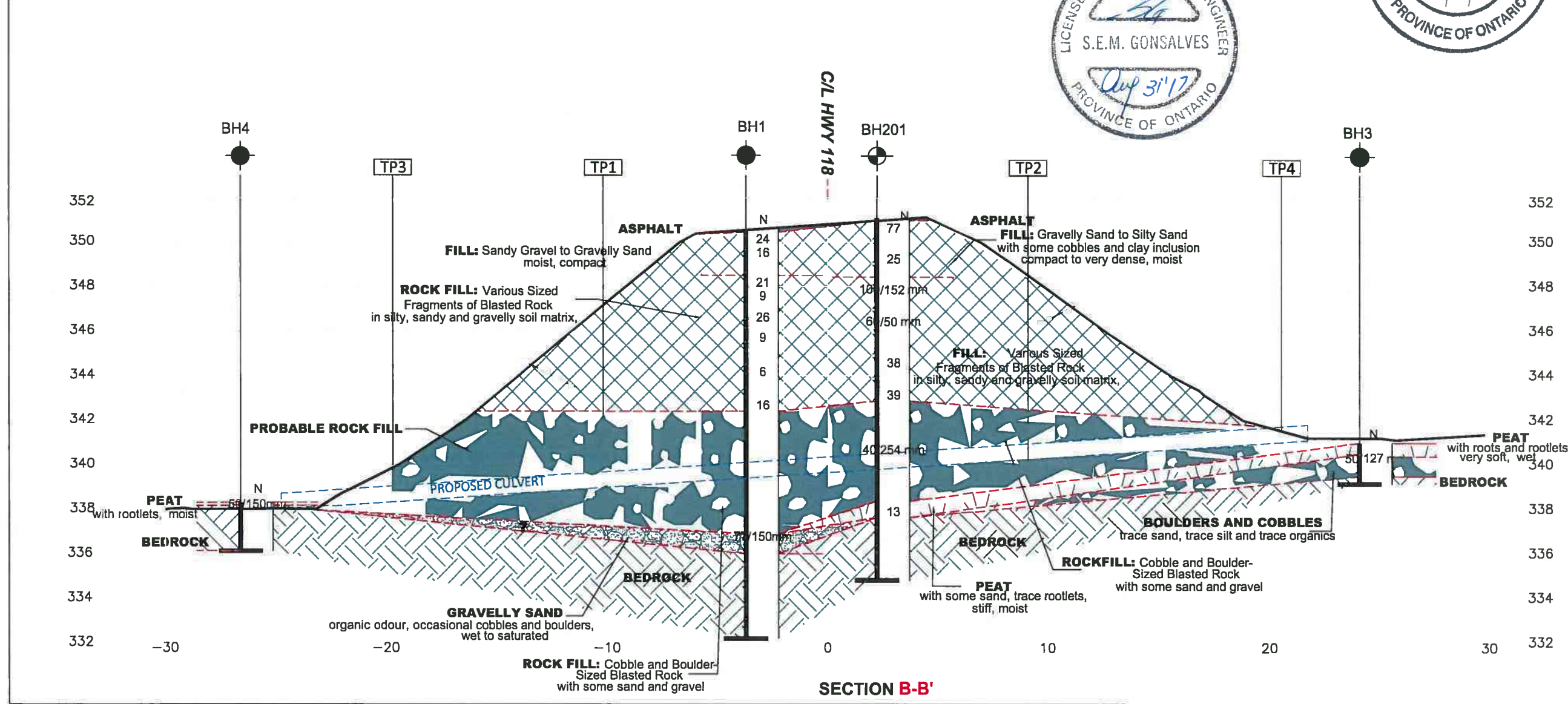








PLAN



SECTION B-B'

NER Agreement No. 5015-E-0007  
Assignment No. 5  
G.W.P. 5140-13-00

PROPOSED REPLACEMENT OF CULVERT ON HWY 118,  
TOWNSHIP OF STANHOPE  
BOREHOLE LOCATION PLAN AND SOIL STRATA

exp Services Inc.

KEY PLAN

LEGEND

- New Borehole by EXP (2017)
- Previous Borehole by EXP (2016)
- Test Pit (2017)
- N Standard Penetration Test (Blows/0.3 m)

SOIL STRATA SYMBOLS

ASPHALT	BEDROCK	SANDY SILT
FILL	COBBLES & BOULDERS	
PEAT	GRAVELLY SAND	

BH No.	APPROX. ELEV.	MTM CO-ORDINATES	
		NORTHING	EASTING
BH 101	350.7	4989980	366933
BH 201	351.1	4989986	366935
BH 1	350.6	4989983	366930
BH 2	351.2	4989983	366938
BH 3	341.0	4989987	366954
BH 4	338.3	4989969	366912
TP 1	-	4989974	366928
TP 2	-	4989985	366944
TP 3	-	4989997	366954
TP 4	-	4989993	366912

NOTE

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

SCALE 0 5 m

DATE	BY	DESCRIPTION
24/08/2017	-	SUBMISSION FOR MTO REVIEW
		GEOCRES NO. 31E 382
		PROJECT NO. ADM-00233185-F0
SUBMD SM	CHECKED SM	DATE 24/08/2017
DRAWN SH	CHECKED SG	APPROVED SG DWG 2



## **Appendix C – Boreholes Logs**

# Explanation of Terms Used on Borehole Records

## SOIL DESCRIPTION

Terminology describing common soil genesis:

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

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

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

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

Terminology describing soil structure:

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

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

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

*Fissured:* material breaks along plane of fracture.

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

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

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

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

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

*Homogeneous:* same color and appearance throughout.

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

*Uniformly Graded:* predominantly on grain size.

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

ISSMFE SOIL CLASSIFICATION											
CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		
<div><div>0.002</div><div>0.006</div><div>0.02</div><div>0.06</div><div>0.2</div><div>0.6</div><div>2.0</div><div>6.0</div><div>20</div><div>60</div><div>200</div></div>											
EQUIVALENT GRAIN DIAMETER IN MILLIMETRES											
CLAY (PLASTIC) TO				FINE		MEDIUM		CRS.		FINE COARSE	
SILT (NONPLASTIC)				SAND				GRAVEL			
UNIFIED SOIL CLASSIFICATION											

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Note 16 in ASTM D2488-09a:

Table a: Percent or Proportion of Soil, Pp

	Criteria
Trace	Particles are present but estimated to be less than 5%
Few	$5 \leq Pp \leq 10\%$
Little	$15 \leq Pp \leq 25\%$
Some	$30 \leq Pp \leq 45\%$
Mostly	$50 \leq Pp \leq 100\%$

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

Table b: Apparent Density of Cohesionless Soil

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

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

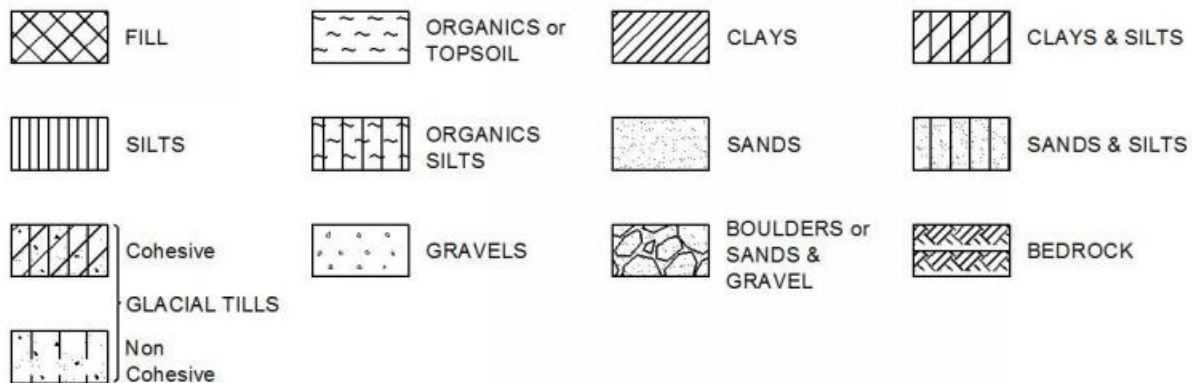
Table c: Consistency of Cohesive Soil

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

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

## STRATA PLOT

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



## WATER LEVEL MEASUREMENT



## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

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

### STRESS AND STRAIN

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

### MECHANICAL PROPERTIES OF SOIL

$m_v$	kPa <sup>-1</sup>	Coefficient of volume change
$c_c$	1	Compression index
$c_s$	1	Swelling index
$c_r$	1	Recompression index
$c_v$	m <sup>2</sup> /s	Coefficient of consolidation
H	m	Drainage path
$T_v$	1	Time factor
U	%	Degree of consolidation
$\sigma'_{v0}$	kPa	Effective overburden pressure
$\sigma'_p$	kPa	Preconsolidation pressure
$\tau_f$	kPa	Shear strength
$c'$	kPa	Effective cohesion intercept
$\phi'$	—°	Effective angle of internal friction
$c_u$	kPa	Apparent cohesion intercept
$\phi_u$	—°	Apparent angle of internal friction
$\tau_R$	kPa	Residual shear strength
$\tau_r$	kPa	Remoulded shear strength
$S_t$	1	Sensitivity = $c_u/\tau_r$

### PHYSICAL PROPERTIES OF SOIL

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

Brampton, Ontario

## RECORD OF BOREHOLE No BH101

1 OF 2

METRIC

W.P. 5140-13-00 LOCATION Highway 118, MTM-10, 5461909.5N, 259501.0E ORIGINATED BY DP  
 DIST Haliburton County HWY 118 TEST PIT TYPE CME 85/SSA/NW/NQ COMPILED BY NT  
 DATUM BM Elev. 343.96 m DATE 2017.05.03 - 2017.05.04 LATITUDE 49.2935 LONGITUDE -81.3728 CHECKED BY SM

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										
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE										
351.0	Road Surface						20	40	60	80	100							
350.9	ASPHALT (~ 115 mm thick)																	
0.1	FILL: GRAVELLY SAND TO SILTY SAND with some cobbles, brown, moist, compact .		1	AS														
			2	SS	13		350								2 73 (25)			
	- Switch to casing/boring @ 1.5 m																	
							349											
348.7																		
2.3	FILL: VARIOUS SIZED FRAGMENTS OF BLASTED ROCK in silty, sandy and gravelly soil matrix Run 1 (3 NQ) - 2.28 m to 2.6 m Hard @2.28 m L = 0.1 m Soft @2.39 m L = 0.050 m Hard @2.44 m L = 0.050 m Soft @2.49 m L = 0.1 m  Run 2 (5 NQ) - 3.05 m to 4.57 m Hard @3.05 m L = 0.74 m Soft @3.78 m L = 0.48 m Hard @4.27 m L = 0.178 m Soft @4.45 m L = 0.127 m		3	NQ														
			4	SS	22		348											
			5	NQ			347											
	-recovery only 0.025 m thick sample		6	SS	7		346											
	Run 3 (7 NQ)- 5.03 m to 6.05 m Hard @5.03 m L = 0.76 m Soft @5.79 m L = 0.254 m																	
			7	NQ			345											
	-recovery only 0.076 m thick sample		8	SS	17		344											
	Run 4 (9 NQ) - 6.66 m to 7.55 m Void @6.66 m L = 0.51 m Hard @7.16 m L = 0.076 m Soft @7.24 m L = 0.1 m Hard @7.34 m L = 0.076 m Soft @7.42 m L = 0.050 m Hard @7.47 m L = 0.076 m																	
			9	NQ			343											
	Run 5 (10 NQ) - 7.55 m to 8.92 m Hard @7.55 m L = 0.152 m Void @7.7 m L = 0.84 m (Soft driven) Hard @8.54 m L = 0.051 m Soft @8.59 m L = 0.20 m Hard @8.79 m L = 0.127 m																	

Continued Next Page

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

ONTARIO MTO ADM-00233185.F0 - HWY 118.GPJ ONTARIO MTO.GDT 7/27/17



**METRIC**

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

Brampton, Ontario

## RECORD OF BOREHOLE No BH201

1 OF 3

METRIC

W.P. 5140-13-00 LOCATION Highway 118, MTM-10, 5461901.9N, 259513.9E ORIGINATED BY DP  
 DIST Haliburton County HWY 118 TEST PIT TYPE CME 75/HSA/NW/NQ COMPILED BY NT  
 DATUM BM Elev. 343.96 m DATE 2016.12.06 - 2016.12.07 LATITUDE 49.29344 LONGITUDE -81.62263 CHECKED BY SM

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 (%)
								○ UNCONFINED	+	FIELD VANE						
						● QUICK TRIAXIAL	×	LAB VANE								
351.1	Road Surface															
351.0	ASPHALT (~ 140 mm thick)															
0.1	FILL: GRAVELLY SAND TO SILTY SAND with some cobbles and clay inclusion, brown, moist, compact to very dense.		1	SS	77		351									
							350									
	- Switch to casing/boring @ 1.5 m		2	SS	25										21 66 (13)	
							349									
348.4																
2.7	FILL: VARIOUS SIZED FRAGMENTS OF BLASTED ROCK in silty, sandy and gravelly soil matrix		3	NQ												
	Run 1 (3 NQ) - 2.67 m to 3.05 m															
	Hard @2.67 m L = 0.076 m															
	Soft @2.74 m L = 0.127 m		4	SS	100/152 mm		348									
	Hard @2.87 m L = 0.178 m															
	Run 2 (5 NQ) - 3.35 m to 4.57 m															
	Soft @3.35 m L = 0.53 m															
	Hard @3.89 m L = 0.076 m															
	Soft @3.96 m L = 0.254 m															
	Hard @4.22 m L = 0.05 m															
	Soft @4.27 m L = 0.127 m		5	NQ			347									
	Hard @4.39 m L = 0.178 m															
			6	SS	60/50 mm											
	-recovery only 0.05 m thick sample															
	Run 3 (7 NQ) - 4.72 m to 6.25 m															
	Hard @4.72 m L = 0.381 m															
	Soft @5.1 m L = 0.584 m															
	Hard @5.69 m L = 0.152 m															
	Soft @5.84 m L = 0.254 m															
	Hard @6.1 m L = 0.152 m		7	NQ			346									
							345									
	-recovery only 0.076 m thick sample		8	SS	38											
	Run 4 (9 NQ) - 6.94m to 7.62 m															
	Soft @6.94 m L = 0.076 m															
	Hard @7.01 m L = 0.127 m															
	Soft @7.14 m L = 0.076 m															
	Hard @7.21 m L = 0.279 m		9	NQ			344									
	Soft @7.49 m L = 0.127 m															
	-recovery only 0.05 m thick sample															
			10	SS	39		343									

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

ONTARIO MTO ADM-00233185.F0 - HWY 118.GPJ ONTARIO MTO.GDT 7/27/17


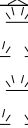

Brampton, Ontario

## RECORD OF BOREHOLE No BH201

2 OF 3

METRIC

W.P. 5140-13-00 LOCATION Highway 118, MTM-10, 5461901.9N, 259513.9E ORIGINATED BY DP  
 DIST Haliburton County HWY 118 TEST PIT TYPE CME 75/HSA/NW/NQ COMPILED BY NT  
 DATUM BM Elev. 343.96 m DATE 2016.12.06 - 2016.12.07 LATITUDE 49.29344 LONGITUDE -81.62263 CHECKED BY SM

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  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 (%)				
								○ UNCONFINED		+ FIELD VANE						● QUICK TRIAXIAL		× LAB VANE		
						20	40	60	80	100	20	40	60							
348.2	ROCKFILL: COBBLE AND BOULDER-SIZED BLASTED ROCK with some sand and gravel Run 5 (11 NQ) - 8.23 m to 9.27 m Soft @8.23 m L = 0.152 m Hard @8.38 m L = 0.356m Soft @8.74 m L = 0.178 m Hard @8.91 m L = 0.356 m		11	NQ																
	Run 6 ( 12 NQ)- 9.27 m to 10.16 m Hard @9.27 m L = 0.533 m Void @9.8 m L = 0.356 m (dropped suddenly)		12	NQ																
	----- -recovery only 0.025 m thick sample		13	SS	40/ 254 mm															
	Run 7 (14 NQ) - 10.67 m to 11.58 m Hard @10.67 m L = 0.432m Soft @11.1 m L = 0.152 m Hard @11.25 m L = 0.178m Soft @11.38 m L = 0.178 m Hard @11.51 m L = 0.076 m		14	NQ																
	Run 8 (15 NQ)- 11.58 m to 12.73 m Soft @11.58 m L = 0.152 m Hard @11.74 m L = 1.0 m Soft @12.74 m L = 0.228 m (Probably Peat Layer)		15	NQ																
338.4	Peat , with some sand, trace rootlets, brown/black, moist, stiff.		16	SS	13									83.7						
337.6	BEDROCK black, grey granite with pink NQ CORING Length (m) RQD(%) Run 1 1.07 21.4 Run 2 1.5 35.6		17	NQ																
			18	NQ																
334.8	END OF BOREHOLE																			
16.3																				

Continued Next Page

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

ONTARIO MTO ADM-00233185.F0 - HWY 118.GPJ ONTARIO MTO.GDT 7/27/17

Brampton, Ontario

## RECORD OF BOREHOLE No BH201

3 OF 3

METRIC

W.P. 5140-13-00 LOCATION Highway 118, MTM-10, 5461901.9N, 259513.9E ORIGINATED BY DP  
 DIST Haliburton County HWY 118 TEST PIT TYPE CME 75/HSA/NW/NQ COMPILED BY NT  
 DATUM BM Elev. 343.96 m DATE 2016.12.06 - 2016.12.07 LATITUDE 49.29344 LONGITUDE -81.62263 CHECKED BY SM

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	W <sub>p</sub>	W	W <sub>L</sub>			
	Borehole terminated @ ~16.28 m  <b>NOTES:</b> 1. This drawing is to be read with the subject report and project numbers as presented above. 2. Since washboring technique was used to advance borehole groundwater level in open hole was not measured															

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

Brampton, Ontario

1 OF 1

**METRIC**

W. P.	5140-13-00	LOCATION	Hwy 118, Township of stanhope	ORIGINATED BY	DP
DIST	Haliburton County	BOREHOLE TYPE	Kobelco-210 excavator	COMPILED BY	NT
DATUM		DATE	2017/11/05 - 2017/11/05	CHECKED BY	SM

[illegible]

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

MTD TEST PIT TEMPLATE TEST PITS.GPJ ONTARIO MOT.GDT 7/28/17

Brampton, Ontario

## RECORD OF TEST PIT No TP2

1 OF 1

METRIC

W. P. 5140-13-00 LOCATION Hwy 118, Township of stanhope ORIGINATED BY DP  
 DIST Haliburton County BOREHOLE TYPE Kobelco-210 excavator COMPILED BY NT  
 DATUM DATE 2017/11/05 - 2017/11/05 CHECKED BY SM

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	20	40	60	80	100	W <sub>p</sub>	W		
0.0	FILL: SAND AND GRAVEL 150 mm thickness															
0.2	FILL: VARIOUS SIZED FRAGMENTS OF BLASTED ROCK in silty, sandy and gravelly soil matrix															
0.4	END OF TEST PIT  NOTES: 1. No groundwater level or cave were observed in this test pit. 2. Test Pit was terminated in boulder layer.															

MTO TEST PIT TEMPLATE TEST PITS.GPJ ONTARIO MOT.GDT 7/28/17



Brampton, Ontario

## RECORD OF TEST PIT No TP3

1 OF 1

METRIC

W. P. 5140-13-00 LOCATION Hwy 118, Township of stanhope ORIGINATED BY DP  
 DIST Haliburton County BOREHOLE TYPE CAT-311 excavator COMPILED BY NT  
 DATUM DATE 2017/11/05 - 2017/11/05 CHECKED BY SM

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: C <sub>u</sub> , KPa									
						20	40	60	80	100							
0.0	Embankment Slope surface/Elevation varies  ROCKFILL: COBBLE AND BOULDER-SIZED BLASTED ROCK with some silty sand and gravel																
1.0	END OF TEST PIT  NOTES: 1. No groundwater level or cave were observed in this test pit.																

MTO TEST PIT TEMPLATE TEST PITS.GPJ ONTARIO MOT.GDT 7/28/17

Brampton, Ontario

## RECORD OF TEST PIT No TP4

1 OF 1

METRIC

W. P. 5140-13-00 LOCATION Hwy 118, Township of stanhope ORIGINATED BY DP  
 DIST Haliburton County BOREHOLE TYPE CAT-311 excavator COMPILED BY NT  
 DATUM DATE 2017/11/05 - 2017/11/05 CHECKED BY SM

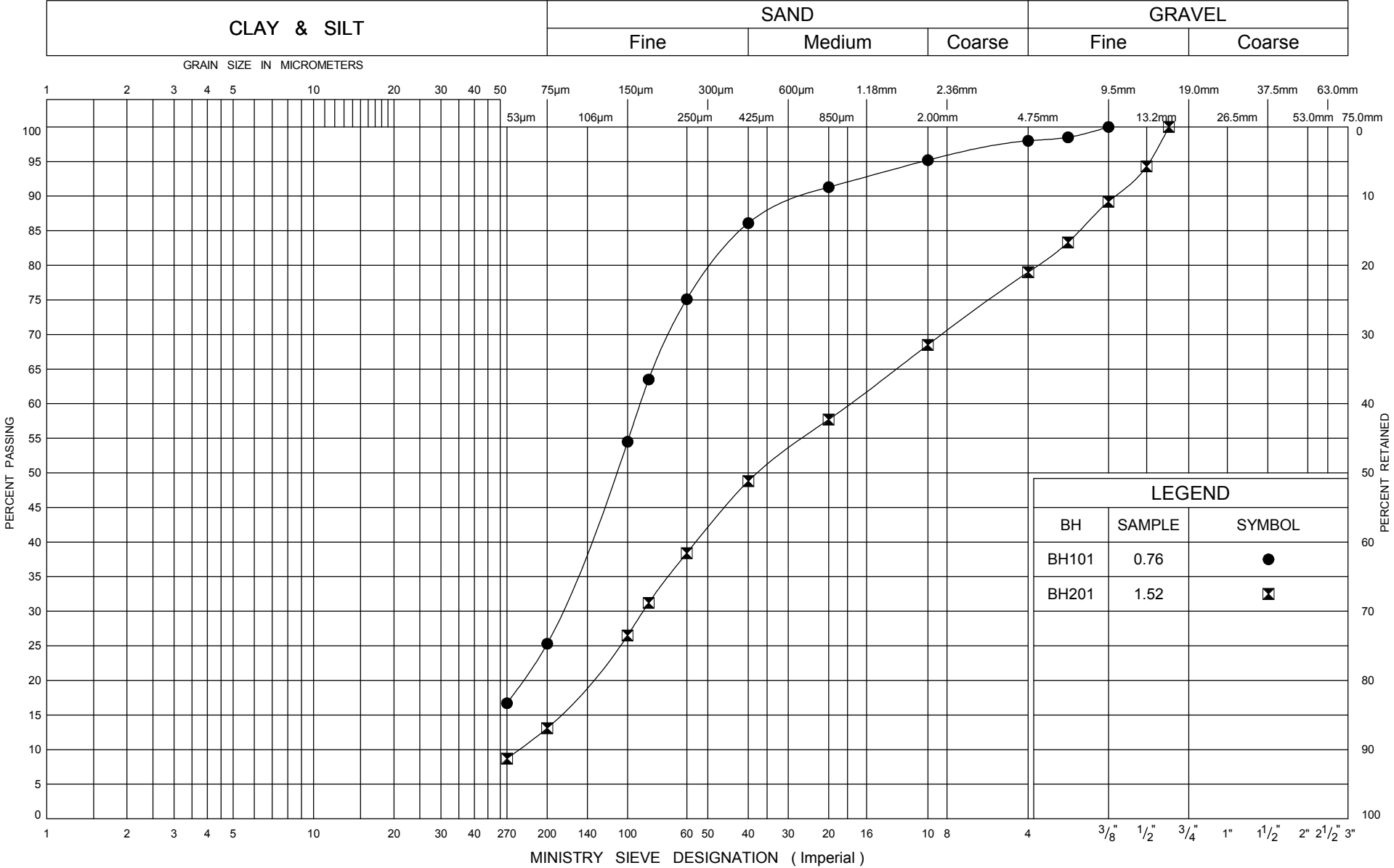
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH: Cu, KPa ○ UNCONFINED + FIELD VANE × QUICK TRIAXIAL LAB VANE					W <sub>p</sub>	W	W <sub>L</sub>		
0.0	Embankment Slope surface/Elevation varies ROCKFILL: COBBLE AND BOULDER-SIZED BLASTED ROCK with some silty sand and gravel																
1.0	END OF TEST PIT  NOTES: 1. No groundwater level or cave were observed in this test pit.																

MTO TEST PIT TEMPLATE TEST PITS.GPJ ONTARIO MOT.GDT 7/28/17

## **Appendix D – Laboratory Test Results**



UNIFIED SOIL CLASSIFICATION SYSTEM



## **Appendix E – Rockfill and Bedrock Core Photographs**

Project NO: ADM 0002331875-F0  
BH NO: 201  
Run NO: 1,2,3,4 & 5 (**Rockfill**)  
Sample Depth: 2.67 m to 9.27 m  
Elevation: 348.4 m to 341.83 m  
Date: December 6 & 7, 2016



Photo 1. Rockfill Core Sample for BH201 from Elevation 348.4 m to 341.83 m

Project NO: ADM 0002331875-F0  
BH NO: 201  
Run NO: 6,7 & 8 (**Rockfill**)  
Sample Depth: 9.27 m to 12.73  
Elevation: 341.83 m to 338.4 m  
Date: December 6 & 7, 2016



Photo 2. Rockfill Core Sample for BH201 from Elevation 341.83 m to 338.4 m

Project NO: ADM 0002331875-F0  
BH NO: 201  
Run NO: 1 & 2 (**Bedrock**)  
Sample Depth: 13.5 m to 16.3 m  
Elevation: 337.6 m to 334.8 m  
Date: December 7, 2016



Photo 3. Bedrock Core Sample for BH201 from Elevation 337.6 m to 334.8 m

Project NO: ADM 0002331875-F0  
BH NO: 201  
Run NO: 1 & 2 (**Bedrock**)  
Sample Depth: 13.5 m to 16.3 m  
Elevation: 337.6 m to 334.8 m  
Date: December 7, 2016



## **Appendix F – Borehole Logs and Laboratory Test Results from the 2016 Investigation**

Brampton, Ontario

## RECORD OF BOREHOLE No BH1

1 OF 2

METRIC

W. P. GWP 5140-13-00 LOCATION MTM ZONE10 N4989983 E366930 ORIGINATED BY CS  
 DIST Hwy 118, Township of Stanhope BOREHOLE TYPE CME-75, Hollow Stem Auger/ NW/ NQ COMPILED BY JH  
 DATUM BM Elev. 343.96 m DATE 2016/03/15 - 2016/03/17 CHECKED BY SM

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			20	40	60	80	100					
350.6	Ground Surface																
350.5	ASPHALT 150 mm thickness																
0.2	FILL: SANDY GRAVEL TO GRAVELLY SAND brown, grey and black, moist, compact		1	SS	24		350										
	-becoming few gravel, brown		2	SS	16												
							349										
348.5	ROCK FILL: VARIETY-SIZED FRAGMENTS OF BLASTED ROCK with some sand, some gravel, pink and grey, moist, loose to compact		3	SS	21		348										
2.1			4	SS	9												
			5	SS	26		347										
			6	SS	9		346										
	-boulder cored sample @ 5.3 m, run length = 0.76 m, granite core (~150 mm)		7	SS	6		345										
							344										
	-boulder cored sample @ 7 m, run length = 0.61 m		8	SS	16		343										
342.4	ROCK FILL: COBBLE AND BOULDER-SIZE BLASTED ROCK pink and grey		9	NQ			342										
8.2	NQ CORING Core sample Length (m) Run 1 @ 8.2 m 0.3 Run 2 @ 9.15 m 0.61 Run 3 @ 9.76 m 0.91 Run 4 @ 11.58 m 0.61 Run 5 @ 12.2 m 0.91 -soft layer @ 9.6 m		10	NQ			341										
			11	NQ			340										
			12	NQ			339										

Continued Next Page

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

EXP RECORD OF BOREHOLE 5013-E-0008 ASSIG. 13 BH LOGS, UPDATED - FINAL.GPJ ONTARIO MOT.GDT 8/5/16

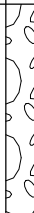
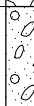

Brampton, Ontario

## RECORD OF BOREHOLE No BH1

2 OF 2

METRIC

W. P. GWP 5140-13-00 LOCATION MTM ZONE10 N4989983 E366930 ORIGINATED BY CS  
 DIST Hwy 118, Township of Stanhope BOREHOLE TYPE CME-75, Hollow Stem Auger/ NW/ NQ COMPILED BY JH  
 DATUM BM Elev. 343.96 m DATE 2016/03/15 - 2016/03/17 CHECKED BY SM

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 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH: Cu, KPa									WATER CONTENT (%)			GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE															
								× QUICK TRIAXIAL LAB VANE															
						20	40	60	80	100	10	20	30										
336.9	ROCK FILL: COBBLE AND BOULDER-SIZE BLASTED ROCK pink and grey NQ CORING (continued)  -soft layer @ 13.1 m		13	NQ																			
13.7	GRAVELLY SAND organic odour, occasional cobbles and boulders, brown, wet to saturated		14	SS	77/ 150mm								○			27	65 (8)						
336.0	BEDROCK pink streaks on grey and white seams of pyrite and mica, granite NQ CORING Length (m) RQD(%) Run 6 1.15 Run 7 1.32 51 Run 8 1.32 67		15	NQ																			
14.6			16	NQ																			
			17	NQ																			
332.2	END OF BOREHOLE																						
18.4	NOTES: 1. This drawing is to be read with the subject report and project numbers as presented above. 2. No groundwater level was measured. Washboring technique was used to drill borehole. 3. The reltve density does not apply to rockfill, however, for information purpose the relative density is provided (which is possibly not representative of the layer) based on obtained SPT "N" values wherever possible.																						

EXP RECORD OF BOREHOLE 5013-E-0008 ASSIG. 13 BH LOGS\_UPDATED - FINAL.GPJ ONTARIO MOT.GDT 8/5/16

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

Brampton, Ontario

## METRIC

ORIGINATED BY CS

COMPILED BY JH

CHECKED BY SM

EXP RECORD OF BOREHOLE 5013-E-0008 ASSIG. 13 BH LOGS\_UPDATED - FINAL.GPJ ONTARIO MOT.GDT 8/5/16

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







Brampton, Ontario

## RECORD OF BOREHOLE No BH2

2 OF 2

METRIC

W. P. GWP 5140-13-00 LOCATION MTM ZONE10 N4989983 E366938 ORIGINATED BY CS  
 DIST Hwy 118, Township of Stanhope BOREHOLE TYPE CME-75, Hollow Stem Auger/ NW/ NQ COMPILED BY JH  
 DATUM BM Elev. 343.96 m DATE 2016/03/18 - 2016/03/19 CHECKED BY SM

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 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH: Cu, KPa									WATER CONTENT (%)			GR	SA	SI	CL	
								○ UNCONFINED + FIELD VANE																40.3
								× QUICK TRIAXIAL LAB VANE																
						20	40	60	80	100	10	20	30											
339.0																								
12.2	<b>SAND AND GRAVEL</b> coarse angular and subangular sand and gravel, reddish brown, dense		11	SS	30												48 45 (7)							
338.5																								
12.7	<b>PEAT</b> saturated, wood fragments, strong earthy odour, trace sand																							
337.9																								
13.3	<b>SANDY SILT</b> fine, trace organics (rootlets), few gravel, trace clay, some pyrite flecks, very dense																							
337.2			12	SS	50/100 mm												6 37 53 4							
14.0	<b>BEDROCK</b> black and grey granite with white and pink seams and striations, occasional pyrite and mica seams <b>NQ CORING</b> Length (m) RQD(%) Run1 1.65 83.2		13	NQ																				
335.5																								
15.7	<b>END OF BOREHOLE</b>  <b>NOTES:</b> 1. This drawing is to be read with the subject report and project numbers as presented above. 2. No groundwater level was measured. Washboring technique was used to drill borehole. 3. The relative density does not apply to rockfill, however, for information purpose the relative density is provided (which is possibly not representative of the layer) based on obtained SPT "N" values wherever possible.																							

EXP RECORD OF BOREHOLE 5013-E-0008 ASSIG. 13 BH LOGS\_UPDATED - FINAL.GPJ ONTARIO MOT.GDT 8/5/16

Brampton, Ontario

## RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W. P. GWP 5140-13-00 LOCATION MTM ZONE10 N4998997 E366954 ORIGINATED BY CS  
 DIST Hwy 118, Township of Stanhope BOREHOLE TYPE HUSQVARNA DS 800 Portable Hydraulic Drill/ NW/ BQ COMPILED BY JH  
 DATUM BM Elev. 343.96 m DATE 2016/03/18 - 2016/03/18 CHECKED BY SM

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			20	40	60	80	100					
341.0	<b>Ground Surface</b>																
	<b>PEAT</b> with roots and rootlets, black, wet, very soft																
340.4																	
0.6	<b>BOULDERS AND COBBLES</b> trace sand, trace silt and trace organics		1	SS	50/127 mm												
	<b>NQ CORING</b>		2	NQ													
	Length (m)																
339.5	Run 1 0.15		3	NQ													
	Run 2 0.46																
1.5	<b>BEDROCK</b> grey and white granite		4	NQ													
339.2	<b>NQ CORING</b>		5	NQ													
1.8	Length (m)																
	Run 3 0.20																
	Run 4 0.13																
	<b>END OF BOREHOLE</b>																
	<b>NOTES:</b> 1. This drawing is to be read with the subject report and project numbers as presented above. 2. No groundwater level was measured. Washboring technique was used to drill borehole.																

EXP RECORD OF BOREHOLE 5013-E-0008 ASSIG. 13 BH LOGS\_UPDATED - FINAL.GPJ ONTARIO MOT.GDT 8/5/16

Brampton, Ontario

## RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

W. P. GWP 5140-13-00 LOCATION MTM ZONE10 N4998969 E366912 ORIGINATED BY CS  
 DIST Hwy 118, Township of Stanhope BOREHOLE TYPE HUSQVARNA DS 800 Portable Hydraulic Drill/ NW/ BQ COMPILED BY JH  
 DATUM BM Elev. 343.96 m DATE 2016/03/19 - 2016/03/19 CHECKED BY SM

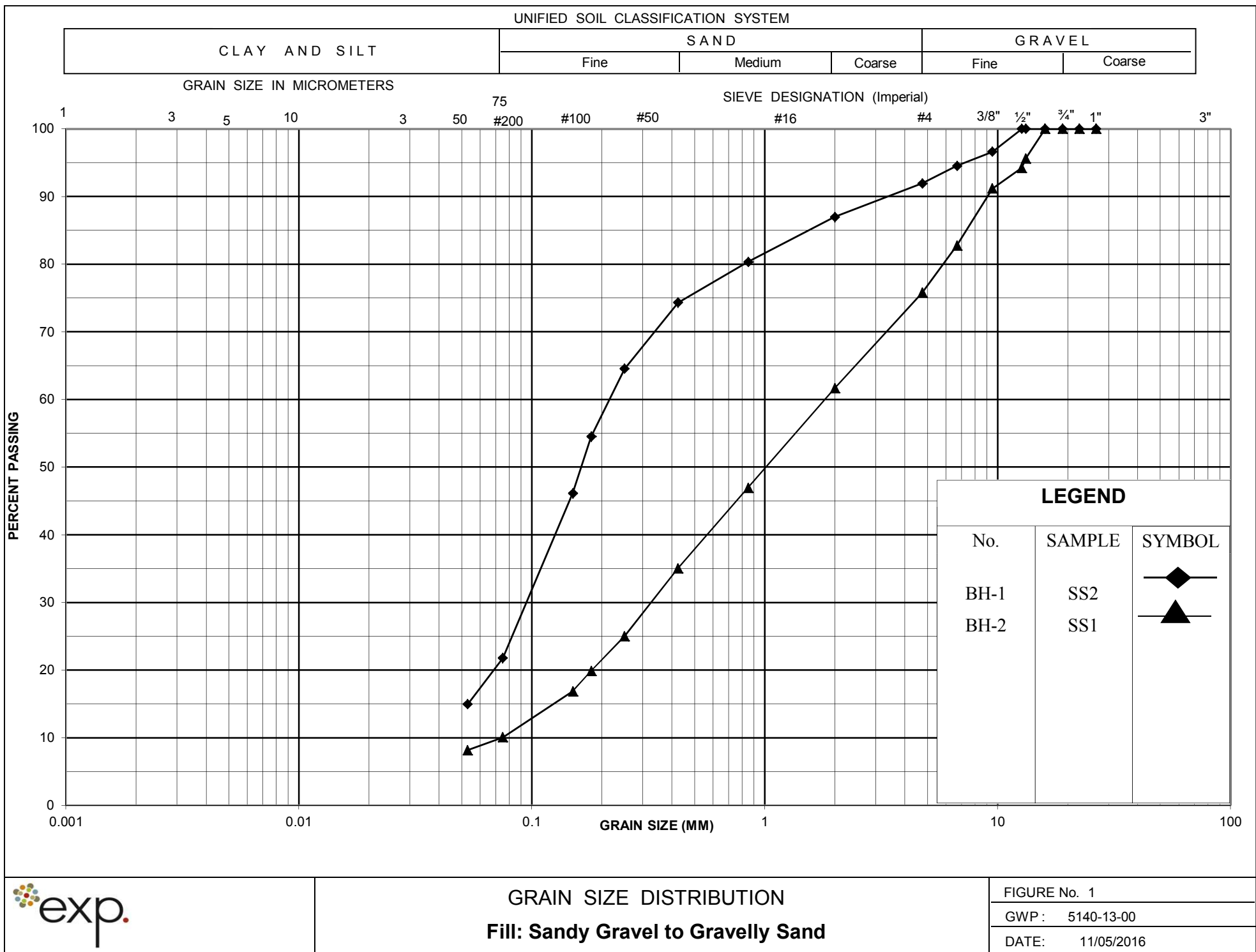
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
338.3	Ground Surface																
338.2	PEAT with rootlets, black, moist		1	SS	50/		338										
0.2	BEDROCK grey and white granite		2	NQ	150mm												
	NQ CORING																
	Length (m) RQD(%)																
	Run 1 0.26 60.0		3	NQ													
	Run 2 0.45 77.7																
	Run 3 0.41 62.5		4	NQ													
	Run 4 0.51 70.0																
	Run 5 0.40 100.0		5	NQ			337										
336.1			6	NQ													
2.2	END OF BOREHOLE																
	NOTES: 1. This drawing is to be read with the subject report and project numbers as presented above. 2. No groundwater level was measured. Washboring technique was used to drill borehole.																

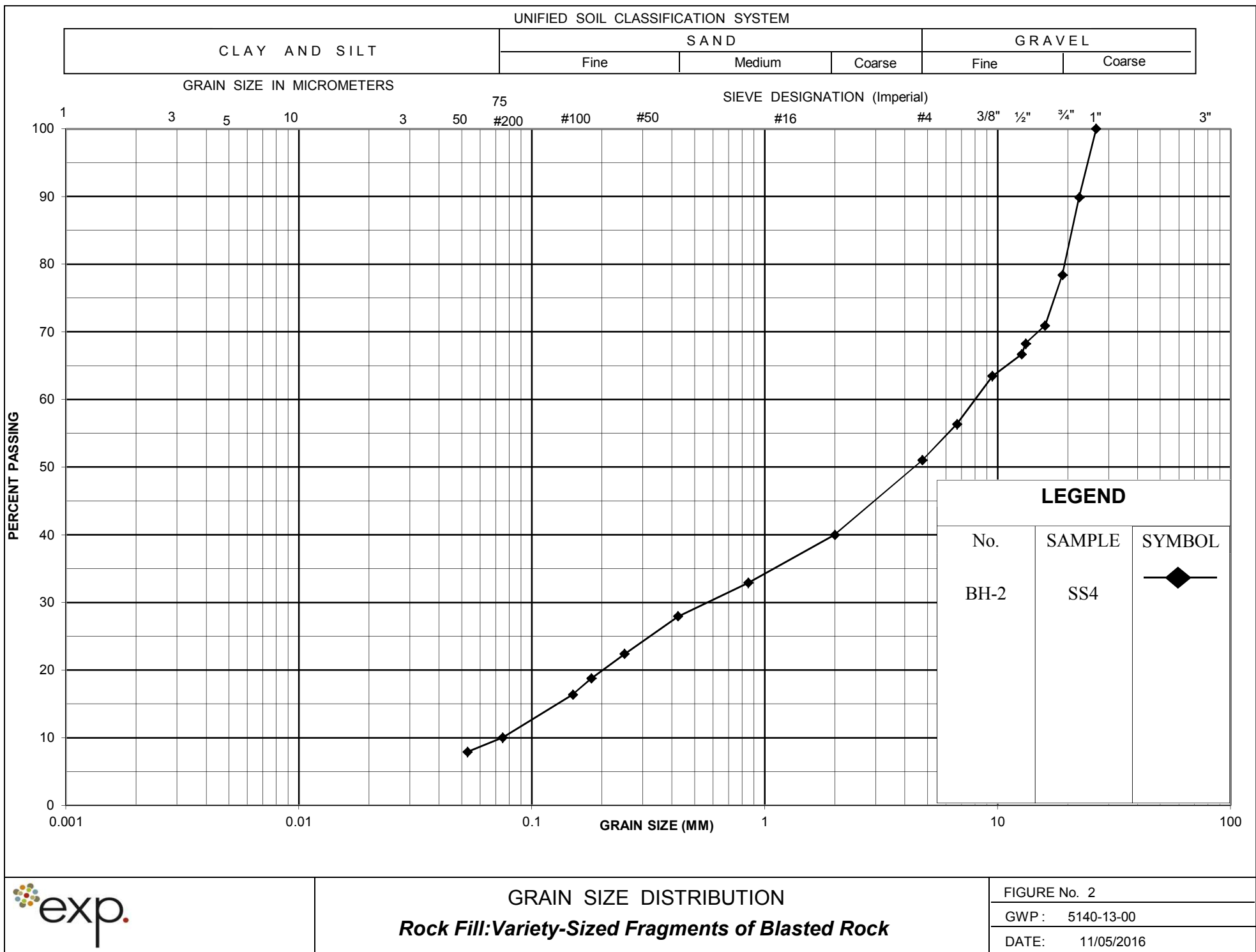
EXP RECORD OF BOREHOLE 5013-E-0008 ASSIG. 13 BH LOGS\_UPDATED - FINAL.GPJ ONTARIO MOT.GDT 8/5/16

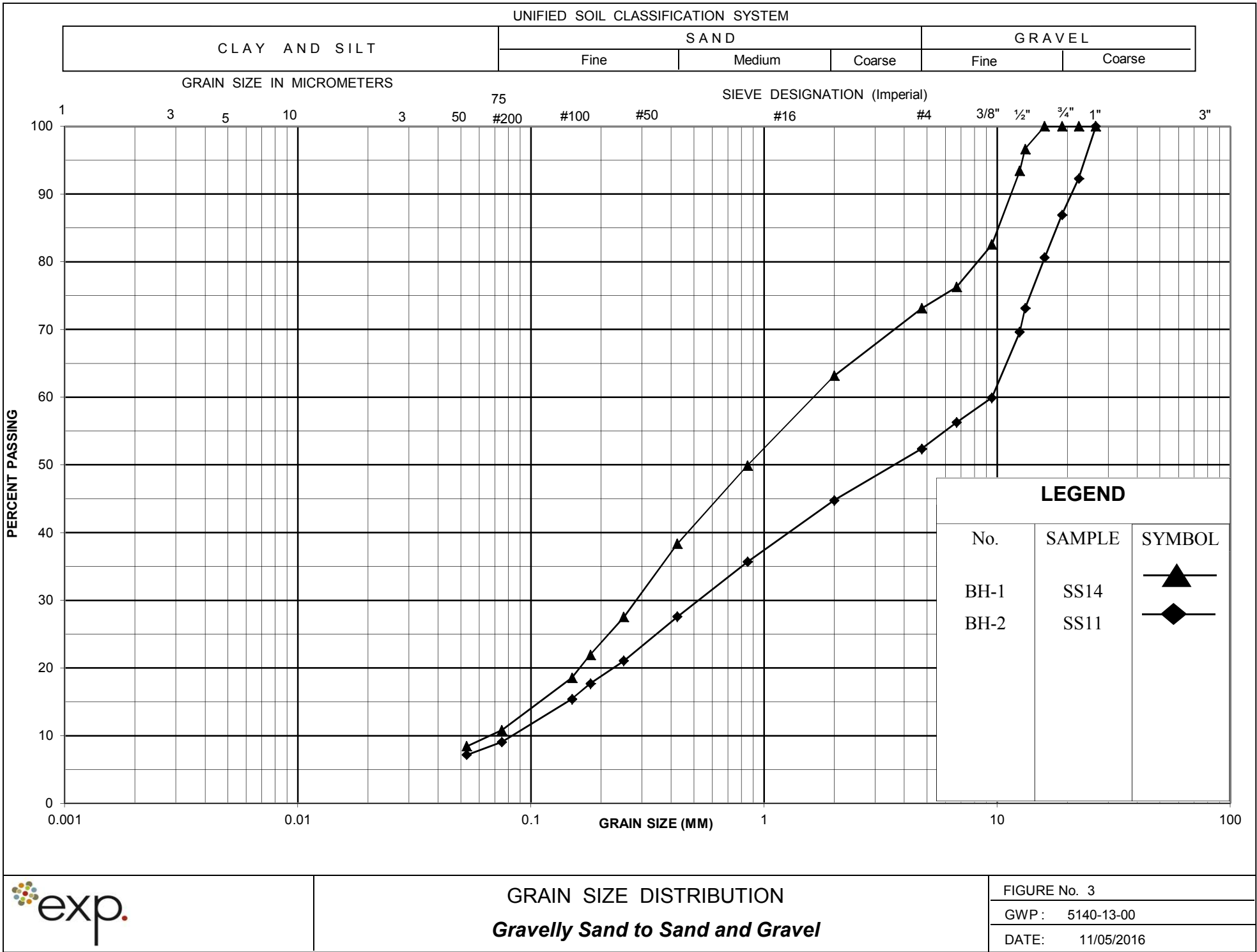
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE



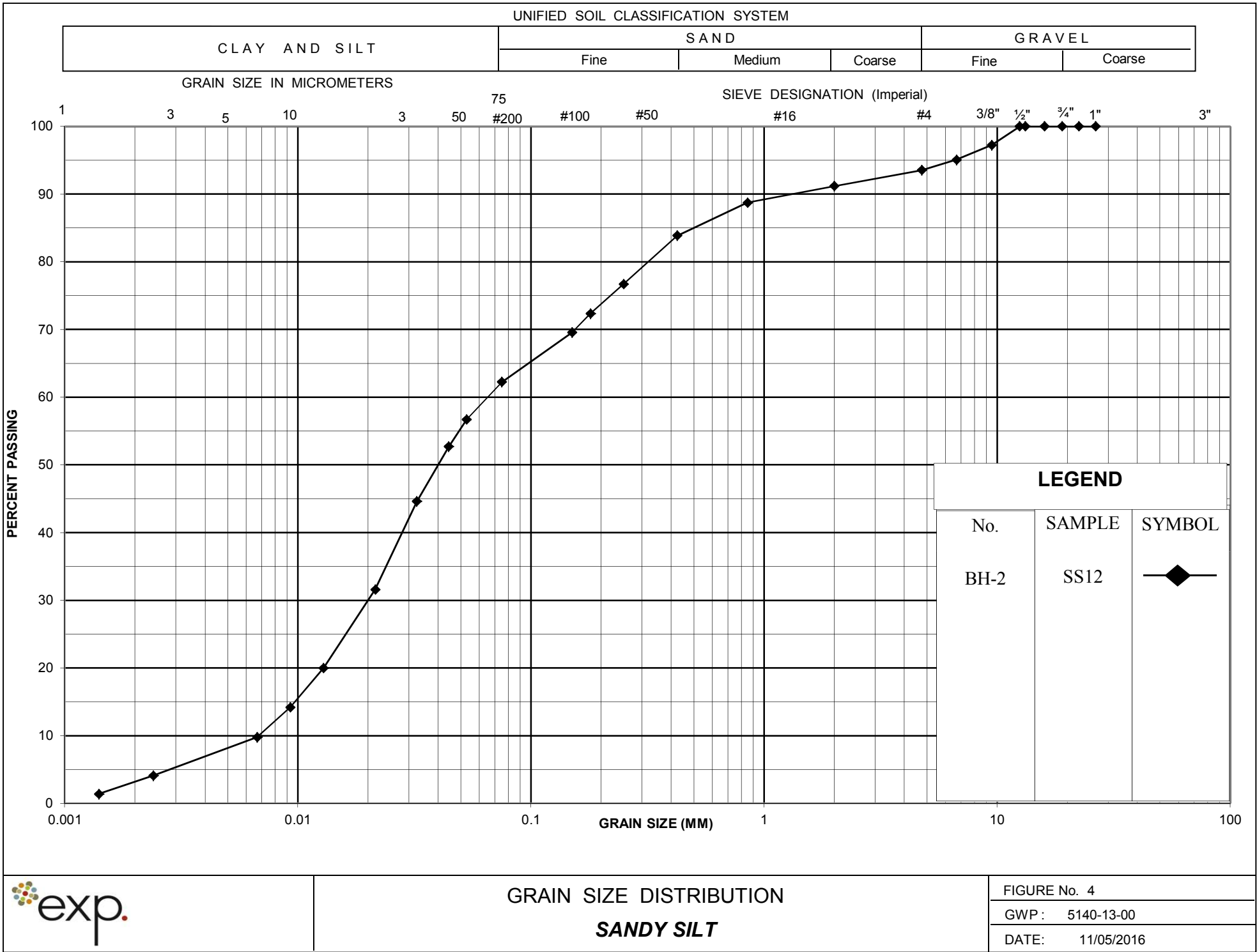
Previous Laboratory Test Results  
exp 2016













exp Services Inc.  
1595 Clark Boulevard  
Brampton, Ontario, L6T 4V1  
Tel: (905) 793-9800  
Fax: (905) 793-0641  
[www.exp.com](http://www.exp.com)

## Uniaxial Compressive Strength of Rock Cores

Project No.: ADM-00282450-P0 ADM-100

Project Name: 5013-E0008 Assignment #13

Date: April 19, 2016

Sample No.	BH1 UCT1	BH1 UCT2	BH1 UCT3
Location	23' – 25'	37'	38' – 40'
Date Received	April 19, 2016		
Date Tested	April 19, 2016		
Height – [mm]	86.0	115.0	117.0
Average Diameter – [mm]	47.0	47.0	47.0
Area [mm <sup>2</sup> ]	1734.9	1734.9	1734.9
L/D Ratio	1.83*	2.45	2.49
Failure Load [kN]	163.22	174.89	96.68
Compressive Strength – [MPa]	94.1	100.8	55.7
Remarks			

ASTM D4543, ASTM D2938

L/D Ratio: 2.0- 2.5

Minimum Diameter: 47.0 mm

\*L/D was less than the minimum requirements of 2.0

Testing Laboratory Representative Signature  
Ammanuel Yousif, C.E.T.

April 19, 2016

Date



# **CERCHAR Abrasivity test of three rock cores**

---

*Final Report*

May 4, 2016

Prepared by: Xin Wang, Research Engineer/Post-Doctoral Fellow  
Geomechanics Research Centre (GRC), MIRARCO

Reviewed by: Sean Maloney, VP Operations, GRC Director  
Geomechanics Research Centre (GRC), MIRARCO

Prepared for: Silvana Micic (PhD, PEng), Senior Geotechnical Engineer  
exp Services Inc.



## 1 Introduction

MIRARCO's Geomechanics Research Centre was contracted by Silvana Micic of exp Services Inc. to undertake a series of abrasivity tests on three select gneiss samples designated AT1, AT2, and AT3. These were collected from depths of 17.5'-20', 32'-35', and 38'-40' respectively and delivered to MIRARCO for testing. The abrasivity tests were conducted in accordance with ASTM Standard D7265-10 "Standard Test Method for Laboratory Determination of Abrasiveness of Rock Using the CERCHAR Method".

## 2 Background

Rock abrasivity is a characteristic of significance in estimating wear on mechanical excavation equipment such as core bits and disc cutters. While a number of tests have been proposed, the most widely accepted remains the CERCHAR scratch test (West 1989; Plinninger et al., 2003). In this test, a conical steel point of cone angle  $90^\circ$  is slowly drawn 10 mm across the rock surface under a normal, static force of 70 N. A drawing of the test device is presented in Figure 1. The abrasivity is then determined by the wear flat of the steel cone; units of measurement correspond to the diameter of the wear flat in tenths of a millimeter (e.g., a 0.3 mm diameter wear flat yields a measurement of 3). It is generally recommended that more than one measurement be made and the CERCHAR Abrasivity Index, *CAI*, be taken as the mean value.

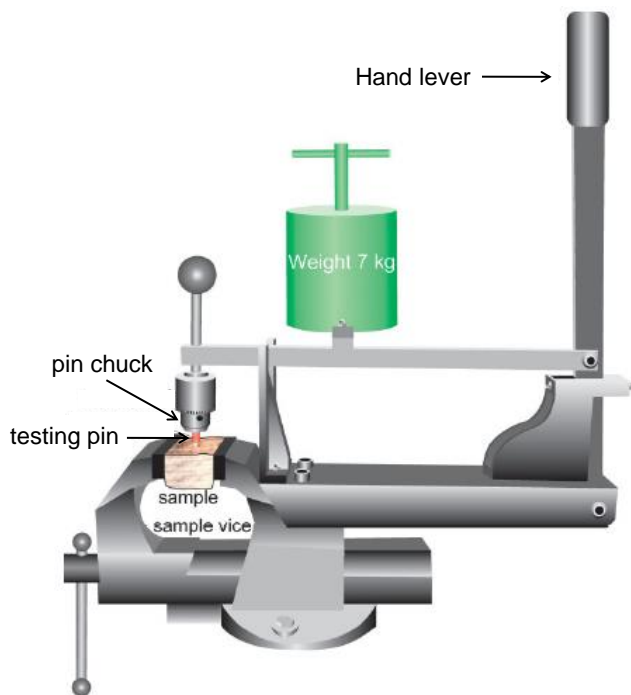


Figure 1 - CERCHAR test apparatus (after Plinninger and Restner, 2008)





Studies conducted by [Plinninger et al. \(2003\)](#) on the influence of surface conditions showed that  $CAI$  values obtained from 'rough' surfaces were about 0.5 higher than those from smooth surfaces. The authors recommended that for rock samples that have unsuitable sample surfaces after breaking, a diamond saw be used for surface formatting. The test result can be corrected according to the following equation:

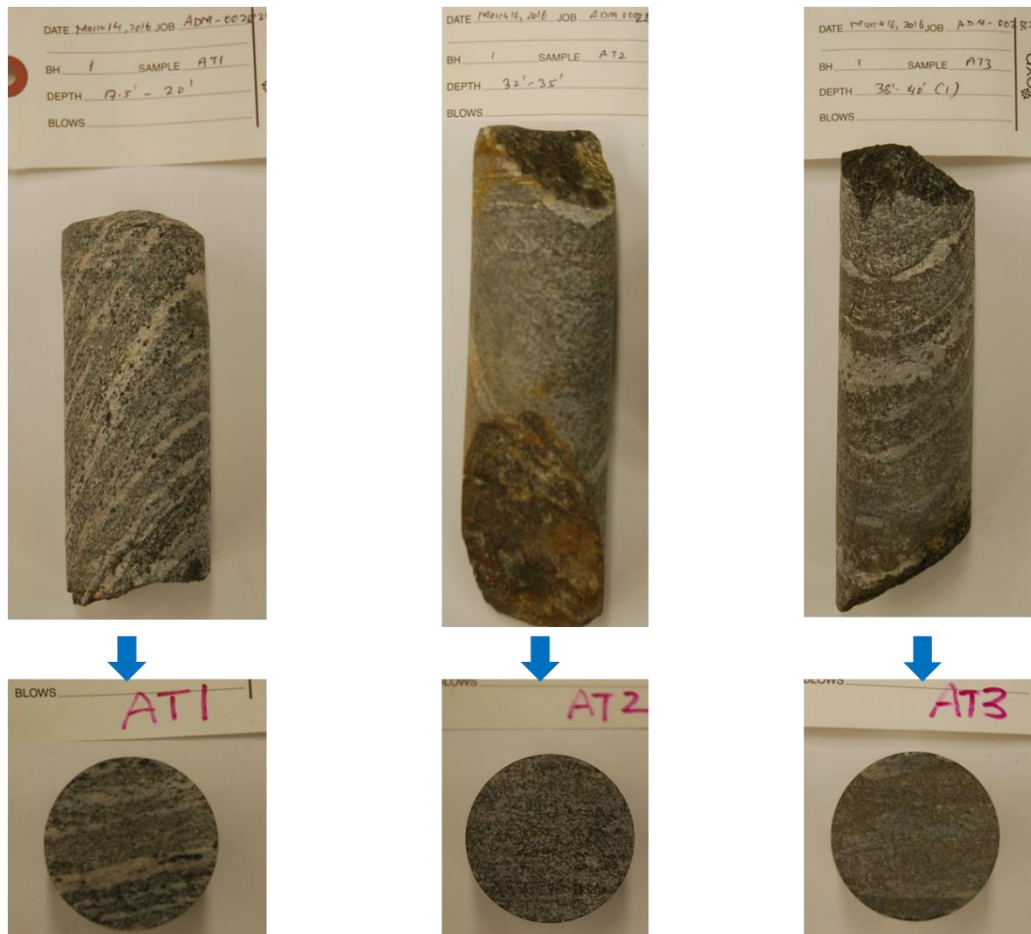
$$CAI = 0.99CAI_s + 0.48$$

where  $CAI_s$  represents the index obtained from the smooth surface.

### 3 Methodology

#### 3.1 Specimen preparation

All the testing processes were undertaken sequentially on each individual specimen to minimize the time of exposure prior to testing. In order to obtain a suitable fresh surface for testing, the samples were wet cut using a diamond saw in MIRARCO'S Laboratory. As shown in [Figure 2](#), three specimens (marked as AT1, AT2, and AT3) were prepared from the supplied core.

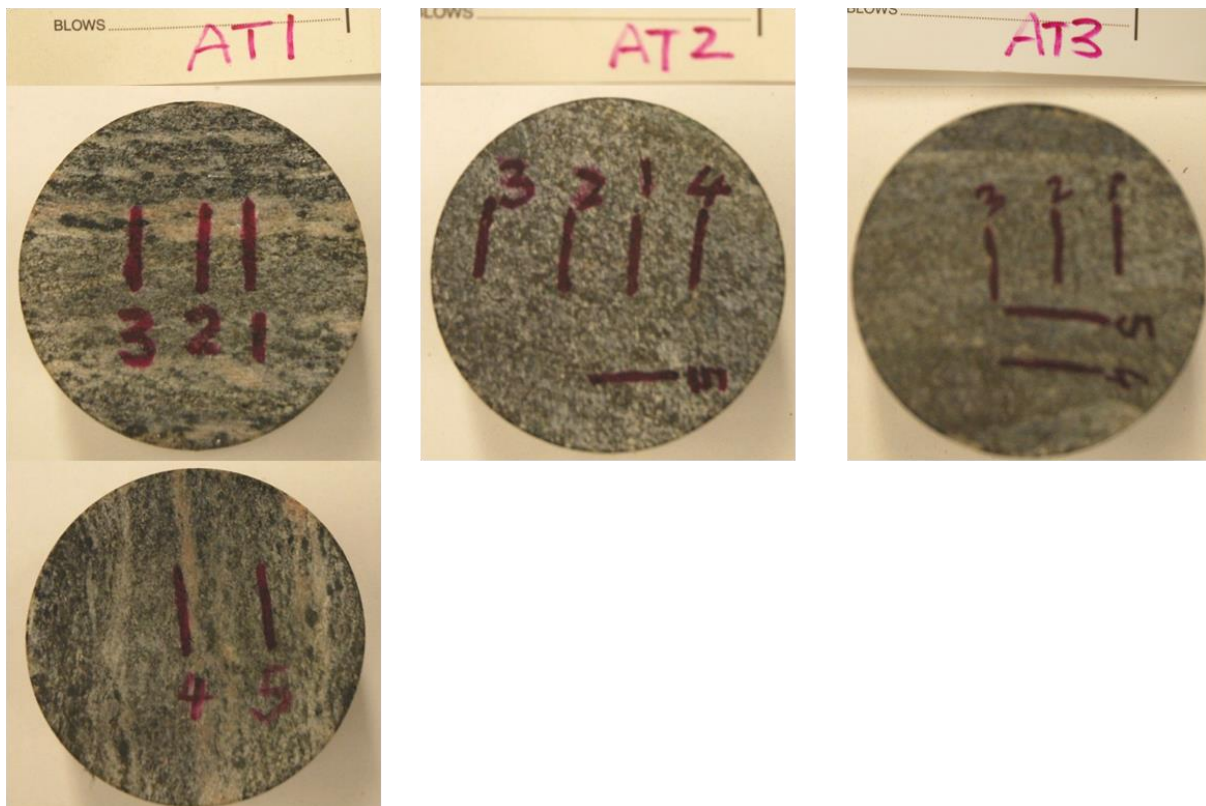


**Figure 2- The supplied core and three test specimens after cutting**



### 3.2 Testing

According to the ASTM Standard D7265-10, each specimen was clamped in position with the test surface horizontal. A new pin was placed in the chuck and carefully brought to bear against the surface under the prescribed load of 70N. Because there is a pronounced fabric existing in the specimens, most of the scratches were made with the fabric oriented perpendicular to draw direction. The pin was then drawn across the surface for a distance of 10 mm. It was then removed for inspection. Then, the specimen was repositioned and the test was repeated two more times for each specimen (the pins were examined after each test). If the first three scratches on a sample yielded relatively consistent results, the following two scratches were performed perpendicular to the first three to investigate the possibility of a directional variability in the abrasiveness. Photographs of the three specimens following testing are presented in [Figure 3](#).



*Figure 3-Specimens AT1, AT2, and AT3 after testing (scratches have been highlighted by marker pen)*

The wear flat of each pin is measured before and after testing using a Wild M38 binocular microscope with a measuring ocular at 40X magnification. All pins and the test surface were also photographed through a 6.0X magnification microscope for archival purposes before and after testing (see [Appendix](#)).

## 4 Results

The abrasivity values determined from the testing of the three specimens are shown in [Table 1](#). Individual CAI values ranged from 4.22 to 4.34 for specimen AT1; a quite consistent result. For



specimens AT2 and AT3, the *CAI* values were only slightly more variable, ranging from 4.22 to 4.83 and from 4.10 to 4.84, respectively. The average *CAI* values for specimens AT1, AT2 and AT3 are 4.32, 4.56 and 4.49, respectively. The overall average *CAI* value of the three specimens is 4.46.

**Table 1: Abrasivity test results**

Sample ID	Trial#	Wear Flat (mm)	<i>CAI<sub>s</sub></i>	<i>CAI</i>
AT1	1	0.39	3.90	4.34
	2	0.39	3.90	4.34
	3	0.38	3.80	4.22
	4	0.39	3.90	4.34
	5	0.39	3.90	4.34
	Mean.		3.88	4.32
	Standard Error.		0.055	0.054
AT2	1	0.39	3.90	4.34
	2	0.38	3.80	4.22
	3	0.44	4.40	4.83
	4	0.41	4.14	4.58
	5	0.44	4.41	4.83
	Mean.		4.12	4.56
	Standard Error.		0.278	0.275
AT3	1	0.41	4.15	4.58
	2	0.37	3.66	4.10
	3	0.39	3.90	4.34
	4	0.44	4.41	4.84
	5	0.41	4.14	4.58
	Mean.		4.05	4.49
	Standard Error.		0.281	0.278
Average <i>CAI</i>	Mean	4.46	Standard Error	0.124

The results obtained are consistent with published data for similar rock types as demonstrated in [Figure 4](#). According to the criteria established by [CERCHAR \(1986\)](#) (see [Table 2](#)), the three specimens would be classified as extremely abrasive. Using the more recent classification proposed by [Restner \(2007\)](#) (see [Table 3](#)) the rock would be considered as highly abrasive for the average *CAI* value (4.46) whereas Specimen AT2 itself would be classified as extremely abrasive.

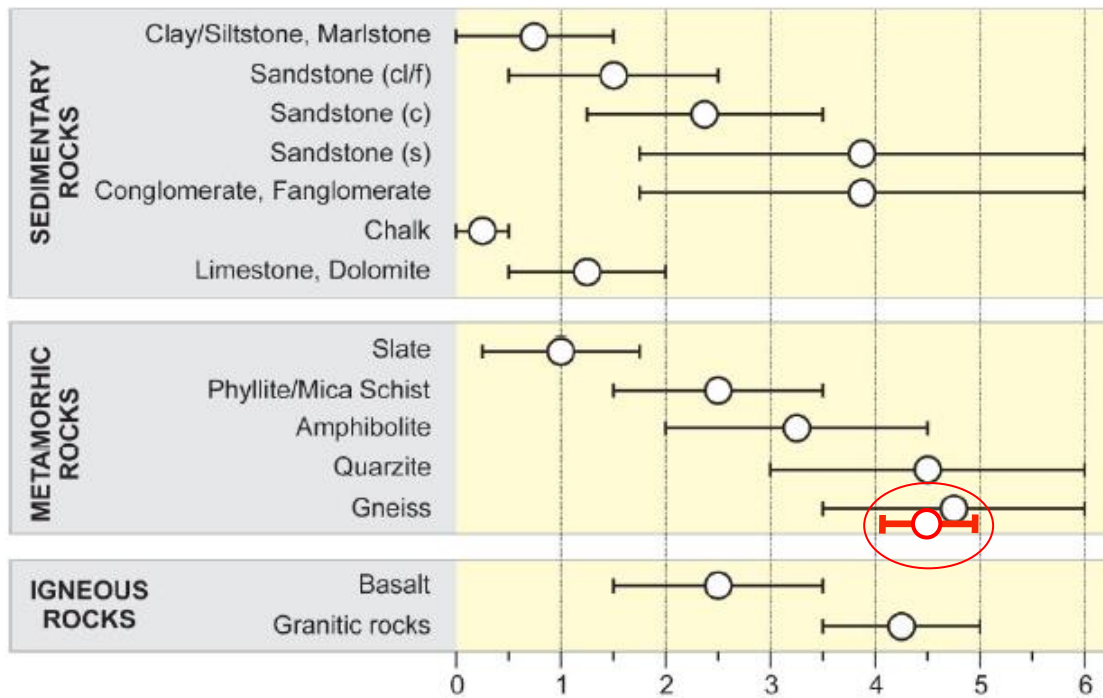


Figure 4- Comparison of test results (red) with compilation of typical CAI values (Plinninger and Restner, 2008)

Table 2: Classification of rock abrasiveness (CERCHAR, 1986)

CAI	Classification
0.3 – 0.5	not very abrasive
0.5 – 1.0	slightly abrasive
1.0 – 2.0	medium abrasive
2.0 – 4.0	very abrasive
4.0 – 6.0	extremely abrasive

Table 3: Modified classification of rock abrasiveness (Restner, 2007)

CAI	Classification
< 0.5	not abrasive
0.5 - 1.0	little abrasive
1.0 – 1.3	moderately abrasive
1.3 – 1.8	considerably abrasive
1.8 – 2.3	abrasive
2.3 – 3.0	very abrasive
3.0 – 4.5	highly abrasive
> 4.5	extremely abrasive





More recently, [Alber \(2008\)](#) showed that the CERCHAR Abrasivity Index is stress-dependent, i.e., the more the rock is confined the higher the CAI will be. This suggests that in situ CAI values are higher than unconfined lab values and correspondingly, more wear can be expected in the field. Note that this is particularly applicable to TBMs where various cutters are acting in different stress environments.

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Plinninger, R. and Restner, U. 2008. Abrasiveness testing, Quo Vadis? – A commented overview of abrasiveness testing methods. *Geomechanik and Tunnelbau*, Heft 1, 61-70.

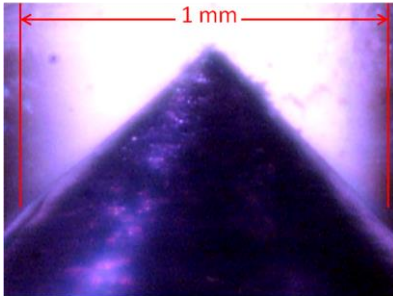
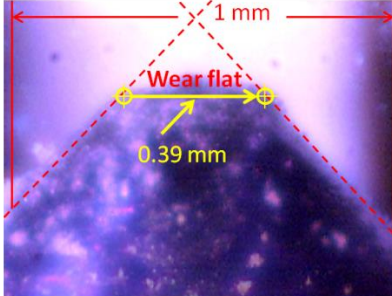
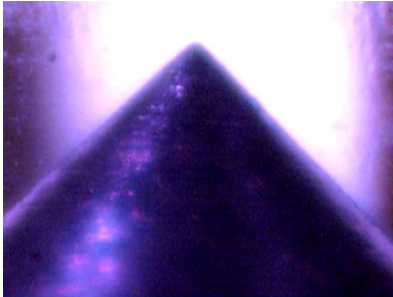
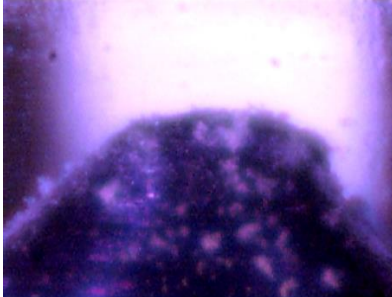
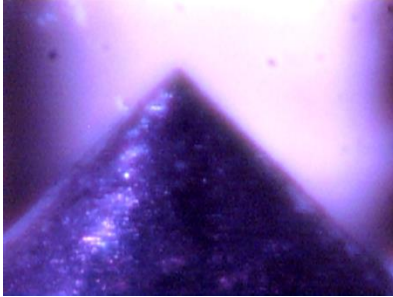
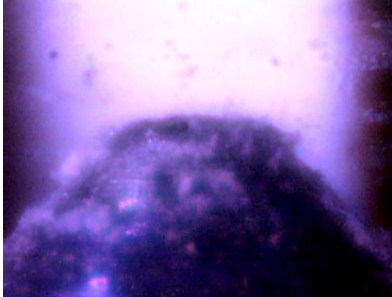
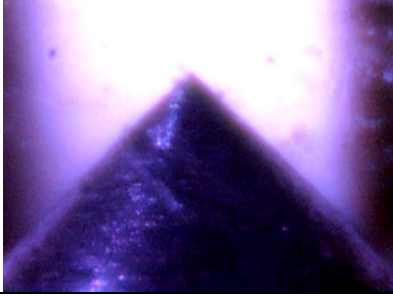
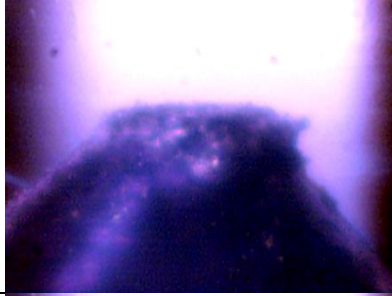
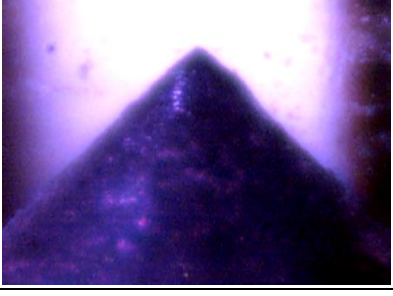
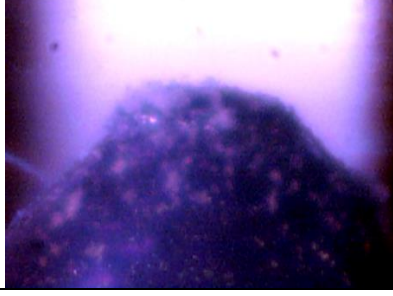
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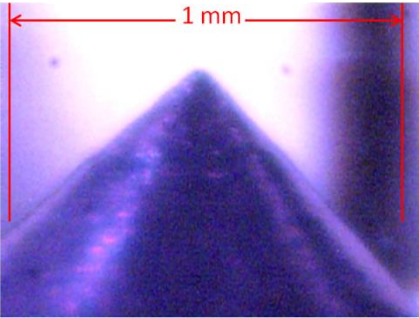
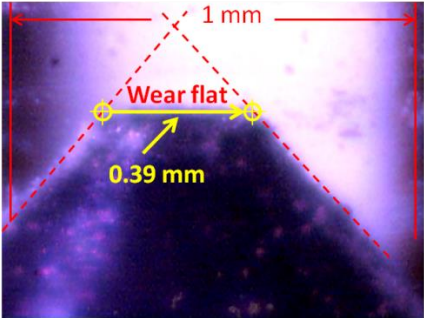
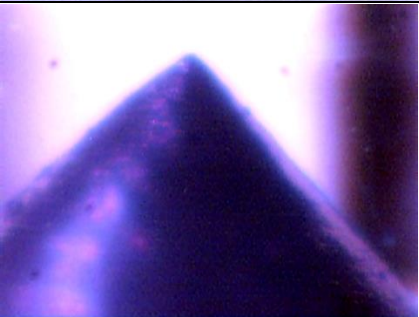
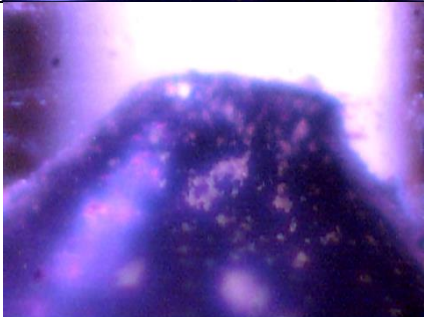
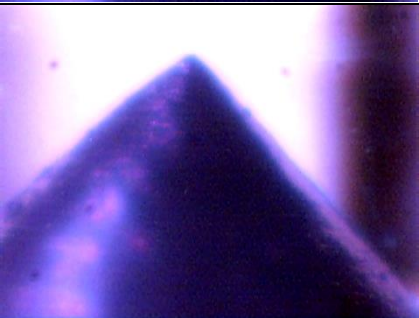
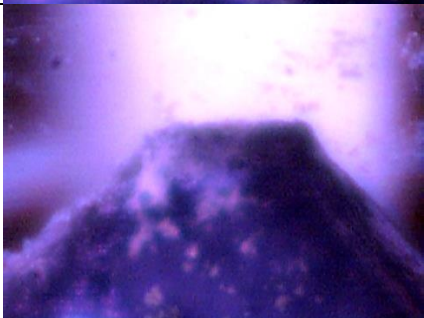
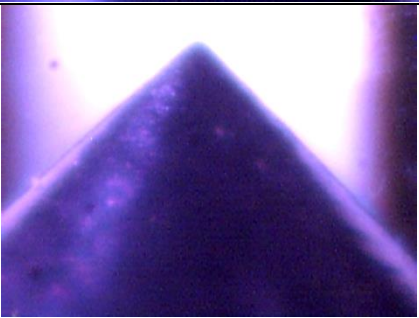
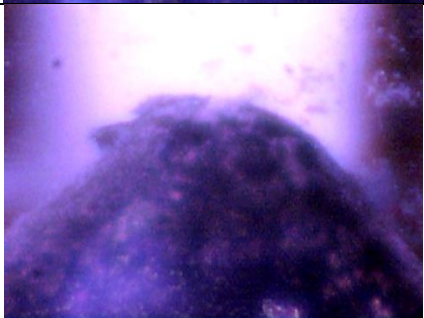
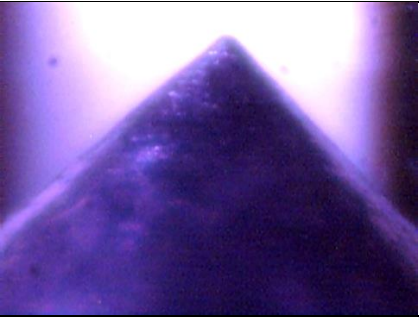
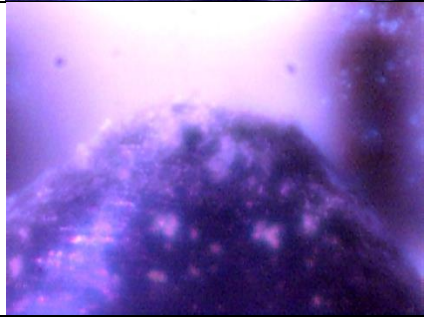
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## Appendix : Photographs of pins before and after testing

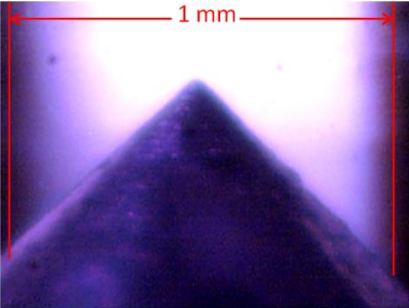
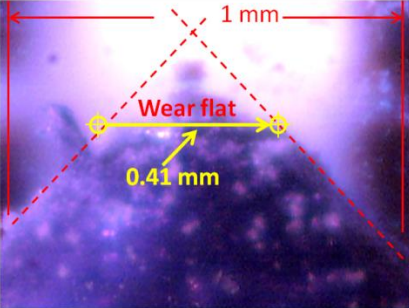
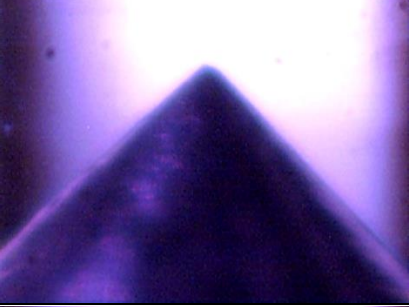
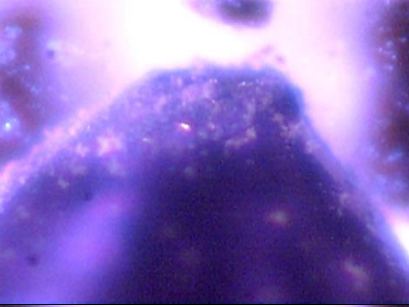
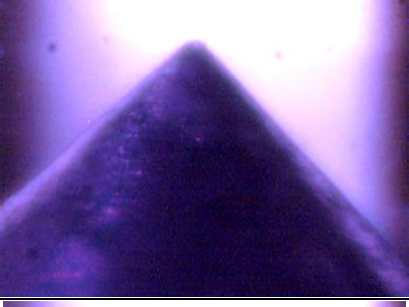
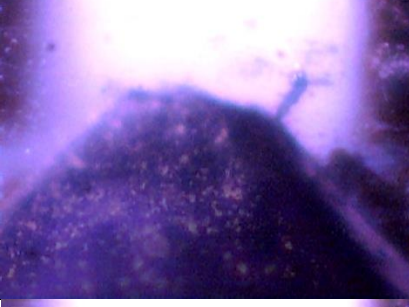
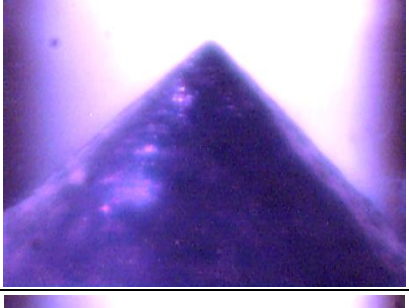
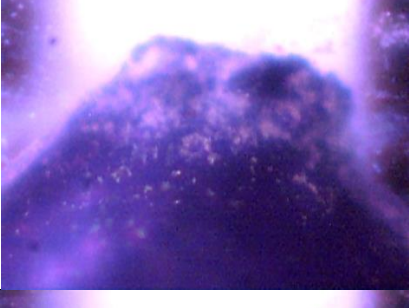
Specimen <b>AT1</b>		
Trail#	Before Test	After Test
AT1 - 1		
AT1 - 2		
AT1 - 3		
AT1 - 4		
AT1 - 5		



Specimen AT2		
Trail#	Before Test	After Test
AT2 - 1		
AT2 - 2		
AT2 - 3		
AT2 - 4		
AT2 - 5		





Specimen AT3		
Trail#	Before Test	After Test
AT3 - 1		
AT3 - 2		
AT3 - 3		
AT3 - 4		
AT3 - 5	