



FINAL REPORT REV.1

## Preliminary Foundation Investigation and Design Report

*Bradford Bypass / Hwy 404 Interchange Ramp Structures (S-W Ramp over Highway 404, W-N Ramp over S-W Ramp, W-N Ramp over Highway 404)  
Highway 400 to Highway 404 Link (Bradford Bypass)*

*Simcoe County and York Region*

*MTO Assignment No. 2019-E-0048*

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# **PART A**

**PRELIMINARY FOUNDATION INVESTIGATION REPORT  
BRADFORD BYPASS AND HIGHWAY 404 INTERCHANGE RAMP  
STRUCTURES (S-W RAMP OVER HIGHWAY 404, W-N RAMP OVER S-W  
RAMP, W-N RAMP OVER HIGHWAY 404)  
HIGHWAY 400 TO HIGHWAY 404 LINK (BRADFORD BYPASS)  
MTO ASSIGNMENT NO. 2019-E-0048**

## 1.0 INTRODUCTION

WSP Canada Inc. (formerly Golder Associates Ltd., now a member of WSP Canada Inc. and hereafter referenced as WSP) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed Bradford Bypass (BBP), a 16.3 km rural controlled access freeway connecting Highway 400 to Highway 404, in the County of Simcoe and Regional Municipality of York. This report presents the results of the foundation investigation carried out for planning and preliminary design of the following proposed ramp structures at the BBP/Highway 404 Interchange shown on the Key Plan of Drawing 1.

- **S-W Ramp over Highway 404:** 178 m long four (4) span structure carrying the Hwy 404/BBP S-W Ramp over Highway 404 located between approximately Station 10+595 to 10+773.
- **W-N Ramp over S-W Ramp:** 22 m long single-span structure carrying BBP/Hwy 404 W-N ramp over the BBP/Hwy 404 S-W Ramp located between approximately Station 10+664 to 10+686.
- **W-N Ramp over Highway 404:** 213 m long four (4) span structure carrying BBP/Hwy 404 W-N Ramp over Highway 404 located between approximately Station 10+789 to 11+002.

## 2.0 SITE DESCRIPTION

The site of the proposed BBP/Hwy 404 Interchange is located in the County of Simcoe and in the Town of East Gwillimbury, Ontario. Highway 404 is currently a four-lane highway with two northbound and two southbound lanes separated by a grassy median. The proposed interchange is located between Holborn Road and Queensville Sideroad (Highway 77) along Highway 404. The site (east and west of Highway 404) generally consists of farmland with some forested area and private residences in the northwest portion of the site. The existing ground surface generally slopes down from west to east at the proposed interchange location, with the Highway 404 grade appearing to have been constructed in a partial cut in this area. A buried telecommunication crossing (Bell) runs below Highway 404 at Holborn Road.



*Photograph 1 – East side of Hwy 404 near proposed Interchange (looking northwest)*



*Photograph 2 – West side of Hwy 404 near proposed Interchange (looking northeast)*

### 3.0 INVESTIGATION PROCEDURES

The field work for the current investigation was carried out between June 10 and 22, 2021 and August 4 to 8, 2023, during which time a total of four boreholes (designated 404-1 to 404-4) were advanced at the locations shown on Drawing 1.

All boreholes were advanced using 210 mm outside diameter (O.D.) hollow-stem augers followed by wash-rotary techniques (advancement of tricone with water/drilling mud) using a track-mounted or truck-mounted drill equipped with water tanks/totes, supplied and operated by Walker Drilling Inc. of Utopia, Ontario. The wash-rotary technique was used to counter-balance hydrostatic forces and reduce disturbance at the sampling and testing interval. Water used for drilling operations was brought to site in totes (portable plastic tanks) by the drilling subcontractor.

Soil samples were generally obtained at 0.75 m, 1.5 m, and 3.0 m intervals of depth using a 50 mm O.D. split-spoon sampler driven with an automatic hammer in general accordance with Standard Penetration Test (SPT) procedure (ASTM D1586)<sup>1</sup>.

The water level was typically not measured in the open boreholes due to the introduction of water during drilling operations, unless otherwise noted on the drilling records. Standpipe piezometers were installed in Boreholes 404-1, 404-2 and 404-4 and were screened within the silt and sand till, clayey silt and clayey silt till deposits, respectively. The installed piezometers consist of a 50 mm diameter PVC pipe, with a 3 m long slotted screen within a filter sand pack. The borehole and annulus surrounding the piezometer pipe above the filter sand pack were backfilled to near ground surface with bentonite pellets. The monitoring wells were capped with flush-mount or monument casings, as appropriate.

The field work was monitored on a full-time basis by a member of WSP's engineering staff who located the boreholes in the field, directed the sampling and in-situ testing operations, logged the boreholes, and examined the soil samples. The soil samples were identified in the field, placed in labelled containers, and transported to WSP's laboratory in Mississauga for further visual review and geotechnical laboratory testing. Index and classification testing consisting of natural moisture content, Atterberg limits and grain size distribution were conducted on selected samples. All laboratory tests were carried out in general accordance with MTO and / or ASTM Standards, as applicable.

Four soil samples, one obtained from each borehole, were submitted to a specialist analytical laboratory (Bureau Veritas Laboratories of Mississauga, Ontario) under chain of custody procedures for testing of electrical conductivity / resistivity, pH, chemical analysis of sulphate and chloride content, to assess the potential for the soil to cause deterioration to buried concrete and corrosion to steel.

The borehole locations were surveyed in the field by Geoverra (a licensed surveyor) or WSP personnel using a Trimble Geo 7X Global Positioning System (GPS) unit. The survey readings achieved a horizontal and vertical accuracy of less than 5 cm. The locations given on the borehole records and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum (CGVD28 datum). The borehole locations, including the geographic (Latitude / Longitude) coordinates, the ground surface elevations, and borehole depths are summarized below.

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<sup>1</sup> ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

Borehole No.	MTM NAD 83 Northing (m) (Latitude, °)	MTM NAD 83 Easting (m) (Longitude, °)	Ground Surface Elevation (m)	Borehole Depth / Termination Elevation (m)
404-1	4890573.8 (44.155147)	309312.9 (-79.443581)	257.8	21.6 / 236.2
404-2	4890800.0 (44.157182)	309464.1 (-79.441689)	252.5	31.0 / 221.6
404-3	4890667.6 (44.155991)	309421.5 (-79.442223)	252.6	18.8 / 233.8
404-4	4890426.9 (44.153824)	309549.5 (-79.440624)	252.1	31.0 / 221.1

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

This section of the Bradford Bypass is located in an area defined as the Simcoe Lowlands physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)<sup>2</sup>.

The Simcoe Lowlands physiographic region covers the central portion of the County of Simcoe. Following the retreat of the last glacial ice sheet, the lowland was flooded by the now extinct post-glacial Lake Algonquin. This past post-glacial lacustrine environment is marked by deep sand, silt and clay beds overlying glacial ground moraine material.

### 4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes from the current investigation including piezometer installation details and water level readings, and the results of the in-situ and laboratory tests are provided on the borehole records in Appendix A. The results of the in-situ field tests (i.e., SPT “N”-values) as presented on the borehole records and in Section 4 are uncorrected and are based on use of an automatic hammer. The detailed results of the geotechnical laboratory testing on soil samples are presented on the laboratory test figures in Appendix B. The results of the analytical testing are provided in Appendix C.

The stratigraphic boundaries shown on the borehole records and on the stratigraphic profile on Drawings 1 and 2 are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected.

In general, the soils encountered at this site consist of surficial layers of topsoil/fill underlain by stiff to hard clayey silt (upper cohesive deposit) to very dense sandy silt, further underlain by a hard clayey silt till and very stiff to hard clayey silt to clayey silt-silt deposit (lower cohesive deposit) or silt and sand to silty sand (till) deposit. A layer of

<sup>2</sup> Chapman, L.J. and Putnam, D.F. 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

very dense sandy silt to silt was encountered within the lower cohesive deposit in Boreholes 404-3 and 404-4 and the lower cohesive deposit generally transitions to a slightly plastic silt at depth.

More detailed descriptions of the major soil layers encountered in the boreholes are provided in the following sections.

#### **4.2.1 Fill**

A 0.7 m to 1.4 m thick layer of fill consisting of sand and gravel to sandy silt was encountered at ground surface in all boreholes (Boreholes 404-1 to 404-4). The sandy gravelly silt transitioned to a sandy clayey silt in the lower 0.4 m and 0.7 m of the fill in Boreholes 404-1 and 404-2, respectively. A 250 mm thick layer of topsoil (possibly re-worked native soil from farming activities) was encountered above the fill in Borehole 404-1.

The SPT 'N'-values measured within the cohesionless fill (sand and gravel to sandy silt) ranged between 4 and 34 blows per 0.3 m of penetration, indicating a loose to dense state of compactness. The SPT 'N'-value measured within the cohesive fill (clayey silt to sandy clayey silt) was 6 and 31 blows per 0.3 m of penetration, suggesting a firm and hard consistency, respectively.

The water content measured on samples of the fill ranges from about 8% to 26%. The results of grain size distribution and Atterberg limits testing carried out on samples of the sandy silt fill are shown on Figures B1 and B2 and indicate the sandy silt has slight plasticity (measured liquid limit of 16%, plastic limit of 13%, and plasticity index of 3%). Atterberg limits testing carried out on a sample of the clayey silt fill measured a liquid limit of 29%, plastic limit of 16%, and plasticity index of 13% as presented on Figure B3. The results of the Atterberg limits testing indicate the cohesive portion of the fill is clayey silt of low plasticity.

#### **4.2.2 Clayey Silt-Silt to Clayey Silt**

A 1.7 m thick layer of sandy clayey silt-silt to clayey silt was encountered below the fill in Borehole 404-1. The upper 0.9 m of the deposit contains rootlets, and the lower 0.8 m of the deposit contains silt seams.

The SPT 'N'-values measured within the clayey silt-silt to clayey silt deposit were 16 and 33 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency.

The water content measured on samples of the deposit were 10% and 29%.

#### **4.2.3 Silt to Sandy Silt**

A 2.3 m and 3.0 m thick layer of silt to sandy silt was encountered below the layer of clayey silt to sandy clayey silt-silt in Borehole 404-1 at a depth of 3 m (El. 254.8 m) and below the fill in Borehole 404-3 at a depth of 0.7 m (El. 252 m).

The SPT 'N'-values measured within the silt to sandy silt range from 76 blows per 0.3 m of penetration to greater than 100 blows per 0.13 m of penetration indicating a very dense state of compactness.

The water content measured on samples of the deposit range between 8% and 20%. The results of grain size distribution and Atterberg limits testing carried out on samples of the sandy silt are shown on Figures B4 and B5 respectively. The Atterberg limits testing measured a liquid limit of 14% and 16%, plastic limit of 12% and 14%, and plasticity index of 2% suggesting the silt to sandy silt is slightly plastic.

#### 4.2.4 Clayey Silt (Upper Cohesive Deposit)

Underlying the fill material in Boreholes 404-2 and 404-4 and below the sandy silt layer in Borehole 404-3, a cohesive deposit of clayey silt, trace sand, trace gravel was encountered. The clayey silt layer (designated upper cohesive deposit) was encountered at a depth of 1.4 m to 3.7 m below ground surface (El. 251.1 m to El. 248.9 m) and is 0.8 m to 5.8 m thick.

The SPT 'N'-values measured in the clayey silt range from 14 to 75 blows per 0.3 m of penetration, suggesting a stiff to hard consistency.

The water content measured on samples of the clayey silt ranges between approximately 13% and 23%. The results of grain size distribution and Atterberg limits testing carried out on samples of the clayey silt are presented on Figures B6 and B7. Atterberg limits measured a liquid limit of 32% to 34%, plastic limit of 17%, and plasticity index of 15% to 17% which indicate the cohesive deposit is clayey silt of low plasticity.

#### 4.2.5 Clayey Silt Till

Below the upper cohesive deposit in Boreholes 404-3 and 404-4, a glacial till deposit consisting of cohesive clayey silt to clayey silt-silt, trace to some sand and trace gravel was encountered at a depth of 4.5 m (El. 248.1 m) and 5.6 m (El. 246.5 m), respectively. The approximate thickness of the till deposit was about 4 m to 5 m.

The SPT 'N' values measured in the till generally range from 31 to 99 blows per 0.3 m penetration suggesting a hard consistency; one sample in Borehole 404-3 has an SPT 'N' value of 67 blows per 0.13 m of penetration. The water content measured on a sample of the cohesive till was 13%. The results of grain size distribution and Atterberg limits testing carried out on a sample of the cohesive till are presented on Figures B8 and B9. Atterberg limits measured a liquid limit of 24%, plastic limit of 12%, and plasticity index of 12% indicating a clayey silt of low plasticity.

#### 4.2.6 Silt to Silty Sand Till

A silt to silty sand till deposit was encountered below the silt to sandy silt deposit in Borehole 404-1. The deposit contained sand seams at a depth of about 19.8 m (El. 238 m). The borehole was terminated in this layer after about 16.3 m of penetration into the non-cohesive till deposit. Auger grinding was noted within the deposit at a depth of 10.1 m (El. 247.7 m).

The SPT 'N'-values measured within the silt to silty sand till deposit range from 100 blows for 0.13 m of penetration to 100 blows for 0.21 m of penetration, and bouncing of the split spoon (i.e. effective refusal) was noted at several sample depths within the deposit. The SPT 'N'-values indicate a very dense state of compactness.

The water contents measured on samples of the non-cohesive till deposit range from 10% to 18%. The results of grain size distribution tests carried out on three samples of the non-cohesive till deposit are presented on Figure B10. Atterberg limits tests were conducted on three samples of the non-cohesive deposit, two of the samples indicate that the soil is non-plastic and one sample indicates that the fines component is a silt of slight plasticity (measured liquid limit of 16%, plastic limit of 14%, and plasticity index of 2%). The results of the Atterberg limits tests are presented on Figure B11.

#### **4.2.7 Clayey Silt to Clayey Silt-Silt (Middle Cohesive Deposit)**

The upper cohesive deposit (clayey silt) generally transitioned to a clayey silt-silt (middle cohesive deposit) in Borehole 404-2, and this middle deposit denotation is also based on the elevations encountered in Boreholes 404-3 and 404-4 where the clayey silt to clayey silt-silt (middle cohesive deposit) was encountered below the till deposit. The middle cohesive deposit was encountered at a depth ranging from 7.2 m to 10.2 m below ground surface (El. 245.4 m to 241.9 m) and was measured to range from 5 m to 21 m thick. The middle cohesive deposit contained an interlayer of sandy silt to silt in Boreholes 404-3 and 404-4 as described in the next section. Borehole 404-4 was terminated in the lower cohesive deposit at a depth of 31.1 m below ground surface (Elevation 221.1 m).

The SPT 'N'-values measured in the clayey silt to clayey silt-silt deposit typically range from 19 to 72 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency. One SPT 'N'-value of greater than 160 blows per 0.3 m of penetration was measured in Borehole 404-3.

The water content measured on samples of the clayey silt to clayey silt-silt was about 22% to 23%. The results of grain size distribution and Atterberg limits testing carried out on samples of the clayey silt to clayey silt-silt are presented on Figures B12 and B13 respectively. Atterberg limits measured liquid limits ranging from 24% to 33%, plastic limits ranging from 17% to 19%, and plasticity indices ranging from 6% to 16% and indicate the deposit is a clayey silt to clayey silt-silt of low plasticity.

#### **4.2.8 Sandy Silt to Silt**

Underlying the middle cohesive deposit, a layer of sandy silt to silt, trace gravel was encountered in Boreholes 404-3 and 404-4. The silty layer was encountered at a depth of 14.8 m below ground surface (El. 237.9 m to El. 237.3 m) and was measured to be about 4 m to 5 m thick. Borehole 404-3 was terminated in this layer.

The SPT 'N'-values measured within this layer range from about 98 blows per 0.3 m penetration to greater than 100 blows per 0.2 m of penetration indicating a very dense state of compactness.

The water contents measured on two samples of the silt were 18% and 19%. The results of a grain size distribution carried out on a sample of the sandy silt to silt is presented on Figure B14. One Atterberg limits test conducted on a sample of the silty soil indicates the layer is non-plastic.

#### **4.2.9 Lower Clayey Silt-Silt to Silt**

Underlying the middle cohesive deposit in Borehole 404-2, a layer of clayey silt-silt to silt with slight plasticity was encountered at a depth of 27.9 m (El. 224.6 m). The borehole was terminated in this layer after about 3 m of penetration into the silty layer.

One SPT 'N' -value measured in this layer was 81 blows per 0.28 m of penetration, suggesting a hard consistency.

The water content measured on a sample of the silty layer was 19%. The results of Atterberg limits testing carried out on one sample of the silty layer are shown on Figure B15 and indicate a liquid limit of 18%, plastic limit of 15%, and plasticity index of 3%, suggesting the silty layer has slight plasticity.

### **4.3 Groundwater Conditions**

The water levels measured in the open boreholes at the time of the investigation are shown on the borehole records and are not considered representative of the hydrostatic water levels at the site due to the addition of drilling fluids/water into the boreholes and/or considering the water levels did not have sufficient time to stabilize.

A standpipe piezometer was installed in Boreholes 404-1, 404-2 and 404-4 to allow monitoring of the groundwater level at this site. The groundwater levels recorded in the piezometers are shown on the borehole records in Appendix A and are summarized below.

Borehole No. (Piezometer)	Depth (Elevation) of Screen Interval / Sand Pack (m)	Depth of Water Level (m)	Water Level Elevation (m)	Date of Water Level Reading
404-1	7.6 – 10.6 (EL. 250.2 to 247.2)	--Note 1	--Note 1	-
		6.7	251.1	November 29, 2023
404-2	3.1 – 6.1 (El. 249.4 to 246.4)	--Note 1	--Note 1	-
		--Note 2	--Note 2	-
404-4	6.1 – 9.1 (El. 245.9 to 242.9)	3.0 <sup>Note 3</sup>	249.1 <sup>Note 3</sup>	June 15, 2021
		4.2	247.9	March 22, 2022

Notes:

1. Water level not measured due to introduction of water during drilling operations.
2. After installation, the well could not be relocated despite several visits to the site and hand digging with a shovel in the general vicinity of the installed location. In July 2022, a portable metal detector capable of scanning for metal underground was used to scan the location for the steel flush mount casing without success. It has been determined that the upper portion of the well has been demolished since installation, likely by site grading activities.
3. Water level measured during drilling activities in open borehole prior to introducing water as part of mud rotary technique.

The groundwater level observations at this site will be subject to seasonal fluctuations and precipitation events; the water levels should be expected to be higher during the spring season or during and following periods of heavy precipitation and snow melt.

## 4.4 Analytical Testing Results

Four soil samples were submitted for analysis of parameters used to assess the potential corrosivity of the site soil to steel and concrete. Detailed analytical test results are included in Appendix C and the test results are summarized below:

Borehole No. - Sample No.	pH	Resistivity (ohm-cm)	Electrical Conductivity (µmho/cm)	Soluble Chlorides (µg/g)	Soluble Sulphates (µg/g)
404-1 – 3	7.70	5800	173	<20	43
404-2 – 4	7.87	3200	316	130	46
404-3 – 3	8.02	810	1240	570	250
404-4 – 4	7.88	700	1430	780	100

## 5.0 CLOSURE

This Preliminary Foundation Investigation Report was prepared by Ms. Priyanka Talukdar, an Engineer in Training at WSP, and Ms. Madison Kennedy, P.Eng., a Geotechnical Engineer with WSP. Mr. Kevin Bentley, P.Eng., a Geotechnical Engineer with WSP and MTO Principal Foundations Contact conducted a technical review of the report. Ms. Lisa Coyne, P.Eng., a Geotechnical Engineer with WSP and MTO Principal Foundations Contact conducted a quality control review of the report.

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# **PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT  
BRADFORD BYPASS AND HIGHWAY 404 INTERCHANGE RAMP  
STRUCTURES (S-W RAMP OVER HIGHWAY 404, W-N RAMP OVER S-W  
RAMP, W-N RAMP OVER HIGHWAY 404)  
HIGHWAY 400 TO HIGHWAY 404 LINK (BRADFORD BYPASS)  
MTO ASSIGNMENT NO. 2019-E-0048**

## 6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

### 6.1 General

This section of the report provides foundation recommendations for planning and preliminary design of the Bradford Bypass and Highway 404 interchange ramp structures. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced as part of the current subsurface exploration.

The Preliminary Foundation Design Report (Part B of this report) including the discussion and preliminary recommendations are intended for the use of MTO and their designers for planning and preliminary design and shall not be relied upon for any other purpose or by any other parties, including the construction contractor or design-build proponents. Contractors undertaking the work must make their own interpretation based on the factual data presented in the Preliminary 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 concept and preliminary design of the project and for which special provisions may be required in the future Contract Documents. Those requiring information on aspects of detail design and construction must make their own interpretation of the factual information provided and supplement as necessary, as such interpretation may affect detail design, equipment selection, proposed construction methods, scheduling and the like.

### 6.2 Project Understanding

Based on the latest Bradford Bypass mainline alignment and profile drawings and Highway 404 Interchange General Arrangement drawings provided by AECOM (dated May and November 2023, respectively), the proposed BBP / Highway 404 Interchange will consist of three ramp structures as follows:

- **S-W Ramp over Highway 404:** a four (4) span structure carrying the Highway 404/BBP S-W Ramp over Highway 404 located between Station 10+595 to 10+773 (about 178 m long and 14 m wide). The east and west approach embankments are anticipated to be up to 10 m high and 4 m high above existing ground surface (adjacent to where Highway 404 is construction in a cut) respectively.
- **W-N Ramp over S-W Ramp:** a single-span structure carrying BBP/Highway 404 W-N ramp over the BBP/Highway 404 S-W Ramp located between Station 10+664 to 10+686 (about 22 m long and 14 m wide). The west and east approach embankments are both anticipated to be up to 12 m high with retaining walls proposed at each quadrant.
- **W-N Ramp over Highway 404:** a four (4) span structure carrying BBP/Highway 404 W-N Ramp over Highway 404 located between Station 10+789 to 11+002 (about 213 m long and 14 m wide). The south and north approach embankments are anticipated to be up to 13.5 m high and 13 m high above existing ground surface respectively. At the south side, the height of the embankment will be almost 19 m higher than the adjacent Highway 404 road surface (which is understood to have been constructed in a cut) to accommodate the height required for the adjacent “ramp over ramp” structure located directly to the west.

The structural classification of the bridge(s) is defined as “major route” by the structural designer at this preliminary stage.

## 6.3 General Foundation Design Context

### 6.3.1 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code CAN/CSA S6-19* (CHBDC, 2019) and its *Commentary*, the ramp structures and foundation system may be classified as having large traffic volumes and their performance as having potential impacts on other transportation corridors, resulting in a “typical consequence level” associated with exceeding limit states design.

Based on the preliminary level of foundation investigation completed to date at this location (see Part A of this report) in comparison to the degree of site understanding, the level of confidence for design of the multi-span ramp foundation elements and approach embankments has been assessed as a “low degree of site and prediction model understanding”. At the time of investigation and issue of this report, the locations of the abutments and pier foundations were not confirmed, and hence boreholes may not be located at/near each of the proposed ramp structure abutments. As such, the recommendations contained in the report are generalized for planning and ongoing preliminary design and further investigation will be required when actual locations of the abutments and piers are confirmed.

Accordingly, the ultimate limit state (ULS) and serviceability limit state (SLS) consequence factor,  $\Psi$ , and geotechnical resistance factors,  $\phi_{gu}$  and  $\phi_{gs}$  for a low degree of site understanding, from Tables 6.1 and 6.2 of CHBDC (2019) have been used at this stage of preliminary design. During detail design, additional investigation and testing must be performed to increase the level of confidence and modify the geotechnical resistance factors as appropriate. In addition, reference is made to the MTO Material Engineering and Research Office (MERO) Memorandum #2020-01 (dated March 23, 2020) for future settlement and stability analyses during detail design, as applicable.

### 6.3.2 Seismic Design

#### 6.3.2.1 Seismic Site Classification

The subsurface conditions for seismic site characterization were assessed based on the results of the field investigation. Based on the energy-corrected average standard penetration resistance,  $\bar{N}_{60}$  and average undrained shear strength,  $s_u$  within the upper 30 m of the overburden below the founding level (assumed to be existing ground surface), the site may be classified as Site Class C for the W-N Ramp Over S-W Ramp structure and the site may be classified as Site Class D for the S-W Ramp Over Highway 404 and W-N Ramp Over Highway 404 structures in accordance with Table 4.1 of the CHBDC (2019), in the absence of site-specific shear wave velocity measurements. Geophysics testing (vertical seismic profiling or multi-channel analysis of surface waves (MASW)), if carried out, may provide a more favourable Site Class designation for the S-W Ramp and W-N Ramp over Highway 404 structures and can be considered during detail design.

The CHBDC (2019) states that the seismic hazard values associated with the design earthquakes should be those established for the *National Building Code of Canada* (NBCC) by the Geological Survey of Canada (GSC). The 2015 seismic hazard maps (referred to as the 5<sup>th</sup> generation seismic hazard maps) were developed by the GSC and were made available for public use in December 2015 and have been used for preliminary design for this project, as referenced in CHBDC (2019).

### 6.3.2.2 Spectral Response Values and Seismic Performance Category

In accordance with Section 4.4.3.1 of the 2019 CHBDC, the peak ground acceleration ( $PGA$ ), peak ground velocity ( $PGV$ ) and 5% damped spectral response acceleration ( $S_a(T)$ ) values for Site Class C and D were obtained for the bridge sites using the NBCC website ([earthquakescanada.nrcan.gc.ca](http://earthquakescanada.nrcan.gc.ca)) and are summarized below.

#### Site Class C – Peak Ground Acceleration, Peak Ground Velocity, and Spectral Response

Seismic Hazard Values for Site Class C	10% Exceedance in 50 years (475-year return period)	5% Exceedance in 50 years (975-year return period)	2% Exceedance in 50 years (2,475-year return period)
$PGA$ (g)	0.030	0.047	0.075
$PGV$ (m/s)	0.027	0.043	0.068
$S_a(0.2)$ (g)	0.053	0.080	0.124
$S_a(0.5)$ (g)	0.037	0.055	0.083
$S_a(1.0)$ (g)	0.022	0.032	0.049
$S_a(2.0)$ (g)	0.011	0.016	0.025
$S_a(5.0)$ (g)	0.002	0.004	0.006
$S_a(10.0)$ (g)	0.001	0.002	0.003

#### Site Class D – Peak Ground Acceleration, Peak Ground Velocity, and Spectral Response

Seismic Hazard Values for Site Class D	10% Exceedance in 50 years (475-year return period)	5% Exceedance in 50 years (975-year return period)	2% Exceedance in 50 years (2,475-year return period)
$PGA$ (g)	0.039	0.061	0.097
$PGV$ (m/s)	0.040	0.063	0.100
$S_a(0.2)$ (g)	0.066	0.099	0.154
$S_a(0.5)$ (g)	0.054	0.081	0.122
$S_a(1.0)$ (g)	0.034	0.050	0.076
$S_a(2.0)$ (g)	0.017	0.025	0.039
$S_a(5.0)$ (g)	0.003	0.006	0.009
$S_a(10.0)$ (g)	0.001	0.003	0.004

The values provided above are for the reference ground condition Site Class C and Site Class D and must be modified (as appropriate) to the site-specific seismic site classification to be confirmed during detail design to obtain applicable design spectral values. The design spectral values will need to be assessed along with the importance

category (defined as “major route” at this preliminary stage by the structural designer as per Section 4.4.2 (CHBDC)) and actual structure periods to determine the Seismic Performance Category and level of seismic analysis required during detail design as per Table 4.10 of the CHBDC (2019).

### **6.3.2.3 Soil Liquefaction**

Liquefaction is a phenomenon whereby seismically induced shaking generates shear stresses within the soil under undrained conditions. These stresses tend to densify the soil which may lead to potentially large surface deformations, and under undrained conditions generate excess pore water pressures that can lead to sudden temporary losses in strength. Where existing static shear stresses are present, the loss of strength can lead to significant lateral movements (analogous to slope failure) often referred to as “lateral spreading” or under certain conditions even catastrophic failure of slopes often referred to as “flow slides”. Lateral spreading and flow slide often accompany liquefaction along rivers and other shorelines.

In general, the soils at these bridge sites consist of interlayered stiff to hard clayey silt to clayey silt-silt soils and very dense sandy silt to silt and hard glacial till. Based on the compactness and consistency of the soils and the site-specific PGA, the soils at this site are considered to have a low potential for liquefaction during a seismic event. Further assessment of the potential for liquefaction and cyclic mobility of the cohesive deposit(s) encountered at this site should be carried out during detail design when more site-specific foundation soil information is available, and the structure period and seismic performance category are confirmed. The settlement and stability analysis will need to be reassessed, as required.

## **6.4 Foundation Types**

Based on the structure configurations (multi-span structures with total span lengths ranging from 178 m to 213 m and a 22 m long single-span structure) and subsurface conditions encountered at the site, both shallow and deep foundation options have been considered for support of the new abutments and piers. The preliminary recommendations provided herein will be subject to change when more detailed soil information and actual foundation locations are known, and when the geotechnical resistance factors can be increased on the basis of such additional investigation.

A summary of the general advantages and disadvantages associated with each option is provided below and a comparison of the alternative foundation options based on advantages, disadvantages, relative costs and risks is provided in Table 1 following the text of this report.

Shallow foundations “perched” on a compacted granular pad and/or founded on the very stiff to hard clayey silt / very dense sandy silt to silt / hard sandy clayey silt-silt / very dense silt and sand to silty sand till within the approach embankments are considered the preferred alternative at the abutments from a geotechnical/foundations perspective, provided the size and design geotechnical resistances are adequate for the anticipated loads. The feasibility of shallow foundations will need to be reassessed if variable (less competent) soil conditions are encountered near the founding levels at the actual abutment and pier locations during detail design. Alternatively, steel H-piles or tube piles (15 m to 30 m long) driven into the non-cohesive till and/or lower cohesive deposit are preferred for the piers (or abutments at the single span structure to reduce the span length) from a geotechnical/foundations perspective as they provide higher geotechnical resistance and lower risk of settlement or significant design changes if variable shallow soil conditions are encountered during detail design.

### 6.4.1 Shallow Foundations

Strip or spread footings founded below the existing fills and native soils containing organics (i.e. rootlets) on the native very stiff to hard clayey silt, very dense sandy silt to silt, hard sandy clayey silt-silt or very dense silt and sand to silty sand till strata (at or below the approximate elevations identified below) are considered feasible for support of the ramp structure abutments and piers. Alternatively, strip or spread footings may be founded on a compacted Granular 'A' pad placed above the very stiff to hard clayey silt, very dense sandy silt to silt, hard sandy clayey silt-silt or very dense silt and sand to silty sand till.

The following geotechnical resistances may be used for preliminary design, assuming a 3 m or 5 m wide footing:

Structure Name	Founding Elevation	Founding Stratum	Footing Width	Factored Ultimate Geotechnical Resistance	Factored Serviceability Geotechnical Resistance <sup>1</sup>
S-W Ramp over Highway 404	250 m (east side) 251.5 m to 255.5 m (west side <sup>2</sup> )	Very Stiff to Hard Clayey Silt / Very Dense Sandy Silt / Hard Sandy Clayey Silt-Silt over Very Dense Silt	3 m	450 kPa (east side) to 500 kPa (west side <sup>2</sup> )	225 kPa (east side) to 325 kPa (west side <sup>2</sup> )
			5 m	500 kPa (east side) to 550 kPa (west side <sup>2</sup> )	175 kPa (east side) to 275 kPa (west side <sup>2</sup> )
		3 m thick Granular Pad <sup>3</sup> over Very Stiff to Hard Clayey Silt / Very Dense Sandy Silt / Hard Sandy Clayey Silt-Silt over Very Dense Silt	3 m	550 kPa (east side) to 600 kPa (west side <sup>2</sup> )	300 kPa (east side) to 400 kPa (west side <sup>2</sup> )
			5 m	525 kPa (east side) to 600 kPa (west side <sup>2</sup> )	225 kPa (east side) to 350 kPa (west side <sup>2</sup> )
W-N Ramp over S-W Ramp <sup>2</sup>	255.5 m (west and east side)	Hard Sandy Clayey Silt-Silt over Very Dense Silt	3 m	500 kPa	325 kPa
			5 m	550 kPa	275 kPa
		3 m thick Granular Pad <sup>3</sup> over Hard Sandy Clayey Silt-Silt over Very Dense Silt	3 m	600 kPa	400 kPa
			5 m	600 kPa	350 kPa
W-N Ramp over Highway 404	250.5 m (north side) 251.5 m to 255.5 m (south side <sup>2</sup> )	Hard Clayey Silt to Clayey Silt-Silt / Very Dense Sandy Silt	3 m	450 kPa (north side) to 500 kPa (south side <sup>2</sup> )	225 kPa (north side) to 325 kPa (south side <sup>2</sup> )
			5 m	500 kPa (north side) to 550 kPa (south side <sup>2</sup> )	175 kPa (north side) to 275 kPa (south side <sup>2</sup> )
		3 m thick Granular Pad <sup>3</sup> over Hard Clayey Silt to Clayey Silt-Silt / Very Dense Sandy Silt	3 m	550 kPa (north side) to 600 kPa (south side <sup>2</sup> )	300 kPa (north side) to 400 kPa (south side <sup>2</sup> )
			5 m	525 kPa (north side) to 600 kPa (south side <sup>2</sup> )	225 kPa (north side) to 350 kPa (south side <sup>2</sup> )

Notes:

1. For 25 mm of settlement independent of any settlements induced by surrounding grade changes / embankment loading.
2. The location of the footing relative to the Highway 404 cut slope (i.e. sloping ground) must be taken into account in assessing the geotechnical resistance during detail design.
3. The granular pad should consist of OPSS.PROV 1010 Granular 'A' compacted to 100% Standard Proctor Maximum Dry Density in accordance with OPSS.PROV 501 (*Compacting*).

The factored ultimate and serviceability geotechnical resistances are dependent on the footing width, founding elevation, and thickness of granular pad (as applicable) and as such, the geotechnical resistances must be reviewed

and revised if the footing width varies from that specified above or if the founding soils differ from that given in the previous section. In general, for larger footing sizes, higher factored ultimate and lower factored serviceability geotechnical resistances would apply. The preliminary factored geotechnical resistances should also be re-evaluated using geotechnical resistance factors for a typical degree of understanding once further investigation data is available at the foundation elements.

Given the variability in the founding soils at this site, it is anticipated that there will be differential settlement across and between foundation elements. Additional investigation will be required to confirm the subsurface conditions within the footprints of the abutments and piers. Depending on the subsurface conditions, different foundation options or mitigation measures may be required to reduce the potential for differential settlement across each foundation, and between foundation elements of the structure(s).

Resistance to lateral loads / sliding resistance between the new concrete footing and the subgrade should be calculated in accordance with Section 6.10.4 of *CHBDC* (2019), applying the appropriate consequence and degree of site understanding factors as applicable during detailed design. Assuming that the founding soils (very stiff to hard clayey silt, very dense sandy silt to silt, hard sandy clayey silt-silt or very dense silt) are not loosened or disturbed during excavation and construction, an angle of friction between the cast-in-place concrete footings and founding soils of  $24^\circ$  and corresponding unfactored coefficient of friction,  $\tan \delta$ , of 0.45 may be used. An angle of friction of  $35^\circ$  and corresponding unfactored coefficient of friction,  $\tan \phi'$ , of 0.7 may be used between the cast-in-place concrete footings and the Granular 'A' pad.

## **6.4.2 Deep Foundations**

### **6.4.2.1 Steel H-Pile or Tube Foundations**

Steel HP 310x110 piles or 324 mm outer diameter closed ended tube piles (assuming a minimum wall thickness of 9.5 mm) driven into the lower clayey silt to silt deposit or non-cohesive till deposit are considered feasible for the foundations at the ramp structures. Long friction piles (30 m) are preferred at the majority of the structure footprints over Highway 404 as no significant thickness of "100-blow" soil was encountered for end-bearing pile design, with the exception of the west limit of the site (i.e. Borehole 404-1) located at the W-N Ramp over S-W Ramp structure and near the west and south abutments of the structures over Highway 404 where "100-blow" silty soil was encountered about 3 m below ground surface, and "100-blow" glacial till was encountered about 5 m below ground surface. A limited 4 m to 5 m thick layer of very dense ("100-blow") sandy silt to silt was encountered at a depth of about 15 m below ground surface in Boreholes 404-3 and 404-4 which could be considered for design of shorter end-bearing piles at the structures over Highway 404 if and where this layer is encountered within the footprint of foundation elements in future investigations.

For the short pile option where limited thickness of "100-blow" soil was encountered, close-ended tube piles are preferred due to the increased end-bearing area / resistance and higher likelihood of achieving design geotechnical resistances without penetrating through the very dense sandy silt layer, although considerable risk exists of penetrating through the limited layer thickness which would result in longer pile lengths to achieve the design resistance during design. Although not specifically encountered or confirmed during the current investigation in all areas of the site, the presence of potential cobbles and/or boulders should be anticipated within the glacially derived till and sandy silt deposits and will need to be considered during detail design. In general, driven steel H-piles are preferred over steel tube piles given that H-piles are most commonly used for integral abutment design and that steel tubes are considered to pose a higher risk of "hanging up" or being deflected from their vertical or battered orientation during installation, due to their larger end area.

The following factored geotechnical resistances may be used for preliminary design:

Structure Name(s)	Foundation Element	Pile Type	Approximate Pile Length	Estimated Pile Tip Elevation	Factored Ultimate Geotechnical Resistance	Factored Serviceability Geotechnical Resistance <sup>1</sup>
S-W Ramp over Hwy 404	East Abutment and Piers	HP 310x110	15 m (short) <sup>2</sup> 30 m (long)	235 m 220 m	800 kN 1,200 kN	800 kN 1,200 kN
		324 mm dia. Tube Pile	15 m (short) <sup>2</sup> 30 m (long)	235 m 220 m	700 kN 1,000 kN	700 kN 1,000 kN
	West Abutment <sup>3</sup>	HP 310x110	8 m	250 m	1,200	1,200
		324 mm dia. Tube Pile	8 m	250 m	1,000	1,000
W-N Ramp over S-W Ramp	East and West Abutment <sup>3</sup>	HP 310x110	8 m	250 m	1,200 kN	1,200 kN
		324 mm dia. Tube Pile	8 m	250 m	1,000 kN	1,000 kN
W-N Ramp over Hwy 404	North Abutment and North Piers	HP 310x110	30 m (long)	220 m	1,200 kN	1,200 kN
		324 mm dia. Tube Pile	30 m (long)	220 m	1,000 kN	1,000 kN
	South Piers	HP 310x110	15 m (short) <sup>2</sup> 30 m (long)	235 m 220 m	800 kN 1,200 kN	800 kN 1,200 kN
		324 mm dia. Tube Pile	15 m (short) <sup>2</sup> 30 m (long)	235 m 220 m	700 kN 1,000 kN	700 kN 1,000 kN
	South Abutment <sup>3</sup>	HP 310x110	8 m	250 m	1,200 kN	1,200 kN
		324 mm dia. Tube Pile	8 m	250 m	1,000 kN	1,000 kN

Notes:

- For 25 mm of settlement independent of any settlements induced by surrounding grade changes / embankment loading
- Short pile option only considered applicable for east abutment and piers for S-W Ramp over Hwy 404 (as per Borehole 404-4) and south piers of W-N Ramp over Hwy 404 structure (as per Borehole 404-3).
- The feasibility of driving 8 m below ground surface to penetrate through the “100-blow” silt soils and about 2 m into the “100-blow” till soil will need to be assessed further during detail design. Pre-drilling may be required to achieve the design tip elevations.

The estimated factored ultimate geotechnical resistances provided above are calculated on both shaft and tip resistances, but predominantly shaft for the long pile option and assume piles have had sufficient time to “set-up” and allow pore pressures to dissipate after initial driving in order to achieve the design geotechnical resistances. Pile installation should be carried out in accordance with Ontario Provincial Standard Specification (OPSS) PROV 903 (*Deep Foundations*) as amended by Special Provision 109F57 with High-Strain Dynamic testing specified on at least 20% of the piles or two piles at each foundation element (whichever is greater) in each stage of construction.

In order to optimize the design and reduce the risk of piles not achieving the design geotechnical resistance at the design tip elevation during construction, the design-builder or contractor can consider a combination of the following options:

- Advanced site-specific investigation during detail design to confirm or adjust axial geotechnical resistances for design based on the use of a typical rather than low degree of understanding;
- High-strain dynamic testing (PDA) on all piles at end-of-initial drive (EOID) and at a specified number of piles on beginning-of-restrike (BOR) or retap;

- Advanced static pile load test as per ASTM D-1143, and/or
- Evaluation of strength gain with time (via PDA testing or static pile load testing or both) to ascertain the potential gain, if any, in geotechnical resistance.

The selected design and testing method(s) must consider logistical challenges and potential schedule impacts as part of the detailed design and planned construction, and optimized design and testing methods must be incorporated into SP109F57 and the contract documents.

The subsequent pile termination or set criteria will be dependent on the pile driving hammer type, helmet, selected pile and length of pile; the criteria must therefore be established at the time of construction after the piling equipment is known to ensure that the piles are not overdriven, to avoid possible damage to the piles, and to calibrate with the results of the high-strain dynamic testing or advanced static pile load testing.

For conventional integral abutment design, corrugated steel piles (CSPs) backfilled with loose sand are recommended to be installed as part of the integral abutment design consistent with the MTO Structural Office Report SO-96-01 titled “Integral Abutment Bridges”.

#### **6.4.2.2 Drilled Shafts (Caissons)**

Caissons founded within the lower clayey silt to silt deposit or non-cohesive till deposit are feasible for supporting the ramp structure abutments and piers. At the S-W Ramp over Highway 404 and the W-N Ramp over Highway 404 structures, short end-bearing caissons (8 m long) founded on the “100-blow” non-cohesive till may be considered at the west and south abutments respectively (near Borehole 404-1) and longer friction caissons (about 20 m long) penetrating into the cohesive clayey silt have been considered for the other foundation elements for preliminary design. Consideration could be given to founding shorter caissons on the 4 m to 5 m thick layer of very dense (“100-blow”) sandy silt to silt encountered at a depth of about 15 m below ground surface for some foundation elements near Boreholes 404-3 and 404-4, where this layer is present; however, as this layer is absent in one of the boreholes, and the borehole coverage is limited at this stage, it is recommended that evaluation of such alternatives be completed in detail design subject to additional investigation. At the W-N Ramp over S-W Ramp structure (Borehole 404-1), 8 m long caissons penetrating into the silty sand to silt and sand till deposit have been evaluated for preliminary design. If adopted, caissons founded within the cohesionless sandy silt to silt and till deposits would require use of appropriate polymer slurry to control basal heave and achieve the design geotechnical resistances.

Although not specifically encountered or confirmed during the current investigation in all areas of the site, consideration must be given to the presence of potential cobbles and boulders that may be present within the glacially derived till and sandy silt deposits.

The following geotechnical resistances may be used for preliminary design of caissons, based on geotechnical resistance factors for a low degree of site understanding:

Structure Name(s)	Foundation Element	Caisson Diameter	Approximate Caisson Length	Estimated Caisson Base Elevation	Factored Ultimate Geotechnical Resistance	Factored Serviceability Geotechnical Resistance <sup>1</sup>
S-W Ramp over Hwy 404	East Abutment and Piers	1.2 m	20 m	230 m	2,500 kN	Does not govern
		1.5 m	20 m	230 m	3,000 kN	Does not govern
	West Abutment	1.2 m	8 m	250 m	4,000 kN	Does not govern
		1.5 m	8 m	250 m	5,500 kN	Does not govern
W-N Ramp over S-W Ramp	East and West Abutment	1.2 m	8 m	250 m	4,000 kN	Does not govern
		1.5 m	8 m	250 m	5,500 kN	Does not govern
W-N Ramp over Hwy 404	North Abutment and Piers	1.2 m	20 m	230 m	2,500 kN	Does not govern
		1.5 m	20 m	230 m	3,000 kN	Does not govern
	South Abutment	1.2 m	8 m	250 m	4,000 kN	Does not govern
		1.5 m	8 m	250 m	5,500 kN	Does not govern

Notes:

1. For 25 mm of settlement independent of any settlements induced by surrounding grade changes / embankment loading

For preliminary design, drilled shafts (caissons) spaced at 8 pile diameters (centre-to-centre) can be assumed for design purposes to act as single caisson piles, with no group interaction effects with regards to axial resistance. For caissons spaced less than 8 diameters, the total caisson axial resistance should be reduced by a group reduction factor ( $R_A$ ) (Reese, 2006) as follows:

Caisson Spacing ( $d$ = Pile Diameter)	Caisson Axial Resistance Group Reduction Factor ( $R_A$ )
9 $d$	1.0
6 $d$	0.9
4 $d$	0.75
3 $d$	0.7

Note: Reduction factors for other caisson pile spacings may be interpolated from the values above.

If caisson foundations are adopted for support of any of the foundation elements, a temporary (at least in the upper zone) or permanent liner is required to support the soils during construction, to reduce disturbance and loss of ground in the water-bearing cohesionless soils and cohesive soils containing silt and sand interlayers. Specialized construction techniques would be required during advancement of the caisson to maintain a sufficient head of water and/or drilling fluid (e.g., polymer slurry or other slurry mix) within the liner / open hole to prevent basal heave and disturbance of water-bearing cohesionless layers/interlayers. If a permanent liner is used, the design geotechnical resistances provided above may need to be revised to account for the reduced adhesion between the liner material

and surrounding soil along the length of the liner compared to the adhesion between concrete and surrounding soil if temporary liners are used. If drilling fluids and partial temporary liners are used, the resistance developed on the side walls would also need to be reevaluated in detail design (e.g., bentonite slurry versus polymer slurry), as using such materials can reduce the design shaft friction component.

Given that the above drilled shaft capacities have both a shaft friction and end-bearing component, the performance of the drilled shafts in compression will depend to a large degree upon the final cleaning and verification of the condition of the base of the drilled shaft. Following cleaning to remove all loose cuttings, the base should be inspected by a qualified geotechnical engineer using a shaft inspection device (SID) or given the use polymer slurry, a shaft quantitative inspection device (SQUID). Should the inspection indicate that loosened material is present at the base of the drilled shaft, the base would need to be re-cleaned and re-inspected.

In order to optimize the design and potentially increase the geotechnical resistances for deep foundations, the Ministry or design-builder or contractor can consider a combination of the following options:

- Advanced site-specific investigation during detail design to confirm or adjust axial geotechnical resistances for design based on the use of a typical rather than low degree of understanding, and/or
- Advanced static pile load test as per ASTM D-1143, bi-directional static load ("Osterberg Cell") test (CFEM, 2006), or Statnamic Load Test (CFEM, 2006).

Caisson installation must be in accordance with OPSS.PROV 903 (Deep Foundations), and it is recommended that MTO's recent special provision be included in the future contract documents to address the requirements for supply and installation of drilled shafts (caissons) including the use of temporary or permanent liners/casings, slurry type, the placement of concrete by tremie methods, cleaning and inspection of the shafts as applicable, and quality control testing. Non-destructive post-construction testing in selected drilled shafts should also be included in the future contract specifications and is recommended to verify the integrity of the concrete given the groundwater conditions, presence of saturated cohesionless soils, and specialized installation methods to counterbalance the hydrostatic pressures.

#### **6.4.2.3 Resistance to Lateral Loads**

The design of piles or caissons subjected to lateral loads should take into account such factors as the relative rigidity of the pile / caisson to the surrounding soil, the fixity condition at the head of the pile / caisson (i.e., at the pile / caisson cap level), the structural capacity of the pile / caisson to withstand bending moments and shear, the soil resistance that can be mobilized, the tolerable lateral deflections at the head of the pile / caisson and group effects. Lateral loading could be resisted fully or partially by the use of battered piles. For vertical piles or caissons, the resistance to lateral loading will have to be derived from the soil in front of the piles.

For design purposes, both the structural and geotechnical resistances should be evaluated to establish the governing case. Lateral pile / caisson analysis for detail design should be carried out using non-linear methods (such as p-y curves) when the pile group configuration is established, as per the CHBDC (2019).

For preliminary design, the resistance to static lateral loading in front of the piles / caissons may be calculated using subgrade reaction theory where the coefficient of horizontal subgrade reaction,  $k_h$  (kPa/m), is based on the following equations (CFEM, 2002 as referenced in CHBDC, 2006):

For non-cohesive soils:

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

Where  $n_h$  is the constant of subgrade reaction (kPa/m);  
 $z$  is the depth (m); and  
 $B$  is the pile / caisson diameter or width (m).

For cohesive soils:

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

Where  $s_u$  is the undrained shear strength of the soil (kPa); and  
 $B$  is the pile / caisson diameter or width (m).

Considering the subgrade reaction equations provided above model linear behaviour, they are only considered appropriate where the maximum pile deflections are small (less than 1% of the pile/caisson diameter), where the loading is static (no cycling) and where the pile/caisson material is linear.

The following values of  $n_h$  and  $s_u$  may be assumed in the structural analyses for a single vertical pile or caisson, using the interpreted stratigraphic conditions from the boreholes. The range in the values reflect the variability of the subsurface conditions, the soil properties and groundwater level, and the approximate nature of the linear-elastic subgrade reaction analysis.

Soil Unit	$n_h$ (kPa/m)		$s_u$ (kPa)
	Above the Water Table	Below the Water Table	
New Granular Fill (Granular 'A' or 'B' Type II)	40,000 – 50,000	20,000 – 30,000	--
Compact Sandy Silt to Sandy Gravel (Existing Fill)	25,000 – 30,000	15,000 – 20,000	--
Stiff to Hard Clayey Silt (Upper Cohesive Deposit)	--	--	100 – 200
Hard Clayey Silt (Till)	--	--	200
Very Dense Silt to Silty Sand (Till)	26,000 – 38,000	17,000 – 23,000	--
Very Dense Sandy Silt to Silt	20,000 – 25,000	10,000 – 15,000	--
Very Stiff to Hard Clayey Silt to Clayey Silt-Silt (Middle/Lower Cohesive Deposit)	--	--	150 – 200

Notes:

1. Although parameters are provided for the full depth of the soil stratigraphy, lateral resistance in the upper 1.5 m should be neglected to account for frost action
2. Where both  $n_h$  and  $s_u$  parameters are provided, the structural assessment should be completed for both undrained and drained conditions, and the selected design should be based on the more conservative approach.

Group action for lateral loading should also be evaluated by reducing the coefficient of horizontal subgrade reaction either in the direction of loading or perpendicular to the direction of loading by relevant group pile / caisson efficiency factors as outlined in Section C6.11.3.4 of the *Commentary to the CHBDC* (2019).

#### 6.4.2.4 Downdrag Loads on Piles / Caissons

Based on the preliminary GA drawings, the approach embankments at the three structures range from approximately 4 m high to 13.5 m high with total post-construction settlements in the foundation soils estimated to

be less than 25 mm (see Section 6.6.2). As a result, downdrag loads are not anticipated to be a concern but must be assessed further during detail design.

## 6.5 Frost Protection

The spread / strip footing(s) and pile / caisson caps should be founded at a minimum depth of 1.5 m below the lowest surrounding final grade, including any distance measured perpendicular to the sloping ground surface to provide adequate protection against frost penetration (as interpreted from OPSD 3090.101 – *Foundation Frost Penetration Depths for Southern Ontario*).

## 6.6 Approach Embankments

Based on the preliminary GA drawings, the approach embankments and anticipated foundation soils at the proposed three bridge structures are summarized in the following table.

Structure	Height of Approach Embankment	Anticipated Foundation Soils
S-W Ramp over Hwy 404	10 m (east side) 4 m (west side) <sup>1</sup>	Stiff to Hard Clayey Silt / Very Dense Sandy Silt and Silt and Sand Till
W-N Ramp over S-W Ramp	12 m (east side) 12 m (west side)	Very Stiff to Hard Clayey Silt to Clayey Silt-Silt / Very Dense Sandy Silt and Silt and Sand Till
W-N Ramp over Hwy 404	13 m (north side) 13.5 m (south side)	Stiff to Hard Clayey Silt / Very Dense Sandy Silt and Silt and Sand Till

Note:

1. Relatively low west approach embankment height adjacent to Highway 404 which is constructed in a cut.

A 2 m wide mid-height bench should be incorporated into the design of the embankment slopes as required for uninterrupted embankment heights greater than 8 m in accordance with OPSD 202.010 (Slope Flattening).

For preliminary design, it is assumed that prior to construction of the new approach embankments, all topsoil, peat/organic soil, existing unsuitable fill materials and any soft/loose surficial alluvial deposits will be stripped from the footprint of the new embankments and replaced with suitable granular fill. Based on the borehole information, stripping of unsuitable soil is assumed to extend up to 1.4 m below existing ground surface at the east and west side of Highway 404. Additional details regarding embankment construction are provided in Section 6.8.1.

Conventional embankment construction is considered feasible at the site. Where space limitations exist, consideration can be given to designing RSS embankments or retaining walls at this site.

Global stability and settlement analyses were carried out for the highest embankments on the east and west side of Highway 404 using the closest borehole information. On the east side, an embankment up to 13 m high was modelled at the north abutment of the W-N Ramp over Highway 404 (Figure 1 and 2), and on the west side, an embankment up to 13.5 m high was modelled at the south abutment (Figures 3 and 4). Given that Highway 404 is constructed in a cut in this area, the stability of the foreslope which is up to about 19 m high (13.5 m high embankment in addition to the existing 5.5 m deep cut adjacent to Highway 404) was also modelled at the south abutment of the W-N Ramp over Highway 404 (Figures 5 and 6). The stability of the 12 m high approach embankments at the W-N Ramp over S-W Ramp structure was also modelled (Figures 7 and 8). The foundation

engineering parameters for the major soil types encountered below the embankment footprints on the east and west side of Highway 404 are summarized below.

Idealized Stratigraphic Unit	$\gamma$ (kN/m <sup>3</sup> )	$\phi'$ (°)	$S_u$ (kPa)	$E'$ (Mpa)
New Granular Fill (Granular 'A' or 'B' Type II)	21	36	--	--
Compact Sandy Silt to Sandy Gravel (Existing Fill)	20	34	--	--
Stiff to Hard Clayey Silt (Upper Cohesive Deposit)	20	32	100 – 200	50 – 125
Hard Clayey Silt (Till)	21	35	200	150
Very Dense Silt and Sand to Silty Sand (Till)	21	35	--	150
Very Dense Sandy Silt to Silt	21	34	--	150
Very Stiff to Hard Clayey Silt to Clayey Silt-Silt (Middle/Lower Cohesive Deposit)	21	34	150 – 200	150

For stability and settlement analysis, the groundwater elevation is assumed to be the highest measured water level in the boreholes / piezometers which was at about Elevation 251 m and 249 m west and east of Highway 404, respectively.

### 6.6.1 Stability

The Factor of Safety for global stability is equal to the inverse of the product of the consequence factor,  $\Psi$ , and the geotechnical resistance factor,  $\phi_{gu}$  (i.e.  $FoS = 1/(\Psi \cdot \phi_{gu})$ ). Accordingly, given the limited geotechnical information at the site and low degree of site understanding, minimum target Factors of Safety of 1.4 and 1.6 have been used for the preliminary design of the approach embankment slopes for the temporary (short-term) and permanent (long-term) conditions, respectively, as per Table 6.2 of CHBDC (2019) and MERO (2020).

The idealized geometry and results of the stability analyses (modelled using *Slide 2 (Version 9.017)*) for the highest approach embankments on the east and west sides of Highway 404 (as discussed in the previous section) are shown in Figures 1 to 8. Based on the results, the new approach embankments constructed with suitable granular fill and side slopes no steeper than 2H:1V (with a mid-height 2 m wide bench for embankments higher than 8 m and additional benches provided as necessary such that the uninterrupted slope height does not exceed 8 m) will have an adequate factor of safety (i.e., greater than 1.4 for short-term (undrained) conditions and greater than 1.6 for long-term (drained) conditions) for global stability.

When more detailed foundation investigation is completed at the site (typical or high level of understanding), the resistance factor can be increased and the target Factor of Safety for the temporary and permanent conditions can be decreased accordingly. During detail design, the stability of the proposed retaining walls at the approach embankments at the W-N Ramp over S-W Ramp structure will need to be further assessed, however, the founding soils are considered suitable for conventional retaining walls (e.g. concrete cantilever or RSS walls) at this preliminary stage.

### 6.6.2 Settlement

Settlement analyses were carried out for the proposed maximum embankment height on the east and west side of Highway 404 for each structure. The thickness of the compressible foundation soils and the height of the approach embankments will vary along the approach embankment alignments for each ramp structure, and as such the

settlements along the length of each profile alignment will similarly vary; however, the settlements estimated from the settlement analysis represent the maximum anticipated values.

The target settlement performance criteria for design of approach embankments are outlined in MTO's "Embankment Settlement Criteria for Design", dated July 2, 2010. In general, new embankments approaching structural elements such as bridge abutments are to be designed such that total settlement and rate of differential settlement do not exceed 25 mm, over a 20-year period following completion of construction.

The estimated magnitude of post-construction settlement for the highest embankments on the east and west sides of Highway 404 are presented below, assuming the use of conventional granular fill for construction. The estimated settlements do not account for immediate settlement of the embankment fill and foundation soils which is expected to occur during or shortly after construction and would need to be assessed during detail design.

Structure	Approach Embankment	Relevant Borehole	Proposed Maximum Embankment Thickness	Estimated Post-Construction Settlement over a 20-Year Period (mm)
S-W Ramp over Hwy 404	East	404-4	10 m	$\delta_{Total} < 25 \text{ mm}$
	West	404-1	4 m	$\delta_{Total} < 25 \text{ mm}$
W-N Ramp over S-W Ramp	East	404-1	12 m	$\delta_{Total} < 25 \text{ mm}$
	West	404-1	12 m	$\delta_{Total} < 25 \text{ mm}$
W-N Ramp over Hwy 404	North	404-2	13 m	$\delta_{Total} < 25 \text{ mm}$
	South	404-1 and 404-3	13.5 m	$\delta_{Total} < 25 \text{ mm}$

Based on the preliminary investigation and calculated results above, post-construction settlements are not anticipated to be a concern at the approach embankments for the ramp structures.

### 6.6.3 Lateral Earth Pressures for Design

The lateral earth pressures acting on the abutment walls and any associated wingwalls should be designed in accordance with Section 6 of the CHBDC (2019) and will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls. The following recommendations are made concerning the design of the abutment walls and wingwalls:

- Free-draining granular fill meeting the specifications of OPSS.PROV 1010 (*Aggregates*) Granular A or Granular B Type II should be used as backfill behind the walls. Longitudinal drains or weep holes should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (*Compacting*). Other aspects of the granular backfill requirements with respect to subdrains and frost taper should be in general accordance with OPSD 3101.150 (*Walls, Abutment, Backfill, Minimum Granular Requirement*), OPSD 3121.150 (*Walls, Retaining, Backfill, Minimum Granular Requirement*), and 3190.100 (*Walls, Retaining and Abutment, Wall Drain*).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with CHBDC (2019) Section 6.12.3 and Figure 6.8. Care must be taken

during the compaction operation not to overstress the wall, with limitations required on heavy construction equipment and requirements for the use of hand-operated compaction equipment per OPSS.PROV 501 (*Compacting*). Other surcharge loadings should be accounted for in the design, as required.

- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.5 m behind the back of the wall in accordance with Figure C6.31(a) of the *Commentary to the CHBDC* (2019). For unrestrained walls, fill should be placed within the wedge-shaped zone defined by a line drawn at flatter than 1 horizontal to 1 vertical (1H:1V) extending up and back from the rear face of the footing or pile cap in accordance with Figure C6.31(b) of the *Commentary to the CHBDC* (2019).

## 6.7 Corrosion Assessment and Protection

Soil corrosivity may affect the concrete and/or steel elements (e.g. reinforcing steel) of foundations or related structures buried in the soil. The long-term performance and durability of the foundations are directly related to their respective corrosion resistance. Generally, the corrosivity potential to a structure can be assessed based on the soil resistivity / electrical conductivity, hydrogen ion concentration (pH), and salts (chloride and sulphate) concentrations. The analytical results for the soil samples submitted for testing are summarized in Section 4.4 and the analytical laboratory test reports are included in Appendix C.

### 6.7.1 Potential for Sulphate Attack

The analytical test results were compared to CSA Standard, CAN/CSA-A23.1-14 Table 3 (*“Additional requirements for concrete subjected to sulphate attack”*) for potential sulphate attack on concrete. The sulphate concentrations measured in the tested samples range from 43 to 250 µg/g (< 0.025%) and are below the exposure class of S-3 (Moderate). Therefore, based on the soil samples tested, when the designer is selecting the exposure class for the structure, the effects of sulphates may not need to be considered.

### 6.7.2 Potential for Corrosion

The test results indicate a pH ranging from 7.7 to 8.0 and a resistivity ranging from 700 to 5800 ohm-cm. According to the Gravity Pipe Design Guidelines (MTO, 2014), the pH is not considered detrimental to concrete durability. However, the resistivity indicates that the soil corrosiveness ranges from Low (6,000 ohm-cm > R > 4,500 ohm-cm) to Severe (R < 2000 ohm-cm), as per Table 3.2 of the Gravity Pipe Design Guidelines (MTO, 2014), and appropriate corrosion protection should be applied to the foundation element / materials. Further, given that the foundations are located adjacent to the highway shoulder and will be exposed to de-icing salt, consideration should be given to selection of a “C” type exposure class as defined by CSA A23.1 Table 1.

These recommendations are provided as guidance only; the design-builder should take the results of the laboratory testing into consideration for selecting appropriate materials and corrosion susceptibility for design service of the structure foundations and determine the appropriate exposure class and ensure that all aspects of CSA A23.1 Section 4.1.1 “Durability Requirements” are followed.

## 6.8 Construction Considerations

### 6.8.1 Subgrade Preparation and Approach Embankment Construction

Prior to construction of the new approach embankments, it is recommended that all unsuitable soils such as topsoil or organics, and existing surficial fill materials or loosened/softened soils from farming activities be stripped from the embankment footprint and replaced with OPSS Select Subgrade Material (SSM), Granular A or Granular B soils. Based on the boreholes, stripping up to about 1.4 m below ground surface may be required to remove the

unsuitable soils at the approach embankments; stripping requirements must be confirmed following completion of additional boreholes.

Engineered fill for construction of the new embankments should consist of OPSS.PROV 1010 (*Aggregates*) granular materials (i.e. SSM, Granular A or Granular B). Earth fill consisting of suitable borrow material from elsewhere on the project may also be considered where sufficient volumes are available. The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*) and OPSS.PROV 206 (*Grading*). Permanent embankment side slopes should be constructed no steeper than 2 horizontal to 1 vertical (2H:1V) in granular fill. Where earth fill is used, slightly flatter side slopes on the order of 2.25H:1V may be necessary depending on the composition of the material to reduce the potential for shallow surficial failures.

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

To reduce surface water erosion on the granular embankment side slopes, vegetative cover should be established as per OPSS.PROV 803 (*Vegetative Cover*). Depending on the time of year, temporary erosion control measures may be required as per OPSS.PROV 804 (*Temporary Erosion Control*) as soon as possible after construction of the embankments.

## 6.8.2 Temporary Excavations

Temporary excavations up to about 2 m deep may be required for shallow foundations and/or subexcavation and replacement with a granular pad, or pile and caisson caps.

All temporary excavations must be carried out in accordance with Ontario Regulation 213 of the Ontario Occupational Health and Safety Act for Construction Projects (OHSA), as amended. The existing fill layers and underlying native stiff clayey silt are classified as Type 3 soils and the very dense sandy silt, very dense silt and sand to silty sand till, and very stiff to hard clayey silt are classified as Type 2 soils. Temporary excavations (i.e., those open for a relatively short time period) should be made with side slopes of no steeper than 1H:1V. For Type 2 soils, the excavation may be sloped to within 1.2 m of the bottom of the excavation.

The relatively wide grassy median separating the Highway 404 NB and SB lanes may allow for conventional open-cut for foundation excavation and construction at pier locations. Where required, temporary protection systems must be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection System*) and Special Provision 105S09. The lateral movement of the temporary protection systems must meet Performance Level 2 as specified in OPSS.PROV 539, provided that any existing adjacent utilities can tolerate this magnitude of deformation.

## 6.8.3 Groundwater / Surface Water Control

The highest groundwater level measured during the foundation investigation was at about Elevation 251 m (6.7 m below ground surface) west of Highway 404 in the monitoring well installed in Borehole 404-1 and Elevation 249.0 m (about 3.0 m below the existing ground surface) east of Highway 404 in the monitoring well installed in Borehole 404-4 located on the east side of the highway. The monitoring well installed in Borehole 404-2 was damaged before a reading could be taken. During several visits to the site, the presence of several localized drainage trenches (rip-rap filled) were observed on the west (cut slope) side of Highway 404 and extended the full height (5 m to 7 m) of the west cut slope near the ramp structures suggesting potentially higher groundwater conditions and/or surface water drainage from the adjacent farmland west of Highway 404.

At this preliminary stage it is anticipated that temporary excavations for shallow foundations / pile caps will likely be above the groundwater table on both the east and west side of the site. An existing stormwater management pond is located on the east side of Highway 404 (about 50 m east of the W-N Ramp alignment) and the operating water level should be confirmed during detail design as it may impact groundwater levels near the foundations. As it is expected that limited excavation (less than 2 m deep) will be required for foundations, any groundwater seepage into the foundation excavations can likely be adequately controlled by ditching and pumping from filtered sumps within or adjacent to the excavations. If the excavation operations are carried out in the wet season, the groundwater level could be higher (especially on the west side of Highway 404) and more extensive groundwater control measures may be required depending on the excavation requirements. Dewatering operations should be in accordance with OPSS.PROV 517 (*Dewatering*) as referenced in OPSS.PROV 902 (*Excavation and Backfilling – Structures*). Inclusion of a special provision for foundation dewatering will need to be considered in the future contract documents during detail design to address potential instability / base heave of the foundation subgrade, and pre-construction survey requirements, as applicable, especially if temporary protections systems or other temporary works may be impacted by dewatering.

Construction water takings in excess of 50,000 L/day are regulated by the Ministry of the Environment, Conservation and Parks (MECP). Certain takings of groundwater for construction dewatering purposes with a combined total less than 400,000 L/day qualify for self-registration on the MECP's Environmental Activity and Sector Registry (EASR), requiring a "Water Taking Plan" and a "Discharge Plan" (to be developed by the Design-Builder). A Category 3 PTTW would be required for water takings in excess of 400,000 L/day. The contractor will be responsible for obtaining any required discharge approvals.

Surface water must be directed away from the excavations at all times. In particular, surface water drainage on the west side of the site must be properly diverted / controlled such that the integrity of any foundation subgrade is maintained.

To reduce erosion of the permanent embankment side slopes due to surface water runoff, placement of topsoil and seeding or pegged sod is recommended as soon as practicable after construction of the embankments. The erosion protection must be in accordance with OPSS.PROV 803 (*Vegetative Cover*).

#### **6.8.4 Obstructions during Pile Driving / Caisson Installation**

During pile installation through the glacially derived soils, especially the till and "100-blow" silt to sandy silt soil layer at this site, there is a risk of encountering cobbles and boulders. It is recommended that steel H-piles or tube piles be reinforced and protected from damage with appropriate driving shoes as per OPSD 3000.100 (Steel H-Pile Driving Shoe) or 3001.100 (Steel Tube Driving Shoe) or equivalent. Pre-augering may be considered where 100-blow soils are present at shallow depth (as at Boreholes 404-1 and 404-3) and/or to ensure penetration through the 100-blow till layer that is present at approximately 3 m to 15 m depth in some boreholes, to reduce the risk of piles "hanging up" on potential "100-blow" stratum. If pre-augering is considered, the design geotechnical resistances provided must be reviewed and revised as necessary during detail design. Caisson installation equipment must be capable of penetrating and/or removing obstructions as required.

#### **6.9 Recommendations for Additional Work**

The preliminary foundation recommendations provided in this report are based on the limited available subsurface information in the four boreholes advanced near the proposed structures. Additional foundation investigation and assessment is recommended to be carried out such that the level of confidence for design meets a minimum "typical degree of site and prediction model understanding" for the ultimate bridge configurations.

Additional investigation is recommended to explore the subsurface soil and groundwater conditions at the location of the bridge foundation elements (abutments and pier locations), approach embankments, and associated retaining

walls to confirm foundation soils and groundwater levels for the ramp structures. Boreholes should be advanced below the anticipated pile tip elevations and beyond 30 m depth to confirm presence and thickness of “100-blow” soils and confirm long friction pile assumptions as required for detail design. It is recommended that the groundwater elevations across the site be assessed further at detail design, including the use of existing monitoring wells installed as part of this investigation. The foundation types, sizes and geotechnical resistances will need to be reassessed and revised as necessary, and the global stability of the approach embankments and retaining walls will need to be checked and the magnitude of foundation settlements and any mitigation measures will need to be reassessed.

Additionally, given that the seismic Site Class based on  $\bar{N}_{60}$  indicates that portions of the site are considered a Site Class D (but near the transition to Site Class C), it is recommended that geophysics testing be completed to measure site-specific shear wave velocities. Multi-Channel Analysis of Surface Waves (MASW) or Vertical Seismic Profiling (VSP) may provide a more favourable Site Class designation across the site, and such testing should be considered during detail design. The use of GSC 5th Generation or 6th Generation seismic hazard maps to define the Site Class must also be confirmed for detail design.

Additional foundation investigation and design should meet the general requirements outlined in the latest version of the *Guideline for MTO Foundation Engineering Services*. It is recommended that the existing standpipe piezometers (installed in Boreholes 404-1 and 404-4) be maintained operational to allow for continued monitoring of the groundwater level during detail design and up to construction, at which time the piezometers will need to be decommissioned in accordance with Ontario Regulation 903 (as amended). Additional piezometers (particularly within the median) should be installed near the proposed foundation elements to provide additional information for assessment of dewatering requirements.

## 7.0 CLOSURE

This Preliminary Foundation Design Report was prepared by Ms. Priyanka Talukdar, a geotechnical EIT with WSP and Ms. Madison Kennedy, P.Eng., a geotechnical engineer with WSP. This report was reviewed by Mr. Kevin Bentley, P.Eng., Senior Principal and MTO Principal Foundations Contact, and Ms. Lisa Coyne, P.Eng., Geotechnical Engineering Fellow and MTO Principal Foundations Contact.

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- 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 Tests and Split Barrel Sampling of Soils.

### Canadian Standards Association (CSA):

CAN/CSA A23.1-14 Concrete Materials and Methods of Concrete Construction

### Commercial Software:

Settle3 (Version 5.015) by Rocscience Inc.

Slide2 (Version 9.017) by Rocscience Inc.

### Ontario Provisional Standard Drawing:

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

OPSD 3090.101 Foundation Frost Penetration Depths for Southern Ontario

OPSD 3101.150 Walls, Abutments, Backfill, Minimum Granular Requirements

OPSD 3121.150 Walls, Retaining, Backfill, Minimum Granular Requirements

**Ontario Provincial Standard Specifications (OPSS)**

OPSS.PROV 206 Construction Specification for Grading

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 517 Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure  
Excavation

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS.PROV 803 Construction Specification for Vegetative Cover

OPSS.PROV 804 Construction Specification for Temporary Erosion Control

OPSS.PROV 903 Construction Specification for Deep Foundations

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

Special Provision 109F57 Amendment to OPSS.PROV 903

**Ontario Water Resources Act**

Ontario Regulation 213 Construction Projects (as amended)

Ontario Regulation 903 Wells (as amended)

**Ministry of Transportation, Ontario**

Gravity Pipe Design Guidelines, Circular Culverts and Storm Sewers, April 2014.

MTO Foundations Guideline, Embankment Settlement Criteria for Design, July 2010.

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2020.

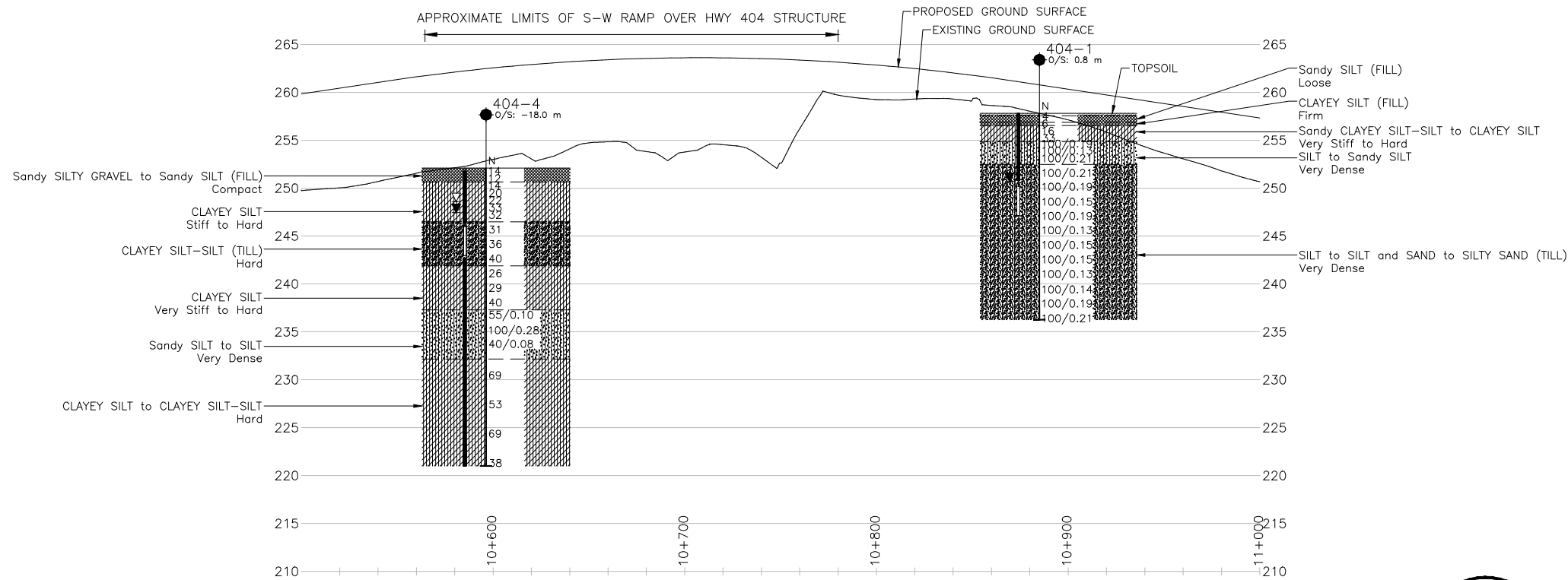
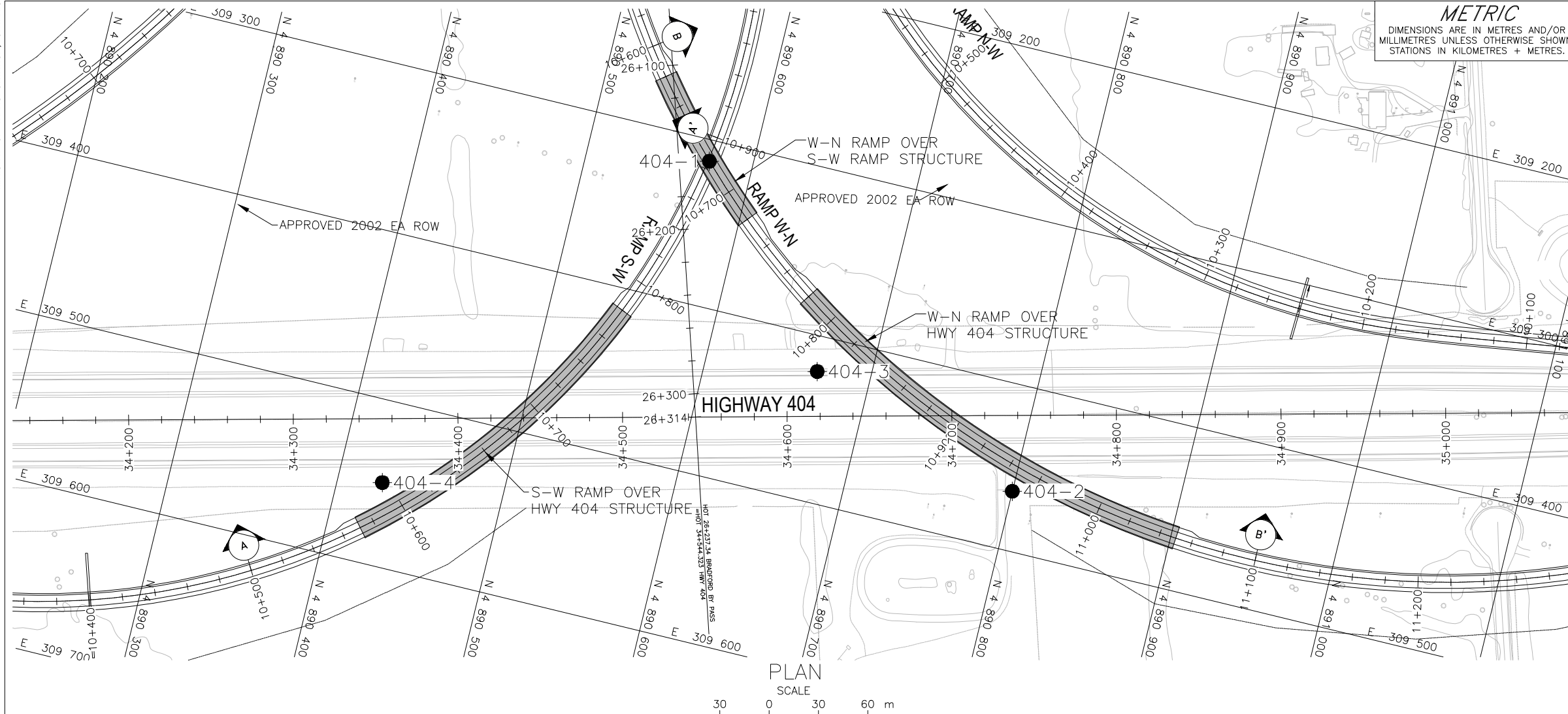
Guideline for MTO Foundation Engineering Services, Version 3, dated April 2022.

Table

Table 1: Comparison of Foundation Alternatives – Bradford Bypass / Hwy 404 Interchange Ramps

Foundation Option	Advantages	Disadvantages	Relative Costs	Risk / Consequences
Strip / spread footings founded on stiff to hard clayey silt or very dense sandy silt	<ul style="list-style-type: none"><li>■ Conventional construction</li><li>■ Relatively competent soils may provide adequate geotechnical resistance</li></ul>	<ul style="list-style-type: none"><li>■ Temporary protection systems may be required within median and near Hwy 404 to accommodate excavation to competent soils.</li><li>■ May require dewatering to allow for excavation and construction of footings in dry conditions and maintain stable foundation subgrade.</li><li>■ Does not allow for conventional integral abutment design at abutments</li></ul>	<ul style="list-style-type: none"><li>■ Lower cost than deep foundations</li><li>■ Costs for subexcavation and dewatering need to be considered</li></ul>	<ul style="list-style-type: none"><li>■ Less competent near surface soils may be encountered during detail design investigation at actual abutment and/or pier locations.</li><li>■ Risk of deeper excavation and increased dewatering and/or temporary shoring efforts</li></ul>
“Perched” abutment spread footings founded on a compacted granular pad within approach embankments (not applicable for piers)	<ul style="list-style-type: none"><li>■ Conventional construction</li><li>■ Granular pad can be constructed within approach embankment for abutment locations.</li><li>■ Founding level can be adjusted within approach embankment.</li><li>■ Reduces depth of excavation and height of abutment wall stems</li><li>■ Increased geotechnical resistance compared to shallow foundation on native deposits</li></ul>	<ul style="list-style-type: none"><li>■ Less appealing and may not be feasible for piers given large granular pad footprint within proximity of Highway 404</li><li>■ Temporary protection systems may be required within median and near Hwy 404 to accommodate excavation to competent soils.</li><li>■ May require dewatering to allow for excavation and construction of footings in dry conditions and maintain stable foundation subgrade.</li><li>■ Does not allow for conventional integral abutment design at abutments</li></ul>	<ul style="list-style-type: none"><li>■ Lower cost than deep foundations</li><li>■ Similar costs for subexcavation and dewatering to constructed granular pad</li></ul>	<ul style="list-style-type: none"><li>■ Less competent near surface soils may be encountered during detail design investigation at actual abutment and/or pier locations.</li><li>■ Risk of deeper excavation and increased dewatering and/or temporary shoring efforts</li></ul>
Steel H-piles or tube piles driven into very dense sandy silt to silt deposit or lower cohesive deposit	<ul style="list-style-type: none"><li>■ Conventional construction methods for H-pile foundations.</li><li>■ Higher axial resistances available compared to shallow foundations.</li><li>■ Allow for integral abutment design if used to support abutments.</li><li>■ Pile caps may be “perched” within approach embankment fill to reduce excavation and dewatering requirements</li></ul>	<ul style="list-style-type: none"><li>■ Pile lengths to achieve adequate capacity may vary as there is generally no consistent presence and thickness of competent “100-blow” end bearing soil at shallow depth (with exception of 4 m to 5 m thick layer of hard sandy silt to silt in Boreholes 404-3 and 404-4 to be confirmed during detail design and Borehole 404-1 where a very dense silt and sand to silty sand till deposit was encountered at shallow depth) or within 30 m depth of exploration.</li><li>■ Dewatering measures may be required at abutments and piers for the construction of pile caps, unless “perched” in embankment fill.</li><li>■ Long (&gt;30 m) friction piles may require sufficient time to “set-up” in clayey and silty soils to achieve design geotechnical resistance upon re-tap.</li></ul>	<ul style="list-style-type: none"><li>■ Lower relative cost than drilled shafts (caissons).</li><li>■ Higher cost than shallow footings but reduced dewatering / excavation costs if “perched” piles caps are designed.</li></ul>	<ul style="list-style-type: none"><li>■ Reduced impact on design if variable near surface soils are encountered during detailed investigation</li><li>■ Risk of damage to piles due to driving &gt;30 m and through hard / very dense sandy glacial deposits. Driving shoes and/or thicker pile section may be required.</li><li>■ Higher risk of penetrating through and not achieving design resistance if considering shorter piles founded on relatively ‘thin’ layer of very dense sandy silt to silt (to be confirmed during detail design) in some areas.</li><li>■ For W-N Ramp over S-W Ramp structure (Borehole 404-1), “100-blow” soil was encountered at shallow depth (3 m bgs) and pre-augering may be required to achieve minimum required pile length if pile caps are not able to be “perched” in approach embankment.</li></ul>
Drilled shafts (caissons) founded within very dense sandy silt to silt deposit or lower cohesive deposit	<ul style="list-style-type: none"><li>■ Offers higher geotechnical resistance per foundation element compared to driven steel piles, requiring fewer foundation elements.</li><li>■ Requires a smaller footprint for construction in constrained working areas, as compared with multiple rows of vertical or battered piles.</li><li>■ May be designed to eliminate pile cap and temporary excavations as the caissons could be cast continuously with structural columns to underside of superstructure. Associated dewatering efforts reduced compared to shallow foundation and pile cap construction.</li></ul>	<ul style="list-style-type: none"><li>■ Temporary or permanent liner will be required, plus special measures such as use of polymer slurry to counterbalance hydrostatic head and groundwater pressures to reduce risk of loosening / softening of the sides of excavation and blow-out at base of shaft during drilling and concrete placement (by tremie methods).</li><li>■ Long (&gt;30 m) caissons anticipated as there is no consistent presence and thickness of competent “100-blow” end bearing soil at shallow depth (with exception of 4 m to 5 m thick layer of hard sandy silt to silt in Boreholes 404-3 and 404-4 to be confirmed during detail design and Borehole 404-1 where a very dense silt and sand to silty sand till deposit was encountered at shallow depth) or within 30 m depth of exploration.</li><li>■ Generation and disposal of soil cuttings / slurry during drilled shaft advancement.</li><li>■ Does not allow for conventional integral abutment design if used at the abutments.</li></ul>	<ul style="list-style-type: none"><li>■ Higher relative cost than driven piles.</li><li>■ Higher cost than shallow foundations but reduced dewatering / excavation costs if cast continuously with pier to eliminate pile cap.</li></ul>	<ul style="list-style-type: none"><li>■ Long caissons (&gt;30 m) likely required and may not be practical from constructability perspective using liners and slurry.</li><li>■ Higher risk of not achieving design resistance if founded higher in relatively ‘thin’ layer of very dense sandy silt to silt (thickness and relative density to be confirmed during detail design).</li><li>■ Challenging to inspect the shaft and base of the drilled shaft due to the need for liners, slurry, and tremie concrete methods.</li></ul>

Drawings

CONT No.  
WP No.BRADFORD BYPASS  
HIGHWAY 404 INTERCHANGE RAMP  
BOREHOLE LOCATIONS AND SOIL  
STRATA

SHEET

KEY PLAN  
SCALE

1 0 1 2 km

## LEGEND

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

## BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
404-1	257.8	4890573.8	309312.9
404-2	252.5	4890800.0	309464.1
404-3	252.6	4890667.6	309421.5
404-4	252.1	4890426.9	309549.5

## NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the 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. X-Base\_Bradford Bypass.dwg and BRADFORD BY-PASS OG\_Combined.xml, received January 11, 2022.  
Horizontal alignments provided in digital format by Aecom, drawing file nos. BBP-Bathurst IC Alignments.xml, BBP-Hwy 400 IC Alignments.xml, BBP-Hwy 404 IC Alignments.xml and BBP-Leslie IC Alignments.xml, received January 26, 2022.  
Vertical alignments provided in digital format by Aecom, drawing file no. BBP-Hwy 404 IC Profiles.dwg, received January 28, 2022.  
Design plan provided in digital format by Aecom, drawing file no. 220420\_X-60636190-C-DES-BBP Overall Plan.dwg, received April 20, 2022.





1	12/01/23	MCK	BOREHOLE 404-1 ADDED, STRATIGRAPHY REVISED
NO.	DATE	BY	REVISION
Geocres No. 31D-806			
HWY. BRADFORD BYPASS	PROJECT NO. 19136074	DIST.	
SUBM'D. MA	CHKD. MA	DATE: 12/01/2023	SITE:
DRAWN: DD/SA	CHKD. MCK	APPD. KJB	DWG. 1

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

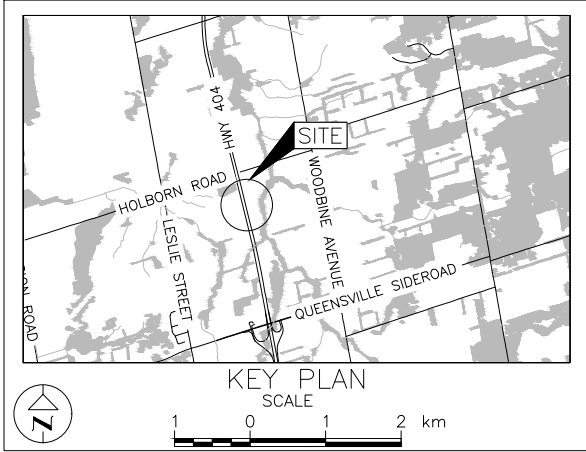
CONT No.  
WP No.

BRADFORD BYPASS  
HIGHWAY 404 INTERCHANGE RAMP  
SOIL STRATA





SHEET



LEGEND

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

BOREHOLE CO-ORDINATES			
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REFERENCE

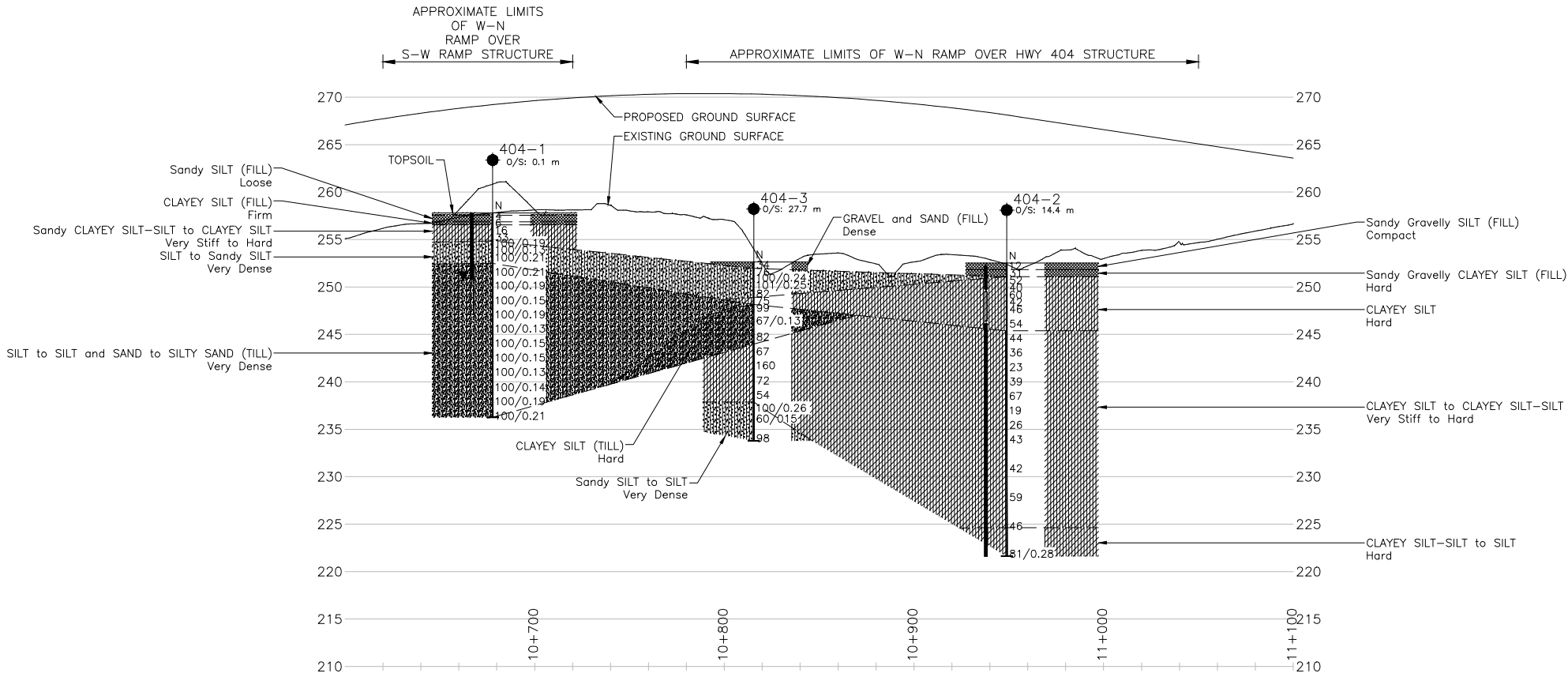
Base plans provided in digital format by Aecom, drawing file nos. X-Base\_Bradford Bypass.dwg and BRADFORD BY-PASS OG\_Combined.xml, received January 11, 2022.

Horizontal alignments provided in digital format by Aecom, drawing file nos. BBP-Bathurst IC Alignments.xml, BBP-Hwy 400 IC Alignments.xml, BBP-Hwy 404 IC Alignments.xml and BBP-Leslie IC Alignments.xml, received January 26, 2022.

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Design plan provided in digital format by Aecom, drawing file no. 220420\_X-60636190-C-DES-BBP Overall Plan.dwg, received April 20, 2022.

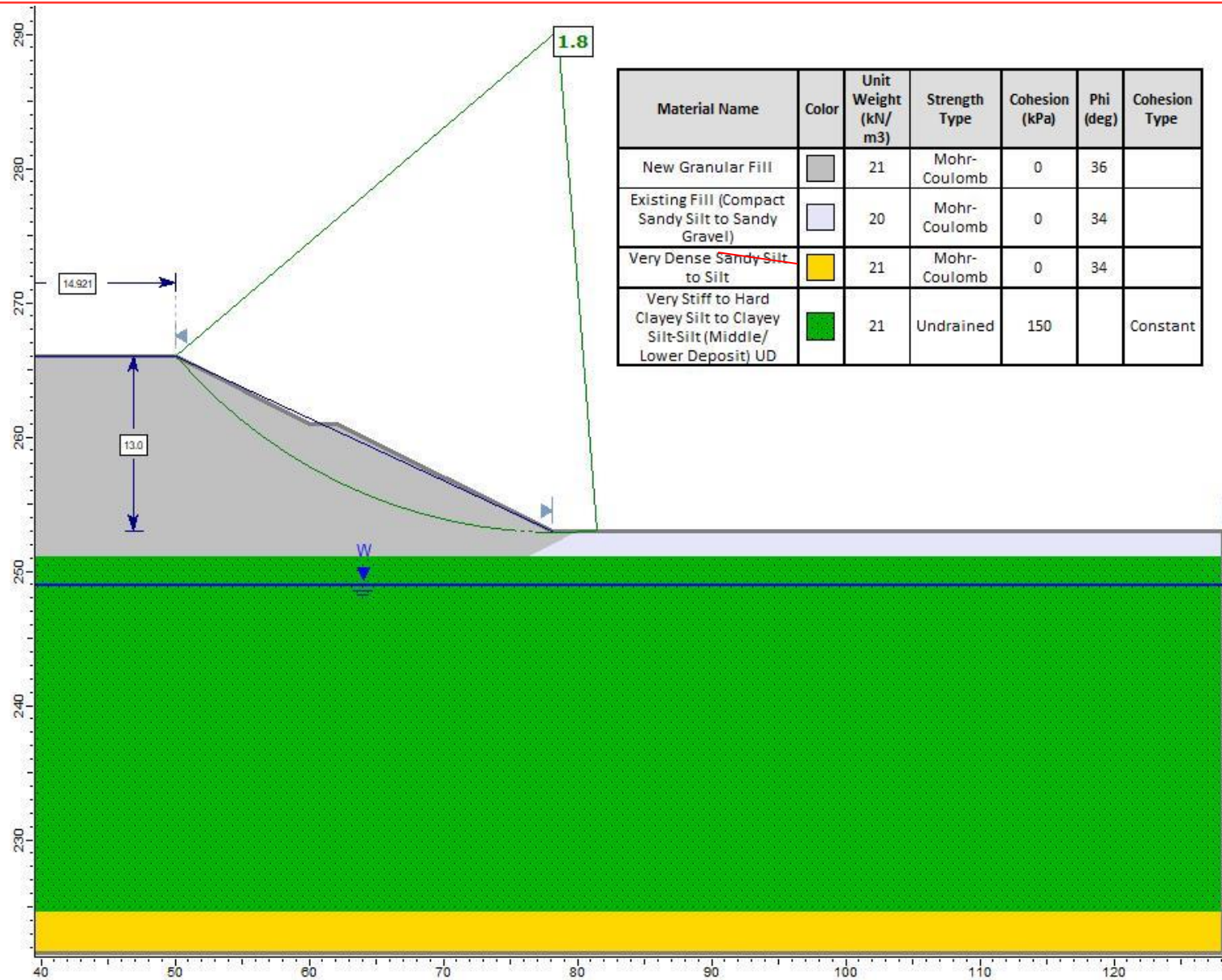
1	12/01/23	MCK	BOREHOLE 404-1 ADDED, STRATIGRAPHY REVISED
NO.	DATE	BY	REVISION
Geocres No. 31D-806			
HWY.	BRADFORD BYPASS	PROJECT NO.	19136074
SUBM'D. MA	CHKD. MA	DATE:	12/01/2023
DRAWN:	DD/SA	CHKD.	MCK
		APPD.	KJB
		SITE:	
		DWG.	2

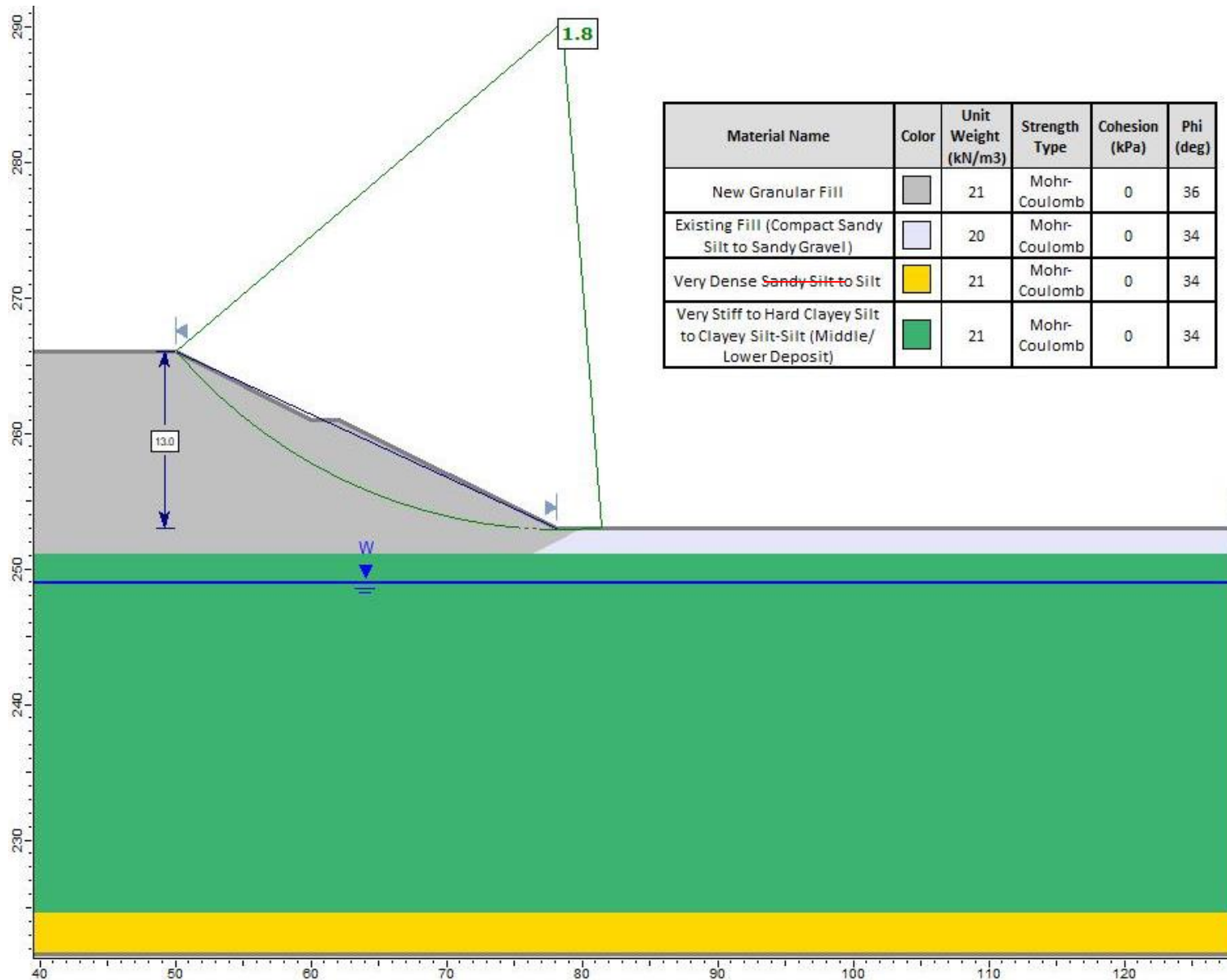


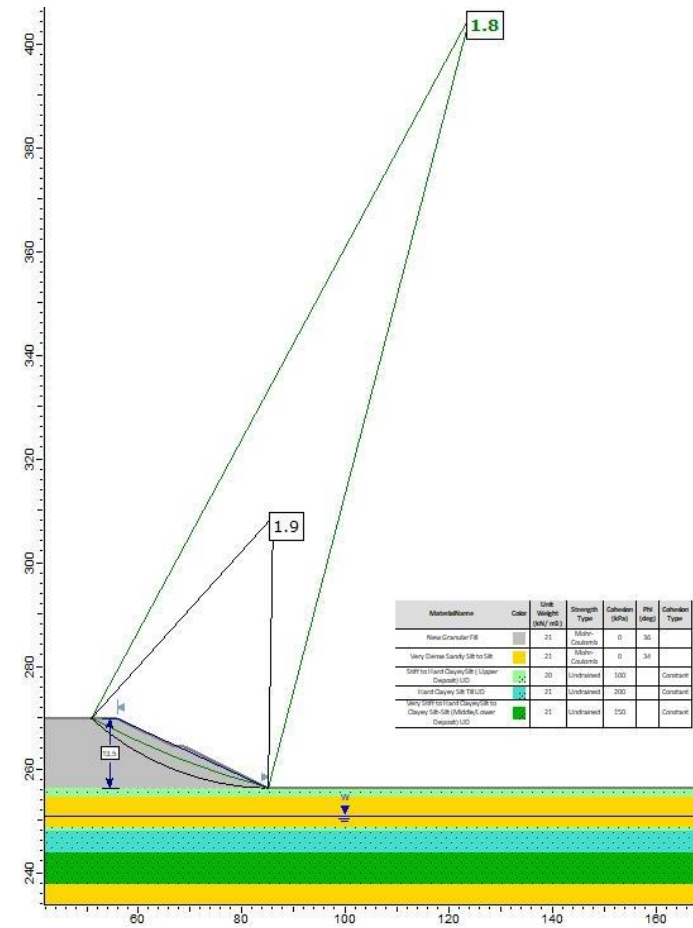
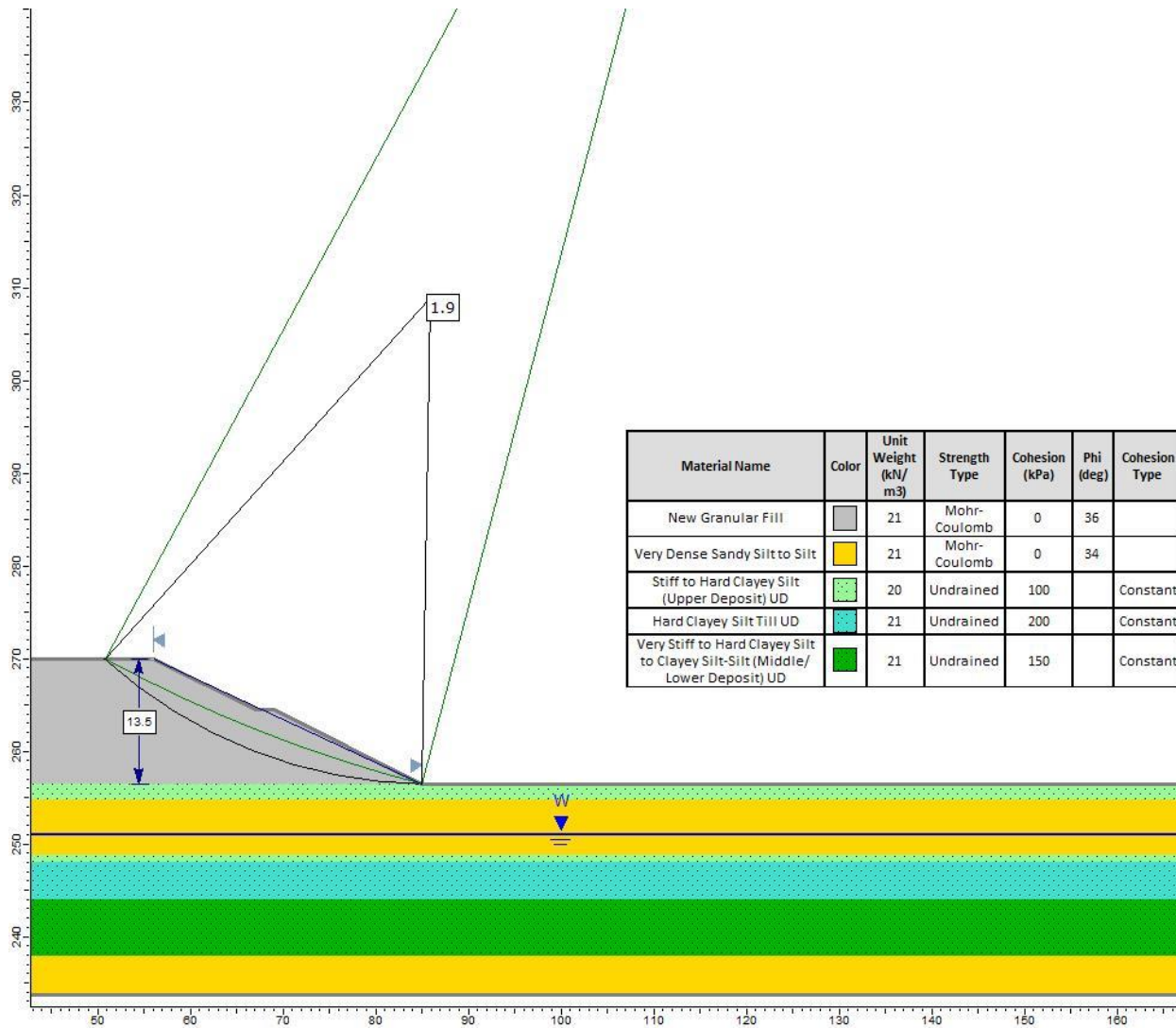
PROFILE B-B' – BRADFORD BYPASS-HIGHWAY 404 W-N RAMP PROFILE



Figures



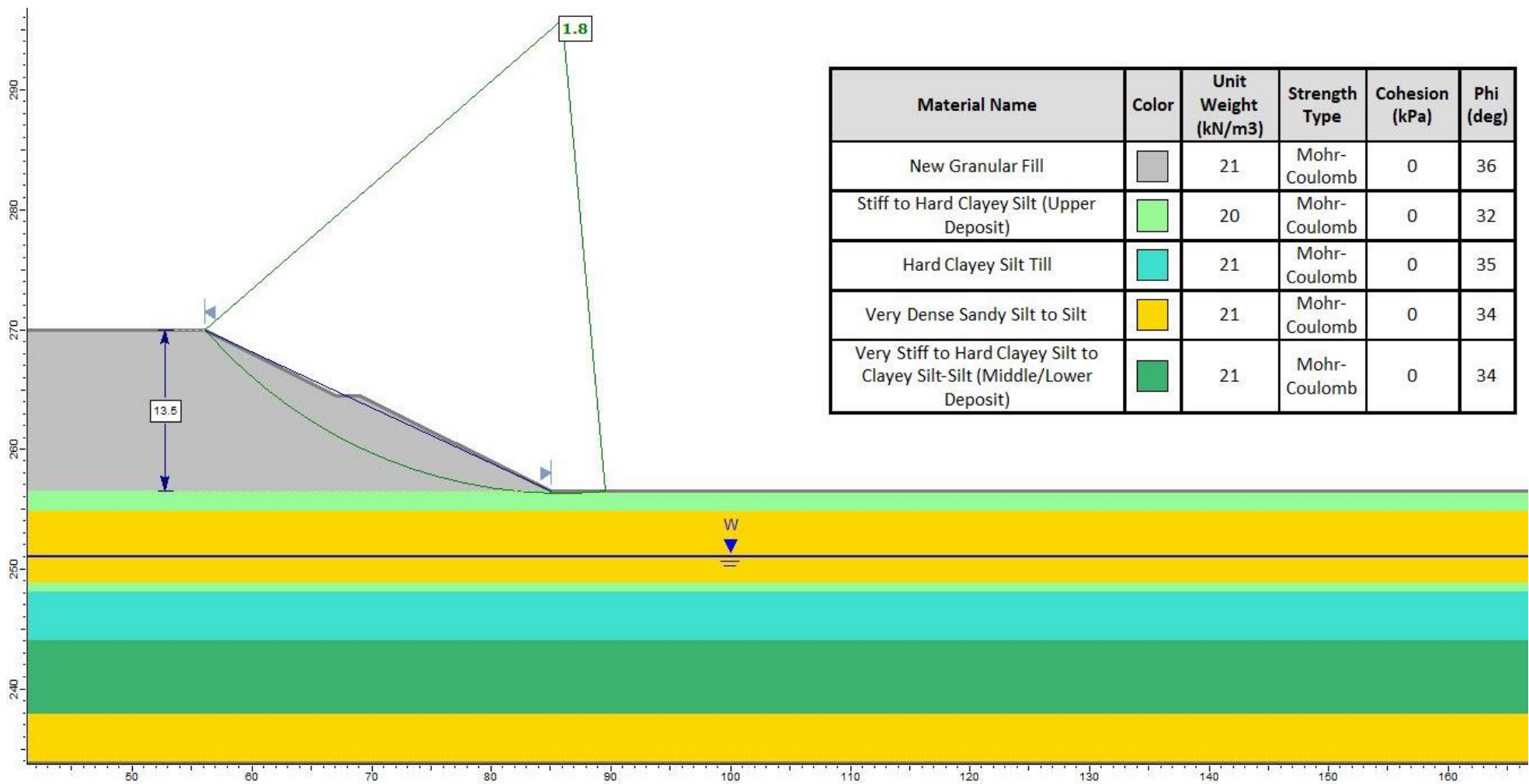






Global Stability Analysis Results (Drained Condition)  
W-N Ramp over Hwy 404 – South Embankment Sideslope (West Side of Hwy 404)

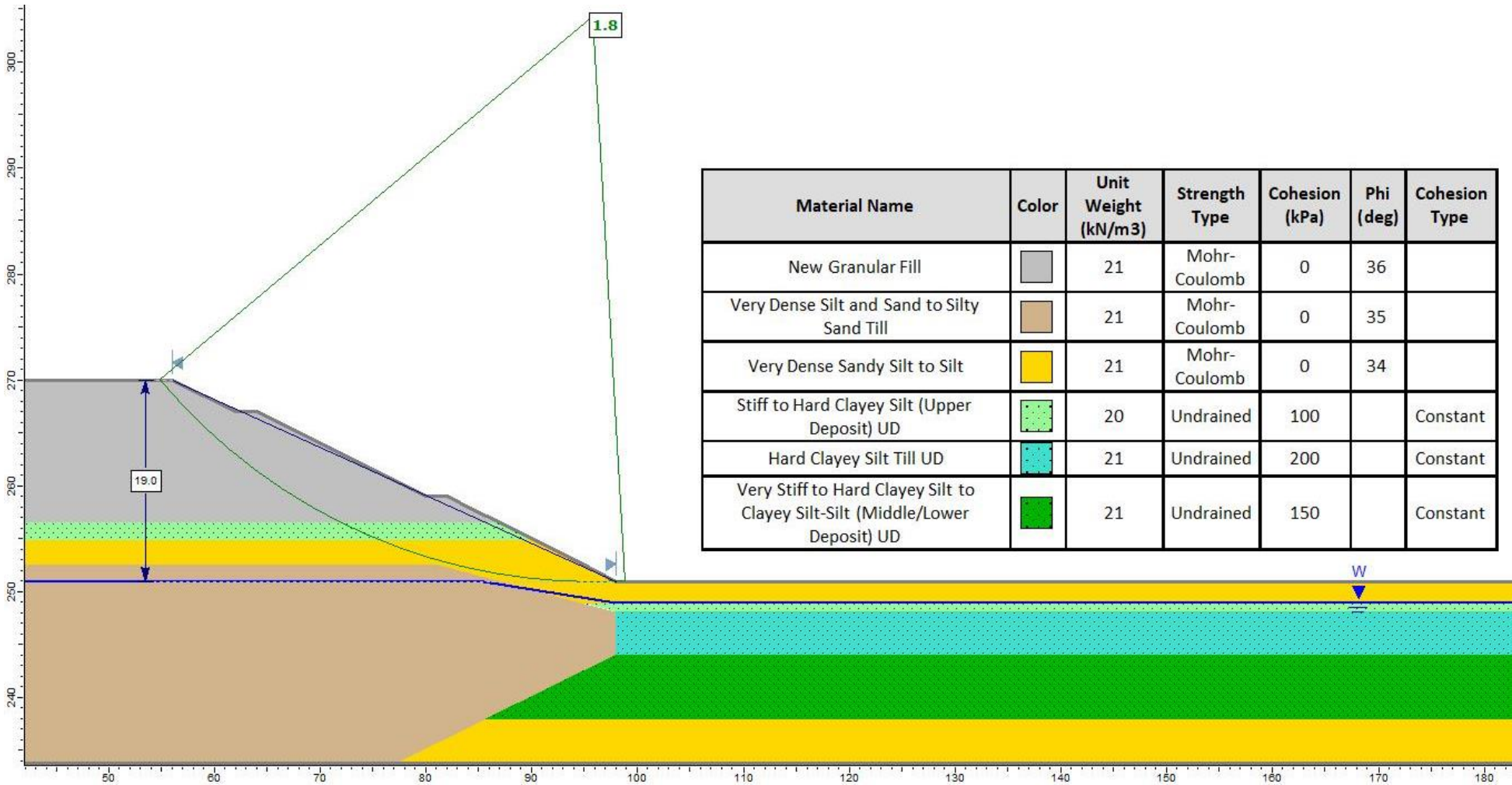
Figure 4

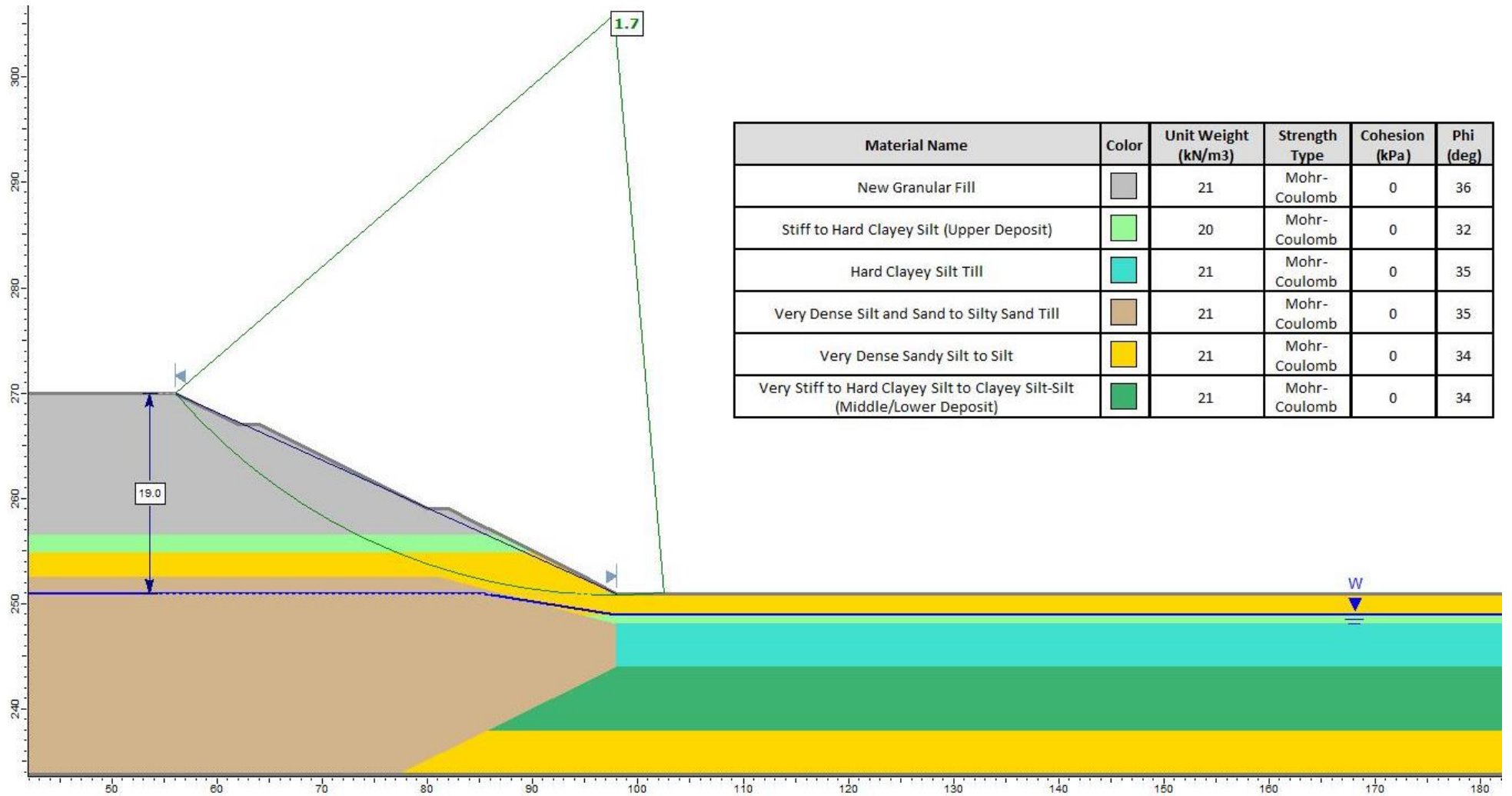




Global Stability Analysis Results (Undrained Condition)  
W-N Ramp over Hwy 404 – South Embankment Foreslope (West Side of Highway 404)

Figure 5

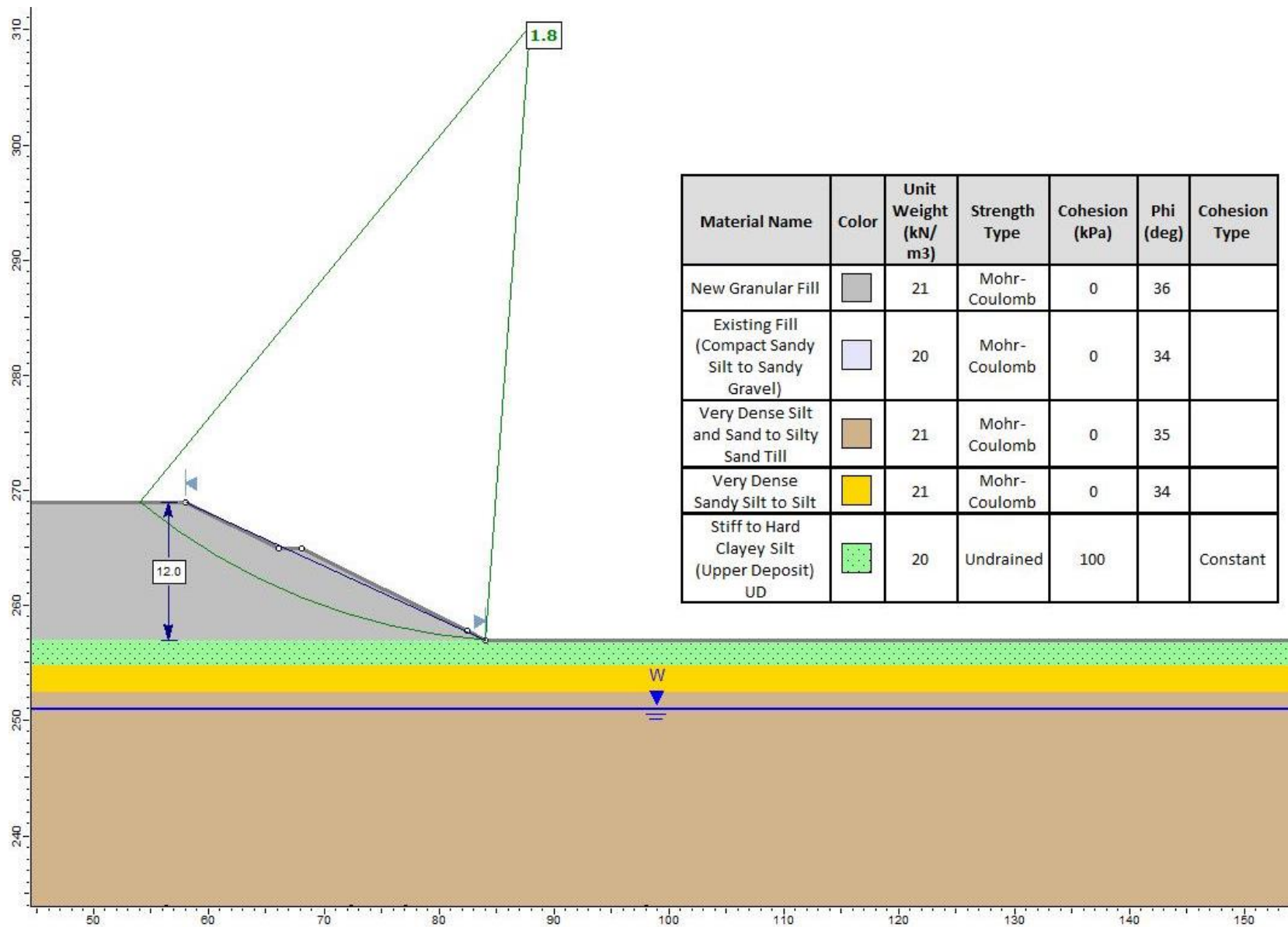


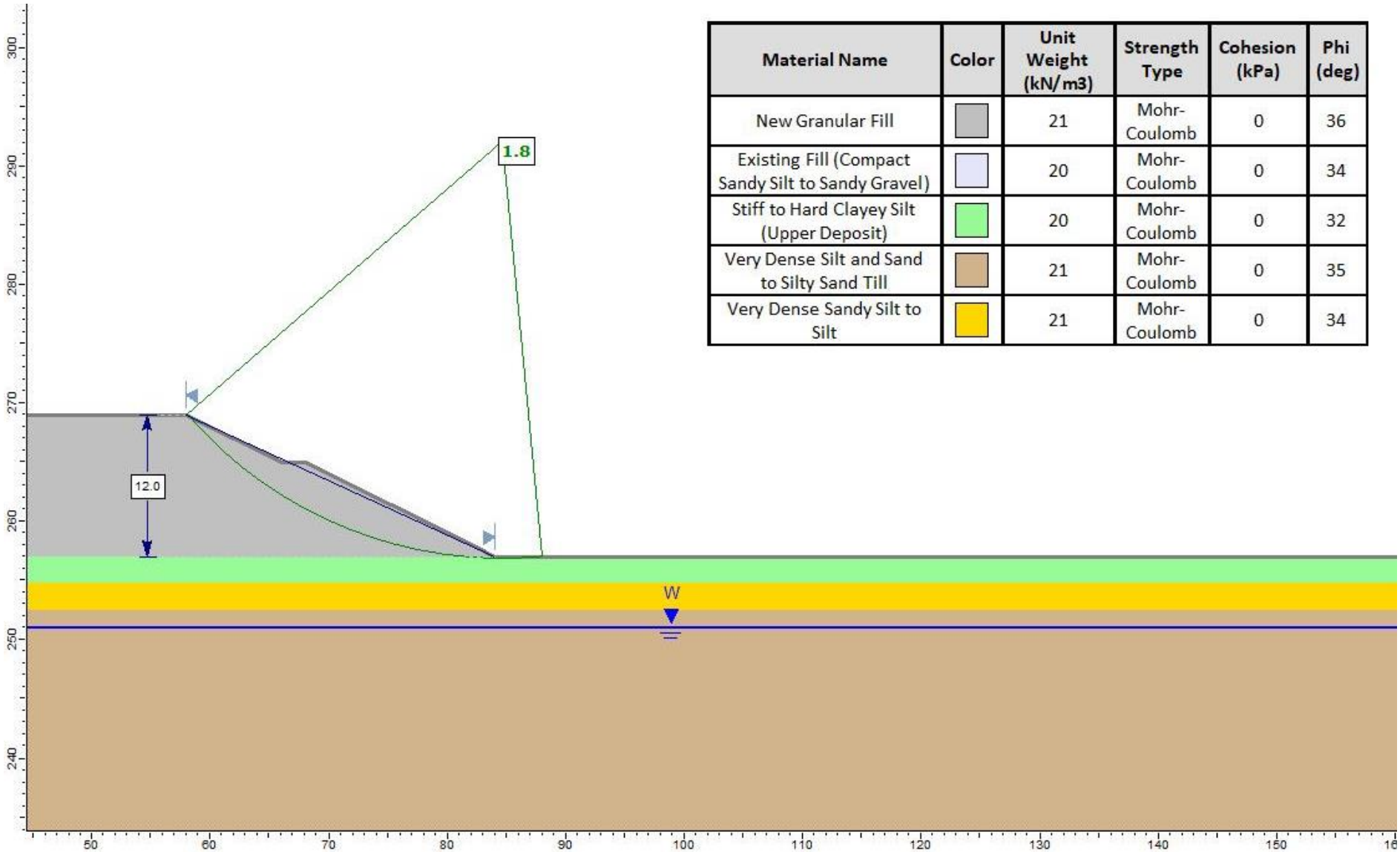




Global Stability Analysis Results (Undrained Condition)  
W-N Ramp over S-W Ramp - East Approach Embankment Sideslope

Figure 7





**APPENDIX A**

**Borehole Records**

# 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 Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

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

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

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

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

### PENETRATION RESISTANCE

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

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

#### Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 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>
$D_R$	relative density (specific gravity, $G_s$ )
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <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

1. 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

1. 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.

2. 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

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

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

### Field Moisture Condition

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

# LIST OF SYMBOLS

## MINISTRY OF TRANSPORTATION, ONTARIO

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

### I. GENERAL

$\pi$	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

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

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

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

#### (b) Hydraulic Properties

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

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

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_{a(e)}$	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

Notes: 1  
2

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

PROJECT 19136074

## RECORD OF BOREHOLE No. 404-1

Sheet 1 of 3

METRIC

G.W.P. Assignment No 2019-E-0048

LOCATION N 4890573.8; E 309312.9 NAD83 / MTM Zone 10 (LAT. 44.155147; LONG. -79.443581)

ORIGINATED BY TC

DIST Central HWY BBP - Hwy 404

BOREHOLE TYPE 210 mm Hollow Stem Auger; Mud Rotary

COMPILED BY MTI

DATUM CGVD28 Surface Elevation:257.8 m

DATE Aug 04, 2023 - Aug 08, 2023

CHECKED BY MCK

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT Y kN/m³	GR	SA	SI	CL	REMARKS
ELEV. ----- DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL	NMC	LL						
								Field Vane	Remoulded	Pocket Pen	Quick Triaxial	Unconfined	W <sub>p</sub>	W	W <sub>L</sub>						
							20	40	60	80	100	20	40	60	NP Nonplastic						
0.0 257.6	TOPSOIL (250 mm)																				
0.2	Sandy SILT (ML), trace clay, containing rootlets, (FILL) Loose Brown Moist		1	SS	4																
256.9			2A																		
0.9	CLAYEY SILT (CL), containing rootlets, (FILL) Firm Brown Moist		2B	SS	6																
256.5																					
1.3	CLAYEY SILT (CL), trace sand, containing rootlets Very stiff Greyish brown Moist		3	SS	16																
255.6																					
2.2	Sandy CLAYEY SILT-SILT (CL-ML), trace gravel containing rock fragments, containing silt seams Hard Brown Moist		4	SS	33																
254.8																					
3.0	SILT (ML) some sand to sandy, trace clay, trace gravel, containing sand seams Very dense Brown Wet		5	SS	100/0.19																
				6	SS	100/0.13															
			7	SS	100/0.21																
252.5																					
5.3	SILTY SAND (SM), trace clay, (TILL) Very dense Greyish brown Wet		8	SS	100/0.21																
250.6																					
7.2	SILT and Sand (ML), trace clay, trace gravel, (TILL) Very dense Grey Wet - 7.6 m: Bouncing of split spoon		9	SS	100/0.19																
				10	SS	100/0.15															

Continued on Next Page


+<sup>3</sup>, x<sup>3</sup> : Numbers refer to Sensitivity o<sup>30</sup>% STRAIN AT FAILURE

PROJECT 19136074		<b>RECORD OF BOREHOLE No. 404-1</b>		Sheet 2 of 3		<b>METRIC</b>	
G.W.P. Assignment No 2019-E-0048		LOCATION N 4890573.8; E 309312.9 NAD83 / MTM Zone 10 (LAT. 44.155147; LONG. -79.443581)		ORIGINATED BY TC			
DIST Central HWY BBP - Hwy 404		BOREHOLE TYPE 210 mm Hollow Stem Auger; Mud Rotary		COMPILED BY MTI			
DATUM CGVD28 Surface Elevation:257.8 m		DATE Aug 04, 2023 - Aug 08, 2023		CHECKED BY MCK			

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT	GR	SA	SI	CL	REMARKS
ELEV. ----- DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL	NMC	LL						
								Field Vane	Remoulded	Pocket Pen	Quick Triaxial	Unconfined	W <sub>p</sub>	W	W <sub>L</sub>						
	SILT and Sand (ML), trace clay, trace gravel, (TILL) Very dense Grey Wet - 10.1 m: Auger grinding		11	SS	100/0.19																
	- 12.2 m: Bouncing of split spoon		12	SS	100/0.13																
	- 13.7 m: Bouncing of split spoon		13	SS	100/0.15																
	- 15.2 m: Bouncing of split spoon		14	SS	100/0.15																
241.5																					
16.3	SILT (ML), some sand, trace gravel, trace clay, (TILL) Very Dense Grey Wet - 16.8 m: Bouncing of split spoon		15	SS	100/0.13																
				16	SS	100/0.14															
	- 19.8 m: Containing sand seams		17	SS	100/0.19																

Continued on Next Page

+<sup>3</sup>, x<sup>3</sup> : Numbers refer to Sensitivity o<sup>30</sup>% STRAIN AT FAILURE

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		WATER CONTENT (%)			UNIT WEIGHT  Y  kN/m³	GR	SA	SI	CL	REMARKS
ELEV. ----- DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)		PL	NMC	LL						
								Field Vane Remoulded Pocket Pen Quick Triaxial Unconfined		W <sub>p</sub>	W	W <sub>i</sub>						
236.3 21.6	SILT (ML), some sand, trace gravel, trace clay, (TILL) Very Dense Grey Wet  - 21.6 m: Bouncing of split spoon  End of Borehole		18	SS	100/0.21		237											
	Notes: 1. Water level not measure during drilling due to addition of water / drilling fluid during advancement. 2. A standpipe piezometer was installed approximately 1.6 m east of Borehole 404-1 (N 4890572.20; E 309313.01). 3. Water level in piezometer measured at a depth of 6.7 m (Elev. 251.1 m) on November 29, 2023						236											
							235											
							234											
							233											
							232											
							231											
							230											
							229											
							228											

+<sup>3</sup>, x<sup>3</sup> : Numbers refer to Sensitivity    o<sup>30%</sup> STRAIN AT FAILURE

PROJECT 19136074

## RECORD OF BOREHOLE No. 404-2

Sheet 1 of 4

METRIC

G.W.P. Assignment No 2019-E-0048

LOCATION N 4890800; E 309464.1 NAD83 / MTM Zone 10 (LAT. 44.157182; LONG. -79.441689)

ORIGINATED BY MM

DIST Central HWY BBP - Hwy 404

BOREHOLE TYPE 210 mm Hollow Stem Auger; Mud Rotary

COMPILED BY MA

DATUM CGVD28 Surface Elevation:252.5 m

DATE Jun 15, 2021 - Jun 16, 2021

CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT Y kN/m³	GR	SA	SI	CL	REMARKS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL W <sub>p</sub>	NMC W	LL W <sub>L</sub>						
0.0	Sandy Gravelly SILT (ML), some clay (FILL) Compact Brownish grey Moist		1	SS	12		252	20	40	60	80	100	20	40	60		24	25	37	14	
251.8																					
0.7	Sandy Gravelly CLAYEY SILT (CL) (FILL) Hard Brownish grey Moist		2	SS	31		251														
251.1																					
1.4	CLAYEY SILT (CL) trace sand, trace gravel Hard Brownish grey to grey Moist		3	SS	52		250														
			4	SS	40																
			5	SS	60		249										0	4	56	40	
			6	SS	42		248														
			7	SS	46		247														
			8	SS	54		246														
245.4																					
7.2	CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML), trace sand Very stiff to hard Grey Wet		9	SS	44		245														
			10	SS	36		244														
							243														

Continued on Next Page

+3, x3 : Numbers refer to Sensitivity o3% STRAIN AT FAILURE

PROJECT 19136074

## RECORD OF BOREHOLE No. 404-2

Sheet 2 of 4

METRIC

G.W.P. Assignment No 2019-E-0048

LOCATION N 4890800; E 309464.1 NAD83 / MTM Zone 10 (LAT. 44.157182; LONG. -79.441689)

ORIGINATED BY MM

DIST Central HWY BBP - Hwy 404

BOREHOLE TYPE 210 mm Hollow Stem Auger; Mud Rotary

COMPILED BY MA

DATUM CGVD28 Surface Elevation:252.5 m

DATE Jun 15, 2021 - Jun 16, 2021

CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE ELEVATION (m)	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT Y kN/m <sup>3</sup>	GR	SA	SI	CL	REMARKS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL W <sub>p</sub>	NMC W	LL W <sub>L</sub>						
								20	40	60	80	100									
	CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML), trace sand Very stiff to hard Grey Wet						242														
			11	SS	23																
							241														
			12	SS	39		240										0	0	62	38	
							239														
			13	SS	67																
							238														
			14	SS	19		237														
							236														
			15	SS	26		235														
			16	SS	43		234														
							233														

Continued on Next Page

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

PROJECT 19136074

## RECORD OF BOREHOLE No. 404-2

Sheet 3 of 4

METRIC

G.W.P. Assignment No 2019-E-0048

LOCATION N 4890800; E 309464.1 NAD83 / MTM Zone 10 (LAT. 44.157182; LONG. -79.441689)

ORIGINATED BY MM

DIST Central HWY BBP - Hwy 404

BOREHOLE TYPE 210 mm Hollow Stem Auger; Mud Rotary

COMPILED BY MA

DATUM CGVD28 Surface Elevation:252.5 m

DATE Jun 15, 2021 - Jun 16, 2021

CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE ELEVATION (m)	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT Y kN/m <sup>3</sup>	GR	SA	SI	CL	REMARKS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL W <sub>p</sub>	NMC W	LL W <sub>L</sub>						
								Field Vane	Remoulded	Pocket Pen	Quick Triaxial	Unconfined									
								20	40	60	80	100	20	40	60						
	CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML), trace sand Very stiff to hard Grey Wet						232														
			17	SS	42		231														
							230														
							229														
			18	SS	59		228														
							227														
							226														
			19A	SS	46		225														
224.6			19B				224														
27.9	CLAYEY SILT-SILT (CL-ML) to SILT (ML) with slight plasticity, trace to some sand Hard Grey Moist						223														

Continued on Next Page

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

PROJECT	19136074		RECORD OF BOREHOLE		No. 404-2	Sheet 4 of 4	METRIC
G.W.P.	Assignment No 2019-E-0048		LOCATION	N 4890800; E 309464.1 NAD83 / MTM Zone 10 (LAT. 44.157182; LONG. -79.441689)			ORIGINATED BY MM
DIST	Central	HWY BBP - Hwy 404	BOREHOLE TYPE	210 mm Hollow Stem Auger; Mud Rotary			COMPILED BY MA
DATUM	CGVD28 Surface Elevation:252.5 m		DATE	Jun 15, 2021 - Jun 16, 2021			CHECKED BY KJB

SOIL PROFILE					
ELEV. ----- DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES
221.6	CLAYEY SILT-SILT (CL-ML) to SILT (ML) with slight plasticity, trace to some sand Hard Grey Moist		20	SS	81/0.28
30.9	End of Borehole				
<p>Note: 1. Water level not measured due to introduction of water during drilling operations.</p>					

+<sup>3</sup>, x<sup>3</sup> : Numbers refer to Sensitivity    o<sup>30%</sup> STRAIN AT FAILURE

PROJECT 19136074

## RECORD OF BOREHOLE No. 404-3

Sheet 1 of 2

METRIC

G.W.P. Assignment No 2019-E-0048

LOCATION N 4890667.6; E 309421.5 NAD83 / MTM Zone 10 (LAT. 44.155991; LONG. -79.442223)

ORIGINATED BY MM

DIST Central HWY BBP - Hwy 404

BOREHOLE TYPE 210 mm Hollow Stem Auger; Mud Rotary

COMPILED BY MA

DATUM CGVD28 Surface Elevation:252.6 m

DATE Jun 17, 2021 - Jun 22, 2021


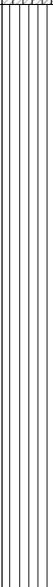
CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT Y	GR	SA	SI	CL	REMARKS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL W <sub>p</sub>	NMC W	LL W <sub>L</sub>						
0.0	GRAVEL and SAND (GP-GM), trace fines (FILL) Dense Brown Dry		1	SS	34		252	20	40	60	80	100	20	40	60						
252.0																					
0.7	Sandy SILT (ML), trace gravel, slight plasticity Very dense Brown Dry		2	SS	76		251											9	28	56	7
			3	SS	100/0.24																
			4	SS	101/0.25		250														
			5	SS	82		249														
248.9																					
3.7	CLAYEY SILT (CL), trace sand Hard Grey Moist		6	SS	75		248														
248.1			7	SS	99		247														
4.5	CLAYEY SILT (CL), some sand, trace gravel (TILL) Hard Grey Moist		8	SS	67/0.13		246														
			9	SS	82		245														
244.0							244														
8.7	CLAYEY SILT (CL) Hard Grey Moist		10	SS	67		243														

Continued on Next Page

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

PROJECT	19136074	RECORD OF BOREHOLE	No. 404-3	Sheet 2 of 2	METRIC
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4890667.6; E 309421.5 NAD83 / MTM Zone 10 (LAT. 44.155991; LONG. -79.442223)	ORIGINATED BY	MM
DIST	Central HWY BBP - Hwy 404	BOREHOLE TYPE	210 mm Hollow Stem Auger; Mud Rotary	COMPILED BY	MA
DATUM	CGVD28 Surface Elevation:252.6 m	DATE	Jun 17, 2021 - Jun 22, 2021	CHECKED BY	KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT Y kN/m³					REMARKS
ELEV. ----- DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL	NMC	LL						
								Field Vane Remoulded Pocket Pen Quick Triaxial Unconfined	20	40	60	80	100	W <sub>p</sub>	W		W <sub>i</sub>				
														NP Nonplastic			----- ----- -----				
	CLAYEY SILT (CL) Hard Grey Moist						242														
			11	SS	160																
							241														
			12	SS	72		240										0	0	55 45		
							239														
			13	SS	54		238														
237.9							237														
14.8	SILT (ML), some sand to sandy, trace gravel Very dense Grey Moist						236														
			14	SS	100/0.26																
							235														
			15	SS	60/0.15		234										6	23	68 3		
							233														
233.8			16	SS	98		232														
18.8	End of Borehole						231														
	Note: 1. Water level not measured due to introduction of water during drilling operations.						230														

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

PROJECT 19136074

## RECORD OF BOREHOLE No. 404-4

Sheet 1 of 4

METRIC

G.W.P. Assignment No 2019-E-0048

LOCATION N 4890426.9; E 309549.5 NAD83 / MTM Zone 10 (LAT. 44.153824; LONG. -79.440624)

ORIGINATED BY MM

DIST Central HWY BBP - Hwy 404

BOREHOLE TYPE 210 mm Hollow Stem Auger; Mud Rotary

COMPILED BY MA

DATUM CGVD28 Surface Elevation:252.1 m

DATE Jun 10, 2021 - Jun 15, 2021

CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT Y kN/m <sup>3</sup>	GR	SA	SI	CL	REMARKS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL W <sub>p</sub>	NMC W	LL W <sub>L</sub>						
0.0	Sandy SILTY GRAVEL (GM), some fines (FILL) Compact Moist to dry		1	SS	14		252	20	40	60	80	100	20	40	60						
251.4																					
0.7	Sandy SILT (ML), trace gravel (FILL) Compact Moist to dry		2	SS	12		251										1	27	59	13	
250.6																					
1.4	CLAYEY SILT (CL), trace sand Stiff to hard Brown to grey, iron oxide staining Moist.		3	SS	14		250														
			4	SS	20																
			5	SS	22		249														
			6	SS	33		248														
			7	SS	32		247										0	1	54	45	
246.5																					
5.6	CLAYEY SILT-SILT (CL-ML), trace sand (TILL) Hard Grey Moist to wet		8	SS	31		246														
							245														
			9	SS	36		244														
			10	SS	40		243														

Continued on Next Page

+<sup>3</sup>, x<sup>3</sup> : Numbers refer to Sensitivity o<sup>30</sup>% STRAIN AT FAILURE

PROJECT 19136074

## RECORD OF BOREHOLE No. 404-4

Sheet 2 of 4

METRIC

G.W.P. Assignment No 2019-E-0048

LOCATION N 4890426.9; E 309549.5 NAD83 / MTM Zone 10 (LAT. 44.153824; LONG. -79.440624)

ORIGINATED BY MM

DIST Central HWY BBP - Hwy 404

BOREHOLE TYPE 210 mm Hollow Stem Auger; Mud Rotary

COMPILED BY MA

DATUM CGVD28 Surface Elevation:252.1 m

DATE Jun 10, 2021 - Jun 15, 2021

CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT Y	GR	SA	SI	CL	REMARKS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL W <sub>p</sub>	NMC W	LL W <sub>L</sub>						
								Field Vane Remoulded Pocket Pen Quick Triaxial Unconfined													
								20 40 60 80 100													
241.9 10.2	CLAYEY SILT-SILT (CL-ML), trace sand (TILL) Hard Grey Moist to wet CLAYEY SILT (CL) Very stiff to hard Grey Moist						242														
			11	SS	26		241											0	0	55	45
							240														
			12	SS	29		239														
							238														
			13	SS	40		237														
237.3 14.8	Sandy SILT (ML) to SILT (ML), some sand Very dense Grey Wet.						236														
			14	SS	55/0.10		235											0	15	74	11
							234														
			15	SS	100/0.28		233														
			16	SS	40/0.08																
232.2 19.9	CLAYEY SILT (CL), trace sand, trace gravel, silt layers Hard Grey Moist to wet																				

Continued on Next Page

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

## METRIC

CHECKED BY                      KJB

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

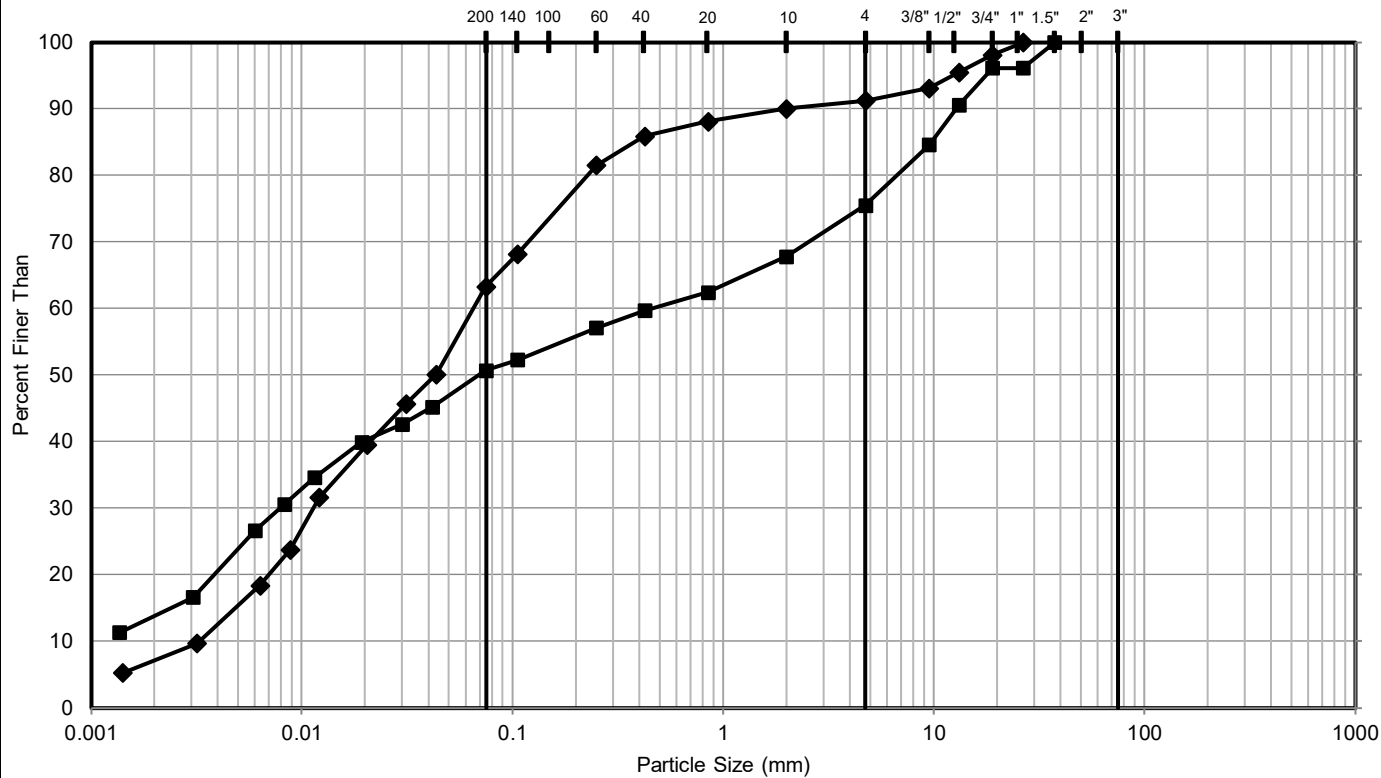
PROJECT	19136074	RECORD OF BOREHOLE	No. 404-4	Sheet 4 of 4	METRIC
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4890426.9; E 309549.5 NAD83 / MTM Zone 10 (LAT. 44.153824; LONG. -79.440624)	ORIGINATED BY	MM
DIST	Central HWY BBP - Hwy 404	BOREHOLE TYPE	210 mm Hollow Stem Auger; Mud Rotary	COMPILED BY	MA
DATUM	CGVD28 Surface Elevation:252.1 m	DATE	Jun 10, 2021 - Jun 15, 2021	CHECKED BY	KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					WATER CONTENT (%)			UNIT WEIGHT	GR	SA	SI	CL	REMARKS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)					PL W <sub>p</sub>	NMC W	LL W <sub>L</sub>						
								Field Vane Remoulded Pocket Pen Quick Triaxial Unconfined													
								20 40 60 80 100					20 40 60								
221.0	CLAYEY SILT (CL), trace sand, trace gravel Hard Grey Moist to wet						222														
221.0 31.1	End of Borehole		20	SS	38		221														
	Notes: 1. Water level measured at a depth of 3.1 m (Elev. 249.0 m) prior to introducing water for mud rotary. 2. Water level in piezometer measured at a depth of 4.2 m (El. 247.9 m) on March 22, 2022.						220														
							219														
							218														
							217														
							216														
							215														
							214														
							213														

**APPENDIX B**

**Geotechnical Laboratory  
Test Results**

# GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	404-2	1	0.0 - 0.6	252.5 to 251.9
◆	404-3	2	0.8 - 1.4	251.9 to 251.3

CLIENT

AECOM / MTO

CONSULTANT



YYYY-MM-DD 2023-11-26

DESIGNED -

PREPARED MCK

REVIEWED KJB

APPROVED KJB

PROJECT

Bradford Bypass - Highway 404 Interchange

TITLE

Grain Size Distribution - Sandy SILT (ML) (FILL)

PROJECT NO.

19136074

CONTROL

1000

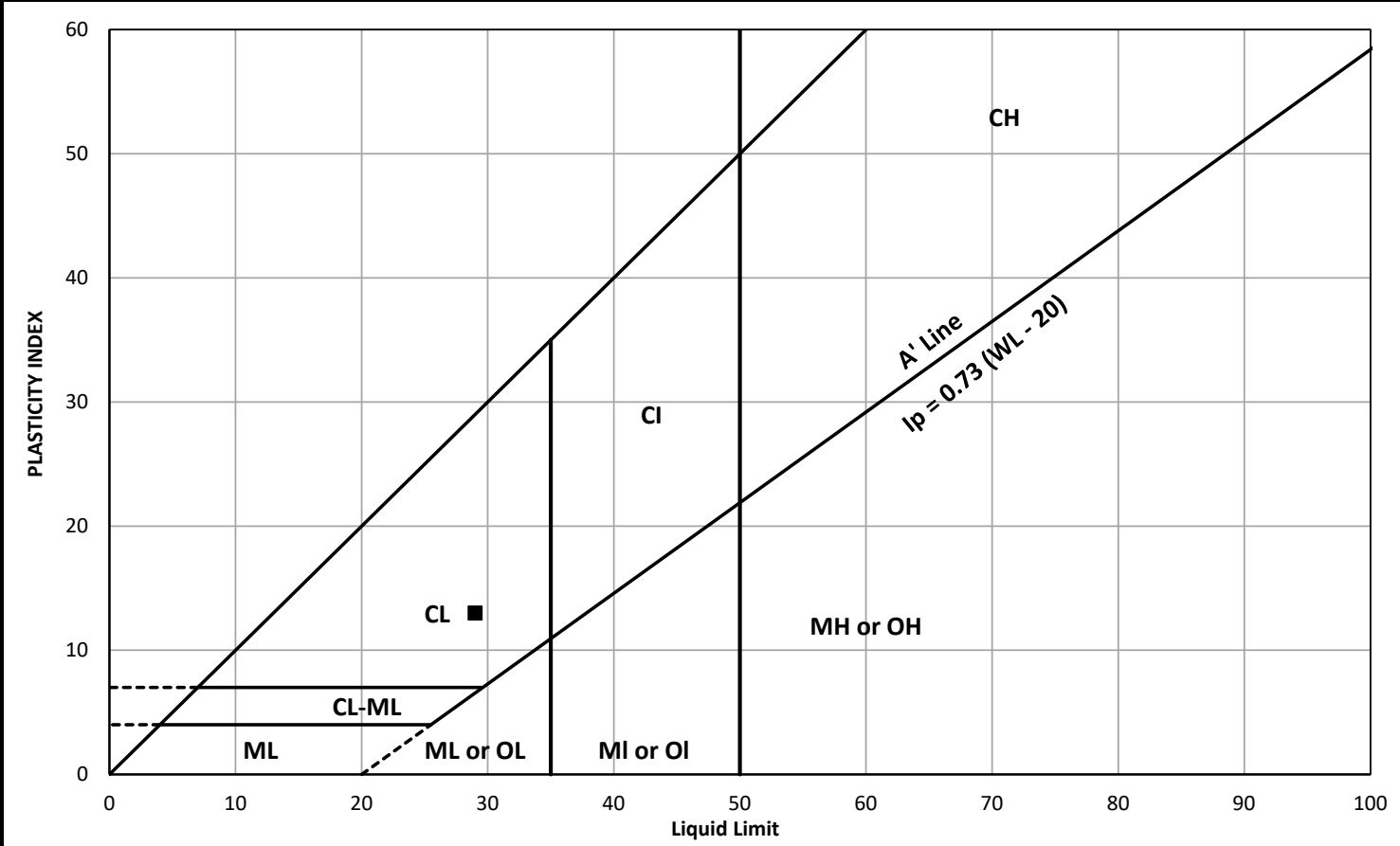
REV.

1


FIGURE

B1

PLASTICITY CHART

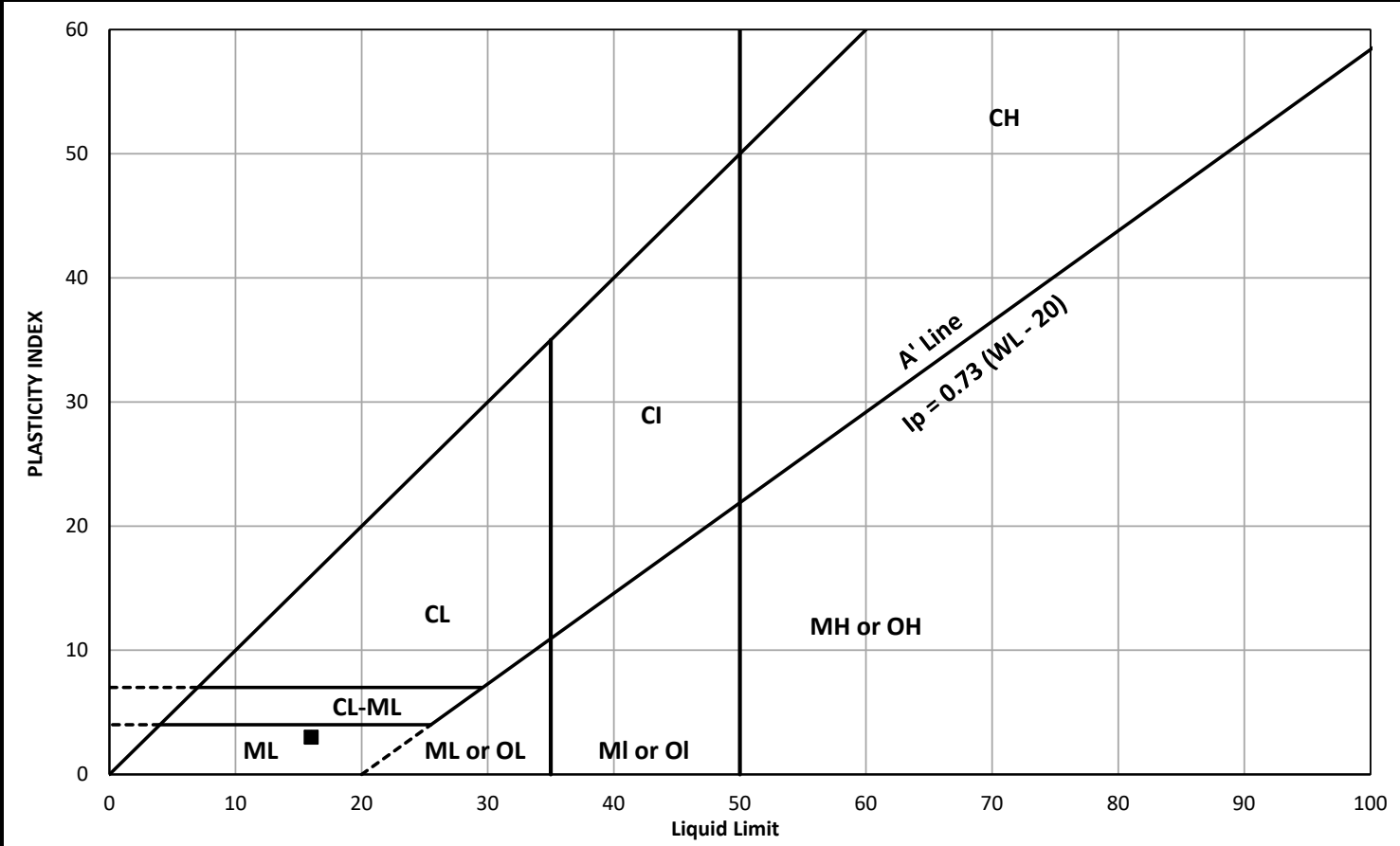


Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	404-2	2	251.8 to 251.2		29	16	13


CLIENT		
AECOM / MTO		
	CONSULTANT	YYYY-MM-DD 2023-11-26
	DESIGNED	--
	PREPARED	MCK
	REVIEWED	KJB
	APPROVED	KJB

PROJECT			
Bradford Bypass - Highway 404 Interchange			
TITLE			
Plasticity Chart - Sandy SILT (ML) (FILL)			
PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B2

PLASTICITY CHART

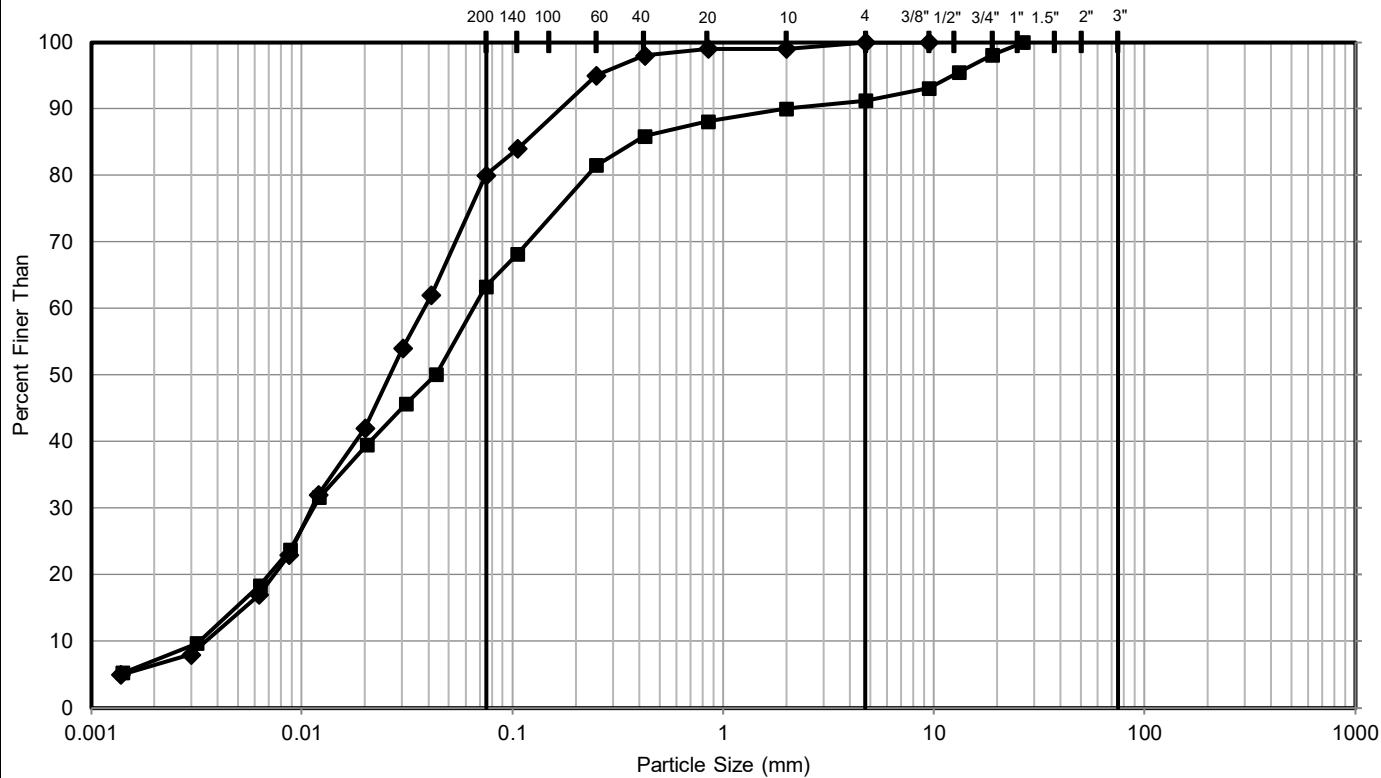


Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	404-4	2	251.3 to 250.7		16	13	3

CLIENT		
AECOM / MTO		
	CONSULTANT	YYYY-MM-DD
	DESIGNED	2023-11-26
	PREPARED	--
	REVIEWED	MCK
	APPROVED	KJB

PROJECT			
Bradford Bypass - Highway 404 Interchange			
TITLE			
Plasticity Chart - CLAYEY SILT (FILL)			
PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B3

# GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	404-3	2	0.8 - 1.4	251.9 to 251.3
◆	404-1	5	3.1 - 3.4	254.8 to 254.4

CLIENT

AECOM / MTO

CONSULTANT



YYYY-MM-DD 2023-11-26

DESIGNED -

PREPARED MCK

REVIEWED KJB

APPROVED KJB

PROJECT

Bradford Bypass - Highway 404 Interchange

TITLE

Grain Size Distribution - Sandy SILT to SILT (ML)

PROJECT NO.

19136074

CONTROL

1000

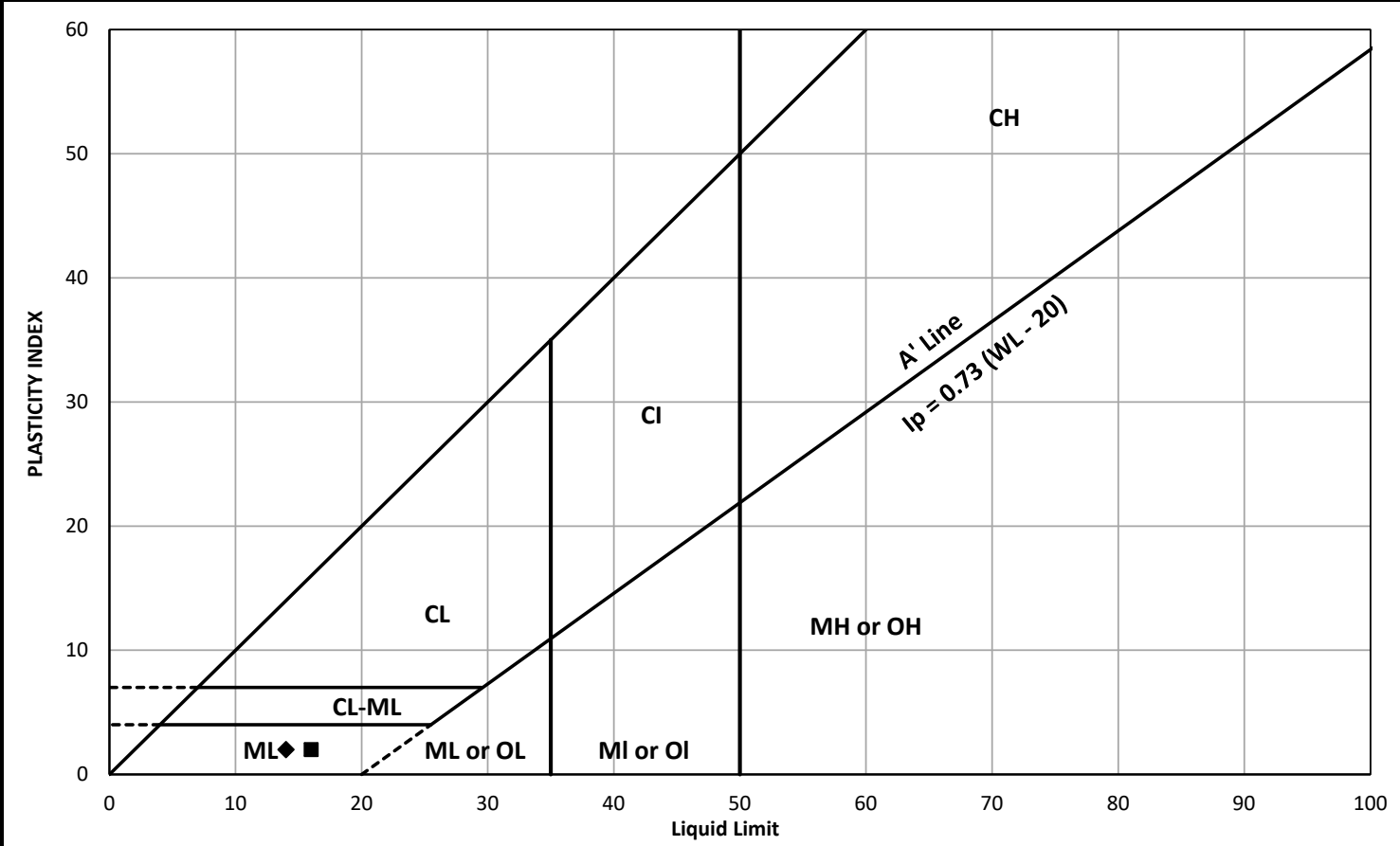
REV.

1


FIGURE

B4

PLASTICITY CHART

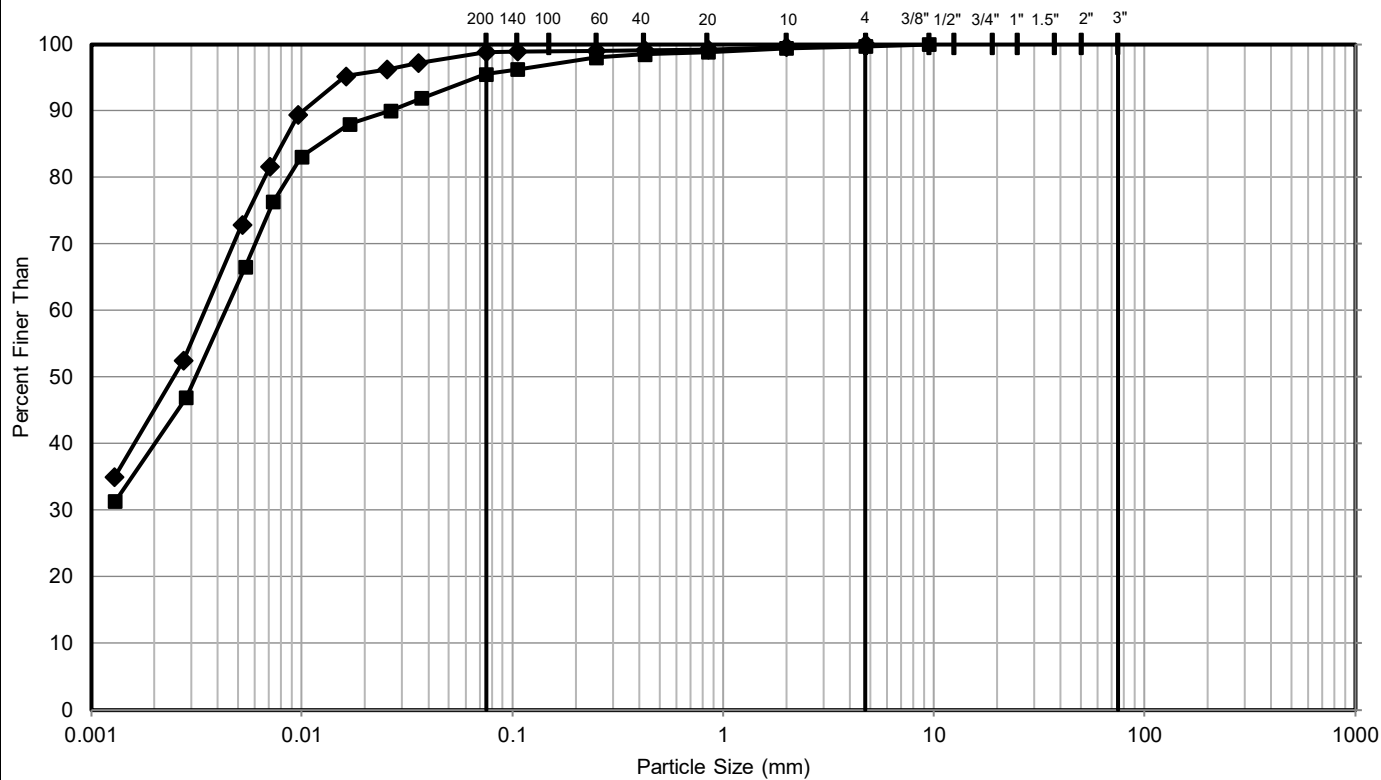


Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	404-1	5	254.8 to 254.4		16	14	2
◆	404-3	2	251.9 to 251.3		14	12	2

CLIENT		
AECOM / MTO		
	CONSULTANT	YYYY-MM-DD 2023-11-26
	DESIGNED	--
	PREPARED	MCK
	REVIEWED	KJB
	APPROVED	KJB

PROJECT			
Bradford Bypass - Highway 404 Interchange			
TITLE			
Plasticity Chart - Sandy SILT to SILT (ML)			
PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B5

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	404-2	5	3.1 - 3.7	249.5 to 248.9
◆	404-4	7	4.6 - 5.2	247.5 to 246.9

CLIENT  
AECOM / MTO

PROJECT  
Bradford Bypass - Highway 404 Interchange

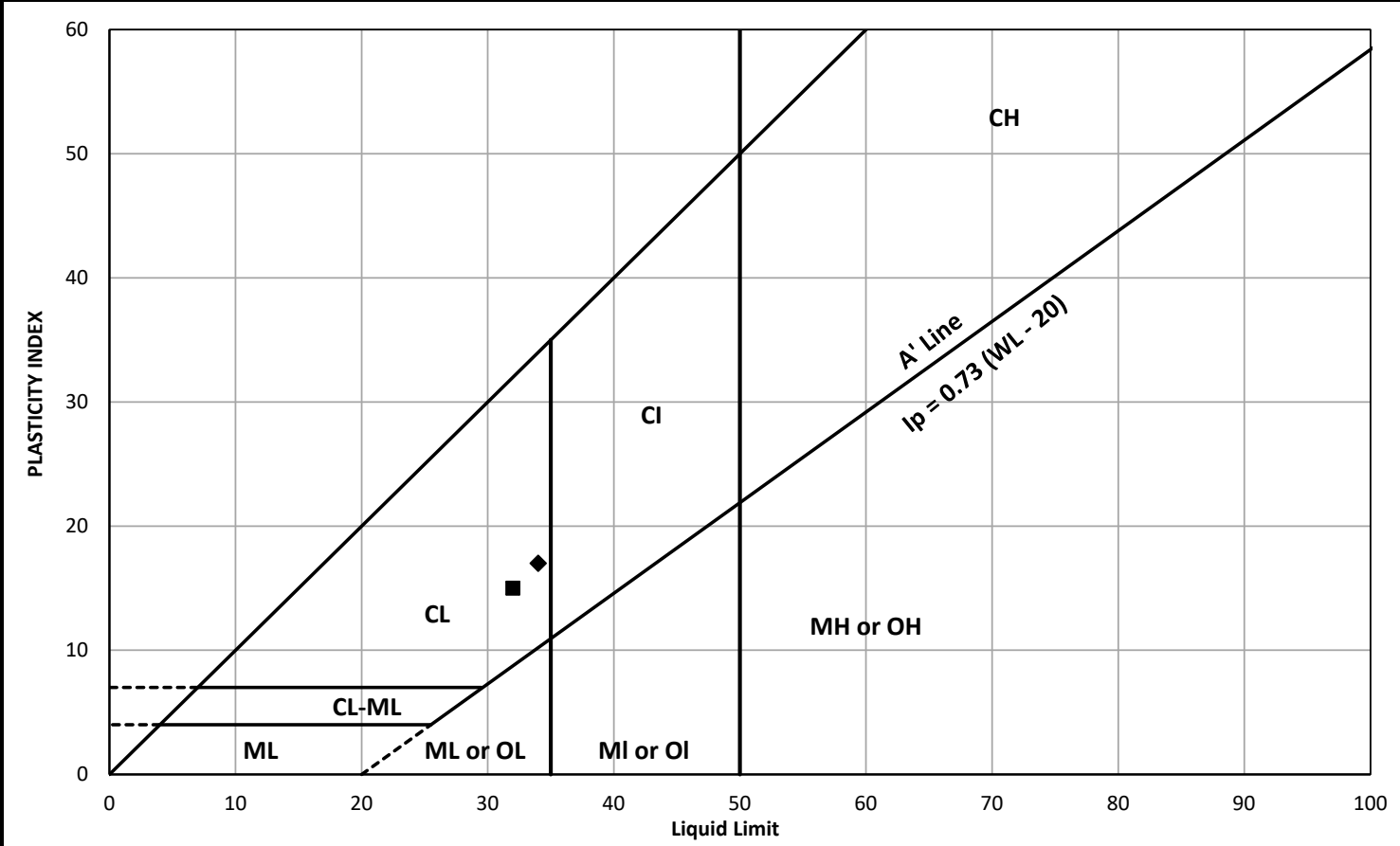


YYYY-MM-DD 2023-11-26  
DESIGNED -  
PREPARED MCK  
REVIEWED KJB  
APPROVED KJB

TITLE  
Grain Size Distribution - CLAYEY SILT (CL)  
- Upper Cohesive Deposit

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B6

PLASTICITY CHART



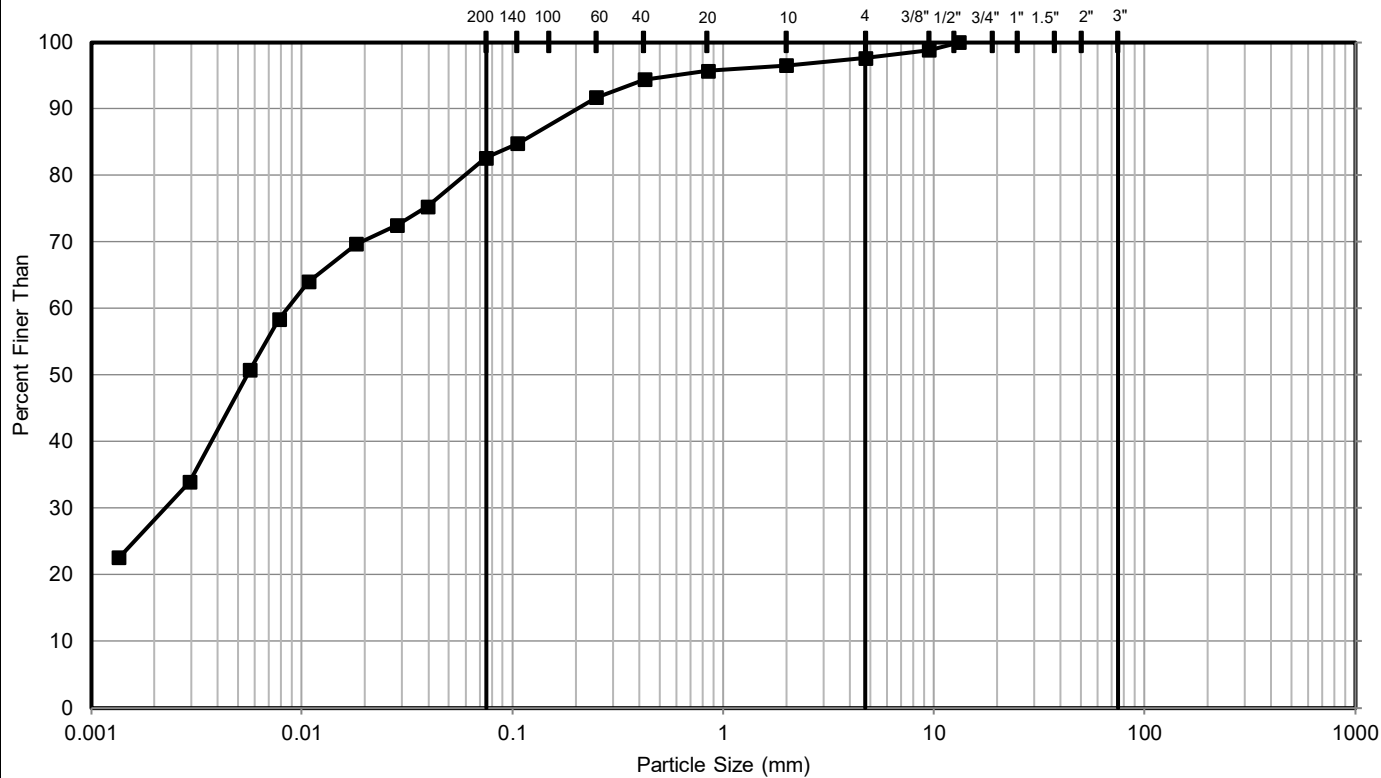
Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	404-4	7	247.5 to 246.9		32	17	15
◆	404-2	8	246.4 to 245.8		34	17	17

CLIENT	AECOM / MTO	
CONSULTANT	YYYY-MM-DD	2023-11-26
	DESIGNED	--
	PREPARED	MCK
	REVIEWED	KJB
	APPROVED	KJB




PROJECT	Bradford Bypass - Highway 404 Interchange		
TITLE	Plasticity Chart - CLAYEY SILT (CL) - Upper Cohesive Deposit		
PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B7

GRAIN SIZE DISTRIBUTION

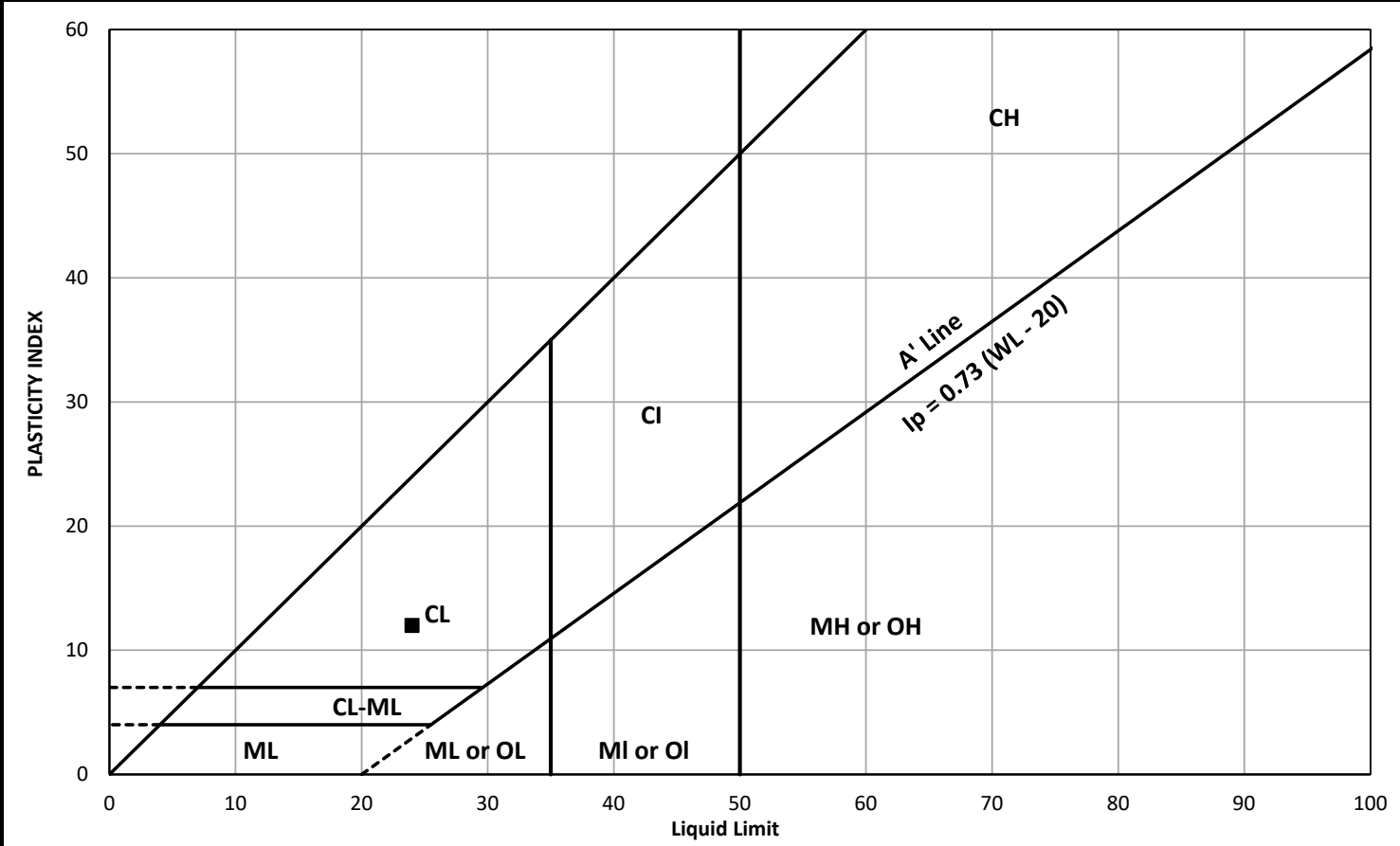


FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		


Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	404-3	7	4.6 - 5.1	248.1 to 247.5

CLIENT		PROJECT	
AECOM / MTO		Bradford Bypass - Highway 404 Interchange	
CONSULTANT	YYYY-MM-DD	2023-11-26	
	DESIGNED	-	
	PREPARED	MCK	
	REVIEWED	KJB	
	APPROVED	KJB	
		TITLE	
		Grain Size Distribution - CLAYEY SILT (CL) (TILL)	
PROJECT NO.		CONTROL	REV.
19136074		1000	1
		FIGURE	
		B8	

PLASTICITY CHART

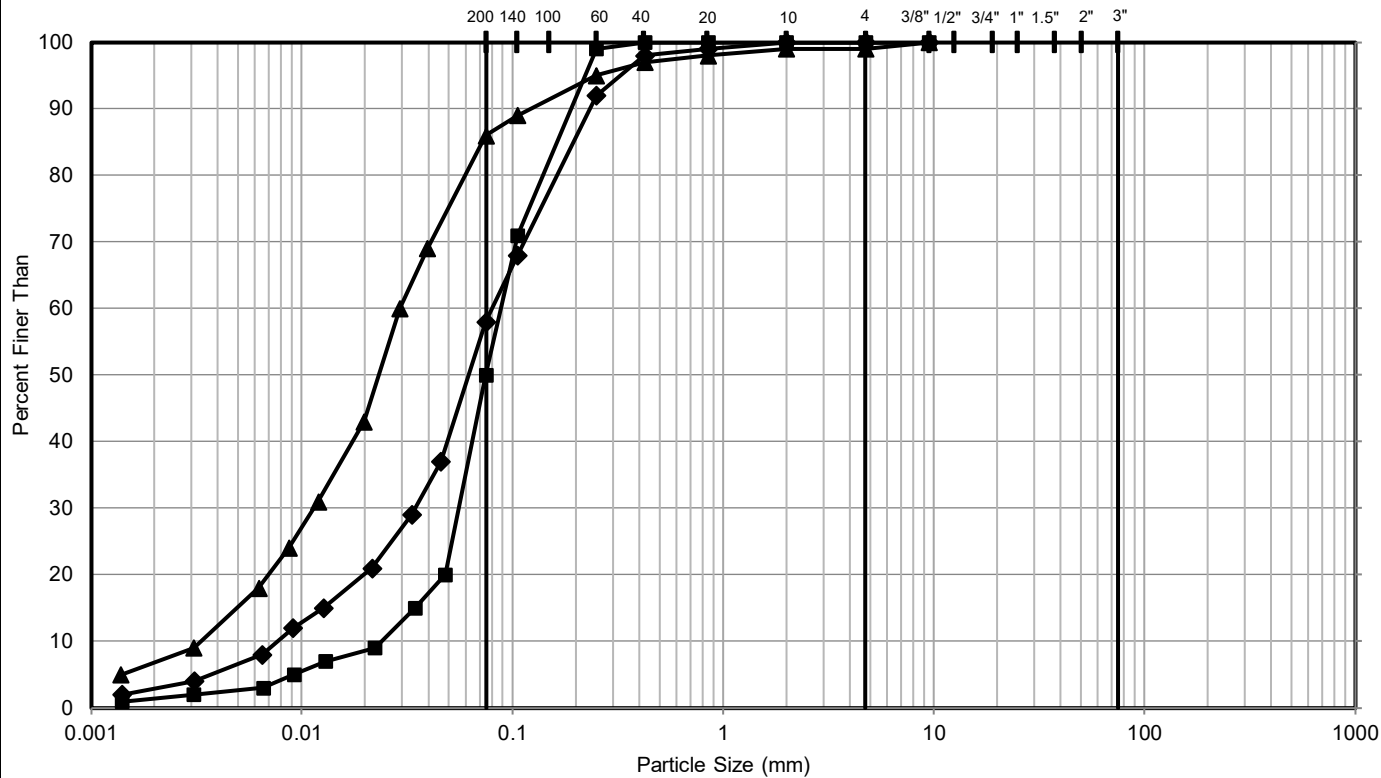


Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	404-3	7	248.1 to 247.5		24	12	12

CLIENT		
AECOM / MTO		
	CONSULTANT	YYYY-MM-DD
		2023-11-26
	DESIGNED	--
	PREPARED	MCK
	REVIEWED	KJB
	APPROVED	KJB

PROJECT			
Bradford Bypass - Highway 404 Interchange			
TITLE			
Plasticity Chart - CLAYEY SILT (CL) (TILL)			
PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B9

# GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	404-1	8	6.1 - 6.5	251.7 to 251.4
◆	404-1	10	9.1 - 9.4	248.7 to 248.4
▲	404-1	16	18.3 - 18.6	239.5 to 239.2

CLIENT  
AECOM / MTO

PROJECT  
Bradford Bypass - Highway 404 Interchange

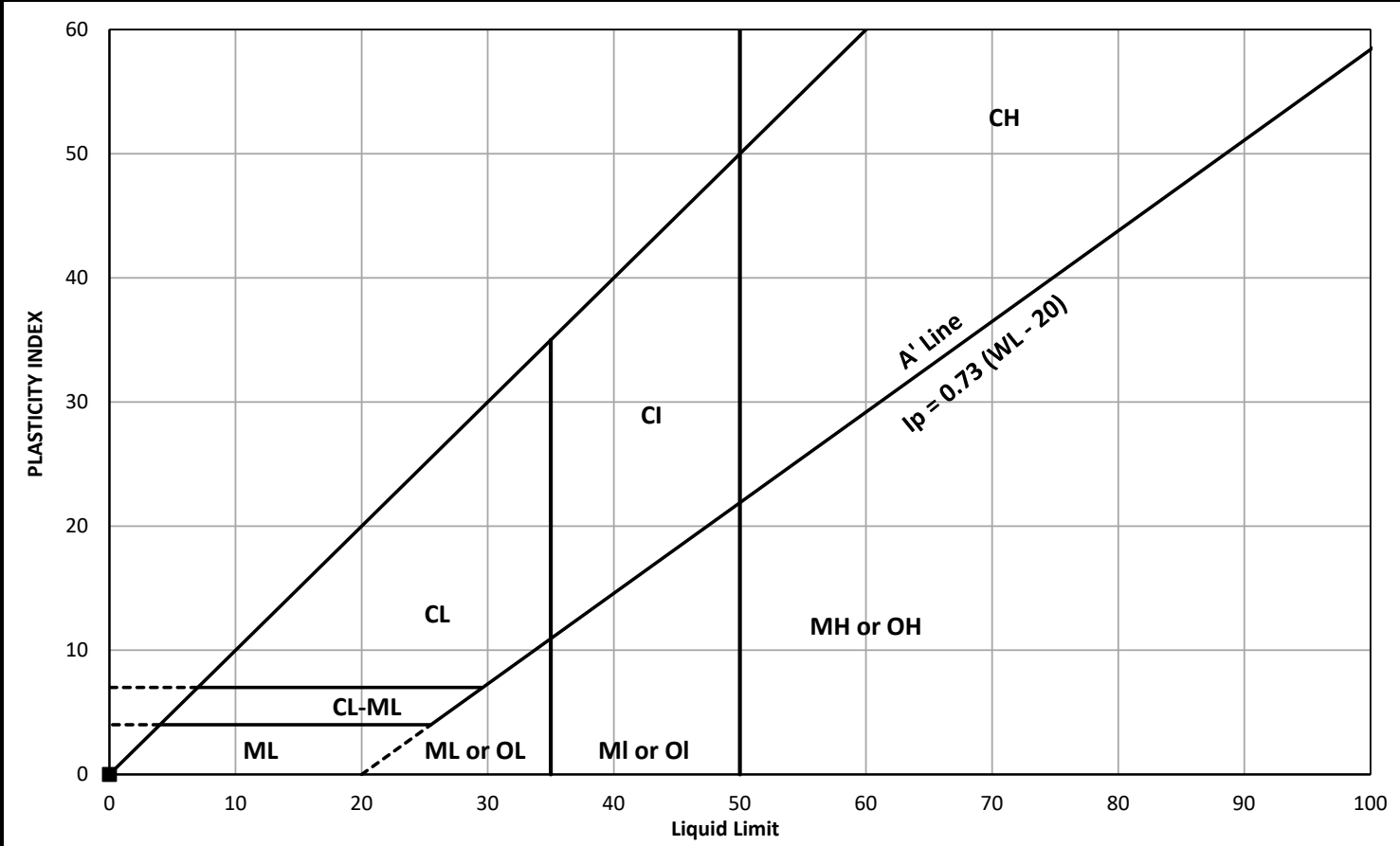


CONSULTANT  
YYYY-MM-DD 2023-11-26  
DESIGNED -  
PREPARED MCK  
REVIEWED KJB  
APPROVED KJB


TITLE  
Grain Size Distribution - SILT to SILTY SAND (ML/SM) (TILL)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B10

PLASTICITY CHART

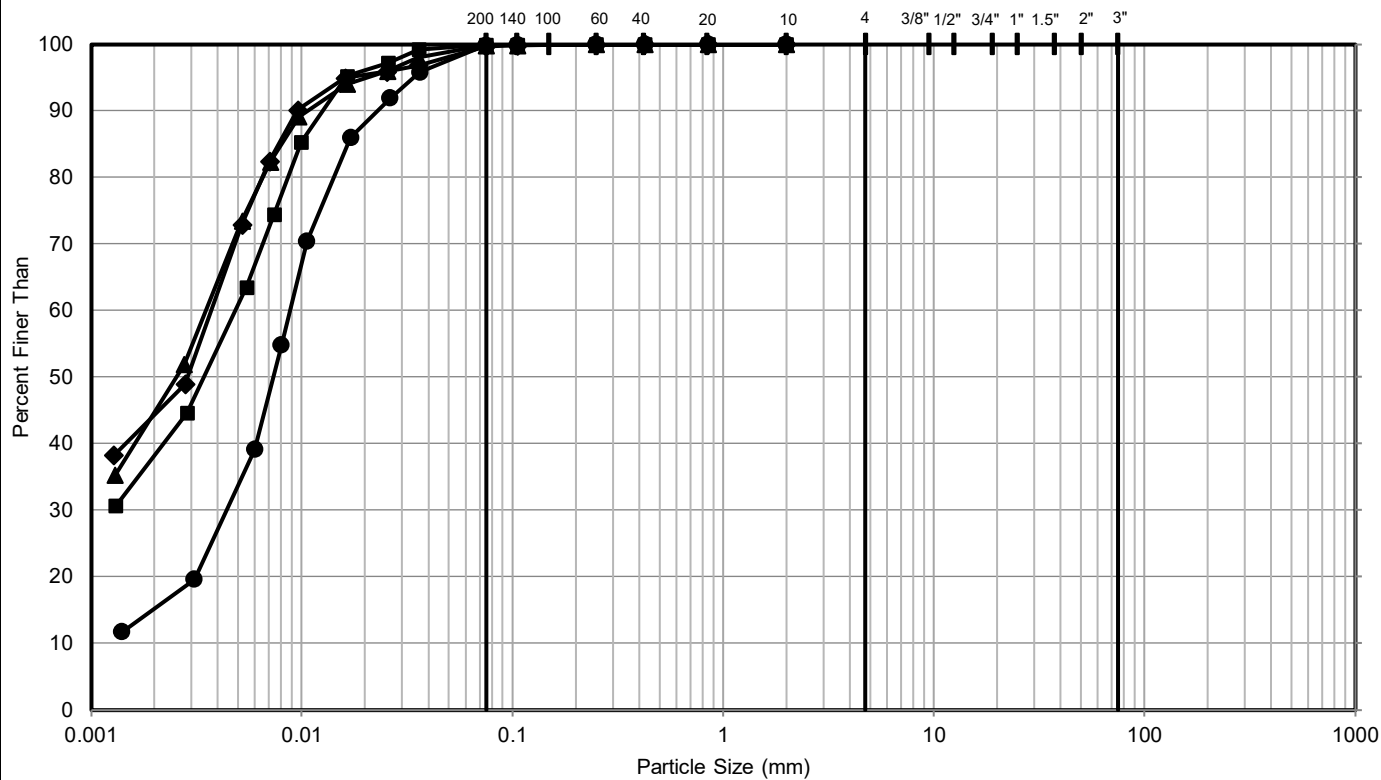


Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	404-1	10	248.7 to 248.4		0	NP	0
◆	404-1	16	239.5 to 239.2			14	
▲	404-1	8	251.7 to 251.4			NP	

CLIENT		
AECOM / MTO		
	CONSULTANT	2023-11-26
	DESIGNED	--
	PREPARED	MCK
	REVIEWED	KJB
	APPROVED	MCK

PROJECT			
Bradford Bypass - Highway 404 Interchange			
TITLE			
Plasticity Chart - SILT to SILTY SAND (ML/SM) (TILL)			
PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B11

# GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	404-2	12	12.2 - 12.8	240.3 to 239.7
◆	404-3	12	12.2 - 12.8	240.5 to 239.8
▲	404-4	11	10.7 - 11.3	241.4 to 240.8
●	404-4	18	24.4 - 24.9	227.7 to 227.2

CLIENT

AECOM / MTO

CONSULTANT



YYYY-MM-DD 2023-11-26

DESIGNED -

PREPARED MCK

REVIEWED KJB

APPROVED KJB

PROJECT

Bradford Bypass - Highway 404 Interchange

TITLE

Grain Size Distribution - CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML)

PROJECT NO.

19136074

CONTROL

1000

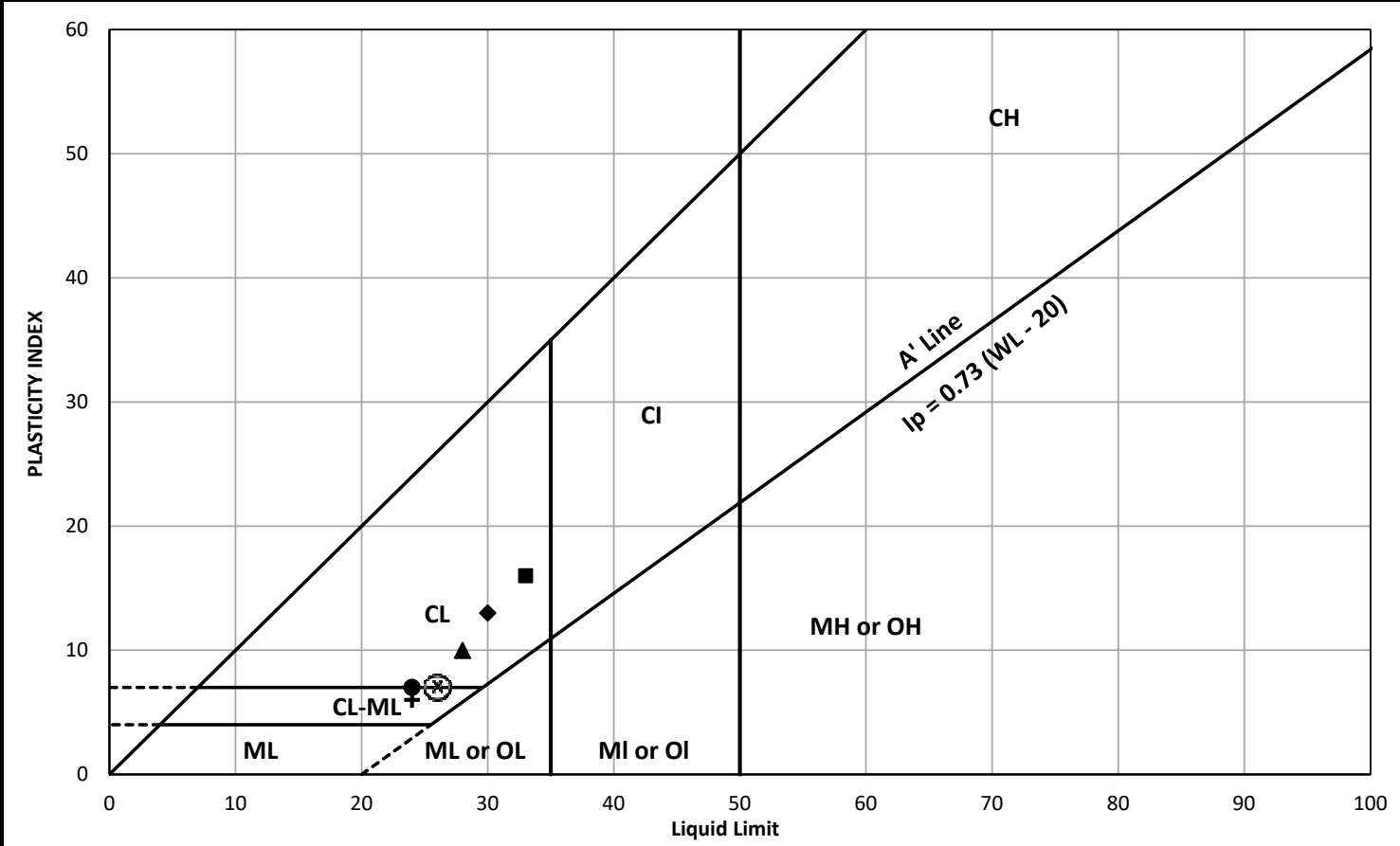
REV.

1

FIGURE

B12

PLASTICITY CHART



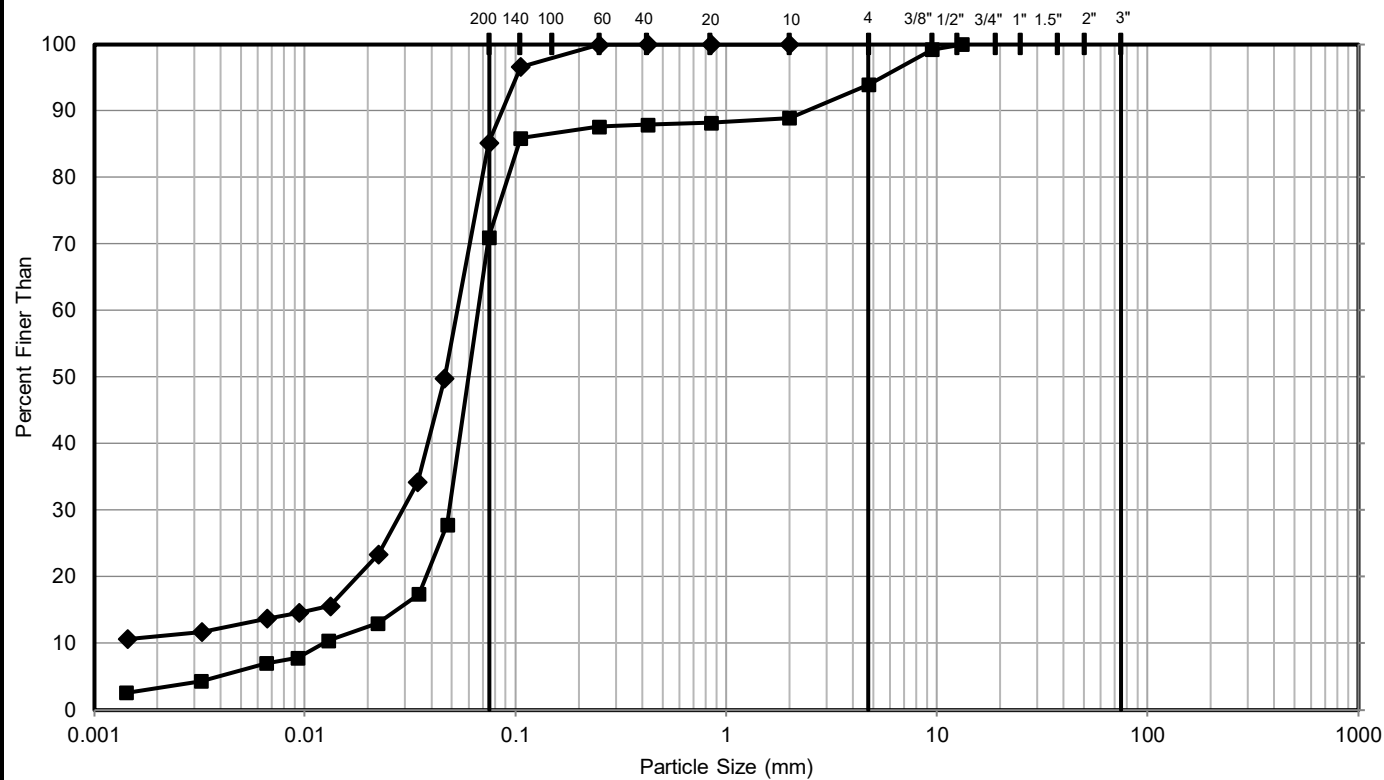
Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	404-2	9	244.9 to 244.3		33	17	16
◆	404-4	11	241.4 to 240.8		30	17	13
▲	404-3	12	240.5 to 239.8		28	18	10
●	404-2	16	234.2 to 233.6		24	17	7
+	404-4	18	227.7 to 227.2		24	18	6
⊗	404-4	19	224.7 to 224.1		26	19	7

CLIENT	AECOM / MTO	
CONSULTANT	YYYY-MM-DD	2023-11-26
	DESIGNED	--
	PREPARED	MCK
	REVIEWED	KJB
	APPROVED	KJB



PROJECT	Bradford Bypass - Highway 404 Interchange		
TITLE	Plasticity Chart - CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML)		
PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B13

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	404-3	15	16.8 - 17.1	235.9 to 235.6
◆	404-4	15	16.8 - 17.2	235.3 to 234.9

CLIENT

AECOM / MTO

CONSULTANT



YYYY-MM-DD 2023-11-26

DESIGNED -

PREPARED MCK

REVIEWED KJB

APPROVED KJB

PROJECT

Bradford Bypass - Highway 404 Interchange

TITLE

Grain Size Distribution - Sandy SILT to SILT (ML)

PROJECT NO.

19136074

CONTROL

1000

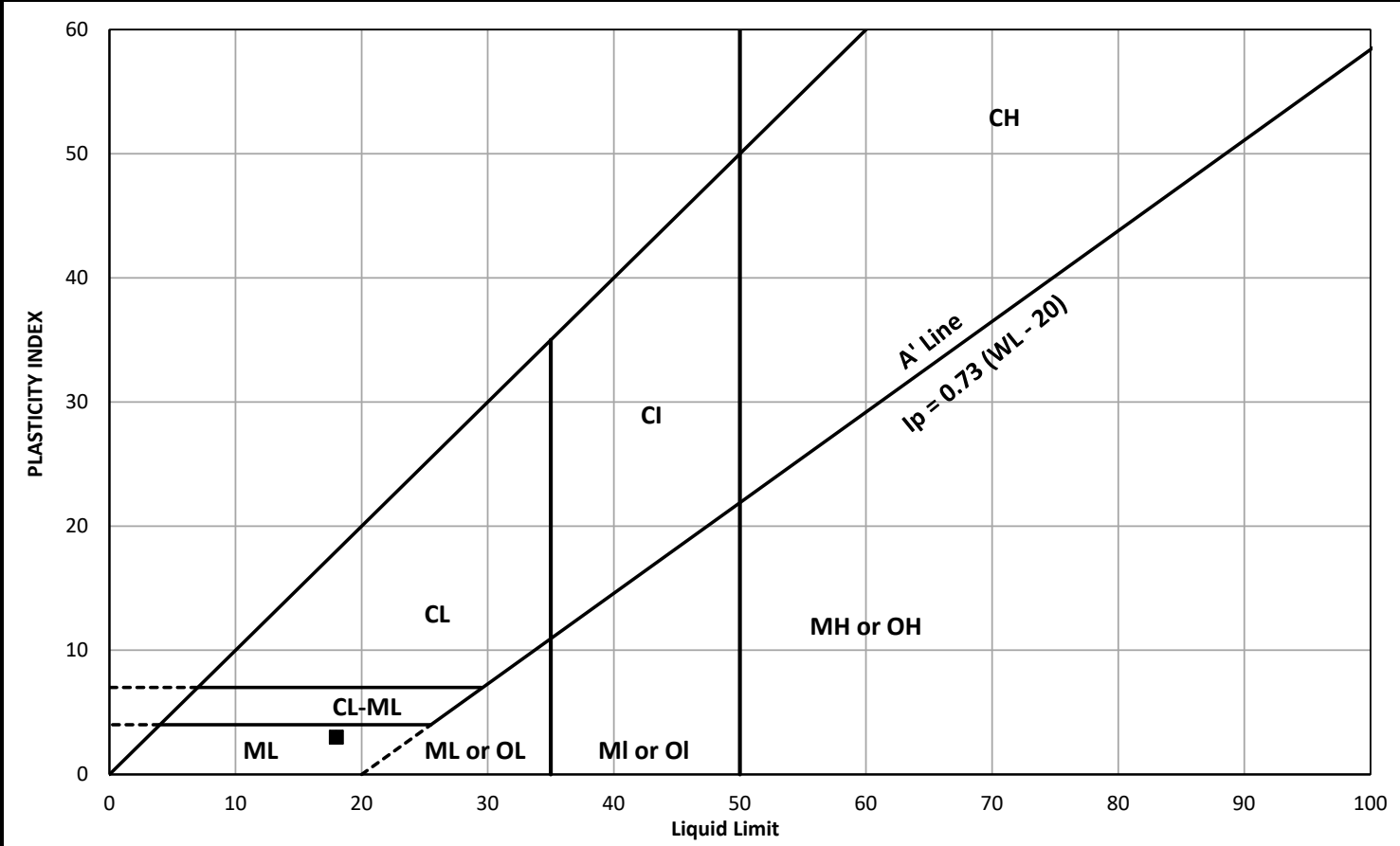
REV.

1


FIGURE

B14

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	404-2	20	222.1 to 221.6		18	15	3

CLIENT		
AECOM / MTO		
	CONSULTANT	2023-11-26
	DESIGNED	--
	PREPARED	MCK
	REVIEWED	KJB
	APPROVED	KJB

PROJECT			
Bradford Bypass - Highway 404 Interchange			
TITLE			
Plasticity Chart - CLAYEY SILT-SILT (CL-ML) to SILT (ML)			
PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	1	B15

**APPENDIX C**

# Soil Analytical Test Results



Your Project #: 19136074; 1002..001  
Site Location: BRAFORD AND EAST GWILLUMBURY  
Your C.O.C. #: n/a

**Attention: Madison Kennedy**

WSP Canada Inc.  
6925 Century Ave  
Suite 100  
Mississauga, ON  
CANADA L5N 7K2

**Report Date: 2023/08/24**  
Report #: R7779931  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C306308**

**Received: 2023/08/15, 13:39**

Sample Matrix: Soil  
# Samples Received: 5

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Chloride (20:1 extract)	5	2023/08/21	2023/08/21	CAM SOP-00463	MOE E3013 m
Conductivity	5	2023/08/21	2023/08/21	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 2)	5	N/A	2023/08/23	AB SOP-00002	CCME PHC-CWS m
Sulphide in Soil (1)	5	N/A	2023/08/24	AB SOP-00080	EPA9030B/SM4500S2-DF
pH CaCl2 EXTRACT	5	2023/08/18	2023/08/18	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	5	2023/08/15	2023/08/21	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	5	2023/08/21	2023/08/21	CAM SOP-00464	MOE E3013 m

**Remarks:**

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCCFP, EPA, APHA.

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

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

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

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

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

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

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

(1) This test was performed by Bureau Veritas Calgary (19th), 4000 19th Street NE, Calgary, AB, T2E 6P8

(2) Offsite analysis requires that subcontracted moisture be reported.



Your Project #: 19136074; 1002..001  
Site Location: BRAFORD AND EAST GWILLUMBURY  
Your C.O.C. #: n/a

**Attention: Madison Kennedy**

WSP Canada Inc.  
6925 Century Ave  
Suite 100  
Mississauga, ON  
CANADA L5N 7K2

**Report Date: 2023/08/24**  
Report #: R7779931  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C306308**

**Received: 2023/08/15, 13:39**

**Encryption Key**

Please direct all questions regarding this Certificate of Analysis to:

Ankita Bhalla, Project Manager

Email: Ankita.Bhalla@bureauveritas.com

Phone# (905) 817-5700

=====

This report has been generated and distributed using a secure automated process.

Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation, please refer to the Validation Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by Rodney Major, General Manager responsible for Ontario Environmental laboratory operations.

**SOIL CORROSIVITY PACKAGE (SOIL)**

<b>Bureau Veritas ID</b>		WRQ490	WRQ491	WRQ492	WRQ493		
<b>Sampling Date</b>		2023/08/03	2023/08/04	2023/08/14	2023/08/10		
<b>COC Number</b>		n/a	n/a	n/a	n/a		
	<b>UNITS</b>	<b>R-BBP-404-2 SS3</b>	<b>404-1 SS3</b>	<b>R-BBP-6A SS3</b>	<b>CL-BBP-9 1'-4'6"</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>							
Resistivity	ohm-cm	6800	5800	9200	5200		8854345
<b>Inorganics</b>							
Soluble (20:1) Chloride (Cl-)	ug/g	<20	<20	<20	<20	20	8865507
Conductivity	umho/cm	148	173	108	191	2	8865793
Available (CaCl2) pH	pH	7.64	7.70	7.75	7.68		8861593
Soluble (20:1) Sulphate (SO4)	ug/g	27	43	<20	61	20	8865517
Sulphide	mg/kg	2.3 (1)	3.6 (1)	3.1 (2)	4.0 (2)	0.5	8874652
RDL = Reportable Detection Limit							
QC Batch = Quality Control Batch							
(1) Extracted past method specified hold time							
(2) Sample contained greater than 10% headspace at time of extraction.							

<b>Bureau Veritas ID</b>		WRQ493			WRQ494		
<b>Sampling Date</b>		2023/08/10			2023/08/11		
<b>COC Number</b>		n/a			n/a		
	<b>UNITS</b>	<b>CL-BBP-9 1'-4'6" Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>	<b>CL-BBP-10 SS2</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>							
Resistivity	ohm-cm				4200		8854345
<b>Inorganics</b>							
Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	8865507	<20	20	8865507
Conductivity	umho/cm	198	2	8865793	239	2	8865793
Available (CaCl2) pH	pH				7.69		8861593
Soluble (20:1) Sulphate (SO4)	ug/g	64	20	8865517	73	20	8865517
Sulphide	mg/kg				4.9 (1)	0.5	8874652
RDL = Reportable Detection Limit							
QC Batch = Quality Control Batch							
Lab-Dup = Laboratory Initiated Duplicate							
(1) Sample contained greater than 10% headspace at time of extraction.							



BUREAU  
VERITAS

Bureau Veritas Job #: C3O6308

Report Date: 2023/08/24

WSP Canada Inc.

Client Project #: 19136074; 1002..001

Site Location: BRAFORD AND EAST GWILLUMBURY

Sampler Initials: TJ

### RESULTS OF ANALYSES OF SOIL

Bureau Veritas ID		WRQ490	WRQ491	WRQ492	WRQ493	WRQ494		
Sampling Date		2023/08/03	2023/08/04	2023/08/14	2023/08/10	2023/08/11		
COC Number		n/a	n/a	n/a	n/a	n/a		
	UNITS	R-BBP-404-2 SS3	404-1 SS3	R-BBP-6A SS3	CL-BBP-9 1'-4'6"	CL-BBP-10 SS2	RDL	QC Batch
<b>Physical Testing</b>								
Moisture-Subcontracted	%	15	22	13	22	3.2	0.30	8874653
RDL = Reportable Detection Limit								
QC Batch = Quality Control Batch								



**BUREAU  
VERITAS**

Bureau Veritas Job #: C3O6308

Report Date: 2023/08/24

WSP Canada Inc.

Client Project #: 19136074; 1002..001

Site Location: BRAFORD AND EAST GWILLUMBURY

Sampler Initials: TJ

## TEST SUMMARY

**Bureau Veritas ID:** WRQ490  
**Sample ID:** R-BBP-404-2 SS3  
**Matrix:** Soil

**Collected:** 2023/08/03  
**Shipped:**  
**Received:** 2023/08/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8865507	2023/08/21	2023/08/21	Samuel Law
Conductivity	AT	8865793	2023/08/21	2023/08/21	Gurparteek KAUR
Moisture (Subcontracted)	BAL	8874653	N/A	2023/08/23	Navpreet Kaur Bajwa
Sulphide in Soil	SPEC	8874652	N/A	2023/08/24	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8861593	2023/08/18	2023/08/18	Gurparteek KAUR
Resistivity of Soil		8854345	2023/08/21	2023/08/21	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8865517	2023/08/21	2023/08/21	Samuel Law

**Bureau Veritas ID:** WRQ491  
**Sample ID:** 404-1 SS3  
**Matrix:** Soil

**Collected:** 2023/08/04  
**Shipped:**  
**Received:** 2023/08/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8865507	2023/08/21	2023/08/21	Samuel Law
Conductivity	AT	8865793	2023/08/21	2023/08/21	Gurparteek KAUR
Moisture (Subcontracted)	BAL	8874653	N/A	2023/08/23	Navpreet Kaur Bajwa
Sulphide in Soil	SPEC	8874652	N/A	2023/08/24	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8861593	2023/08/18	2023/08/18	Gurparteek KAUR
Resistivity of Soil		8854345	2023/08/21	2023/08/21	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8865517	2023/08/21	2023/08/21	Samuel Law

**Bureau Veritas ID:** WRQ492  
**Sample ID:** R-BBP-6A SS3  
**Matrix:** Soil

**Collected:** 2023/08/14  
**Shipped:**  
**Received:** 2023/08/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8865507	2023/08/21	2023/08/21	Samuel Law
Conductivity	AT	8865793	2023/08/21	2023/08/21	Gurparteek KAUR
Moisture (Subcontracted)	BAL	8874653	N/A	2023/08/23	Navpreet Kaur Bajwa
Sulphide in Soil	SPEC	8874652	N/A	2023/08/24	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8861593	2023/08/18	2023/08/18	Gurparteek KAUR
Resistivity of Soil		8854345	2023/08/21	2023/08/21	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8865517	2023/08/21	2023/08/21	Samuel Law

**Bureau Veritas ID:** WRQ493  
**Sample ID:** CL-BBP-9 1'-4'6"  
**Matrix:** Soil

**Collected:** 2023/08/10  
**Shipped:**  
**Received:** 2023/08/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8865507	2023/08/21	2023/08/21	Samuel Law
Conductivity	AT	8865793	2023/08/21	2023/08/21	Gurparteek KAUR
Moisture (Subcontracted)	BAL	8874653	N/A	2023/08/23	Navpreet Kaur Bajwa
Sulphide in Soil	SPEC	8874652	N/A	2023/08/24	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8861593	2023/08/18	2023/08/18	Gurparteek KAUR



**BUREAU**  
**VERITAS**

Bureau Veritas Job #: C3O6308

Report Date: 2023/08/24

WSP Canada Inc.

Client Project #: 19136074; 1002..001

Site Location: BRAFORD AND EAST GWILLUMBURY

Sampler Initials: TJ

## TEST SUMMARY

**Bureau Veritas ID:** WRQ493  
**Sample ID:** CL-BBP-9 1'-4'6"  
**Matrix:** Soil

**Collected:** 2023/08/10  
**Shipped:**  
**Received:** 2023/08/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Resistivity of Soil		8854345	2023/08/21	2023/08/21	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8865517	2023/08/21	2023/08/21	Samuel Law

**Bureau Veritas ID:** WRQ493 Dup  
**Sample ID:** CL-BBP-9 1'-4'6"  
**Matrix:** Soil

**Collected:** 2023/08/10  
**Shipped:**  
**Received:** 2023/08/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8865507	2023/08/21	2023/08/21	Samuel Law
Conductivity	AT	8865793	2023/08/21	2023/08/21	Gurparteek KAUR
Sulphate (20:1 Extract)	KONE/EC	8865517	2023/08/21	2023/08/21	Samuel Law

**Bureau Veritas ID:** WRQ494  
**Sample ID:** CL-BBP-10 SS2  
**Matrix:** Soil

**Collected:** 2023/08/11  
**Shipped:**  
**Received:** 2023/08/15

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8865507	2023/08/21	2023/08/21	Samuel Law
Conductivity	AT	8865793	2023/08/21	2023/08/21	Gurparteek KAUR
Moisture (Subcontracted)	BAL	8874653	N/A	2023/08/23	Navpreet Kaur Bajwa
Sulphide in Soil	SPEC	8874652	N/A	2023/08/24	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8861593	2023/08/18	2023/08/18	Gurparteek KAUR
Resistivity of Soil		8854345	2023/08/21	2023/08/21	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8865517	2023/08/21	2023/08/21	Samuel Law



### GENERAL COMMENTS

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

Package 1	5.3°C
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Results relate only to the items tested.



**BUREAU  
VERITAS**

Bureau Veritas Job #: C3O6308

Report Date: 2023/08/24

## QUALITY ASSURANCE REPORT

WSP Canada Inc.

Client Project #: 19136074; 1002..001

Site Location: BRAFORD AND EAST GWILLUMBURY

Sampler Initials: TJ

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8861593	Available (CaCl <sub>2</sub> ) pH	2023/08/18			101	97 - 103			0.50	N/A
8865507	Soluble (20:1) Chloride (Cl <sup>-</sup> )	2023/08/21	107	70 - 130	102	70 - 130	<20	ug/g	NC	35
8865517	Soluble (20:1) Sulphate (SO <sub>4</sub> )	2023/08/21	NC	70 - 130	101	70 - 130	<20	ug/g	4.5	35
8865793	Conductivity	2023/08/21			103	90 - 110	<2	umho/cm	3.7	10
8874652	Sulphide	2023/08/24	43 (1)	75 - 125	95	75 - 125	<0.5	mg/kg	6.6	30
8874653	Moisture-Subcontracted	2023/08/23					<0.30	%	7.2	20

N/A = Not Applicable

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

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

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

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

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

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.



BUREAU  
VERITAS

Bureau Veritas Job #: C3O6308  
Report Date: 2023/08/24

WSP Canada Inc.  
Client Project #: 19136074; 1002..001  
Site Location: BRAFORD AND EAST GWILLUMBURY  
Sampler Initials: TJ

## VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

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Cristina Carriere, Senior Scientific Specialist

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Veronica Falk, B.Sc., P.Chem., QP, Scientific Specialist, Organics

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Suwan (Sze Yeung) Fock, B.Sc., Scientific Specialist

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Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation, please refer to the Validation Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by {0}, {1} responsible for {2} {3} laboratory operations.



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Phone: 905-817-5700 Fax: 905-817-5779 Toll Free: 800-563-6266

CHAIN OF CUSTODY RECORD

ENV COC - 00014v3

Page 1 of 1

Invoice Information				Report Information (if differs from invoice)				Project Information							
Company: WSP Canada Inc.				Company: WSP Canada Inc.				Quotation #:							
Contact Name: Kevin Bentley				Contact Name: Madison Kennedy				P.O. #/ AFER:							
Street Address: 6925 Century Ave, #600				Street Address: 6925 Century Ave, #600				Project #:							
City: Mississauga Prov: ON Postal Code: L5N 7K2				City: Mississauga Prov: ON Postal Code: L5N 7K2				Site #:							
Phone: 905-567-4444				Phone: 905-302-1162				Site Location: Bradford and East Gwillumbury							
Email: kevin.bentley@wsp.com				Email: madison.kennedy@wsp.com				Site Location Province: Ontario							
Copies:				Copies: muhammad.irshad@wsp.com				Sampled By: TJ; MTI							
<b>Regulatory Criteria</b>															
<input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Med/Fine <input type="checkbox"/> CCME <input type="checkbox"/> Reg 406, Table: <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Course <input type="checkbox"/> Reg 558* <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/other <input type="checkbox"/> For RSC <input type="checkbox"/> *min 3 day TAT <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> Table <input type="checkbox"/> MISA <input type="checkbox"/> Municipality <input type="checkbox"/> PWQO <input type="checkbox"/> Other:															
Include Criteria on Certificate of Analysis (check if yes): <input type="checkbox"/>															
SAMPLES MUST BE KEPT COOL (<10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS															
Sample Identification				Date Sampled		Time (24hr)		Matrix							
				YY	MM	DD	HH	MM							
1	R-BBP-404-2 SS 3			23	08	03			Soil						
2	404-1 SS 3			23	08	04			Soil						
3	R-BBP-6A SS 3			23	08	14			Soil						
4	CL-BBP-9 1'- 4'6"			23	08	10			Soil						
5	CL-BBP-10 SS 2			23	08	11			Soil						
6															
7															
8															
9															
10															
11															
12															
*UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO BUREAU VERITAS STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS AND CONDITIONS WHICH ARE AVAILABLE FOR VIEWING AT WWW.BVNA.COM/TERMS-AND-CONDITIONS OR BY CALLING THE LABORATORY LISTED ABOVE TO OBTAIN A COPY															
LAB USE ONLY				LAB USE ONLY				LAB USE ONLY				Temperature reading by:			
Seal present				Seal present				Seal present							
Seal intact				Seal intact				Seal intact							
Cooling media present				Cooling media present				Cooling media present							
Relinquished by: (Signature/ Print)				Received by: (Signature/ Print)				Special Instructions							
M. Talha Irshad				M. Talha Irshad											
Date: 23 08 15				Date: 23 08 15											
Time: 13 35				Time: 13 35											

15-Aug-23 13:39

Ankita Bhalla



C306308

JK

ENV-1705



Your P.O. #: 19136074  
Your Project #: 19136074  
Site Location: BRADFORD  
Your C.O.C. #: n/a

**Attention: Mohammed Taha**

Golder Associates Ltd  
6925 Century Ave  
Suite 100  
Mississauga, ON  
CANADA L5N 7K2

**Report Date: 2022/09/06**  
Report #: R7285025  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C205551**

**Received: 2022/08/26, 15:58**

Sample Matrix: Soil  
# Samples Received: 9

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Chloride (20:1 extract)	9	2022/09/01	2022/09/02	CAM SOP-00463	SM 23 4500-Cl E m
Conductivity	9	2022/08/31	2022/09/01	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 2)	9	N/A	2022/09/02	AB SOP-00002	CCME PHC-CWS m
Sulphide in Soil (1)	9	N/A	2022/09/02	AB SOP-00080	EPA9030B/SM4500S2-DF
pH CaCl2 EXTRACT	9	2022/08/31	2022/08/31	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	9	2022/08/29	2022/09/01	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	9	2022/09/01	2022/09/02	CAM SOP-00464	EPA 375.4 m

**Remarks:**

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

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

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

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

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

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

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

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

(1) This test was performed by Bureau Veritas Calgary (19th), 4000 19th Street NE, Calgary, AB, T2E 6P8

(2) Offsite analysis requires that subcontracted moisture be reported.



Your P.O. #: 19136074  
Your Project #: 19136074  
Site Location: BRADFORD  
Your C.O.C. #: n/a

**Attention: Mohammed Taha**

Golder Associates Ltd  
6925 Century Ave  
Suite 100  
Mississauga, ON  
CANADA L5N 7K2

**Report Date: 2022/09/06**  
Report #: R7285025  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**BUREAU VERITAS JOB #: C205551**

**Received: 2022/08/26, 15:58**

**Encryption Key**

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

Ankita Bhalla, Project Manager

Email: Ankita.Bhalla@bureauveritas.com

Phone# (905) 817-5700

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For Service Group specific validation please refer to the Validation Signature Page.



BUREAU  
VERITAS

Bureau Veritas Job #: C2O5551

Report Date: 2022/09/06

Golder Associates Ltd

Client Project #: 19136074

Site Location: BRADFORD

Your P.O. #: 19136074

Sampler Initials: MTI

### SOIL CORROSIVITY PACKAGE (SOIL)

<b>Bureau Veritas ID</b>		TOL232			TOL232			TOL233		
<b>Sampling Date</b>		2021/06/15			2021/06/15			2021/06/17		
<b>COC Number</b>		n/a			n/a			n/a		
	<b>UNITS</b>	<b>404-2 SA#4</b>	<b>RDL</b>	<b>QC Batch</b>	<b>404-2 SA#4 Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>	<b>404-3 SA#3</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Calculated Parameters</b>										
Resistivity	ohm-cm	3200		8193773				810		8193773
<b>Inorganics</b>										
Soluble (20:1) Chloride (Cl-)	ug/g	130	20	8201208				570	20	8201208
Conductivity	umho/cm	316	2	8198559				1240	2	8198559
Available (CaCl2) pH	pH	7.87		8199338				8.02		8199338
Soluble (20:1) Sulphate (SO4)	ug/g	46	20	8201217				250	20	8201217
Sulphide	mg/kg	6.4 (1)	0.5	8205122	5.2	0.5	8205122	3.7 (2)	0.5	8205122
<b>Physical Testing</b>										
Moisture-Subcontracted	%	18	0.30	8205121				3.9	0.30	8205121
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate (1) Sample extracted past method-specified hold time. Sample contained greater than 10% headspace at time of extraction. Analyzed past method specified hold time (2) Sample extracted past method-specified hold time. Analyzed past method specified hold time										

BUREAU  
VERITAS

Bureau Veritas Job #: C2O5551

Report Date: 2022/09/06

Golder Associates Ltd

Client Project #: 19136074

Site Location: BRADFORD

Your P.O. #: 19136074

Sampler Initials: MTI

**SOIL CORROSIVITY PACKAGE (SOIL)**

<b>Bureau Veritas ID</b>		TOL233			TOL234	TOL235	TOL236	TOL237		
<b>Sampling Date</b>		2021/06/17			2021/06/10	2021/12/21	2021/07/07	2022/01/13		
<b>COC Number</b>		n/a			n/a	n/a	n/a	n/a		
	<b>UNITS</b>	<b>404-3 SA#3 Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>	<b>404-4 SA#4</b>	<b>2-1 SA#4</b>	<b>L-4B SA#4</b>	<b>HRE-3 SA#3B</b>	<b>RDL</b>	<b>QC Batch</b>

**Calculated Parameters**

Resistivity	ohm-cm				700	2800	990	9000		8193773
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**Inorganics**

Soluble (20:1) Chloride (Cl-)	ug/g	570	20	8201208	780	65	540	<20	20	8201208
Conductivity	umho/cm				1430	359	1010	111	2	8198559
Available (CaCl2) pH	pH				7.88	7.82	8.04	7.72		8199338
Soluble (20:1) Sulphate (SO4)	ug/g				100	210	53	<20	20	8201217
Sulphide	mg/kg				4.9 (1)	89.9 (1)	4.8 (1)	5.1 (1)	0.5	8205122

**Physical Testing**

Moisture-Subcontracted	%				18	11	11	21	0.30	8205121
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RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Lab-Dup = Laboratory Initiated Duplicate

(1) Sample extracted past method-specified hold time. Analyzed past method specified hold time

<b>Bureau Veritas ID</b>		TOL238			TOL238			TOL239		
<b>Sampling Date</b>		2022/02/22			2022/02/22			2021/11/11		
<b>COC Number</b>		n/a			n/a			n/a		
	<b>UNITS</b>	<b>HRE-4 SA#4</b>	<b>RDL</b>	<b>QC Batch</b>	<b>HRE-4 SA#4 Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>	<b>HRW-1B SA#5</b>	<b>RDL</b>	<b>QC Batch</b>

**Calculated Parameters**

Resistivity	ohm-cm	7200		8193773				6000		8193773
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**Inorganics**

Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	8201208				59	20	8201208
Conductivity	umho/cm	138	2	8198559				167	2	8198559
Available (CaCl2) pH	pH	7.86		8199338				7.94		8199338
Soluble (20:1) Sulphate (SO4)	ug/g	27	20	8201217	24	20	8201217	<20	20	8201217
Sulphide	mg/kg	5.6 (1)	0.5	8205122				1.7 (1)	0.5	8205122

**Physical Testing**

Moisture-Subcontracted	%	18	0.30	8205123				14	0.30	8205121
------------------------	---	----	------	---------	--	--	--	----	------	---------

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Lab-Dup = Laboratory Initiated Duplicate

(1) Sample extracted past method-specified hold time. Analyzed past method specified hold time



BUREAU  
VERITAS

Bureau Veritas Job #: C205551

Report Date: 2022/09/06

Golder Associates Ltd

Client Project #: 19136074

Site Location: BRADFORD

Your P.O. #: 19136074

Sampler Initials: MTI

### SOIL CORROSIVITY PACKAGE (SOIL)

<b>Bureau Veritas ID</b>		TOL239			TOL240		
<b>Sampling Date</b>		2021/11/11			2022/05/20		
<b>COC Number</b>		n/a			n/a		
	<b>UNITS</b>	<b>HRW-1B SA#5 Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>	<b>FD-02 SA#3</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Calculated Parameters</b>							
Resistivity	ohm-cm				5800		8193773
<b>Inorganics</b>							
Soluble (20:1) Chloride (Cl <sup>-</sup> )	ug/g				<20	20	8201208
Conductivity	umho/cm				173	2	8198559
Available (CaCl <sub>2</sub> ) pH	pH				7.71		8199338
Soluble (20:1) Sulphate (SO <sub>4</sub> )	ug/g				<20	20	8201217
Sulphide	mg/kg				2.0 (1)	0.5	8205122
<b>Physical Testing</b>							
Moisture-Subcontracted	%	14	0.30	8205121	10	0.30	8205123
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate (1) Sample extracted past method-specified hold time. Analyzed past method specified hold time							



BUREAU  
VERITAS

Bureau Veritas Job #: C205551  
Report Date: 2022/09/06

Golder Associates Ltd  
Client Project #: 19136074  
Site Location: BRADFORD  
Your P.O. #: 19136074  
Sampler Initials: MTI

## TEST SUMMARY

**Bureau Veritas ID:** TOL232  
**Sample ID:** 404-2 SA#4  
**Matrix:** Soil

**Collected:** 2021/06/15  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal
Conductivity	AT	8198559	2022/08/31	2022/09/01	Roya Fathitil
Moisture (Subcontracted)	BAL	8205121	N/A	2022/09/02	Eric Tse
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison
pH CaCl2 EXTRACT	AT	8199338	2022/08/31	2022/08/31	Taslina Aktar
Resistivity of Soil		8193773	2022/09/01	2022/09/01	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law

**Bureau Veritas ID:** TOL232 Dup  
**Sample ID:** 404-2 SA#4  
**Matrix:** Soil

**Collected:** 2021/06/15  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison

**Bureau Veritas ID:** TOL233  
**Sample ID:** 404-3 SA#3  
**Matrix:** Soil

**Collected:** 2021/06/17  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal
Conductivity	AT	8198559	2022/08/31	2022/09/01	Roya Fathitil
Moisture (Subcontracted)	BAL	8205121	N/A	2022/09/02	Eric Tse
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison
pH CaCl2 EXTRACT	AT	8199338	2022/08/31	2022/08/31	Taslina Aktar
Resistivity of Soil		8193773	2022/09/01	2022/09/01	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law

**Bureau Veritas ID:** TOL233 Dup  
**Sample ID:** 404-3 SA#3  
**Matrix:** Soil

**Collected:** 2021/06/17  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal

**Bureau Veritas ID:** TOL234  
**Sample ID:** 404-4 SA#4  
**Matrix:** Soil

**Collected:** 2021/06/10  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal
Conductivity	AT	8198559	2022/08/31	2022/09/01	Roya Fathitil
Moisture (Subcontracted)	BAL	8205121	N/A	2022/09/02	Eric Tse
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison



BUREAU  
VERITAS

Bureau Veritas Job #: C205551

Report Date: 2022/09/06

Golder Associates Ltd

Client Project #: 19136074

Site Location: BRADFORD

Your P.O. #: 19136074

Sampler Initials: MTI

## TEST SUMMARY

**Bureau Veritas ID:** TOL234  
**Sample ID:** 404-4 SA#4  
**Matrix:** Soil

**Collected:** 2021/06/10  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
pH CaCl2 EXTRACT	AT	8199338	2022/08/31	2022/08/31	Taslina Aktar
Resistivity of Soil		8193773	2022/09/01	2022/09/01	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law

**Bureau Veritas ID:** TOL235  
**Sample ID:** 2-1 SA#4  
**Matrix:** Soil

**Collected:** 2021/12/21  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal
Conductivity	AT	8198559	2022/08/31	2022/09/01	Roya Fathitil
Moisture (Subcontracted)	BAL	8205121	N/A	2022/09/02	Eric Tse
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison
pH CaCl2 EXTRACT	AT	8199338	2022/08/31	2022/08/31	Taslina Aktar
Resistivity of Soil		8193773	2022/09/01	2022/09/01	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law

**Bureau Veritas ID:** TOL236  
**Sample ID:** L-4B SA#4  
**Matrix:** Soil

**Collected:** 2021/07/07  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal
Conductivity	AT	8198559	2022/08/31	2022/09/01	Roya Fathitil
Moisture (Subcontracted)	BAL	8205121	N/A	2022/09/02	Eric Tse
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison
pH CaCl2 EXTRACT	AT	8199338	2022/08/31	2022/08/31	Taslina Aktar
Resistivity of Soil		8193773	2022/09/01	2022/09/01	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law

**Bureau Veritas ID:** TOL237  
**Sample ID:** HRE-3 SA#3B  
**Matrix:** Soil

**Collected:** 2022/01/13  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal
Conductivity	AT	8198559	2022/08/31	2022/09/01	Roya Fathitil
Moisture (Subcontracted)	BAL	8205121	N/A	2022/09/02	Eric Tse
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison
pH CaCl2 EXTRACT	AT	8199338	2022/08/31	2022/08/31	Taslina Aktar
Resistivity of Soil		8193773	2022/09/01	2022/09/01	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law



BUREAU  
VERITAS

Bureau Veritas Job #: C205551

Report Date: 2022/09/06

Golder Associates Ltd

Client Project #: 19136074

Site Location: BRADFORD

Your P.O. #: 19136074

Sampler Initials: MTI

## TEST SUMMARY

**Bureau Veritas ID:** TOL238  
**Sample ID:** HRE-4 SA#4  
**Matrix:** Soil

**Collected:** 2022/02/22  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal
Conductivity	AT	8198559	2022/08/31	2022/09/01	Roya Fathitil
Moisture (Subcontracted)	BAL	8205123	N/A	2022/09/02	Simranjeet Batth
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison
pH CaCl2 EXTRACT	AT	8199338	2022/08/31	2022/08/31	Taslina Aktar
Resistivity of Soil		8193773	2022/09/01	2022/09/01	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law

**Bureau Veritas ID:** TOL238 Dup  
**Sample ID:** HRE-4 SA#4  
**Matrix:** Soil

**Collected:** 2022/02/22  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law

**Bureau Veritas ID:** TOL239  
**Sample ID:** HRW-1B SA#5  
**Matrix:** Soil

**Collected:** 2021/11/11  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal
Conductivity	AT	8198559	2022/08/31	2022/09/01	Roya Fathitil
Moisture (Subcontracted)	BAL	8205121	N/A	2022/09/02	Eric Tse
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison
pH CaCl2 EXTRACT	AT	8199338	2022/08/31	2022/08/31	Taslina Aktar
Resistivity of Soil		8193773	2022/09/01	2022/09/01	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law

**Bureau Veritas ID:** TOL239 Dup  
**Sample ID:** HRW-1B SA#5  
**Matrix:** Soil

**Collected:** 2021/11/11  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture (Subcontracted)	BAL	8205121	N/A	2022/09/02	Eric Tse

**Bureau Veritas ID:** TOL240  
**Sample ID:** FD-02 SA#3  
**Matrix:** Soil

**Collected:** 2022/05/20  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8201208	2022/09/01	2022/09/02	Chandra Nandlal
Conductivity	AT	8198559	2022/08/31	2022/09/01	Roya Fathitil
Moisture (Subcontracted)	BAL	8205123	N/A	2022/09/02	Simranjeet Batth
Sulphide in Soil	SPEC	8205122	N/A	2022/09/02	Bailey Morrison



BUREAU  
VERITAS

Bureau Veritas Job #: C2O5551  
Report Date: 2022/09/06

Golder Associates Ltd  
Client Project #: 19136074  
Site Location: BRADFORD  
Your P.O. #: 19136074  
Sampler Initials: MTI

## TEST SUMMARY

**Bureau Veritas ID:** TOL240  
**Sample ID:** FD-02 SA#3  
**Matrix:** Soil

**Collected:** 2022/05/20  
**Shipped:**  
**Received:** 2022/08/26

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
pH CaCl2 EXTRACT	AT	8199338	2022/08/31	2022/08/31	Taslima Aktar
Resistivity of Soil		8193773	2022/09/01	2022/09/01	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8201217	2022/09/01	2022/09/02	Samuel Law



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VERITAS

Bureau Veritas Job #: C2O5551

Report Date: 2022/09/06

Golder Associates Ltd

Client Project #: 19136074

Site Location: BRADFORD

Your P.O. #: 19136074

Sampler Initials: MTI

### GENERAL COMMENTS

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

Package 1	4.7°C
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**Results relate only to the items tested.**



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VERITAS**

Bureau Veritas Job #: C205551

Report Date: 2022/09/06

## QUALITY ASSURANCE REPORT

Golder Associates Ltd

Client Project #: 19136074

Site Location: BRADFORD

Your P.O. #: 19136074

Sampler Initials: MTI

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8198559	Conductivity	2022/09/01			99	90 - 110	<2	umho/cm	0.34	10
8199338	Available (CaCl <sub>2</sub> ) pH	2022/08/31			100	97 - 103			1.2	N/A
8201208	Soluble (20:1) Chloride (Cl <sup>-</sup> )	2022/09/02	NC	70 - 130	103	70 - 130	<20	ug/g	0.69	35
8201217	Soluble (20:1) Sulphate (SO <sub>4</sub> )	2022/09/02	NC	70 - 130	103	70 - 130	<20	ug/g	12	35
8205121	Moisture-Subcontracted	2022/09/02					<0.30	%	0.73	20
8205122	Sulphide	2022/09/02	120	75 - 125	115	75 - 125	<0.5	mg/kg	21	30
8205123	Moisture-Subcontracted	2022/09/02					<0.30	%		

N/A = Not Applicable

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

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

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

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

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



BUREAU  
VERITAS

Bureau Veritas Job #: C2O5551

Report Date: 2022/09/06

Golder Associates Ltd

Client Project #: 19136074

Site Location: BRADFORD

Your P.O. #: 19136074

Sampler Initials: MTI

### VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

Anastassia Hamanov, Scientific Specialist

Ghayasuddin Khan, M.Sc., P.Chem., QP, Scientific Specialist, Inorganics

Gita Pokhrel, Senior Analyst

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Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



26-Aug-22 15:58

Ankita Bhalla



C205551

L8

Free: 800-563-6266

## WORK ORDER

## CHAIN OF CUSTODY RECORD

Page \_\_\_ of 1

Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required	
Company Name: <b>Golder Associates Ltd.</b>	Company Name: <b>Golder Associates Ltd.</b>	Quotation #: <b>Golder rates</b>	<input checked="" type="checkbox"/> Regular TAT (5-7 days) Most analyses PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS		
Contact Name: <b>Kevin Bentley</b>	Contact Name: <b>Muhammad Talha Irshad</b>	P.O. #/ AFE#: <b>19136074</b>	<b>Rush TAT (Surcharges will be applied)</b> <input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days		
Address: <b>6925 Century Ave., Suite 100</b>	Address: <b>6925 Century Ave., Suite 100</b>	Project #: <b>19136074</b>	<b>Date Required:</b>		
Mississauga, ON	Mississauga, ON	Site Location: <b>Bradford</b>	<b>Rush Confirmation #:</b>		
Phone: 905 567-6100 Fax:	Phone: 778 228-5756 Fax:	Site #:	<b>Date Required:</b>		
Email: <b>canadaaccounts@bureauveritas.com; Kevin_Bentley@golder.com</b>	Email: <b>mirshad@golder.com; 120387@golder.com</b>	Site Location Province: <b>Ontario</b>	<b>Rush Confirmation #:</b>		
MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE BUREAU VERITAS LABORATORIES' DRINKING WATER CHAIN OF CUSTODY		Sampled By:	<b>LABORATORY USE ONLY</b>		
<b>Regulation 153</b> <input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Med/ Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/ Other <input type="checkbox"/> Table _____ FOR RSC (PLEASE CIRCLE) Y / N		<b>Other Regulations</b> <input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> MISA <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> PWQO <input type="checkbox"/> Region <input type="checkbox"/> Other (Specify) _____ <input type="checkbox"/> REG 558 (MIN. 3 DAY TAT REQUIRED)		<b>Analysis Requested</b> # OF CONTAINERS SUBMITTED FIELD FILTERED (CIRCLE) Metals / Hg / Cr VI BTEX / PHC F1 PHC F2 - F4 VOCs REG 153 METALS & INORGANICS REG 153 (CPMS) METALS REG 153 METALS (Hg, Cr VI, CPMS Metals, HWS - B) CORROSIVITY PACKAGE (SULPHIDE) HOLD-DO NOT ANALYZE	
Include Criteria on Certificate of Analysis: Y / N		CUSTODY SEAL Y / N		COOLER TEMPERATURES	
SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS		Present Intact		5/4/5	
		COOLING MEDIA PRESENT: Y / N			
SAMPLE IDENTIFICATION		DATE SAMPLED (YYYY/MM/DD)		TIME SAMPLED (HH:MM)	
MATRIX					
1	404-2 SA#4	2021-06-15	AM	Soil	2
2	404-3 SA#3	2021-06-17	AM	Soil	2
3	404-4 SA#4	2021-06-10	AM	Soil	2
4	2-1 SA#4	2021-12-21	AM	Soil	2
5	L-4B SA#4	2021-07-07	AM	Soil	2
6	HRE-3 SA#3B	2022-01-13	AM	Soil	2
7	HRE-4 SA#4	2022-02-22	AM	Soil	2
8	HRW-1B SA#5	2021-11-11	AM	Soil	2
9	FD-02 SA#3	2022-05-20	AM	Soil	2
10					
RELINQUISHED BY: (Signature/Print)		DATE: (YYYY/MM/DD)		TIME: (HH:MM)	
Muhammad Talha Irshad		2022-08-26		15:58	
RECEIVED BY: (Signature/Print)		DATE: (YYYY/MM/DD)		TIME: (HH:MM)	
Ham Ham		2022/08/26		15:58	
BV JOB #					

MSA with BV Signed May 18, 2020.  
 Golder standing offer rates in email from Julie Clement dated Sept 20, 2021.  
 Corrosivity package including chloride, conductivity, resistivity, pH, sulphate, sulphide is \$98.60/sample.

Unless otherwise agreed to in writing, work submitted on this Chain of Custody is subject to Bureau Veritas Laboratories' standard Terms and Conditions. Signing of this Chain of Custody document is acknowledgment and acceptance of our terms available at <http://www.bvlabs.com/terms-and-conditions>

