Foundation Investigation and Design Report

Retaining Walls No. 1 and 2
Bridge Replacement and Interchange Reconfiguration at
Highway 11/12 (Old Barrie Road), Orillia
Ministry of Transportation, Ontario
GWP 2129-18-00

Submitted to:

Egis Canada Ltd.
1-1329 Gardiners Road, Kingston, ON K7P 0L8

Submitted by:

WSP Canada Inc.
6925 Century Ave., Suite 600, Mississauga, ON L5N 7K2

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PART A

FOUNDATION INVESTIGATION REPORT
RETAINING WALLS NO. 1 AND 2
BRIDGE REPLACEMENT AND INTERCHANGE RECONFIGURATION AT HIGHWAY 11/12 (OLD BARRIE ROAD), ORILLIA
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 2129-18-00

1.0 INTRODUCTION

WSP Canada Inc. (WSP, formerly Golder Associates Ltd., amalgamated with WSP in 2023), has been retained by Egis Canada Ltd. (Egis, formerly McIntosh Perry Consulting Engineers Ltd.) on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary design foundation engineering services as part of the design-build ready assignment for the interchange improvements at the Highway 11 and Highway 12 (Old Barrie Road) south junction. This report presents the results of the foundation investigation for the proposed retaining walls (designated as Retaining Walls No. 1 and 2) at the Highway 11/12 (Old Barrie Road) interchange.

The purpose of this foundation investigation is to establish the subsurface conditions along the alignment of the proposed retaining walls by methods of borehole drilling, in-situ testing, and laboratory testing on selected soil samples.

This report summarizes the factual results of the current (2021 – 2022) foundation investigation and is supplemented with select boreholes from a previous investigation (GEOCRES No. 31D-647) carried out in 2015 in the vicinity of the proposed Retaining Wall No. 1. Based on the information from the current and previous investigations, this report provides a description of the interpreted soil and groundwater conditions along the proposed retaining walls.

2.0 PROJECT AND SITE DESCRIPTION

The orientation stated (i.e., north, south, east, and west) in the text of this report is referenced to project north and therefore may differ from magnetic north shown on Drawings 1 and 2. For this report, Highway 11 (in the vicinity of the City of Orillia) is considered oriented in a south-north direction and Highway 12 (Old Barrie Road) is considered oriented in a west-east direction.

2.1 Project Description

The overall assignment includes the preparation of two separate contracts. The first contract includes the replacement of the Coldwater Road Underpass and the reconfiguration/reconstruction of the Highway 11 and Highway 12 (Coldwater Road) interchange. The second contract includes the replacement of the Old Barrie Road Underpass; the reconfiguration/reconstruction of the Highway 11 and Highway 12 (Old Barrie Road) interchange, including the construction of deep cuts and high fill embankments; construction of two retaining walls (designated as Retaining Wall No. 1 and 2); construction of two noise barrier wall (designated as Noise Barrier Walls No. 1 and 2); and construction of a stormwater management pond and stormwater management swale.

The proposed Retaining Wall No. 1 is located between the proposed Highway 11 N-E/W Ramp and Harvie Settlement Road at Highway 12 (Old Barrie Road), as shown on Drawing 1. The retaining wall is proposed to be about 45 m long, extending from about Station 10+175 to 10+220 and will have a maximum height of about 7 m.

The proposed Retaining Wall No. 2 is located between the proposed Highway 11 W-N Ramp and the Highway 11 S-E/W Ramp at Highway 12 (Old Barrie Road), as shown on Drawing 2. The retaining wall is proposed to be about 65 m long, extending from about Station 10+240 to 10+305 and will have a maximum height of about 6 m.

2.2 Site Description

The proposed Retaining Wall No. 1 is located on the northwest side of the current N-E/W Ramp. Currently a vegetated slope separates Harvie Settlement Road and the existing N-E/W Ramp, with the road grade at Harvie Settlement Road at about Elevation 282 m and the road grade at the ramp at about Elevation 275 m. Residential properties are located on the northwest side of Harvie Settlement Road.

The proposed Retaining Wall No. 2 is located on the southeast side of the current S-E/W Ramp at the base of the ramp embankment extending in a densely vegetated area. This wall will separate the new W-N Ramp and the realigned S-E/W Ramp. The current road grade at the S-E/W Ramp is at about Elevation 253 m and the current ground surface along the proposed retaining wall is at about Elevation 249 m.

3.0 INVESTIGATIONS

3.1 Previous (2015) Investigation

A previous foundation investigation was carried out at the site in 2015, which included the advancement of one borehole (designated as Borehole BH15-02) in the vicinity of Retaining Wall No. 1, at the location shown on Drawing 1. The borehole location, ground surface elevation, and depth are summarized in the table below. The borehole record from Borehole BH15-02 is provided in Appendix A. Additional information from the previous foundation investigation can be found in GEOCRES No. 31D-647.

Borehole No.	Coordinates (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude, °)	Easting (m) (Longitude, °)		
BH15-02	4939050.1	308964.9	282.4	14.0

3.2 Current (2021-2022) Investigation

The fieldwork for the current subsurface investigation was carried out between November 25, 2021 and April 26, 2022, during which time two boreholes (designated as Boreholes DC-1 and DC-4) were advanced in the vicinity of the proposed Retaining Wall No. 1 and seven boreholes (designated as Boreholes RW-1 to RW-7) were advanced in the vicinity of the proposed Retaining Wall No. 2. The locations of the current boreholes are shown in plan on Drawings 1 and 2.

The boreholes were advanced using a D-52 track-mounted drill rig, supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. Traffic control was performed in accordance with the Ontario Traffic Manual Book 7 – Temporary Conditions by Alliance Traffic Control Inc. of Etobicoke, Ontario. The boreholes were advanced using 115 mm inner diameter and 210 mm outer diameter, continuous flight hollow stem augers. Soil samples were typically obtained at 0.75 m and 1.5 m intervals of depth, using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer in general accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The split-spoon samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 35 mm. Therefore, particles or objects that may exist within the soils that are larger than this dimension would not be sampled or represented in the grain size distributions.

Water levels were observed in the open boreholes during and immediately following the drilling operations. A standpipe piezometer was installed in selected boreholes (Borehole RW-2 and RW-5) to permit monitoring of the groundwater level. The standpipe piezometers consist of a 50 mm outer diameter Schedule 40 PVC pipe, with a slotted screen surrounded with a sand filter pack, sealed at a selected depth within the borehole. The annulus surrounding the pipe above the well screen and sand filter pack was backfilled to the ground surface with bentonite.

All boreholes excluding Boreholes RW-2 and RW-5 were backfilled with bentonite upon completion of drilling operations in accordance with Ontario Regulation 903 (*Wells*), as amended. Boreholes RW-2 and RW-5 are to be decommissioned by the Design-Build Contractor at the time of construction.

Prior to commencement of the field work, WSP arranged for the clearance of underground utilities. The field work was supervised by a member of WSP's engineering staff, who observed the borehole drilling, in-situ testing, and soil sampling operations, and logged the boreholes in the field. The soil samples were placed in appropriate containers, labelled, and transported to WSP's Mississauga geotechnical laboratory where the samples underwent further visual and tactile examination and geotechnical laboratory testing.

Geotechnical index testing, such as water content, Atterberg limits, and grain size distribution, was carried out on selected soil samples in accordance with MTO and/or ASTM Standards, as appropriate, and the results of which are presented in Appendix B and Appendix D. In addition, two soil samples were submitted for corrosivity testing, under chain-of-custody procedures, to Bureau Veritas Laboratories (a Standards Council of Canada (SCC) accredited laboratory) of Mississauga, Ontario. The samples were analyzed for a suite of corrosivity parameters which includes conductivity/resistivity, soluble chloride and soluble sulphate concentrations, sulphide concentrations, and pH. The results of the corrosivity testing are presented in Appendix E.

The as-drilled borehole locations and the corresponding ground surface elevations were surveyed on-site by Callon Dietz Inc. of London, Ontario, with an accuracy of about 0.1 m (vertical) and 0.5 m (horizontal). The borehole survey information, including northing/easting coordinates (reference to the NAD83 Canadian Spatial Reference System (CSRS) V6:2010 MTM Zone 10 coordinate system), latitude/longitude coordinates, and corresponding ground surface elevations (referenced to the Canadian Geodetic Vertical Datum (CGVD) 1928:1978), as well as borehole depths are provided on the borehole records in Appendix A and summarized below.

Borehole No.	Coordinates (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude, °)	Easting (m) (Longitude, °)		
DC-1	4938953.2 (44.590583)	308913.3 (-79.448198)	278.9	12.5
DC-4	4938926.2 (44.590341)	308948.3 (-79.447757)	272.9	9.5
RW-1	4938719.5 (44.588478)	309189.6 (-79.444720)	247.9	11.3
RW-2	4938764.4 (44.588882)	309221.3 (-79.444320)	246.3	14.2
RW-3	4938803.2 (44.589231)	309241.3 (-79.444068)	247.0	10.9
RW-4	4938724.7 (44.588525)	309219.0 (-79.444349)	246.3	11.1
RW-5	4938774.4 (44.588972)	309246.7 (-79.444000)	246.2	11.0
RW-6	4938739.0 (44.588654)	309203.6 (-79.444544)	247.5	11.3
RW-7	4938787.1 (44.589086)	309227.6 (-79.444240)	246.9	11.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 12 lies within the Simcoe Lowlands, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984). The Simcoe Lowlands consist of a series of steep sided, flat-floored valleys that were flooded by glacial lake Algonquin. The surficial soils in this area of the Simcoe Lowlands typically comprise glaciolacustrine sediments of very fine to medium-grained sand, silt and minor clay; and fluvial and glaciofluvial ice-contact sediments of fine to very coarse-grained sand, gravelly sand and gravel with minor amounts of silt, clay and flowtill. Modern alluvial deposits of clay, silt, sand gravel that may contain organics are also present.

4.2 Subsurface Conditions

The subsurface soil and groundwater conditions encountered in the current and previous boreholes advanced in the vicinity of Retaining Wall No. 1 and 2 are presented on the record of boreholes in Appendix A and C, respectively. For the records of boreholes for the current investigation, *Method of Soil Classification, Abbreviations and Terms Used on Records of Boreholes and Test Pits* and *List of Symbols* sheets are provided in Appendix A and C to assist in the interpretation of the borehole records. The geotechnical laboratory results from the boreholes advanced as part of current investigation in the vicinity of Retaining Walls No. 1 and 2 are included in Appendix B and D, respectively. The analytical laboratory results from the boreholes advanced as part of the current investigation are provided in Appendix E. The results of in-situ tests as presented on the record of boreholes are uncorrected for overburden pressure and energy transfers. The 'N'-values are based on SPT sampling procedures carried out with a standard weight (i.e., 63.5 kg), and an automatic hammer.

The stratigraphic boundaries shown on the borehole records and on the profile shown on Drawings 1 and 2 have been inferred from observations of drilling progress, generally non-continuous sampling and in-situ testing, and therefore represent transitions between soil types rather than exact planes of geologic change. Further, subsurface conditions will vary between and beyond the borehole locations.

4.2.1 Retaining Wall No. 1

The subsurface soils encountered in the vicinity of Retaining Wall No. 1 consist of asphalt underlain by fill, which in turn is underlain by compact to very dense silty sand glacial till. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1.1 Asphalt

An approximately 60 mm to 150 mm thick layer of asphalt was encountered at ground surface in Boreholes BH12-02, DC-1, and DC-4.

4.2.1.2 Fill

An approximately 1.5 m to 2.8 m thick layer of fill was encountered underlying the asphalt in Boreholes BH15-02, DC-1, and DC-4. The fill extends to depths ranging from 1.5 m to 2.9 m below ground surface (Elevations 271.5 m to 280.3 m). The fill ranges from gravelly sand to silty sand to silt and sand to clayey sand-silty sand. The fill contains organics at Borehole BH15-02 and contains rock fragments at Boreholes DC-1.

SPT 'N'-values measured within the fill generally range from 12 to 31 blows per 0.3 m of penetration indicating a compact to dense degree of compactness. One SPT 'N'-value of 100 blows of less than 0.3 m of penetration was measured at Boreholes DC-1, likely due to the presence of rock fragments within the fill.

From the current investigation, grain size distribution testing was carried out on two samples of the fill and the results are presented on Figure B-1 in Appendix B. Atterberg Limits testing was carried out on two samples of the fill from the current investigation and one sample from the previous investigation. The Atterberg Limits testing measured liquid limits of 13% and 16%, plastic limits of 11% and 13%, and plasticity indices between 2% and 5%, suggesting the fill at these sample locations has low plasticity. The results of the Atterberg Limit tests from the current investigation are presented on Figure B-2 in Appendix B.

The water contents measured on select samples of the fill range from about 1% to 9%.

4.2.1.3 Glacial Till

A glacial till deposit was encountered underlying the fill in Boreholes BH15-02, DC-1, and DC-4 at depths ranging from about 1.5 m to 2.9 m below ground surface (Elevations 271.5 m to 280.3 m). The till deposit extends to the borehole termination depths ranging from about 9.5 m to 14.0 m below ground surface (Elevations 263.4 m to 268.4 m). The glacial till consists of silty sand, some gravel, trace to some clay. It is noted that the silt and sand till composition noted on Borehole BH15-02, translates to silty sand based on the current soil classification system. Rock fragments and auger grinding were noted when advancing through the till deposit at Borehole DC-1. Cobbles and boulders are inferred within the till deposit, based on the observed rock fragments and auger grinding.

SPT-‘N’ values measured within the till range from 13 blows to greater than 100 blows per 0.3 m of penetration, indicating a compact to very dense state of compactness.

From the current investigation, grain size distribution testing was carried out on four samples of the glacial till deposit and the results are presented on Figure B-3 in Appendix B. Atterberg Limits testing was carried out on four samples of the glacial till from the current investigation and on one sample from the previous investigation. One of the five samples yielded a non-plastic result and the remaining five samples measured liquid limits between 14% and 16%, plastic limits of 11%, and plasticity indices between 3% and 5%, suggesting the till deposit ranges from non-plastic to low plasticity. The results of the Atterberg Limit tests from the current investigation are presented on Figure B-4 in Appendix B.

Water contents measured on select samples of the till deposit range from about 4% to 8%.

4.2.2 Retaining Wall No. 2

In general, the subsurface soils encountered in the vicinity of Retaining Wall No. 2 consist of topsoil underlain by fill, which in turn is underlain by a compact to dense non-cohesive deposit varying in composition from silt to sand. The silt to sand deposit is subsequently underlain by a dense to very dense / hard, non-cohesive / cohesive glacial till deposit and a clayey silt deposit. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.2.1 Topsoil

An approximately 80 mm to 130 mm thick layer of topsoil was encountered at ground surface elevations in Boreholes RW-1 to RW-7.

4.2.2.2 Fill

An approximately 1.2 m to 2.1 m thick layer of fill was encountered underlying the topsoil in Boreholes RW-3, and RW-5 to RW-7. The fill extends to depths ranging from 1.4 m to 2.2 m below ground surface (Elevations 244.0 m to 246.1 m). The fill ranges from gravelly silty sand to silty sand and gravel. The fill contains rock fragments at Boreholes RW-5 to RW-7 and contains cobbles at Borehole RW-5. Auger grinding was encountered while advancing the borehole through the fill in Boreholes RW-3 and RW-5.

SPT ‘N’-values measured within the fill generally range from 9 to 49 blows per 0.3 m of penetration indicating a loose to dense degree of compactness. SPT ‘N’-values of 100 blows for less than 0.3 m of penetration were measured at Borehole RW-5. These measurements, along with the observed difficulty drilling through the fill (as noted on the borehole record), suggest the presence of cobbles and/or boulders within the fill at Borehole RW-5.

Grain size distribution testing was carried out on three samples of the fill and the results are presented on Figure D-1 in Appendix D.

The water contents measured on select samples of the fill range from about 4% to 11%.

4.2.2.3 Silt to Sand

A silt to sand deposit was encountered underling the topsoil in Boreholes RW-1, RW-2, and RW-4 and underlying the fill in Boreholes RW-3, and RW-5 to RW-7 at depths ranging from 0.1 m to 2.2 m below ground surface (Elevations 244.0 m to 247.8 m). Where fully penetrated, the silt to sand deposit extends to depths ranging from about 8.6 m to 10.1 m below ground surface (Elevations 237.6 m to 238.4 m). At Boreholes RW-5 to RW-7, the silt to sand deposit extended to the borehole termination depths of 11.0 m to 11.3 m (Elevations 235.2 m to 236.2 m). The deposit ranges in composition from silt to silty sand to sand, trace gravel, trace clay.

SPT ‘N’-values measured within silt to sand deposit range from 3 and 100 blows per 0.3 m of penetration, indicating a very loose to very dense state of compactness. It is noted that the very loose to loose conditions are generally within the upper portion of the deposit and the overall deposit is generally compact to dense.

Grain size distribution testing was carried out on twenty-one samples of the silt to sand deposit and the results are presented on Figures D-2A to D-2C in Appendix D. Atterberg Limits testing was carried out on five samples of the silt to sand deposit. Three of the five samples yielded non-plastic results and the remaining two samples measured liquid limits of about 21%, plastic limits of 19%, and plasticity indices of 2%, suggesting the deposit ranges from non-plastic to slightly plastic. The results of the Atterberg Limit tests are presented on Figure D-3 in Appendix D.

The water contents measured on select samples of the silt to sand deposit range from about 6% and 26%.

4.2.2.4 Glacial Till

A glacial till deposit was encountered below the silt to sand deposit in Boreholes RW-1 to RW-4 at depths ranging from about 8.6 m to 10.1 m below ground surface (Elevations 238.4 m to 238.6 m). The till deposit generally extends to the borehole termination depths ranging from about 10.9 m to 14.2 m below ground surface (Elevations 236.6 m to 232.1 m). At Borehole RW-4, the glacial till deposit extended to a depth of 10.0 m below ground surface (Elevation 236.3 m). The glacial till generally consists of sandy silt, trace to some gravel, trace clay, except at Borehole RW-1 where the glacial till consists of sandy clayey silt-silt, some gravel. Although not specifically encountered in the boreholes, cobbles and boulders should be anticipated in glacial till.

SPT-‘N’ values measured within the till range from 42 blow to greater than 100 blows per 0.3 m of penetration, indicating a dense to very dense state of compactness / a hard consistency.

Grain size distribution testing was carried out on four samples of the glacial till deposit and the results are presented on Figure D-4 in Appendix D. Atterberg Limits testing was carried out on four samples of the glacial till deposit. Two of the four samples yielded non-plastic results and the remaining two samples measured liquid limits of about 18% and 19%, plastic limits of about 14% and 16%, and plasticity indices of about 2% and 5%, suggesting the till deposit ranges from a non-plastic to slightly plastic sandy silt to a clayey silt-silt of low plasticity. The results of the Atterberg Limit test are presented on Figure D-5 in Appendix D.

Water contents measured on select samples of the till deposit range from about 9% to 17%.

4.2.2.5 Clayey Silt

A clayey silt deposit was encountered below the till deposit in Borehole RW-4 at a depth of about 10.0 m below ground surface (Elevation 236.3 m) and extended to the borehole termination depth of about 11.1 m below ground surface (Elevation 235.2 m).

The SPT-'N' value measured within the clayey silt deposit was 104 blows for 0.28 m of penetration, indicating a hard consistency.

Grain size distribution testing was carried out on one sample of the clayey silt deposit and the results are presented on Figure D-6 in Appendix D. Atterberg Limits testing was carried out on one sample of the clayey silt deposit and measured a liquid limit of about 27%, a plastic limit of about 18%, and a plasticity index of about 9% suggesting the deposit is of low plasticity. The results of the Atterberg Limit test are presented on Figure D-7 in Appendix D.

Water contents measured on one sample of the clayey silt deposit is about 15%.

4.2.3 Groundwater Conditions

In general, the soil samples recovered from the boreholes were moist to wet. The groundwater levels were measured in the open boreholes upon completion of drilling operations. A standpipe piezometer was installed in Boreholes RW-2 and RW-5 to monitor the groundwater level. The groundwater level measurements and standpipe piezometer installation details and are presented below and on the borehole records.

Retaining Wall No.	Borehole No.	Water Level		Reading Type	Date
		Depth (m)	Elevation (m)		
Retaining Wall No. 1	BH15-02	13.5	268.9	Open borehole	September 29, 2015
	DC-1	3.8	275.1	Open borehole	January 26, 2022
	DC-4	4.6	268.3	Open borehole	November 29, 2022
Retaining Wall No. 2	RW-1	4.6	243.3	Open borehole	April 18, 2022
	RW-2	3.3	243.1	Standpipe piezometer*	April 20, 2022
		4.2	242.1	Standpipe piezometer	May 13, 2022
	RW-3	Dry	Dry	Open borehole	April 27, 2022
	RW-4	4.0	242.3	Open borehole	April 20, 2022
	RW-5	4.0	242.2	Standpipe piezometer*	April 26, 2022
		4.0	242.2	Standpipe piezometer	May 3, 2022
		4.3	241.9	Standpipe piezometer	May 13, 2022
	RW-6	4.0	243.5	Open borehole	April 19, 2022
	RW-7	4.2	242.7	Open borehole	April 25, 2022

*Reading obtained immediately following installation of standpipe piezometer.

The groundwater level observations/measurements are subject to seasonal fluctuations and precipitation events; therefore, the groundwater level should be expected to be higher during wet periods or during any period of heavy and/or sustained precipitation.

4.3 Analytical Testing

Two soil samples were collected and submitted to Bureau Veritas Laboratories for analysis of parameters used to assess corrosion potential and sulphate attack. A summary of the results is presented in the following table. The Certificates of Analysis are provided in Appendix E.

Borehole No.	Sample No.	Sample Depth [Elevation] (m)	Soil Type	Parameters				
				Chloride (µg/g)	Sulphate (µg/g)	pH	Conductivity (µohm/cm)	Resistivity (ohm-cm)
RW-1	3	1.5 – 2.1 [245.5 – 244.9]	Silt and sand	<20	<20	7.8	83	12,000
RW-3	3	1.5 – 2.1 [246.4 – 245.8]	Silty sand to sand	<20	<20	7.9	66	15,000

The sulphide concentration measured in the soil samples noted above was also analyzed and the results were 1.1 mg/kg and 1.0 mg/kg, respectively.

5.0 CLOSURE

The Foundation Investigation Report was prepared by Ms. Anastasia Poliacik, P.Eng., a Senior Foundation Engineer at WSP. Mr. David Staseff, P.Eng., a Senior Principal and MTO Principal Foundations Contact with WSP conducted an independent technical and quality review of this report.

Signature Page

WSP Canada Inc.

Anastasia Poliacik, P.Eng.
Senior Geotechnical Engineer

David Staseff, P.Eng.
Senior Principal, MTO Foundations Designated Contact

AMP/DS/al

https://wsponline.sharepoint.com/sites/gld-120052/project files/6 deliverables/2. reporting/04 - retaining wall/7. final_rev1/19135676-r-rev1_rw hwy 11 obr fidr_20mar2024.docx

PART B

FOUNDATION DESIGN REPORT
RETAINING WALLS NO. 1 AND 2
BRIDGE REPLACEMENT AND INTERCHANGE RECONFIGURATION AT HIGHWAY 11/12 (OLD BARRIE ROAD), ORILLIA
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 2129-18-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report (Part B) provides foundation engineering design recommendations for the proposed retaining walls (designated as Retaining Wall No. 1 and 2) associated with the reconstruction / reconfiguration of the Highway 11/12 (Old Barrie Road) interchange. The discussion and recommendations are based on interpretation and analysis of the factual data obtained from the boreholes and other subsurface explorations advanced during the foundation investigation(s) at this site as described in the Foundation Investigation Report (Part A of this report).

This section of the report (Part B) is intended for the use of the MTO and their procurement-ready designer for this assignment and shall not be relied upon for any other purpose or by any other parties. The discussion, recommendations and geotechnical/foundation aspects of any preliminary design or reference concept design are provided for information purposes only. Where any comments are made on construction, they are provided only to highlight those aspects which could affect the detailed design of the project. The design-build proponent(s) shall make their own interpretations based on the factual data presented in the Foundation Investigation Report (Part A of this report) and supplement with additional information as necessary, to generate and assess foundation alternatives and develop the design of the preferred alternative. The design-build proponent is responsible for all aspects of the detailed design and construction for the preferred alternative.

6.1 General

Based on the conceptual drawings of the proposed retaining walls provided by Egis, dated December 2023, the proposed retaining wall details are as summarized in the table below. It is noted that Retaining Wall No. 1 will separate the new N-E/W Ramp and Harvie Settlement Road and Retaining Wall No. 2 will separate the new S-E/W Ramp and the new W-N Ramp. Based on the information provided in the table below, it is anticipated that Retaining Wall No. 1 will be founded approximately 2 m below the existing ground surface in a cut while Retaining Wall No. 2 will be founded about 8 m above the existing ground surface in a fill on the new ramp embankment. Foundation recommendations for the high fill associated with the new ramp embankment at this location are provided under a separate report.

Retaining Wall ID	Location	Length (m)	Existing Ground Surface Elevation (m)	Base of Wall Elevation (m)	Maximum Height (m)
Retaining Wall No. 1	N-E/W Ramp Station 10+220 to 10+175	45	~275	273.0 to 273.7	7.1
Retaining Wall No. 2	S-E/W Ramp Station 10+240 to 10+305	65	~247	254.3 to 255.9	6.0

6.2 Retaining Walls and Foundations Options

Based on the geometries shown on the conceptual drawings and the subsurface conditions at the site, retained soil system (RSS) walls and concrete cantilever walls are considered feasible options. A summary comparison of these feasible retaining wall options based on geotechnical/foundations-related advantages, disadvantages, relative costs, and risks/consequences is presented in Table 1, following the text of this report, and key points are also summarized below. It should be noted that the selection of the type of walls and foundation alternatives will also depend on factors beyond geotechnical/foundation recommendations, such as structural, economic and environmental factors.

- **Retained Soil System (RSS) Wall:** An RSS wall with the front facing supported on a concrete levelling pad is feasible for the proposed retaining walls. RSS walls include a reinforced soil zone behind the wall with a distance (width) equal to 70% of the wall height or 0.7H, where H is the RSS wall height.

For Retaining Wall No. 1, temporary excavations to the recommended founding stratum would be in the order of about 1 m to 2 m deep relative to the ground surface in front of the wall to ensure the footings or levelling pads are founded below existing fill and any soft/loose soils. Excavations for the reinforced soil zone (up to 5.0 m at Retaining Wall No. 1 for 0.7H) would extend about 6 m behind the wall, which would require cutting into the existing embankment slope between Harvie Settlement Road and the existing N-E/W Ramp. As such, it is understood that a temporary protection system will be required along the back of this excavation (i.e., along the east side of Harvie Settlement Road) to facilitate traffic staging during construction.

For Retaining Wall No. 2, considering the wall would be founded on the new ramp embankment (about 8 m above existing ground surface), excavations into existing site soils would not be required for the shallow strip footing or levelling pad. However, is it noted that the existing topsoil, existing fill containing organics and any existing soft/loose soils should be removed from below the new embankment construction, as further discussed in the Foundation Investigation and Design Report for the High Fill and Deep Cuts in this area. Excavations for the reinforced soil zone (up to 4.2 m at Retaining Wall No. 2 for 0.7H) would extend about 5 m behind the wall and may require cutting into the new W-N Ramp embankment, depending on embankment construction sequence for the two ramps (the W-N Ramp and the S-E/W Ramp).

- **Concrete Cantilever Wall on Shallow Foundations:** A concrete retaining wall supported on shallow foundations (concrete strip footing) is feasible for the proposed retaining walls.

For Retaining Wall No. 1, temporary excavations for the concrete strip footings would be in the order of 1.7 m to 2 m deep relative to the ground surface in front of the wall to ensure the footings are founded below frost depth and below existing fill and any soft/loose soils. Excavations for the strip footings would likely require minimal excavation into the existing embankment slope between Harvie Settlement Road and the existing N-E/W Ramp. However, it is understood that a temporary protection system along the back of this excavation (i.e., along the east side of Harvie Settlement Road) would be required to facilitate traffic staging during construction.

For Retaining Wall No. 2, considering the wall would be founded on the new ramp embankment (about 8 m above existing ground surface), excavations for the concrete strip footings would extend 1.7 m below the new ground surface in front of the wall to ensure the footings are founded below frost depth. The need for temporary protection systems is dependant on the construction staging of the two ramps (the W-N Ramp and the S-E/W Ramp).

- **Concrete Cantilever Wall on Deep Foundations – Driven Piles:** A concrete retaining wall supported on driven steel H-piles or steel tube piles that extend into the dense to very dense till deposit at Retaining Wall No. 1 and No. 2 could also be considered for the retaining walls. However, pile caps for such a configuration would need to be founded below frost depth, and hence excavations would be similar to those needed for a concrete retaining wall on shallow foundations, affording no advantage related to excavation depths. Further, due to the proposed embankment height at Retaining Wall No. 2, relatively long piles would be required at this location to extend the piles into competent soils. Considering the existing site soils (at Retaining Wall No. 1) and proposed embankment fill (at Retaining Wall No. 2) provide adequate geotechnical resistances for design of shallow foundations, driven piles are not a preferred solution for Retaining Walls No. 1 and 2. No further discussion of this retaining wall foundation option is provided within this report.

- **Deep Foundations – Secant Pile Wall:** Drilled shaft (caisson) walls founded in the very dense / hard glacial till deposit may be considered for the proposed retaining walls, although this solution is not considered necessary given that reasonable founding conditions are available for shallow strip footings as described above. This wall type consists of primary (king) and secondary (filler) caissons of an appropriate diameter and embedment length to provide the required axial and lateral resistances for the retained soil behind the wall and other surcharge loads applicable to the wall design. Soil anchors can be used to provide additional lateral stiffness to maintain horizontal movement within tolerable limits, if necessary. This option would likely require more significant working pad preparation to support the caisson rig, as compared with the conventional construction equipment that would be used for shallow foundation construction. Therefore, a secant pile wall is not a preferred solution for Retaining Walls No. 1 and 2. No further discussion of this retaining wall foundation option is provided within this report.

Based on a comparison of the advantages/disadvantages between the various wall types and supporting foundation alternatives presented in Table 1 and described above, and given the subsurface conditions encountered in the boreholes, the preferred retaining wall alternatives from a geotechnical/foundations perspective for the proposed retaining walls are an RSS wall and a concrete cantilever wall on shallow foundations. From an economic and construction perspective, an RSS wall is preferred.

6.3 General Design Considerations

6.3.1 Consequence and Site Understanding Classification

Highway 11 and Highway 12 both carry a relatively large volume of traffic and both highways have the potential to impact alternative transportation corridors. Therefore, a “typical consequence level” is considered appropriate for this project, as outlined in Section 6.5 of the *Canadian Highway Bridge Design Code* (CHBDC 2019) and its *Commentary*. Further, given the scope of work of this foundation investigation program, as presented in Sections 3.0 and 4.0 of this report, a “typical degree of site and prediction model understanding” has been assumed. Accordingly, the appropriate corresponding ULS and SLS consequence factor, Ψ, and geotechnical resistance factors, Φ_{gu} and Φ_{gs}, from Tables 6.1 and 6.2 of the CHBDC (2019) have been used for foundation design.

6.3.2 Seismic Design

The seismic hazard values associated with the design earthquakes are those established for the National Building Code of Canada (NBCC 2020) by the Geological Survey of Canada (GSC). The current seismic hazard maps (referred to as the 6^{th} generation seismic hazard maps) were developed by the GSC and were made available for public use in December 2020.

6.3.2.1 Seismic Site Classification

The subsurface conditions for seismic site characterization were assessed based on the results of the current and previous foundation investigations. Based on the energy-corrected average standard penetration resistance, $\bar{N}_{60}$, below the estimated founding level, the site may be classified as Site Class C “very dense soil” in accordance with Clause 4.4.3.2 and Table 4.1 of CHBDC (2019), in the absence of site-specific geophysical testing. The Site Class should be confirmed during detailed design by the Design-Builder. In this regard, consideration should be given to carrying out geophysics testing such as Multi-Channel Analysis of Surface Waves (MASW) or vertical seismic profiling during detailed design to obtain the site-specific shear wave velocity which may improve the seismic design conditions.

6.3.2.2 Spectral Response Values

In accordance with Section 4.4.3.1 of the CHDBC (2019) and based on the location of the proposed bridge structure and interchange, the peak seismic hazard values for Site Class C were obtained from the Earthquakes Canada website (www.earthquakescanada.nrcan.gc.ca) as referenced in the NBCC and are provided below.

Parameter	2% Probability of Exceedance in 50 Years (2,475-year return period) (g)
Sa(0.2)	0.217
Sa(0.5)	0.156
Sa(1.0)	0.090
Sa(2.0)	0.044
Sa(5.0)	0.012
Sa(10.0)	0.004
PGA	0.095
PGV [m/s]	0.101

The values given above should be checked and modified as appropriate if the Site Class changes during detailed design. The retaining walls should be designed in accordance with the latest version of the NBCC and CHBDC, and the more conservative approach used for design.

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”.

In general, the fill materials and native soils at these retaining wall locations consist of compact to very dense silt to sand and compact to dense glacial till deposits. Based on the compactness of the soils at the retaining wall locations, the soils at these locations are considered to have a low potential for liquefaction during a seismic event.

6.3.3 Frost Protection

The estimated frost penetration depth in the Orillia area is 1.7 m, as interpreted from Ontario Provincial Standard Drawing (OPSD) 3090.101 (Foundation Frost Penetration Depths for Southern Ontario). As such, the footings for concrete cantilever walls should be provided with a minimum of 1.7 m of soil cover or an equivalent combination of insulation and soil cover. As a general guideline, 25 mm of rigid polystyrene foam insulation provides a 300 mm reduction in soil cover.

6.4 Retained Soil System (RSS) Walls

Mechanically reinforced soil retaining systems (retained soil system or RSS walls) are the preferred option for both Retaining Wall No. 1 and Retaining Wall No. 2. RSS walls include a reinforced soil zone behind the wall with a distance (width) equal to 70% of the wall height. The reinforced soil zone (i.e., the reinforced soil mass) is comprised of reinforcing strips or grids and RSS backfill. The RSS backfill shall consist of material meeting OPSS.PROV 1010 (*Aggregates*) Granular 'A', Granular 'B' Type II, placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

The detailed design and construction of RSS walls will be the responsibility of the proprietary wall designer and contractor. RSS walls at this site must be designed in accordance with the MTO RSS Design Guidelines (2008), the 2019 CHBDC Section 6.19 for MSE Wall Systems, and constructed in accordance with MTO SP 599 S22 (General RSS Specification) and MTO SP 599 S23 (Concrete Elements). The contractor must select RSS from the DSM MTO RSS Wall/Slope List that meet the requirements for performance and appearance specified in the contract documents. Internal stability of the RSS wall must be analyzed by the supplier/designer of the proprietary RSS selected by the contractor for this site.

Further, where the wall and soil mass require cutting into the existing slope (i.e., at the location of Retaining Wall No. 1 and possibly at the location of Retaining Wall No. 2, depending on construction staging), the back of the excavation / reinforced soil mass should be keyed into the existing embankment by benching, as per OPSD 208.010 (Benching of Earth Slopes). As noted above in Section 6.2, a temporary protection system will be required along the back of the excavation.

6.4.1 Founding Elevations

A typical RSS wall has a front facing panel system that is supported on a concrete levelling pad placed at a shallow depth below the ground surface at the front of the wall. As shown on Figures 5.1 and 5.2 of the MTO RSS Design Guidelines (2008), the concrete levelling pad is to be founded on a minimum 0.3 m thick compacted granular pad, extending a minimum of 0.5 m below the top of the concrete levelling pad and a minimum of 1.0 m in front of the wall face. The compacted granular pad should consist of granular material meeting OPSS.PROV 1010 (*Aggregates)* Granular 'A', Granular 'B' Type I or II, placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

The compacted granular pad and reinforced soil mass are recommended to be founded at or below the maximum (highest) founding elevations in the table below. Depending on the final grade at the base of the RSS wall, the compacted granular pad may need to be installed below the elevations recommended below to achieve the minimum embedment depth of 0.5 m.

Retaining Wall ID	Final Ground Surface in front of Wall (m)	Maximum (Highest) Founding Elevation (m)	Anticipated Bearing Soil Below Granular Pad
Retaining Wall No. 1	273.0 to 273.7	272.5 to 273.2	Engineered fill (meeting OPSS.PROV 1010 Granular 'A', Granular 'B' Type I or II, or SSM) over very dense silty sand till[1]
Retaining Wall No. 2	254.3 to 255.9	253.7 to 255.4	New embankment fill (engineered fill meeting OPSS.PROV 1010 Granular 'A', Granular 'B' Type I or II, or SSM)

Note 1. Up to about 1.5 m of sub-excavation of existing fill may be required at this location.

The subgrade for the granular pad and reinforced soil mass should be inspected by qualified geotechnical personnel following excavation, in accordance with OPSS 902 (*Excavating and Backfilling Structures*) to check that all existing fill and/or other unsuitable material have been removed. Where sub-excavation of fill or unsuitable materials is required, the sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010

(*Aggregates)* Granular 'A', Granular 'B' Type I or II, or SSM placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), or the thickness of the granular pad increased to the full sub-excavation depth.

6.4.2 Geotechnical Resistance

For RSS facing panels supported on a 0.3 m wide concrete levelling pad over a minimum 300 mm thick compacted granular pad, constructed as described in the section above, the factored ultimate and serviceability geotechnical resistances given below may be used for assessment of the facing panels.

Retaining Wall ID	Assumed With of Concrete Levelling Pad (m)	Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance for 25 mm of Settlement (kPa)
Retaining Wall No. 1	0.3	150	N/A[1]
Retaining Wall No. 2	0.3	150	N/A[1]

1. Factored serviceability geotechnical resistance is greater than the factored ultimate geotechnical resistance, and as a result, the SLS condition does not apply.

For bearing resistance at ULS under the levelling pad, CHBDC (2019) Section 6.19.9.4 requires that the load on the levelling pad shall be taken to be not less than twice the weight of the wall facing.

Assuming that the RSS walls act as a unit and use the full width of the reinforced soil mass (which has been taken as equal to 0.7 times the wall height to achieve the minimum required factor of safety for global stability), the factored ultimate and serviceability geotechnical resistances given below may be used for assessment of the reinforced mass founded on the properly prepared subgrade soils, at or below the highest founding elevations provided in Section 6.4.1.

Retaining Wall ID	Recommended Minimum Strip Length[1] (m)	Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance (kPa)	
			For 25 mm of Settlement	For 50 mm of Settlement
Retaining Wall No. 1	5.0	550	150	300
Retaining Wall No. 2	4.2	500	100	200

1. The recommended minimum strip length is 70% of the wall height, which achieves the required minimum factor of safety for global stability. Longer strip lengths may be required by the proprietary designer to address internal stability of the wall, or if the geometry is modified such that there is sloping ground above the wall.

The geotechnical resistances provided above are given for loads applied perpendicular to the subgrade surface. Where the load is not applied perpendicular to this surface, inclination of the load should be considered in accordance with Section 6.10.2 of the CHBDC (2019).

The factored ultimate and serviceability geotechnical resistances provided above are dependent on the levelling pad width / reinforced soil mass length and founding elevation and as such, the geotechnical resistances should be reviewed if the levelling pad widths / reinforced soil mass lengths varies from that specified above or if the founding elevations differ from that given in Section 6.5.1. The factored ultimate geotechnical resistances provided are based on a load applied concentrically to the centreline/centroid of the levelling pad / reinforced soil mass. Where a load is applied eccentrically from the centreline/centroid of the levelling pads / reinforced soil masses, the pressure distribution at ULS and SLS and the eccentricity limit of the levelling pads / reinforced soil masses should be taken into consideration in accordance with Section 6.10.5 of the CHDBC (2019) and its Commentary. If this option is selected, once the structural design is substantially complete, the structural engineer should verify with WSP whether the factored ultimate and serviceability geotechnical resistances provided above require revision based on any load inclination.

6.4.3 Resistance to Lateral Loads

Resistance to lateral forces / sliding between the compacted granular pad and the subgrade should be calculated in accordance with Section 6.10.4 of the *CHBDC* (2019). The coefficient of friction, $tan\ \varphi'$, for the compacted granular pad on the properly prepared subgrade may be taken as summarized below. The coefficient of friction value should be reviewed and revised, if necessary, by the proprietary RSS wall designer.

Retaining Wall ID	Subgrade Material	Coefficient of Friction, $tan\ \emptyset'$
Retaining Wall No. 1	Compacted Granular Pad (Granular 'A', or Granular 'B' Type I or II) on very dense native silty sand till	0.6
Retaining Wall No. 2	Compacted Granular Pad (Granular 'A', or Granular 'B' Type I or II) on new embankment fill (engineered fill meeting OPSS.PROV 1010 Granular 'A', Granular 'B' Type I or II, or SSM)	0.6

6.5 Concrete Cantilever Wall

A concrete cantilever wall is a conventional retaining wall comprised of a concrete footing and concrete wall face. Backfill behind the wall may be comprised of Granular 'A' or Granular 'B' Type I or II.

6.5.1 Founding Elevations

Strip footing (shallow) foundations are feasible for supporting the proposed retaining walls and should be founded on compact to very dense silty sand till at Retaining Wall No. 1 and on compacted engineered fill at Retaining Wall No. 2. All footings should be founded at a minimum depth of 1.7 m below the adjacent final grade to provide adequate protection against frost penetration, in accordance with OPSD 3090.101. The following founding elevations are recommended for strip footings:

Retaining Wall ID	Final Ground Surface in front of Wall (m)	Maximum (Highest) Founding Elevation (m)[1]	Anticipated Founding Soil
Retaining Wall No. 1	273.0 to 273.7	271.3 to 272.0	Very dense silty sand till
Retaining Wall No. 2	254.3 to 255.9	252.6 to 254.2	New embankment fill (engineered fill meeting OPSS.PROV 1010 Granular 'A', Granular 'B' Type I or II, or SSM)

Note: 1. The highest founding elevations provided are based on the finished ground elevation in front of the walls and a minimum soil cover depth of 1.7 m to protect against frost penetration.

The footing subgrade should be inspected by qualified geotechnical personnel following excavation, in accordance with OPSS 902 (*Excavating and Backfilling Structures*) to check that all existing fill and/or other unsuitable material have been removed. Where sub-excavation of fill or unsuitable materials is required, the sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates)* Granular 'A', Granular 'B' Type I or II, or SSM, placed and compacted in accordance with OPSS.PROV 501 (*Compacting*),

6.5.2 Geotechnical Resistance

Strip footings constructed on the properly prepared subgrade, at or below the design elevations given in Section 6.5.1, should be designed based on the factored ultimate geotechnical resistance and the factored serviceability geotechnical resistance (for 25 mm of settlement) given below.

Retaining Wall ID	Assumed Footing Width (m)	Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance (kPa)	
			For 25 mm of Settlement	For 50 mm of Settlement
Retaining Wall No. 1	4.5	600	225	475
Retaining Wall No. 2	4.0	600	100	200

The factored ultimate and serviceability geotechnical resistances are dependent on the footing width and founding elevation and as such, the geotechnical resistances should be reviewed if the footing width varies from that specified above or if the founding elevations differ from that given in Section 6.5.1. The factored ultimate geotechnical resistances provided are based on a load applied concentrically to the centreline/centroid of the footing, as shown on Figure 6.4 of the CHBDC (2019). Where a load is applied eccentrically from the centreline/centroid of the footing, the pressure distribution at ULS and SLS and the eccentricity limit of the footing should be taken into consideration in accordance with Section 6.10.5 of the CHDBC (2019) and its Commentary. If this option is selected, once the structural design is substantially complete, the structural engineer should verify with WSP whether the factored ultimate and serviceability geotechnical resistances provided above require revision based on any load inclination.

6.5.3 Resistance to Lateral Loads

Resistance to lateral forces / sliding between the concrete footing and the subgrade should be calculated in accordance with Section 6.10.4 of the *CHBDC* (2019). The coefficient of friction, $tan\ \emptyset'$, for a cast-in-place concrete footing on the property prepared subgrade are summarized in the table below.

Retaining Wall ID	Subgrade Material	Coefficient of Friction, $tan\ \emptyset'$
Retaining Wall No. 1	Cast-in-place concrete footing on very dense native silty sand till	0.4
Retaining Wall No. 2	Cast-in-place concrete footing on new embankment fill (engineered fill meeting OPSS.PROV 1010 Granular 'A', Granular 'B' Type I or II, or SSM)	0.5

6.6 Lateral Earth Pressures for Design

The lateral earth pressures acting on the retaining walls will depend on the type and method of placement of backfill materials, the nature of the soils behind the backfill, the magnitude of the surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the wall.

The following recommendations are made concerning the design of the walls. These design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- 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 concrete cantilever walls. Longitudinal drains or weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to subdrains and frost taper for a concrete cantilever wall should be in accordance with OPSD 3121.150 (*Walls, Retaining, Backfill, Minimum Granular Requirement*), and OPSD 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 a retaining wall constructed on shallow foundations (i.e., an unrestrained, concrete cantilever retaining wall), 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).

6.6.1 Static Lateral Earth Pressures

The following guidelines and recommendations are provided regarding the lateral earth pressures for static loading conditions. The parameters below assume level backfill and ground surface behind the retaining wall. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope in accordance with the equations provided in CHBDC Section C6.12.1, Figures C6.28 (for active earth pressure), and Section C6.12.2.2 (for at-rest earth pressure).

For an unrestrained retaining wall, in the case of the cantilever wall option, the pressures are based on the properties of the granular backfill, and the following parameters (unfactored) may be used:

Fill Type	Unit Weight of Material (kN/m^3)	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Granular 'A' and Granular 'B' Type II	22	0.43	0.27
Granular 'B' Type I	21	0.47	0.31

If the wall support allows for lateral yielding, active earth pressures may be used in the geotechnical design of the retaining wall. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.12 of the *Commentary of the CHBDC* (2019).

If the wall does not allow lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition), at-rest earth pressures (plus any compaction surcharge) should be assumed for geotechnical design.

6.7 Global Stability and Settlement

6.7.1 Parameter Selection

The parameters used in the global stability and settlement analyses are summarized in the table below and have been established based on field and laboratory test data as well as accepted correlations (Bowles, 1984 and

Kulhawy and Mayne, 1990). A groundwater level at Elevation 269 m has been used for the analysis at Retaining Wall No. 1 and a groundwater level at Elevation 242 m has been used for the analysis at Retaining Wall No 2.

Stratigraphic Unit	γ (kN/m^3)	φ' (°)	S_u (kPa)	E (kPa)
New Engineered Fill (Granular ‘A’ or Granular ‘B’ Type II)	21	35	-	-
New Embankment Fill (Select Subgrade Material)	20	32	-	30
Existing Fill (compact to dense)	20	31	-	30
Silt to sand (loose to very dense)	20	32	-	30
Silty sand till (very dense) / Sandy clayey silt-silt to sandy still till (hard / dense to very dense)	21	35	-	75

6.7.2 Global Stability Analyses

Limit equilibrium global slope stability analyses were carried out for the proposed retaining walls using the commercially available program Slide (version 9.0), developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. For the analyses, the Factors of Safety (FoS) of numerous potential failure surfaces were computed to establish the minimum FoS. The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. The FoS is equal to the inverse of the product of the consequence factor Ψ, and the geotechnical resistance factor, ϕ_{gu} (i.e., $FoS = 1/(\Psi \cdot \phi_{gu})^{FoS = \; 1/\left(\Psi \cdot \phi_{gu}\right)}$.

A target minimum FoS of 1.5 has been used for the design of the proposed retaining walls for the long-term (permanent) condition, as per Table 6.2 of *CHBDC* (2019).

The stability analyses indicate that the proposed RSS and concrete cantilever wall options at Retaining Wall No. 1 and 2 locations will have a FoS greater than 1.5 against global instability. The results of the stability analyses are shown on Figures F-1 to F-4 in Appendix F.

6.7.3 Settlement Analyses

Settlement analyses were carried out to estimate the magnitude of expected settlement under the maximum height of fill at the proposed retaining walls using the commercially available program Settle3 (Version 5.012), developed by Rocscience Inc. The results of settlement analyses are presented below.

Retaining Wall ID	Height of Retaining Wall Fill (m)	Estimated Settlement (mm)		
		Non-Cohesive Deposits	Cohesive Deposits	Total / Differential
Retaining Wall No. 1	7.1	15	0	15
Retaining Wall No. 2	6.2	30	0	30

Given that the retaining walls will be founded on non-cohesive native soils, the estimated settlement is expected to occur during construction of the retaining walls and therefore, settlement mitigation will not be required.

The above preliminary settlement estimates do not include compression of the new fill materials, which would occur during construction of the retaining walls. The magnitude of granular fill compression may range from 0.5% to 1%

of the height of the fill, assuming approximately 98% compaction of the fill is achieved relative to the material's standard Proctor maximum dry density (SPMDD). Non-granular earth fill materials are not recommended for retaining wall construction as they may exhibit some additional settlement over time depending on their gradation, plasticity, and field compaction effort.

Further, the above preliminary settlement estimates do not include settlement of the new high fill embankment on which Retaining Wall No. 2 will be constructed. The settlement estimates associated with the new high fill embankment at the location of Retaining Wall No. 2 are provided under a separate report (Foundation Investigation and Design Report, Deep Cut Areas and High Fill Embankments, Bridge Replacement and Interchange Reconfiguration at Highway 11/12 (Old Barrie Road), Orillia). Construction Considerations

6.7.4 Open-Cut Excavations

At the location of Retaining Wall No. 1, excavations for the granular pad / reinforced soil mass or concrete footing are anticipated to extend through the topsoil, existing asphalt and fill and into native silty sand till. Any organics, fill and any other deleterious materials encountered within the footprint of the proposed granular pad / reinforced soil mass or concrete footing should be sub-excavated and replaced with OPSS.PROV 1010 *(Aggregates)* Granular 'A', Granular 'B' Type I, Granular 'B' Type II or SSM.

At the location of Retaining Wall No. 2, excavations for the granular pad / reinforced soil mass or concrete footing are anticipated to extend through new embankment fill (engineered fill anticipated to consist of material meeting OPSS.PROV 1010 (*Aggregates*) Granular 'A', Granular 'B' Type I or II, or SSM). However, prior to placement of the new embankment fill, the existing topsoil, fill and any deleterious materials encountered within the footprint of the new embankment should be sub-excavated and replaced with OPSS.PROV 1010 *(Aggregates)* Granular 'A', Granular 'B' Type I, Granular 'B' Type II or SSM).

All 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 soils to be excavated are above the groundwater level and can be classified according to OHSA as Type 3 soils. Temporary excavations (i.e., those open for a relatively short time period) should be made with side slopes of 1H:1V or flatter.

Temporary excavations should be observed and reviewed during construction to confirm that the soil and groundwater conditions are as anticipated. If unexpected conditions are encountered, a qualified geotechnical engineer should review the excavation plan considering the conditions at that time.

6.7.5 Temporary Protection Systems

It is understood that temporary protection systems will be required for the staged construction for retaining wall construction to facilitate construction staging. The temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection System), as amended by SP 105S09. The lateral movement should meet Performance Level 2 provided that any existing adjacent utilities can tolerate this magnitude of deformation.

The selection and design of the protection system will be the responsibility of the contractor. Driven, interlocking sheet pile systems are considered feasible at this site, although the sheet type would need to accommodate very dense portions of the existing till at the location of Retaining Wall No. 1, as well as rock fragments / cobbles and boulders likely to be encountered within the till deposit. Alternatively, a soldier pile and lagging system may be implemented. Although groundwater is not anticipated above the bottom of the proposed excavations, if this type of system is used it would be necessary to control groundwater seepage or include measures to mitigate loss of soil particles through the lagging boards. The sheet piles or soldier piles would have to be driven to sufficient depth to provide the necessary passive resistance for the retained soil height, including any surcharge loads behind the protection system within at least a 1H:1V zone relative to the base of the excavation. Lateral support to the sheet piles or soldier piles could be provided in the form of rakers or temporary anchors.

Consideration could be given to either partial or full removal of the protection system upon completion of construction or each stage of construction (as required). Where possible, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work at the retaining wall locations. If the temporary protection system is left in place, it should be cut off at or below frost depth, not less than 1.7 m below the pavement surface.

6.7.6 Engineered and Granular Fill

The existing site soils that do not contain topsoil or organics or any other deleterious materials can generally be reused on site as engineered fill. Soils from within the project limits to be reused as engineered fill must satisfy the gradation of OPSS.PROV 1010 (*Aggregates*) Select Subgrade Material (SSM). Based on the measured natural water contents, the existing site soils are generally at or above their estimated optimum water contents for compaction and therefore soil “wetting” will likely not be required; however, some drying may be necessary to achieve the required compaction levels. Alternatively, imported materials meeting the required of OPSS.PROV 1010 (*Aggregates*) Granular ‘B’ Type I or SSM may be used for engineered fill for embankment widening behind the backfill zone, or as a replacement material where very loose to loose, soft or other deleterious soils are sub-excavated at subgrade level.

Following proof-rolling and approval of the subgrade, the engineered fill should be placed in accordance with OPSS.PROV 501 (*Compacting*) and compacted to 98% of the material’s Standard Proctor maximum dry density. Where sub-excavation is required below the retaining wall footing or reinforced soil mass, it is recommended that the engineered fill extend at least 1 m beyond the edges of the footings.

The final surface of the engineered fill should be protected as necessary from construction traffic and should be sloped to provide positive drainage for surface water during the construction period.

6.7.7 Groundwater and Surface Water Control

The groundwater levels in the vicinity of Retaining Wall No. 1 and 2 are anticipated to be about Elevation 269 m and 242 m. As such, excavations for the retaining wall construction are not anticipated to extend below the groundwater level.

Surface water should be directed away from the excavations at all times.

6.7.8 Obstructions

The Design-Build Contractor should be alerted to the potential presence of cobble and boulder obstructions within the existing fill and native soils as noted on the borehole records. The potential presence of cobble and boulder obstructions has been inferred based on the presence of rock fragments within the collected soil samples and several instances of auger grinding and split-spoon refusal. Further, glacially derived till deposits, such as those encountered at this site, should be expected to contain coarse gravel, cobbles and/or boulders. Note that the extent and depth of the cobble and boulder obstructions may vary beyond and between the borehole locations.

The presence of obstructions (i.e., cobbles and/or boulders) may affect excavation operations for Retaining Wall No. 1. The Design-Build Contractor must be prepared with suitable equipment and procedures to remove/penetrate through any obstructions that may be encountered during construction.

6.7.9 Analytical Testing of Construction Materials

The summary results of analytical tests carried out on two samples of the silt to sand deposit are presented in Section 4.3 and on the Certificate of Analysis in Appendix E.

The analytical test results for sulphate were compared to CSA A23.1 Table 3 (*Additional requirements for concrete subjected to sulphate attack*) to assess the potential severity of sulphate attack on concrete during its service life. The sulphate concentrations measured on the soil sample is less than 0.2%, which is below the Moderate degree of exposure (i.e., below the Class S3 exposure limits), and the degree of sulphate attack is considered “Negligible” according to Table 7.2 in MTO’s Gravity Pipe Design Guidelines (2014). Therefore, based on the soil sample tested, when the designer is selecting the exposure class for the concrete structure, the effects of sulphates from within the site soils in contact with any portion of the proposed structure constructed below the ground surface may not need to be considered.

The analytical test results of the soil sample for resistivity were also compared to Table 3.2 of MTO’s Gravity Pipe Design Guidelines (2014), to assess the relative level of corrosion potential on buried steel in contact with soil. The measured resistivity values of 12,000 ohm-cm and 15,000 ohm-cm indicate the soil corrosiveness is less than “Very low” (10,000 ohm-cm > R >6,000 ohm-cm). Given that the proposed structure will be exposed to de-icing salt/chemicals, consideration should be given by the designer to designing the concrete structure for a “C” type exposure class as defined by CSA A23.1 Table 1.

It is also noted that the measured pH levels were about 8.0, suggesting the presence of alkaline soils.

Ultimately, it is the structural designer’s decision to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 (Durability Requirements) are satisfied.

7.0 CLOSURE

The Foundation Design Report was prepared by Ms. Anastasia Poliacik, P.Eng., a Senior Geotechnical Engineer with WSP and MTO Foundations Designated Contact. Mr. David Staseff, P.Eng., a Senior Principal and MTO Principal Foundations Contact with WSP conducted an independent technical and quality review of this report.

Signature Page

WSP Canada Inc.

Anastasia Poliacik, P.Eng.
Senior Geotechnical Engineer

David Staseff, P.Eng.
Senior Principal, MTO Foundations Designated Contact

AMP/DS/al

https://wsponline.sharepoint.com/sites/gld-120052/project files/6 deliverables/2. reporting/04 - retaining wall/7. final_rev1/19135676-r-rev1_rw hwy 11 obr fidr_20mar2024.docx

REFERENCES

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

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.

Ministry of Transportation, Ontario. 2014. *Gravity Pipe Design Guidelines*.

Ontario Provisional Standard Drawings (OPSD)

OPSD 3090.101 Foundation Frost Penetration Depths for Southern Ontario

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection System
OPSS 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1010	Construction Specifications for Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material

Special Provisions

SP 760F01 Amendment to OPSS 760

Ontario Water Resources Act

Ontario Regulation 903 Wells (as amended)

Table 1 - Comparison of Retaining Wall Type and Foundation Options

Foundation Option	Feasibility	Advantages	Disadvantages	Relative Costs	Risks / Consequences
Shallow Foundations - Retained Soil System (RSS) Wall	Feasible and is the preferred foundation option if a retaining wall solution is selected for Retaining Wall No. 1 and 2.	• Conventional excavation and construction techniques, particularly at Retaining Wall No. 2 where the wall and reinforced soil mass could be constructed concurrently with the placement of new embankment fill for the new W-N Ramp (at Retaining Wall No. 2). • Shallower excavation as compared with concrete retaining wall option at Retaining Wall No. 1. • Aesthetically appealing panels are available. • Tolerant of differential settlement. • Ease of construction with elimination of formwork, steel rebar placement, and curing of cast-in-place concrete. • Quicker to construct than cast-in-place concrete wall.	• Coordination required to address any obstructions through front face of wall or reinforced backfill (splaying or skewing reinforcement straps).	• Lowest cost	• Temporary protection systems required at Retaining Wall No. 1.
Shallow Foundations – Concrete Cantilever Wall	Feasible	• Conventional excavation and construction techniques, particularly at Retaining Wall No.2 where the wall could be constructed prior to construction of the new W-N Ramp embankment.	• Deeper excavations required to found the footings below frost depth. • Less tolerant to settlement. • Requires formwork, steel rebar placement, and curing of cast-in-place concrete.	• Third highest cost	• Temporary protection systems required at Retaining Wall No. 1.
Deep Foundations – Driven Piles	Feasible, but not required and less advantageous compared to shallow foundation options	• Provides higher geotechnical resistances than shallow foundation options, although this is not required for these retaining walls, particularly given that the shallow soils provide adequate bearing resistance for footings.	• Requires more significant working pad for construction compared to shallow foundation options.	• Second highest cost	• Risk of piles getting “hung-up” within the till deposits.
Deep Foundations - Secant pile wall	Feasible, but not required and less advantageous compared to shallow foundation options, particularly given that “top-down” construction is not needed at this site	• Provides higher geotechnical resistances than shallow foundation options, although this is not required for these retaining walls, particularly given that the shallow soils provide adequate bearing resistance for footings.	• Requires more significant working pad for construction compared to shallow foundation options. • Temporary liners would be required to advance drilled shafts, due to water-bearing non-cohesive soils; appropriate methods would be required to minimize potential for disturbance of soils at base of caisson or soldier pile holes	• Highest cost	• Risk of cobble and boulder obstructions within the till deposits. • Risk of disturbance of soils during installation of drilled shafts, requiring temporary liners and tremie concrete techniques

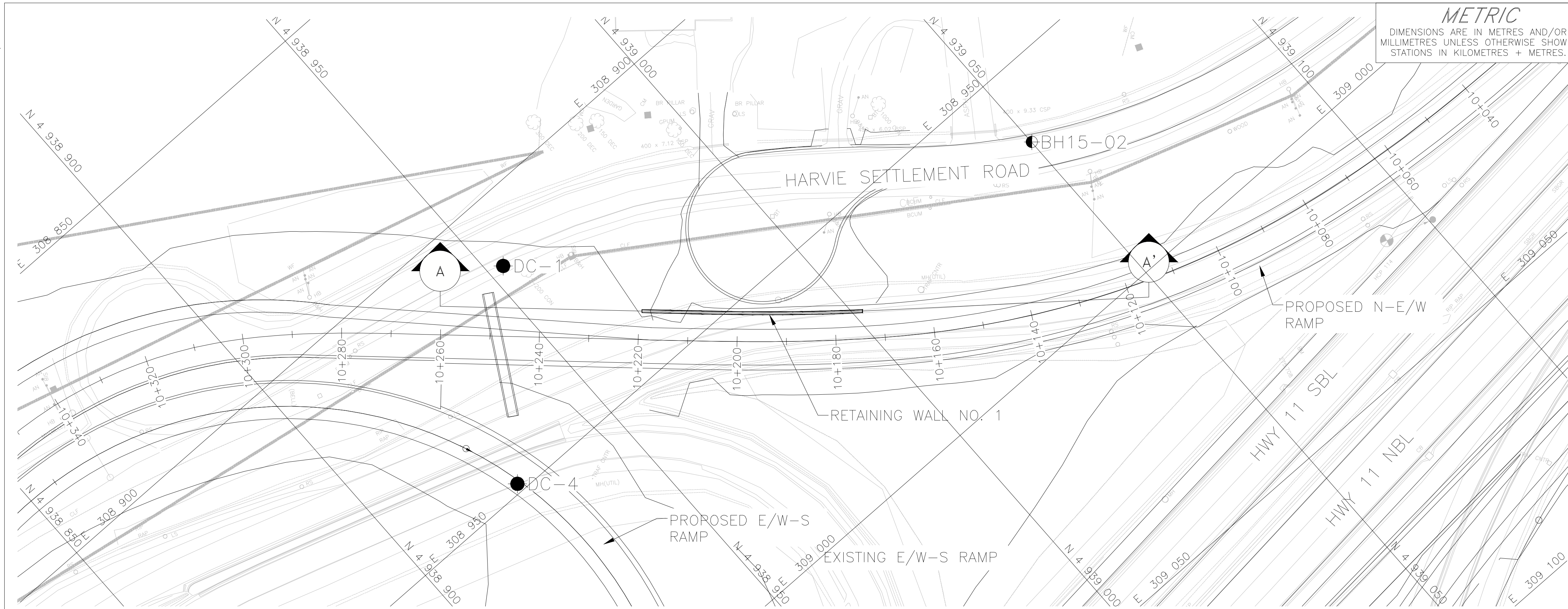
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2129-18-00

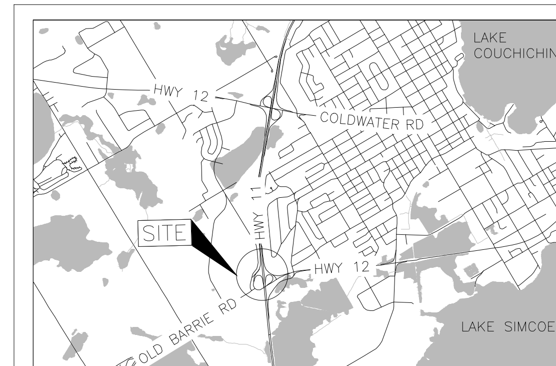
SHEET

HWY 11/12 (OLD BARRIE ROAD)
RETAINING WALL 1
BOREHOLE LOCATION PLAN AND SOIL STRATA

wsp



PLAN
SCALE
10 0 10 20 m

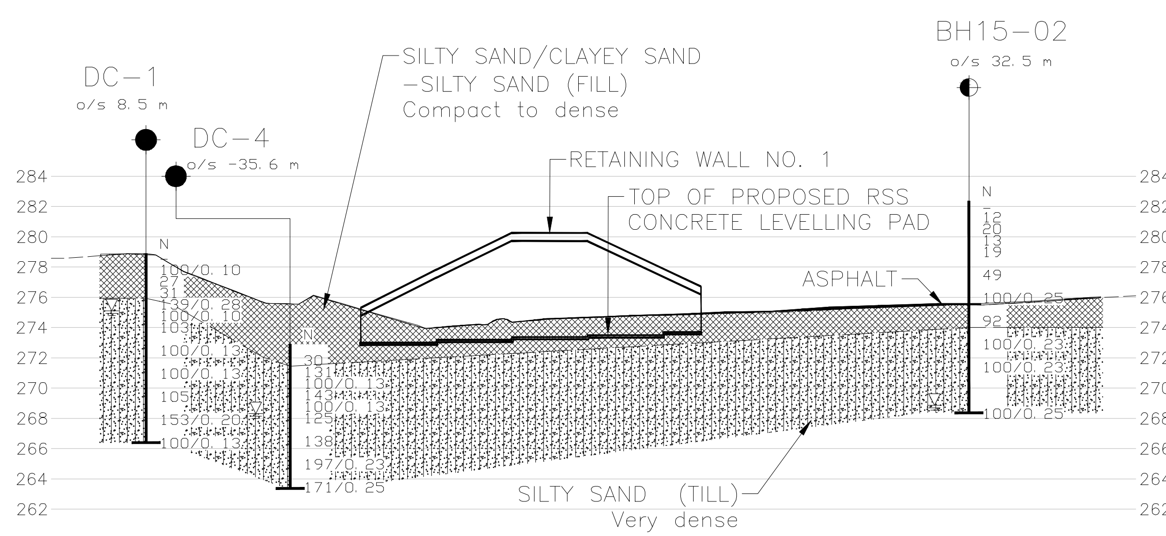


KEY PLAN
SCALE
1 0 1 2 km

LEGEND

●	Borehole – Current Investigation
◐	Borehole – Previous Investigation (GEOCRES 31D-647)
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
BH15-02	282.4	4939050.1	308964.9
DC-1	278.9	4938953.2	308913.3
DC-4	272.9	4938926.2	308948.3



PROFILE – RETAINING WALL 1
VERTICAL SCALE
5 0 5 10 m
HORIZONTAL SCALE
10 0 10 20 m

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.

REFERENCE

Retaining wall profile provided in digital format by Egis, drawing file no. 197147-00A_BR02_P01RWL.dwg, received March 6, 2023.
Horizontal alignments provided in provided in digital format by McIntosh Perry, drawing file no. 2494-15_c2_Hwy 12 _ ali-Interim .xml, received December 7, 2023.
Retaining wall plan provided in digital format by McIntosh Perry, drawing file no. 197147-00A_BR02_P01RWL.dwg, received December 7, 2023.
Design provided in digital format by McIntosh Perry, drawing file no. 197147-c2_hwy011_dph-ncp.dwg, received August 23, 2023.
Base plans provided in digital format by McIntosh Perry, drawing file nos. x_197147_BASE.dwg, received May 19, 2021.

LICENSED PROFESSIONAL ENGINEER A. POLIACIK 100158821 Mar. 19, 2024 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER D. STASEFF Mar. 19, 2024 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31D11-002

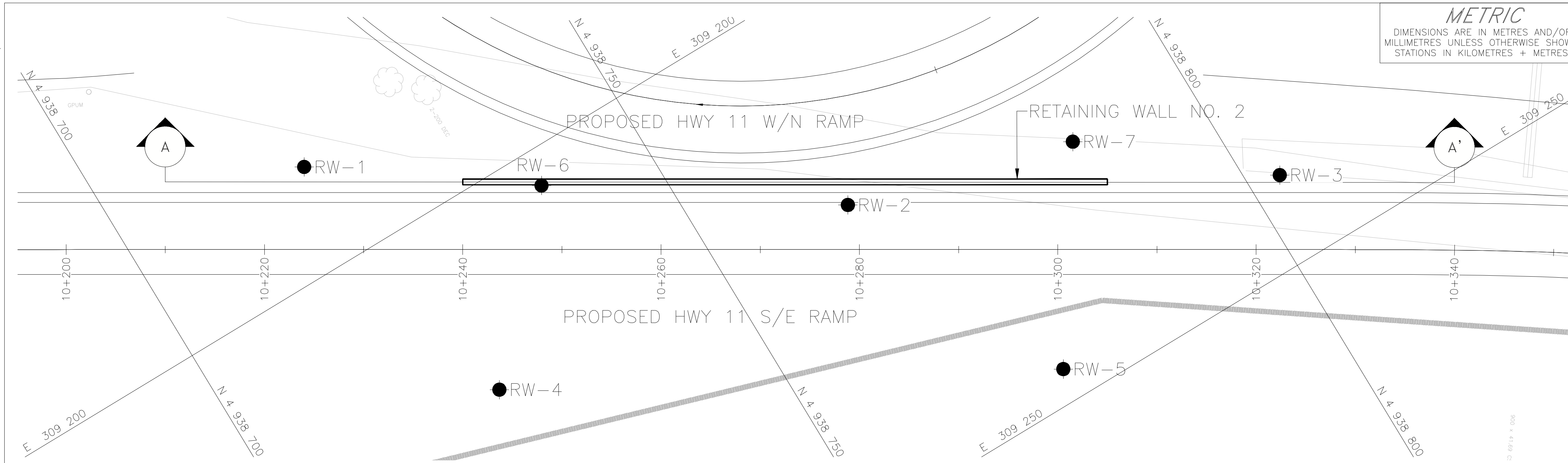
HWY. 11 AND 12		PROJECT NO. 19135676	DIST.
SUBM'D. MH	CHKD. MH	DATE: 03/19/2024	SITE: 30-076
DRAWN: DD/SA	CHKD. AMP	APPD. DS	DWG. 1

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

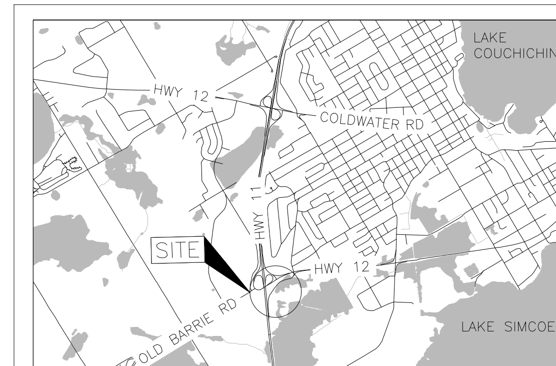
CONT No.
GWP No. 2129-18-00

SHEET

HWY 11/12 (OLD BARRIE ROAD)
RETAINING WALL 2
BOREHOLE LOCATION PLAN AND SOIL STRATA



PLAN
SCALE
5 0 5 10 m



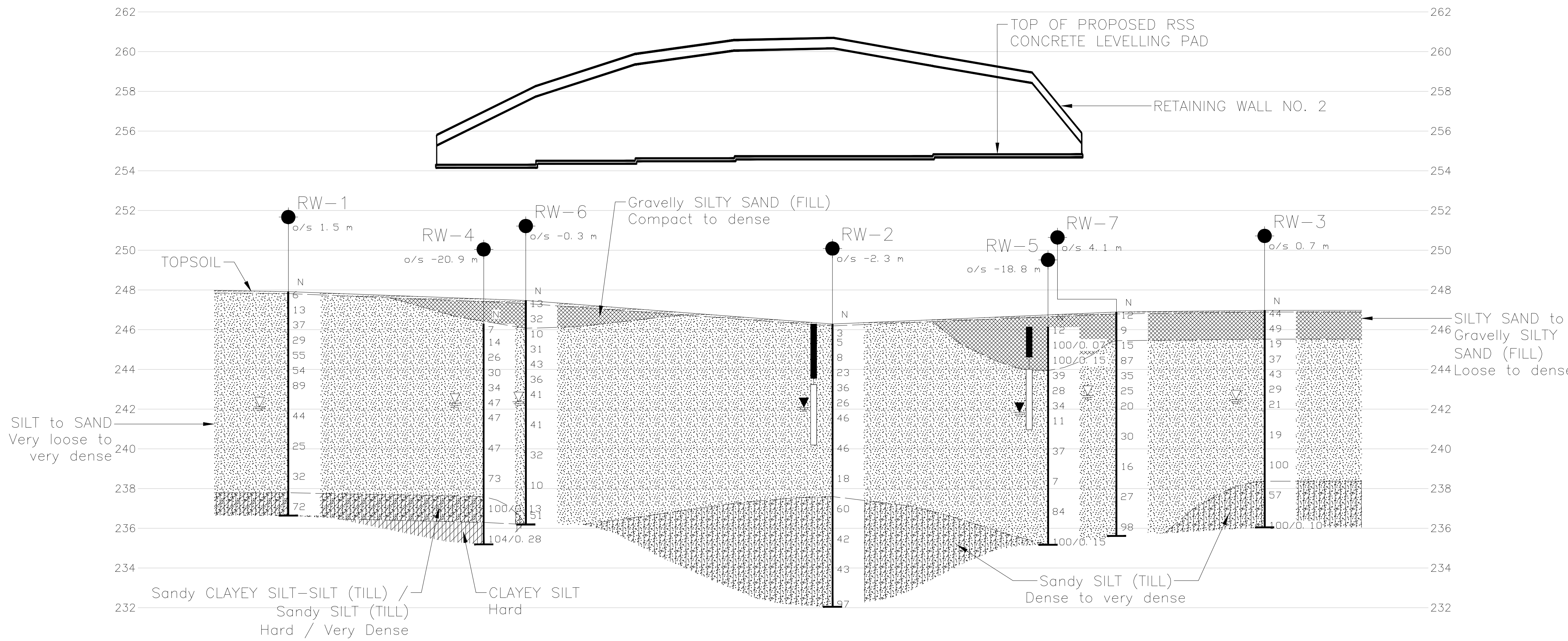
KEY PLAN
SCALE
1 0 1 2 km

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
RW-1	247.9	4938719.5	309189.6
RW-2	246.3	4938764.4	309221.3
RW-3	247.0	4938803.2	309241.3
RW-4	246.3	4938724.7	309219.0
RW-5	246.2	4938774.4	309246.7
RW-6	247.5	4938739.0	309203.6
RW-7	246.9	4938787.1	309227.6



PROFILE – RETAINING WALL 2
VERTICAL SCALE
2.5 0 2.5 5 m
HORIZONTAL SCALE
5 0 5 10 m

NOTES

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A. POLIACIK
100158821
Mar. 19, 2024
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
D. STASEFF
Mar. 19, 2024
PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31D11-002

HWY. 11 AND 12	PROJECT NO. 19135676		DIST.
SUBM'D. MH	CHKD. MH	DATE: 03/19/2024	SITE: 30-076
DRAWN: DD/SA	CHKD. AMP	APPD. DS	DWG. 2

PLOT DATE: March 19, 2024
FILENAME: S:\Clients\MTO\Hwy_11&12_Old_Barrie_Rd_to_Coldwater_Rd\99_PROJ\19135676_MPV40_PROD\0004_Retaining_Walls\19135676-0004-BG-0002.dwg

APPENDIX A

Record of Borehole Sheets – Retaining Wall No. 1

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[1,2]

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

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^2 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[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
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_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

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

COARSE-GRAINED SOILS

Compactness[1]

Term	SPT 'N' (blows/0.3m)[2]
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 grainsize. 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'[1,2] (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

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$ - u)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

* Density symbol is ρ. Unit weight symbol is γ. 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
$C_{\alpha(e)}$	secondary compression index
C_α	rate of secondary compression
$C_{\alpha(\varepsilon)}$	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
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
c′	effective cohesion
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c_u, s_u	undrained shear strength (ϕ = 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. $\tau = c' + \sigma' \tan \phi'$
2. shear strength = (compressive strength)/2

wsp

Foundation Design

RECORD OF BOREHOLE No DC-1

SHEET 1 OF 1 — **METRIC**

PROJECT 19135676
G.W.P. 2129-18-00
LOCATION N 4938953.2; E 308913.3 MTM NAD 83 ZONE 10 (LAT. 44.590583; LONG. -79.448198)
ORIGINATED BY ML
DIST Central HWY 11/12
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
COMPILED BY AM
DATUM Geodetic
DATE January 26, 2022
CHECKED BY MH

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
278.9	GROUND SURFACE					
0.0 / 0.1	ASPHALT (60 mm)					
	SILTY SAND (SM), some gravel, trace clay, containing rock fragments (FILL) Dense Brown Moist	1	AS	-		19 64 13 4
		2	SS	100/0.10		
277.6 / 1.3	CLAYEY SAND-SILTY SAND (SC-SM), some gravel, containing rock fragments (FILL) Compact to dense Brown Moist	3	SS	27		
		4	SS	31		16 35 39 10
275.9 / 3.0	SILTY SAND (SM), some gravel, trace clay (TILL) Very dense Brown to grey Moist	5	SS	139/0.28		
		6	SS	100/0.10	▽ (Elev. 275.1)	
	- Augers grinding from 4.6 m to 9.1 m depth	7	SS	103		
		8	SS	100/0.13		
	- Rock fragments between 7.6 m and 11.0 m depth (Elev. 271.3 m and 267.9 m)	9	SS	100/0.13		10 47 33 10
		10	SS	105		
		11	SS	153/0.20		
266.4 / 12.5		12	SS	100/0.13		
	END OF BOREHOLE					

NOTE:

1. Water level measured in open borehole at a depth of 3.8 m below ground surface (Elev. 275.1 m) upon completion of drilling on January 26, 2022.

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (278–267); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

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

GTA-MTO 001 S:\CLIENTS\MTO\HWY_11&12_OLD_BARRIE_RD_TO_COLDWATER_RD\02_DATA\GINT\HWY_11&12_OLD_BARRIE_RD_TO_COLDWATER_RD.GPJ GAL-GTA.GDT 12/11/23

Foundation Design

RECORD OF BOREHOLE No DC-4

SHEET 1 OF 1 — **METRIC**

PROJECT 19135676
G.W.P. 2129-18-00
DIST Central HWY 11/12
DATUM Geodetic
LOCATION N 4938926.2; E 308948.3 MTM NAD 83 ZONE 10 (LAT. 44.590341; LONG. -79.447757)
BOREHOLE TYPE 108 mm ID Hollow Stem Augers
DATE November 25, 2021
ORIGINATED BY ML
COMPILED BY AM
CHECKED BY MH

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
272.9	GROUND SURFACE											
0.0	ASPHALT (90 mm)											
0.1	SILTY SAND (SM), some gravel (FILL) Compact Brown Moist	1	SS	30		272						
271.5 1.5	SILTY SAND (SM), trace to some gravel, some clay (TILL) Very dense Brown Moist	2	SS	131		271			8	48	30	14
		3	SS	100/0.13								
		4	SS	143		270		NP	7	55	27	11
		5	SS	100/0.13		269						
		6	SS	125	∇	268						
		7	SS	138		267 / 266						
		8	SS	97/0.23		265			11	50	27	12
		9	SS	71/0.25		264						
263.4 9.5	END OF BOREHOLE											

NOTE:

1. Water level measured at a depth of 4.6 m below ground surface (Elev. 268.3 m) on November 29, 2022 (i.e. 4 days after completion of drilling).

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10, 20, 30; REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

GTA-MTO 001 S:\CLIENTS\MTO\HWY_11&12_OLD_BARRIE_RD_TO_COLDWATER_RD\02_DATA\GINT\HWY_11&12_OLD_BARRIE_RD_TO_COLDWATER_RD.GPJ GAL-GTA.GDT 12/11/23

Golder Associates

RECORD OF BOREHOLE No BH15-02

 METRIC

PROJECT 13-1111-0026

W.P. 11-20002 | LOCATION N 4939050.1; E 308964.9 | ORIGINATED BY DM

DIST CENTRAL HWY 12 | BOREHOLE TYPE 200 mm Diameter Hollow Stem Augers | COMPILED BY NL

DATUM GEODETIC | DATE September 29, 2015 | CHECKED BY JMAC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
282.4	GROUND SURFACE						
0.0	ASPHALT (150 mm)						
0.2	Gravelly sand, trace silt, trace cobbles (FILL) Brown Moist	1	CS	-	282		
281.8 0.6	Silt and sand, trace to some gravel, trace to some clay (FILL) Compact Brown Moist	2	SS	12	281		
	Trace organics noted in Sample 2.	3	SS	20		plotted	19 44 32 5
280.3 2.1	SILT and SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Brown to grey Moist	4	SS	13	280		
		5	SS	19	279	plotted	
		6	SS	49	278, 277		
		7	SS	100/0.25	276	plotted	12 46 32 10
		8	SS	92	275, 274		
		9	SS	100/0.23	273	plotted	
		10	SS	100/0.23	272, 271		

Column headings also include: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No BH15-02

 METRIC

PROJECT 13-1111-0026
W.P. 11-20002
LOCATION N 4939050.1; E 308964.9
ORIGINATED BY DM
DIST CENTRAL HWY 12
BOREHOLE TYPE 200 mm Diameter Hollow Stem Augers
COMPILED BY NL
DATUM GEODETIC
DATE September 29, 2015
CHECKED BY JMAC

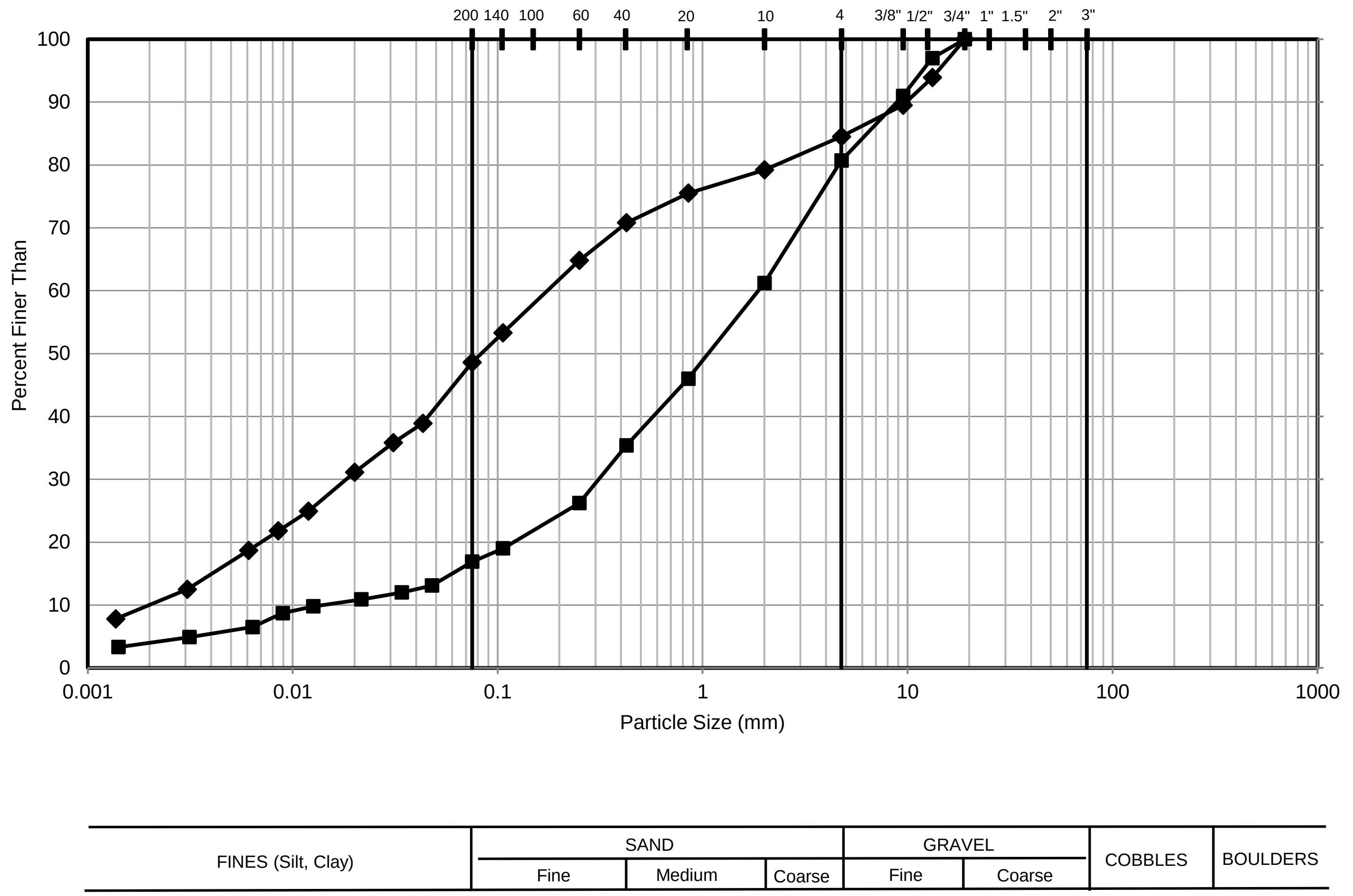
ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED) 20 40 60 80 100	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SILT and SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Brown to grey Moist						270				
						∇	269				
268.4			11	SS	100/0.25				○		
14.0	END OF BOREHOLE Note: 1. Water level inside augers at a depth of 13.5 m below ground surface (Elev. 268.9 m) upon completion of drilling.										

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

APPENDIX B

Geotechnical Laboratory Test Results – Retaining Wall No. 1

GRAIN SIZE DISTRIBUTION



Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-1	1	0.0 - 0.6	278.9 to 278.3
◆	DC-1	4	2.3 - 2.9	276.6 to 276.0

CLIENT

MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONATRIO (MTO)

PROJECT

HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT

wsp

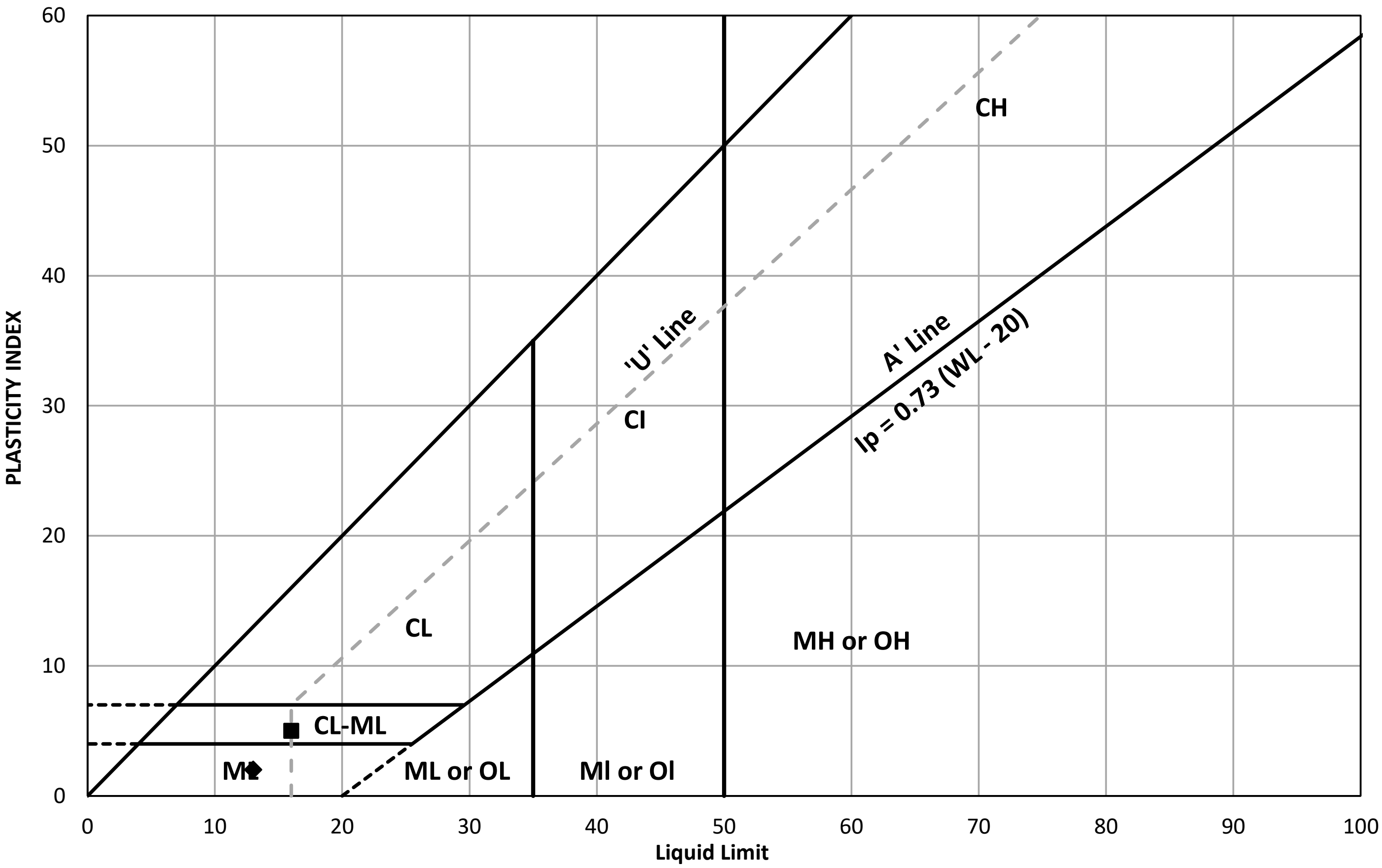
YYYY-MM-DD	2023-12-14
DESIGNED	TB
PREPARED	TB
REVIEWED	AMP
APPROVED	DS

TITLE

GRAIN SIZE DISTRIBUTION
SILTY SAND (SM) / CLAYEY SAND-SILTY SAND (SC-SM) (FILL)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	0	B-1

PLASTICITY CHART



	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index
■	DC-1	4	273.21 to 272.60	8.1	16	11	5	-0.58
◆	DC-4	1	272.14 to 271.53	5.9	13	11	2	-2.55

CLIENT
MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONATRIO (MTO)

PROJECT
HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT

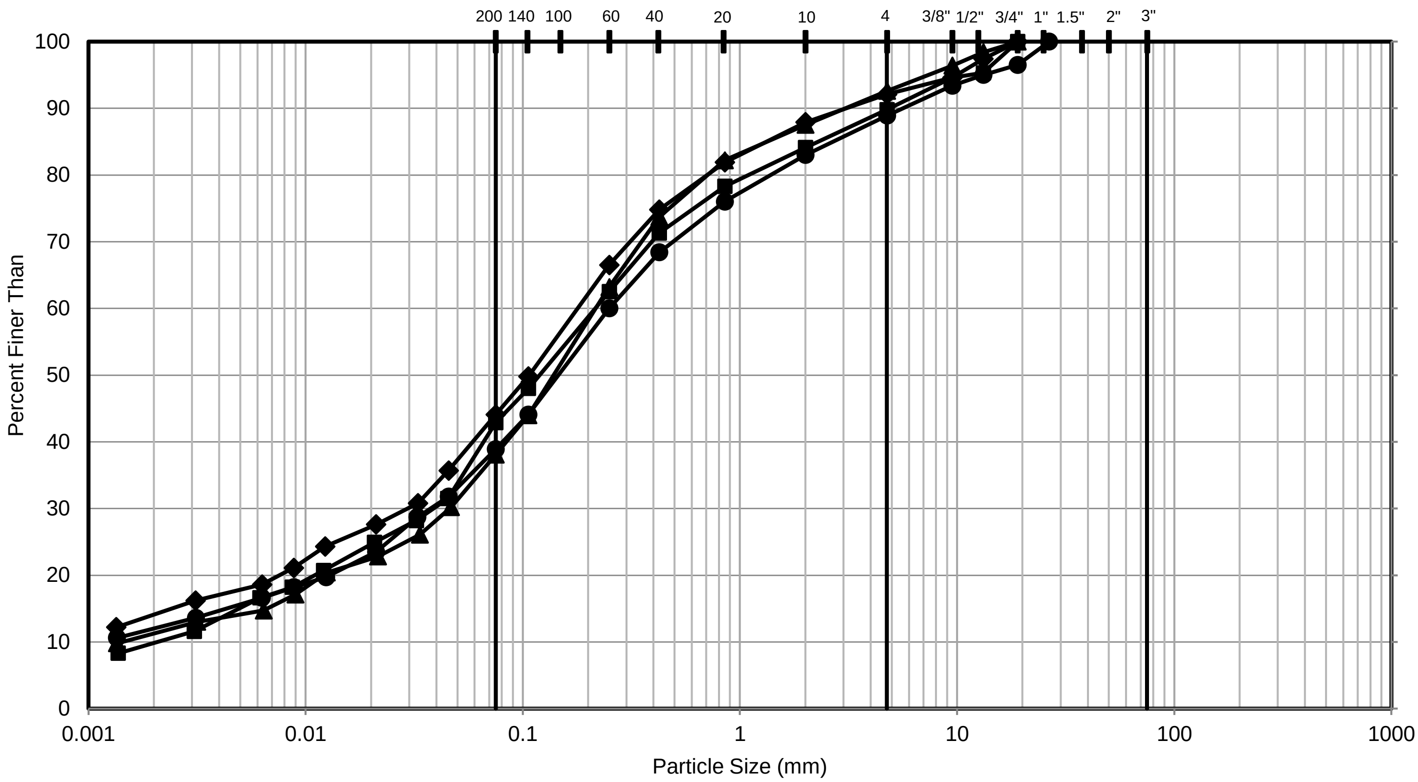
wsp

YYYY-MM-DD	2023-12-14
DESIGNED	TB
PREPARED	TB
REVIEWED	AMP
APPROVED	DS

TITLE
PLASTICITY CHART
SILTY SAND (SM) / CLAYEY SAND-SILTY SAND (SC-SM) (FILL)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	0	B-2

GRAIN SIZE DISTRIBUTION



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

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-1	9	7.6 - 7.9	271.3 to 271.0
◆	DC-4	2	1.5 - 2.1	271.4 to 270.8
▲	DC-4	4	3.1 - 3.7	269.9 to 269.2
●	DC-4	8	7.6 - 8.0	265.3 to 264.9

CLIENT

MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONATRIO (MTO)

PROJECT

HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	TB
PREPARED	TB
REVIEWED	AMP
APPROVED	DS

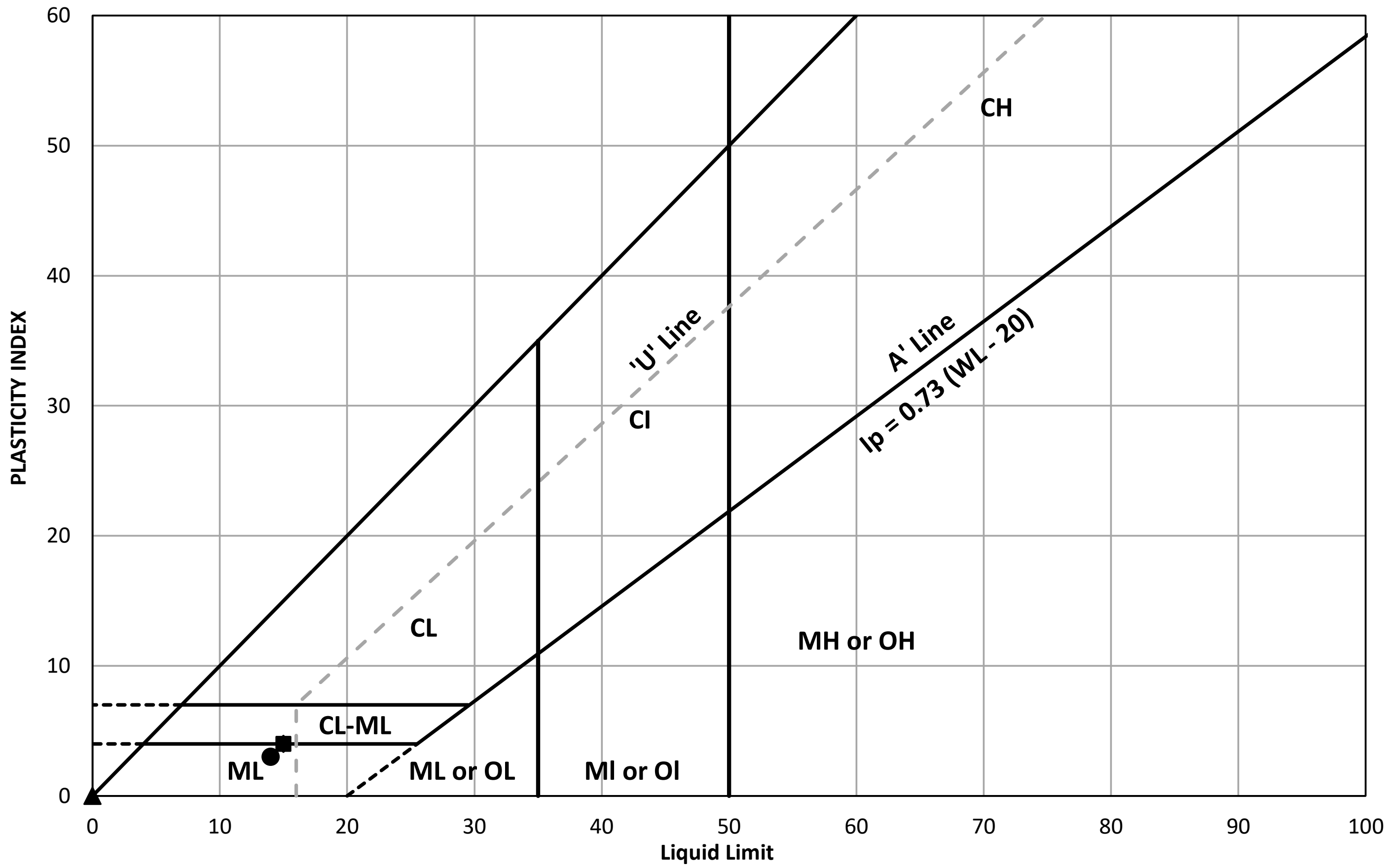
TITLE

GRAIN SIZE DISTRIBUTION
SILTY SAND (TILL)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	0	B-3

PATH: https://golderassociates.sharepoint.com/sites/120052/Project Files/6 Deliverables/2. Reporting/04 - Retaining Wall/1. PreDraft/Appendix B - Geotechnical Testing RW1 | FILE NAME: GSD Figures.xlsm

PLASTICITY CHART



	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index
■	DC-1	7	274.33 to 274.02	3.8	15	11	4	-1.80
◆	DC-1	9	271.28 to 271.00	5.2	15	11	4	-1.45
▲	DC-4	4	269.85 to 269.24	5.5	0	NP	0	
●	DC-4	8	265.28 to 264.90	8	14	11	3	-1.00

CLIENT
MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONATRIO (MTO)

PROJECT
HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	TB
PREPARED	TB
REVIEWED	AMP
APPROVED	DS

TITLE
PLASTICITY CHART
SILTY SAND (SM) (TILL)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	0	B-4

APPENDIX C

Records of Borehole Sheets - Retaining Wall No. 2

Foundation Design

RECORD OF BOREHOLE No RW-1

SHEET 1 OF 1

METRIC

PROJECT 19135676

G.W.P. 2129-18-00

LOCATION N 4938719.5; E 309189.6 MTM NAD 83 ZONE 10 (LAT. 44.588478; LONG. -79.444720)

ORIGINATED BY MTI

DIST Central HWY 11/12

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

COMPILED BY AN

DATUM Geodetic

DATE April 18, 2022

CHECKED BY AMP

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
247.9	GROUND SURFACE				
0.0	TOPSOIL (100 mm)				
0.1	SILT (ML) and sand, trace clay, contains rootlets to about 0.7 m depth Loose to dense Brown Moist	1	SS	6	
		2	SS	13	0 39 60 1
		3	SS	37	
245.3 2.6	SILTY SAND (SM), trace gravel, trace clay Compact to very dense Brown Moist to wet - Wet below 5.8 m depth (Elev. 242.1 m) - Rock fragments at about 6.1 m (Elev. 241.8 m) depth	4A 4B	SS	29	
		5	SS	55	
		6	SS	54	
		7	SS	89	1 66 29 4
		8	SS	44	
		9	SS	25	
238.4 9.5	Sandy SILT (ML), trace clay Dense Brown Moist	10A 10B	SS	32	
237.8 10.1	Sandy CLAYEY SILT-SILT (CL-ML), some gravel (TILL) Hard Brown Moist	11	SS	72	12 25 51 12
236.6 11.3	END OF BOREHOLE				

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (247, 246, 245, 244, 243, 242, 241, 240, 239, 238, 237); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

NOTES:

1. Water level encountered at a depth of 5.8 m below ground surface (Elev. 242.1 m) during drilling

2. Borehole caved to a depth of 5.5 m below ground surface (Elev. 242.4 m) upon completion of drilling.

3. Water level measured at a depth of 4.6 m below ground surface (Elev. 243.3 m) upon completion of drilling (i.e., after caving).

+ 3, × 3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

GTA-MTO 001 S:\CLIENTS\MTO\HWY_11&12_OLD_BARRIE_RD_TO_COLDWATER_RD\02_DATA\GINT\HWY_11&12_OLD_BARRIE_RD_TO_COLDWATER_RD.GPJ GAL-GTA.GDT 12/21/23

RECORD OF BOREHOLE No RW-2

SHEET 1 OF 2 **METRIC**

PROJECT 19135676
G.W.P. 2129-18-00
DIST Central HWY 11/12
DATUM Geodetic

LOCATION N 4938764.4; E 309221.3 MTM NAD 83 ZONE 10 (LAT. 44.588882; LONG. -79.444320)
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
DATE April 20, 2022

ORIGINATED BY MTI
COMPILED BY AN
CHECKED BY AMP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT w (%)	UNIT WEIGHT kN/m³	GR	SA	SI	CL
246.3	GROUND SURFACE										
0.0	TOPSOIL (100 mm)	1A									
0.1	Sandy SILT (ML), trace clay, contains rootlets to about 0.7 m depth Very loose to compact Brown to grey Moist	1B	SS	3	246						
		2	SS	5	245						
		3	SS	8		~26		0	35	59	6
		4	SS	23	244	~11					
243.3 3.0	SILTY SAND (SM) to SAND (SP-SM), trace silt, trace clay Compact to dense Brown to grey Moist to wet - Wet below 3.6 m depth (Elev. 242.7 m).	5	SS	36	243						
		6	SS	26	242	~18		0	90	9	1
241.4 4.9	Sandy SILT (ML), trace clay Compact to dense Grey Wet	7A 7B	SS	46	241						
		8	SS	46	240	~22					
		9	SS	18	239, 238	~20					
237.6 8.7	Sandy SILT (ML), some gravel, trace clay (TILL) Dense to very dense Grey Moist	10	SS	60	237	~12 (H)		12	26	56	6
	- Heave inside augers at 10.7 m depth (Elev. 235.6 m).	11	SS	42	236, 235	~11					
	- Augers grinding below 12.2 m depth (Elev. 234.1 m). - 200 mm gravel seam at about 12.2 m depth	12	SS	43	234	~13	NP	11	35	52	2
		13A 13B 13C 13D	SS	97	233						
232.1 14.2	-125 mm sand and gravel seam at about 14.0 m depth - Split spoon refusal (i.e., spoon bouncing at 14.2 m depth).										

Groundwater conditions: water level symbol shown at approx. Elev. 242.7 m.

Continued Next Page

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

RECORD OF BOREHOLE No RW-2 SHEET 2 OF 2 **METRIC**

PROJECT 19135676
G.W.P. 2129-18-00
LOCATION N 4938764.4; E 309221.3 MTM NAD 83 ZONE 10 (LAT. 44.588882; LONG. -79.444320)
ORIGINATED BY MTI
DIST Central HWY 11/12
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE April 20, 2022
CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE (SPLIT-SPOON REFUSAL)										

NOTES:

1. Water level encountered at a depth of 3.6 m below ground surface (Elev. 242.7 m) during drilling.

2. Borehole caved to a depth of 5.5 m below ground surface (Elev. 240.8 m) upon completion of drilling.

3. Water level in standpipe piezometer measured at a depth of 3.2 m below ground surface (Elev. 243.1 m) upon completion of installation.

4. Water level measurement in standpipe piezometer:

Date	Depth (m)	Elev. (m)
13-May-22	4.2	242.1

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

wsp

Foundation Design

RECORD OF BOREHOLE No RW-3

SHEET 1 OF 1 **METRIC**

PROJECT 19135676
G.W.P. 2129-18-00
DIST Central HWY 11/12
DATUM Geodetic

LOCATION N 4938803.2; E 309241.3 MTM NAD 83 ZONE 10 (LAT. 44.589231; LONG. -79.444068)
BOREHOLE TYPE 57 mm I.D. Hollow Stem Augers
DATE April 26 to 27, 2022

ORIGINATED BY MTI
COMPILED BY AN
CHECKED BY AMP

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
247.0	GROUND SURFACE
246.9 / 0.1	TOPSOIL (80 mm)
	SILTY SAND (SM) and gravel, trace clay (FILL) Dense Brown Moist
245.6 / 1.5	- Auger grinding above 1.5 m depth (Elev. 245.6 m) SILTY SAND (SM) to SAND (SP), trace clay Compact to dense Brown Moist to wet - Wet below 4.5 m depth (Elev. 242.5 m)
241.4 / 5.6	Sandy SILT (ML), trace gravel, trace clay Compact to very dense Grey Wet
238.4 / 8.6	Sandy SILT (ML), trace gravel, trace clay (TILL) Very dense Grey Moist
236.1 / 10.9	END OF BOREHOLE (SPLIT-SPOON REFUSAL)

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
1A / 1B	SS	44					
2	SS	49		39	49	11	1
3	SS	19		0	64	35	1
4	SS	37					
5	SS	43					
6	SS	29					
7	SS	21					
8	SS	19					
9	SS	100		2	34	61	3
10	SS	57	NP	9	21	65	5
11	SS	100/0.10					

GROUND WATER CONDITIONS: ∇ (at approx. Elev. 242.5)

ELEVATION SCALE: 246, 245, 244, 243, 242, 241, 240, 239, 238, 237

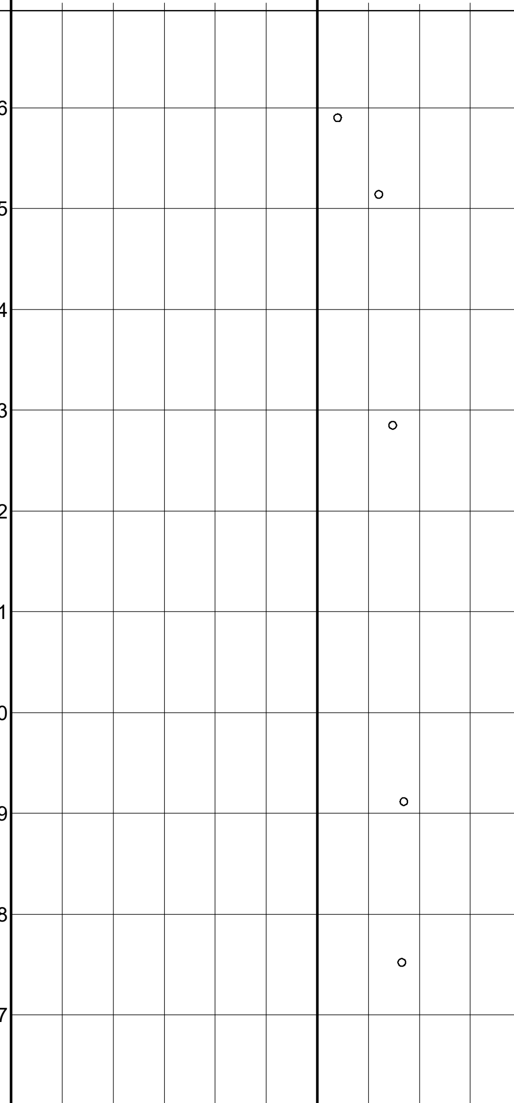
DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT W_L

WATER CONTENT (%) 10 20 30

REMARKS & GRAIN SIZE DISTRIBUTION (%)



NOTES:

1. Water level encountered at a depth of 4.5 m below ground surface (Elev. 242.5 m) during drilling.

2. Borehole was dry upon completion of drilling.

3. Borehole caved to a depth 4.6 m below ground surface (Elev. 242.4 m) upon completion of drilling.

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

Foundation Design

RECORD OF BOREHOLE No RW-4

SHEET 1 OF 1 **METRIC**

PROJECT 19135676
G.W.P. 2129-18-00
LOCATION N 4938724.7; E 309219.0 MTM NAD 83 ZONE 10 (LAT. 44.588525; LONG. -79.444349)
ORIGINATED BY MTI
DIST Central HWY 11/12
BOREHOLE TYPE 57 mm I.D. Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE April 19 and 20, 2022
CHECKED BY AMP

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
246.3	GROUND SURFACE
0.0	TOPSOIL (130 mm)
0.1	SILTY SAND (SM) to SAND (SP-SM), trace gravel, trace clay Loose to dense Brown to grey Moist to wet - Auger grinding above 2.6 m depth (Elev. 243.7 m) - Wet below 4.1 m depth (Elev. 242.2 m)
240.7 5.6	Sandy SILT (ML), trace clay Dense to very dense Grey Moist
237.6 8.7	Sandy SILT (ML), trace gravel, trace clay (TILL) Very dense Grey Moist - Augers grinding below 9.6 m depth (Elev. 236.7 m)
236.3 10.0	CLAYEY SILT (CL) Hard Grey Moist
235.2 11.1	END OF BOREHOLE (SPLIT- SPOON REFUSAL)

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT kN/m³	GR	SA	SI	CL
1	SS	7					
2	SS	14					
3	SS	26		4	86	9	1
4	SS	30					
5	SS	34					
6	SS	47					
7	SS	47		0	58	40	2
8	SS	47	NP	0	27	71	2
9	SS	73					
10	SS	100/0.13					
11	SS	104/0.28		0	0	75	25

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (246, 245, 244, 243, 242, 241, 240, 239, 238, 237, 236); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (20, 40, 60, 80, 100) — O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

NOTES:

1. Water level encountered at a depth of 4.1 m below ground surface (Elev. 242.2 m) during drilling.

2. Borehole caved to a depth 4.6 m below ground surface (Elev. 241.7 m) upon completion of drilling.

3. Water measured in open borehole at a depth of 4.0 m below ground surface (Elev. 242.3 m) upon completion of drilling (i.e., after caving).

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

Foundation Design

RECORD OF BOREHOLE No RW-5

SHEET 1 OF 2 **METRIC**

PROJECT 19135676
G.W.P. 2129-18-00
LOCATION N 4938774.4; E 309246.7 MTM NAD 83 ZONE 10 (LAT. 44.588972; LONG. -79.444000)
ORIGINATED BY MTI
DIST Central HWY 11/12
BOREHOLE TYPE 108 mm and 57 mm I.D. Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE April 25 and 26, 2022
CHECKED BY AMP

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
246.2	GROUND SURFACE									
0.0	TOPSOIL (130 mm)	1A	SS	12	246					
0.1	Gravelly SILTY SAND (SM), trace clay, containing rock fragments and cobbles (FILL) Compact to very dense Brown to grey Moist	1B								
		2	SS	100/0.0	245					
	- Auger grinding/refusal at 1.5 m depth (Elev. 244.7m). Switched to 57 mm I.D. Hollow stem augers (See Note 1)	3	SS	100/0.15		o	30	49	19	2
244.0 2.2	SILTY SAND (SM) to SAND (SP-SM), trace silt, trace clay, trace gravel Loose to very dense Brown to grey Moist to wet	4	SS	39	244					
		5	SS	28	243	o	2	85	12	1
	- Grey and wet below 3.8 m depth (Elev. 242.4 m).	6	SS	34	242					
		7	SS	11	241	o	0	68	31	1
		8	SS	37	240					
		9A / 9B	SS	7	239 / 238					
		10	SS	84	237	o	6	59	30	5
236.1 10.1	SILT (ML), trace sand, trace clay Very dense Grey Wet				236					
235.2 11.0		11	SS	100/0.15		H	0	3	90	7

Groundwater level symbol (▼) shown at approx. Elev. 242.

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

Foundation Design

RECORD OF BOREHOLE No RW-5

SHEET 2 OF 2 **METRIC**

PROJECT 19135676
G.W.P. 2129-18-00
LOCATION N 4938774.4; E 309246.7 MTM NAD 83 ZONE 10 (LAT. 44.588972; LONG. -79.444000)
ORIGINATED BY MTI
DIST Central HWY 11/12
BOREHOLE TYPE 108 mm and 57 mm I.D. Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE April 25 and 26, 2022
CHECKED BY AMP

SOIL PROFILE: ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED) 20 40 60 80 100	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE (SPLIT- SPOON REFUSAL) NOTES: 1. Frequent auger grinding and difficult drilling was encountered above 2.2m depth (Elev. 244.0 m) due to the presence of cobbles within the fill. Numerous attempts were made to advance through the fill using 108 mm I.D. Hollow Stem Augers within the vicinity of the borehole. Ultimately, the auger teeth were destroyed and the borehole was switched to 57 mm I.D. Hollow Stem Augers and was able to advance through the fill. 2. Water level encountered at a depth of 3.8 m below ground surface (Elev. 242.4 m) during drilling. 3. Borehole caved to a depth of 3.4 m below ground surface (Elev. 242.8 m) upon completion of drilling. 4. Water level in standpipe piezometer measured at a depth of 4.0 m below ground surface (Elev. 242.2 m) upon completion of installation. 5. Groundwater measurement in the standpipe piezometer: Date Depth (m) Elev. (m) 13-May-22 4.3 241.9										

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

RECORD OF BOREHOLE No RW-6

SHEET 1 OF 1 — **METRIC**

PROJECT	19135676	LOCATION	N 4938739.0; E 309203.6 MTM NAD 83 ZONE 10 (LAT. 44.588654; LONG. -79.444544)
G.W.P.	2129-18-00	ORIGINATED BY	MTI
DIST	Central	HWY	11/12
BOREHOLE TYPE	57 mm I.D. Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	April 19, 2022
CHECKED BY	AMP		

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
247.5	GROUND SURFACE
0.0	TOPSOIL (150 mm)
0.2	Gravelly SILTY SAND (SM), trace clay, containing rock fragments (FILL) Compact to dense Brown Moist
246.1 / 1.4	SILT (ML) some sand, trace clay Compact to dense Brown to grey Moist
243.8 / 3.7	SILTY SAND (SM) to SAND (SP), trace gravel, trace clay Dense Brown Moist to wet - Auger grinding up to about 4.6 m depth (Elev. 242.9 m). - Wet below 5.1 m depth (Elev. 242.4 m).
239.5 / 8.0	Sandy SILT (ML), trace gravel, trace clay Compact to very dense Grey Wet
236.2 / 11.3	END OF BOREHOLE

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ (kN/m³)	GR	SA	SI	CL
1A / 1B	SS	13					
2	SS	32					
3	SS	10	NP	0	18	79	3
4	SS	31					
5	SS	43					
6	SS	36		0	75	24	1
7	SS	41					
8	SS	41		1	89	9	1
9A / 9B	SS	32					
10	SS	10					
11	SS	51	NP	1	20	76	3

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (247 to 237); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

NOTES:

1. Water level encountered at 5.1 m below ground surface (Elev. 242.4 m) during drilling.

2. Borehole caved to a depth 4.9 m (Elev. 242.6 m) upon completion of drilling.

3. Water measured in open borehole at a depth of 4.0 m below ground surface (Elev. 243.5 m) upon completion of drilling (i.e., after caving).

$+^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

wsp

Foundation Design

RECORD OF BOREHOLE No RW-7

SHEET 1 OF 1 **METRIC**

PROJECT 19135676			
G.W.P. 2129-18-00	LOCATION N 4938787.1; E 309227.6 MTM NAD 83 ZONE 10 (LAT. 44.589086; LONG. -79.444240)	ORIGINATED BY MTI
DIST Central HWY 11/12	BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers	COMPILED BY AN
DATUM Geodetic	DATE April 25, 2022	CHECKED BY AMP

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
246.9	GROUND SURFACE
246.8 / 0.1	TOPSOIL (100 mm)
	Gravelly SILTY SAND (SM), trace clay, containing rock fragments (FILL) Loose to compact Brown Moist
245.5 / 1.5	SAND (SP-SM), trace clay, trace silt Compact to dense Brown to grey Moist to wet - Wet below 4.2 m depth (Elev. 242.7 m) - Auger grinding above about 4.5 m depth (Elev. 242.4 m)
240.6 / 6.3	SILT (ML) and sand, trace gravel, trace clay Compact to very dense Grey Wet
235.6 / 11.3	END OF BOREHOLE

NOTES:

1. Water level encountered at a depth 4.2 m below ground surface (Elev. 242.7 m) during drilling.

2. Borehole dry upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1A / 1B	SS	12				
2	SS	9	35	40	23	2
3	SS	15	0	94	6	0
4	SS	87				
5	SS	35				
6	SS	25	0	89	10	1
7	SS	20				
8A / 8B	SS	30				
9	SS	16	5	42	51	2
10	SS	27	1	38	58	3
11A / 11B	SS	98				

GROUND WATER CONDITIONS: ∇ (at Elev. approx. 242.7, sample 6)

ELEVATION SCALE: 246, 245, 244, 243, 242, 241, 240, 239, 238, 237, 236

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

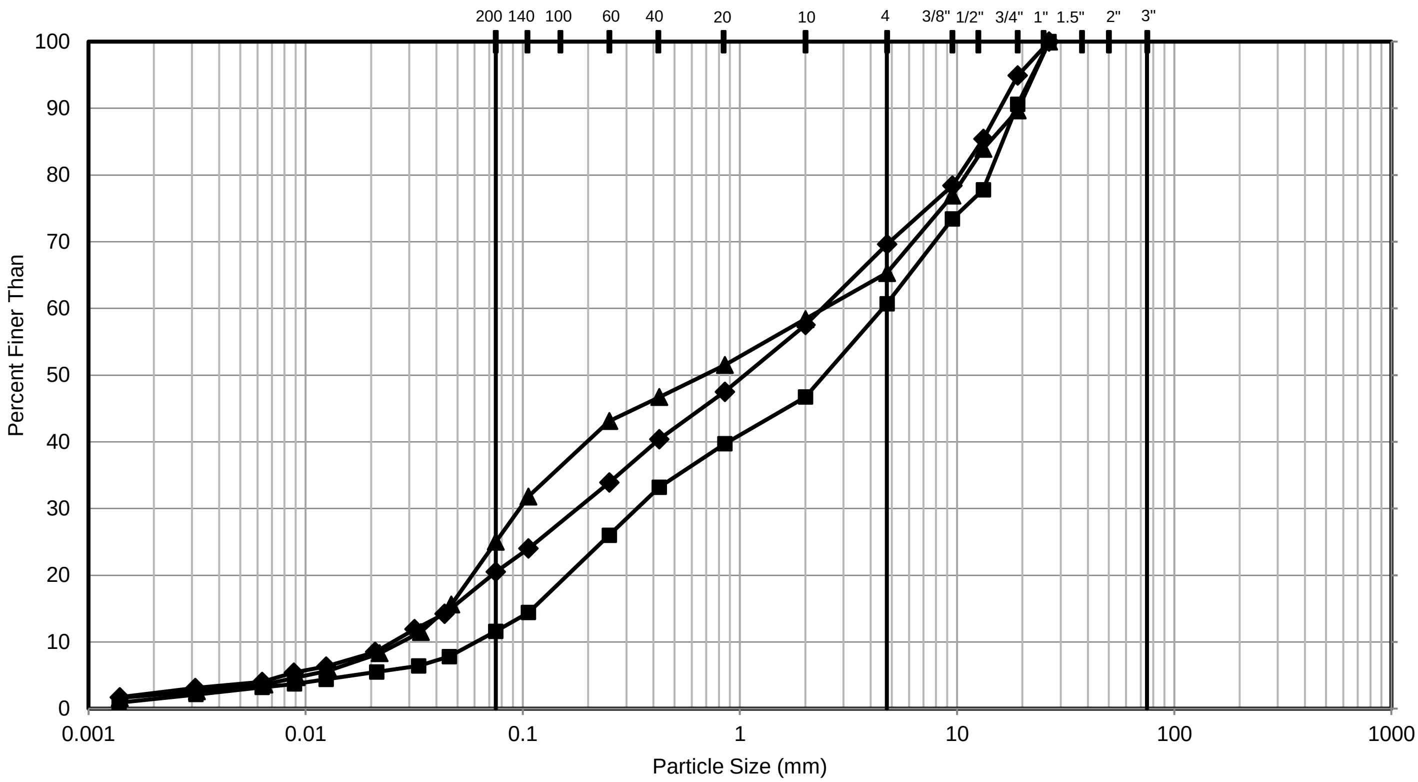
+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GTA-MTO 001 S:\CLIENTS\MTO\HWY_11&12_OLD_BARRIE_RD_TO_COLDWATER_RD\02_DATA\GINT\HWY_11&12_OLD_BARRIE_RD_TO_COLDWATER_RD.GPJ GAL-GTA.GDT 12/21/23

APPENDIX D

Geotechnical Laboratory Test Results - Retaining Wall No. 2

GRAIN SIZE DISTRIBUTION



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

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	RW-3	2	0.8 - 1.4	246.2 to 245.6
◆	RW-5	3	1.5 - 1.6	244.7 to 244.6
▲	RW-7	2	0.8 - 1.4	246.2 - 245.6

CLIENT

MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONATRIO (MTO)

PROJECT

HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT

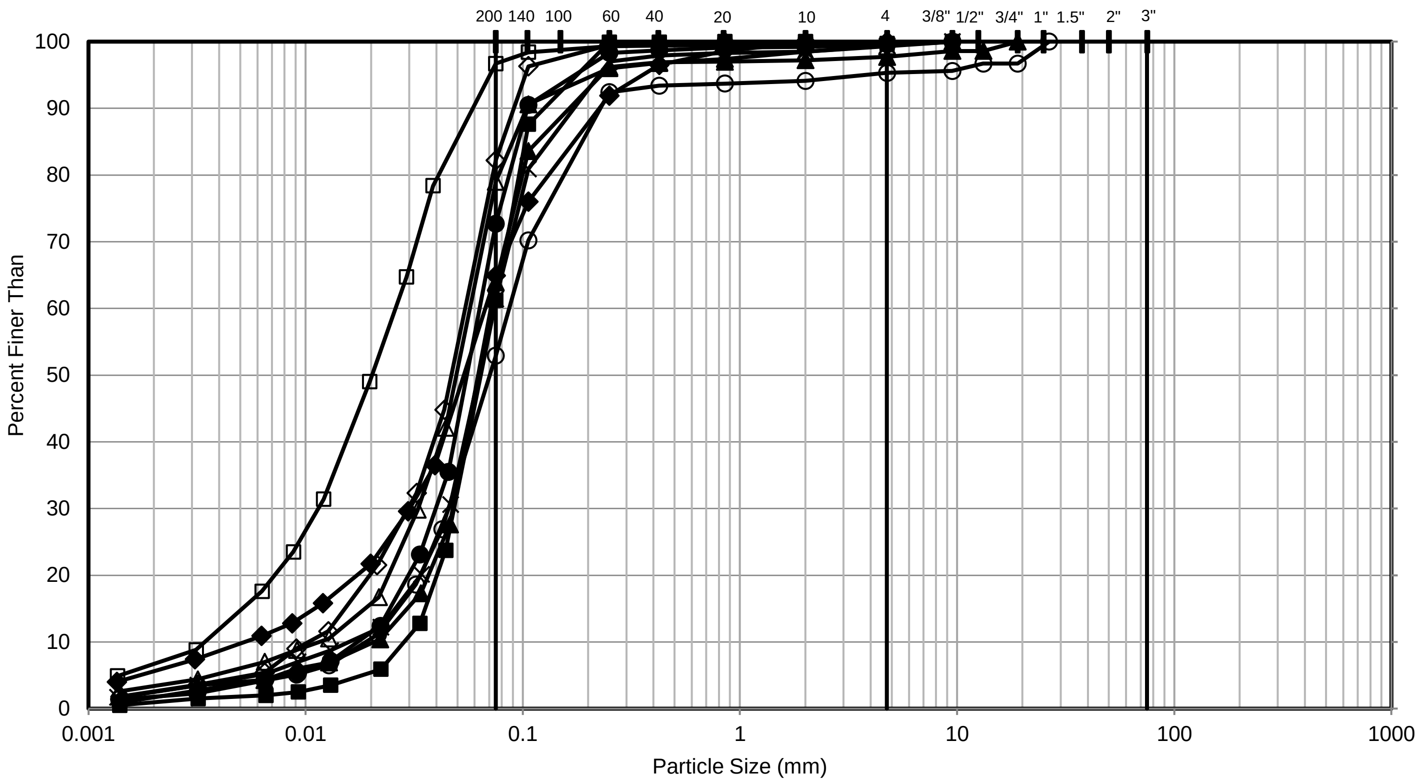
YYYY-MM-DD	2023-11-20
DESIGNED	NM
PREPARED	NM
REVIEWED	AMP
APPROVED	LCC

TITLE

GRAIN SIZE DISTRIBUTION
Gravelly SILTY SAND (SM) to SILTY SAND (SM) and gravel (FILL)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	A	D-1

GRAIN SIZE DISTRIBUTION



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

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	RW-1	2	0.8 - 1.4	247.2 to 246.5
◆	RW-2	3	1.5 - 2.1	244.8 to 244.2
▲	RW-3	9	7.6 - 8.2	239.4 to 238.7
●	RW-4	8	6.1 - 6.7	240.2 to 239.6
□	RW-5	11	10.7 - 11.3	236.8 to 236.2
◇	RW-6	3	1.5 - 2.1	245.4 to 244.8
△	RW-6	11	10.7 - 11.3	236.2 to 235.6
○	RW-7	9	7.6 - 8.2	239.3 to 238.7
×	RW-7	10	9.1 - 9.8	237.8 to 237.1

CLIENT

MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONATRIO (MTO)

PROJECT

HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT

wsp

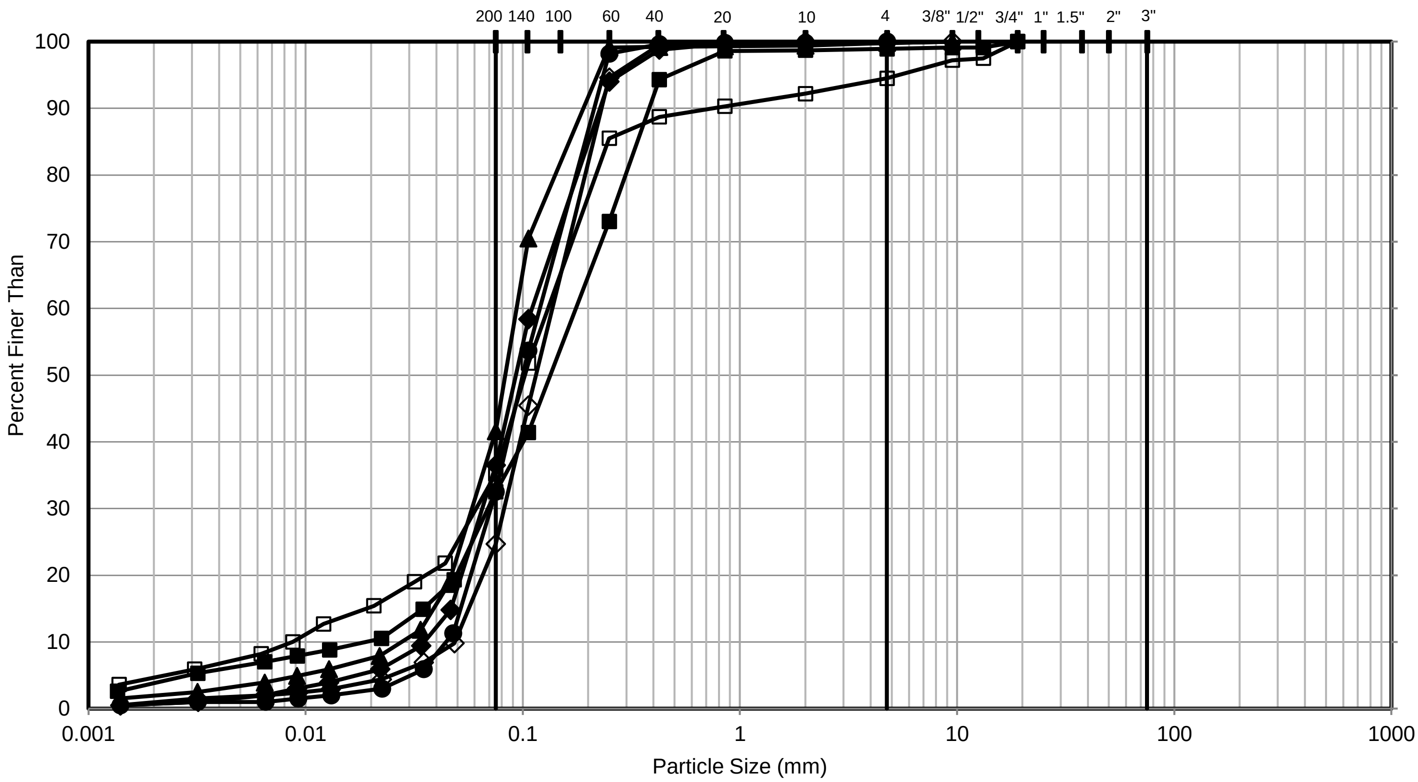
YYYY-MM-DD	2023-11-20
DESIGNED	NM
PREPARED	NM
REVIEWED	AMP
APPROVED	LCC

TITLE

GRAIN SIZE DISTRIBUTION
SILT (ML) to SILT (ML) and sand

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	A	D-2A

GRAIN SIZE DISTRIBUTION



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

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	RW-1	7	4.6 - 5.2	243.3 to 242.7
◆	RW-3	3	1.5 - 2.1	245.5 to 244.8
▲	RW-4	7	4.6 - 5.2	241.7 to 241.1
●	RW-5	7	4.5 - 5.2	243.0 to 242.3
□	RW-5	10	9.1 - 9.8	238.3 to 237.7
◇	RW-6	6	3.8 - 4.4	243.1 to 242.5

CLIENT

MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONATRIO (MTO)

PROJECT

HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT

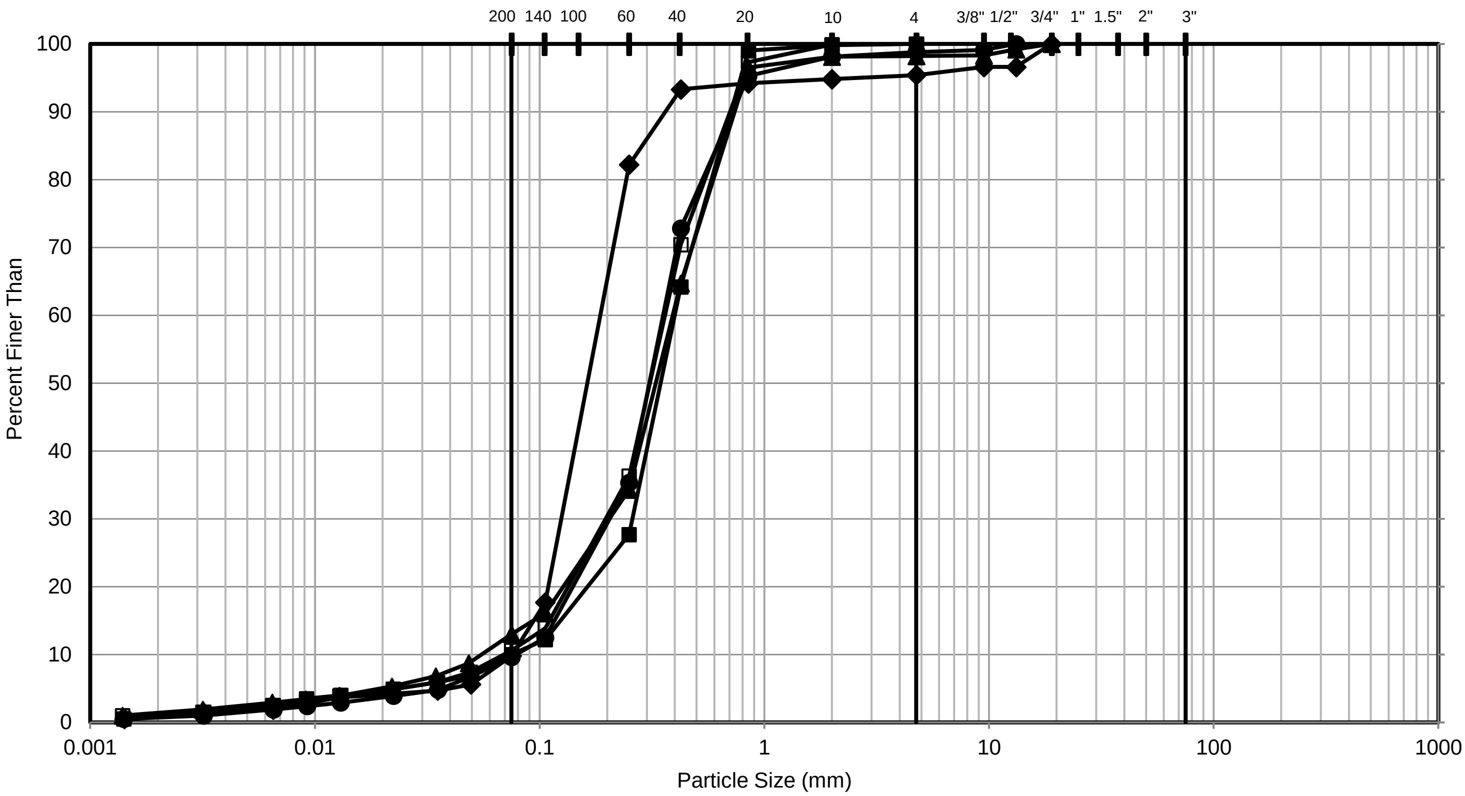
YYYY-MM-DD	2023-11-20
DESIGNED	NM
PREPARED	NM
REVIEWED	AMP
APPROVED	LCC

TITLE

GRAIN SIZE DISTRIBUTION
SILTY SAND (SM)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	A	D-2B

GRAIN SIZE DISTRIBUTION



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

Symbol	Location ID	Sample Number	Depth (m)	Elevation (m)
■	RW-2	6	3.8 - 4.4	242.5 to 241.9
◆	RW-4	3	1.5 - 2.1	244.8 to 244.2
▲	RW-5	5	3.1 - 3.7	244.4 to 243.8
●	RW-6	8	6.1 - 6.7	240.8 to 240.2
□	RW-7	6	3.8 - 4.4	243.1 to 242.5

CLIENT

MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONTARIO (MTO)

PROJECT

RETAINING WALL
BRIDGE REPLACEMENT AND INTERCHANGE RECONFIGURATIONS AT HIGHWAY 11/12 (COLDWATER ROAD) AND HIGHWAY 11/12 (OLD BARRIE ROAD)

CONSULTANT

wsp

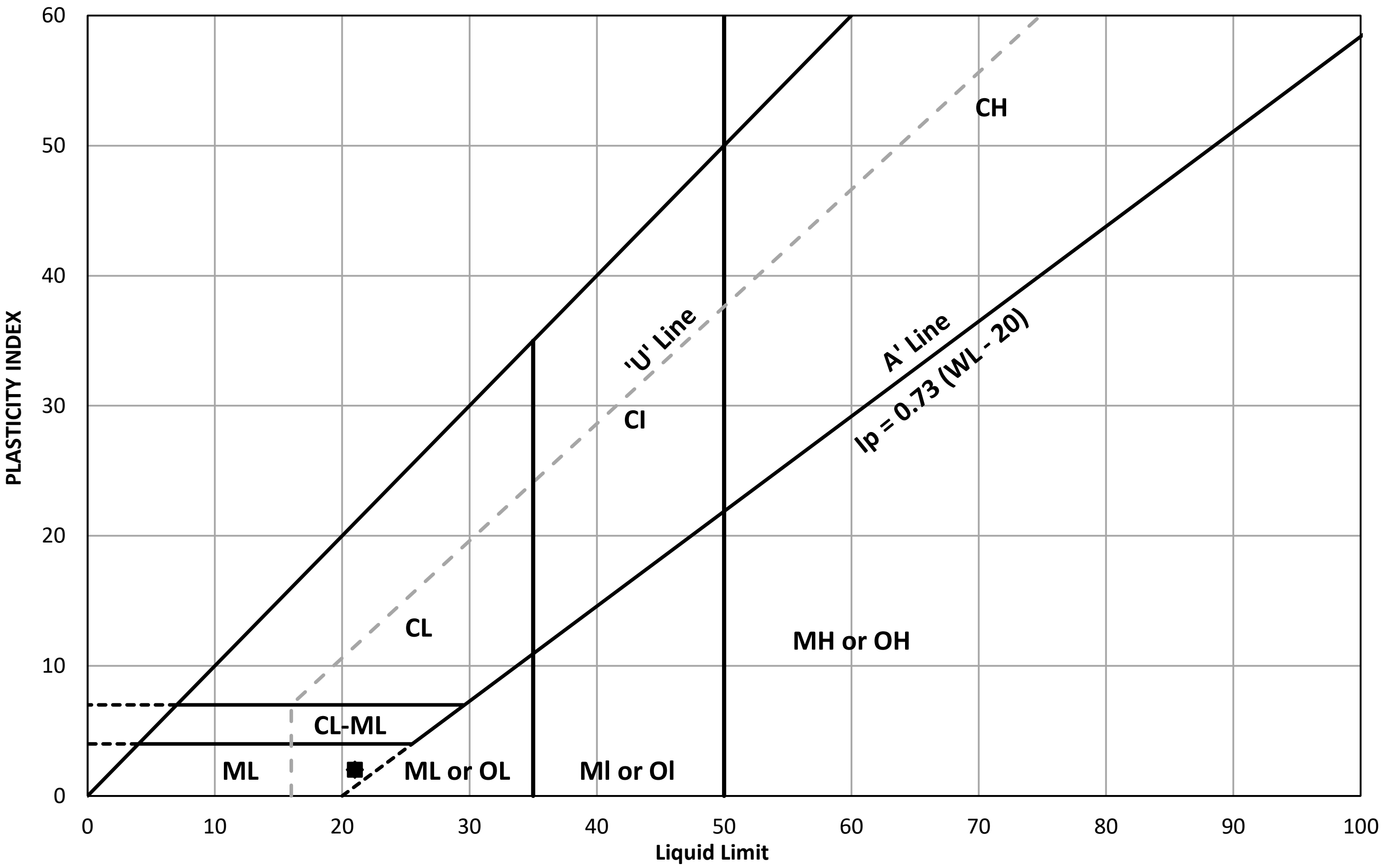
YYYY-MM-DD	2023-11-20
DESIGNED	NM
PREPARED	NM
REVIEWED	AMP
APPROVED	LCC

TITLE

GRAIN SIZE DISTRIBUTION
SAND (SP-SM) TO SAND (SP)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	A	D-2C

PLASTICITY CHART



	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index
■	RW-5	11	236.8 to 236.2	19.3	21	19	2	0.15
◆	RW-7	11A	236.2 to 235.9	NA	21	19	2	NA

CLIENT
MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONTARIO (MTO)

PROJECT
HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

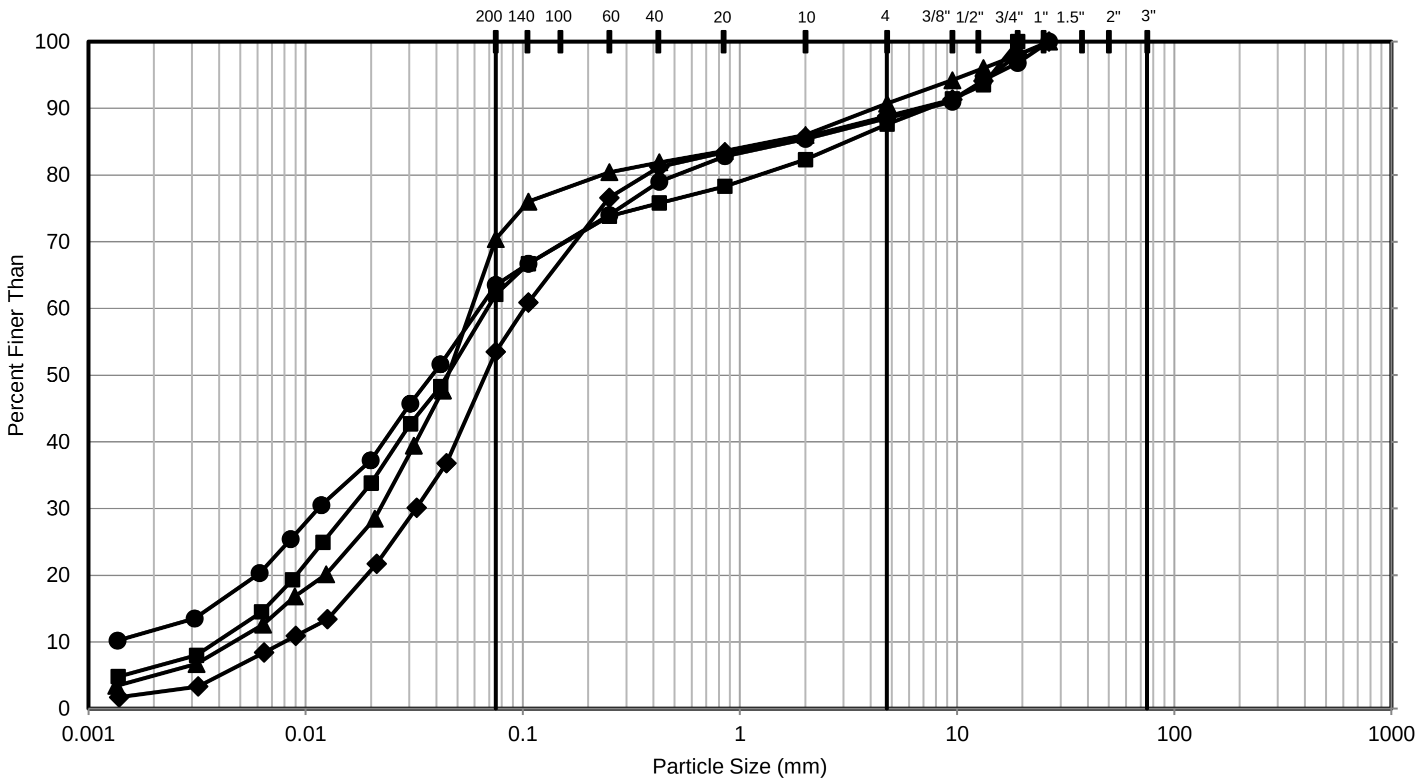
CONSULTANT
wsp

YYYY-MM-DD	2023-12-14
DESIGNED	AN/MH
PREPARED	AN/MH
REVIEWED	AMP
APPROVED	DS

TITLE
PLASTICITY CHART
SILT (ML) to SILT (ML) and sand

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	0	D-3

GRAIN SIZE DISTRIBUTION



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

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	RW-2	10	9.1 - 9.8	237.2 to 236.6
◆	RW-2	12	12.2 - 12.8	234.1 to 233.5
▲	RW-3	10	9.1 - 9.8	237.8 to 237.2
●	RW-1	11	10.7 - 11.3	237.2 to 236.6

CLIENT

MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONATRIO (MTO)

PROJECT

HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT

wsp

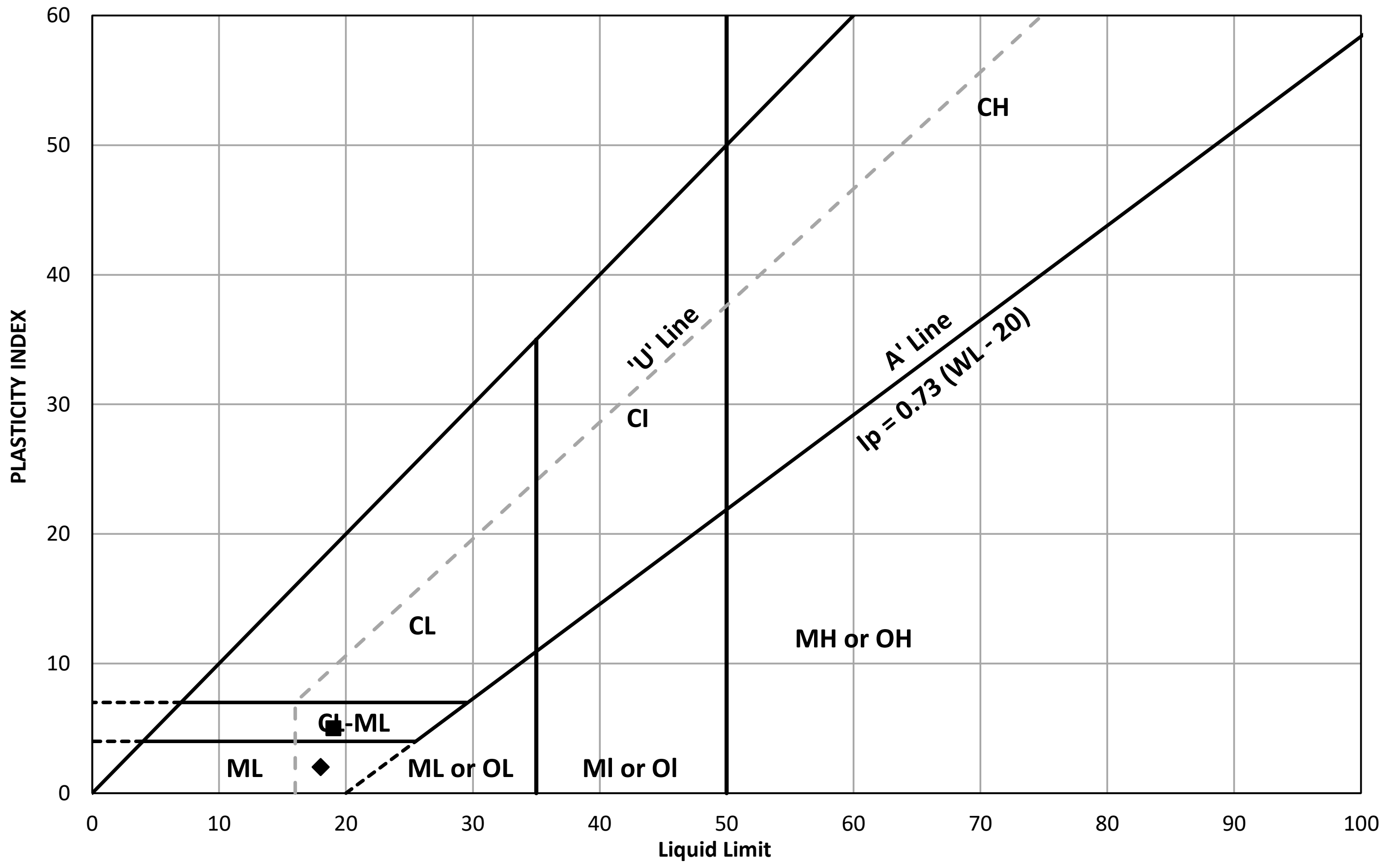
YYYY-MM-DD	2023-11-20
DESIGNED	NM
PREPARED	NM
REVIEWED	AMP
APPROVED	LCC

TITLE

GRAIN SIZE DISTRIBUTION
Sandy SILT (ML) to Sandy CLAYEY SILT-SILT (CL-ML) (TILL)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	A	D-4

PLASTICITY CHART



	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index
■	RW-1	11	237.24 to 236.63	12.5	19	14	5	-0.30
◆	RW-2	10	237.19 to 236.58	13.1	18	16	2	-1.45

CLIENT
MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONTARIO (MTO)

PROJECT
HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

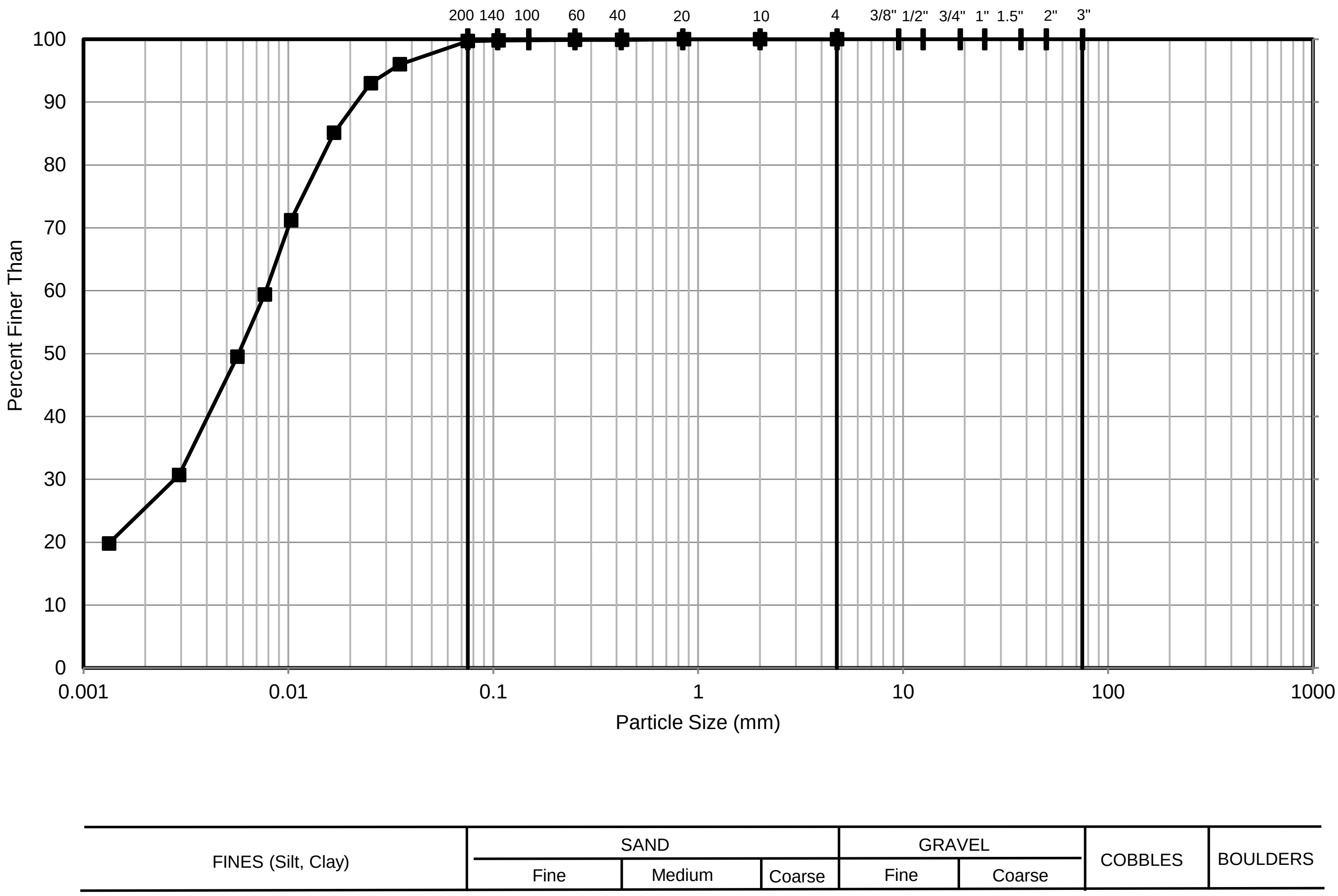
CONSULTANT: wsp

YYYY-MM-DD	2023-12-14
DESIGNED	AN/MH
PREPARED	AN/MH
REVIEWED	AMP
APPROVED	DS

TITLE
PLASTICITY CHART
Sandy SILT (ML) to Sandy CLAYEY SILT-SILT (CL-ML) (TILL)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	0	D-5

GRAIN SIZE DISTRIBUTION



Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	RW-4	11	10.7 - 11.3	235.6 to 235.0

CLIENT

MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONATRIO (MTO)

PROJECT

HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT

wsp

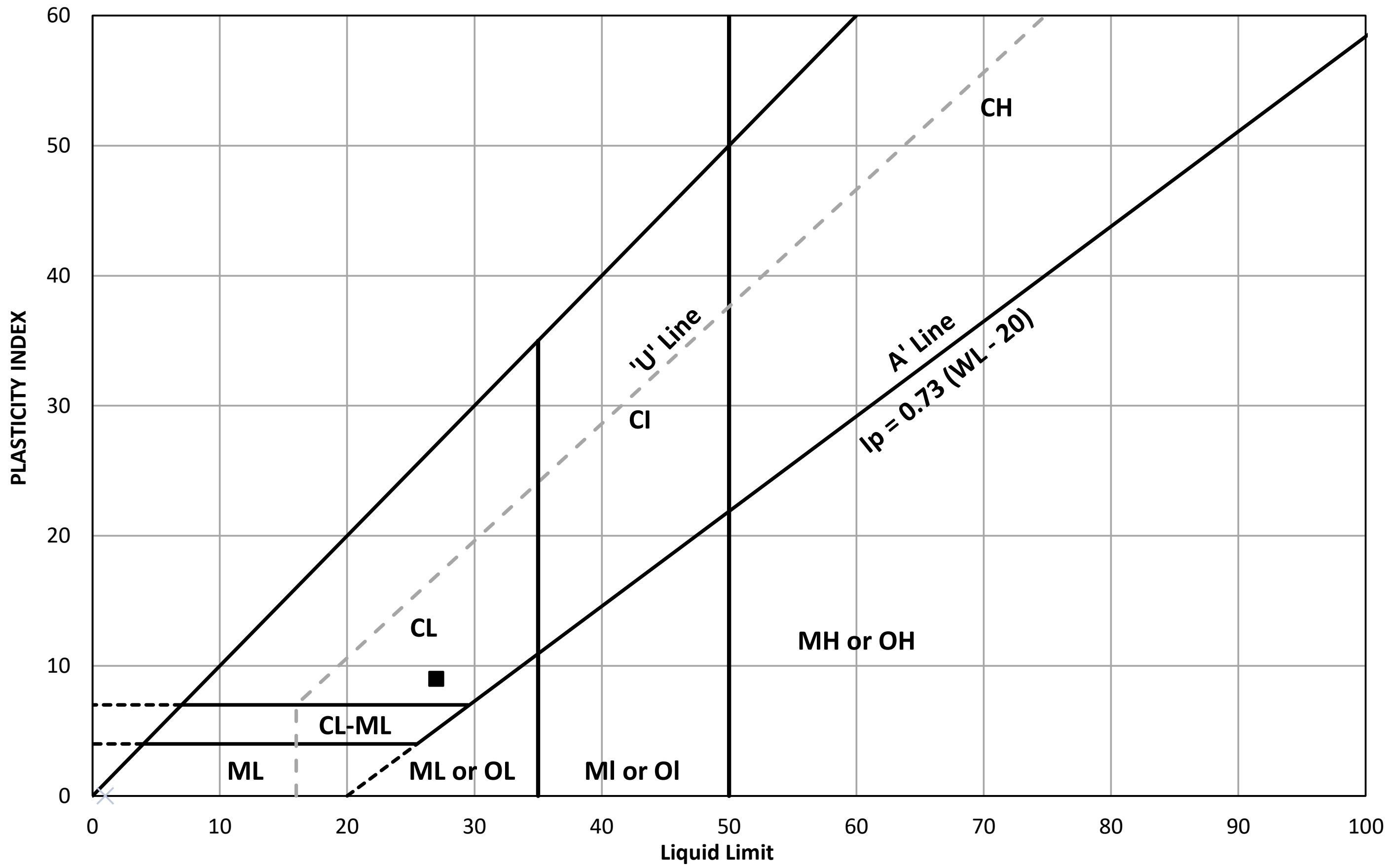
YYYY-MM-DD	2023-11-20
DESIGNED	NM
PREPARED	NM
REVIEWED	AMP
APPROVED	LCC

TITLE

GRAIN SIZE DISTRIBUTION
CLAYEY SILT (CL)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	A	D-6

PLASTICITY CHART



	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index
■	RW-4	11	235.62 to 235.01	15.7	27	18	9	-0.26
				-				-

CLIENT
MCINTOSH PERRY /
MINISTRY OF TRANSPORTATION ONTARIO (MTO)

PROJECT
HIGHWAY 11/12 (OLD BARRIE ROAD)
RETAINING WALLS NO. 1 AND 2

CONSULTANT
wsp

YYYY-MM-DD	2023-12-14
DESIGNED	AN/MH
PREPARED	AN/MH
REVIEWED	AMP
APPROVED	DS

TITLE
PLASTICITY CHART
CLAYEY SILT (CL)

PROJECT NO.	CONTROL	REV.	FIGURE
19135676	0	0	D-7

APPENDIX E

Analytical Laboratory Test Results

BUREAU VERITAS

Your Project #: 19135676
Site Location: HWY 11/12, ORILLIA
Your C.O.C. #: n/a

Attention: Anastasia Poliacik

Golder Associates Ltd
100 Scotia Crt
Whitby, ON
CANADA L1N 8Y6

Report Date: 2023/12/19
Report #: R7961633
Version: 2 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C3AS550
Received: 2023/12/01, 11:09

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (20:1 extract)	2	2023/12/06	2023/12/06	CAM SOP-00463	MOE E3013 m
Conductivity	2	2023/12/06	2023/12/06	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 2)	2	N/A	2023/12/08	AB SOP-00002	CCME PHC-CWS m
Sulphide in Soil (1)	2	N/A	2023/12/11	AB SOP-00080	EPA9030B/SM4500S2-DF
pH CaCl2 EXTRACT	2	2023/12/06	2023/12/06	CAM SOP-00413	EPA 9045 D m
Redox Potential (3)	2	2023/12/07	2023/12/08	CAM SOP-00421	SM 24 2580 B
Resistivity of Soil	2	2023/12/02	2023/12/06	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	2	2023/12/06	2023/12/06	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.
(3) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode. The test is therefore, not SCC accredited for this matrix.

Your Project #: 19135676
Site Location: HWY 11/12, ORILLIA
Your C.O.C. #: n/a

Attention: Anastasia Poliacik

Golder Associates Ltd
100 Scotia Crt
Whitby, ON
CANADA L1N 8Y6

Report Date: 2023/12/19
Report #: R7961633
Version: 2 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C3AS550
Received: 2023/12/01, 11:09

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
==
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Bureau Veritas Job #: C3AS550
Report Date: 2023/12/19

Golder Associates Ltd
Client Project #: 19135676
Site Location: HWY 11/12, ORILLIA
Sampler Initials: TT

SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		XTT382			XTT382			XTT383		
Sampling Date		2023/11/30			2023/11/30			2023/11/30		
COC Number		n/a			n/a			n/a		
	UNITS	**BH RW-1-SS-3**	**RDL**	**QC Batch**	**BH RW-1-SS-3 Lab-Dup**	**RDL**	**QC Batch**	**BH RW-3-SS-3**	**RDL**	**QC Batch**
Calculated Parameters										
Resistivity	ohm-cm	12000		9087359				15000		9087359
CONVENTIONALS										
Redox Potential	mV	460	N/A	9097488				470	N/A	9097488
Inorganics										
Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	9093919				<20	20	9093919
Conductivity	umho/cm	83	2	9093957	81	2	9093957	66	2	9093957
Available (CaCl2) pH	pH	7.83		9094175				7.87		9094175
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	9093930				<20	20	9093930
Sulphide	mg/kg	1.1 (1)	0.5	9105148	1.0	0.5	9105148	1.0 (2)	0.5	9105148

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable
(1) Matrix spike exceeds acceptance limits due to matrix interference.
Sample contained greater than 10% headspace at time of extraction.
(2) Sample contained greater than 10% headspace at time of extraction.

Bureau Veritas 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.bvna.com

Bureau Veritas Job #: C3AS550
Report Date: 2023/12/19

Golder Associates Ltd
Client Project #: 19135676
Site Location: HWY 11/12, ORILLIA
Sampler Initials: TT

RESULTS OF ANALYSES OF SOIL

Bureau Veritas ID		XTT382	XTT383		
Sampling Date		2023/11/30	2023/11/30		
COC Number		n/a	n/a		
	UNITS	**BH RW-1-SS-3**	**BH RW-3-SS-3**	**RDL**	**QC Batch**
Physical Testing					
Moisture-Subcontracted	%	11	3.7	0.30	9107720

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

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Bureau Veritas Job #: C3AS550
Report Date: 2023/12/19

Golder Associates Ltd
Client Project #: 19135676
Site Location: HWY 11/12, ORILLIA
Sampler Initials: TT

TEST SUMMARY

Bureau Veritas ID: XTT382
Sample ID: BH RW-1-SS-3
Matrix: Soil

Collected: 2023/11/30
Shipped:
Received: 2023/12/01

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	SKAL/EC	9093919	2023/12/06	2023/12/06	Massarat Jan
Conductivity	AT	9093957	2023/12/06	2023/12/06	Leily Karimi
Moisture (Subcontracted)	BAL	9107720	N/A	2023/12/08	Ashley Henderson
Sulphide in Soil	SPEC	9105148	N/A	2023/12/11	Ly Vu
pH CaCl2 EXTRACT	AT	9094175	2023/12/06	2023/12/06	Kien Tran
Redox Potential	COND	9097488	2023/12/07	2023/12/08	Leily Karimi
Resistivity of Soil		9087359	2023/12/06	2023/12/06	Automated Statchk
Sulphate (20:1 Extract)	SKAL/EC	9093930	2023/12/06	2023/12/06	Massarat Jan

Bureau Veritas ID: XTT382 Dup
Sample ID: BH RW-1-SS-3
Matrix: Soil

Collected: 2023/11/30
Shipped:
Received: 2023/12/01

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	9093957	2023/12/06	2023/12/06	Leily Karimi
Sulphide in Soil	SPEC	9105148	N/A	2023/12/11	Ly Vu

Bureau Veritas ID: XTT383
Sample ID: BH RW-3-SS-3
Matrix: Soil

Collected: 2023/11/30
Shipped:
Received: 2023/12/01

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	SKAL/EC	9093919	2023/12/06	2023/12/06	Massarat Jan
Conductivity	AT	9093957	2023/12/06	2023/12/06	Leily Karimi
Moisture (Subcontracted)	BAL	9107720	N/A	2023/12/08	Ashley Henderson
Sulphide in Soil	SPEC	9105148	N/A	2023/12/11	Ly Vu
pH CaCl2 EXTRACT	AT	9094175	2023/12/06	2023/12/06	Kien Tran
Redox Potential	COND	9097488	2023/12/07	2023/12/08	Leily Karimi
Resistivity of Soil		9087359	2023/12/06	2023/12/06	Automated Statchk
Sulphate (20:1 Extract)	SKAL/EC	9093930	2023/12/06	2023/12/06	Massarat Jan

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GENERAL COMMENTS

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

Package 1	0.7°C

Results relate only to the items tested.

Bureau Veritas Job #: C3AS550
Report Date: 2023/12/19

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 19135676
Site Location: HWY 11/12, ORILLIA
Sampler Initials: TT

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**UNITS**	**Value (%)**	**QC Limits**
9093919	Soluble (20:1) Chloride (Cl-)	2023/12/06	NC	70 - 130	89	70 - 130	<20	ug/g	8.8	35
9093930	Soluble (20:1) Sulphate (SO4)	2023/12/06	NC	70 - 130	90	70 - 130	<20	ug/g	2.7	35
9093957	Conductivity	2023/12/06			103	90 - 110	<2	umho/cm	2.6	10
9094175	Available (CaCl2) pH	2023/12/06			100	97 - 103			0.035	N/A
9097488	Redox Potential	2023/12/08			100	95 - 105			2.0	35
9105148	Sulphide	2023/12/11	65 (1)	75 - 125	98	75 - 125	<0.5	mg/kg	9.7	30
9107720	Moisture-Subcontracted	2023/12/08					<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)

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

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VALIDATION SIGNATURE PAGE

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

Anastassia Hamanov, Scientific Specialist

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

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

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BUREAU VERITAS

6740 Campobello Road, Mississauga, Ontario L5N 2L8
Phone: 905-817-5700 Fax: 905-817-5779 Toll Free: 800-563-6266
CAM FCD-01191/6

WORK ORDER

CHAIN OF CUSTODY RECORD

Page 1 of 1

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)	
Company Name:	WSP Canada Inc.	Company Name:	WSP Canada Inc.	Quotation #:	
Contact Name:	Canada Accounts Payable	Contact Name:	Anastasia Poliacik	P.O. #/ AFE#:	19135676
Address:	6925 Century Ave. Suite 100, Mississauga, ON	Address:	6925 Century Ave. Suite 100, Mississauga, ON L5N 7K2	Project #:	
Phone:	905-567-4444 Fax: 905-567-6561	Phone:	905-723-2727 Fax:	Site Location:	Hwy 11/12, Orillia
Email:	CAPayables Invoice@wsp.com	Email:	anastasia.poliacik@wsp.com	Site #:	
				Site Location Province:	Ontario
				Sampled By:	T.T. ~~MH/ACK~~

Turnaround Time (TAT) Required

- [X] Regular TAT (5-7 days) Most analyses

PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS

Rush TAT (Surcharges will be applied): [ ] 1 Day [ ] 2 Days [ ] 3-4 Days

Date Required:

Rush Confirmation #:

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE BUREAU VERITAS DRINKING WATER CHAIN OF CUSTODY

Regulation 153

- [X] Table 1 [ ] Res/Park [ ] Med/ Fine
- [ ] Table 2 [ ] Ind/Comm [ ] Coarse
- [ ] Table 3 [ ] Agri/ Other
- [ ] Table ____

FOR RSC (PLEASE CIRCLE) Y / N

Other Regulations

- [ ] CCME [ ] Sanitary Sewer Bylaw
- [ ] MISA [ ] Storm Sewer Bylaw
- [ ] PWQO Region ____
- [ ] Other (Specify) ____
- [ ] REG 558 (MIN. 3 DAY TAT REQUIRED)
- [ ] REG 406 Table ____

Include Criteria on Certificate of Analysis: Y / N

SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS

LABORATORY USE ONLY

CUSTODY SEAL Y / N Present	Intact	COOLER TEMPERATURES
N	N	1 / 10 / 1

COOLING MEDIA PRESENT: (Y) / N

Analysis Requested

	SAMPLE IDENTIFICATION	DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CrVI	BTEX/ PHC F1	PHCs F2 - F4	VOCs	REG 153 METALS & INORGANICS	REG 153 ICPMS METALS	REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B)	Corrosivity Package (+ Sulphide)	HOLD- DO NOT ANALYZE	COMMENTS
1	BH-RW-1-SS-3	2023/11/30	PM	SOIL									X		2 Jars
2	BH RW-3-SS-3	2023/11/30	PM	SOIL									X		2 Jars
3															
4															
5															
6															
7															
8															
9															
10															

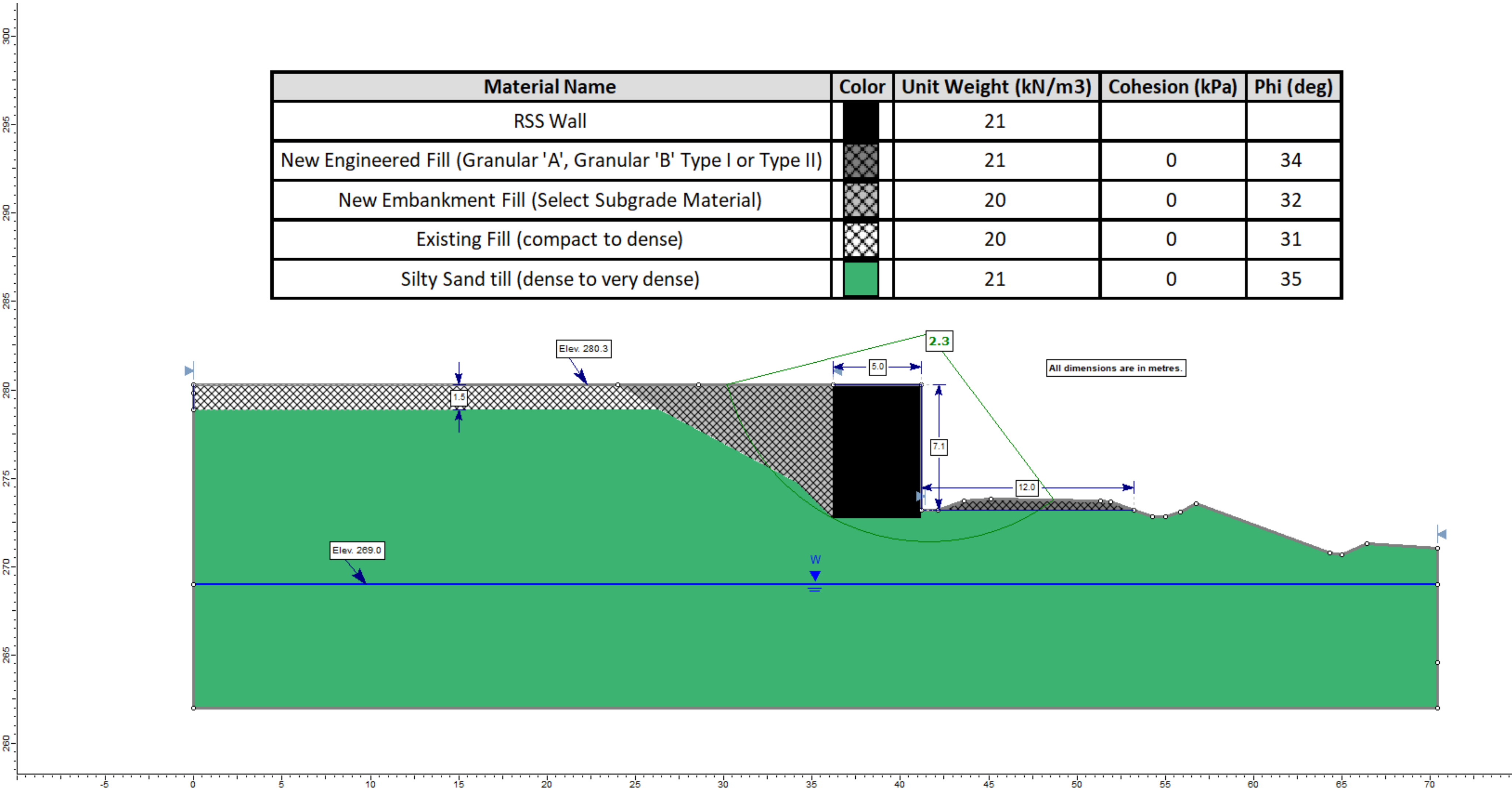
01-Dec-23 11:09
Ankita Bhalla
C3AS550
AK0 ENV-420

RELINQUISHED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	BV JOB #
Thomas Tingson	2023/12/01	11:15	[signature]	2023/12/01	1109	

APPENDIX F

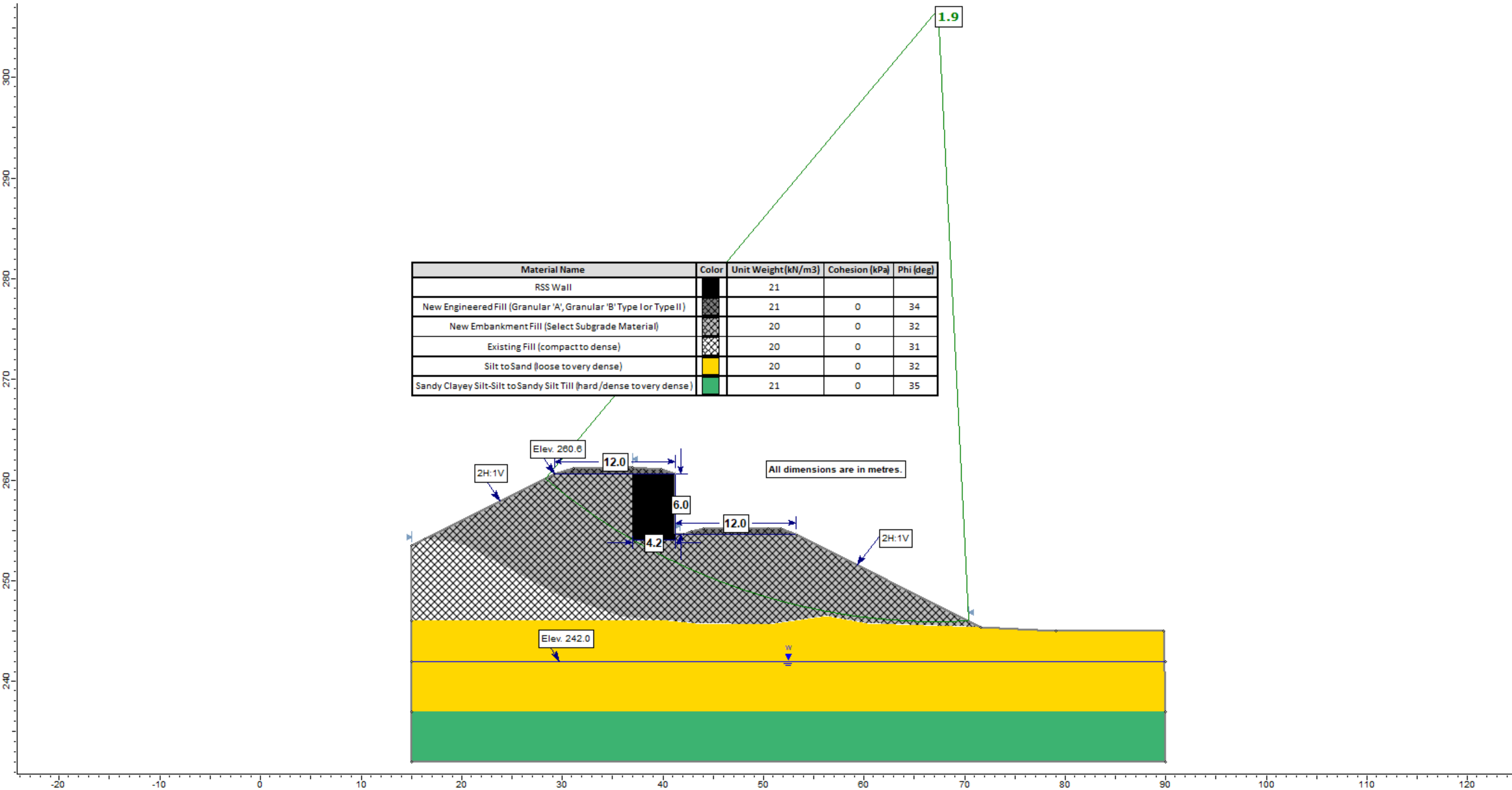
Global Stability Figures

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
RSS Wall		21		
New Engineered Fill (Granular 'A', Granular 'B' Type I or Type II)		21	0	34
New Embankment Fill (Select Subgrade Material)		20	0	32
Existing Fill (compact to dense)		20	0	31
Silty Sand till (dense to very dense)		21	0	35



RSS WALL – Retaining Wall No. 2

Figure F-2



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
RSS Wall		21		
New Engineered Fill (Granular 'A', Granular 'B' Type I or Type II)		21	0	34
New Embankment Fill (Select Subgrade Material)		20	0	32
Existing Fill (compact to dense)		20	0	31
Silt to Sand (loose to very dense)		20	0	32
Sandy Clayey Silt-Silt to Sandy Silt Till (hard/dense to very dense)		21	0	35

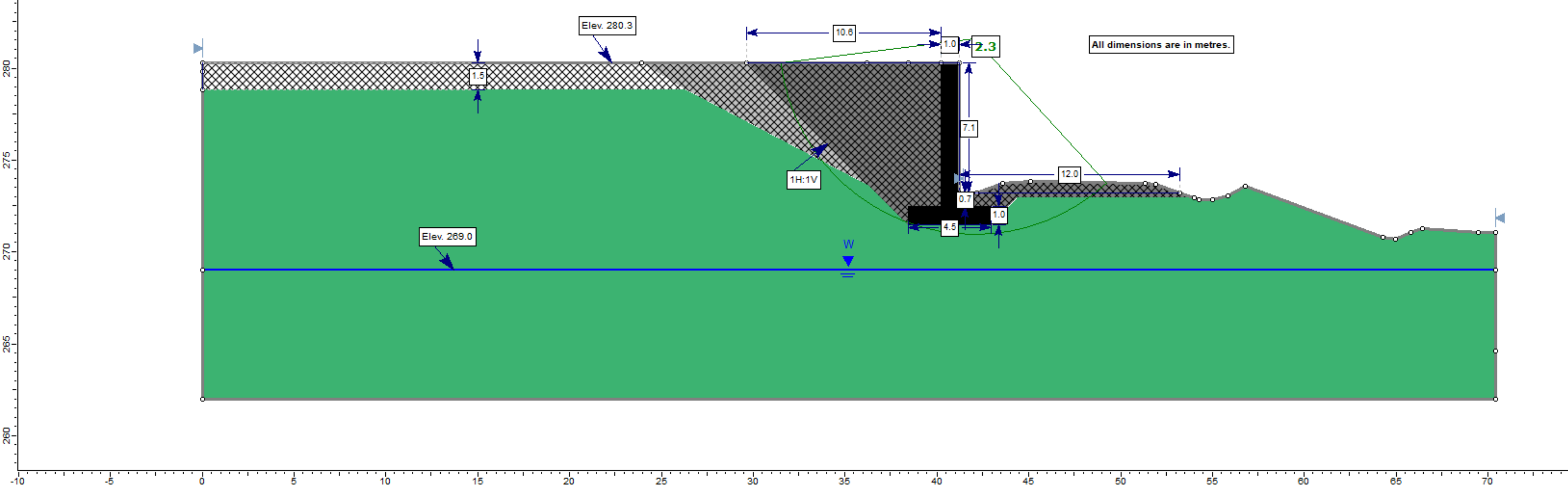
Date: December 2023
Project No: 19135676

Analysis By: JNS
Reviewed By: AP

CONCRETE CANTILEVER WALL – Retaining Wall No. 1

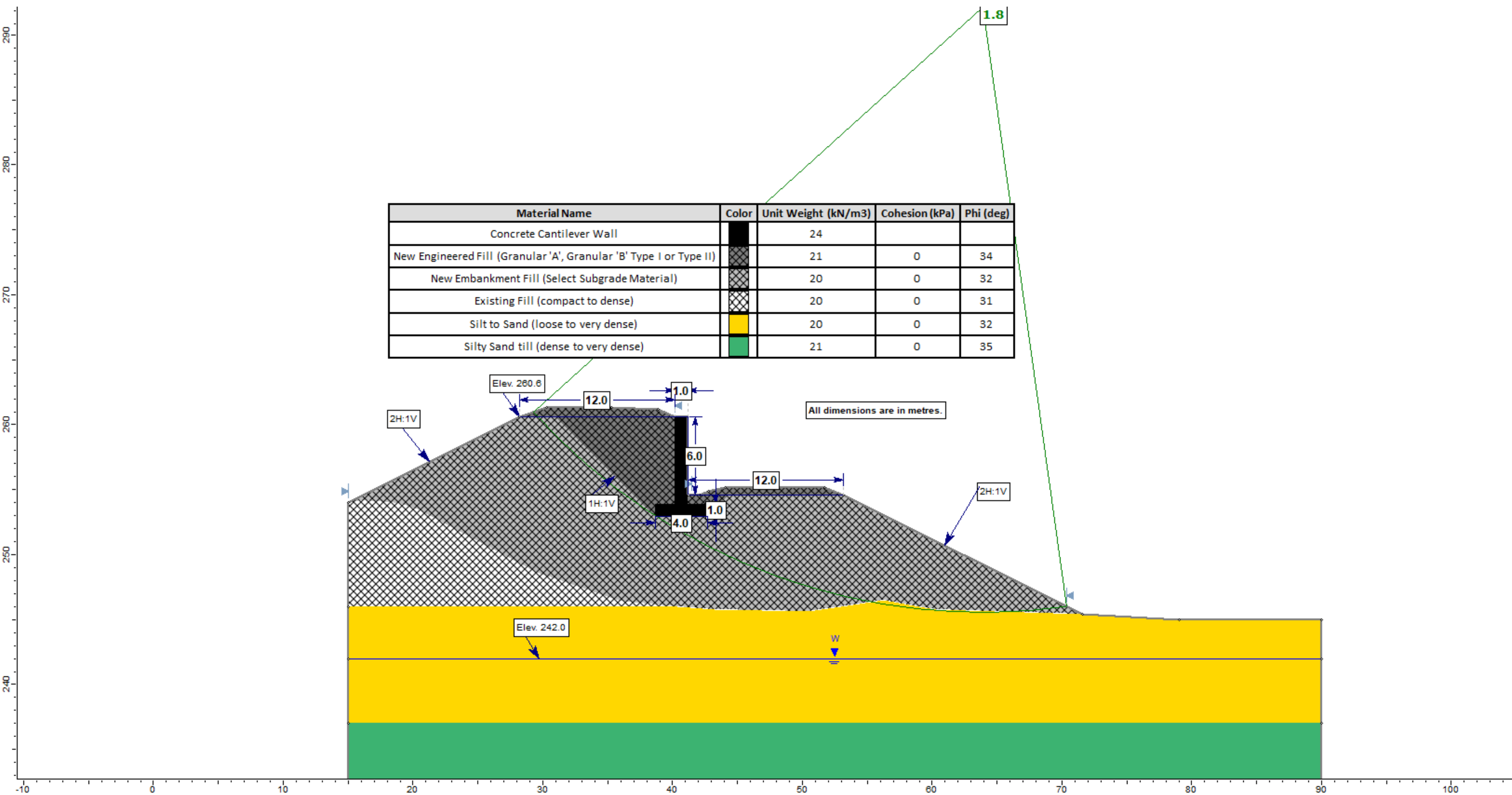
Figure F-3

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Concrete Cantilever Wall		24		
New Engineered Fill (Granular 'A', Granular 'B' Type I or Type II)		21	0	34
New Embankment Fill (Select Subgrade Material)		20	0	32
Existing Fill (compact to dense)		20	0	31
Silty Sand till (dense to very dense)		21	0	35



CONCRETE CANTILEVER WALL – Retaining Wall No. 2

Figure F-4



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Concrete Cantilever Wall		24		
New Engineered Fill (Granular 'A', Granular 'B' Type I or Type II)		21	0	34
New Embankment Fill (Select Subgrade Material)		20	0	32
Existing Fill (compact to dense)		20	0	31
Silt to Sand (loose to very dense)		20	0	32
Silty Sand till (dense to very dense)		21	0	35

Date: December 2023
Project No: 19135676

Analysis By: JNS
Reviewed By: AP

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