



Foundation Investigation and Design Report

*New Material Storage Facility at Hearst Patrol Yard,
Hearst, ON*

Agreement No. 5018-E-0012

Assignment No. 14

Latitude: 49.690653; Longitude: -83.691094

GWP 5234-18-00

Geocres No. 42G-76

Type of Document:

Final Report

Prepared For:

Ontario Ministry of Transportation
Geotechnical Section, Northeastern Region
447 McKeown Avenue, Suite 301
North Bay, ON P1B 9S9
Attn: Mark Winmill

Prepared By:

EXP Services Inc.
56 Queen St, East, Suite 301
Brampton, ON L6V 4M8
Canada

Date Submitted:

2021-10-21

*Ministry of Transportation Ontario
Northeastern Region Geotechnical Section*

Foundation Investigation and Design Report

Project Name:

New Material Storage Facility at Hearst Patrol Yard, Hearst, ON

Agreement No. 5018-E-0012

Assignment No. 14

Latitude: 49.690653; Longitude: -83.691094

GWP 5234-18-00

Geocres No. 42G-76

Type of Document:

Final Report

EXP Project Number:

ADM-00257843-N0

Issue and Revised Record

Rev.	Date	Format	Prepared by	Reviewed by	Approved by	Description
A	July 9, 2021	pdf	S. Anandakumar S. Micic	T.C. Kim	S. Gonsalves	Draft Report
B	October 21, 2021	pdf	S. Anandakumar S. Micic	T.C. Kim	S. Gonsalves	Final Report

Table of Contents

1	FOUNDATION INVESTIGATION REPORT	1
1.1	Introduction	1
1.2	Site Description and Geological Setting	1
1.2.1	Site Description	1
1.2.2	Geological Setting	1
1.3	Available Documents of Previous Investigations	2
1.4	Investigation Procedures	2
1.4.1	Fieldwork.....	2
1.4.2	Laboratory Testing	3
1.5	Subsurface Conditions	3
1.5.1	Surface Treatment	4
1.5.2	Fill: Sand and Gravel to Sand.....	4
1.5.3	Peat	4
1.5.4	Clayey Silt to Silty Clay	5
1.5.5	Silt	5
1.5.6	Sandy Silt Till	6
1.5.7	Bedrock	7
1.6	Groundwater Conditions.....	7
1.7	Chemical Analyses.....	8
1.8	Environmental Analyses.....	8
2	DISCUSSIONS AND ENGINEERING RECOMMENDATIONS	9
2.1	General.....	9
2.2	Geotechnical Design Considerations for Foundations	9
2.2.1	Structure Foundation Alternatives.....	10
2.2.2	Evaluation of Foundation Alternatives	10
2.2.3	Shallow Foundation	12
2.2.4	Deep Foundation.....	14
2.3	Earthquake Considerations	16
2.4	Liquefaction Considerations	17
2.5	Perimeter Wall and Floor Construction	17
2.6	Stability and Settlement Analyses.....	18
2.6.1	Stability	18
2.6.2	Settlement	19
2.7	Site Preparation and Engineered Fill Construction	21

2.8	Excavation	21
2.9	Groundwater Control.....	22
2.10	Corrosion Protection.....	22
2.11	Environmental Consideration	23
3	CLOSURE	24
4	REFERENCES	25
5	LIMITATIONS AND USE OF REPORT	27

Appendices

APPENDIX A: SITE PHOTOGRAPHS
APPENDIX B: DRAWINGS
APPENDIX C: BOREHOLE LOGS
APPENDIX D: LABORATORY DATA
APPENDIX E: ROCK CORE PHOTOGRAPHS
APPENDIX F: SLOPE STABILITY ANALYSES
APPENDIX G: SETTLEMENT ANALYSES
APPENDIX H: SEISMIC HAZARD CALCULATION

1 FOUNDATION INVESTIGATION REPORT

1.1 Introduction

This report presents the results of a geotechnical investigation carried out by EXP Services Inc. (EXP) for the proposed new winter sand/salt storage facility at the Hearst Patrol Yard, located in Hearst, Cochrane, Northeastern Ontario. The work was undertaken under Agreement # 5018-E-0012, Work Item No. 14. The terms of reference (TOR) were as presented in the Ministry of Transportation (MTO) email received on April 12, 2021.

The purpose of this investigation is to establish existing subsurface conditions at the proposed location of the patrol yard structure within construction limits defined by MTO and modelled after a recently constructed facility at the Powassan Patrol Yard in Powassan, ON. Similarly as the Powassan building, the new building at the Hearst Patrol Yard will be 82' x 160' (25 m x 48.8 m) and 41' (12.5 m) high building and it will include a 27.5' x 51' (8.4 m x 15.5 m) and 32'10" (10 m) high truck loading area. This Hearst Patrol Yard building will not include the brine storage area. The site-specific geotechnical investigation consisted of field investigation including visual inspection, drilling, soil sampling, and laboratory testing.

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

1.2 Site Description and Geological Setting

1.2.1 Site Description

The Hearst Patrol Yard is located on Trans-Canada Highway 11, approximately 250 m west of the Highway 11 and Fontaline Drive junction in Hearst, Cochrane District, Northeastern Ontario (Key Map on Drawing 1, Appendix B). The site is bound by Highway 11 to the north, a barren land followed by commercial space to the east and west, and surrounded by bush and mature trees to the south.

A paved roadway and parking area lead from the site entrance on Highway 11 to two buildings, a five-bay maintenance garage and a four-bay maintenance garage, located approximately 70 m east, and facility and salt sheds, located approximately 125 m west of entrance gate. Two existing dome structures, sand dome and salt dome, are located approximately 45 m southeast from the storage shed and approximately 165 m south from the site entrance. The new storage building will be placed mostly at the location of existing salt dome. The finish floor (FF) elevations of the existing buildings are between Elev. 246.66 m and 247.06 m.

The topography of the site is considered generally flat lying with borehole elevations ranging from 246.1 to 246.6 m. The ground surface of Hearst Patrol Yard is paved around the existing buildings and has sand and gravel in the other areas. Photographs of the site are included in Appendix A.

1.2.2 Geological Setting

According to the Ministry of Northern Development and Mines Map 2555, Quaternary Geology of Ontario, East Central Sheet, the site generally consists of glaciolacustrine deposits: silt and clay, minor sand; basin and quiet water deposits. According to the Ministry of Northern Development and Mines Map 25434, Bedrock Geology of Ontario, East Central Sheet, the bedrock at the site consists of muscovite-bearing granitic rocks with mafic and ultramafic intrusive rocks: muscovite-biotite and cordierite-biotite granite, granodiorite-tonalite, with Matachewan and Hearst swarms.

1.3 Available Documents of Previous Investigations

The nearest available previous investigation report in the MTO GEOCRE library for the Hearst Patrol Yard location is about 2 km east from the site location:

Geocres No. 42G-25: "Geotechnical Investigation Report for Sewer Construction, Highway 11, Hearst, Ontario" W.P. 722-89-00 prepared by Peto MacCallum Ltd. For Stanley Consulting Group Ltd., May 1998.

1.4 Investigation Procedures

1.4.1 Fieldwork

The site reconnaissance was completed on June 7, 2021 and field investigation was performed between June 7 and June 10, 2021. The field program consisted of drilling four (4) sampled boreholes (BH21-1 to BH21-4). The boreholes were strategically located at the proposed location of the new building (i.e. at each corner of the building) to provide the subsurface information for the design of the proposed material storage facility. The borehole locations are shown on Drawing 1 in Appendix B.

The borehole locations (referenced to the MTM NAD83 coordinate system) and their ground surface elevations were surveyed by EXP personnel by EXP personnel using a GPS (Magellan 316XS Hand Held) and a basic level and survey rod, respectively, having an accuracy of 2 m in the horizontal directions and 0.1 m in the vertical direction, with reference to the benchmark (BM) established on the FF of salt shed located in front of the existing domes at the yard. The elevation of the BM was considered as Elev. 246.72 m based on the Patrol Facility Site Plan (H-325-11-2) from January 2011, provided by MTO with the TOR. The BM location is shown on Drawing 1, in Appendix B.

The boreholes were advanced using a truck mounted CME 55 and/or CME 75 drill rig (i.e. the CME 55 drill rig, which was initially used, broke down during drilling operation; therefore, another drill rig had to be mobilized to site), equipped with a hollow stem augers and diamond bit NW casing. All borehole drilling and sampling operations were performed by a specialist drilling contractor, Landcore Drilling Services. The locations, elevations and depths of boreholes are shown below in Table 1.1.

Table 1.1. Locations, elevations and depths of boreholes completed by EXP Services Inc.

BH #	Location	MTM NAD83 Northing	MTM NAD83 Easting	Ground Elevation (m)	Borehole Depth (m)
BH21-1	Northwest corner of existing dome	5505962	327077	246.40	9.1
BH21-2	Northeast corner of existing dome	5505957	327102	246.18	11.5
BH21-3	Southeast corner of existing dome	5505912	327090	246.12	9.8
BH21-4	Southwest corner of existing dome	5505916	327064	246.63	13.1

During the drilling of the boreholes, soil samples were obtained using a 51 mm outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D 1586), at intervals shown on the attached borehole logs (Appendix C). The original field (uncorrected) SPT "N" values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual (CFEM pg. 40) and used to provide an assessment of in-situ consistency of cohesive soils or relative density of non-cohesive soils. When a hard stratum was

reached sampling of hard material was performed by diamond core drilling, using a 1.5 m long NQ double tube wireline core barrel. The water supply from the site was used for soil sampling and rock coring.

To obtain undisturbed cohesive soil samples for consolidation tests the Shelby tube samplers were driven in boreholes BH21-2 and BH21-4 at depth ~2.6 m. However, no recovery was achieved.

As wash boring technique was used during sampling of dense material, groundwater levels could not be measured in the open holes. The boreholes were decommissioned by bentonite/cement mixtures in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act).

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

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

1.4.2 Laboratory Testing

All samples recovered from boreholes undertaken by EXP during this investigation were returned to the laboratory and subjected to visual examination and classification. The laboratory testing program on soil samples included the determination of natural moisture content, particle size distribution and Atterberg Limits tests for approximately 25% of the collected soil samples. On four (4) rock cores, UCS tests were carried out. Soil chemical (Corrosivity and Contamination) package tests were performed on two soil samples, while one (1) soil sample was analyzed for metals and general inorganics parameters and BTEX/ Petroleum Hydrocarbons (PHCs) – (F1-F4). All the laboratory tests were carried out in accordance with MTO and/or ASTM standards as appropriate.

The laboratory test results are provided on the attached borehole log sheets in Appendix C. The results of the grain size analyses are presented graphically in Appendix D. Appendix D also contains the results of chemical and environmental tests.

1.5 Subsurface Conditions

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

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

In general, the stratigraphic sequence at the proposed structure site consists of pavement structure or sand and gravel to sand fill on the ground surface followed by the firm to very stiff clayey silt to silty clay layer, then the compact silt layer underlain by the compact to very dense sandy silt till layer followed by bedrock.

A detailed description of the subsurface conditions encountered is discussed further in subsequent sections. It should be noted that the following sections are based on the geotechnical investigation conducted by EXP.

1.5.1 Surface Treatment

Asphalt was encountered at the surface of boreholes BH21-1 and BH21-2, and ranged in thickness from approximately 65 mm to 75 mm. Asphalt thicknesses may further vary beyond the borehole locations.

1.5.2 Fill: Sand and Gravel to Sand

A sand and gravel/gravelly sand/sand fill layer was encountered in all boreholes, below pavement structure in boreholes BH21-1 and BH21-2 and at the surface of boreholes BH21-3 and BH21-4. The approximate elevations of the surface and base of the fill and the thickness of fill as encountered in boreholes are summarized in Table 1.2 below:

Table 1.2. Summary of sand and gravel to sand fill layer

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)
	Top	Bottom		
BH21-1	246.4	244.9	0.075	1.5
BH21-2	246.2	245.4	0.065	0.8
BH21-3	246.1	245.4	0.0	0.8
BH21-4	246.6	245.1	0.0	1.5

This layer consists of sand and gravel with trace to some silt and clay. The material is brown to grey in color, and moist to wet. The SPT “N” values within this layer is ranged from 7 to 32 blows per 300 mm penetration suggesting loose to dense compactness condition.

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

Moisture Content:

- 6.2% to 14.3%

Grain Size Distribution:

- 2% to 21% gravel;
- 71% to 86% sand;
- 9% to 12% silt and clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution test is also provided on Figure 1 in Appendix D.

1.5.3 Peat

A thin layer of peat (~0.3 m thick) was encountered below the gravelly sand fill in borehole BH21-3. The material is black in color, and wet. The SPT “N” values within this layer is about 10 blows per 300 mm penetration suggesting compact compactness condition.

The moisture content of this layer is about 23.9%. The result of the moisture content test is provided on the record of borehole sheets in Appendix C.

1.5.4 Clayey Silt to Silty Clay

A layer of native clayey silt to silty clay was encountered below the fill and peat in all boreholes BH21-1 to BH21-4. The approximate elevations of the surface and base of the deposit and the thickness of deposit as encountered in boreholes are summarized in Table 1.3 below:

Table 1.3. Summary of clayey silt to silty clay

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)
	Top	Bottom		
BH21-1	244.9	241.8	1.5	3.1
BH21-2	245.4	242.4	0.8	3.0
BH21-3	245.1	243.8	1.1	1.2
BH21-4	245.1	243.7	1.5	1.4

The composition of this layer is silt and clay, trace organics, trace gravel, trace to some sand. The material is dark brown/grey to brown in color and moist to wet. The SPT “N” values within this layer ranged from 6 to 18 blows per 300 mm penetration, suggesting firm to very stiff consistency. Boreholes BH21-2 and BH21-4 has organics present in the top 0.8m of this layer.

Laboratory testing performed on selected sample consisted of moisture content, grain size distribution and Atterberg Limit tests. The test results are as follow:

Moisture Content:

- 20.8% to 37.3%

Grain Size Distribution:

- 0% to 1% gravel;
- 4% to 14% sand;
- 29% to 75% silt; and
- 21% to 67% clay

Atterberg limits:

- Liquid Limit: 22% to 46%
- Plastic Limit: 13% to 20%
- Plasticity Index: 8% to 29%

The results of the moisture content grain size distribution and Atterberg Limit tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution test and Atterberg Limit tests are also provided on Figures 2 and 5, respectively, in Appendix D.

1.5.5 Silt

A layer of native silt was encountered in all boreholes, BH21-1 to BH21-4 below the native clayey silt to silty clay layer. The approximate elevations of the surface and base of the deposit and the thickness of deposit as encountered in boreholes are summarized in Table 1.4 below:

Table 1.4. Summary of silt layer

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)
	Top	Bottom		
BH21-1	241.8	240.3	4.6	1.5
BH21-2	242.4	240.1	3.8	2.3
BH21-3	243.8	241.6	2.3	2.3
BH21-4	243.7	241.3	2.9	2.4

The composition of this layer is silt, with trace gravel, trace to some sand, trace to some clay. The material is brown in color, and moist to wet. The SPT “N” values within this layer were between 0 and 25 blows per 300 mm penetration, suggesting very loose to compact, but generally compact compactness condition.

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

Moisture Content:

- 13.1% to 24.8%

Grain Size Distribution:

- 0% to 3% gravel;
- 1% to 14% sand;
- 75% to 89% silt; and
- 9% to 12% clay

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

1.5.6 Sandy Silt Till

A layer of native sandy silt till was encountered in all boreholes, BH21-1 to BH21-4, below the native silt layer. The borehole BH21-3 was terminated within this layer. The approximate elevations of the surface and base of the deposit and the thickness of deposit as encountered in boreholes are summarized in Table 1.5 below:

Table 1.5. Summary of sandy silt till layer

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)
	Top	Bottom		
BH21-1	240.3	238.4	6.1	1.9
BH21-2	240.1	237.7	6.1	2.4
BH21-3	241.6	236.4	4.6	5.2
BH21-4	241.3	236.7	5.3	4.7

The composition of this layer is sand and silt, with trace to some gravel and trace clay. The material is brown to grey in color, and moist. The SPT “N” values within this layer were between 13 and 100 blows per 300 mm penetration, suggesting compact to very dense compactness condition.

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

Moisture Content:

- 7.6% to 19.4%

Grain Size Distribution:

- 3% to 4% gravel;
- 24% to 28% sand;
- 69% to 73% silt and clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The result of grain size distribution tests performed is also provided on Figure 4, in Appendix D.

1.5.7 Bedrock

The bedrock was encountered below the sandy silt till deposit in boreholes BH21-1, BH21-2 and BH21-4 at depths ranging from 8 to 10 m below the ground surface with elevation ranging from 238.4 m to 236.7 m. The bedrock was confirmed by coring. These boreholes are terminated within bedrock. The bedrock surface depth and elevation are summarized in Table 1.6 below:

Table 1.6. Depth and elevation of bedrock surface

Borehole	Depth Below Ground Surface (m)	Elevation (m)	Description
BH21-1	8.0	238.4	Bedrock Cored
BH21-2	8.5	237.7	Bedrock Cored
BH21-4	10.0	236.7	Bedrock Cored

Based on the bedrock cores recovered, the bedrock is identified as granitic rocks with mafic and ultramafic intrusive rocks. In general, the bedrock sample is described as grey groundmass with coarse grained with slightly weathered to fresh and intensively to very slightly fractured bedrock. The Rock Quality Designation (RQD) measured on the core samples ranges from 32.1% to 93.3%, indicating a rock mass of poor to very good, mostly good quality. Based on the International Society for Rock Mechanics and Rock Engineering classification (ISRM 1980) the rock can be described as very strong strength (R5 grade) having the measured Uniaxial Compressive Strength (UCS) of between 112.1 MPa and 146.5 MPa. Results of UCS tests are included in Appendix D. Photographs of rock cores are included in Appendix E.

1.6 Groundwater Conditions

The groundwater levels in the boreholes were not measured in open hole upon completion of drilling, since water was used to advance boreholes, during EXP’s investigation in June 2021. However, based on observation on the site during the drilling and observed moisture condition of split spoon samples it is estimated that the groundwater table could be approximately 1.1 m below the existing ground corresponding to approximate Elev. 245 m.

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

1.7 Chemical Analyses

One (1) soil sample was selected for chemical analyses, and were sent via courier, in a secure cooler under chain of custody, to SGS Canada Inc., a CALA-certified and accredited laboratory in Lakefield, Ontario.

The sample SS4 from borehole BH21-3 was subjected to corrosivity chemical analyses. The analytical results are summarized in Table 1.7 below and are presented in Appendix D.

Table 1.7. Corrosivity chemical analysis

Sample Identification	pH (unitless)	Soluble Chloride (ppm)	Soluble Sulphate (ppm)	Resistivity (ohm-cm)	Conductivity (mS/cm)	Redox Potential (mV)
BH21-3-SS4 Silt	7.82	3200	11	319	3.13	222

1.8 Environmental Analyses

In addition to corrosivity testing, one (1) sample SS3 from boreholes BH21-2 was analyzed for metals and general inorganics parameters and BTEX/ Petroleum Hydrocarbons (PHCs) – (F1-F4). The analytical results are summarized in Table 1.8 below and Certificate of Analysis are compiled in Appendix D.

Table 1.8. Environmental analysis

Parameter (µg/g)	Result (µg/g)
BH21-2-SS3 Clayey Silt to Silty Clay	
BTEX:	
Benzene	< 0.02
Ethylbenzene	< 0.05
Toluene	< 0.05
Zylene (total)	< 0.05
m/p-zylene	< 0.05
o-xylene	< 0.05
PHCs:	
F1 (C6 – C10)	< 10
F1 BTEX (C6 – C10)	< 10
F2 (C10 – C16)	< 10
F3 (C16 – C34)	< 50
F4 (C34 – C50)	< 50

2 DISCUSSIONS AND ENGINEERING RECOMMENDATIONS

2.1 General

This section of the report provides geotechnical design recommendations for the proposed patrol yard sand/salt storage structure at the Hearst Patrol Yard, located in Hearst, Cochrane, Northeastern Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site and presented in Part I-Foundation Investigation Report. The interpretation and recommendations provided are intended solely to permit designers to assess foundation alternatives and design the proposed structure. Comments on construction are only provided to highlight issues that could affect the design. Contractors bidding on the works should make their own assessments of the factual data and how it might affect construction means and methods, scheduling and the like.

Based on information included in the TOR and correspondence with MTO it is understood that the new sand/salt storage building will be constructed at the MTO Hearst Patrol Yard at the location defined by MTO. Based on information provided in the MTO email from April 12, 2021, it is understood that the existing 31 m diameter salt dome will be replaced by the building having the footprint about 25 m x 48.8 m and 12.5 m height to the bottom of the trusses (underside of roof truss) and it will be encompassed with a 3.4 m high, cast-in-place concrete retaining walls along with 9.1 m high steel cladding walls around the perimeter, a total of 12.5 m (3.4 m + 9.1 m) above grade. The existing ground surface at the structure location is approximately at Elev. 246.66 m and it is assumed that finished top of floor will be at that current ground level to tie-in to the adjacent exterior paved areas. It is also planned that a truck loading area having the footprint about 8.4 m x 15.5 m and 10 m high will be located in the northeast corner of new sand/salt storage building.

This report addresses the geotechnical design of the foundation for the proposed structure by providing geotechnical design parameters at the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) as well as other geotechnical parameters that may be required in accordance with the latest edition of the Canadian Highway Bridge Design Code (CHBDC) (CAN/CSA-S6-19), Guidelines for MTO Foundation Engineering Services, Version 02 (October 2020), the Guideline for Professional Engineers Providing Geotechnical Engineering Service (1992), the Canadian Foundation Engineering Manual (CFEM) (2006), the provisions in the TOR and good practice. It also provides discussion about the structure foundation type, stability and settlement analyses, frost protection, construction considerations and dewatering during construction, if necessary, as requested in the TOR from the MTO email dated April 12, 2021.

As further requested in the TOR, the settlement and stability analyses were completed for a scenario in which the new structure would be loaded to its full allowable capacity. This scenario consists of sand/salt stacked to the maximum allowable height of the concrete walls with a stockpile area covering the entire footprint of the building. The angle of repose for sand/salt was assumed to be 33°.

2.2 Geotechnical Design Considerations for Foundations

The subsurface conditions at the site below the pavement structure or sand and gravel to sand fill consist of firm to very stiff clayey silt to silty clay layer followed by compact silt underlain by compact to very dense sandy silt till layer which is underlain by bedrock. It should be noted that below the fill, borehole BH21-3 encountered a 0.3 m thick layer of peat and BH21-2 and BH21-4 encountered organic material within the clayey silt to silty clay layer for the top ~0.8 m in this layer. The bedrock was encountered at depths ranging from 8.0 to 10.0 m below the ground surface with elevation ranging from 238.4 m to 236.7 m (i.e. sloping bedrock towards south). The groundwater level was not measured in open hole since water was used to advance boreholes. However, based on water content results, observation on the site and available geotechnical data from relatively adjacent sites it is estimated that the groundwater table could be at approximately Elev. 245 m.

2.2.1 Structure Foundation Alternatives

Based on the results of this investigation, several foundation alternatives for the structure are evaluated in this report. Advantages, disadvantages relative cost and risk/consequences of shallow foundations such as strip/spread footings and deep foundations such as driven steel H-piles and drilled caissons are presented in Table 2.1.

2.2.2 Evaluation of Foundation Alternatives

Considering the findings during the geotechnical investigation, as well as the high cost of pile foundations and the structure's operating life it is unlikely that deep foundations can be considered practical for this patrol yard structure. Shallow foundations are assessed as more practicable. Therefore, as noted in Table 2.1, the shallow foundation using strip/spread footings on the native stiff clayey silt to silty clay and/or compact silt is ranked as the preferred foundation design option if the geotechnical resistance is adequate. However, if higher geotechnical resistance is required, shallow foundation using strip footings on 1.2 m thick engineered fill over the compact silt will be the recommended option, as discussed in the following sections. Both of these options require full excavation of the peat and organics within clayey silt to silty clay encountered at the site.

Given the subsurface conditions at the site, the impact of settlement at the foundations of the structure will be influenced by the operating/stockpiling practices. It is our understanding that the structure will accommodate stockpiles of sand/salt at strategic locations within the structure. Based on the information mentioned in Section 2.1, the maximum loading condition is likely to be sand/salt stockpiled to at least the level of the concrete wall over the full footprint. Mounding in the center at the angle of repose material of 33° beyond the height of the concrete wall is also a possibility.

These types of structures generally have service lives of about 20 years. Typically, in settings of poor soil conditions, the approach would be to mitigate potential distress for a shallow foundation supported on it rather than employ expensive deep foundations for building support. Mitigation to create stable foundation soils can include preloading of the footprint area before construction, structure support on engineered fill and/or stockpiling constrains in order to enhance serviceability. However, since the new building is going to be partially placed at the location of the existing building it is reasonable to expect that the post construction settlement within the existing stockpile area will be less reflecting the preload effects from previous operations.

Based on the provided typical design for the sand/salt storage structure, it is understood that the strip/spread footings for the structure will be about 1.0 to 3.7 m. As mentioned, the footings could be founded on/within the native stiff clayey silt to silty clay deposit and/or compact silt, or on free draining engineered fill, such as Granular 'A' or Granular 'B', Type I or Type II (OPSS.PROV 1010).

The feasibility of shallow foundations depends on whether the structure can be accommodated in ground conditions with the axial resistance and settlement conditions described below. If the geotechnical resistances provided below for strip/spread footings are not sufficient for the design of the structure driven steel piles or caissons can be also considered.

Table 2.1 Evaluation of foundation alternatives

	Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Shallow Foundation	Strip/Spread Footings on Native Stiff Clayey Silt to Silty Clay and/or Compact Silt	1*	Straightforward construction	<ul style="list-style-type: none">Fairly low geotechnical resistance availablePreloading the footprint of structure area might be required if new structure is outside the previous footprintMay require dewatering for the construction of footing	<ul style="list-style-type: none">Significantly lower relative cost compared to piles and other shallow foundation option	<ul style="list-style-type: none">Risk of differential settlements due to loading patterns in the past and during operationsRisk of groundwater and subgrade disturbancePossible constraints on storage volume
	Strip/Spread Footings on Engineered Fill	2	<ul style="list-style-type: none">Straightforward constructionHigher geotechnical resistance than footing on native soil layerCompaction control	<ul style="list-style-type: none">May require dewatering to allow the construction of footing in dry and prevention of subgrade disturbance	<ul style="list-style-type: none">Significantly lower relative cost compared to deep foundation, but higher cost compared to shallow foundation on native soil	<ul style="list-style-type: none">Risk of groundwater and subgrade disturbance
Deep Foundation	Driven Steel H-Piles	3	<ul style="list-style-type: none">Higher geotechnical resistanceDo not require preloadingDo not require dewateringNegligible settlementNo subgrade disturbance	<ul style="list-style-type: none">Not typical for this type of structureRelatively short piles	<ul style="list-style-type: none">Higher relative costs compared with shallow foundations	<ul style="list-style-type: none">Not viable due to costSloping bedrock

Drilled Caissons (Option A: drilled to bedrock; Option B: socketed in bedrock)	4	<ul style="list-style-type: none"> • High geotechnical resistance available • Reduced number of deep elements compared to steel-H-piles • Do not require preloading • Negligible settlement • No subgrade disturbance 	<ul style="list-style-type: none"> • Not typical for this type of structure • Temporary liners might be required for groundwater control and support through overburden • Concrete for caissons would have to be placed by tremie methods below the water level 	<ul style="list-style-type: none"> • Higher relative costs compared with other deep foundation option and shallow foundations 	<ul style="list-style-type: none"> • Not viable due to cost • Sloping bedrock
--	---	--	--	--	---

*Note: * If geotechnical resistance is adequate, otherwise preloading and/or founding on engineered fill and/or stockpiling constraints may be necessary.*

2.2.3 Shallow Foundation

2.2.3.1 Footing Elevation

Based on the results of the geotechnical investigation and a requirement for adequate protection against frost penetration in the project area (i.e. a minimum ~2.6 m below the lowest surrounding area or equivalent thermal insulation to be provided, see Section 2.2.3.4), the following founding elevations of strip/spread footings are recommended:

Table 2.2 Recommendations for footing elevation

Soil at Founding Level	Foundation Elevation (m)	Depth Below Existing Grade
Native stiff clayey silt to silty clay and/or compact silt	~243.5	~2.6 m
Native stiff clayey silt to silty clay and/or compact silt with ~ 50 mm polystyrene protect against frost*	~244.7	~1.4 m
1.2 m thick engineered fill over compact silt	~243.5	~2.6 m (requires excavation up to Elev. 242.3 m)
1.2 m thick engineered fill over compact silt with ~ 50 mm polystyrene protect against frost*	~244.7	~1.4 m (requires excavation up to Elev. 243.5 m)

*Note: * It is accepted that 25 mm of polystyrene provides a frost protection which is equivalent to 600 mm of soil.*

2.2.3.2 Geotechnical Resistances

In the context of the CHBDC, a satisfactory foundation design would require, in terms of Limit States Design, the factored geotechnical resistance of its foundation to withstand and not exceed the imposed Ultimate Limit State (ULS) Loads Design Approach, and its ability to deform acceptably under the Service Limit State (SLS) Loads Design Approach. These associated loads are typically known as unfactored and factored loads, respectively. Therefore,

strip/spread footings placed on the properly prepared subgrade at the design elevation given in Table 2.2, should be designed based on the factored resistances at ULS and geotechnical reactions at SLS for 25 mm of settlement given in Table 2.3 below.

Based on the GA drawings for the Powassan Patrol Yard the width of the footings could be approximately 1.0, 2.2 and 3.7 m. Settlement of the footings under the loading from the stockpile inside the structure which will occur after its construction is considered and discussed in Section 2.6.2. In determining the settlement characteristics of the proposed building (tolerable total and differential settlement), the unfactored loads are required to be provided by the Structural or Design Engineer. The ULS and SLS consequence factor of 1.0 and degree of site understanding of 0.9 were applied in accordance with Tables 6.1 and 6.2 in the CHBDC S6-19, respectively.

Table 2.3 Factored geotechnical resistances for different footing width

Soil at Founding Level	Width of Footing (m)	Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance* (kPa) (for 25 mm settlement)
Native stiff clayey silt to silty clay and/or compact silt	1.0	360	200
	2.2	345	195
	3.7	350	195
Native stiff clayey silt to silty clay and/or compact silt with ~ 50 mm polystyrene protect against frost*	1.0	325	180
	2.2	305	170
	3.7	665	365
1.2 m thick engineered fill over compact silt	1.0	560	310
	2.2	545	305
	3.7	405	225
1.2 m thick engineered fill over compact silt with ~ 50 mm polystyrene protect against frost*	1.0	355	195
	2.2	355	195
	3.7	360	200

Note: * Factored serviceability geotechnical resistance values can be reviewed, if higher settlement is tolerable.

Since the ULS resistance and the settlement depend on the footing size and depth of embedment, the geotechnical resistances given in Table 2.3 should be reviewed if the selected footing width or founding elevations differ from those given in the table. Similarly, if an inclined load is applied instead of a vertical load, which is used in these calculations, the values given in Table 2.3 should be reviewed to consider those inclinations.

Prior to placing footings, the exposed native subgrade should be inspected according with OPSS 902 and SP 109S12. A Qualified Geotechnical Engineer should check that the design foundation elevation is achieved and all unsuitable soils including fill and organics should be removed.

2.2.3.3 Resistance to Lateral Loads

Resistance to lateral forces/sliding resistance between the subgrade and concrete should be calculated in accordance with Section 6.10.5 of the CHBDC. The unfactored values of the coefficient of friction, $\tan \delta$ between the base of

cast-in-place concrete footing and the native clayey silt to silty clay subgrade soils below the frost level are presented in Table 2.4.

Table 2.4 Recommendations for coefficient of friction

Interface	Coefficient of Friction, $\tan \delta$
Cast-in- place concrete and native stiff clayey silt to silty clay and/or compact silt	0.45
Cast-in-place concrete and engineered fill	0.60

A factor of 0.8 should be applied in calculation of the horizontal resistance in accordance with CHBDC.

In a case of the unbalanced lateral earth pressures caused by sand/salt stockpiles being piled against the perimeter walls, these walls should be designed based on the following geotechnical parameters assuming a triangular lateral earth pressure distribution:

- Unit weight of sand/salt stockpile material = 20 kN/m³
- Friction angle of sand/salt stockpile material= 33°
- Lateral earth pressure coefficient (K_o) = 0.5

2.2.3.4 Frost Protection

According to Ontario Provincial Standard Drawing (OPSD – 3090.100), the frost depth in the Hearst area is about 2.6 m. Consequently, all footings exposed to seasonal freezing conditions should be protected from frost action by at least 2.6 m of soil cover or equivalent approved insulation for frost protection. Equivalent protection could be provided by using polystyrene as suggested by the “Canadian Foundation Engineering Manual 2006, Section 13.5.2. page 196”. It is usually accepted that 25 mm of polystyrene provides a protection which is equivalent to 600 mm of soil.

2.2.4 Deep Foundation

2.2.4.1 Driven Steel Piles

Deep foundations are not considered the most practical foundation option for this patrol yard structure; however, steel H-piles (HP 310 x 110) driven to the underlying bedrock can be used to support the patrol yard structure and the information provided to support that design is presented in these sections of this report just for completeness. The piles could be installed through the sand and gravel to sand fill layer and native clayey silt to silty clay, followed by silt and then sandy silt till layers and terminated on the bedrock. For design purpose, tip elevations for the piles discussed in this report are estimated and given in Table 2.5.

Geotechnical Axial Resistances of Piles:

The factored ultimate geotechnical axial resistances and factored serviceability geotechnical axial reactions for 25 mm of displacement for recommended driven piles are presented in Table 2.5. It is anticipated that for H-piles driven and seated on the underlying unyielding bedrock, the factored serviceability geotechnical axial resistance for 25 mm of settlement will be greater than the factored ultimate geotechnical axial resistance; as such, ULS conditions will govern for this foundation type.

Table 2.5 Factored geotechnical resistances for considered HP 310 x 110 piles

Pile Founding Stratum	Estimated Tip Elevation (m)	Approx. Design Pile Length ¹ (m)	Factored Ultimate Geotechnical Axial Resistance (kN/pile)	Factored Serviceability Geotechnical Axial Resistance (kN/pile) ²
Bedrock	Varies (238.4 to 236.7)	Varies (~6 m to 7.5 m)	2,000	NA

Notes:

1. Below frost depth of about 2.6 m; ground elevation ~244.1 m
2. Structural capacity of pile per MTO note

Resistance of Piles to Lateral Loads:

The resistance of a vertical pile to lateral loads may be calculated using subgrade reaction theory, Broms' Method where the coefficient of lateral subgrade reaction, K_h (MPa/m) for granular soils is based on the following equations:

For cohesionless soils:

$$K_h = nh(z/d)$$

For cohesive soils:

$$K_h = 67C_u/d$$

where,

K_h = coefficient of horizontal subgrade reactions (MPa/m)

d = pile diameter/ width (m)

nh = constant of horizontal subgrade reaction (MPa/m)

C_u = undrained shear strength (kPa)

z = depth below ground surface (m)

Pile Installation:

The piles could be fitted with a driving shoe section (Titus pile point due to sloping bedrock, APF Hard Bite bearing points or similar) offering some protection against buckling at the toe or the piles should be stiffened as per OPSD 3000.100, Type I to minimize damage to the piles in anticipation of heavy driving conditions. Care must be taken to avoid overdriving and damaging the pile tip (i.e., the structural capacity of the piles should not be exceeded).

In addition, all piles should be visually monitored by experienced personnel during installation to check for plumbness, set, internal damage, etc. All damaged piles should be rejected, or if the damage is considered to be minor, the pile can be dynamically tested to determine the available pile capacity.

2.2.4.2 Drilled Caissons

Alternatively, the patrol yard structure may also be supported on caissons drilled to underlying bedrock or caissons socketed into the underlying bedrock. The high axial capacity of caissons would result in fewer units being required to support the structure than that required for the H-piles. Temporary liners and tremie concrete will be required to install caissons at this site.

Table 2.6 below provides the factored ultimate geotechnical axial resistances for 1.2 m diameter caissons drilled to underlying bedrock or caissons socketed a minimum of 1.5 m into the bedrock. The given value for caissons includes the shaft resistance of the bedrock socket and its end bearing.

Table 2.6. Geotechnical resistance for a 1.2 m diameter caisson

Options	Relevant Borehole	Foundation Elevation (m)	Factored Ultimate Geotechnical Axial Resistance (kN/pile)	Factored Serviceability Geotechnical Axial Resistance (kN/pile)
Caissons drilled to bedrock	BH21-1, BH21-2	~237.7	15,000	N/A
	BH21-3, BH21-4	~236.4		
Caissons socketed on bedrock	BH21-1, BH21-2	236.2	17,000	N/A
	BH21-3, BH21-4	234.9		

Note: NA - not applicable since for caissons socketed into the bedrock, the factored serviceability geotechnical axial resistance for 25 mm of settlement will be greater than the factored ultimate geotechnical axial resistance and, therefore, ULS conditions will govern.

The socketed caissons should be installed in accordance with the latest version of OPSS 903 and its amendment. According to that document, the rock surface at the base of each caisson should be thoroughly cleaned of any cuttings and loose soils, loose rock, and debris prior to concreting.

To verify the soundness/structural integrity of the caissons, one of the following non-destructive evaluation tests may be performed:

- Cross-hole acoustic testing and backscatter gamma ray (gamma-gamma) tests through access tubes installed within the caissons during the placement of the concrete; or
- Sonic echo tests. The advantage of these tests is that they do not require preparation during construction of the caissons. The disadvantage is that these tests do not identify all imperfections in a caisson, but provides information about continuity, defects, such as cracks, necking, soil incursions, changes in cross section and approximate pile lengths, unless the pile is very long or the skin friction is too high.

Cross-hole Sonic Logging should be in general accordance with the latest version of ASTM D6760 - Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Cross-Hole Testing. Static load tests to confirm the bearing capacity of the caissons may also be completed as described in ASTM D1143-81 (Compression Test Quick Method) and ASTM D3966-90 (Lateral Test) or as per designer's specification.

2.3 Earthquake Considerations

Recommendations for the geotechnical aspects to determine the earthquake loading are presented below.

Subsoil Conditions:

The subsoil and groundwater information at this site have been examined in relation to Section 4.1.8.4 A of the Ontario Building Code (OBC, 2012). The subsoil generally consists of sand and gravel to sand fill, firm to very stiff

clayey silt to silty clay layer followed by compact silt underlain by compact to very dense sandy silt till layer followed by bedrock at depths ranging from 8.0 to 10.0 m below the ground surface. It is expected that the foundations will be founded in the stiff clayey silt to silty clay and/or compact silt layer. The reported N-values for the soil below 3 m of the founding level ranged from 6 to 25 blows for 300 mm of penetration, with an average value being around 17 blows per 300 mm of penetration.

Depth of Boreholes:

Table 4.1.8.4.A. Site Classification for Seismic Site Response in OBC 2012 indicated that the average properties in the top 30 m are to be used to determine the site classification. The four (4) boreholes advanced for building construction at this site were between 9.1 m and 13.1 m deep. The total overburden thickness was between 8 m and 10 m at the tested locations. The overburden soils are typically underlain by bedrock of poor to very good, mostly good quality.

Site Classification:

Based on the above assumptions and interpretations, and the soil conditions, the Site Class for this site is estimated to be Class "D" as per Table 4.1.8.4.A, Site Classification for Seismic Site Response, OBC 2012.

These parameters should be reviewed by a Structural Engineer.

2.4 Liquefaction Considerations

Using Bray et al (2004) criteria for liquefaction assessment of fine-grained soils it is estimated that the soils at the site are not susceptible to liquefaction. Therefore, based on soils and groundwater condition encountered at the site, no liquefaction is expected due to the ground motion from an earthquake having 10% probability of exceedance in a 50-year period.

2.5 Perimeter Wall and Floor Construction

The perimeter wall of the proposed structures may be constructed as a cantilever retaining wall with an extended heel toward the inside of the structure and founded on native soils or engineered fill. Structural steel bars should be provided in the footings and in the walls.

The concrete and/or asphalt floor slabs supported on the existing granular fill or on engineered fill could be designed inside the structure. Based on available information, the floor slab/asphalt surface elevation will be around 246.66 m. Below the floor, a sub-floor drainage system should be placed and compacted as described later in this section. The asphalt pavement structure will need to be designed by a pavement engineer. The concrete floor slab has to be design by a structural engineer specialist as well. However, it is recommended that for the concrete floor slab the final lift of granular fill beneath the floor slabs should consist of a minimum thickness of 200 mm of OPSS Granular A material, uniformly compacted to 100% of SPMDD. For this condition, a modulus of subgrade reaction k_v of 50 MPa/m may be assumed for preliminary assessment purposes. For design purposes, the value provided above needs to be modified to account for size effects as per standard design methods as outlined in the CFEM 2006. The concrete floor slabs should be structurally separate from the foundation walls and columns and saw-cut control joints should be provided at regular intervals along column lines to minimize shrinkage cracking and allow for normal differential settlement of the floor slabs. Considering that the floor will be covered by sand/salt stockpile during cold weather, a frost protection is not considered necessary.

The construction of spread footing and subgrade for the floor may be carried out in accordance with the following recommendations:

Prior to construction, all obviously unsuitable material should be fully removed from the entire underfooting and underfloor area (see Section 2.7). Following rough grading, the exposed subgrade should be proof-rolled with a roller

under the full-time supervision of a qualified geotechnical personnel. Any soft spots detected during proof-rolling should be sub-excavated and replaced with Granular A or Granular B, Type I or Type II materials compacted to at least 98 % of the Standard Proctor Maximum Dry Density (SPMDD). The prepared subgrade should be covered with at least 200 mm thick layer of Granular A compacted to not less than 100% of the material's SPMDD, crowned slightly in the central area.

Around the perimeter of the building the ground surface should be sloped on a positive grade away from the structure to promote surface water run-off and reduce groundwater infiltration adjacent to the foundations. Permanent perimeter drains are not required if the interior base is set at least 200 mm above the exterior grade and the grade is sloped away from the structure. However, a permanent subfloor drainage system may be required to collect salt-bearing water. To minimize contamination into the native soils and subsequently into the groundwater, a barrier such as a compacted low-permeability clay liner or geomembrane usually should be installed below a salt storage area. In practice, the use of geomembrane shows advantage over the compacted clay liner in terms of improved performance of the barrier. The geomembrane should be installed on a minimum 75 mm thick sand layer (OPSS PROV 1004 or OPSS PROV 1002) and covered with a 300 mm thick layer of sand fill on top of the geomembrane to protect it from the overlying pavement structure. At this particular site, the presence of layer of natural firm to very stiff clayey silt to silty clay could be considered as a natural barrier system for contaminant transport.

2.6 Stability and Settlement Analyses

2.6.1 Stability

To assess the global stability of the material storage facilities and to check that a minimum Factor of Safety of 1.3 will be achieved for the maximum height winter sand/salt stockpiles, a series of slope stability analyses were performed. The static slope stability analyses were performed using the Morgenstern-Price method developed based on limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

Stability assessments were performed for the proposed new structure of 25 m x 48.8 m dimensions assuming that the maximum sand/salt stockpile height could be 11.7 m having side slopes of 1.5H:1V as shown on in Appendix F. The stratigraphy and groundwater condition at the site were developed based on the results of the geotechnical investigation presented in Part I - Foundation Investigation Report.

Given the above, effective stress analyses for a long-term stability assessment and total stress analysis for a short-term stability assessment was performed taking into consideration the subsoil conditions encountered directly beneath and adjacent to the proposed structure. The areas extending at least 1.0 meters beyond the outside edge of any footings of the building should be stripped/excavated and cleared of asphalt, surface vegetation, peat, topsoil, excessive organics, fill, weak/ disturbed/ deleterious/ compressible or loose materials and debris prior to construction, should be replaced with engineered fill comprised of Granular A or Granular B, Type II (below the groundwater table). This includes sand and gravel to sand fill from all boreholes BH21-1 to BH21-4 and peat from Borehole BH21-3 at the footing location. The sand and gravel fill inside the proposed storage building can be recompacted but all peat near BH21-3 should be removed and replace with granular material properly compacted.

Tabulated below in Table 2.7 are the soil parameters used for the slope stability analyses. The soil parameters were generally estimated based on the results of field and laboratory testing.

Table 2.7 Soil properties used in slope stability analyses

Material Type	Effective Stress Parameters			Total Stress Parameters		
	ϕ (degrees)	c (kPa)	γ (kN/m ³)	ϕ (degrees)	c (kPa)	γ (kN/m ³)
Engineered Fill	32	0	21	32	0	21
Sand and Gravel to Sand Fill	30	0	20	30	0	20
Clayey Silt to Silty Clay (Firm to Very Stiff)	29	0	20	0	80	20
Silt (Compact to Very Loose)	27	0	19	27	0	19
Sandy Silt Till (Compact to Very Dense)	29	0	21	29	0	21
Stockpile Material (Winter sand/salt)	33	0	20	33	0	20

The graphical results of these analyses can be seen on figures in Appendix F. As shown on figures, the results of stability analyses for an approximately 11.7 m high winter sand/salt stockpile (in the center, with the side slopes of 1.5H:1V) restrained with 3.4 m high concrete walls on both sides in the building suggest that the factor of safety of minimum 1.3 or greater can be obtained for a deep-seated failure surface.

Stability analyses are also performed for preloaded condition of the virgin footprint area (i.e. the area behind the existing salt dome) as discussed in Section 2.6.2. The graphical results of these analyses can be also seen in Appendix F. As shown on Figures F5 and F6, the results of stability analyses for an approximately 4 m high granular stockpile with the side slopes of 1.5H:1V and an area extending at least 1.0 meters beyond the outside edge of the proposed building footprint suggest that the factor of safety of minimum 1.5 or greater can be obtained for a deep-seated failure surface.

2.6.2 Settlement

To evaluate the maximum settlement and differential settlement values below the winter sand/salt stockpile loadings in the proposed storage building, a 3D computer program; Settle3D (Rocscience) was employed. The properties for the encountered soil layers used in the settlement model are evaluated based on the results of the laboratory and field tests as per CHBDC.

To obtain undisturbed cohesive soil samples for consolidation tests the Shelby tube samplers were driven in boreholes BH21-2 and BH21-4 at depth ~2.6 m. However, no recovery was achieved. It is suspected that the soil was too silty and wet to adhere to the tube. Therefore, consolidation tests were not able to be performed.

The estimated parameters for settlement analyses are listed in Table 2.8.

Table 2.8 Soil properties used in settlement analyses

Material Type	γ (kN/m ³)	E (MPa)	C _c	C _r	P _c (kPa)	e ₀	C _v (cm ² /s)
Engineered Fill	21	50	-	-	-	-	-
Sand and Gravel to Sand Fill	20	35	-	-	-	-	-
Clayey Silt to Silty Clay (Firm to Very Stiff)	20	-	0.13	0.015	300	0.5	0.002
Silt (Compact to Very Loose)	19	25	-	-	-	-	-
Sandy Silt Till (Compact to Very Dense)	21	90	-	-	-	-	-

The geometry of the stockpiles was assumed based on its maximum allowable capacity which is a maximum height of approximately 11.7 m at the center and 3.4 m along the sides at the wall. The model is illustrated on Figures G1 and G2 included in Appendix G for the north side and on Figures G5 and G6 for the south side.

The results of the settlement analyses are plotted on Figures G1 to G6 (Appendix G). The estimated settlements under the stockpile at the center and at the edges of the stockpile (i.e. location of footings) are presented in Table 2.9.

Table 2.9 Results of settlement analyses

Location	Foundation Soil Type	Thickness of		Estimated Settlement (mm)				
		Compressible Soil (m)	Elastic		Consolidation		Total	
			Edge	Centre	Edge	Centre	Edge	Centre
North Side (BH21-1, BH21-2)	Clayey Silt to Silty Clay (Firm to Very Stiff)	3.1	8	28	10	23	18	51
South Side (BH21-3, BH21-4)	Clayey Silt to Silty Clay (Firm to Very Stiff)	1.4	8	42	4	13	12	55

The calculated settlements are anticipated to occur immediately after the stockpile loadings are applied or within a period of one month. However, the loadings and consequent consolidation settlement would occur after the footings have been constructed. Therefore, the footings for this structure should be designed under the full allowable stockpile loadings. The geometries of stockpiles under the full allowable loadings including their possible maximum heights are recommended above. Since, the northern portion of the proposed storage building lies within the footprint of existing building, the post construction settlement within the existing stockpile area would be less than estimated above. Assuming preconsolidated condition, the consolidation settlement is expected to be less than 23 mm at the north side outline above.

The southern portion of the proposed building will lie on a virgin land, so it is expected that settlement of that area could be greater than the northern portion. However, the Clayey Silt to Silty Clay (compressible soil) thickness is less and consolidation soil is less than the northern portion. If that virgin footprint area is preloaded by a gravel/sand stockpile prior of construction, the post-construction settlement could be significantly reduced. For example, the settlement analysis for a 4 m high stockpile preloading with granular material was performed and the result is presented in Table 2.10 and attached Figures G3 and G6 in Appendix G for the north and south, respectively. The result shows that the total settlement of approximately 21 mm and 20 mm at the center could be expected by placing the 4 m high preloading for the north and south, respectively. A total settlement of about 12 mm and 2 mm can be expected at the proposed location of the footings for the north and south, respectively. Therefore, these analyses demonstrate that preloading can significantly reduce the post construction settlement if the compressible clayey soil exists below. It is anticipated that these predicted total settlements will take place as the load is applied (elastic) and within a time period of about 30 days (consolidation).

Table 2.10 Results of settlement analyses for preloading the virgin footprint area

Height of Stockpile Preloading (m)		Estimated Settlement (mm)					
		Elastic		Consolidation		Total	
		Edge	Centre	Edge	Centre	Edge	Centre
North Side (BH21-1, BH21-2)	4	5	9	7	12	12	21
South Side (BH21-3, BH21-4)	4	2	15	0	6	2	20

Assuming preloading of the virgin area for a period of one month is undertaken, there should be no significant settlement issues at this site. Some monitoring of the preloading and perimeter walls after construction is indicated to confirm expectation.

2.7 Site Preparation and Engineered Fill Construction

As mentioned previously, the areas within the limits of the buildings should be stripped and cleared of asphalt, surface vegetation, peat, topsoil and debris prior to construction. Any soils containing excessive organics or loose/disturbed materials are not suitable for the subgrade of building foundations, floor slabs or engineered fill. Therefore, areas with those soils should be excavated and replaced with engineered fill comprised of Granular A or Granular B, Type II (below the groundwater table). In particular, at location of BH21-3, peat underlying gravelly sand fill from 0.8 m to 1.1 m depth (Elev. 245.4 m to 245.1 m) from the ground surface has to be fully excavated. It is also recommended to provide about 0.1 m (4 inches) mud slab under all footings to protect foundation soils, similar to the GA drawings for the Powassan Patrol Yard provided by MTO.

Engineered fill could be placed after stripping all topsoil, peat, organic matter, fill and other compressible, weak and deleterious materials within an area extending at least 1.0 meters beyond the outside edge of the founding level of any footings. After stripping, the entire area should be heavily proof-rolled inspected and approved by a Geotechnical Engineer. Engineered fill should be placed in accordance with OPSS 501 and SP105S22. The fill material should be placed in thin layers not exceeding approximately 300 mm when loose. Oversize particles larger than 120 mm should be discarded, and each fill layer should be uniformly compacted with heavy compactors, suitable for the type of fill used. The engineered fill below the footing and floor slab should be compacted to 100% of its SPMDD, while within outside/exterior paved areas, the fill should be compacted to 98% of its SPMDD.

Full-time geotechnical inspection and quality control (by means of frequent field density and laboratory testing) should be provided by the Geotechnical Engineer. Every lift should be evaluated by a sufficient number of tests to ensure that the level of compaction is constantly achieved, and the compaction procedure is applied.

2.8 Excavation

All excavations should be carried out in accordance with the latest version of the Occupational Health and Safety Act. For the act, the existing materials are considered as Type 3 soils above the groundwater table and Type 4 soils below the groundwater table. Temporary excavations (i.e. those that are open only for a short period) above the groundwater table may be made with side slopes not steeper than about 1H:1V, while the temporary slopes below

the groundwater table must be formed at 3H:1V unless a suitable dewatering system is installed to lower the water level below the base of the excavation.

Qualified geotechnical personnel should be on-site during the foundation installation and for fill material placement, to verify the design assumptions, and to verify the design recommendations.

2.9 Groundwater Control

The groundwater level at the site was not measured since water was used to drill boreholes; however, based on observations on the site during the drilling, measured water content in the soil samples and available information from the adjacent sites it is estimated that the groundwater level was at Elev. 245 m which is approximately 1.1 m below the existing ground. Since the depth of excavation for footings will be up to 2.6 m, it is expected that groundwater enters into the excavation at the site. Considering that the soils encountered at the bottom of the excavation and within potential excavation depths could be clayey silt to silty clay and/or silt, it is assessed that these soils are susceptible to disturbance from groundwater and mobilized equipment. Therefore, the groundwater level needs to be controlled to at least 0.5 m below the excavation level to avoid disturbance, and any groundwater seepage should be removed from the excavation prior to placement of granular backfill in dry.

In general, where the excavation base is within 0.5 m of the prevailing groundwater level at the time of construction, it is anticipated that control of seepage can be accomplished by using properly filtered sumps, and/or filtered drains placed along the base the excavation. However, given the conditions at the site, it is expected that positive dewatering systems might be required to control the groundwater seepage.

Surface water should be directed away of the excavation. Dewatering shall be carried out in accordance with OPSS 517 and SP517F01. It is responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions. The method used should not undermine the existing utilities/ structures (if any).

2.10 Corrosion Protection

As stated above, one (1) soil sample was selected for analyses of pH, water soluble sulphate, chloride concentrations, resistivity, conductivity and oxidation-reduction potential. The testing was completed to determine the potential for degradation of the concrete in the presence of soluble sulphate and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are summarized in summarized in Section 1.6 of this report and detailed results are included in Appendix D.

The chemical data presented in Section 1.6 indicates resistivity of the tested soil of 319 ohm-cm, which suggests a severe potential for corrosion of buried metallic elements (MTO Gravity Pipe Design Guidelines, Page 34). The maximum chloride content reported is 3200 ppm ($\mu\text{g/g}$) which also indicates some potential for additional corrosion. The soil pH was about 7.82 which is within what is considered the normal range for soil pH of 5.0 to 9.0. The test results in Table 1.8 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. Based on the results of sample tested, and given that the structure is a salt/sand storage, consideration should be given by the designer to designing for a «C» type of exposure concrete class as defined by CSA A23.1 Table 1.

The maximum water-soluble sulphate content of the soils tested is 11 ppm ($\mu\text{g/g}$), i.e. 0.0011% which is less than 0.10%. It indicates low potential to corrode normal Portland cement concrete. Therefore, no particular precautions are required to provide protection against sulphate attack such as special cements or mixtures.

2.11 Environmental Consideration

One (1) sample of sand soil from BH21-2 (SS3) was analyzed for metals and general inorganics parameters and for BTEX/ Petroleum Hydrocarbons (PHCs) – (F1-F4) in accordance with land use criteria listed in the Ministry of the Environment standards (Ontario Regulation 153). The results were compared with soil criteria in Table 2 (Potable Groundwater Condition) and Table 3 (Non-Potable Groundwater Condition). The analytical results (Certificate of Analysis) are compiled in Appendix D and summarized below.

The soil sample meets all property use standards in Table 2 and Table 3 of Ontario Regulation 153.

3 CLOSURE

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

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

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

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

This Foundation Investigation and Design Report has been prepared by Sugitha Anandakumar, M.Eng., P.Eng., PMP and Silvana Micic, Ph.D., P.Eng., and reviewed by TaeChul Kim, M.E.Sc., P.Eng. and Stan E. Gonsalves, M.Eng., P.Eng., MTO Designated Foundation Contact. The field investigation was conducted by Shane Tobias.

EXP Services Inc.



Sugitha Anandakumar, M.Eng. , P.Eng., PMP
Geotechnical Engineer



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



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



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



Encl.

4 REFERENCES

- Bray, J.D., Sancio, R.B., Riemer, M.F. and Durgunoglu, T. 2004. Liquefaction susceptibility of fine-grained soils. In Proceedings of the 11th International Conference on Soil Dynamics and Earthquake Engineering and 3rd International Conference on Earthquake Geotechnical Engineering, Berkeley, CA, Jan. 7-9, 655-662
- Bureau of Reclamation, 1963. Earth Manual, 1st Edition, p 783.
- Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.
- Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi, p 1-50.
- Ministry of Northern Development and Mines, Map 2555. Quaternary Geology of Ontario, East-Central Sheet, 1991
- Ministry of Northern Development and Mines Map 2543. Bedrock Geology of Ontario, East-Central Sheet, 1991
- Terzaghi, K., 1955. Evaluation of Coefficients of Subgrade Reaction. Geotechnique, Vol. 5, No. 4, 297-326.

ASTM International:

- ASTM D1143-81 Standard Test Method for Piles Under Static Axial Compressive Load
- ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
- ASTM D2573-08 Standard Test Method for Field Vane Shear Test in Cohesive Soil
- ASTM D3966-90 Standard Test Method for Piles Under Lateral Loads
- ASTM D4044-15 Standard Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
- ASTM D6760 Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing

Ontario Provincial Standard Specifications (OPSS):

- OPSS 1010 Material Specification for Aggregates - Base, Subbase, Select Subgrade, And Backfill Material
- OPSS 501 Construction Specification for Compacting
- OPSS 517 Construction Specification for Dewatering
- OPSS 902 Construction Specification for Excavating and Backfilling – Structures
- OPSS 903 Construction Specification for Deep Foundations
- OPSS 1002 Material Specification for Aggregates - Concrete
- OPSS 1004 Material Specification for Aggregates - Miscellaneous

Ontario Provincial Standard Drawings (OPSD):

- OPSD 3090.100 Foundation Frost Depths for Northern Ontario

Special Provisions (SP):

SP 105S22	AMENDMENT TO OPSS 501
SP 517F01	AMENDMENT TO OPSS 517
SP 109S12	AMENDMENT TO OPSS 902

Ontario Water Resources Act:

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

Ontario Occupational Health and Safety Act (OHSA):

Ontario Regulation 213/91 Construction Projects

5 LIMITATIONS AND USE OF REPORT

BASIS OF REPORT

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

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

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

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

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

RELIANCE ON INFORMATION PROVIDED

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to EXP by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. EXP has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to EXP.

STANDARD OF CARE

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

COMPLETE REPORT

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

USE OF REPORT

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

REPORT FORMAT

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

Appendix A – Site Photographs



Photo 1. Hearst Patrol Yard - Drilling borehole BH21-1, facing southwest (June 9, 2021)




Photo 2. Hearst Patrol Yard - Drilling borehole BH21-4, facing northeast (June 10, 2021)

Appendix B – Drawings



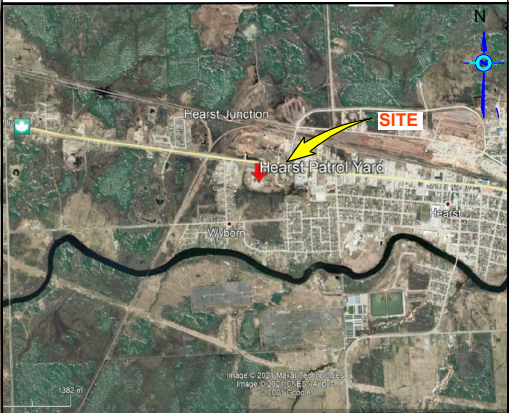
METRIC

DIMENSIONS ARE IN METERS AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETERS +METERS

CONT. No. 5018-E-0012 GWP No. - Assignment No. 14	
HEARST PATROL YARD, HIGHWAY 11 HEARST, ON (Latitude: 49°41'26.35", Longitude: 83°41'27.94") BOREHOLE LOCATION PLAN AND SOIL STRATA	SHEET 1

exp.	EXP Services Inc.
------	-------------------

KEY PLAN



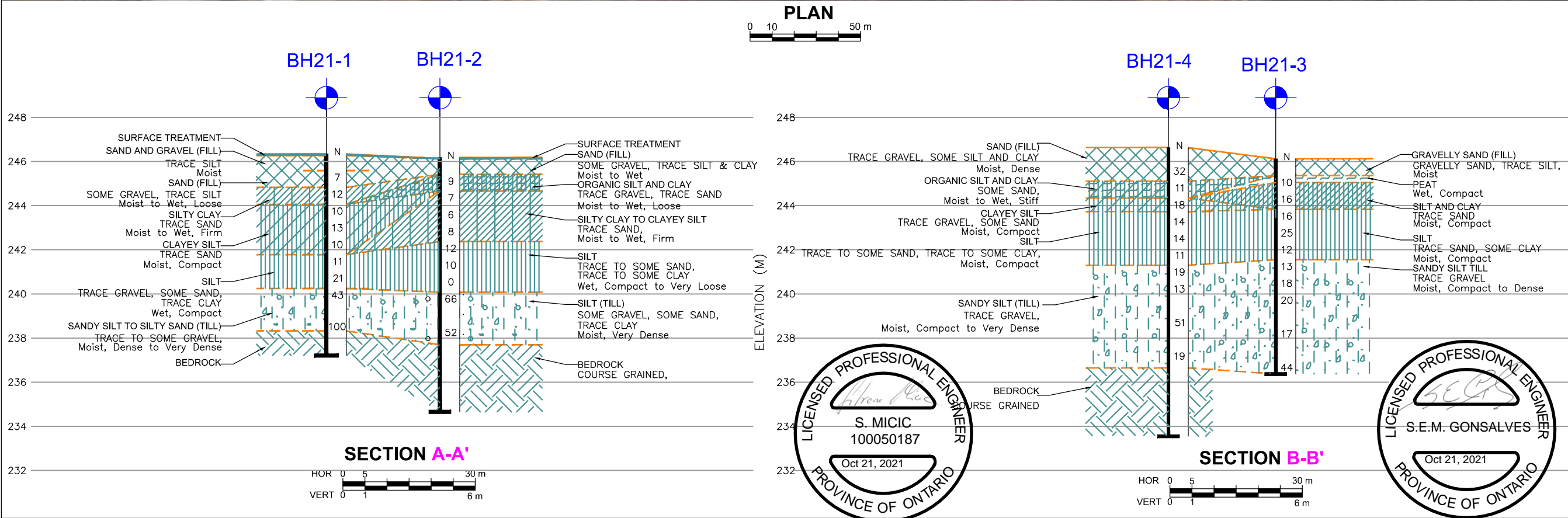
LEGEND	
	Borehole Location
	Standard Penetration Test (Blows/0.3 m)
	Groundwater level measured in open hole
	Bench Mark Location (Elev. 246.72 m)

SOIL STRATA SYMBOLS					
	SURFACE TREATMENT		FILL		PEAT
	SILTY CLAY		CLAYEY SILT		SILT
	SANDY SILT TO SILTY SAND/ SILT (TILL)		ORGANIC CLAYEY SILT		ORGANIC SILT & CLAY
	BEDROCK				

BH No.	ELEV.	MTM CO-ORDINATES NAD 83 (ZONE ON-13)	
		NORTHING	EASTING
BH21-1	246.4	5505962	327077
BH21-2	246.2	5505957	327102
BH21-3	246.1	5505912	327090
BH21-4	246.6	5505916	327064

NOTES		
This drawing is for subsurface information only. The proposed structure details/ works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents		
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.		

	SM	SUBMISSION FOR MTO REVIEW	
DATE	BY	DESCRIPTION	
		GEOCRES NO. 42G-76	
		PROJECT NO. ADM-00257843-N0	
SUBM'D SH	CHECKED SM	DATE	Oct. 21, 21
DRAWN SH	CHECKED SM	APPROVED SG	DWG. 1



Appendix C - Borehole Logs

Explanation of Terms Used on Borehole Records

SOIL DESCRIPTION

Terminology describing common soil genesis:

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

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

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

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

Terminology describing soil structure:

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

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

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

Fissured: material breaks along plane of fracture.

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

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

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

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

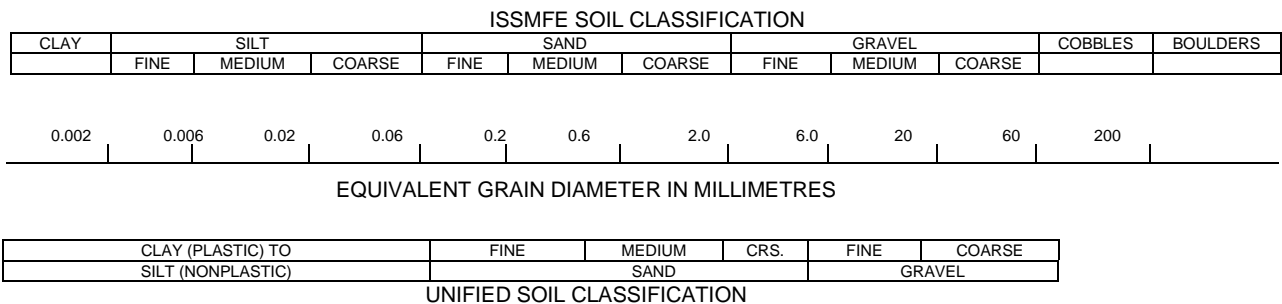
Seam: a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

Homogeneous: same color and appearance throughout.

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

Uniformly Graded: predominantly on grain size.

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



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

Table a: Percent or Proportion of Soil

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

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

Table b: Apparent Density of Cohesionless Soil

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

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

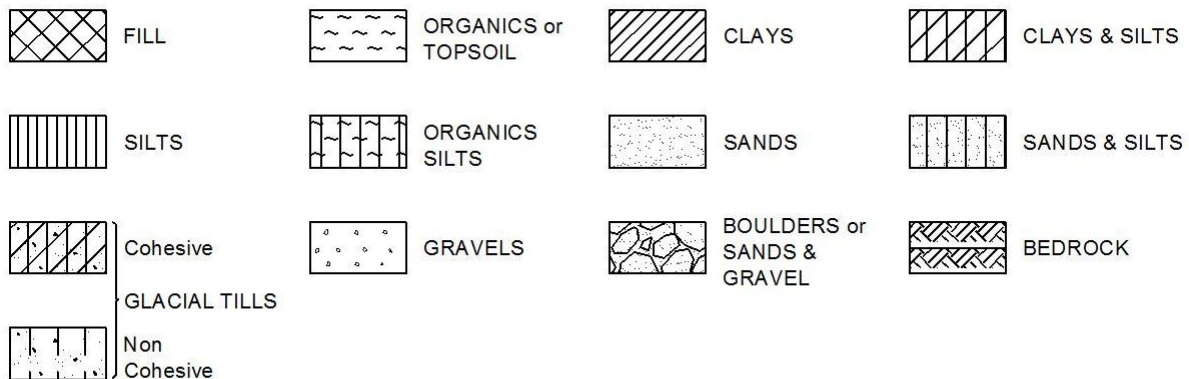
Table c: Consistency of Cohesive Soil

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

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

STRATA PLOT

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



WATER LEVEL MEASUREMENT



Open Borehole or Test Pit



Monitoring Well, Piezometer or Standpipe

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

Brampton, Ontario

RECORD OF BOREHOLE No BH21-1

1 OF 1

METRIC

W.P. Agreement No. 5018-E-0012, WO No. 14 LOCATION Hearst Patrol Yard, 327077 E, 5505962 N NAD83 MTM Zone 13 ORIGINATED BY ST
 DIST Cochrane HWY 11 BOREHOLE TYPE Continuous Flight HSA, NW Casing, NQ Core Barrel (CME 55) COMPILED BY SA
 DATUM Local (Non-Geodetic) DATE 2021.06.08 - 2021.06.08 LATITUDE 49.69089338 LONGITUDE -83.69123298 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _P W W _L				
246.4														
246.3														
0.1	SURFACE TREATMENT (~ 75mm thick asphalt) FILL , sand and gravel to sand, some gravel, trace silt, brown, moist to wet, loose		AG1	AUGER			246							
			SS2	SS	7									
244.9							245							
1.5	CLAYEY SILT TO SILTY CLAY , trace sand, brown, moist to wet, stiff		SS3	SS	12									0 9 30 61
	- attempted shelly, no recovery		SS4	SS	10		244							
			SS5	SS	13		243							0 4 75 21 Non-plastic
			SS6	SS	10		242							
241.8							241							3 14 75 9 Non-plastic
4.6	SILT , trace gravel, some sand, trace clay, brown, wet, compact		SS7	SS	11		240							
			SS8	SS	21		239							
240.3							238							
6.1	SANDY SILT TILL , trace to some gravel, brown to grey, moist, dense to very dense		SS9	SS	43									4 27 (69)
			SS10	SS	100									
238.4														
8.0	BEDROCK , coarse grained, grey coloured granitic rocks with mafic and ultramafic intrusive rocks		R1	NQ										
	Length RQD Recovery (m) (%) (%)													
237.3	Run 1 1.1 41.0 86.4													
9.1	BOREHOLE TERMINATED AT ~ 9.1 m DEPTH Groundwater Level: Since water was used to advanced borehole, no groundwater level was measured in open hole.													

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

ONTARIO MTO ADM-00257843-NO - HIGHWAY 11.GPJ ONTARIO MTO.GDT 7/11/21

Brampton, Ontario

RECORD OF BOREHOLE No BH21-2

1 OF 2

METRIC

W.P. Agreement No. 5018-E-0012, WO No. 14 LOCATION Hearst Patrol Yard, 327102 E, 5505957 N NAD83 MTM Zone 13 ORIGINATED BY ST
 DIST Cochrane HWY 11 BOREHOLE TYPE Continuous Flight HSA, NW Casing, NQ Core Barrel (CME 75) COMPILED BY SA
 DATUM Local (Non-Geodetic) DATE 2021.06.09 - 2021.06.09 LATITUDE 49.69085651 LONGITUDE -83.69088426 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
246.2														
246.1	SURFACE TREATMENT (~ 65mm thick asphalt)		AG1	AUGER			246							17 74 (10)
245.4	FILL , sand, some gravel, trace silt and clay, brown to grey, moist to wet													
0.8	CLAYEY SILT TO SILTY CLAY , trace ORGANICS, trace gravel, trace sand, dark grey to brown, moist to wet, stiff		SS2	SS	9		245							1 10 41 49
244.7	CLAYEY SILT TO SILTY CLAY , trace sand, brown, moist to wet, firm to stiff													
1.5			SS3	SS	7		244							
	- attempted shelly, no recovery		SS4	SS	6		243							0 4 29 67
			SS5	SS	8		242							
242.4	SILT , trace to some sand, trace to some clay, brown, wet, compact to very loose													
3.8			SS6	SS	12		241							
			SS7	SS	10		240							
			SS8	SS	0		239							
240.1	SANDY SILT TILL , some gravel, some sand, trace clay, grey, moist, very dense													
6.1			SS9	SS	66		238							
			SS10	SS	52		237							
237.7	BEDROCK , coarse grained, grey coloured granitic rocks with mafic and ultramafic intrusive rocks													
8.5														
	Length (m) RQD (%) Recovery (%)		R1	NQ			236							
	Run 1 1.5 93.3 100													
	Run 2 1.5 93.3 91.6		R2	NQ										

Continued Next Page

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

ONTARIO MTO ADM-00257843-N0 - HIGHWAY 11.GPJ ONTARIO MTO GDT 7/11/21

Brampton, Ontario

RECORD OF BOREHOLE No BH21-2

2 OF 2

METRIC

W.P. Agreement No. 5018-E-0012, WO No. 14 LOCATION Hearst Patrol Yard, 327102 E, 5505957 N NAD83 MTM Zone 13 ORIGINATED BY ST
 DIST Cochrane HWY 11 BOREHOLE TYPE Continuous Flight HSA, NW Casing, NQ Core Barrel (CME 75) COMPILED BY SA
 DATUM Local (Non-Geodetic) DATE 2021.06.09 - 2021.06.09 LATITUDE 49.69085651 LONGITUDE -83.69088426 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL & P. PENETROMETER																	
							20	40	60	80	100						
234.7							235										
11.5	BOREHOLE TERMINATED AT ~ 11.5 m DEPTH Groundwater Level: Since water was used to advanced borehole, no groundwater level was measured in open hole.																

Brampton, Ontario

RECORD OF BOREHOLE No BH21-3

1 OF 1

METRIC

W.P. Agreement No. 5018-E-0012, WO No. 14 LOCATION Hearst Patrol Yard, 327090 E, 5505912 N NAD83 MTM Zone 13 ORIGINATED BY ST
 DIST Cochrane HWY 11 BOREHOLE TYPE Continuous Flight HSA, NW Casing, NQ Core Barrel (CME 75) COMPILED BY SA
 DATUM Local (Non-Geodetic) DATE 2021.06.10 - 2021.06.10 LATITUDE 49.69044825 LONGITUDE -83.69105073 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER									
246.1								20	40	60	80	100					
0.0	FILL, gravelly sand, trace silt, brown, moist		AG1	AUGER			246										21 71 (9)
245.4																	
0.8	PEAT, black, wet, compact																
245.1			SS2	SS	10		245										
1.1	CLAYEY SILT TO SILTY CLAY, trace sand, brown, moist, stiff to very stiff																
			SS3	SS	16												0 8 44 48
243.8							244										
2.3	SILT, trace sand, some clay, brown, moist, compact		SS4	SS	16												
							243										0 1 88 12 Non-plastic
			SS5	SS	25												
							242										
			SS6	SS	12												
241.6																	
4.6	SANDY SILT TILL, trace gravel, grey, moist, compact to dense		SS7	SS	13		241										3 24 (73)
			SS8	SS	18												
							240										
			SS9	SS	20												
							239										
			SS10	SS	17		238										
							237										
			SS11	SS	44												
236.4																	
9.8	BOREHOLE TERMINATED AT ~ 9.8 m DEPTH Groundwater Level: Since water was used to advanced borehole, no groundwater level was measured in open hole.																

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

ONTARIO MTO ADM-00257843-NO - HIGHWAY 11.GPJ ONTARIO MTO.GDT 7/11/21

Brampton, Ontario

RECORD OF BOREHOLE No BH21-4

1 OF 2

METRIC

W.P. Agreement No. 5018-E-0012, WO No. 14 LOCATION Hearst Patrol Yard, 327064 E, 5505916 N NAD83 MTM Zone 13 ORIGINATED BY ST
 DIST Cochrane HWY 11 BOREHOLE TYPE Continuous Flight HSA, NW Casing, NQ Core Barrel (CME 75) COMPILED BY SA
 DATUM Local (Non-Geodetic) DATE 2021.06.10 - 2021.06.10 LATITUDE 49.69048518 LONGITUDE -83.69141087 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
246.6														
0.0	FILL, sand, trace gravel, some silt and clay, brown, moist, dense		AG1	AUGER										
			SS2	SS	32									2 86 (12)
245.1														
1.5	CLAYEY SILT TO SILTY CLAY, trace ORGANICS, some sand, dark brown to brown, moist to wet, stiff		SS3	SS	11									
244.3														
2.3	CLAYEY SILT TO SILTY CLAY, trace gravel, some sand, brown, moist to wet, very stiff		SS4	SS	18									1 14 60 26
243.7														
2.9	SILT, trace to some sand, trace to some clay, brown, moist, compact		SS5	SS	14									
			SS6	SS	14									
			SS7	SS	11									0 1 89 11
241.3														
5.3	SANDY SILT TILL, trace gravel, grey, moist, compact to very dense		SS8	SS	19									
			SS9	SS	13									3 28 (70)
			SS10	SS	51									
			SS11	SS	19									
236.7														
10.0	BEDROCK, coarse grained, grey coloured granitic rocks with mafic and ultramafic intrusive rocks		R1	NQ										
235.6														

Continued Next Page

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

ONTARIO MTO ADM-00257843-N0 - HIGHWAY 11.GPJ ONTARIO MTO.GDT 7/11/21

Brampton, Ontario

RECORD OF BOREHOLE No BH21-4

2 OF 2

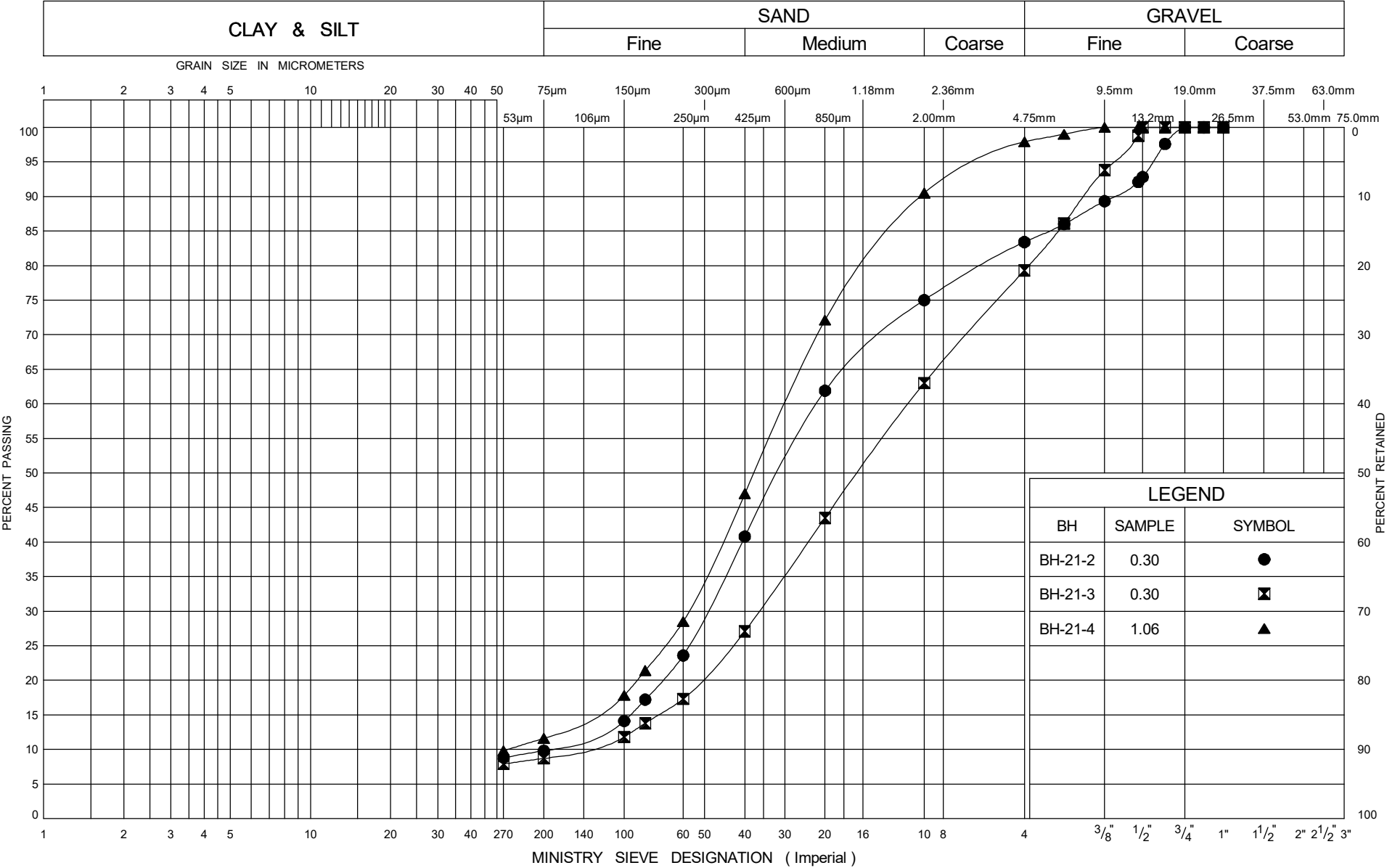
METRIC

W.P. Agreement No. 5018-E-0012, WO No. 14 LOCATION Hearst Patrol Yard, 327064 E, 5505916 N NAD83 MTM Zone 13 ORIGINATED BY ST
 DIST Cochrane HWY 11 BOREHOLE TYPE Continuous Flight HSA, NW Casing, NQ Core Barrel (CME 75) COMPILED BY SA
 DATUM Local (Non-Geodetic) DATE 2021.06.10 - 2021.06.10 LATITUDE 49.69048518 LONGITUDE -83.69141087 CHECKED BY SM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			SHEAR STRENGTH kPa					W _p	W	W _L		
				"N" VALUES			20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER					WATER CONTENT (%)				
							20	40	60	80	100	20	40	60		
11.0	Length RQD Recovery (m) (%) (%) Run 1 0.7 32.1 57.2 Run 2 1.5 55.0 76.7 Run 3 0.9 85.3 85.3		R2	NQ		235										
			R3	NQ		234										
233.6																
13.1	BOREHOLE TERMINATED AT ~ 13.1 m DEPTH Groundwater Level: Since water was used to advanced borehole, no groundwater level was measured in open hole.															

Appendix D - Laboratory Data

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

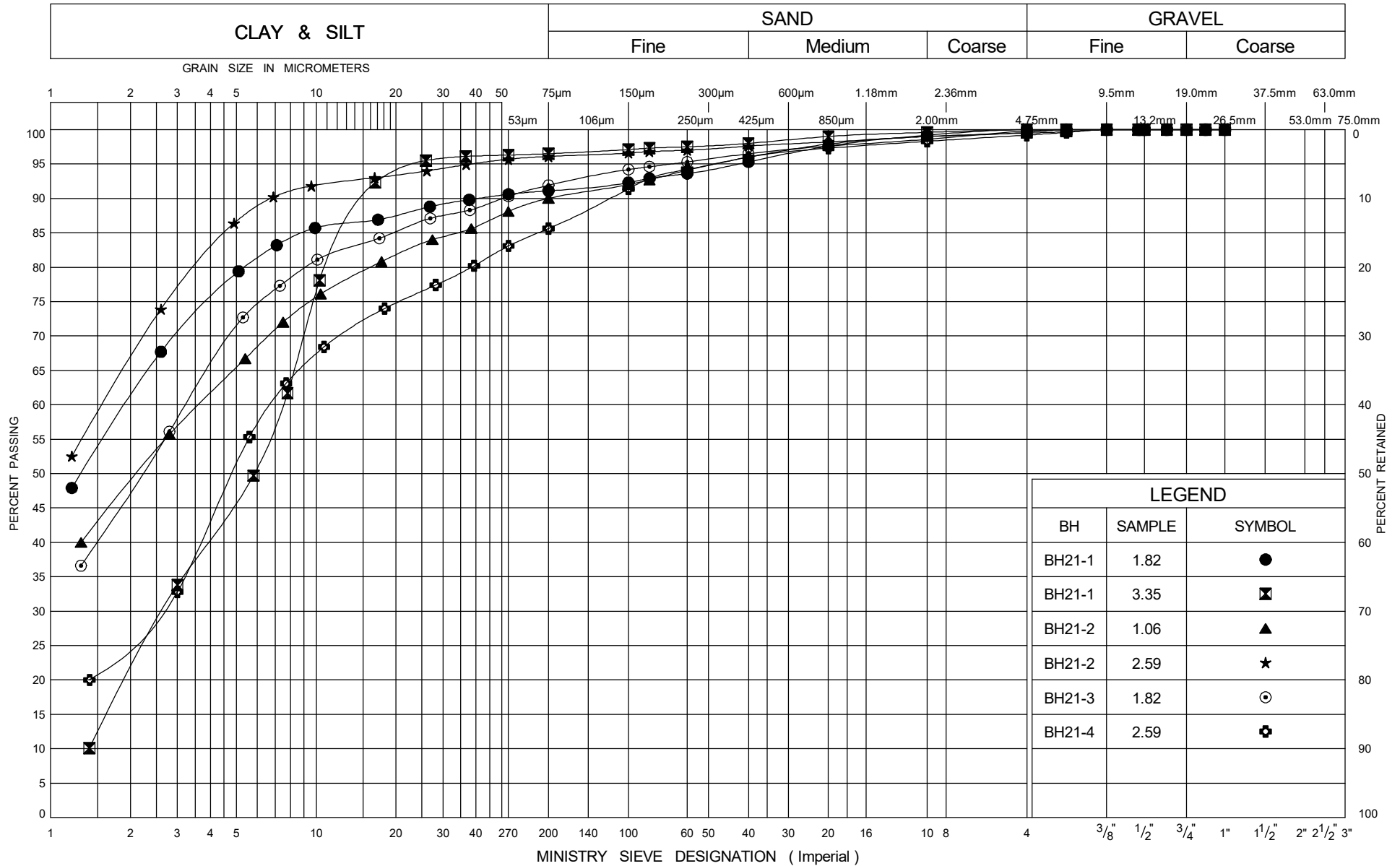
Fill: Sand and Gravel to Sand

FIG No 1

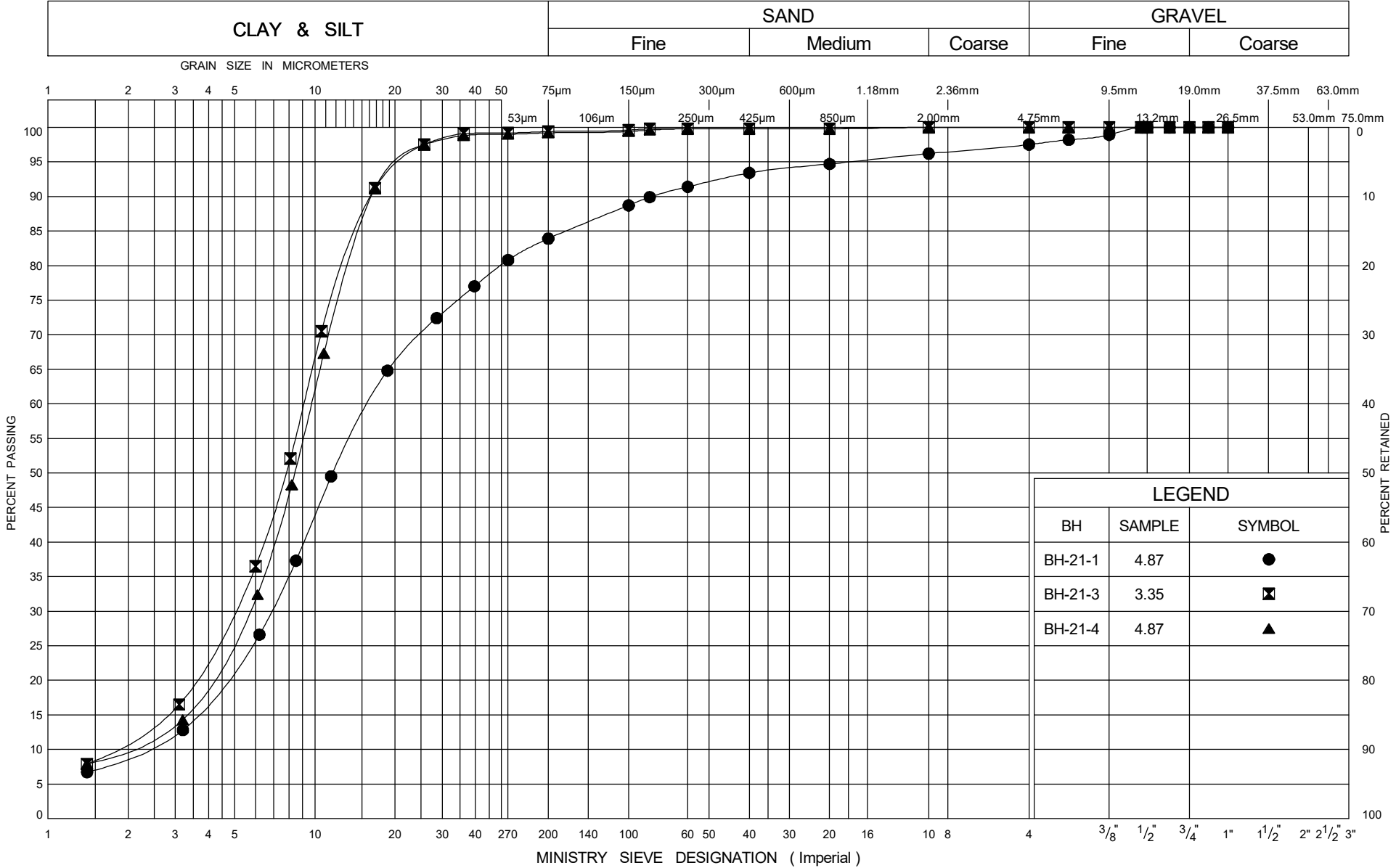
W P Agreement No. 5018-E-0012, W

Hearst Patrol Yard, Highway 11, Coc

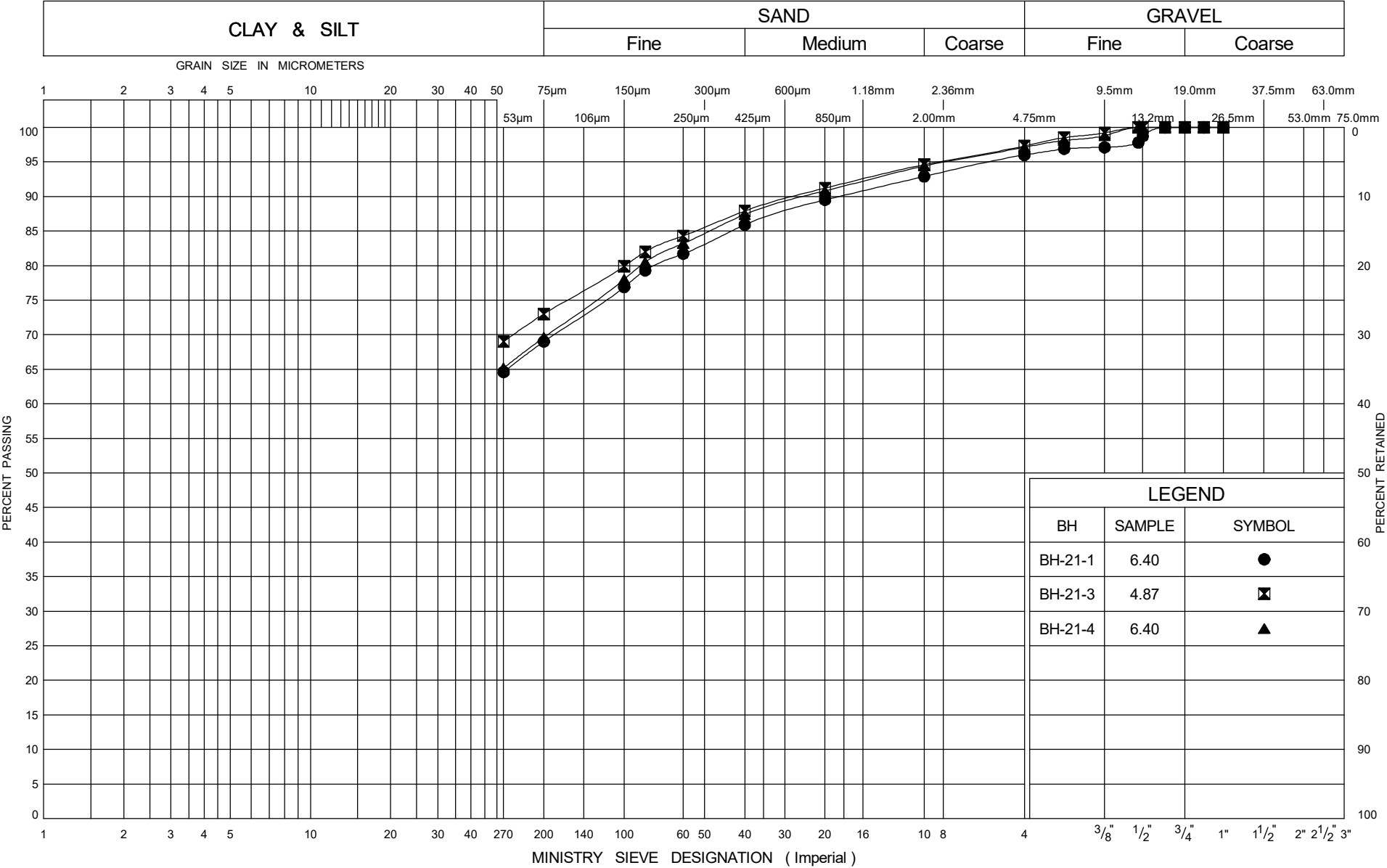
UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



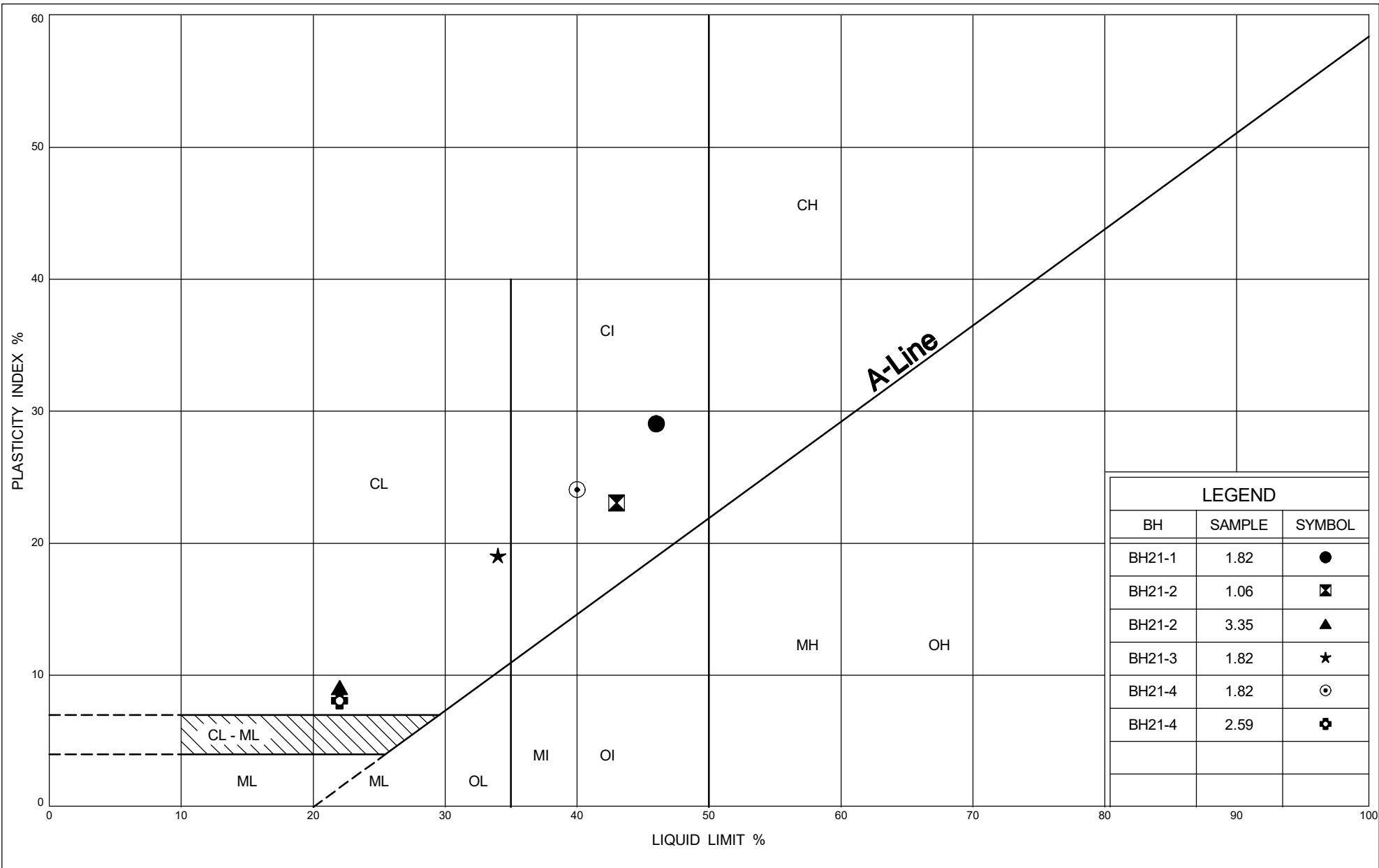
GRAIN SIZE DISTRIBUTION

Sandy Silt Till

FIG No 4

W P Agreement No. 5018-E-0012, W

Hearst Patrol Yard, Highway 11, Coc



Ministry of
Transportation

PLASTICITY CHART

Clayey Silt to Silty Clay

FIG No 5

W P Agreement No. 5018-E-0012, W

Hearst Patrol Yard, Highway 11, Coc



FINAL REPORT

CA14216-JUN21 R1

757843

Prepared for

EXP Services Inc.

First Page

CLIENT DETAILS

Client EXP Services Inc.

Address 885 Reagent Street
Sudbury, Ontario
P3E 5M4, Canada

Contact Ian MacMillan

Telephone 705-674-9681

Facsimile 705-674-5583

Email ian.macmillan@exp.com

Project 757843

Order Number

Samples Soil (1)

LABORATORY DETAILS

Project Specialist Jill Campbell, B.Sc.,GISAS

Laboratory SGS Canada Inc.

Address 185 Concession St., Lakefield ON, K0L 2H0

Telephone 2165

Facsimile 705-652-6365

Email jill.campbell@sgs.com

SGS Reference CA14216-JUN21

Received 06/15/2021

Approved 06/21/2021

Report Number CA14216-JUN21 R1

Date Reported 06/21/2021

COMMENTS

Temperature of Sample upon Receipt: 2 degrees C

Cooling Agent Present:Yes

Custody Seal Present:Yes

Chain of Custody Number:NA

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

SIGNATORIES

Jill Campbell, B.Sc.,GISAS





TABLE OF CONTENTS

First Page..... 1-2

Index..... 3

Results..... 4-5

QC Summary..... 6-7

Legend..... 8

Annexes..... 9



FINAL REPORT

CA14216-JUN21 R1

Client: EXP Services Inc.

Project: 757843

Project Manager: Ian MacMillan

Samplers: Phil Laframboise

PACKAGE: - Corrosivity Index (SOIL)

Sample Number 5
Sample Name 21-3, SS4
Sample Matrix Soil
Sample Date 09/06/2021

Parameter	Units	RL	Result
Corrosivity Index			
Corrosivity Index	none	1	11
Soil Redox Potential	mV	-	222
Sulphide (Na ₂ CO ₃)	%	0.04	< 0.04
pH	pH Units	0.05	7.82
Resistivity (calculated)	ohms.cm	-9999	319

PACKAGE: - General Chemistry (SOIL)

Sample Number 5
Sample Name 21-3, SS4
Sample Matrix Soil
Sample Date 09/06/2021

Parameter	Units	RL	Result
General Chemistry			
Conductivity	uS/cm	2	3130

PACKAGE: - Metals and Inorganics (SOIL)

Sample Number 5
Sample Name 21-3, SS4
Sample Matrix Soil
Sample Date 09/06/2021

Parameter	Units	RL	Result
Metals and Inorganics			
Moisture Content	%	0.1	17.7
Sulphate	µg/g	0.4	11



FINAL REPORT

CA14216-JUN21 R1

Client: EXP Services Inc.
Project: 757843
Project Manager: Ian MacMillan
Samplers: Phil Laframboise

PACKAGE: - Other (ORP) (SOIL)

Sample Number 5
Sample Name 21-3, SS4
Sample Matrix Soil
Sample Date 09/06/2021

Parameter	Units	RL	Result
Other (ORP)			
Chloride	µg/g	0.4	3200



FINAL REPORT

CA14216-JUN21 R1

QC SUMMARY

Anions by IC
Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0269-JUN21	µg/g	0.4	<0.4	NV	20	97	80	120	94	75	125
Sulphate	DIO0269-JUN21	µg/g	0.4	<0.4	13	20	93	80	120	103	75	125

Carbon/Sulphur
Method: ASTM E1915-07A | Internal ref.: ME-CA-IENVIARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide (Na2CO3)	ECS0043-JUN21	%	0.04	< 0.04	8	20	108	80	120			

Conductivity
Method: SM 2510 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0320-JUN21	uS/cm	2	< 2	0	20	100	90	110	NA		



FINAL REPORT

CA14216-JUN21 R1

QC SUMMARY

pH
Method: SM 4500 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0320-JUN21	pH Units	0.05	NA	0		100			NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

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

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

Multielement Scan Qualifier: as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

Duplicate Qualifier: for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Matrix Spike Qualifier: for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

LEGEND

FOOTNOTES

NSS Insufficient sample for analysis.

RL Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

NA The sample was not analysed for this analyte

ND Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/terms_and_conditions.htm. The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

This report must not be reproduced, except in full. This report supersedes all previous versions.

-- End of Analytical Report --



FINAL REPORT

CA14215-JUN21 R

757843

Prepared for

EXP Services Inc.

First Page

CLIENT DETAILS

Client EXP Services Inc.

Address 885 Reagent Street
Sudbury, Ontario
P3E 5M4, Canada

Contact Ian MacMillan

Telephone 705-674-9681

Facsimile 705-674-5583

Email ian.macmillan@exp.com

Project 757843

Order Number

Samples Soil (1)

LABORATORY DETAILS

Project Specialist Jill Campbell, B.Sc.,GISAS

Laboratory SGS Canada Inc.

Address 185 Concession St., Lakefield ON, K0L 2H0

Telephone 2165

Facsimile 705-652-6365

Email jill.campbell@sgs.com

SGS Reference CA14215-JUN21

Received 06/15/2021

Approved 06/18/2021

Report Number CA14215-JUN21 R

Date Reported 06/18/2021

COMMENTS

CCME Method Compliance: Analyses were conducted using analytical procedures that comply with the Reference Method for the CWS for Petroleum Hydrocarbons in Soil and have been validated for use at the SGS laboratory, Lakefield, ON site.

Hydrocarbon results are expressed on a dry weight basis.

Temperature of Sample upon Receipt: 2 degrees C

Cooling Agent Present:Yes

Custody Seal Present:Yes

Chain of Custody Number:NA

SIGNATORIES

Jill Campbell, B.Sc.,GISAS





TABLE OF CONTENTS

First Page..... 1-2

Index..... 3

Results..... 4-5

Exceedance Summary..... 6

QC Summary..... 7-9

Legend..... 10

Annexes..... 11



FINAL REPORT

CA14215-JUN21 R

Client: EXP Services Inc.
Project: 757843
Project Manager: Ian MacMillan
Samplers: Phil Laframboise

PACKAGE: REG153 - BTEX (SOIL)

Sample Number 8
Sample Name 21-2, SS3
Sample Matrix Soil
Sample Date 09/06/2021

L1 = REG153 / SOIL / COARSE - TABLE 3 - Industrial/Commercial - UNDEFINED
L2 = REG153 / SOIL / COARSE - TABLE 3 - Residential/Parkland - UNDEFINED

Parameter	Units	RL	L1	L2	Result
BTEX					
Benzene	µg/g	0.02	0.32	0.21	< 0.02
Ethylbenzene	µg/g	0.05	9.5	2	< 0.05
Toluene	µg/g	0.05	68	2.3	< 0.05
Xylene (total)	µg/g	0.05	26	3.1	< 0.05
m/p-xylene	µg/g	0.05			< 0.05
o-xylene	µg/g	0.05			< 0.05

PACKAGE: REG153 - Metals and Inorganics (SOIL)

Sample Number 8
Sample Name 21-2, SS3
Sample Matrix Soil
Sample Date 09/06/2021

L1 = REG153 / SOIL / COARSE - TABLE 3 - Industrial/Commercial - UNDEFINED
L2 = REG153 / SOIL / COARSE - TABLE 3 - Residential/Parkland - UNDEFINED

Parameter	Units	RL	L1	L2	Result
Metals and Inorganics					
Moisture Content	%	-			20.2



FINAL REPORT

CA14215-JUN21 R

Client: EXP Services Inc.
Project: 757843
Project Manager: Ian MacMillan
Samplers: Phil Laframboise

PACKAGE: REG153 - PHCs (SOIL)

Sample Number 8
Sample Name 21-2, SS3
Sample Matrix Soil
Sample Date 09/06/2021

L1 = REG153 / SOIL / COARSE - TABLE 3 - Industrial/Commercial - UNDEFINED
L2 = REG153 / SOIL / COARSE - TABLE 3 - Residential/Parkland - UNDEFINED

Parameter	Units	RL	L1	L2	Result
PHCs					
F1 (C6-C10)	µg/g	10	55	55	< 10
F1-BTEX (C6-C10)	µg/g	10			< 10
F2 (C10-C16)	µg/g	10	230	98	< 10
F3 (C16-C34)	µg/g	50	1700	300	< 50
F4 (C34-C50)	µg/g	50	3300	2800	< 50
Chromatogram returned to baseline at nC50	Yes / No	-			YES

EXCEEDANCE SUMMARY

No exceedances are present above the regulatory limit(s) indicated



FINAL REPORT

CA14215-JUN21 R

QC SUMMARY

Petroleum Hydrocarbons (F1)

Method: CCME Tier 1 | Internal ref.: ME-CA-IENVIGC-LAK-AN-010

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
F1 (C6-C10)	GCM0309-JUN21	µg/g	10	<10	ND	30	102	80	120	92	60	140

Petroleum Hydrocarbons (F2-F4)

Method: CCME Tier 1 | Internal ref.: ME-CA-IENVIGC-LAK-AN-010

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
F2 (C10-C16)	GCM0304-JUN21	µg/g	10	<10	ND	30	90	80	120	88	60	140
F3 (C16-C34)	GCM0304-JUN21	µg/g	50	<50	ND	30	90	80	120	88	60	140
F4 (C34-C50)	GCM0304-JUN21	µg/g	50	<50	ND	30	90	80	120	88	60	140



FINAL REPORT

CA14215-JUN21 R

QC SUMMARY

Volatile Organics

Method: EPA 5035A/5030B/8260C | Internal ref.: ME-CA-IENVIGC-LAK-AN-004

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Benzene	GCM0308-JUN21	µg/g	0.02	< 0.02	ND	50	102	60	130	94	50	140
Ethylbenzene	GCM0308-JUN21	µg/g	0.05	< 0.05	ND	50	101	60	130	95	50	140
m/p-xylene	GCM0308-JUN21	µg/g	0.05	< 0.05	ND	50	103	60	130	91	50	140
o-xylene	GCM0308-JUN21	µg/g	0.05	< 0.05	ND	50	102	60	130	91	50	140
Toluene	GCM0308-JUN21	µg/g	0.05	< 0.05	ND	50	101	60	130	93	50	140

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

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

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

Multielement Scan Qualifier: as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

Duplicate Qualifier: for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Matrix Spike Qualifier: for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.



FINAL REPORT

CA14215-JUN21 R

QC SUMMARY

LEGEND

FOOTNOTES

NSS Insufficient sample for analysis.

RL Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

NA The sample was not analysed for this analyte

ND Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/terms_and_conditions.htm. The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

This report must not be reproduced, except in full. This report supersedes all previous versions.

-- End of Analytical Report --

Request for Laboratory Services and CHAIN OF CUSTODY

Laboratory/Information Section - Lab use only

Received By: Ryan Lawrence
Received Date: 06/14/21 (mm/dd/yy)
Received Time: 16:00 (hr : min)Received By (signature): _____
Custody Seal Present: Yes ☒ No ☐
Custody Seal Inact: Yes ☒ No ☐Cooling Agent Present: Yes ☒ No ☐ Type: Ice
Temperature Upon Receipt (°C): 2.2

LAB LIMS #: _____

CA14215-16 Jan 21

REPORT INFORMATION

INVOICE INFORMATION

Company: EXP
Contact: Ian Williams
Address: 885 Regent St
Sudbury P3E 5M4
Phone: 705 674 0681
Fax: _____
Email: ian.williams@exp.comQuotation #: 50A
Project #: 257843-NO
P.O. #: _____
Site Location/ID: _____
TURNAROUND TIME (TAT) REQUIRED
☒ Regular TAT (5-7 days)
RUSH TAT (Additional Charges May Apply): ☐ 1 Day ☐ 2 Days ☐ 3 Days ☐ 5 Days
PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION
Specify Due Date: _____TAT's are quoted in business days (exclude statutory holidays & weekends).
Samples received after 5pm or on weekends: TAT begins next business day
NOTE: DRINKING (POTABLE) WATER SAMPLES FOR HUMAN CONSUMPTION MUST BE SUBMITTED WITH SGS DRINKING WATER CHAIN OF CUSTODY

REGULATIONS

ANALYSIS REQUESTED

☐ O.Reg 153/04 ☐ O.Reg 406/19
Other Regulations: _____
☐ Res/Part ☐ Soil Texture: _____
☐ Table 1 ☐ Ind/Com ☐ Coarse ☐ PW/QO ☐ JMER ☐ Sanitary ☐ Storm
☐ Table 2 ☐ Agri/Other ☐ Medium/Fine ☐ CCME ☐ Other: _____
☐ Table 3 ☐ MISA ☐ Municipality: _____
Soil Volume: ☒ <350m3 ☐ >350m3 ☐ O.DWS Not Reportable *See note

RECORD OF SITE CONDITION (RSC)

☐ YES ☐ NO

SAMPLE IDENTIFICATION

DATE SAMPLED 6/9/21 TIME SAMPLED AM # OF BOTTLES 3 MATRIX S

Field Filtered (Y/N)

Metals & Inorganics
(incl CrVI, CN, Hg, pH, B(HWS), EC, SAR-soil)
(Cl, Na-water)Full Metals Suite
ICP metals plus B(HWS-soil only) Hg, CrVIICP Metals only
Sb, As, Ba, Be, B, Cd, C, Co, Cu, Pb, Mo, Ni

PAHs only

SVOCs
All incl PAHs, ABNs, CPsPCB: ☐ Total ☐ Aroclor☒ F1-F4 + BTEXF1-F4 only
no BTEXVOCs
all incl BTEX

BTEX only

Pesticides
Organochlorine or specify other☒ CorrosivityAppendix 2: 406/19 Leachate
Screening Levels Table: _____Sewer Use:
Specify pkg:

Water Characterization Pkg

General ☐ Extended ☐
☐ TCLP ☐ VOC ☐ ICP ☐ MSA ☐ Specific
☐ Ignit ☐ ABN ☐ Bie/p ☐ PCB ☐ Tests

COMMENTS:

Bogged Sample

Observations/Comments/Special Instructions

332979918544 09

Sampled By (NAME): PHIL AFRAMBOISESignature: Phil AframboiseDate: 06.14.21 (mm/dd/yy)

Pink Copy - Client

Relinquished by (NAME): PHIL AFRAMBOISESignature: Phil AframboiseDate: 06.14.21 (mm/dd/yy)

Yellow & White Copy - SGS

Revision # 1.4

Date of Issue: 22 May, 2020

Note: Submission of samples to SGS is acknowledgement that you have been provided direction on sample collection, handling and transportation of samples. (2) Submission of samples to SGS is considered authorization for completion of work. Signatures may appear on this form or be retained on file in the contract, or in an alternative format (e.g. shipping documents). (3) Results may be sent by email to an unlimited number of addresses for no additional cost. Fax is available upon request. This document is issued by the Company under its General Conditions of Service accessible at http://www.sgs.com/terms_and_conditions.htm. (Printed copies are available upon request). Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.



exp Services Inc.
885 Regent Street
Sudbury, Ontario
P3E 5M4
Telephone: (705) 674-9681
Facsimile: (705) 674-8271

SUMMARY OF ROCK CORE TEST DATA
ASTM D7012 - 14 (Method C)

CLIENT: Ministry of Transportation
JOB NUMBER: ADM-257843-N0
JOB NAME: Hearst MTO Yard

DATE: June 16, 2021

LAB No.	21150	21151	21152	21153
CORE LOCATION	BH 21-2 (Run 1)	BH 21-2 (Run 2)	BH 21-4 (Run 2)	BH 21-4 (Run 2)
DEPTH	27'-27'9"	36'7"-37'10"	35'6"-35'10"	42'5"-42'11"
DATE TESTED	16-Jun-21	16-Jun-21	16-Jun-21	16-Jun-21
LENGTH (mm)	115.0	109.0	106.0	116.0
DIAMETER (mm)	47.0	47.0	47.0	47.0
DENSITY (kg/m ³)	2696	2824	2730	2723
COMPRESSIVE STRENGTH (MPa)	112.1	136.2	118.2	146.5
TYPE OF FRACTURE	SHEAR	SHEAR	SHEAR	SHEAR
CONDITION AT TIME OF TESTING	DRY	DRY	DRY	DRY

COMMENTS:

DISTRIBUTION:

Appendix E – Rock Core Photographs



Figure E1. Rock core from BH21-1

Project No: ADM 00257843-N0
BH No: 21-1
Sample Depth: 8.0 m to 9.1 m
Elevation: 238.4 m to 237.3 m
Description: Granitic rocks with mafic and
ultramafic intrusive rocks
Date: June 8, 2021

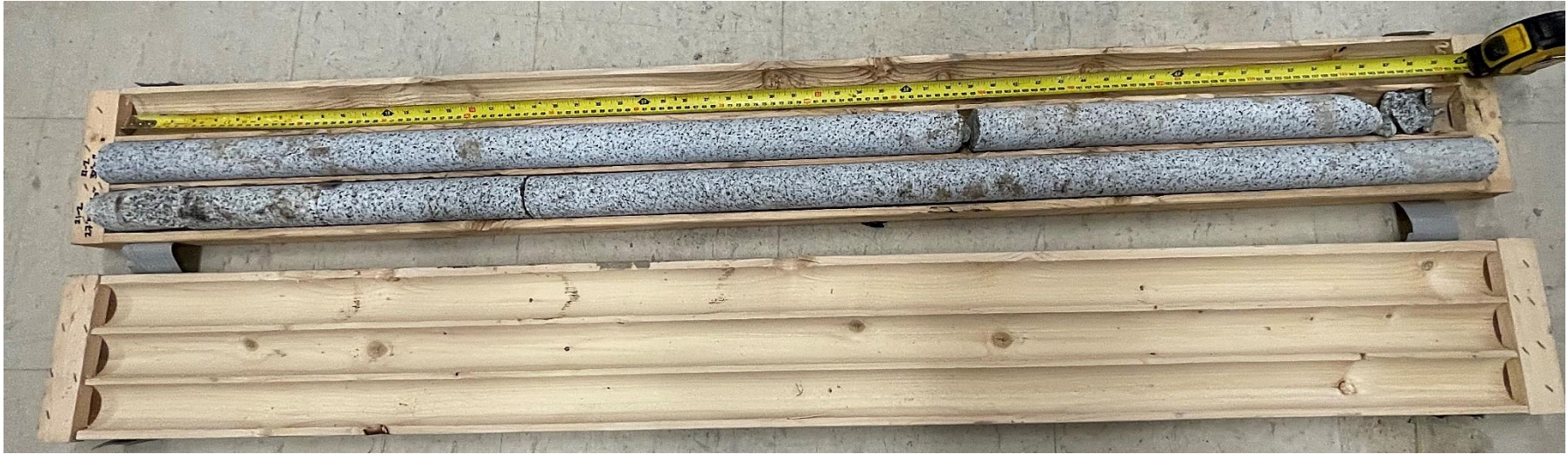


Figure E2. Rock core from BH21-2

Project No: ADM 00257843-N0
BH No: 21-2
Sample Depth: 8.5 m to 11.5 m
Elevation: 237.7 m to 234.7 m
Description: Granitic rocks with mafic and
ultramafic intrusive rocks
Date: June 9, 2021



Figure E3. Rock core from BH21-4

Project No: ADM 00257843-N0
BH No: 21-4
Sample Depth: 10.0 m to 13.1 m
Elevation: 236.7 m to 233.6 m
Description: Granitic rocks with mafic and
ultramafic intrusive rocks
Date: June 10, 2021

Appendix F – Results of Stability Analyses

**Hearst Patrol Yard
Global Stability
East-West Section
Undrained Static Analysis**

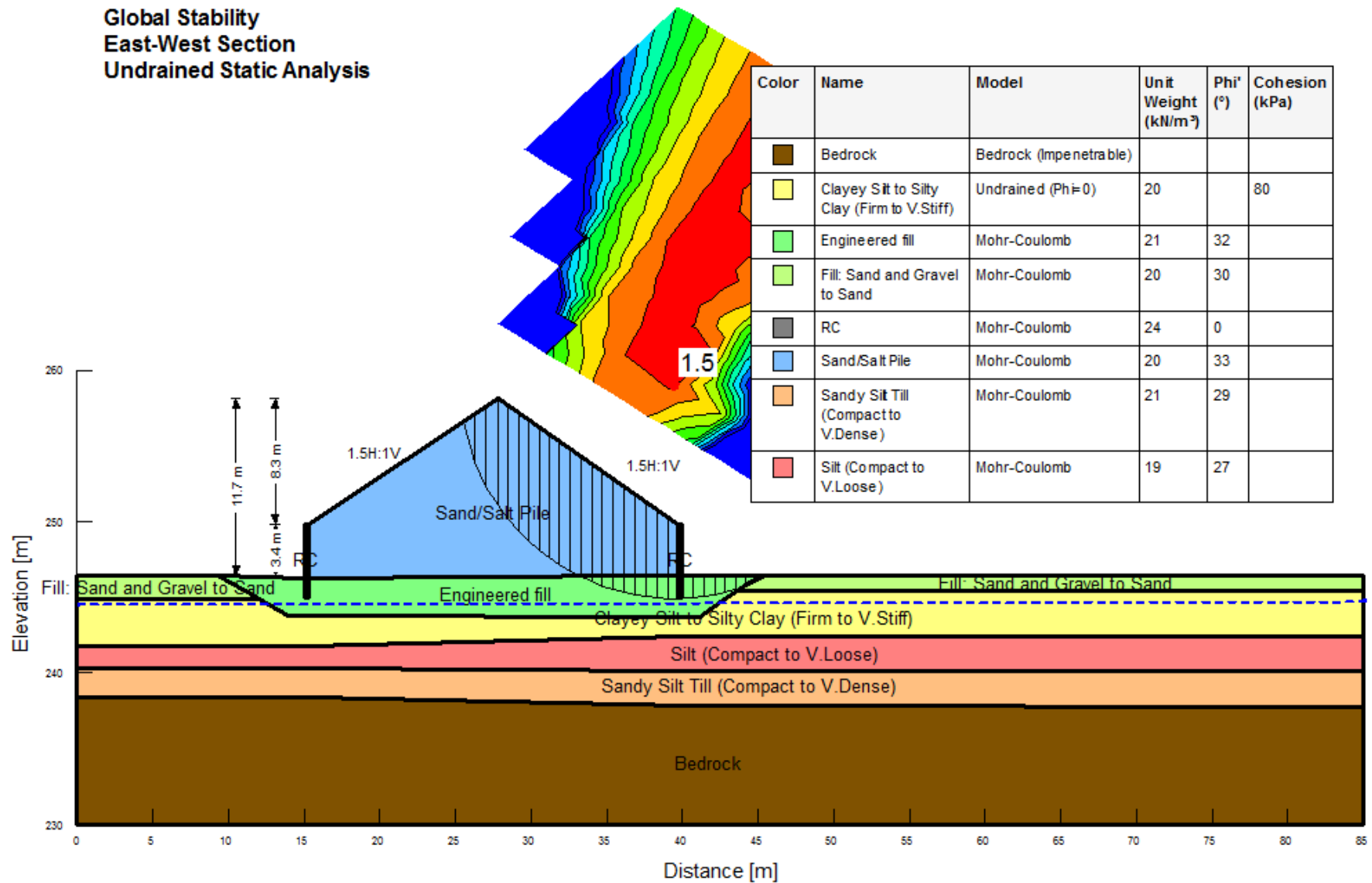


Figure F1. Global stability analyses for Hearst Patrol Yard – Undrained static analysis

Hearst Patrol Yard
Global Stability
East-West Section
Drained Static Analysis

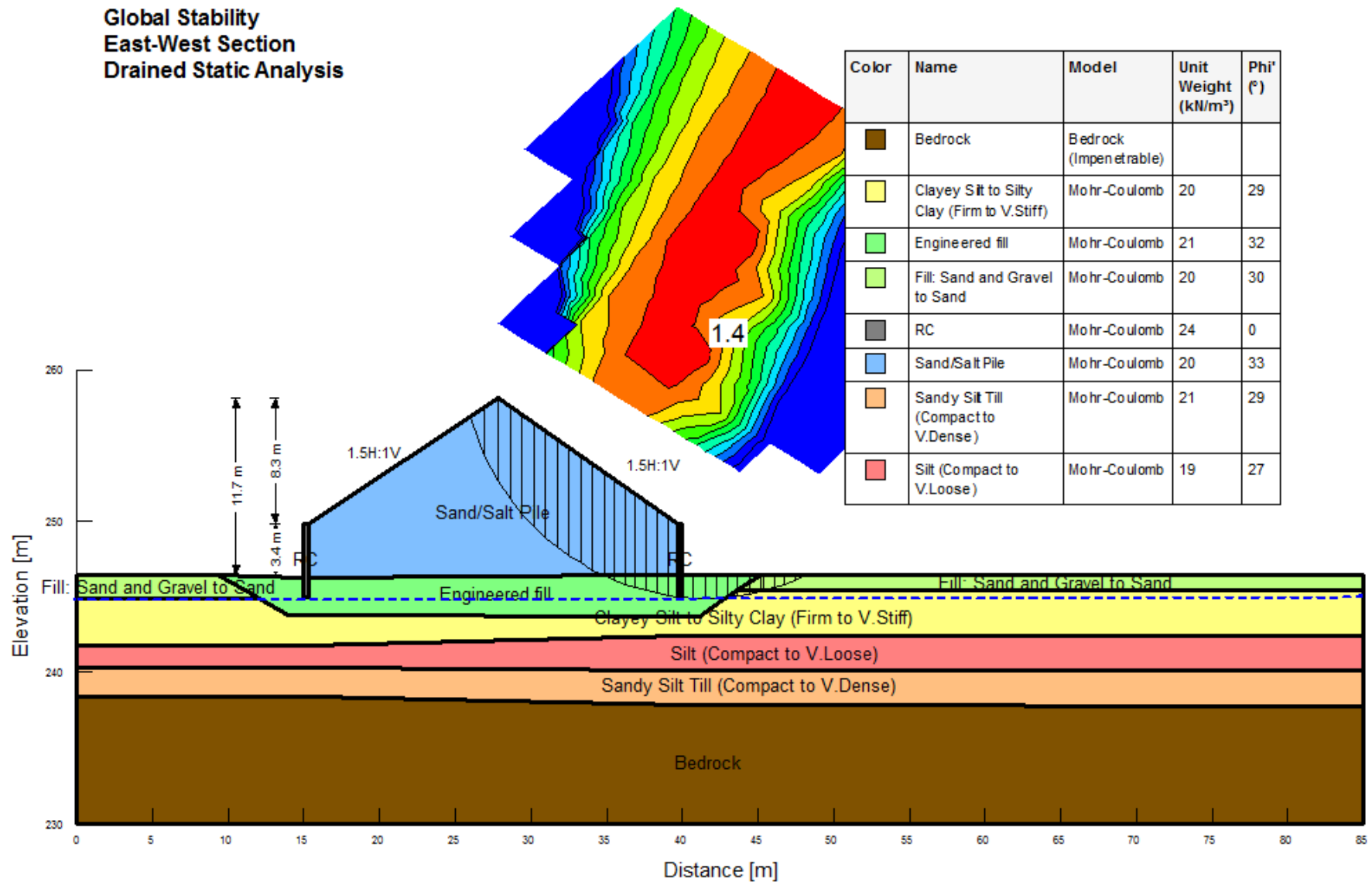


Figure F2. Global stability analyses for Hearst Patrol Yard – Drained static analysis

Hearst Patrol Yard
Stockpile Stability
North-South Section
Undrained Static Analysis

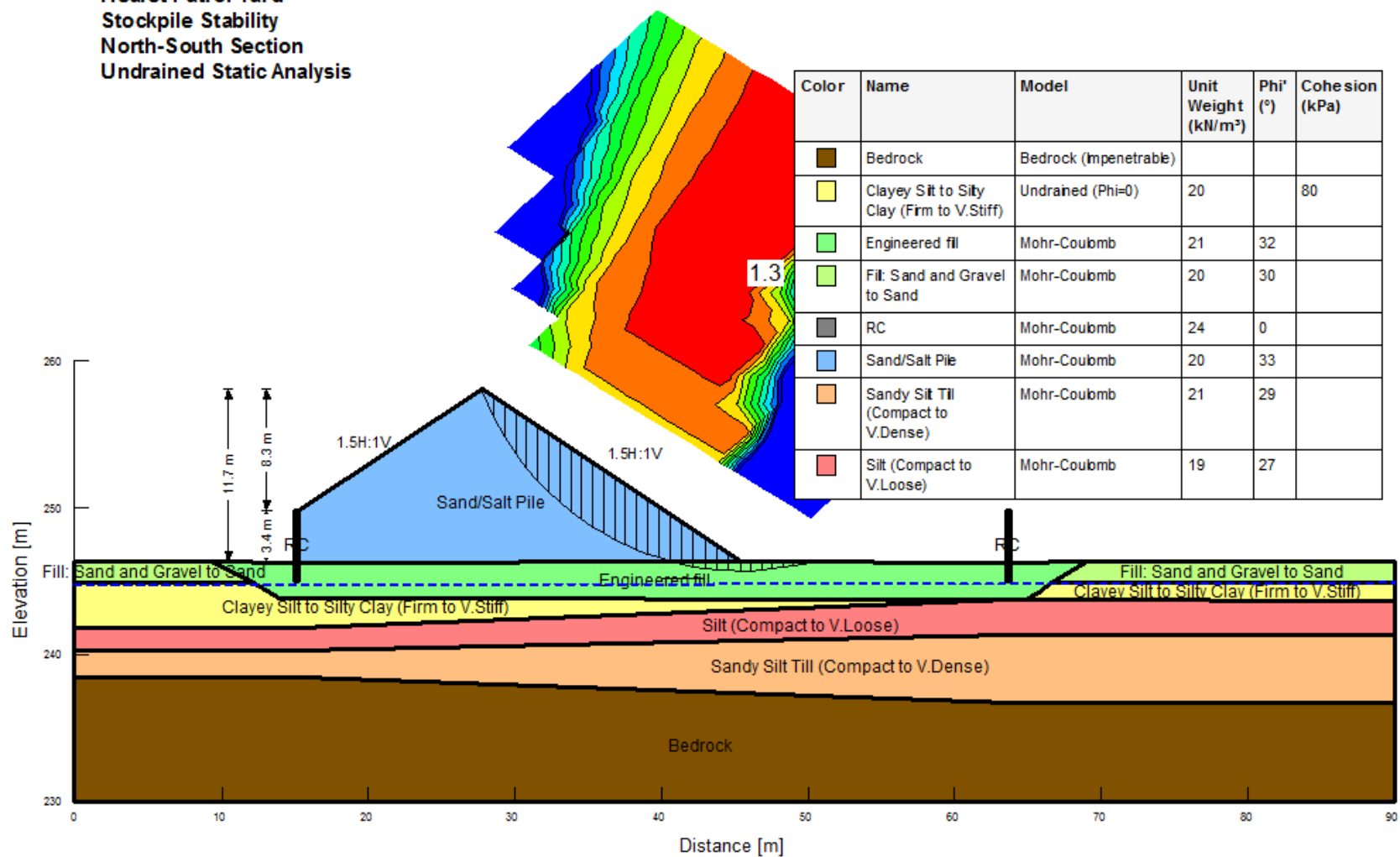


Figure F3. Stockpile stability for Hearst Patrol Yard – Undrained static analysis

**Hearst Patrol Yard
Stockpile Stability
North-South Section
Drained Static Analysis**

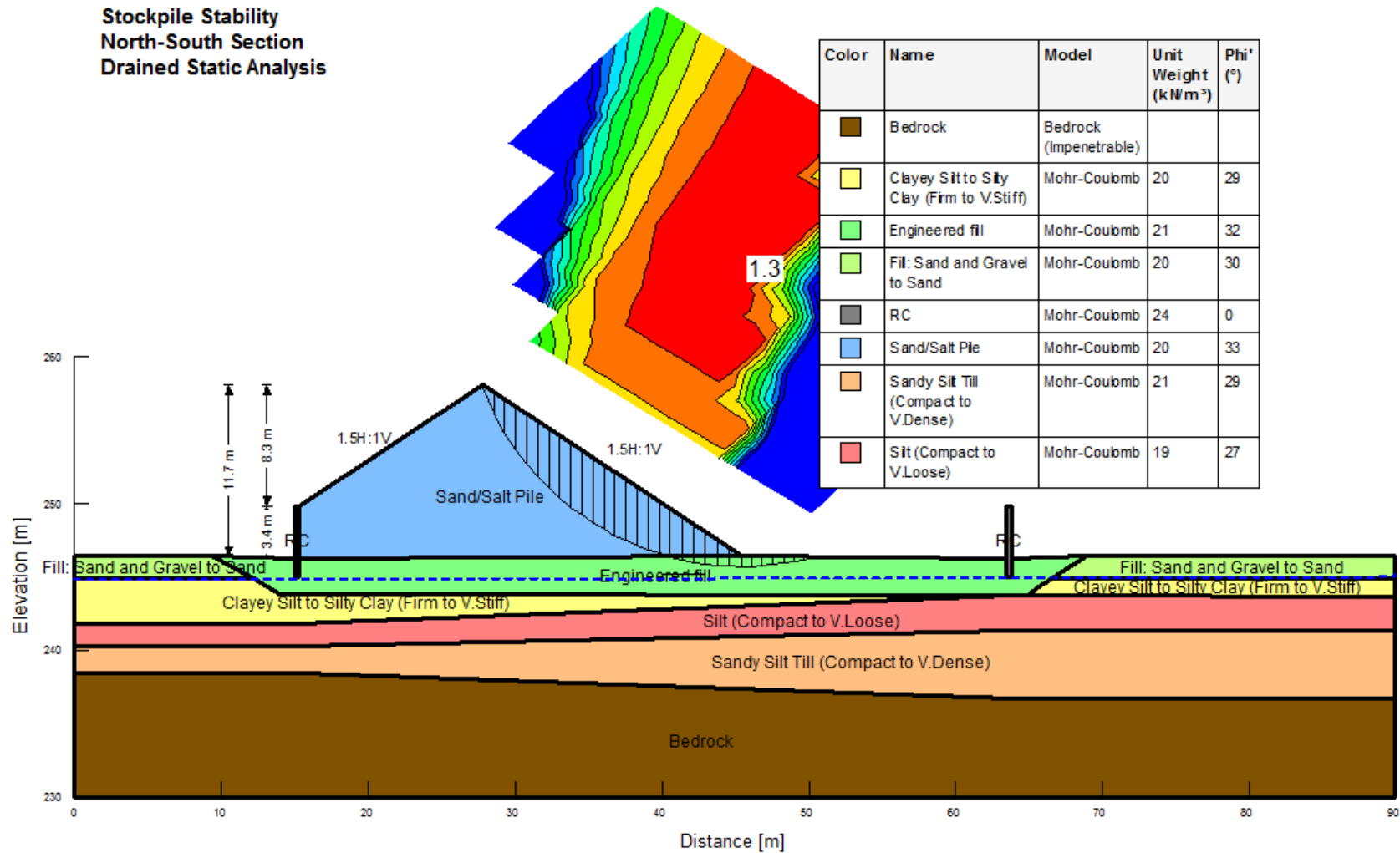


Figure F4. Stockpile stability for Hearst Patrol Yard – Drained static analysis

**Hearst Patrol Yard
Global Stability
East-West Section
Undrained Static Analysis
Preload virgin footprint of proposed building**

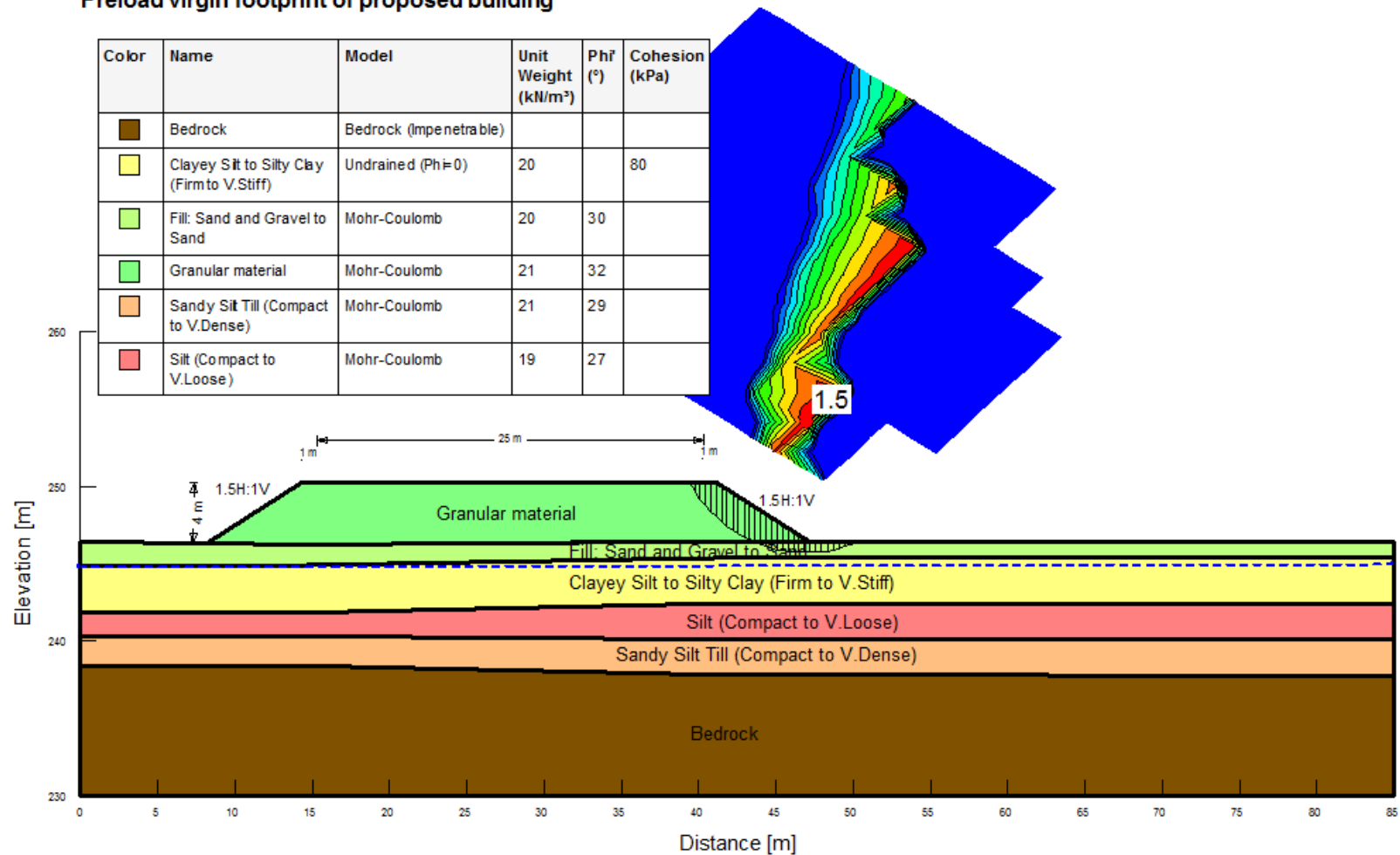


Figure F5. Stability analyses - Preloading (~4m high granular material) of virgin area of proposed building footprint – Undrained static analysis

Hearst Patrol Yard
Global Stability
East-West Section
Drained Static Analysis
Preload virgin footprint of proposed building

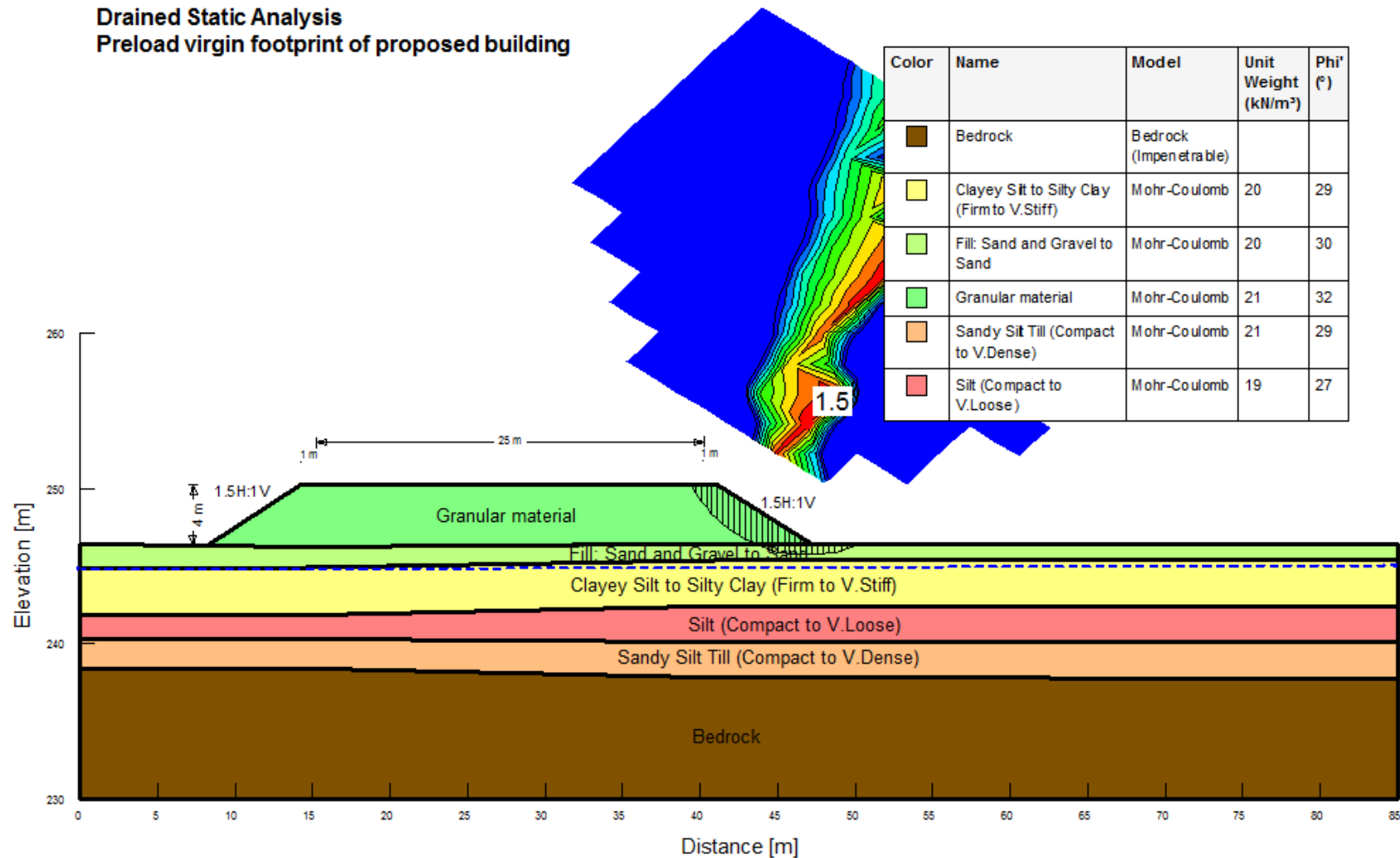
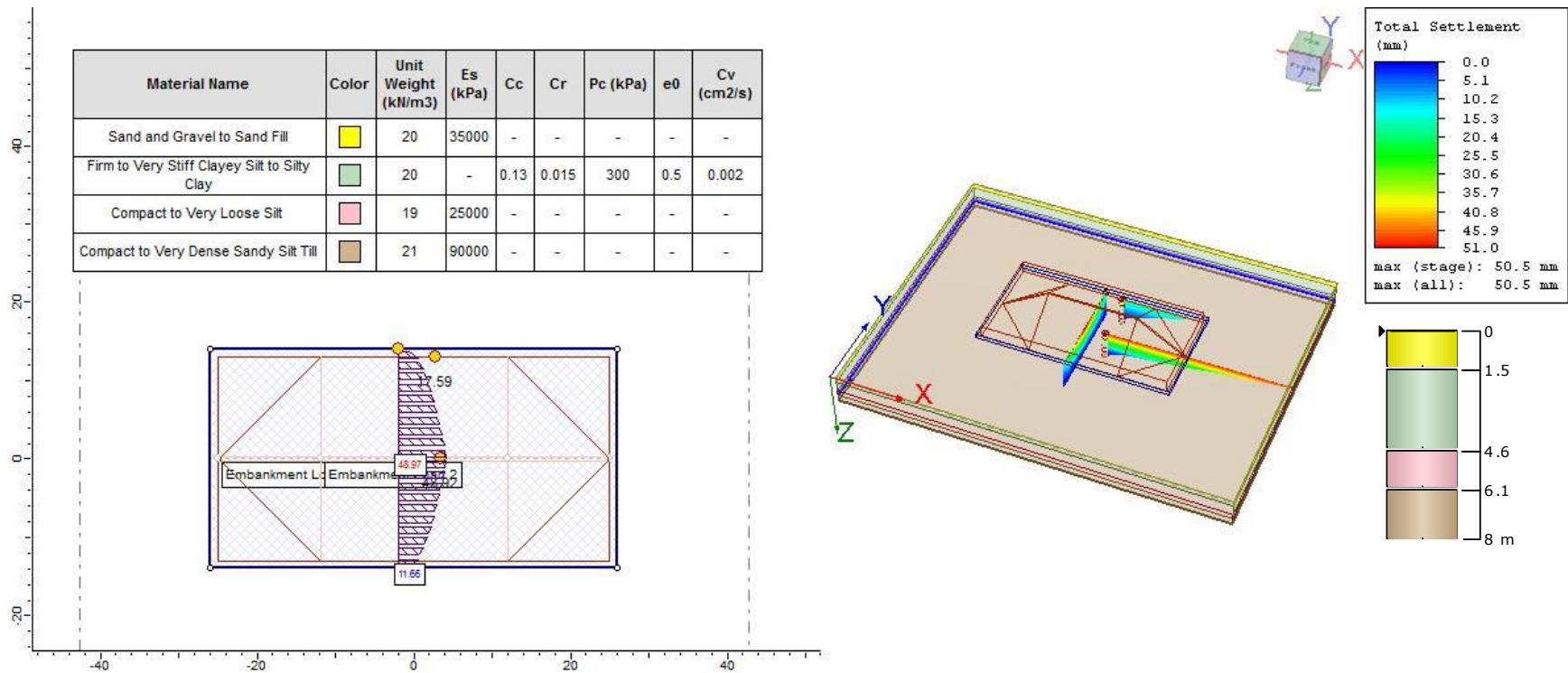


Figure F6. Stability analyses - Preloading (~4m high granular material) of virgin area of proposed building footprint – Drained static analysis

Appendix G – Results of Settlement Analyses



Project: Hearst Patrol Yard

Analysis Description: Full loading (North side)– **Total Settlement**

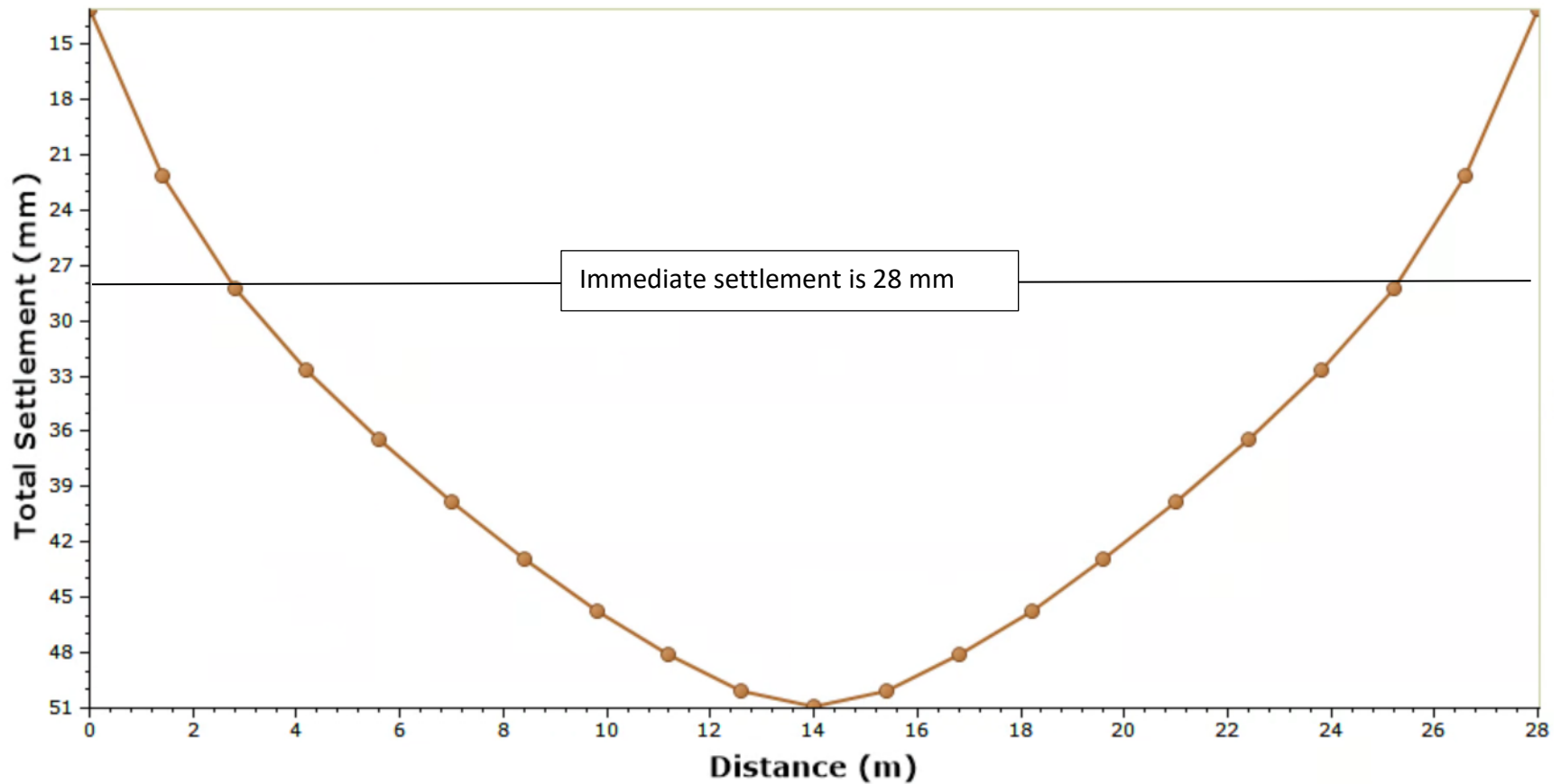
Figure No: G1

Company: EXP Services Inc.

Date: July, 2021

File Name: Settlement Analysis – Assignment 14

Distance vs. Total Settlement



Project: Hearst Patrol Yard

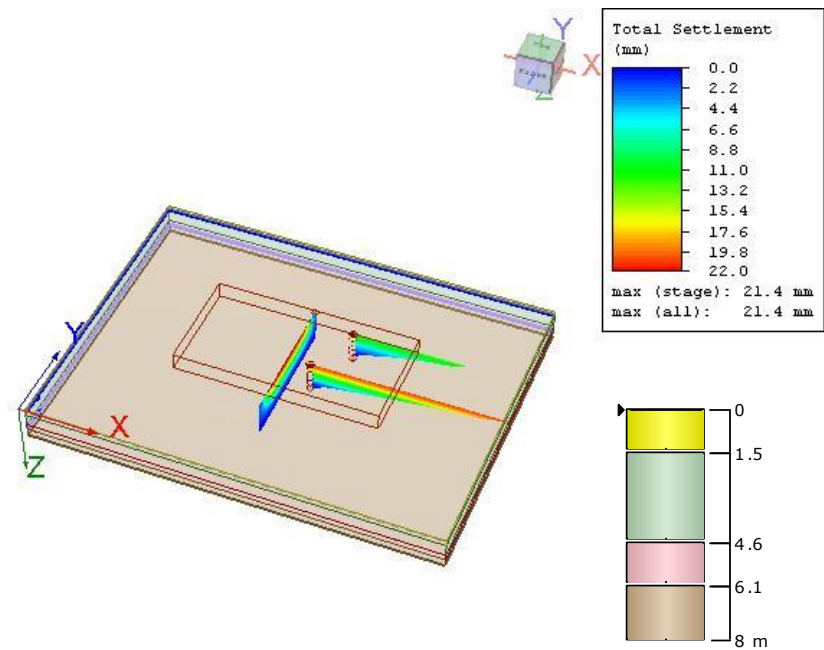
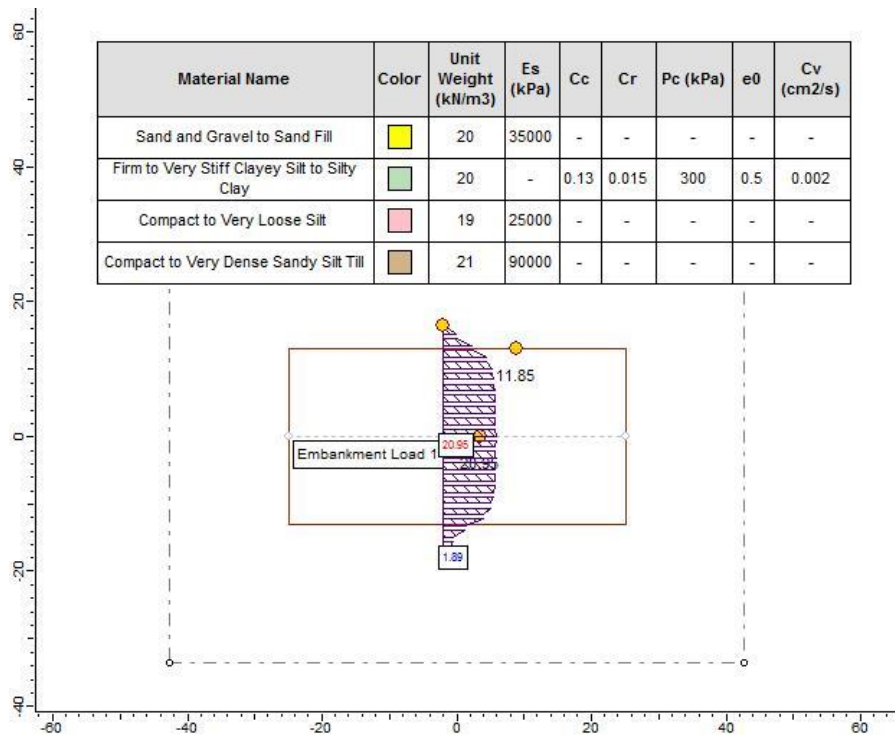
Analysis Description: Full loading (North side) – **Total Settlement Graph**

Figure No: G2

Company: EXP Services Inc.

Date: July, 2021

File Name: Settlement Analysis – Assignment 14



Project: Hearst Patrol Yard

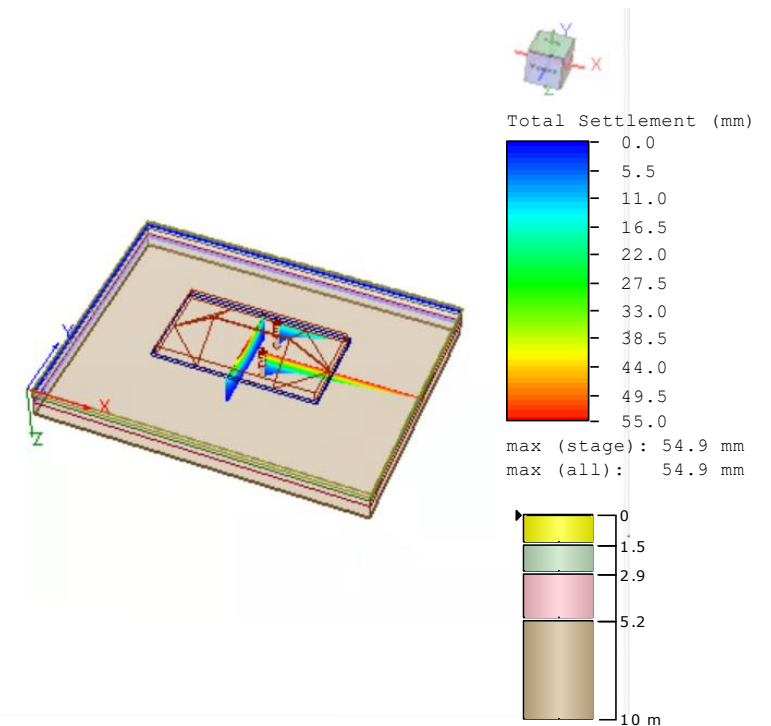
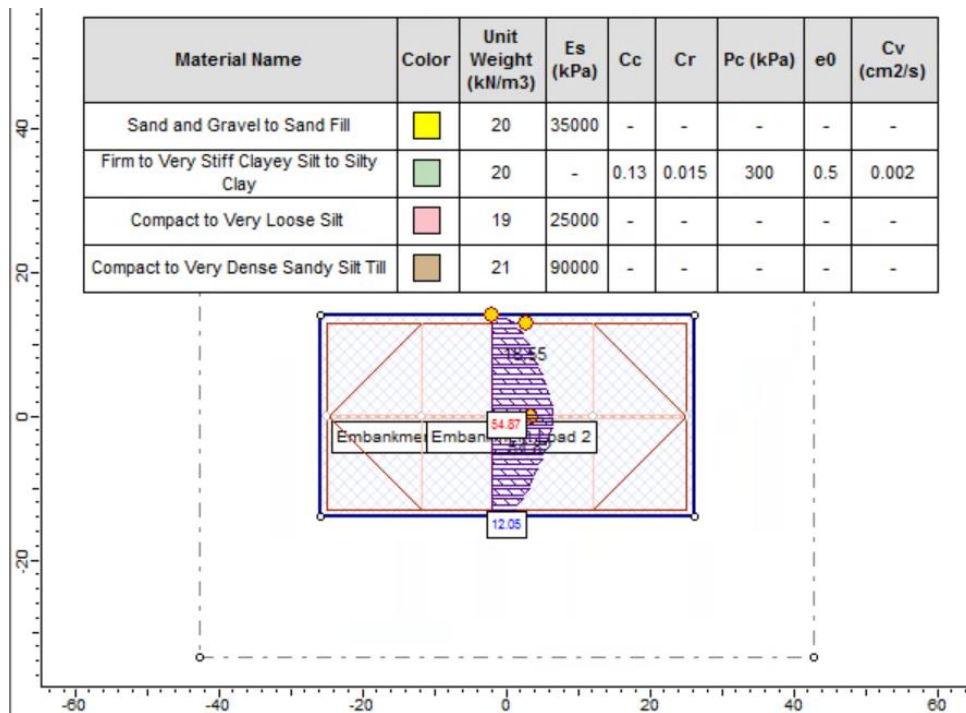
Analysis Description: Preloading: 4m (North side)– **Total Settlement**

Figure No: G3

Company: EXP Services Inc.

Date: July, 2021

File Name: Settlement Analysis – Assignment 14



Project: Hearst Patrol Yard

Analysis Description: Full loading (South side) – **Total Settlement**

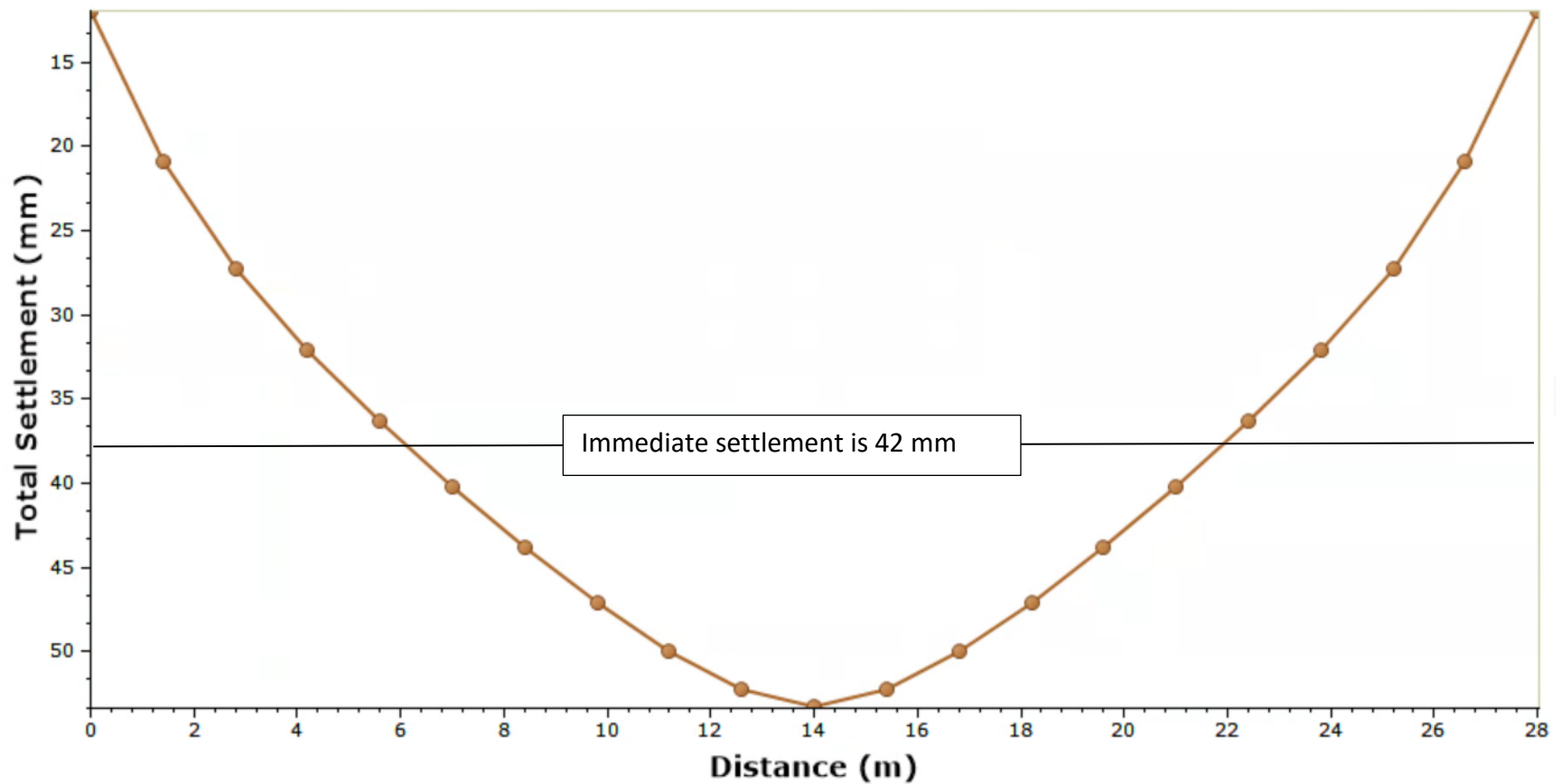
Figure No: G4

Company: EXP Services Inc.

Date: Oct, 2021

File Name: Settlement Analysis – Assignment 14

Distance vs. Total Settlement



Project: Hearst Patrol Yard

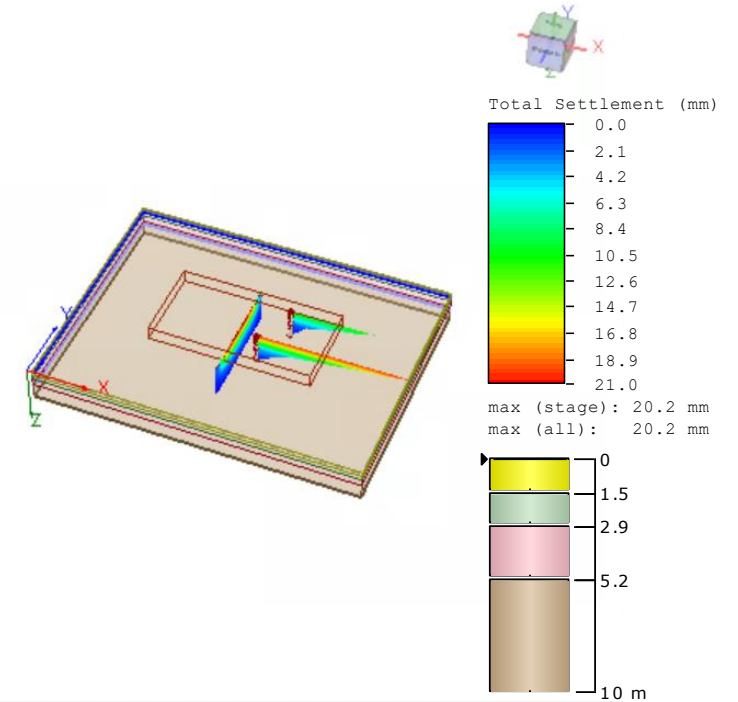
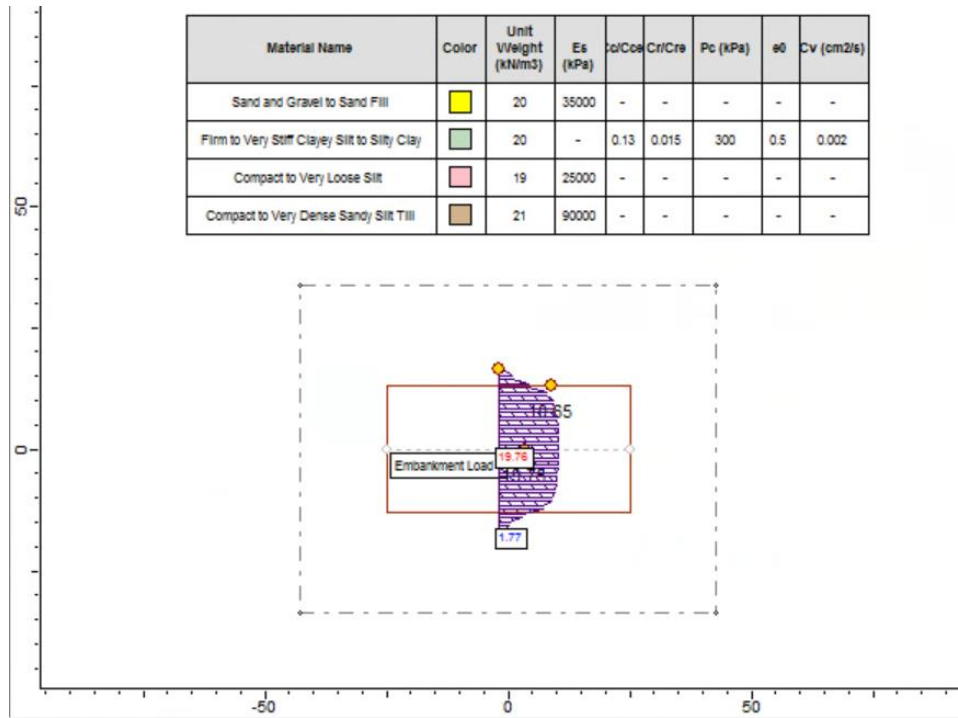
Analysis Description: Full loading (South side) – **Total Settlement Graph**

Figure No: G5

Company: EXP Services Inc.

Date: Oct, 2021

File Name: Settlement Analysis – Assignment 14



Project: Hearst Patrol Yard

Analysis Description: Preloading: 4m (South side)– **Total Settlement**

Figure No: G6

Company: EXP Services Inc.

Date: Oct, 2021

File Name: Settlement Analysis – Assignment 14

Appendix H – Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Site: 49.691N 83.691W

2021-07-02 23:37 UT

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.056	0.030	0.017	0.004
Sa (0.1)	0.078	0.043	0.026	0.007
Sa (0.2)	0.073	0.043	0.027	0.009
Sa (0.3)	0.060	0.037	0.024	0.008
Sa (0.5)	0.047	0.030	0.020	0.006
Sa (1.0)	0.028	0.017	0.011	0.003
Sa (2.0)	0.014	0.008	0.005	0.001
Sa (5.0)	0.003	0.002	0.001	0.000
Sa (10.0)	0.001	0.001	0.001	0.000
PGA (g)	0.043	0.024	0.015	0.004
PGV (m/s)	0.036	0.021	0.013	0.003

Notes: Spectral ($S_a(T)$, where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

References

National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information



Natural Resources
Canada

Ressources naturelles
Canada

Canada