APPENDIX A

SHM Canada Consulting Limited

Geotechnical Investigation
Port Bickerton East – Harbour Redevelopment

Type of Document:
Final

Project Name:
Port Bickerton East – Harbour Redevelopment

Project Number:
exp HFX-00231668-A1

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Date Completed:
2017-03-20

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Project No.: HFX-00231668-A1	Date: 2017.03.20
Type of Document: Final	Revision No.: 0
Prepared By: Brian Walker, P.Eng.	B Walker
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1 Introduction

Exp Services Inc. (**exp**) was retained by SHM Canada Consulting Limited (SHM) to carry out a geotechnical investigation for the Port Bickerton East Harbour Redevelopment project. This work was carried out to investigate the sub-surface conditions at the site and to provide geotechnical recommendations for the design and reconstruction of a portion of the existing wharf facility.

The heavy civil component of the proposed redevelopment generally includes:

- Reconstruction, and 20 m extension (approximately), of the existing cribwork wharf stem.
- Demolition of the existing wharf ell, and construction of a new 50 m ell (approximately) section to the west of the extended stem section.
- Construction of a 6 m wide service area on the east side of the wharf stem, with armoured embankment.
- Construction of new concrete retaining walls, floating docks and gangways, and relocation of existing docks, to the west of the existing cribwork wharf stem.

We understand that this work is being undertaken for Public Works and Government Services Canada (PWGSC), on behalf of the Department of Fisheries and Oceans (DFO). Port Bickerton East is a Small Craft Harbour, utilized primarily by the Canadian Coast Guard and local commercial fishery interests.

2 Site Description

The project site is located at Port Bickerton, approximately 20 km east of Sherbrooke, NS. Highway 211 (Marine Drive) runs through Port Bickerton, between Holland Harbour and Isaacs Harbour.

The existing Port Bickerton Wharf facility is comprised of a timber crib wharf stem and ell, a slip, and floating docks. The existing wharf stem is constructed in two pieces, with a service area located in the middle portion. Grades in the middle service area are above harbour level, surrounded by armour stone erosion protection, and occupied by several small buildings east and west of the wharf alignment. A reinforced concrete deck surface covers the timber crib sections of the wharf stem, the middle service area has a gravel travelling surface, and the ell has timber deck. A Coast Guard storage building and fueling station are located on the existing ell.

3 Fieldwork

The fieldwork for the geotechnical investigation consisted of a total of four boreholes advanced to depths ranging from approximately 3.2 m to 14.3.2 m below the harbour bottom. The investigation was carried out using a marine barge-mounted CME 45 drill rig, supplied and operated by Lantech Drilling. The investigation took place between December 12, 2016 and January 18, 2017.

The borehole investigation was conducted under the supervision of **exp** staff, who logged the sub-surface stratigraphy and collected representative soil and bedrock samples during the field investigation. Upon completion of the field investigation the samples were stored and transported to **exp** for review and laboratory index testing.

3.1 Investigation Methodology

Exp was responsible for service clearances to confirm that underground utilities were not present at the borehole locations. This is provided as general information only. Third parties should make their own inquiries with local authorities to confirm the presence or absence of utilities.

The borehole locations were selected to provide representative coverage of the area where the new wharf and service areas will be constructed. The boreholes were also placed in locations not covered by two historical investigations, conducted by Inspec-Sol. The locations of the boreholes are shown on attached Figure 1, which is based on PWGSC's May 2016 Concept Plan, labelled Sht1. It should be noted that proposed borehole BH-03 was not conducted due to delays in drilling operations related to challenging wind, wave and weather conditions. The information attained in the other boreholes, in conjunction with the historical borehole data, was determined to be sufficient for design.

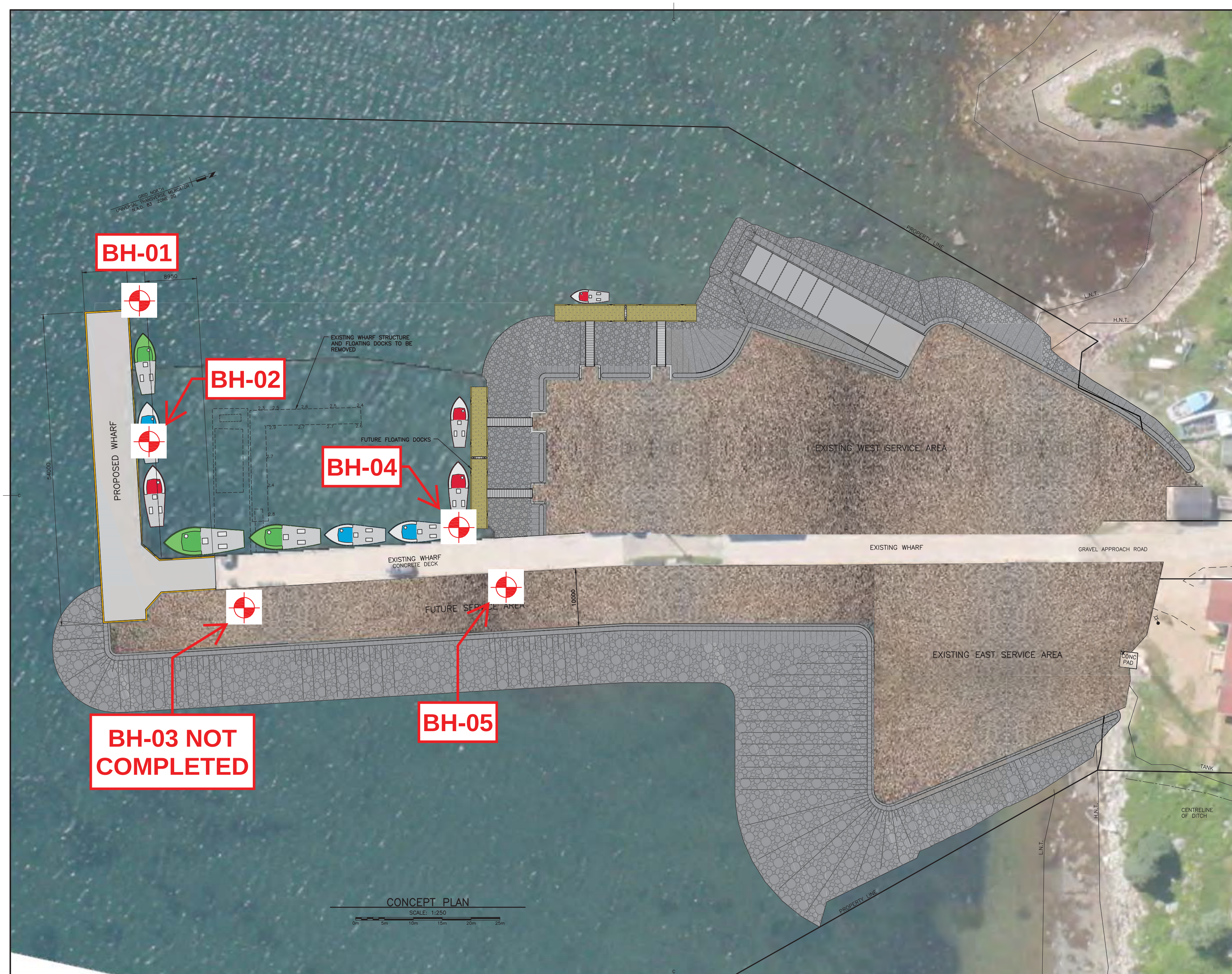
The boreholes were advanced using conventional casing/coring equipment. Representative soil samples were obtained from the 50 mm diameter split spoon sample during Standard Penetration Tests (SPT), conducted ahead of the casing. Coring was conducted using HQ sized equipment. A preliminary assessment of particle size, density, moisture, and colour was recorded for each soil sample. Rock cores were reviewed for colour, quality (RQD) and natural discontinuities.

3.2 Sample Storage and Lab Testing

Recovered samples from the field investigation were reviewed in the laboratory by an **exp** junior engineer and checked by a senior engineer in order to confirm stratigraphy and descriptions. Representative samples from different soil and bedrock strata were selected for laboratory analysis. The following tests were carried out:

- Moisture Content tests were conducted on 5 soil samples.
- Sieve tests were conducted on 4 soil samples to classify the soil strata.
- Unconfined Compressive Strength tests were performed on 2 representative bedrock samples.

The results of geotechnical laboratory tests are summarized on Table 1, attached. Copies of all lab test reports are included in Appendix 1.



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revisions | date

project | projet

NEW WHARF AND SERVICE AREA
PORT BICKERTON (EAST)
GUYSBOROUGH COUNTY
NOVA SCOTIA

drawing | dessin

CONCEPT PLAN

designed | conçu: M. WALSH
date: MAY 2016
drawn | dessiné: G. PROSPER
date: MAY 2016
approved | approuvé
date
Tender | Soumission
PWGSC Project Manager | Administrateur de projets TPSGC
project number | no. du projet
drawing no. | no. du dessin: Sht 1

E-DRM/GDD-E:

PWGSC B1 (2004)

Table 1- SUMMARY OF LABORATORY TEST RESULTS

CLIENT SHM Canada Consulting

LOCATION Port Bickerton (East) Wharf Expansion, NS

PROJECT No. HFX-00231668-A1

TESTING:
Moisture Content: 5
Atterberg Limits: 0
Sieve Analysis: 4
Hydrometer Test: 0
UCS: 2

Soil Deposit	Borehole/Sample	Depth (m)	Water Content (%)	Atterberg Limits			Sieve Analysis			UCS (MPa)
				Liquid Limit	Plastic Limit	Plasticity Index	Gravel (%)	Sand (%)	Fines (%)	
Bedrock	BH-01/RC - 6	12.0								70.6
Bedrock	BH-02/RC - 9	14.0								198.4
Sand and Gravel	BH-01/SS - 3	7.9	9.3				44.0	36.2	19.8	
Sand and Gravel	BH-02/SS - 1	4.7	21.5				45.3	44.1	10.6	
Sand and Gravel	BH-04/SS - 1	3.7	25.7				57.8	34.3	7.9	
Sand and Gravel	BH-04/SS - 4	5.5	7.3				48.2	42.5	9.3	
Sand and Gravel	BH-05/SS - 2	2.9	11.6				45.3	42.2	12.5	

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4 Surface and Subsurface Conditions

4.1 Summary of Conditions

The general stratigraphy encountered on the site included the following:

- **Thin layer of organic sediments at harbour bottom**
- **Native Sand and Gravel (GW-GM, GP-GM, GM)**
- **Quartzite Bedrock**

A summary of the subsurface profile encountered during the investigation is provided below in Table 2. Detailed borehole logs are provided in Appendix 2, and summary descriptions of the sub-surface conditions are given below in subsequent paragraphs. Note that elevations shown on borehole logs and discussed herein are relative to Chart Datum for Port Bickerton.

The sub-surface stratigraphy detailed on the borehole logs and in the descriptions of sub-surface conditions is only valid at the location where the boreholes were conducted. Stratigraphy should be expected to vary between borehole locations.

In general, the conditions encountered in the current boreholes were found to be consistent with those described from the two historical investigations. However, the thickness of the organic sediment layer was noted to be significantly thinner in the current boreholes compared to some nearby boreholes conducted in 2008. It should be noted that harbour maintenance and dredging has occurred between the current and historical investigations. We suspect the difference in the conditions at harbour bottom can be attributed to this recent maintenance work.

Table 2: Summary of Sub-Surface Stratigraphy

Borehole Location	Thickness of Organic Sediments (m)	Thickness of Sand and Gravel (m)	Depth to Bedrock below harbour bottom (m)	Elevation of Bedrock (m) [Chart datum]
BH-01	0.10	4.5	4.5	- 7.9
BH-02	0.10	4.9	5.0	- 8.0
BH-04	-	2.6	2.6	-4.4
BH-05	-	> 1.2*	-	-

* Borehole terminated prematurely in Sand and Gravel layer due to high winds and waves from incoming gale.

4.2 Detailed Descriptions of Sub-Surface Strata

4.2.1 Organic Harbour Sediments

A thin layer of organic sediment was found at harbour bottom in boreholes BH-01 and BH-02, only. The organic laden sediment was wet, very soft, brown to black in colour and exhibited an odour of organic decay.

4.2.2 Native Sand and Gravel (GW-GM, GP-GM, GM)

The primary layer of overburden soil encountered in the boreholes was compact to very dense native Sand and Gravel with trace to some silt. Under the Unified Soil Classification System (USCS), the material ranged in classification from 'Silty Gravel with Sand (GM)' to 'Well Graded Gravel with Silt and Sand (GW-GM)' to 'Poorly Graded Gravel with Silt and Sand (GP-GM)'. The Sand and Gravel was moist to wet, and grey-brown in colour. Occasional cobbles and small boulders were encountered throughout the layer, generally increasing in frequency with depth.

4.2.3 Quartzite Bedrock

Quartzite bedrock (Greywacke, meta-sediment) was encountered in all boreholes except BH-05 and was confirmed by coring operations. Competent bedrock was encountered at depths ranging from approximately 2.6 m to 5.0 m below harbour bottom. This corresponds to an elevation of approximately -8 m along the proposed new ell wharf section (BH-01 and BH-02). The elevation at BH-04, located near the middle of the stem section, was -4.4 m.

The bedrock generally exhibited very poor to good quality. However, the quality of the bedrock in BH-04 was notably poor, with low recovery and RQD values of 0 over the depth investigated. The bedrock had very close to moderate fracture spacing ranging from horizontal to approximately 35^{o} to horizontal, and it was grey in colour.

Unconfined compressive strength tests on intact core samples yielded strengths ranging from 70.6 MPa to 198.4 MPa. This classifies the rock strength as 'strong' to 'very strong'.

4.3 Geological Mapping

The available surficial geology indicates the overburden in the immediate vicinity of the of wharf is 'Stony Till Plain (Ground Moraine)' - Stony, sandy matrix, material derived from local bedrock sources. The native sand and gravel encountered on site is consistent with published mapping in the immediate area.

Published bedrock geology mapping indicates the site is underlain by the Goldenville Formation of the Meguma Group. This includes meta-sedimentary rocks consistent with the bedrock encountered in the current boreholes.

5 Discussion and Recommendations

We understand that the heavy civil component of the proposed redevelopment of the Port Bickerton East facility generally includes:

- Reconstruction, and 20 m extension (approximately), of the existing cribwork wharf stem.
- Demolition of the existing wharf ell, and construction of a new 50 m ell (approximately) section to the west of the extended stem section.
- Construction of a 6 m wide service area on the east side of the wharf stem, with armoured embankment.
- Construction of new concrete retaining walls, floating docks and gangways, and relocation of existing docks, to the west of the existing cribwork wharf stem.

We understand that the design concept under consideration for the stem section, would leave the majority of the existing cribwork in place. A Berlin type wall (soldier piles with concrete panel lagging) would be constructed with lateral pressures resisted by a buried concrete dead-man. The extended stem/tee section will be supported driven steel H piles, with new crib work possibly needed where the at-grade portion of the gravel service area extends beyond the existing crib work. The new ell section will be supported on driven steel vertical and battered H piles. Timber fender piles will be driven on the perimeter of the new ell section.

The major site-specific geotechnical considerations for the proposed Port Bickerton East redevelopment are summarized in the following points. Additional commentary and recommendations are provided in subsequent report sections.

- The site is underlain by a thin layer of soft organic sediments and compact to very dense native sands and gravels. These conditions are amenable to the placement of fills and structures without the need for special measures to mitigate excessive settlement. Local removal of the organic layer at harbour bottom will allow placement of materials directly over the native sands and gravels.
- We understand that the new wharf will be supported on driven steel HP 360x132 piles. The site is conducive to the use of driven steel H piles to support the wharf structure.
  - The overburden soils on the site will provide moderate to high shaft friction for driven piles but are relatively thin so total uplift resistance from the overburden will be relatively low.
  - The heavily fractured quartzite bedrock will provide high shaft friction, but like the overburden layer the thickness is limited so total uplift resistance will be relatively low.
  - The very strong competent quartzite bedrock will provide high end bearing resistance for driven steel piles. However, it will be important to use a heavy pile section to help ensure that driven piles penetrate the overburden and fractured bedrock, or penetrate far enough into the fractured rock to achieve design capacities without damage.
- SSP walls may also be considered in lieu of the Berlin type wall mentioned above. However, the presence of cobbles and boulders and relatively thin overburden layer presents some risk for an SSP wall design, where some SSP sections cannot penetrate the overburden and bedrock to the required depths. In general, we anticipate that SSP sections could be driven approximately 1 m to 1.5 m into the highly fractured bedrock. However, local over-excavation should be anticipated to facilitate driving some SSP sections to design depths, where large cobbles or small boulders are encountered in the

overburden. Some sections may also be refused at shallow depth in bedrock, where local strong beds are encountered.

- Either micro-piles or socketed pipe piles (caissons) would be feasible drilled solutions and could be designed to achieve high capacities on this site. However, it is not anticipated that drilled piles will be utilized, since the site is amenable to driven piles and the higher costs for drilled piles. Site specific design information can be provided for the design of micro-piles or socketed pipe piles, if designers consider this option during the detailed design process.

5.1 Driven Steel H Piles

Driven steel H piles may be used to support the new main wharf and ell sections. It is anticipated that steel H piles would reach practical refusal in the quartzite bedrock underlying the site.

5.1.1 Geotechnical Pile Capacity

The following design recommendations and geotechnical parameters are based on experience at similar sites and from published values for the types of soil and bedrock encountered on this site. It should be noted that these parameters are estimates to facilitate design and do not represent site-specific values. Consideration should be given to confirming that design values are achieved during construction by PDA (Pile Driving Analyzer) testing or full scale load testing on constructed piles.

We recommend that the maximum design value for factored ultimate geotechnical resistance of driven steel piles in axial compression be based on a stress in the pile section equal to 80 MPa, where piles are terminated in the quartzite bedrock layer. For the proposed HP360x132 pile section with a cross sectional area of 168 cm^2, the design factored ultimate geotechnical resistance is 1344 kN in axial compression. This includes a geotechnical resistance factor of 0.4, in accordance with the Canadian Foundation Engineering Manual (CanFEM, 4th Ed.)

We anticipate that driven steel H piles will be refused in the heavily fractured quartzite bedrock where larger, competent boulder size particles are intercepted by pile tips, or on the competent underlying quartzite bedrock. Pile penetration in bedrock is estimated at 2 m to 3 m, however, it should be noted that pile penetration depends on many factors which are not known and precise estimates are not possible. As mentioned above, it will be important to use a heavy pile section to help ensure that driven piles penetrate the fractured bedrock, or penetrate far enough into the fractured rock to achieve design capacities without damage.

For the proposed HP360x132 pile, the ultimate geotechnical uplift capacity from skin friction is estimated at 450 kN for this site. A geotechnical resistance factor of 0.3 should be applied to the calculated total ultimate uplift resistance, including the weight of the pile, as recommended in CanFEM, 4th Ed.

Preliminary lateral pile analysis suggests that the depth to fixity for the proposed driven steel H piles is 3.0 m below harbour bottom.

The parameters given above for pile capacities include the following assumptions:

- Piles are driven to practical refusal (pile set) of at least 15 blows per 25 mm for two consecutive sets.
- Piles terminate with tips in competent quartzite bedrock or on larger boulder size particles in the fractured quartzite bedrock.
- Piles are driven to practical refusal with a pile hammer having a rated energy of between 350 J/cm^2 and 450 J/cm^2.
- Piles are installed by driving over their entire length; drilling or vibratory methods are not used for installation.

It should be noted that the design shaft friction should be reduced by 50% for any piles that are to be advanced by drilled or vibratory methods. It is highly recommended that piles are installed over their entire length by driving with diesel, gravity, air or hydraulic pile hammers.

5.1.2 Down-Drag Loads

Given the limited thickness of the organic silt layer comprising harbour bottom, we recommend that down-drag loads (negative skin friction) do not need to be considered in pile design for the proposed redevelopment work.

5.1.3 Additional Considerations for Piles

A minimum pile spacing of three (3) times the outside diameter of the piles is recommended. This requirement can be reviewed if the need for smaller spacing arises during design.

Protective steel driving shoes should be utilized to minimize potential damage during hard driving in the fractured bedrock, for driven piles.

The pile set criteria for driven piles should be assessed by wave equation analyses once the final pile and pile driving system are determined. The pile set criteria should be confirmed, and adjusted as necessary, based on the results of PDA testing on initial production piles.

PDA testing should be conducted at the end of initial driving and during re-striking on representative driven piles. PDA measurements during re-strike is recommended to assess the potential effects of relaxation at the toe and/or soil set-up. A waiting period of at least one day is recommended before pile restrikes. A longer waiting period would be beneficial in assessing potential soil setup.

Full time inspection should be undertaken for the construction of pile foundations. Field records including pile equipment, pile lengths, depth to refusal, location of splices, blow counts, stroke, blow rate, drill spoils, rock type, etc. should be taken. The engineer should be notified of any anomalies or problems during installation, such as damage to piles during driving and early refusal, so that design assumptions can be reviewed.

5.2 Geotechnical Design Parameters

5.2.1 Parameters for Retaining Structures

The recommended geotechnical parameters to determine lateral earth pressures for design of the retaining structures are summarized below in Table 3. These parameters are given assuming that level, compacted structural fill will be used to backfill retaining structures. If a different type of backfill, or inclined slopes behind structures are planned, the geotechnical engineer should be consulted for the appropriate earth pressure coefficients for design.

Table 3: Recommended Geotechnical Parameters for Retaining Structures

Parameter	Compacted Structural (Granular) Backfill
Total Unit Weight, kN/m^3	21.5
Buoyant Unit Weight, kN/m^3	11.5
Effective Friction Angle, degrees	36
Coefficient of Active Earth Pressure, K_a	0.26
Coefficient of Passive Earth Pressure, K_p	3.90
Coefficient of Earth Pressure at Rest, K_o	0.4

Care should be taken not to damage walls when performing backfilling and compaction operations. Compaction within 1.5 m of retaining structures should be carried out with a walk-behind vibratory plate roller or plate tamper rather than a large vibratory drum roller.

5.2.2 Soil Profile Type for Seismic Response

We recommend that designers use Site Class C for seismic design considerations, in accordance with Table 4.1.8.4.A of section 4.1.8.4 'Site Properties' of the National Building Code of Canada, 2015 (NBC 2015). Site Class C soil is defined as the average properties in the top 30 m being "Very dense soil and soft rock". Designers may utilize Site Class B, 'Rock', if it is determined that the clause limiting designations of Site Class A and B does not apply, where more than 3 m of softer materials is present between rock and the underside of foundations.

5.3 General Recommendations

5.3.1 Structural Fill

Where required for development, structural fill should consist of well graded, granular materials with less than 10% fines. The particles comprising the fill should be durable and it should be free of organics, flat or elongated particles and all other deleterious materials. Examples of suitable structural fill would be a 'Type 1' or 'Type 2' Gravel, 'Gravel Borrow', or 'Fill Against Structure' as specified in the Nova Scotia Transportation and Infrastructure Renewal's Standard Specifications. The 'Core Stone' and '100 mm diameter crushed rock' indicated on conceptual drawings qualifies as Structural Fill.

6 Closure

This report has been prepared to assist in the design and construction of the proposed refurbishment of the Port Bickerton East facility. If any details are included in the final design of the proposed structure differ from the assumptions outlined in this report, the geotechnical engineer should be consulted. Similarly, if conditions different from those detailed on the borehole logs are noted during construction, the engineer should be notified to allow reassessment of any design assumptions, if necessary.

Appendix 1 –
Laboratory Test Results

Table 1- SUMMARY OF LABORATORY TEST RESULTS

CLIENT SHM Canada Consulting

LOCATION Port Bickerton (East) Wharf Expansion, NS

PROJECT No. HFX-00231668-A1

TESTING:
Moisture Content: 5
Atterberg Limits: 0
Sieve Analysis: 4
Hydrometer Test: 0
UCS: 2

Soil Deposit	Borehole/Sample	Depth (m)	Water Content (%)	Atterberg Limits			Sieve Analysis			UCS (MPa)
				Liquid Limit	Plastic Limit	Plasticity Index	Gravel (%)	Sand (%)	Fines (%)	
Bedrock	BH-01/RC - 6	12.0								70.6
Bedrock	BH-02/RC - 9	14.0								198.4
Sand and Gravel	BH-01/SS - 3	7.9	9.3				44.0	36.2	19.8	
Sand and Gravel	BH-02/SS - 1	4.7	21.5				45.3	44.1	10.6	
Sand and Gravel	BH-04/SS - 1	3.7	25.7				57.8	34.3	7.9	
Sand and Gravel	BH-04/SS - 4	5.5	7.3				48.2	42.5	9.3	
Sand and Gravel	BH-05/SS - 2	2.9	11.6				45.3	42.2	12.5	

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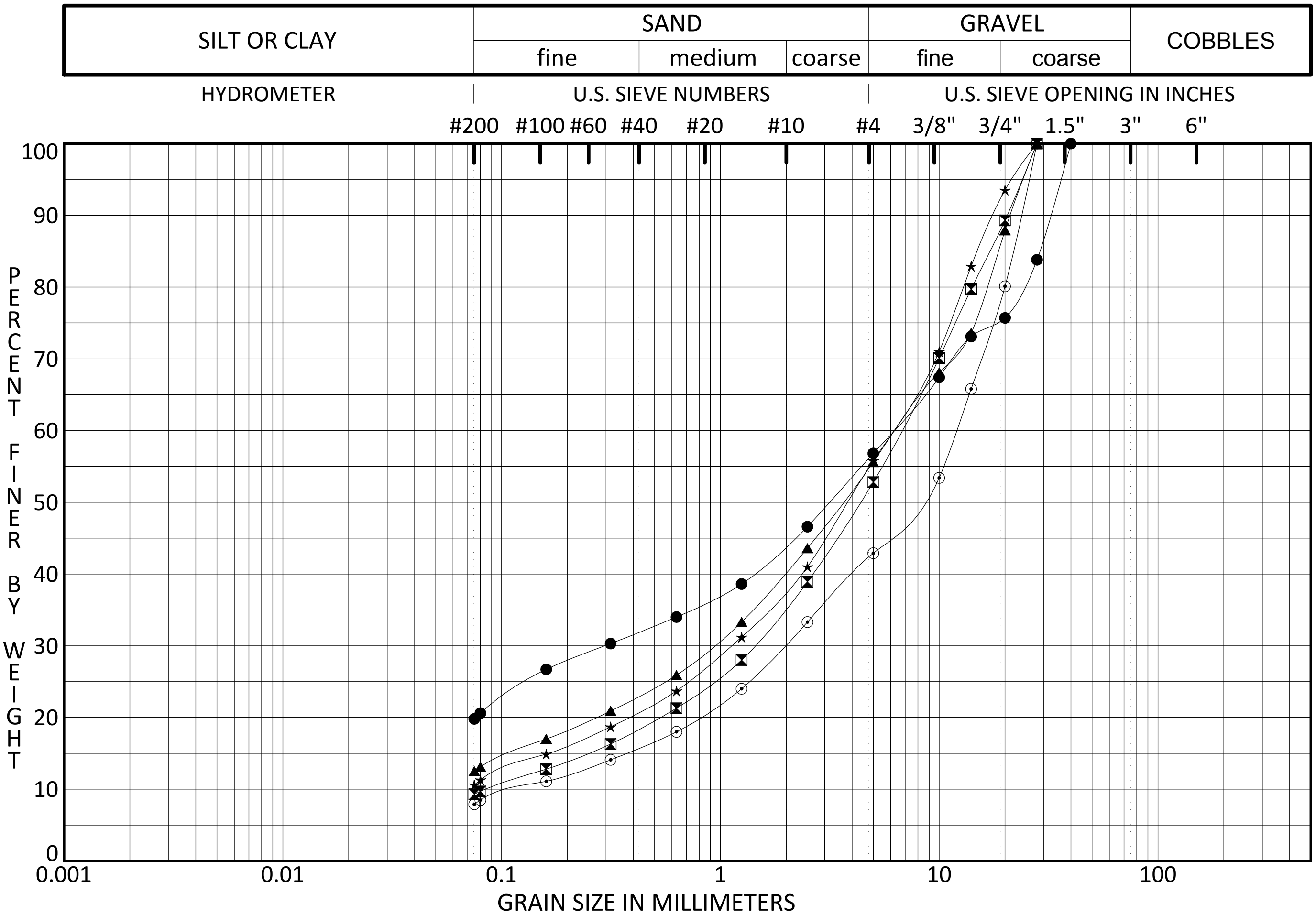
GRAIN SIZE DISTRIBUTION



	BH	SAMPLE	DEPTH(m)	Classification (USCS)	WC%	LL	PL	PI	Cc	Cu
●	**BH-01**	**SS - 3**	**7.9**	**SILTY GRAVEL with SAND GM**	**9.3**					
⧗	**BH-04**	**SS - 4**	**5.5**	**POORLY GRADED GRAVEL with SILT and SAND GP-GM**	**7.3**				**3.53**	**77.99**
▲	**BH-05**	**SS - 2**	**2.9**	**SILTY GRAVEL with SAND GM**	**11.6**					
★	**BH-02**	**SS - 1**	**4.7**	**WELL-GRADED GRAVEL with SILT and SAND GW-GM**	**21.5**				**2.92**	**85.33**
⊙	**BH-04**	**SS - 1**	**3.7**	**WELL-GRADED GRAVEL with SILT and SAND GW-GM**	**25.7**				**2.68**	**100.23**

	BH	SAMPLE	DEPTH(m)	D60	D30	D10	%Gravel	%Sand	%Fines	Soil Deposit
●	**BH-01**	**SS - 3**	**7.9**	**6.16**	**0.298**		**44.0**	**36.2**	**19.8**	**Sand and Gravel**
⧗	**BH-04**	**SS - 4**	**5.5**	**6.67**	**1.420**	**0.086**	**48.2**	**42.5**	**9.3**	**Sand and Gravel**
▲	**BH-05**	**SS - 2**	**2.9**	**6.38**	**0.921**		**45.3**	**42.2**	**12.5**	**Sand and Gravel**
★	**BH-02**	**SS - 1**	**4.7**	**6.06**	**1.120**		**45.3**	**44.1**	**10.6**	**Sand and Gravel**
⊙	**BH-04**	**SS - 1**	**3.7**	**11.96**	**1.955**	**0.119**	**57.8**	**34.3**	**7.9**	**Sand and Gravel**

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CLIENT SHM Canada Consulting

LOCATION Port Bickerton (East) Wharf Expansion, NS

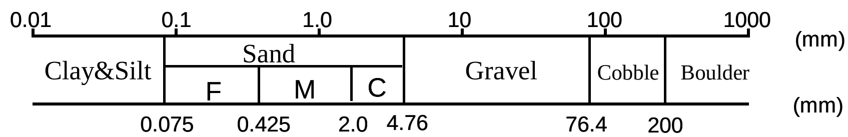
PROJECT No. HFX-00231668-A1

Appendix 2 –
Descriptive Terms Used on Borehole Logs
Borehole Logs

Descriptive Terms - Borehole and Test Pit Logs

Soils

Grain Size



Compactness (gravel, sand, tills)

N, Range	0 - 4	4 - 10	10 - 30	30 - 50	>50
Density	V. Loose	Loose	Compact	Dense	V. Dense

Consistency (silt, clay)

S, KPa	< 12.5	12.5 - 25	25 - 50	50 - 100	100 - 200
Consistency	V. Soft	Soft	Firm	Stiff	V. Stiff

Rock

RQD	**Overall Quality**	**Fracture Spacing**
0 - 25	Very Poor	< 50 mm Very Close
25 - 50	Poor	50 - 300 mm Close
50 - 75	Fair	0.3 - 1 m Moderate
75 - 90	Good	1 - 3 m Wide
90 - 100	Excellent	> 3 m Very Wide

Comp. Str., MPa	0.25 - 1	1 - 5	5 - 25	25 - 50	50 - 100	100 - 250	> 250
Description	Extremely Weak	Very Weak	Weak	Medium Strong	Strong	Very Strong	Extremely Strong

Sample Types (location to scale on log)

SS	Split Spoon	**B**	Shovel (bulk)
T	Shelby Tube	**H**	Carved Block
P	Piston	**V**	In Situ Vane
F	Auger	**NR**	No Recovery
W	Wash		

Rock Cores: BQ (36.5mm), NQ (47.6mm), HQ (63.5mm)

Notation and Symbols

N - N-value from standard penetration test; blows by 475 J drop hammer to advance std. 50mm O.D. split spoon sampler 0.3m

RQD - percent of core consisting of hard, sound pieces in excess of 100mm long (excluding machine breaks)

Recovery - sample recovery expressed as percent or length

S	- shear strength, kPa	**PL**	- plastic limit, percent
Sr	- shear strength, remoulded	**LL**	- liquid limit, percent
Dd	- dry density, t/m^3	▼	- groundwater level
W	- natural moisture content, percent	▽	- seepage

SYMBOLS AND TERMS USED ON THE BOREHOLE AND TEST PIT RECORDS

Soil Description

Behavioral properties (i.e., plasticity, permeability) take precedence over particle gradation in describing soils.

Terminology Describing Soil Structure

Desiccated	Having visible signs of weathering by oxidation of clay minerals,
Fissured	Having cracks and, hence, a blocky structure
Varved	Composed of regular alternating layers of silt and clay
Stratified	Composed of alternating layers of different soil type, e.g., silt and sand
Well Graded	Having wide range in grain size and substantial amounts of all
Uniformly Graded	Predominantly of one grain size

Terminology used for describing soil strata based upon the proportion of individual particle sizes present:

Trace, or occasional	Less than 10%
Some	10–20%
Adjective (e.g., silty or sandy)	20–35%
And (e.g., silt and sand)	35–50%

The standard terminology to describe cohesionless soils includes the relative density, as determined by laboratory test or by the Standard Penetration Test "N"-value: the number of blows of 140 pound (64 kg) hammer falling 30 inches (760 mm), required to drive a 2-inch (50.8 mm) O.D. splitspoon sampler one foot (305 mm) into the soil.

Relative Density	"N" Value	Relative Density %
Very Loose	<4	<15
Loose	4–10	15–35
Compact	10–30	35–65
Dense	30–50	65–85
Very Dense	50	>85

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by in-situ vane tests, penetrometer tests, unconfined compression tests, or occasionally by standard penetration tests.

Undrained Shear Strength

Consistency	kips/sq. ft.	kPa	"N" Value
Very Soft	<0.25	<12.5	<2
Soft	0.25–.50	12.5–25	2–4
Firm	0.5–1.0	25–50	4–8
Stiff	1.0–2.0	50–100	8–15
Very Stiff	2.0–4.0	100–200	15–30
Hard	>4.0	>200	>30

BOREHOLE RECORD

CLIENT SHM Canada Consulting
PROJECT No. HFX-00231668-A1
LOCATION Port Bickerton (East) Wharf Expansion, NS
BOREHOLE No. BH-01
DATES of BORING Jan 18, 2017
WATER LEVEL
DATUM Chart Datum

DEPTH (m)	ELEV. (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD	OTHER TESTS
0	1.3	PORT BICKERTON HARBOUR							
	-3.4								
	-3.5	ORGANICS Organic harbour sediments with strong decaying odor.			SS	1	110	0	
		SAND AND GRAVEL Silty Gravel with Sand (GM), compact to very dense, greyish brown. Cobbles and Boulders increasing in size and frequency with depth.			SS	2	0	50 for 0"	
					SS	3	200	20,28,50 for 3"	WC SVE

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8

Undrained Shear Strength, kPa: 20 40 60 80

Water Content & Atterberg Limits W_p W W_l

Dynamic Penetration Test, blows/0.3m ★

Standard Penetration Test, blows/0.3m ●

10 20 30 40 50 60 70 80 90

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△ Unconfined Compression Test
□ Field Vane Test ■ Remoulded

BOREHOLE RECORD

CLIENT: SHM Canada Consulting
PROJECT No. HFX-00231668-A1
LOCATION: Port Bickerton (East) Wharf Expansion, NS
BOREHOLE No. BH-01
DATES of BORING: Jan 18, 2017
WATER LEVEL:
DATUM: Chart Datum

DEPTH (m)	ELEV. (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD	SAMPLES OTHER TESTS
8	-6.7	SAND AND GRAVEL Silty Gravel with Sand (GM), compact to very dense, greyish brown. Cobbles and Boulders increasing in size and frequency with depth.*(continued)*			RC	4	14%	0	
9	-7.9	BEDROCK Quartzite Bedrock, strong to very strong, very poor to poor quality, very close to close fracture spacing.			RC	5	86%	0	
11–12		UCS = 70.6 MPa @ 12.0 m Depth.			RC	6	76%	28	UCS
	-11.0	End of Borehole @ 12.3 m Depth.							

Undrained Shear Strength, kPa: 20 40 60 80
Water Content & Atterberg Limits W_p W W_l
Dynamic Penetration Test, blows/0.3m ★
Standard Penetration Test, blows/0.3m ●
10 20 30 40 50 60 70 80 90

Depth scale: 8 9 10 11 12 13 14 15 16

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BOREHOLE RECORD

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CLIENT SHM Canada Consulting — PROJECT No. HFX-00231668-A1

LOCATION Port Bickerton (East) Wharf Expansion, NS — BOREHOLE No. BH-02

DATES of BORING Jan 18, 2017 — WATER LEVEL — DATUM Chart Datum

DEPTH (m)	ELEV. (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD	OTHER TESTS	Undrained Shear Strength, kPa / Water Content & Atterberg Limits / Dynamic Penetration Test, blows/0.3m / Standard Penetration Test, blows/0.3m
0	1.4	PORT BICKERTON HARBOUR								
4.4	-3.0									
4.5	-3.1	ORGANICS Organic harbour sediments with strong decaying odor.			SS	1	310	16	WC SVE	SPT ≈ 16; W ≈ 22
		SAND AND GRAVEL Well Graded Gravel with Silt and Sand (GW-GM), compact to very dense, greyish brown. Cobbles and Boulders increasing in size and frequency with depth.			RC	2	33%	0		
					RC	3	16%	0		

Undrained Shear Strength scale: 20, 40, 60, 80. Lower scale: 10 20 30 40 50 60 70 80 90. Legend: Wp, W, Wl; Dynamic Penetration Test ★; Standard Penetration Test ●.

△ Unconfined Compression Test

□ Field Vane Test ■ Remoulded

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BOREHOLE RECORD

CLIENT SHM Canada Consulting
PROJECT No. HFX-00231668-A1
LOCATION Port Bickerton (East) Wharf Expansion, NS
BOREHOLE No. BH-02
DATES of BORING Jan 18, 2017
WATER LEVEL
DATUM Chart Datum

DEPTH (m)	ELEV. (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD	OTHER TESTS
8	-6.6	SAND AND GRAVEL Well Graded Gravel with Silt and Sand (GW-GM), compact to very dense, greyish brown. Cobbles and Boulders increasing in size and frequency with depth. *(continued)*			RC	4	30%	87	
9					SS	5	190	20,28,50 for 6"	
	-8.0	BEDROCK Quartzite Bedrock, strong to very strong, very poor to poor quality, very close to moderate fracture spacing.			RC	6	100%	86	
10–11					RC	7	100%	57	
12–13					RC	8	89%	41	
14	-12.9	UCS = 198.4 MPa @ 14.0 m Depth.			RC	9	92%	70	UCS
		End of Borehole @ 14.3 m Depth.							
15–16									

Undrained Shear Strength, kPa: 20 40 60 80

Water Content & Atterberg Limits W_p W W_l

Dynamic Penetration Test, blows/0.3m ★

Standard Penetration Test, blows/0.3m ●

10 20 30 40 50 60 70 80 90

>>● (SS 5)

△ Unconfined Compression Test
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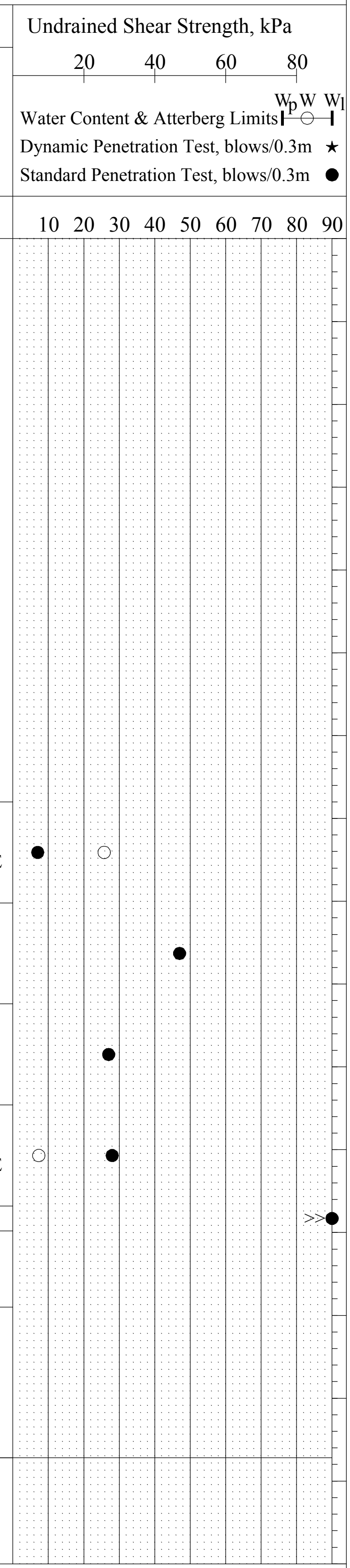
BOREHOLE RECORD

CLIENT SHM Canada Consulting
PROJECT No. HFX-00231668-A1
LOCATION Port Bickerton (East) Wharf Expansion, NS
BOREHOLE No. BH-04
DATES of BORING Dec 13, 2016
WATER LEVEL
DATUM Chart Datum

DEPTH (m)	ELEV. (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD	OTHER TESTS
0	1.6	PORT BICKERTON HARBOUR							
3.4	-1.8	SAND AND GRAVEL Well-Graded Gravel with Silt and Sand (GW-GM) to Poorly Graded Gravel with Silt and Sand (GP-GM), loose to dense, greyish brown. Cobbles and Boulders increasing in size and frequency with depth.			SS	1	100	7	WC SVE
					SS	2	230	47	
					SS	3	90	27	
					SS	4	310	28	WC SVE
					SS	5	100	70 for 6"	
6.0	-4.4	WEATHERED QUARTZITE BEDROCK			RC	6	11%	0	
					RC	7	11%	0	
7.4	-5.7	End of Borehole @ 7.4 m Depth.							



△ Unconfined Compression Test
☐ Field Vane Test ■ Remoulded

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BOREHOLE RECORD

CLIENT SHM Canada Consulting
LOCATION Port Bickerton (East) Wharf Expansion, NS
DATES of BORING Dec 12, 2016 WATER LEVEL
PROJECT No. HFX-00231668-A1
BOREHOLE No. BH-05
DATUM Chart Datum

DEPTH (m)	ELEV. (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD	OTHER TESTS
0	0.4	PORT BICKERTON HARBOUR							
2	-1.6	SAND AND GRAVEL Silty Gravel with Sand (GM), compact, greyish brown. Cobbles and Boulders increasing in size and frequency with depth.			SS	1	50	0	
					SS	2	470	27	WC SVE
3.2	-2.8	Borehole Terminated Prematurely @ 3.2 m Depth due to Inclement Weather.							

Undrained Shear Strength, kPa: 20 40 60 80
Water Content & Atterberg Limits W_p W W_l
Dynamic Penetration Test, blows/0.3m ★
Standard Penetration Test, blows/0.3m ●
10 20 30 40 50 60 70 80 90

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