FINAL

Geotechnical Investigation
Wind Turbine Installation
Green Island, NL

Submitted to:

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IMPORTANT NOTICE

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1.0 INTRODUCTION

1.1 General

Amec Foster Wheeler Environment & Infrastructure (Amec Foster Wheeler), a division of Amec Foster Wheeler Americas Limited was retained by the Department of Fisheries & Oceans (DFO) to perform a geotechnical investigation in support of the proposed wind turbine installation at Green Island, NL. The installation will comprise the addition of five (5) turbines; four (4) of which will be placed at new locations across the site. One (1) will be constructed at the location of the existing turbine after it has been decommissioned. The following report outlines the results of the investigation and provides geotechnical recommendations and preliminary design parameters required for construction.

1.2 Objectives and Scope of Work

The objective of the investigation was to determine the subsurface condition beneath each proposed turbine site along with the provision of geotechnical recommendations and preliminary design parameters. The following parameters are addressed:

- Overburden thickness and depth to apparent bedrock;
- Geological mapping of exposed bedrock (where encountered);
- Analysis and determination of bedrock quality;
- Observations pertaining to groundwater and natural drainage conditions; and
- Bearing capacity of subsoil and bedrock.

The scope of this program included:

- Preparation of a project specific Health & Safety Plan (HASP);
- Visual inspection at each turbine location in an effort to determine the subsurface condition;
- Geological mapping of exposed bedrock within the vicinity of the turbine sites to record bedrock characteristics, fault patterns, orientation and an overall assessment of bedrock quality;
- Rebound hammer testing on exposed bedrock to estimate bearing capacity and strength;
- Bedrock probing within the vicinity of the turbine sites to delineate overburden thickness and bedrock depth;
- The collection and laboratory testing of representative bedrock samples; and

- Preparation of the accompanying geotechnical report outlining the findings of the field work, results of the laboratory testing and preliminary design recommendations.

1.3 Health & Safety

A project specific HASP and Emergency Plan was developed by Amec Foster Wheeler prior to the start of the program. Emphasis was placed on the identification, assessment and control of physical hazards that could potentially arise during the field work. Such hazards included helicopter safety and working in remote locations. A helicopter safety orientation, provided by the on-duty Canadian Coast Guard pilot, was also given to all personnel prior to take-off for site.

2.0 SITE DESCRIPTION

Green Island is located in the waters of Fortune Bay; off the southwestern tip of the Burin Peninsula and near the approximate mid-point between Saint Pierre et Miquelon and Newfoundland. It is approximately 6.5 nautical miles due southwest of the community of Point May, NL. Existing infrastructure on the east side of Green Island includes: a helicopter landing pad, navigational aid / lighting, fog horn, staff house, generator housing, fuel tanks, solar panels and the existing wind turbine. The west section of the island remains undeveloped.

The proposed location(s) for the additional wind turbines is also on the Islands east section (ie the study area). Here vegetation is sparse and comprised of shrubs and wild grasses with undulating, rolling topography that is generally down-gradient from the WNW to ESE. Refer to Figure 1 in Appendix A for a generalized layout of the site.

3.0 SITE GEOLOGY

3.1 Bedrock Geology

Published information pertaining to the bedrock geology of Green Island is limited. Provincial data for the nearby Burin Peninsula and Saint Pierre et Miquelon indicate the presence of Late Proterozoic to Early Ordovician-aged marine, mainly fine grained siliclastic sedimentary rocks and submarine to sub-aerial volcanic rocks. Bedrock comprised of fine-grained siliclastic siltstone and minor shale was observed within the study area; conforming to the above description.

3.2 Site Surficial Geology

Published surficial data is also limited. Site observations indicate relatively thin soil (possibly high in organic content) coupled with areas of exposed bedrock. Bedrock exposure is extensive along the shoreline. Bedrock probing carried out at (or near) the turbine sites indicates that site soils within the study area range from 0.2 - >0.9 m in thickness.

4.0 GEOTECHNICAL INVESTIGATION METHODOLOGY

The field program was carried out on March 8, 2016. Brad Walsh, P.Geo, of Amec Foster Wheeler carried out the work. Tasks included: geological mapping, visual estimations of bedrock quality, rebound hammer testing and bedrock probing within the vicinity of each proposed turbine location. Helicopter support was provided by DFO. A DFO representative was also present during the site works.

The proposed turbine locations were not staked prior to Amec Foster Wheeler's arrival on-site. Their coordinates were also not available at the time of the investigation. Turbine locations were subsequently scaled, measured and field referenced from the locations provided on the Public Works and Government Services Canada Drawing (Stantec Document No.) S-G-01 and should therefore be regarded as approximate. Upon completion of field referencing, coordinates and elevation of each were obtained with a hand-held GPS unit capable of +/- 5 to 10 m accuracy. Refer to Figure 1 (Appendix A) for the approximate turbine locations.

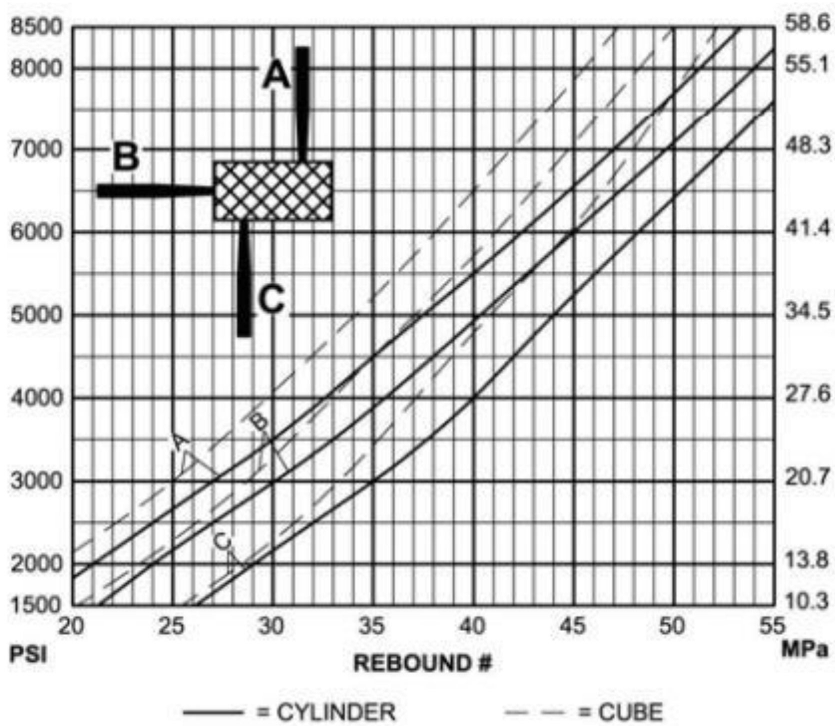
4.1 Geological Mapping

Geological mapping comprised the recording of bedrock type, joint orientation / frequency and a visual estimate of rock quality / rock quality designation (RQD). A total of eight (8) areas of exposed bedrock were mapped within the vicinity of the turbine sites. Three (3) outcrops were mapped adjacent to Turbine 14-01 and one (1) was mapped near Turbine 14-02. Four (4) additional outcrops were mapped approximately 15-50 m from Turbines 14-03, 14-04 and 14-05. Mapping observations are further detailed in Section 5.0.

4.2 Rebound Hammer Testing

Rebound hammer testing was also performed in areas where bedrock was exposed within the vicinity of the turbine sites. The rebound (Schmidt) hammer is a handheld instrument which interpolates the rebound number to the compressive strength of bedrock. The resulting compressive strength is then utilized to correlate its bearing capacity. The test consists of a series of ten (10) readings which are gathered by compressing the instrument on a clean, dry rock surface. The readings are averaged; if an individual reading is more than seven (7) units from the average, it is dismissed to create an adjusted average. The adjusted average is then used to correlate compressive strength, obtained from the graph below:

Figure 1: Rebound Number vs. Compressive Strength



The orientation of the hammer while testing determines the appropriate curve. The resulting bearing capacity is determined by multiplying the compressive strength by the coefficient of discontinuity spacing (i.e. the spacing of natural breaks, fractures, discontinuities observed in the bedrock). Rebound hammer test results are further detailed in Section 5.0.

4.3 Bedrock Probing

A series of bedrock probes were advanced in areas where bedrock was not exposed within the vicinity of the turbine sites in an attempt to delineate approximate overburden thickness and bedrock depth. Probes were generally performed in a 10 - 20 m swath to gain representative values. This was achieved by manually advancing 5/8" diameter threaded rod with a sledge hammer in to the ground until refusal is met. The penetration distance was measured and recorded. Results of the bedrock probing are further detailed in Section 5.0.

4.4 Laboratory Testing

Representative bedrock samples were collected within the study area and transported to the Amec Foster Wheeler Material Laboratory in St. John's, NL for point load strength index testing. The testing adhered to the following ASTM standard:

- ASTM D 5731-08: “Standard Test Method for Determination of the Pont Load Strength Index of Rock Application to Rock Strength Classifications.”

The ASTM standard states that a minimum of 10 samples shall be prepared for testing. Unfortunately, only seven samples were obtained due to fracturing while attempting to prepare the samples for testing. The testing results are presented in section 5.6.

5.0 INVESTIGATION RESULTS

Surficial soils throughout the study area are interpreted to consist of relatively thin organic soil overlying bedrock. Areas of exposed bedrock exist throughout the site while bedrock exposure is extensive along the shoreline. Photographs of the bedrock outcrop and existing conditions at the approximate locations of the turbine sites are presented Appendix B.

5.1 Turbine 14-01

Turbine 14-01 is planned to be constructed at the location of the existing 18.3 m turbine after it has been decommissioned. The existing turbine is supported by concrete blocking at its hub in addition to four (4) concrete anchor blocks. Each block is ~1.5 x 1.5 m and appear to be in reasonable condition with no observable cracking or weathering. It is understood that the existing blocking may be used to support Turbine 14-01 if minimal damage is incurred during decommissioning efforts. The ground within the immediate area within the existing turbine has been levelled during previous construction. Topography outside of its footprint is sloped and generally up-gradient toward to W-NW.

Geological Mapping

Three (3) areas of exposed bedrock were observed near the proposed location of Turbine 14-01. The first (termed Outcrop A) is adjacent to the existing east anchor block; the second (Outcrop B) is ~3 m W of the existing west anchor block. Outcrop C is located ~ 10 m SE of the existing tower.

The exposure at Outcrop A was ~ 4 x 4 m in size and described as green-grey siliceous siltstone. Evidence of slight to moderate surface weathering and iron oxide staining was noted on exposed surfaces. The rock mass was jointed two (2) prominent joint sets generally striking NW-SE. Both sets were dipping near vertical and had extremely close to close joint spacing (10 - 80 mm). Extremely close to very close spaced (10 mm - 50 mm) cleavage planes generally trending toward the NE-SW were also observed on the surface of the outcrop. The bedrock surface exhibited some fracturing due to the joint / cleavage patterns and their spacing. Bedding plane orientation was not determined due to insufficient exposure.

Outcrop B was ~ 3 x 2 m in size and described as green-grey siliceous siltstone. Evidence of slight to moderate surface weathering and iron oxide staining was noted on exposed surfaces. Trace to some moss / lichen growth was observed on the bedrock surface. Quartz veins spaced 30 - 50 mm apart and trending N-S were also noted. The rock mass was jointed two (2) prominent joint sets generally striking NW-SE. Both sets were dipping near vertical and had very close to close joint spacing (20 - 100 mm). Extremely close to very close spaced (10 mm - 50 mm) cleavage planes generally trending toward the NE-SW were also observed on the surface of the outcrop. The bedrock surface exhibited some fracturing due to the joint / cleavage patterns and their spacing. Bedding plane orientation was not determined due to insufficient exposure.

Outcrop C was ~ 5 x 3 m in size and described as green-grey siliceous siltstone. Evidence of slight to moderate surface weathering and iron oxide staining was noted on exposed surfaces. The rock mass was jointed two (2) prominent joint sets generally striking NW-SE (to ESE). Both sets were dipping near vertical and had very close to moderately close joint spacing (30 - 200 mm). Extremely close to very close spaced (5 mm - 20 mm) cleavage planes generally trending E-W were also observed on the surface of the outcrop. The bedrock surface exhibited some fracturing due to the joint / cleavage patterns and their spacing. Bedding plane orientation was not determined due to insufficient exposure.

Refer to Table 5.1 (below) for a summary of observations recorded at Outcrops A, B and C.

Table 5-1: Summary of Observations Recorded at Outcrops A, B & C (Turbine 14-01)

Outcrop ID	Northing	Easting	Geological Feature	Dip	Dip Direction	Description
A	5192259	569758	Cleavage	65	130	Green-grey siliceous siltstone, slight to moderate surface weathering, weathered buff white, some iron-oxide staining, 2 prominent joint sets - Joint Set 1 (spaced 10 mm - 80 mm apart) with near vertical dip, Joint Set 2 (spaced 20 mm - 60 mm, near vertical dip, smooth to rough faces, some weathering on joint faces, cleavage planes (spaced 10 mm - 50 mm) observed on surface of outcrop, near vertical dip, evidence of some fracturing at surface, no large scale fracturing noted. Estimated RQD: 30 - 50%
				85	140	
				76	132	
			Joint Set 1	85	252	
				80	250	
				75	235	
			Joint Set 2	86	056	
				85	048	
				80	052	
B	5192244	569747	Cleavage	65	130	Green-grey siliceous siltstone, slight to moderate surface weathering, weathered buff white, trace to some moss / lichen growth, some iron-oxide staining, quartz veins spaced 30 mm - 50 mm and trending N-S, 2 prominent joint sets - Joint Set 1 (spaced 30 mm - 100 mm apart) with near vertical dip, Joint Set 2 (spaced 20 mm - 80 mm, near vertical dip, smooth to rough faces, some weathering on joint faces, cleavage planes (spaced 10 mm - 50 mm) observed on surface of
				85	140	
				76	132	
			Joint Set 1	90	068	
				88	058	
				85	060	
			Joint Set 2	75	210	
				80	205	

				84	212	outcrop, near vertical dip, evidence of some fracturing at surface, no large scale fracturing noted. Estimated RQD: 30 - 50%
C	5192232	569751	Cleavage	-	-	Green-grey siliceous siltstone, slight to moderate surface weathering, weathered buff white in places, some iron-oxide staining, 2 prominent joint sets - Joint Set 1 (spaced 30 mm - 80 mm apart) with near vertical dip, Joint Set (spaced 40 mm - 200 mm, near vertical dip, smooth to rough faces, some weathering on joint faces, cleavage planes (spaced 5 mm - 20 mm) observed on surface of outcrop, cleavage planes trending E-W, evidence of some fracturing at surface, no large scale fracturing noted. Estimated RQD: 30 - 50%
			Joint Set 1	90	060	
				90	055	
				85	062	
			Joint Set 2	90	020	
				80	022	
				84	028	

Rebound Hammer Testing

Rebound hammer testing was carried out on Outcrops A, B and C. Readings are provided in Table 5.2.

Table 5-2: Summary of Rebound Hammer Testing - Outcrop A, B & C (Turbine 14-01)

Rebound Test No.	Outcrop A	Outcrop B	Outcrop C
1	40	48	34
2	50	24	40
3	28	30	46
4	24	40	36
5	28	42	42
6	38	32	40
7	30	40	38
8	32	26	36
9	28	30	30
10	30	28	34
Average Rebound Number	**32.8**	**34.0**	**37.6**
Interpolated Compressive Strength (MPa)	**27.5**	**29.5**	**34.5**
Discontinuity Coefficient (Ksp)	**0.1**	**0.1**	**0.1**
Correlated Bearing Capacity (kPa)	**2750**	**2950**	**3450**

Note: 1) Estimated Bearing Capacity on Bedrock = Compressive Strength * Ksp (Based on Eq. 9.1 from CFEM, 2006)
2) Ksp factor of 0.1 is assigned if the discontinuity spacing in the rock mass ranges from 0.3 to 1 m

Results for Outcrop A show the interpolated compressive strength and bearing capacity of bedrock to be 27.5 MPa and 2750 kPa, respectively. Additionally, the interpolated compressive strength and bearing capacity of bedrock exposed at Outcrop B is 29.5 MPa and 2950 kPa and the interpolated compressive strength and bearing capacity of bedrock exposed at Outcrop C is

34.5 MPa and 3450 kPa. A discontinuity coefficient (Ksp) of 0.1 was assigned to each to equate bearing capacity.

Bedrock Probing

Results of the bedrock probes carried out within the general area of Turbine 14-01 are presented in Table 5.3. The probes were advanced in 10-15 m swath in an attempt to delineate overburden thickness and bedrock depth.

Table 5-3: Summary of Bedrock Probing Results - Area of Turbine 14-01

Bedrock Probe ID	Refusal Depth (mbgs[1])	Comments
BP1	>0.6	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP2	0.5	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP3	0.5	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP4	0.4	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP5	0.7	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval

Note: 1) mbgs = meters below existing ground surface

Apparent bedrock was encountered in four (4) of the five (5) probed locations at depths ranging from 0.4 meters below ground surface (mbgs) to 0.7 mbgs. Apparent bedrock was not encountered in probes BP1 as the bedrock, if present, extended beyond 0.6 m.

5.2 Turbine 14-02

The proposed location of Turbine 14-02 is approximately 30 m W-NW of Turbine 14-01 (refer to Drawing 1, Appendix A). Existing topography is sloped and generally up-gradient topography toward the W-NW.

Geological Mapping

One (1) bedrock outcrop (Outcrop D) was noted near the approximate location of Turbine 14-02. The exposure was ~ 6 x 2 m in size and described as green-grey siliceous siltstone. Evidence of slight to moderate surface weathering and trace iron oxide staining was noted on exposed surfaces. The rock mass was jointed with near-vertical, very close to close spaced joints (20 mm - 100 mm). Extremely close to close spaced (5 mm - 20 mm) cleavage planes generally trending toward the NE-SW were also observed on the surface of the outcrop. Bedding plane orientation was not determined due to insufficient exposure. Refer to Table 5.4 for a summary of observations recorded at Outcrop D.

Table 5-4: Summary of Observations Recorded at Outcrop D (Turbine 14-02)

Outcrop ID	Northing	Easting	Geological Feature	Dip	Dip Direction	Description
D	5192250	569717	Cleavage	75	320	Green-grey siliceous siltstone, slight to moderate surface weathering, weathered buff white, some iron-oxide staining, jointed (spaced 20 mm - 100 mm apart) with smooth to rough faces, some weathering on joint faces, cleavage planes observed on surface of outcrop, evidence of some fracturing at surface, no large scale fracturing noted. Estimated RQD: 50 - 60%
				80	330	
				76	300	
			Joint Set	85	052	
				80	060	
				80	070	

Rebound Hammer Testing

Rebound hammer testing was carried out on Outcrop D. Readings are provided in Table 5.5.

Table 5-5: Summary of Rebound Hammer Testing - Outcrop D (Turbine 14-02)

Rebound Test No.	Outcrop D
1	28
2	38
3	36
4	32
5	36
6	34
7	52
8	32
9	28
10	30
Average Rebound Number	**34.6**
Interpolated Compressive Strength (MPa)	**30.0**
Discontinuity Coefficient (Ksp)	**0.1**
Correlated Bearing Capacity (kPa)	**3000**

Note: 1) Estimated Bearing Capacity on Bedrock = Compressive Strength * Ksp (Based on Eq. 9.1 from CFEM, 2006)
2) Ksp factor of 0.1 is assigned if the discontinuity spacing in the rock mass ranges from 0.3 to 1 m

Results show that the interpolated compressive strength and bearing capacity is 30 MPa and 3000 kPa, respectively. A discontinuity coefficient (Ksp) of 0.1 was assigned to equate bearing capacity.

Bedrock Probing

Results of the bedrock probes carried out within the general area of Turbine 14-02 are presented in Table 5.6. The probes were advanced in 10-15 m swath in an attempt to delineate overburden thickness and bedrock depth.

Table 5-6: Summary of Bedrock Probing Results - Area of Turbine 14-02

Bedrock Probe ID	Refusal Depth (mbgs[1])	Comments
BP1	0.2	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP2	0.4	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP3	0.4	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP4	0.3	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP5	0.3	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP6	0.4	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP7	0.3	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP8	0.2	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP9	0.3	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP10	0.3	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval

Note: 1) mbgs = meters below existing ground surface

Apparent bedrock was encountered in all of probed locations at depths ranging from 0.2 mbgs to 0.4 mbgs.

5.3 Turbine 14-03

The proposed location of Turbine 14-03 is approximately 60 m W-SW of the staff house (see Drawing 1, Appendix A). Existing topography is generally flat with up-gradient topography toward the W-NW. Bedrock was not exposed within the immediate vicinity. An apparent concealed bedrock ridge (with poorly exposed bedrock at the base ridge) was observed approximately 20 m toward the N-NW.

Geological Mapping

Two (2) areas of exposed bedrock were noted within ~50 m of the approximate location of Turbine 14-03. The first (Outcrop E) is ~50 m to the W-SW; the second (Outcrop F) is ~35 m to the NE.

The exposure at Outcrop E was ~ 1.5 x 1.5 m in size and described as green-grey siliceous siltstone. Evidence of slight to moderate surface weathering and iron oxide staining was noted on exposed surfaces. The rock mass was jointed two (2) prominent joint sets striking E-W and NE-SW. Both sets were dipping near vertical and had very close to close joint spacing (30 – 100 mm).

The bedrock surface exhibited some fracturing due to joint patterns and their spacing. Bedding plane orientation was not determined due to insufficient exposure.

Outcrop F was ~ 1 x 4 m in size and described as green-grey siliceous siltstone and shale. Moderate surface weathering was noted on exposed surfaces. Approximately 40% of the outcrop was comprised of shale that is fractured, brittle and exhibits very close spaced cleavage planes that generally trend E-W with a near-vertical dip. Bedding plane orientation was not determined due to insufficient exposure.

Refer to Table 5.7 for a summary of observations recorded at Outcrops E and F.

Table 5-7: Summary of Observations Recorded at Outcrops E & F (Turbine 14-03)

Outcrop ID	Northing	Easting	Geological Feature	Description
E	Not Recorded	Not Recorded	Joint Set 1	Located ~ 50 m W-SW of approximate location of Turbine 14-03, green-grey siliceous siltstone, slight to moderate surface weathering, weathered buff white, some iron-oxide staining, jointed with 2 prominent joint sets - Joint Set 1 striking E-W, near vertical dip, spaced 30 - 50 mm apart; Joint Set 2 striking NE-SW, near vertical dip, spaced 50 - 100 mm apart, some fractured surfaces. Estimated RQD: 40 - 60%
			Joint Set 2	
F	5192163	569740	Cleavage	Located ~ 35 m NE of approximate location of Turbine 14-03, green-grey siliceous siltstone and shale, moderate surface weathering, weathered buff white, ~40% of outcrop comprised fractured, brittle, shale that exhibits very closely spaced cleavage planes that trend E-W with near vertical dip. Estimated RQD: 30 - 50%
			-	

Rebound Hammer Testing

Rebound hammer testing was carried out on Outcrops E and F. Readings are provided in Table 5.8.Table 5-8: Summary of Rebound Hammer Testing - Outcrops E & F (Turbine 14-03)

Rebound Test No.	Outcrop E	Outcrop F
1	28	28*
2	30	24*
3	24	22*
4	26	18*
5	24	32
6	22	30

7	23	46
8	36	28
9	34	42
10	30	42
Average Rebound Number	**27.7**	**31.2**
Interpolated Compressive Strength (MPa)	**21.0**	**24.5**
Discontinuity Coefficient (Ksp)	**0.1**	**0.1**
Correlated Bearing Capacity (kPa)	**2100**	**2450**

Note: 1) Estimated Bearing Capacity on Bedrock = Compressive Strength * Ksp (Based on Eq. 9.1 from CFEM, 2006)
2) Ksp factor of 0.1 is assigned if the discontinuity spacing in the rock mass ranges from 0.3 to 1 m
3) * Tests 1 - 4 (Outcrop F) were performed on fractured shale

Results show the interpolated compressive strength and bearing capacity of bedrock exposed at Outcrop E to be 21 MPa and 2100 kPa. The interpolated compressive strength and bearing capacity of bedrock exposed at Outcrop F is 24.5 MPa and 2450 kPa. A discontinuity coefficient (Ksp) of 0.1 was assigned to each to equate bearing capacity.

Bedrock Probing

Results of the bedrock probes carried out within the general area of Turbine 14-03 are presented in Table 5.9. The probes were advanced in 15-20 m swath in an attempt to delineate overburden thickness and bedrock depth.

Table 5-9: Summary of Bedrock Probing Results - Area of Turbine 14-03

Bedrock Probe ID	Refusal Depth (mbgs[1])	Comments
BP1	>0.9	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP2	>0.9	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP3	0.7	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval Probe advanced on (or near) nearby concealed bedrock ridge
BP4	0.6	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval Probe advanced on (or near) nearby concealed bedrock ridge
BP5	0.3	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval Probe advanced on (or near) nearby concealed bedrock ridge
BP6	>0.9	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP7	0.7	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval Probe advanced on (or near) nearby concealed bedrock ridge

Note: 1) mbgs = meters below existing ground surface

Apparent bedrock was encountered in four (4) of the seven (7) probed locations at depths ranging from 0.3 mbgs to 0.7 mbgs. These probes were advanced on (or near) the nearby concealed bedrock ridge. Apparent bedrock was not encountered in probes BP1, BP2 and BP6 as the bedrock, if present, extended beyond the maximum penetration length probe (0.9 m).

5.4 Turbine 14-04

Turbine 14-04 is proposed to be located approximately 45 m SW of the staff house (see Drawing 1, Appendix A). Existing topography gradually grades toward the E-SE with up-gradient topography toward the W-NW. Bedrock was not exposed within the immediate vicinity.

Geological Mapping

Three (3) areas of exposed bedrock were noted within ~45 m of the approximate location of Turbine 14-04. Outcrop F (previously discussed in Section 5.3 for Turbine 14-03) is ~35 m to the NW. Outcrop G is located ~30 m to the NE; whereas Outcrop H is ~45 m to the E.

The exposure at Outcrop G was ~ 1 x 1 m in size and described as green-grey siliceous siltstone. Evidence of slight to moderate surface weathering was noted on exposed surfaces. The rock mass exhibited one (1) dominant joint set striking E-W with a near vertical dip with very close to close spacing (20 - 100 mm). Bedding plane orientation was not determined due to insufficient exposure.

Outcrop H was ~ 3 x 3 m in size and described as green-grey siliceous siltstone. Slight to moderate surface weathering was noted on exposed surfaces. The rock mass exhibited one (1) dominant joint set striking E-W with a near vertical dip with very close to close spacing (50 - 100 mm). Very close to close spaced (20 mm - 120 mm) cleavage planes generally trending toward the N-S dipping near vertical were also observed on the surface of the outcrop. Bedding plane orientation was not determined due to insufficient exposure.

Refer to Table 5.10 for a summary of observations recorded at Outcrops F, G and H.

Table 5-10: Summary of Observations Recorded at Outcrops F, G & H (Turbine 14-04)

Outcrop ID	Northing	Easting	Geological Feature	Description
F	5192163	569740	Cleavage	Located ~ 35 m NW of approximate location of Turbine 14-04, green-grey siliceous siltstone and shale, moderate surface weathering, weathered buff white, some iron-oxide staining, ~40% of outcrop comprised fractured, brittle, shale that exhibits very closely spaced cleavage planes that trend E-W with near vertical dip. Estimated RQD: 30 - 50%
			-	
G	5192158	569776	Joint Set 1	Located ~ 30 m NE of approximate location of Turbine 14-04, green-grey siliceous siltstone, slight to moderate surface weathering, joint set with very close to close spacing (20 - 100 mm) striking E-W with near vertical dip, smooth to rough joint surfaces with some weathered surfaces. Estimated RQD: 40 - 60%

H	5192173	569786	Joint Set 1	Located ~ 45 m E of approximate location of Turbine 14-04, green-grey siliceous siltstone, slight to moderate surface weathering, joint set with very close to close spacings (50 - 100 mm) striking E-W with near vertical dip, smooth to rough joint surfaces with some weathered surfaces, very close to close spaced cleavage planes (20 - 120 mm) trending N-S and dipping near vertical. Estimated RQD: 40 - 60%
			Cleavage	

Rebound Hammer Testing

Rebound hammer testing was carried out on Outcrops F, G and H. Readings are provided in Table 5.11.

Table 5-11: Summary of Rebound Hammer Testing - Outcrops F, G & H (Turbine 14-04)

Rebound Test No.	Outcrop F	Outcrop G	Outcrop H
1	28*	40	32
2	24*	28	28
3	22*	48	50
4	18*	38	50
5	32	28	32
6	30	30	34
7	46	32	32
8	28	30	36
9	42	32	30
10	42	28	28
Average Rebound Number	**31.2**	**32.7**	**35.2**
Interpolated Compressive Strength (MPa)	**24.5**	**27.6**	**31.0**
Discontinuity Coefficient (Ksp)	**0.1**	**0.1**	**0.1**
Correlated Bearing Capacity (kPa)	**2450**	**2760**	**3100**

Note: 1) Estimated Bearing Capacity on Bedrock = Compressive Strength * Ksp (Based on Eq. 9.1 from CFEM, 2006)
2) Ksp factor of 0.1 is assigned if the discontinuity spacing in the rock mass ranges from 0.3 to 1 m
3) * Tests 1 - 4 (Outcrop F) were performed on fractured shale

As discussed in Section 5.3, results for Outcrop F show the interpolated compressive strength and bearing capacity of bedrock to be 24.5 MPa and 2450 kPa. Additionally, the interpolated compressive strength and bearing capacity of bedrock exposed at Outcrop G is 27.6 MPa and 2760 kPa and the interpolated compressive strength and bearing capacity of bedrock exposed at Outcrop H is 31.0 MPa and 3100 kPa. A discontinuity coefficient (Ksp) of 0.1 was assigned to each to equate bearing capacity.

Bedrock Probing

Results of the bedrock probes carried out within the general area of Turbine 14-04 are presented in Table 5.12. The probes were advanced in 15-20 m swath in an attempt to delineate overburden thickness and bedrock depth.

Table 5-12: Summary of Bedrock Probing Results - Area of Turbine 14-04

Bedrock Probe ID	Refusal Depth (mbgs[1])	Comments
BP1	>0.9	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP2	0.6	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP3	0.6	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP4	>0.9	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP5	>0.9	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP6	0.4	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval

Note: 1) mbgs = meters below existing ground surface

Apparent bedrock was encountered in three (3) of the six (6) probed locations at depths ranging from 0.4 mbgs to 0.6 mbgs. Apparent bedrock was not encountered in probes BP1, BP4 and BP5 as the bedrock, if present, extended beyond the maximum penetration length probe (0.9 m).

5.5 Turbine 14-05

Turbine 14-05 is proposed to be located approximately 30 m E-SE of Turbine 14-04 (see Drawing 1, Appendix A). Existing topography gradually grades toward the E-SE with up-gradient topography toward the W-NW. Bedrock was not exposed within the immediate vicinity; however two (2) areas of exposed bedrock were noted within ~25 m of its approximate location. These include Outcrop G (~15-20 m to N-NW) and Outcrop H (~ 25 m to the NE). Geological observations and rebound hammer results pertaining to these exposures are detailed previously in Section 5.4. Bedrock is also exposed along the shoreline ~20 - 25 m to the E but was not mapped in detail due to accessibility and time constraints. Preliminary observations show jointed rock of similar composition with an apparent dip toward the NE-E. Existing joint patterns and wave processes have created a blocky structure to bedrock exposed along the shoreline.

Geological Mapping

Refer to Section 5.4.

Rebound Hammer Testing

Refer to Section 5.4.

Bedrock Probing

Results of the bedrock probes carried out within the general area of Turbine 14-05 are presented in Table 5.13. The probes were advanced in 15-20 m swath in an attempt to delineate overburden thickness and bedrock depth.

Table 5-13: Summary of Bedrock Probing Results - Area of Turbine 14-05

Bedrock Probe ID	Refusal Depth (mbgs[1])	Comments
BP1	>0.9	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP2	0.6	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP3	0.8	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP4	0.6	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP5	0.6	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP6	>0.9	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval
BP7	0.3	Upper 50 - 100 mm frozen / frost - probe wet upon retrieval

Note: 1) mbgs = meters below existing ground surface

Apparent bedrock was encountered in five (5) of the seven (7) probed locations at depths ranging from 0.3 mbgs to 0.8 mbgs. Apparent bedrock was not encountered in probes BP1 and BP6 as the bedrock, if present, extended beyond the maximum penetration length probe (0.9 m).

5.6 Laboratory Results

A total of seven point load test were conducted on bedrock samples collected in the vicinity of the proposed wind turbine towers. The test samples consisted of cored sections bedrock fragments that were collected around the proposed wind turbine tower locations. The diameter of the core pieces was approximately 44.5 mm. The cored sections were tested in two directions, axial and diametral. A total of five axial and two diametral test were conducted. The test results can be seen in Table 5-14, below.

The point load test provides an uncorrected point load index value (Is). The uncorrected point load index value is corrected for size to provide an equivalent value for cores of approximately 50 mm in diameter, known as $Is_{(50)}$. The Is(50) value is correlated to uniaxial compressive strength by multiplying by an empirical factor "K". The value of "K" is typically determined from correlation studies of point load test index with uniaxial compressive strength test results. The value of "K" can vary based on rock type. A "K" value of 21 is generally found to work well for a variety of different rock types, over different geographical regions (Mark and Rusnak, 2000).

The point load strength anisotropy index ($Ia_{(50)}$) is the ratio of the average of the $Is_{(50)}$ values measured perpendicular and parallel to planes of weakness. The $Ia_{(50)}$ value for the results presented in Table 5-14 is approximately 4:1.

The estimated bearing capacity based on a Ksp value of 0.1 is also presented in Table 5-14. It should be noted that lower values associated with the weaker plane are in reasonable agreement with the rebound hammer results.

Table 5-14: Summary of Point Load Testing Results

TEST NUMBER	TEST TYPE	Is (Mpa)	Size Correction Factor	$Is_{(50)}$ (Mpa)	Estimated Uniaxial Compressive Strength (K=21) (Mpa)	Estimated Bearing Capacity (Ksp=0.1) (Mpa)
1	Axial	9.72	0.796	7.74	162.48	16.2
2	Axial	8.77	0.779	6.82	143.32	14.3
3	Axial	8.56	0.859	7.36	154.54	15.4
4	Diametral	2.65	0.949	2.52	52.85	5.3
5	Diametral	1.62	0.949	1.54	32.24	3.2
6	Axial	11.95	0.868	10.38	217.90	21.7
7	Axial	9.72	0.807	7.84	164.70	16.5

6.0 DISCUSSION AND RECOMMENDATIONS

It is understood that the wind turbines are to be bolted to a grout levelling pad which will be situated on bedrock. Lateral support will be provided by series of guywires and anchor blocks. No doweling or anchoring of the guy anchor blocks is to be performed.

In general, the bedrock conditions are considered suitable for the proposed tower placement, provided the following considerations are observed.

6.1 Site Preparation

It is recommended that the site for the wind turbine pad shall be levelled to allow for a uniform distribution of loading.

Snow, ice, standing water, debris, and/or fill material should not be present on the surface of the bedrock prior to placing concrete.

Where possible, construction on areas of excessive faults or jointing should be avoided. In the event that, after excavation, bedrock is encountered which appears to be significantly different from what has been observed as mentioned in this report, Amec Foster Wheeler should be notified.

6.2 Geotechnical Parameters

Geotechnical design parameters and consideration for each of the turbine sites are presented in table 6.1, below.

Table 6-1: Summary of Geotechnical Parameters

Tower	Allowable Bearing Capacity[1] (kPa)	Unit Weight (kN/m^3)	Estimated RQD (%)	Estimated Angle of Internal Friction (Degrees)
14-01	2750	26.5	30 - 50	31
14-02	3000	26.5	50 - 60	31
14-03	2100	26.5	30 - 60	31
14-04	2450	26.5	30 - 60	31

Notes:
1. Allowable bearing Capacity includes a factor of safety of approximately three.

Settlement is considered to be negligible on bedrock, and is not considered to be an issue in this case.

6.3 Construction Considerations

We expect the concrete will be cast directly on the rock surface to reduce voids between the concrete and the rock surface. Snow, ice, standing water, debris, and/or fill material not be present on the surface of the bedrock prior to placing concrete.

Any concrete to be used as part of the construction of the proposed tower must be resistant to the adverse effects of being exposed to sea water. All concrete used during construction shall meet, or exceed exposure conditions as defined by CSA A23.1 09 (CSA, 2009).

6.4 Seismic Design Parameters

Based on the field observations, the seismic classification of the material observed in the test site is "B" (un-weathered bedrock), in conformance with the criteria in Table 4.1.8.4A, Part 4, Division B of the National Building Code (NBC 2010). The four (4) values of the Spectral response acceleration $S_a(T)$ for different periods and the Peak Ground Acceleration (PGA) can be obtained from Table C-2 in Appendix C, Division B of the NBC (2010) or from http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2010-eng.php if the location is not in the table. The design values of F_a and F_v for the project site should be calculated in accordance to Table 4.1.8.4 B and C.

7.0 CLOSING REMARKS

This report was prepared for the exclusive use of the Department of Fisheries and Oceans for the specific application to the project site. The geotechnical investigation was conducted in accordance with the work plan developed for this site and verbal requests from the Client. The work was performed using accepted assessment practices and procedures commonly used in the industry. The limitations of this report are stated in Appendix C.

Respectfully submitted,

Yours truly,

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DATE
NEWFOUNDLAND & LABRADOR

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PEG
PERMIT HOLDER
This Permit Allows
Amec Foster Wheeler Americas Limited
To practice Professional Engineering in Newfoundland and Labrador.
Permit No. as issued by PEGNL N0844
which is valid for the year 2016

8.0 REFERENCES

ASTM Standard D5731, 2008, "Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications," ASTM International, West Conshohocken, PA

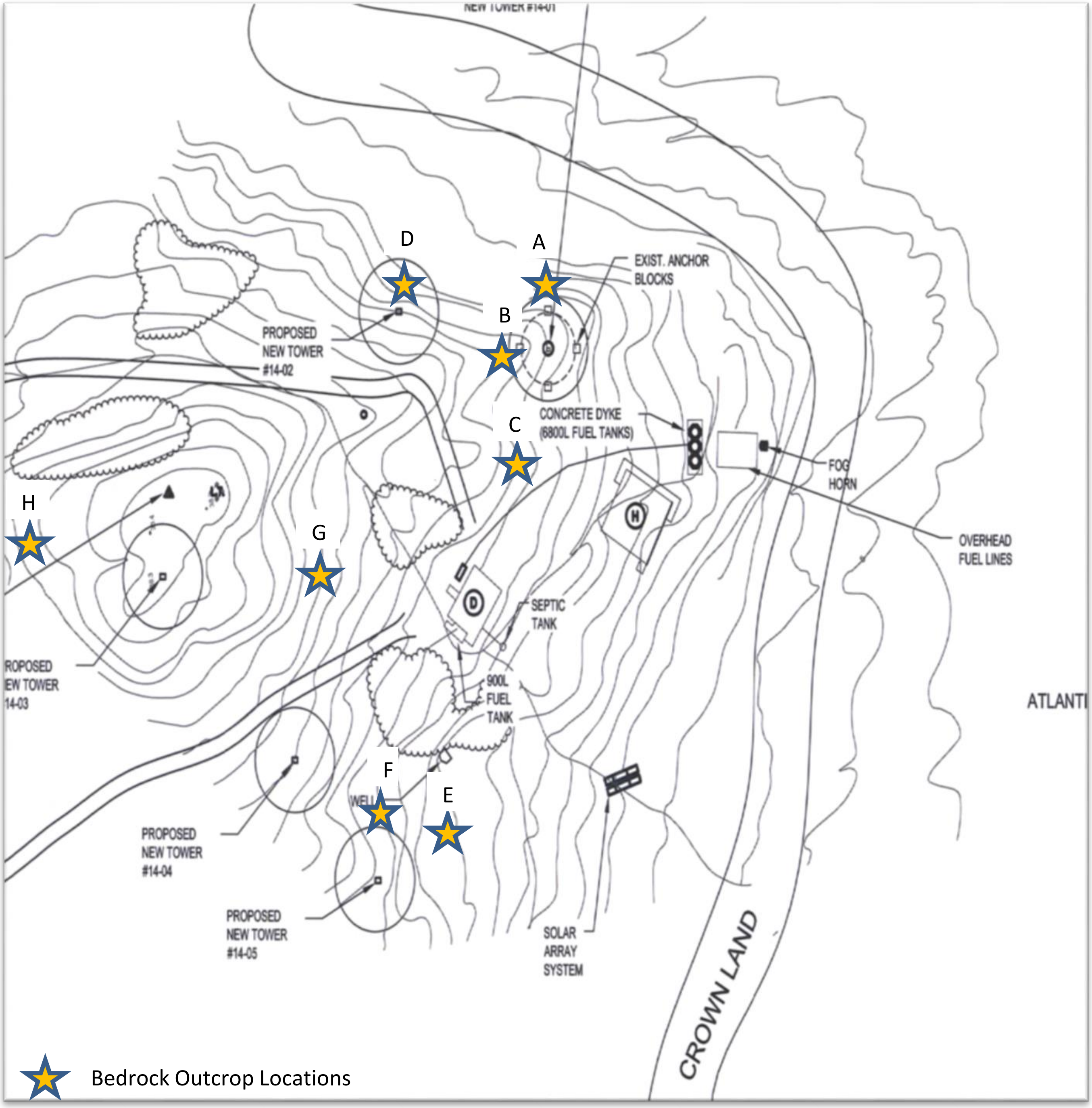
Canadian Foundation Engineering Manual, 2006. 4th Edition. Canadian Geotechnical Society.

CSA (Canadian Standards Association), 2009. A23.1-09, "Concrete Materials and Methods of Concrete Construction".

NBCC. (2010). National Building Code of Canada 2010. Ottawa, Ontario: National Research Council of Canada.

Rusnak, J., Mark, C., 2000. Using the point load test to determine the uniaxial compressive strength of coal measure rock. In: Peng, S.S., Mark, C. (Eds.), Proceedings of the 19th International Conference on Ground Control in Mining, Morgantown, West Virginia, 2000, pp. 362–371.

APPENDIX A: Location Plan



NOTES: 1) NOT TO SCALE - DO NOT SCALE FROM THIS FIGURE.
2) THIS FIGURE IS MODIFIED FROM CLIENT SUPPLIED DRAWING S-G-01

Amec Foster Wheeler Environment & Infrastructure 133 Crosbie Road St. John's, NL A1B 4A5	PROJECT: TF1611038 - Department of Fisheries and Oceans Geotechnical Investigation Wind Turbine Installation, Green Island			
	TITLE: **Green Island Site Plan**			
CLIENT: Department of Fisheries and Oceans	DATE: March 2016	Work Task Order:	FIGURE No.: Figure 1	REV. A

APPENDIX B: Photographic Journal

	
Photo 1: Existing Turbine & Concrete Support Blocking. Existing Turbine to be decommissioned and replaced with Turbine 14-01.	**Photo 2: Proposed Location of Turbine 14-01 after decommissioning of existing turbine.**

Photo 3: Outcrop A – near proposed location of Turbine 14-01. Located adjacent to east anchor block. Note close spacing of joints / cleavage planes with some surface fracturing.

Photo 4: Alternate view of Outcrop A.

	
Photo 5: Outcrop B – near proposed location of Turbine 14-01. Located ~ 3 m west of the existing west anchor block. Note close spacing of joints / cleavage planes with some surface fracturing.	**Photo 6: Alternate view of Outcrop B.**

 **Photo 7: Outcrop C – near proposed location of Turbine 14-01. Located ~ 10 m southeast of the existing tower. Note close spacing of joints / cleavage planes with some surface fracturing.**	 **Photo 8: Alternate view of Outcrop C.**

 Photo 9: View of existing tower (proposed Turbine Site 14-01) from approximate location of Turbine 14-02.	 Photo 10: View of approximate location of Turbine 14-02.

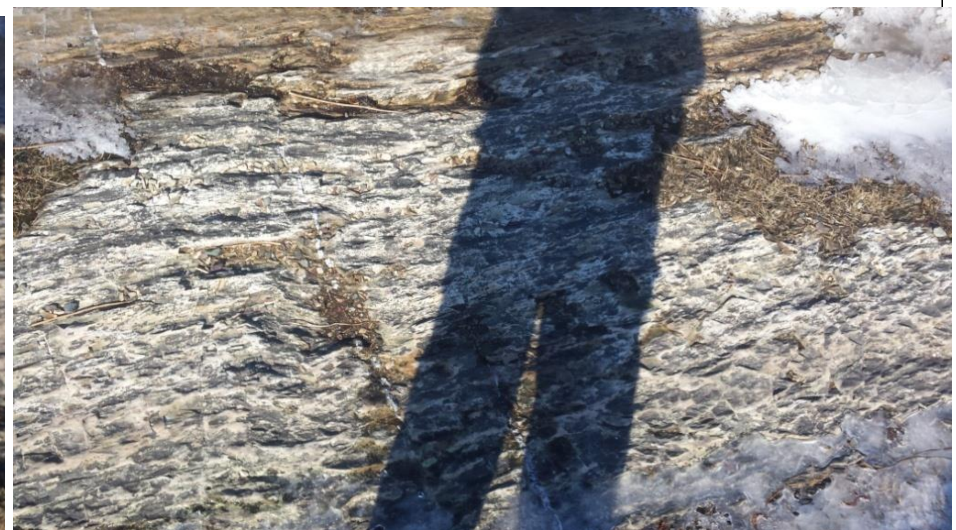
	
Photo 11: Outcrop D – near approximate location of Turbine 14-02. Note close spacing of joints / cleavage planes with some surface fracturing.	**Photo 12: Alternate view of Outcrop D.**

 Photo 13: View of approximate location of Turbine 14-03.	 Photo 14: View of concealed bedrock ridge ~ 20 N-NW of approximate location of Turbine 14-03.

	
Photo 15: Outcrop E located ~ 50 m W-SW of approximate location of Turbine 14-03. Some fracturing from joint patterns.	**Photo 16: Alternate view of Outcrop E.**

Photo 17: Outcrop F located ~ 35 m NE of approximate location of Turbine 14-03. Note close spacing of cleavage planes with some surface fracturing.

Photo 18: Alternate view of Outcrop F.

	
Photo 19: View of approximate location of Turbine 14-04.	**Photo 20: View to shoreline (toward South) from approximate location of Turbine 14-04.**

Photo 21: Outcrop G located ~ 30 m NE of approximate location of Turbine 14-04. One dominant joint set striking E-W with near vertical dip.

Photo 22: Alternate view of Outcrop G.

 **Photo 23: View of approximate location of Turbine 14-05.**	 **Photo 24: View to shoreline (toward SW) from approximate location of Turbine 14-05.**

	
Photo 25: Outcrop H located ~ 25 m NE of approximate location of Turbine 14-05 exhibiting close spaced jointing and cleavage planes.	**Photo 26: Alternate view of Outcrop H.**

	
Photo 27: Site view toward west.	**Photo 28: View of exposed bedrock along south shoreline.**

Photo 29: Site view toward north-northwest.

APPENDIX C: Limitations

Amec Foster Wheeler Environment & Infrastructure
LIMITATIONS OF REPORT

The conclusions and recommendations given in this report are based on information determined at the test locations. The information contained herein in no way reflects on the environmental aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the test locations may differ from those encountered at the test locations, and conditions may become apparent during construction, which could not be detected or anticipated the time of the site investigation. It is recommended practice that the Geotechnical Consultant be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered at the test locations. The elevations used in this report are primarily to establish relative elevation differences between the test locations and should not be used for other purposes, such as grading, excavating, planning development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Any comments made in this report on potential construction problems and possible methods are intended only for guidance of the designer. The number of test locations may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of superficial fill and organic layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices. No other warranty is expressed or implied.

Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC Foster Wheeler accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.