FINAL

Geotechnical Investigation
Proposed Radar Tower
Robin Hood Bay, NL

Submitted to:

Department of Fisheries and Oceans Canadian Coast Guard

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Submitted by:

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Amec Foster Wheeler Project #: TF1811054

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1.0 INTRODUCTION

1.1 General

Amec Foster Wheeler Environment & Infrastructure, a Division of Amec Foster Wheeler Americas Limited (Amec Foster Wheeler), has been retained by the Canadian Coast Guard (CCG) to perform a Geotechnical Investigation at the proposed location for a new radar tower in Robin Hood Bay.

1.2 Objectives and Scope of Work

The objective of the investigation is to determine the localized subsurface stratigraphy and the condition of the bedrock and/or soil beneath the proposed self-support tower base (as per CSA Standard S37-13). The investigation addresses the following geotechnical aspects including:

- Surface soil and bedrock types;
- Preliminary Bearing capacity of soil and/or bedrock;
- Frost considerations;
- Seismic considerations; and
- Site preparation considerations.

2.0 SITE DESCRIPTION

The tower site is located on land currently occupied by a tower site owned and operated by the Canadian Coast Guard (CCG), on a hill (Robin Hood Bay) within the municipal limits of the City of St. John’s, NL. The site is accessible via a gravel road. This area was also the location of a number of towers owned by CCG and others. The site location can be seen in Appendix A.

3.0 SITE GEOLOGY

3.1 Surficial Geology

The surficial geology at the site is comprised of a thin veneer of rootmat (topsoil) overlying glacial till, overlying bedrock. The ground surface was vegetated with wild grass, bushes, and scrub trees.

3.2 Bedrock Geology

Geological mapping shows the bedrock to belong to the Signal Hill Group of rocks, and is a red sandstone and conglomerate. This was confirmed in the test pit excavation and is visible in outcrops throughout the site.

4.0 GEOTECHNICAL INVESTIGATION METHODOLOGY

4.1 General

Field work for the investigation was carried out on March 12th, 2018. Supervision of the test pit excavation was provided by Andrew Guest, EIT, of Amec Foster Wheeler. The investigation comprised of one (1) excavation; TP-01 and logging of the test pit. The Location of the test pit was taken with an etrex 20 © hand held GPS.

4.2 Test Pit Excavations

The test pit was excavated with a Case 160 track mounted excavator owned and operated by Fowler's Excavation Limited. During excavation, the soil was visually described with respect to gradation, relative density, colour, structure/texture, and inferred moisture content. Encountered soils were classified in general accordance with the Canadian Foundation Engineering Manual (Canadian Foundation Engineering Manual, 2006). Relative density and soil strength were interpreted from the excavator resistance to digging.

One soil sample was taken from the test pit. The sample was logged and transported to Amec Foster Wheeler's St. John's Materials Testing Laboratory for further analysis.

Upon completion, the open test pit was inspected for indication of the groundwater level. The test pit was backfilled upon completion using nominal compactive effort with the excavator bucket.

5.0 INVESTIGATION RESULTS

The Test Pit log for the site can be seen in Appendix B. A summary of the test pit can be seen in Table 1, below. The soil boundaries tabled below and indicated on the test pit log are inferred from field observations and resistance to the excavator advancement. These boundaries normally represent a transition from one stratum to another and they do not necessarily represent exact surfaces of geological change. The subsurface conditions may vary substantially beyond the tested location.

5.1 Subsurface Conditions

Table 1 Summary of Subsurface Conditions

Test Pit ID	Northing[1] (m)	Easting[1] (m)	Depth Below Surface (mbgs)[2]				
			Topsoil	Till	Weak Bedrock[4]	Bedrock	Groundwater
TP-01	5274417	374537	0.0 – 0.2	0.2 – 1.0	1.0 – 1.9	1.9	1.2

Notes: 1) Coordinates referenced to UTM – Zone 22 – NAD 83.
2) mbgs = meters below ground surface.
3) Ne = not encountered
4) Weak bedrock was rippable with excavator effort

5.1.1 Rootmat / Topsoil

A layer of rootmat / topsoil was encountered at the surface of the test pit and consisted of rootlets, organic material with sand and gravel. Overburden material was loose, brown, and wet.

5.1.2 Till

Till was encountered underlying the rootmat. This soil was typically loose to compact, brown, silty sand and gravel with occasional cobbles and boulders.

5.1.3 Bedrock

Bedrock was encountered underlying the till. Observed rock was a weak sedimentary rock comprising interbedded sandstone and pea size conglomerate. The bedrock was rippable with excavator effort from 1.0 to 1.9 mbgs.

5.1.4 Groundwater

Groundwater was encountered at 1.2 mbgs. Groundwater can be expected to be near the bedrock interface during construction.

5.2 Laboratory Test Results

5.2.1 Test Methodology

A grain size analysis was conducted on the sample taken from TP-01 (0.5 mbgs). The test was performed, and soil classified, in accordance with ASTM standards.

5.2.2 Test Results

The ASTM classification based on the grain size analysis of the soil samples can be seen in Table 2, below. The lab test result is included in Appendix C of this report.

Table 2: Soil Classification from Grain Size Analysis

Location	% Cobbles	% Gravel	% Sand	% Fines	Group Name	Group Symbol
TP-01	7	39	32	22	Silty Gravel with Sand	GM

5.3 Estimated Geotechnical Parameters

The following geotechnical parameters are estimated based on site observations and industry accepted correlations, see Tables 3, and 4, below.

Table 3: Geotechnical Parameters of Till

Soil Type	Unit Weight (kN/m3)	Unit Weight Submerged (kN/m3)	Effective Friction Angle (deg)	Effective Cohesion (kPa)	Active Earth Pressure, Ka	Passive Earth Pressure, Kp	At-Rest Earth Pressure, Ko
Till	17	7	30	0	0.33	3.0	0.5

Table 4: Geotechnical Parameters for Competent Bedrock

Soil Type	Unit Weight (kN/m3)	Unit Weight Submerged kN/m3	Effective Friction Angle (deg)	Effective Cohesion (kPa)	Estimated RQD (%)	Unconfined Compressive Strength (MPa)	Shear Strength (MPa)
Competent Bedrock	25	15	30	100	50	30	2.5

6.0 DISCUSSION AND RECOMMENDATION

It is understood that the self-support radar tower foundations will be cast in place concrete foundations on competent bedrock, which are secured with rock anchors. It is also understood that the proposed location will be built up with engineered fill after the installation of the foundations. A conceptual design of the foundation system (provided by the client) can be seen in Figure 1, below.

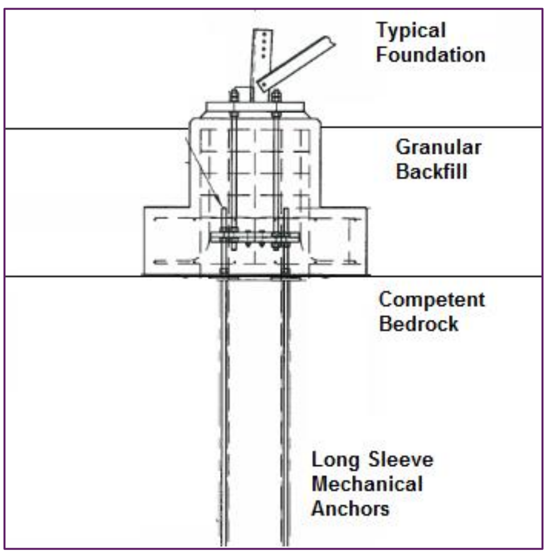

Figure 1: Conceptual Foundation Design

6.1 Site Preparation

Proper surface drainage is essential in order to reduce the potential for excess moisture penetration below foundation elements. Site grading should provide positive drainage away from the structure.

Improper site preparation could result in voids along the concrete bedrock interface, frost heave and weathering of the concrete/bedrock. The following considerations are related to site preparation.

6.1.1 Subgrade Preparation

Any organic soils, weak or loose soil and existing fill should be stripped and removed from the site to expose competent bedrock prior to placement of engineered fill.

It was noted during the investigation that the bedrock surface is dipping toward the coast and has weak areas susceptible to frost. A rock breaker may be required to remove weak and/or weather bedrock to a competent bedrock surface. The foundation surface preparation should be inspected and approved by the qualified geotechnical personnel.

Footings shall rest on undisturbed rock. The bedrock shall be cleaned of loose and unsound material and shall be adequate to support the design of the load taking into account temperature, precipitation, construction activities, and other factors that may lead to changes in the properties of soil or rock.

6.1.2 Backfill

Soil on site is not recommended for use as backfill due to concerns for compactability and man-made debris noted during the investigation. It is recommended that a suitable backfill be sourced offsite. It is recommended that the backfill material be a well graded granular material such as a 4" minus or pit run.

The backfill material should be placed in thin layers ranging from 200 to 300 mm in thickness, depending on the compaction equipment used. Oversize particles (cobbles and boulders) larger than 150 mm should be discarded, and each fill layer should be uniformly compacted with heavy compactors, suitable for the type of fill used, to at least 95% of its Standard Proctor Maximum Dry Density (SPMDD).

The backfill should not be frozen and should be placed at a moisture content within 2 % of the optimum value for compaction. The backfill should not be placed during winter months when freezing ambient temperatures occur persistently or intermittently.

Recommended geotechnical parameters of backfill for preliminary design purposes can be seen in Table 5, below:

Table 5: Recommended Geotechnical Parameters for Granular Fill

Soil Type	Unit Weight (kN/m3)	Unit Weight Submerged kN/m3	Effective Friction Angle (deg)	Effective Cohesion (kPa)	Active Earth Pressure,	Passive Earth Pressure, Kp	At-Rest Earth Pressure, Ko
Granular Fill	21	11	32	0	0.31	3.2	0.47

6.1.3 Frost Depth Penetration

The frost depth penetration for the site was calculated using the modified Berggren formula. Historical climate data required for the calculation of frost penetration, such as: Mean Annual Air Temperature, Number of freezing days, and Freezing Index, was obtained from the Government of Canada website: http://climate.weather.gc.ca/climate_normals/index_e.html.

Historical climate data from the St. Johns Airport Station was used to estimate the frost penetration for the proposed radar tower. The frost penetration depth for was calculated as approximately 1.2 m *for a snow covered turf* (Canadian Foundation Engineering Manual, 2006). It is recommended that a foundation be placed below the frost line to avoid damage due to frost uplift. Where excavation to this depth is considered unfeasible, some alternatives to excavation are: backfilling to achieve the required cover, or thermal insulation may be used to reduce the penetration of frost below a foundation. Under no conditions should backfill be placed on frozen soil.

Although the modified Berggren formula is specifically designed for frost heave of soils, frost depth penetration may also be a concern in the case of fractured bedrock. Water trapped between large fractures, or voids, may create ice lenses and cause movement of the foundation. Where practical, heavily fractured bedrock should be excavated to more competent bedrock. Proper site drainage may help to avoid this issue as well.

6.2 Estimated Bearing Capacity

Following the site preparation methods outlined in Section 6.1 the following bearing capacities can be used for the site:

For foundations placed on competent Sandstone or Pebble Conglomerate:

Geotechnical Resistance at ULS	3000 kPa
Factored Geotechnical Resistance at ULS	1500 kPa
Geotechnical Resistance at SLS	1000 kPa

During construction, the footing subgrade should be reviewed by a qualified geotechnical engineer to confirm that the underlying bedrock has adequate bearing capacity.

Concrete should not be placed on frozen soil, nor bedrock which may be susceptible to frost (weak and/or weathered bedrock).

Settlements of shallow spread footings will vary depending on the magnitude of load, load distribution, depth and size of footing and subgrade soil/rock type(s). However, if the recommendations of this report are adhered to, it is expected that settlements associated with the geotechnical resistances at SLS provided above would be negligible.

6.3 Anchor Considerations

It is understood that rock anchors will be used to secure the tower foundation to the competent bedrock surface. It is recommended that long sleeve mechanical anchors be used. For anchor design purposes the following geotechnical parameters may be used:

- Groundwater level at surface (worst case);
- Assumed apex angle of 60°;
- Minimum depth of embedment of 4.0 m.

An in-depth rock investigation was not proposed for this investigation. The values provided above are estimates based on technical knowledge and industry standards. Should bedrock be of poorer quality than assumed during drilling and/or issues be encountered with installing mechanical anchors, consideration should be given to revising the anchor type to grout or epoxy.

For design purposes it is recommended that the rock be considered fractured throughout the depth of the anchors. The anchor design should be based on the weight of the rock and overlying soil in the zone of influence of the anchor. This zone should be considered as a cone of soil and rock with the apex at the bottom of the anchor and side slopes of 30° from the anchor shaft. The anchors must be proof tested to a minimum of 133% of the design load. Corrosion protection should be provided for the anchors.

The contractor must excavate to solid, un-weathered rock before drilling any anchor holes. Prior to the placement or construction of the anchors/foundation, all surficial soils and any loose or weathered bedrock should be removed. Should differing conditions be encountered during installation than those presented in this report, Amec Foster Wheeler must be contacted to review these findings and determine if the published perimeters are applicable and revise accordingly.

6.4 Earthquake Load and Effects

Based on the type and strength of material encountered, the site coefficient value for this site is Fs = 1.0 (rock site).

The site coefficient value provided is estimated in accordance with the requirements of the National Building Code of Canada (2015) for the rock strength as described in Section 4.1.8.1 (b), for the top 30 m of soil/rock below footings, pile cap, or mat foundations (National Buidling Code of Canada Volume 1, 2015). It should be noted that investigation depths were not advanced to the minimum 30 m depth the site coefficient was based on the observations within the depths of investigation (1.9 mbgs) and interpretation of available geological information.

6.4.1 Site Classification for Seismic Response

Based on the type and strength of material encountered, the site classification value for this site is Site Class C.

The site classification provided is estimated in accordance with the requirements of the National Building Code of Canada (2015) for the soil/rock strength as described in Table 4.1.8.4.-A for the top 30 m of soil below footings, pile caps, or mat foundations (National Buidling Code of Canada Volume 1, 2015).

It should be noted that investigation depths were not advanced to the minimum 30 m depth and this seismic classification was based on the observations within the depths of investigation (1.9 mbgs) and interpretation of available geological information.

6.5 Quality Control and Quality Assurance

The following minimum inspection and testing activities should be conducted during construction:

- Foundations – subgrade inspection prior to placing concrete;
- Concrete testing – to ensure compliance with design requirements; and
- Anchor testing – to ensure the anchors are engaged and can hold the required loads

Should the subsurface conditions vary significantly during construction from those noted within this report, Amec Foster Wheeler should be notified immediately in order to review the recommendations presented herein in light of any new findings. At the time this report was prepared, information on subsurface stratigraphy was available only at the test pit location and recommendations were based on extrapolation and interpretation of this location. Adequate monitoring during construction should be provided to confirm that these assumptions are reasonable. Qualified persons, under the supervision of a geotechnical engineer independent of the contractor, should carry out all monitoring.

It is important that the foundation design and the foundation construction procedures become available for review by the geotechnical engineer prior to construction to confirm consistency with the intent of this report. In addition, a program of stringent quality control should be in place during construction of the foundation to verify that the construction methodology and material comply with design requirements.

7.0 CLOSING REMARKS

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.

Yours Sincerely,

Amec Foster Wheeler Environment & Infrastructure
A Division of Amec Foster Wheeler Americas Limited

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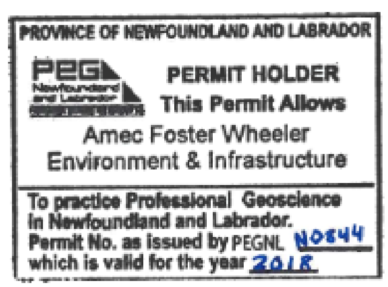
Senior Geotechnical Engineer



8.0 REFERENCES

Canadian Foundation Engineering Manual (4th ed.). (2006). Canadian Geotechnical Society.

National Buidling Code of Canada Volume 1. (2015). Canadian Commission on Building and Fire Codes.

APPENDIX A: SITE PLAN

Department of Fisheries and Oceans – Canadian Coast Guard
Geotechnical Investigation
Proposed Radar Tower
Robin Hood Bay
Project # TF1811054
March 27, 2018

APPENDIX B: TEST PIT LOGS

Test Pit: 01					
Firm:	Department of Fisheries & Oceans – Canadian Coast Guard				Date: Mar. 12th 2018
Project:	Robin Hood Bay Geotechnical Investigation – Proposed Radar Tower				
Contract No.	TF1811054	Location	N 5274417	E 374537	Inspector: A. Guest

PHOTOGRAPHS

Soil and Groundwater Conditions

Depth (m) From - To	Description	Sample ID.	Sample Depth (m)	Sample Type
0.0 – 0.2	Rootlets/Topsoil – organic material, black to brown, loose	-	-	-
0.2 – 1.0	TILL – GRAVEL AND SAND – trace fines to silty, trace cobbles and boulders, sub angular to angular, well graded, compact, brown, moist.	GS-01	0.5 m	Grab
1.0 – 1.9	WEATHERED BEDROCK – Conglomerate, weathered and rippable with digging bucket, weak, red in colour.			
1.9	BEDROCK – Conglomerate, low rippability, red in colour.	-	-	-

Estimated Cobbles (%) <10	Estimated Boulders (%) <5	Estimated Max Diameter (m) 0.3

General Notes

1. Groundwater noted at 1.2 m during test pit excavation.
2. Test pit walls stable.
3. Some debris noted during excavation (broken PVC pipe / old cable).
4. Test pit terminated at 1.9 m depth due to refusal on bedrock.
5. Test pit conducted with CASE 160 excavator with digging bucket

APPENDIX C: LABORATORY TEST RESULTS

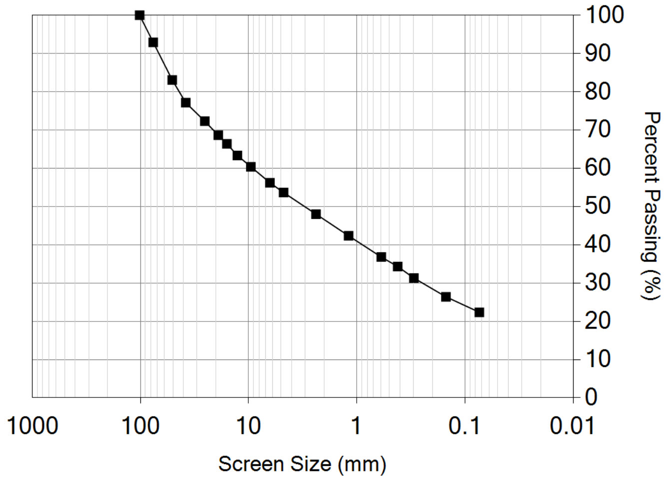
Sieve Analysis

Report Date: March 23, 2018

Client		Project	
Name:	Department of Fisheries and Oceans Canada	**Name:**	(TF1811054) Robin Hood Bay - Geotechnical Investigation
Address:	10 Barter's Hill PO Box 5667 St. John's , Newfoundland A1C 5x1	**Address:**	St. John's, NL
Attention:	Mike Hedderson	**Phase:**	**Task:**
PO Number:	F6839-175608	**Manager:**	Andrew Guest
Sample Date:	3/22/2018 by Andrew Guest	**Lab/Ref. #:**	7693
Source:	Robin Hood Bay, Test Pit	**Description:**	Grab Sample, Till

Type of Specification: No project specification was provided.

Cumulative Particle Distribution



Sieve Analysis: (ASTM C117-13/C136-14)

200 Wash Procedure: A

	Sieve Size	Passing	Specification Min	Specification Max
Coarse Portion:	100mm	100%		
	75mm	93%		
	50mm	83%		
	37.5mm	77%		
	25mm	72%		
	19.0mm	69%		
Fine Portion:	16.0mm	66%		
	12.5mm	63%		
	9.5mm	60%		
	6.3mm	56%		
	4.75mm	54%		
	2.36mm	48%		
	1.18mm	42%		
	600µm	37%		
	425µm	34%		
	300µm	31%		
	150µm	26%		
	75µm	22%		

Particle Size (bold indicates value was interpolated)

Over 3" / 76mm	Gravel		Sand			Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
7.0%	24.0%	15.0%	**8.0%**	**12.0%**	12.0%	22.0%	

Remarks:

Distribution: Andrew Guest, Tim Park

Reviewed By: Dawn O'Keefe

Dawn O'Keefe

Reporting of these test results constitutes a testing service only. Engineering evaluation of the test results is provided only on written request.

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