Appendix A - Site Location Photos

(starts on following page)

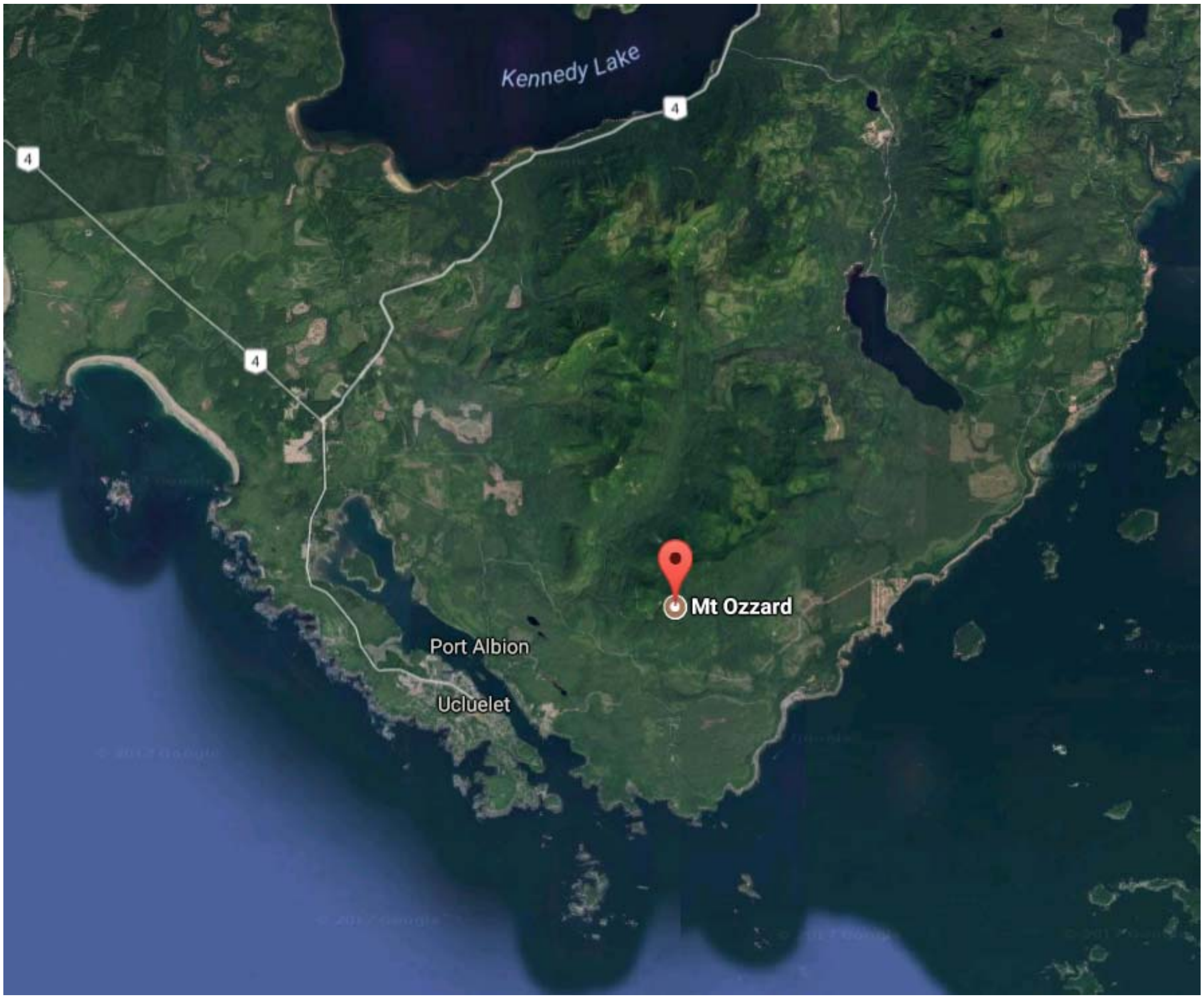


Figure 1 - Site Location

Figure 2 - Proposed Tower Location

Appendix B - Summary of Submittals

DESCRIPTION	SECTIONS	DEADLINE
Design package	01 11 00 – 1.4.1.1	28 days following contract award
• Tower design drawings		
• Foundation design drawings		
Fabrication Plan	01 11 00 – 1.4.1.2	28 days following contract award
• Fabrication shop drawings		
• Fabrication schedule		
Installation Package	01 11 00 – 1.4.1.3	28 days following contract award
• Erection drawings		
• Material lists		
• Bolt installation procedures		

Appendix C - Antenna Schedule

(starts on following page)

Table 1 – CCG EQUIPMENT

#	ELEV (m)	ANTENNA	INITIAL or FUTURE	AZIMUTH	Tx-LINE
1	45.0	VHF-DF Servo Antenna	Initial	Omni	Apha Wire P/N 86318C4
2	39.3	SRL 210C-HD	Initial	200°	LDF4-50
3	33.2	SRL 210C-HD	Initial	200°	LDF4-50
4	27.1	SRL 210C-HD	Initial	200°	LDF4-50
5	28.0	SRL 206	Initial	300°	LDF4-50
6	27.7	SRL 206	Initial	134°	LDF4-50
7	24.0	SRL 206	Initial	300°	LDF4-50
8	22.0	SRL 210C-HD	Future	200°	LDF4-50
9	18.8	Andrew HP10	Initial	138°	EW77 (2)
10	18.8	Andrew HP10	Initial	138°	EW77 (2)
11	15.2	Andrew HP4	Initial	220°	EW77 (2)
12	15.2	Andrew HP10	Initial	300°	EW77 (2)
13	10.2	SRL307 With Radome	Initial	93°	LDF4-50
14	10.2	SRL307 With Radome	Initial	313°	LDF4-50
15	7.0	Andrew HP10	Initial	300°	EW77 (2)

Table 2 - FUTURE OTHER EQUIPMENT

ANTENNA	AZIMUTH	ANTENNA CABLES	TOWER MOUNTED EQUIPMENT	DATA / POWER FEED FROM EQUIPMENT ROOM
UPPER BOOM SET (Antennas 16-21 @ELEV 42.0m)				
Panel	270°	LDF4-50 Jumpers (4) RET Cable (2)	Remote Radio Units (4) Junction Boxes (1)	Fibre Trunk Cables (1) DC Power Trunk Cables (1)
Panel	270°	LDF4-50 Jumpers (2) RET Cable (1)		
Panel	30°	LDF4-50 Jumpers (4) RET Cable (2)	Remote Radio Units (4) Junction Boxes (1)	Fibre Trunk Cables (1) DC Power Trunk Cables (1)
Panel	30°	LDF4-50 Jumpers (2) RET Cable (1)		
Panel	150°	LDF4-50 Jumpers (4) RET Cable (2)	Remote Radio Units (4) Junction Boxes (1)	Fibre Trunk Cables (1) DC Power Trunk Cables (1)
Panel	150°	LDF4-50 Jumpers (2) RET Cable (1)		
LOWER BOOM SET (Antennas 22-27 @ELEV 36.0m)				
Panel	270°	LDF4-50 Jumpers (4) RET Cable (2)	Remote Radio Units (4) Junction Boxes (1)	Fibre Trunk Cables (1) DC Power Trunk Cables (1)
Panel	270°	LDF4-50 Jumpers (2) RET Cable (1)		
Panel	30°	LDF4-50 Jumpers (4) RET Cable (2)	Remote Radio Units (4) Junction Boxes (1)	Fibre Trunk Cables (1) DC Power Trunk Cables (1)
Panel	30°	LDF4-50 Jumpers (2) RET Cable (1)		
Panel	150°	LDF4-50 Jumpers (4) RET Cable (2)	Remote Radio Units (4) Junction Boxes (1)	Fibre Trunk Cables (1) DC Power Trunk Cables (1)
Panel	150°	LDF4-50 Jumpers (2) RET Cable (1)		

Appendix D – Site Specific Wind Pressure Report

(starts on following page)

Mt Ozzard, BC 48.8m Tower

Site-Specific 10-yr. Wind Pressure Report (V2.1 2016-01-04 Format)

Site Information:

Name: Mt Ozzard, BC
Latitude: 48° 57' 34.59" N
Longitude: 125° 29' 35.45" W
Tower Height (m): 48.8
Elevation MSL (m): 671

Results:

Note: **Following direction from the S37 Committee, Qe can no longer be provided.**

Q_{nbc} (Pa):	530	$Q_{nbc} = 530(Z/10)^{0.2}$	V_{nbc} = 64.05 mph
Icing:	As per CAN/CSA S37-13		
Q_{Min} (Pa)	250	$Q_{Min} = 250(Z/10)^{0.2}$	V_{Min} = 43.99 mph

Wind Pressure Formula (for z in metres and result in Pa):

$$Q_h = 0.12919 \{[0.6000\, e^{(-0.0032\, z)} + 1.0000 \ln(z/0.8000) / \ln(z/0.8000)]\, 50.03\}^2 \, (z/10)^{0.319}$$

Profile Formula General Form:

$$Q_h = 0.12919 \{[a_1 \, e^{(-a2\, z)} + a_3 \ln(z/z_h) / \ln(z/z_{01})]\, v_{01}\}^2 \, (z/10)^{0.319}$$

Site Values of Coefficients:

$$a_1 = 0.6000,\ a_2 = 0.0032,\ a_3 = 1.0000,\ z_h = 0.8000,\ z_{01} = 0.8000,\ v_{01} = 50.03 \text{ mph}$$

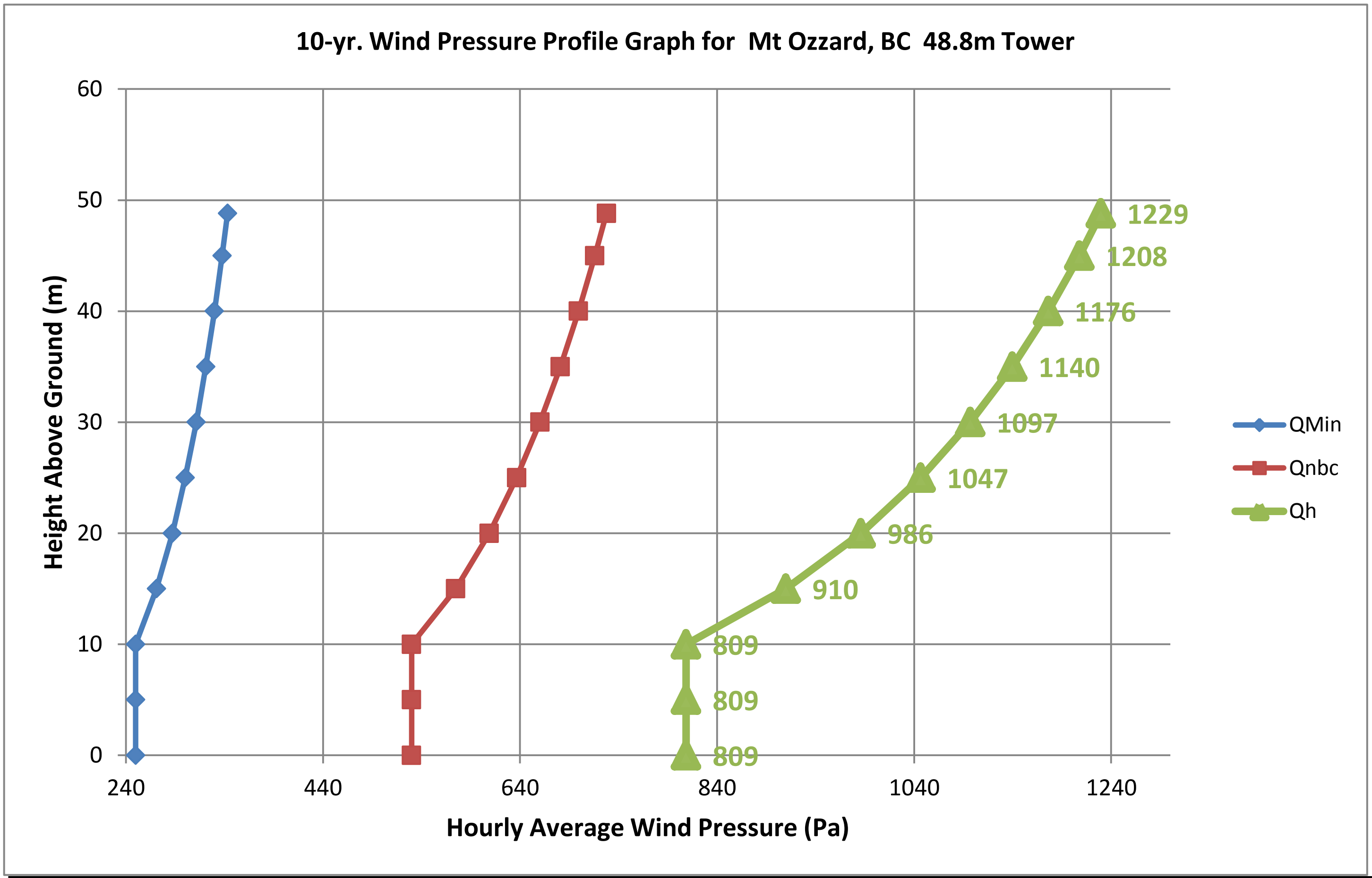
Definitions

Tower Height: Height of the tower from ground level at the base of the tower to the top of the structure.
Q_{nbc}: Regionally representative reference wind pressure at 10 m in the format of the National Building Code of Canada and the Q_{nbc} value is profiled with the $^2/_{10}$ power law.
Q_{Min}: Minimum reference wind pressure (320 Pa, 300 Pa, and 250 Pa for the 50-year, 30-year, and 10-year return periods respectively) profiled with the $^2/_{10}$ power law as per Section 5.4.1 of S37-13.

Wind Pressure Formula: Formula for the design wind pressure as a function of height. (Ref.: S37-13, 5.3.1)
Height (Z): the vertical distance (m) above ground level at the base of the tower.

Note: No wind pressure value less than 90% of the value at 10 m should be used for heights less than 10 m a.g.l.

These wind pressures were evaluated using a version of the methods described by Taylor and Lee (1984) "Simple Guidelines for Estimating Wind Speed Variations Due to Small Scale Topographic Features", Climatological Bulletin 18 2, using the Boyd (1969) analysis of thirty year return period wind speeds (which is also used for the National Building Code of Canada), modified by a technique described by Wieringa (1980) "Representativeness of Wind Observations at Airports" Bulletin of the American Meteorological Society, 61 9, as input data. The uncertainty in NBCC regionally representative reference wind pressures is about [+15%,-15%].



Q_{nbc} Profile: Regionally representative reference wind profiled with the $^{2}/_{10}$ power law.
Q_{Min} Profile: Minimum site-specific wind pressure (320 Pa, 300 Pa, and 250 Pa for the 50-year, 30-year, and 10-year return periods respectively) profiled with the $^{2}/_{10}$ power law.
Q_h.Profile: The site-specific wind pressure profile directly from the Taylor and Lee (1984) simple guidelines.

Explanatory notes regarding the new report format and changes to calculation methods.

1. The most significant change from the previous versions of the reports is that the exponent used in the Q_h equation is no longer fixed at 0.2. The exponent now varies continuously from 0.2 for open terrain to 0.32 for closed terrain.
2. A new Q_{min} profile has been added to the graphs and it represents the minimum acceptable reference wind pressure profile. It starts with the minimum 10-metre reference wind pressure of 320 Pa for a 50-year return period as per section 5.4.1 of S37-13 and then uses the same $^{2}/_{10}$ power law formulation as the Q_{NBC} profile to generate the curve. The corresponding 10-metre reference wind pressures for the 10-year and 30-year return periods are 250 Pa and 300 Pa respectively.
3. Q_h will always be plotted even when they are less than Q_{Min}. This will allow designers to see how Q_h varies over the height of the tower. Also, in rough terrain and for taller towers, the Q_h profile might cross the Q_{Min} profile.
4. The coefficients for the Q_h equation will now always be given regardless of the Q_{NBC} or Q_{Min} values.
5. The wind speeds will be given for each of the 4 equations (Q_h, Q_{NBC}, or Q_{Min}) too.

Mt Ozzard, BC 48.8m Tower

Site-Specific 30-yr. Wind Pressure Report (V2.1 2016-01-04 Format)

Site Information:

Name:	Mt Ozzard, BC
Latitude:	48° 57' 34.59" N
Longitude:	125° 29' 35.45" W
Tower Height (m):	48.8
Elevation MSL (m):	671

Results:

Note: **Following direction from the S37 Committee, Qe can no longer be provided.**

Q_{nbc} (Pa):	630	$Q_{nbc} = 630(Z/10)^{0.2}$	V_{nbc} = 69.83 mph
Icing:	As per CAN/CSA S37-13		
Q_{Min} (Pa)	300	$Q_{Min} = 300(Z/10)^{0.2}$	V_{Min} = 48.19 mph

Wind Pressure Formula (for z in metres and result in Pa):

$$Q_h = 0.12919 \{[0.6000\, e^{(-0.0032\, z)} + 1.0000\, ln(z/0.8000) / ln(z/0.8000)]\, 54.75\}^2\ (z/10)^{0.319}$$

Profile Formula General Form:

$$Q_h = 0.12919 \{[a_1\, e^{(-a2\, z)} + a_3\, ln(z/z_h) / ln(z/z_{01})]\, v_{01}\}^2\ (z/10)^{0.319}$$

Site Values of Coefficients:

$$a_1 = 0.6000,\ a_2 = 0.0032,\ a_3 = 1.0000,\ z_h = 0.8000,\ z_{01} = 0.8000,\ v_{01} = 54.75 \text{ mph}$$

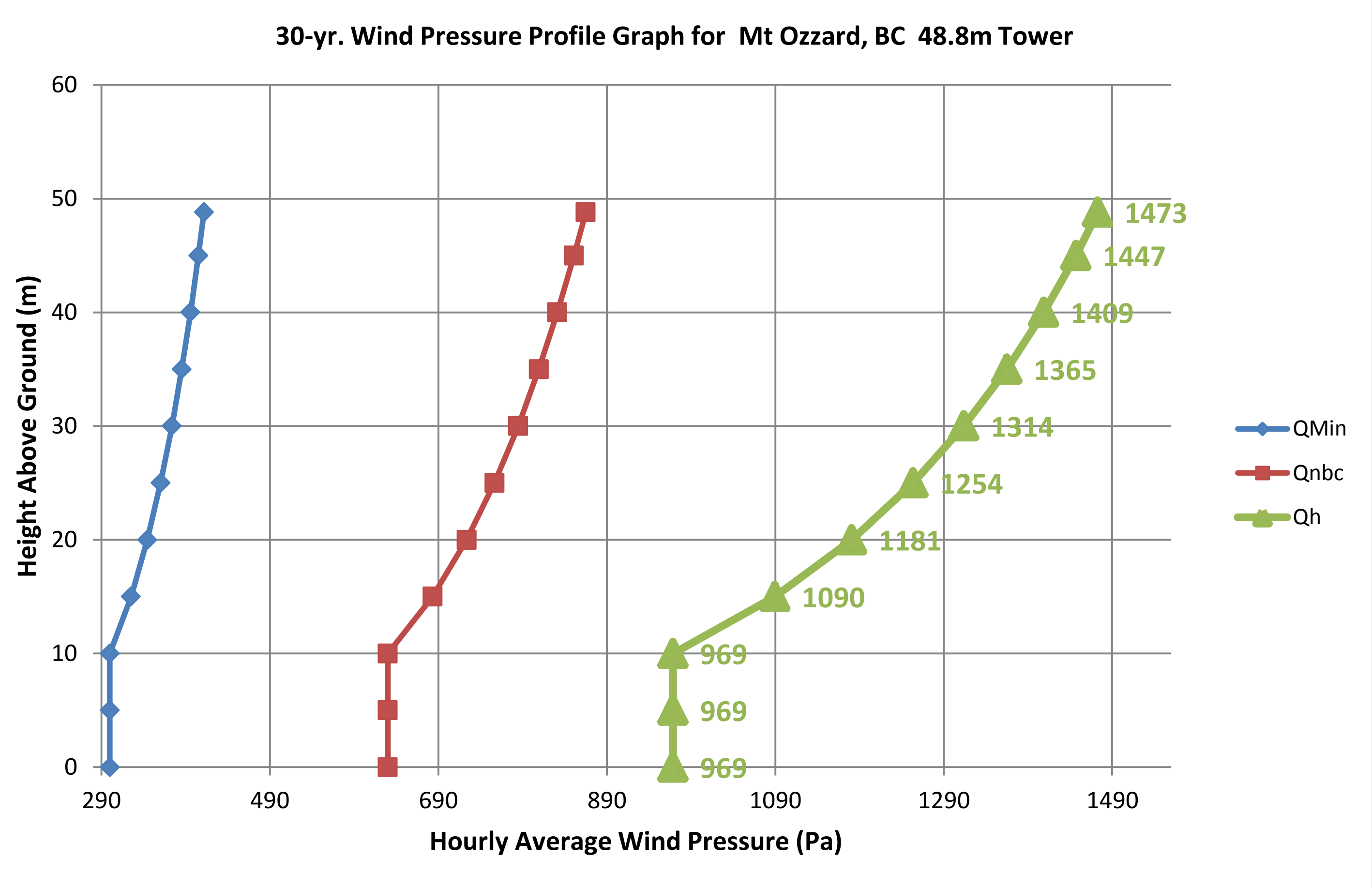
Definitions

Tower Height: Height of the tower from ground level at the base of the tower to the top of the structure.
Q_{nbc}: Regionally representative reference wind pressure at 10 m in the format of the National Building Code of Canada and the Q_{nbc} value is profiled with the $^2/_{10}$ power law.
Q_{Min}: Minimum reference wind pressure (320 Pa, 300 Pa, and 250 Pa for the 50-year, 30-year, and 10-year return periods respectively) profiled with the $^2/_{10}$ power law as per Section 5.4.1 of S37-13.

Wind Pressure Formula: Formula for the design wind pressure as a function of height. (Ref.: S37-13, 5.3.1)
Height (Z): the vertical distance (m) above ground level at the base of the tower.

Note: No wind pressure value less than 90% of the value at 10 m should be used for heights less than 10 m a.g.l.

These wind pressures were evaluated using a version of the methods described by Taylor and Lee (1984) "Simple Guidelines for Estimating Wind Speed Variations Due to Small Scale Topographic Features", Climatological Bulletin 18 2, using the Boyd (1969) analysis of thirty year return period wind speeds (which is also used for the National Building Code of Canada), modified by a technique described by Wieringa (1980) "Representativeness of Wind Observations at Airports" Bulletin of the American Meteorological Society, 61 9, as input data. The uncertainty in NBCC regionally representative reference wind pressures is about [+15%,-15%].



Q_{nbc} Profile: Regionally representative reference wind profiled with the $^{2}/_{10}$ power law.
Q_{Min} Profile: Minimum site-specific wind pressure (320 Pa, 300 Pa, and 250 Pa for the 50-year, 30-year, and 10-year return periods respectively) profiled with the $^{2}/_{10}$ power law.
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1. The most significant change from the previous versions of the reports is that the exponent used in the Q_h equation is no longer fixed at 0.2. The exponent now varies continuously from 0.2 for open terrain to 0.32 for closed terrain.
2. A new Q_{min} profile has been added to the graphs and it represents the minimum acceptable reference wind pressure profile. It starts with the minimum 10-metre reference wind pressure of 320 Pa for a 50-year return period as per section 5.4.1 of S37-13 and then uses the same $^{2}/_{10}$ power law formulation as the Q_{NBC} profile to generate the curve. The corresponding 10-metre reference wind pressures for the 10-year and 30-year return periods are 250 Pa and 300 Pa respectively.
3. Q_h will always be plotted even when they are less than Q_{Min}. This will allow designers to see how Q_h varies over the height of the tower. Also, in rough terrain and for taller towers, the Q_h profile might cross the Q_{Min} profile.
4. The coefficients for the Q_h equation will now always be given regardless of the Q_{NBC} or Q_{Min} values.
5. The wind speeds will be given for each of the 4 equations (Q_h, Q_{NBC}, or Q_{Min}) too.

Mt Ozzard, BC 48.8m Tower

Site-Specific 50-yr. Wind Pressure Report (V2.1 2016-01-04 Format)

Site Information:

Name: Mt Ozzard, BC
Latitude: 48° 57' 34.59" N
Longitude: 125° 29' 35.45" W
Tower Height (m): 48.8
Elevation MSL (m): 671

Results:

Note: **Following direction from the S37 Committee, Qe can no longer be provided.**

Q_{nbc} (Pa):	680	$Q_{nbc} = 680(Z/10)^{0.2}$	V_{nbc} = 72.55 mph
Icing:	As per CAN/CSA S37-13		
Q_{Min} (Pa)	320	$Q_{Min} = 320(Z/10)^{0.2}$	V_{Min} = 49.77 mph

Wind Pressure Formula (for z in metres and result in Pa):

$$Q_h = 0.12919\ \{[0.6000\ e^{(-0.0032\ z)} + 1.0000\ \ln(z/0.8000) / \ln(z/0.8000)]\ 56.91\}^2\ (z/10)^{0.319}$$

Profile Formula General Form:

$$Q_h = 0.12919\ \{[a_1\ e^{(-a2\ z)} + a_3\ \ln(z/z_h) / \ln(z/z_{01})]\ v_{01}\}^2\ (z/10)^{0.319}$$

Site Values of Coefficients:

$$a_1 = 0.6000,\ a_2 = 0.0032,\ a_3 = 1.0000,\ z_h = 0.8000,\ z_{01} = 0.8000,\ v_{01} = 56.91 \text{ mph}$$

Definitions

Tower Height: Height of the tower from ground level at the base of the tower to the top of the structure.
Q_{nbc}: Regionally representative reference wind pressure at 10 m in the format of the National Building Code of Canada and the Q_{nbc} value is profiled with the $^2/_{10}$ power law.
Q_{Min}: Minimum reference wind pressure (320 Pa, 300 Pa, and 250 Pa for the 50-year, 30-year, and 10-year return periods respectively) profiled with the $^2/_{10}$ power law as per Section 5.4.1 of S37-13.

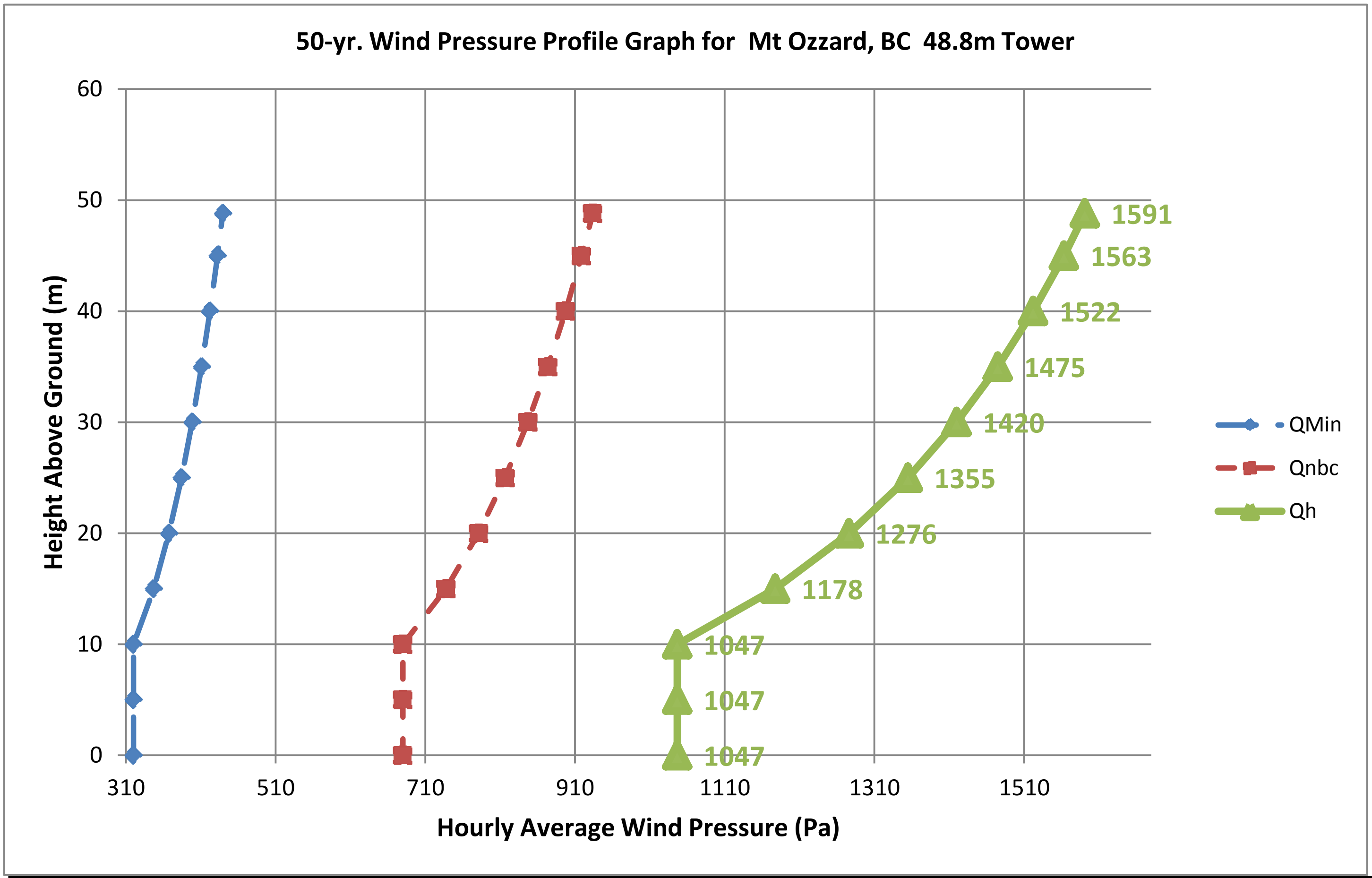
Wind Pressure Formula: Formula for the design wind pressure as a function of height. (Ref.: S37-13, 5.3.1)
Height (Z): the vertical distance (m) above ground level at the base of the tower.

Note: No wind pressure value less than 90% of the value at 10 m should be used for heights less than 10 m a.g.l.

These wind pressures were evaluated using a version of the methods described by Taylor and Lee (1984) "Simple Guidelines for Estimating Wind Speed Variations Due to Small Scale Topographic Features", Climatological Bulletin 18 2, using the Boyd (1969) analysis of thirty year return period wind speeds (which is also used for the National Building Code of Canada), modified by a technique described by Wieringa (1980) "Representativeness of Wind Observations at Airports" Bulletin of the American Meteorological Society, 61 9, as input data. The uncertainty in NBCC regionally representative reference wind pressures is about [+15%,-15%].

Environment Canada has not made and does not make any representations or warranties, either expressed or implied, arising by law or otherwise, respecting the accuracy of recommended climatic information. In no event will Environment Canada be responsible for any prejudice, loss or damages which may occur as a result of the use of design wind pressure recommendations.

December 15, 2017



Q_{nbc} Profile: Regionally representative reference wind profiled with the $^2/_{10}$ power law.

Q_{Min} Profile: Minimum site-specific wind pressure (320 Pa, 300 Pa, and 250 Pa for the 50-year, 30-year, and 10-year return periods respectively) profiled with the $^2/_{10}$ power law.

Q_h.Profile: The site-specific wind pressure profile directly from the Taylor and Lee (1984) simple guidelines.

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2. A new Q_{min} profile has been added to the graphs and it represents the minimum acceptable reference wind pressure profile. It starts with the minimum 10-metre reference wind pressure of 320 Pa for a 50-year return period as per section 5.4.1 of S37-13 and then uses the same $^2/_{10}$ power law formulation as the Q_{NBC} profile to generate the curve. The corresponding 10-metre reference wind pressures for the 10-year and 30-year return periods are 250 Pa and 300 Pa respectively.
3. Q_h will always be plotted even when they are less than Q_{Min}. This will allow designers to see how Q_h varies over the height of the tower. Also, in rough terrain and for taller towers, the Q_h profile might cross the Q_{Min} profile.
4. The coefficients for the Q_h equation will now always be given regardless of the Q_{NBC} or Q_{Min} values.
5. The wind speeds will be given for each of the 4 equations (Q_h, Q_{NBC}, or Q_{Min}) too.

Appendix E - Geotechnical Assessment Report

(starts on following page)

Canadian Coast Guard - Marine & Civil Infrastructure
25 Huron Street
Victoria, BC
V8V 4V9

July 18, 2017
File: 13974-B

Re: Geotechnical Report - Self-Supported Communication Tower, Mt. Ozzard, Ucluelet, B.C.

1.0 INTRODUCTION

We understand that the Canadian Coast Guard (CGC) proposes to construct a 24 to 31 m self supported communications tower at Mt. Ozzard near Ucluelet, British Columbia. It is our understanding that the tower is a relatively light structure and will be constructed on concrete columns and pads bearing on competent bedrock.

This report has been prepared exclusively for the Canadian Coast Guard (CGC), for their use and the use of others on their design team for this project. The report presents the results of a geotechnical site investigation and makes recommendations for the design and construction of the new tower.

2.0 SITE DESCRIPTION

The site of the proposed tower is located on top of Mt. Ozzard located approximately 4 kilometres northwest, inland from the east coast of Ucluelet, British Columbia. The proposed location of the tower was approximately located by CGC Engineer Andrew Wight, who was present at the time of the site investigation. The site of the proposed tower is located on the gravel road, to the north of the existing radar tower and immediately south of existing secants. West of the site is a steeply dipping slope of exposed bedrock and vegetation. A CGC Bell 429 Helicopter provided access to the site and a backhoe excavator was present to dig the test pit at the proposed site. The observed ground surrounding the existing radar tower is improved with a top layer gravel fill to provide near horizontal grades. South of the existing radar tower, bedrock is exposed which appears to show moderately fractured bedrock, interpreted to be damaged during blasting to grade the foundation for the radar tower. Further down the access road to the north and northwest of the proposed tower, in-tact to lightly fractured bedrock is exposed. The fill underlying the gravel fill appears to be of similar lithology as the bedrock and could be assumed to have been crushed or blasted on site during construction.

The approximate location of the test pit with respect to surrounding infrastructure on the site can be found in Drawing No. 13794-B-01, following the text of this report.

3.0 FIELD INVESTIGATION

The area was investigated on July 5, 2017. The investigation consisted of 1 test pit terminated at a depth of approximately 1.4 m below existing grade as well as a review of the rock exposed along the access road and to the south of the existing radar tower.

The approximate location of the test pit can be found in Drawing 13974-B-01, following the text of this report.

4.0 SUBSURFACE CONDITIONS

4.1 Soil/Bedrock Conditions

The subgrade observed at the site of TP17-01 consisted of approximately 150 mm of gravel fill underlain by fragmented bedrock, all over massive to moderately fractured bedrock.

Due to blasting to level the grade before construction of existing infrastructure at the site, bedrock immediately underlying the gravel fill was found to be highly fragmented in the form of angular cobbles. These cobbles increased in size with depth until moderately fractured bedrock was observed at a depth of approximately 1.4 m which resembled the lithology exposed near the south end of the existing radar tower.

The bedrock outcrops exposed at the face of the road cuts directly north and west of the proposed tower along the access road revealed a more intact and massive bedrock.

Bedrock at the site was interpreted to consist of very fine grained, dense, and crystalline andesite of the Bonanza Group. The high degree of fracturing in the bedrock near surface was interpreted to be damage due to blasting while grading the site for the existing radar tower.

Detailed logs can be found in Figure 1 of Appendix A of this report.

4.2 Groundwater Conditions

Due to the site being located on a mountain top, the static groundwater table was not encountered during our investigation and is well below the development grades of the site. Some perched groundwater seepage may occur during wetter periods.

5.0 RECOMMENDATIONS

5.1 Discussion

The site is located on bedrock with limited fill cover and thus we would expect that the compression loads from the tower would be supported on a conventional pad foundation bearing on competent bedrock.

5.2 Site Preparation

Prior to construction of any foundations, all organic material and weathered and loose rock must be removed to expose a subgrade of competent, unweathered bedrock. Variable overbreak can be expected due to reduced rock strength along weathered zones if encountered in the upper few feet.

5.3 Spread Foundations

The tower loads can be supported directly on the competent bedrock. Foundations on the competent bedrock may be designed for serviceability limit state (SLS) bearing pressures of up to 2 MPa. Factored ultimate bearing pressures can be taken as 1.5 x the SLS bearing pressures for short term transient loadings such as those induced by winds and earthquakes.

Footings should not be less than 18 inches (450 mm) in width for strip footings and not less than 24 inches (600 mm) for square or rectangular footings. Foundations on competent bedrock do not require frost protection.

We expect that post construction settlements should be less that 13 mm total and 5 mm per 5 metre differential at the recommended bearing pressures.

5.4 Rock Anchors

We expect that the foundation design will be dictated by the requirement for uplift capacity rather than compressive capacity, due to the expected wind loading imposed on the tower. We expect that rock anchors may be employed to provide restraint against uplift, therefore, the grout-to-rock bond capacity of the anchors should be considered during design. The capacity of rock anchors is dependent on the cleanliness and roughness of the drilled socket. We recommend utilizing an ultimate grout-to-rock bond stress capacity of 2.0 MPa for the local bedrock geology.

We understand that rock anchors for towers of this type are often designed to resist conical failures of the rock surrounding each rock anchor. For design purposes, we recommend that the unfactored unit weight and cone apex angle be taken as 25 kN/m^3 and 90 degrees, respectively. We expect that the grout-to-rock bond stress will govern the design of rock anchors.

A minimum anchor length of 6 metres in solid rock is recommended for all new rock anchors. The anchors should be fully grouted with microsil non-shrink grout or equivalent. Each new anchor should be proof tested to at least 150 percent of the design load capacity.

Rock anchors must be reviewed by the geotechnical engineer.

5.5 Seismic Design

The site is considered to be generally underlain by bedrock which can be considered as Site Class B, in accordance with Table 4.1.8.4.A. of the 2012 BCBC provided that footings are supported directly on the bedrock. Peak ground accelerations on firm ground for the approximate site location is 0.513 g (National Resource Canada, Site Coordinates: 48.959 degrees North, 125.493 degrees West).

The subsurface soils beyond the depth of foundations are not considered prone to ground liquefaction or other forms of ground softening caused by earthquake induced ground motions.

6.0 FIELD REVIEWS

The preceding sections make recommendations for the design and construction of the proposed 24 to 31 m tall self-supported communication tower on Mount Ozzard in Ucluelet, B.C. We have recommended the review of certain aspects of the design and construction. It is important that these reviews are carried out to ensure that our intentions have been adequately communicated. It is also important that any contractors working on the site review this document prior to commencing their work.

Geo technical field reviews are normally required at the time of the following:

1. Review of foundation subgrade prior to footing construction for the tower
2. Review of rock anchor installations and testing

7.0 CLOSURE

This report has been prepared exclusively for the Canadian Coast Gaurd (CGC) for the purpose of providing geotechnical recommendations for the design and construction of the proposed 24 to 3 1 m self-supported communication tower, temporary excavations and related earthworks.

LEGEND:

⯀TP17-# - TEST PIT (TP) LOCATION

SITE PLAN

*TEST HOLE LOCATIONS ARE APPROXIMATE

REFERENCE:

DATE: JULY 18, 2017

DRAWN BY: R.J. | APPROVED BY: M.J.K. | REVIEWED BY: M.K.

SCALE: NOT TO SCALE

COMMUNICATION TOWER
MT. OZZARD, UCLUELET, BC
TEST HOLE SITE PLAN

FILE NO.: 13974-B

DWG. NO.: 13974B-01

REVISIONS:
A.
B.
C.

Test Pit Log: TP17-01

File: 13974-B
Project: Proposed Self-Supported Communications Tower
Client: Canadian Coast Guard - Marine and Civil Infrastructure
Site Location: Mt. Ozzard, Ucluelet, B.C.

INFERRED PROFILE			Depth (m)/Elev (m)	Moisture Content (%)	Groundwater / Well	Remarks
Depth	Symbol	SOIL DESCRIPTION				
ft: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 m: 0 1 2 3 4 5 6 7		Ground Surface	0.0			
	▨	**Gravel (Fill)**	0.0			
	▨	**Cobbles and Gravel (Fill)** Orangish-grey gravel with some cobbles and silty sand. Consists of angular cobbles and gravel at the top of unit and increases in size. Same lithology as bedrock, likely used as fill following blasting	-1.4 1.4			Moderately fractured bedrock encountered @4.5 ft depth. Excavator refusal
		End of Borehole				

Logged: MK
Method: Backhoe Excavator
Date: 7/5/2017

Datum: Ground Level
Figure Number: 1
Page: 1 of 1

Appendix F - Canadian Coast Guard Grounding Standard

(starts on following page)

Fisheries and Oceans Canada
Pêches et Océans Canada
Canadian Coast Guard
Garde côtière canadienne

67-013-000-ES-EQ-001

Lightning and Grounding Protection for MCTS Sites

SALUTI PRIMUM AUXILIO SEMPER

Canadian Coast Guard

Standard

Canada

Published under the Authority of:

Integrated Technical Services Directorate
Fisheries and Oceans Canada
Canadian Coast Guard
Ottawa, Ontario

K1A 0E6

67-013-000-ES-EQ-001
LIGHTNING AND GROUNDING PROTECTION FOR MCTS SITES

FIRST EDITION – MARCH 2010

EKME# 2122925-v1

Available on CCG Intranet site at:
http://ccg-gcc.ncr.dfo-mpo.gc.ca

Disponible en français : **Protection contre la foudre et mise à la terre des sites des MCTM**

Document template :	English
Print Format:	Double Sided
Last revision:	Sept 01, 2004
Compatibility:	Word 97 & 2002 (XP)

♻ Printed on recycled paper

Document Control

Record of Amendments

#	Date	Description	Initials
1	March 2010	First Edition	R.M.

Approvals

Office of Primary Interest (OPI)	Rocco Maso	Approved:	
		Date:	June 24, 2010
Manager, Integrated Technical Services – Civil & Marine Aids	Stephanie Verbit	Approved:	
		Date:	July 15, 2010
Director, Integrated Technical Services, Engineering Services	Gilles Gareau	Approved:	
		Date:	July 20, 2010
Director General, Integrated Technical Services	Robert Wight	Approved:	
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Table of Contents

DOCUMENT MANAGEMENT .... **IX**

1. AUTHORITY IX
2. RESPONSIBILITY IX
3. INQUIRIES AND/OR REVISION REQUESTS IX

FOREWORD **XI**

1. PURPOSE XI

CHAPTER 1 BACKGROUND AND DEFINITIONS **1**

1.1 LIGHTNING 1
1.1.1 Theory of Lightning 1
1.2 LIGHTNING PROTECTION 2
1.2.1 Theory of Lightning Protection 2
1.3 GROUNDING 2
1.3.1 Basic Principles of Grounding 2
1.3.2 Site Grounding Systems 3
1.3.2.1 Lightning/Tower Ground *3*
1.3.2.2 Power Ground *3*
1.3.2.3 Building Perimeter Ground *3*
1.3.2.4 Equipment Ground *4*
1.4 CONNECTIONS 4
1.4.1 Exothermic 4
1.4.2 Bolt-on 4
1.4.3 Clamping and crimping 4
1.4.4 Silver soldering 5

CHAPTER 2 STANDARDS **7**

2.1 LIGHTNING PROTECTION OF TOWERS 7
2.1.1 Guyed Towers 7
2.1.2 Free-Standing or Self-Supporting Towers 8
2.1.3 Isolated Towers (AM Towers) 9
2.1.4 Cantilever or Roof-Top Mounted Towers 10
2.2 LIGHTNING PROTECTION OF TOWER MOUNTED EQUIPMENT 11
2.2.1 Antennas 11
2.2.2 Transmission Lines, Waveguides, and Cable Trays 11
2.2.3 Tower Lights 13

2.2.4 Tower Mounted Electronics 13
2.3 LIGHTNING PROTECTION AND GROUNDING OF BUILDING AND SITES 14
2.3.1 Building Perimeter Ground........ 14
2.3.2 Equipment Room Ground........ 15
2.3.3 Incoming Lines; Power, UPS, Telephone, and Data 16
2.3.4 Other Site Grounding Requirements........ 16
2.3.4.1 Grounding of Chain-Link Fences 16
2.4 LIGHTNING PROTECTION AND GROUNDING OF ELECTRONIC EQUIPMENT 17
2.4.1 Electronic Equipment inside Equipment Rooms 17
2.5 SPECIAL GROUNDING CONSIDERATIONS 18
2.5.1 Grounding Towers and Anchors in Rock 18
2.5.2 Grounding in Permafrost 20
2.5.3 Grounding in Low-Conductive Soil 20
2.5.4 Grounding in Corrosive Environments........ 21
2.5.5 Grounding in Co-locating Environments........ 21

CHAPTER 3 INSPECTION AND MAINTENANCE 23

3.1 NEW INSTALLATIONS 23
3.1.1 Newly installed lightning protection and grounding systems shall be inspected for the following:.. 23
3.1.2 The above ground and connection inspection of new installations shall be repeated six months after installation and thereafter in conjunction with the scheduled tower inspections. 23
3.2 EXISTING INSTALLATIONS 23
3.2.1 Existing sites shall be inspected in conjunction with the scheduled tower inspection as follows: 23
3.3 CONNECTIVITY MEASUREMENTS 24
3.4 TESTING SOIL RESISTIVITY........ 24

ANNEX A SOIL RESISTIVE VALUES 1

ANNEX B GROUND ENHANCING MATERIALS (GEM) 1

B.1 FEATURES........ 1
B.2 APPLICATIONS 1
B.3 MORE INFORMATION 1
B.3.1 GEM Calculator........ 1
B.3.2 How to Specify 1
B.4 GROUND ENHANCING MATERIAL (GEM) INSTALLATION METHODS........ 2
B.4.1 Trench Installation........ 2
B.4.1.1 Method........ 2
B.4.2 Ground Rod Backfill Installation........ 3

B.4.2.1 Method ... *3*

ANNEX C TERMS AND DEFINITIONS ... **1**

ANNEX D TEST ... **1**

ANNEX E TEST 2 ... **1**

List of Tables

Soil Resistive Values in Ω-cm ... 25
Effect of salt content on the resistivity of sandy loam with a moisture content of 15% by weight at 17°C. ... 25
Effect of temperature on the resistivity of sandy loam with a moisture content of 20% by weight and with salt weighing 5% of moisture. ... 26
Effect of moisture content by weight. ... 26
Estimated linear feet of ground conductor covering with each bag of GEM ... B-2
Estimated bags of GEM for backfilling around ground rods to a density of 1442 kg/m3 (90 lb/cu ft) ... B-3

List of Figures

Figure 1-1 and 1-2 ... 2
Figure 2-1 ... 7
Figures 2-2 and 2-3 ... 8
Figures 2-4 and 2-5 ... 10
Figures 2-6 and 2-7 ... 12
Figure 2-8 ... 13
Figures 2-9, 2-10 and 2-11 ... 13
Figure 2-12 ... 14
Figure 2-13 ... 15
Figure 2-14 ... 16
Figure 2-15 ... 17
Figure 2-16 ... 18
Figure 2-17 ... 19
Figure 3-1 ... 24

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Document Management

1. Authority

This document is issued by the Director General, Integrated Technical Services, CCG's National Technical Authority under delegation from the Deputy Minister, Fisheries and Oceans and the Commissioner of the Canadian Coast Guard.

2. Responsibility

a) The Director of Engineering Services is responsible for:

  i) the creation and promulgation of the document; and

  ii) the identification of an Office of Primary Interest (OPI) who is responsible for the coordination and the content of the document.

b) The OPI is responsible for:

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  ii) the availability of this information;

  iii) the update as needed;

  iv) the periodical revision; and

  v) the follow-up of all requests, comments and/or suggestions received by the originator.

3. Inquiries and/or Revision Requests

All inquiries regarding this document, including suggestions for revision and requests for interpretation shall be addressed to:

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All requests should:

  vi) be clear and concise; and

  vii) reference the specific Chapter, Section, Figure or Table.

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Foreword

1. Purpose

The purpose of these Lightning Protection and Grounding Standards is to ensure that Canadian Coast Guard (CCG) Maritime Communication and Traffic Services (MCTS) communication towers and sites comply with all applicable Canadian Acts and Codes including the Lightning Rod Act and Canadian Electrical Code.

These Standards apply the legal requirements of the referenced Act and Code, the requirements of various Canadian Standards Association (CSA) Standards (and others), and apply the best practices developed by the CCG and industry to CCG's operation and maintenance of MCTS communication towers and sites, see Annex D for a list of reference documents. Because the Act, Code, and CSA Standards may be revised at any time, it is an ongoing requirement to refer to them for currency and any changes that may be required to these Standards.

CCG is responsible for a variety of services for Canada's coastal regions, the Great Lakes and some inland waterways. A number of these services require the transmission of radio signals that are transmitted from communication towers and because of their height and metallic structure, are prone to being struck by lightning. To ensure the safety of staff on site and to prevent damage to critical communication equipment, good grounding is essential for good lightning protection.

Canada’s many topographical and geological formations, combined with the extreme climatic conditions found in the Arctic, require a comprehensive and site-specific approach to grounding. The detailed assessment of how many ground rods have to be used, the number and configuration of ground radials employed, and the calculations of how well the surrounding soil can absorb and dissipate lightning induced charges is largely a function of the geological formation and its soil resistivity. The site engineer developing a communication site is best able to design the appropriate grounding systems for the protection of the communication tower, the equipment building, equipment racks, and electronics.

Accordingly, this Standard deals primarily with standards that are applicable to the design and construction of new communication towers and sites. This Standard also covers the cause of lightning, the theory of lightning protection and grounding before addressing lightning protection and grounding standards for CCG MCTS communication towers and sites.

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Chapter 1 BACKGROUND AND DEFINITIONS

1.1 LIGHTNING

1.1.1 Theory of Lightning

When the lower atmosphere and the earth's surface are highly charged, a lightning strike occurs to restore the equilibrium. The voltage potential in a lightning strike can be as high as 100,000,000 volts with an average current charge of 30,000 amperes. Normally the earth's surface has a negative charge. During a thunderstorm, clouds in the lower atmosphere become negatively charged as the warm air moves upwards and the upper layers of the clouds become positively charged. The strong negative charge of the lower atmosphere/clouds repels the negative charge of the ground below even further, causing more positive charges to travel up to the earth's surface. When the difference in potential is high enough, the positive charges of the earth's surface recombine with the negative charges from the lower atmosphere/clouds via a lightning strike. The extremely hot air in the lightning path explodes, causing shockwaves that expand rapidly into compression waves that we hear as thunder.

As the electric field becomes very strong, the air around the clouds breaks down and ionizes, turning it to plasma. This in turn creates a highly conductive environment and allows the incremental formation of *step leaders* to find the best conductive path to recombine with the positive charges on the ground. Once the step leader has mapped out a conductive path, the lightning strike occurs to restore the in-balance.

When the negative charges in the clouds of the lower atmosphere have become strong enough to enable the ground's surface to become positive, some of those positive charges try to travel upward to meet the negative charged clouds. Since at this point the air is still non-conductive, the positive charges have to use conductive mediums to shorten the gap. Communication towers made of steel enable positive charges to travel upwards in an effort to get closer to the negatively charged clouds in the lower atmosphere and thereby shorten the distance. These moving charges are called *streamers* and they in turn try to attract the *step leaders*, negative charges building the downward path for the eventual lightning strike when the equilibrium is restored.

Damage caused to a Canadian Coast Guard tower site in Estavan by a direct lightning strike. (see Fig 1-1 & Fig 1-2)

Figure 1-1 - Lightning strike on tower causing part of foundation to break apart

Figure 1-2 - Lightning strike traveling down transmission line, into communication

Figure 1-1 and 1-2

1.2 LIGHTNING PROTECTION

1.2.1 Theory of Lightning Protection

Lightning protection is achieved by providing a controlled conductive path for the lightning strike to discharge its energy to ground. A lightning rod, a tower itself or anything conductive that is elevated above its surrounding area is, because of its height and conductivity, more likely to be used as part of the discharge path of a lightning strike. Good lightning protection and the prevention of damage to equipment installed on towers or in equipment rooms is achieved by ensuring that the incoming strike can bypass the equipment via the various grounding systems (see para 2.3.2) and discharge its energy quickly and effectively into the ground and surrounding area.

1.3 GROUNDING

1.3.1 Basic Principles of Grounding

The purpose of electrical grounding is to shunt fault currents associated with a power system or faulty electrical equipment to ground, whereas grounding for lightning protection deals with lightning induced energy and its discharge path into ground. Both grounding systems should be tied together into what is commonly referred to as single point ground.

Good grounding for lightning protection is the provision of a non-corrosive, highly conductive path for lightning induced energy to dissipate and be absorbed into the ground to prevent injury to personnel and protect equipment.

Lightning strikes have a very short duration and the induced energy is a high frequency pulse. All discharge paths have inductance and resistance, causing voltage drops to develop that can damage equipment, harm people and destroy communication sites. Keeping the ground conductors as straight as possible and using conductors with a large surface area reduces the inductance and allows the lightning induced energy to discharge quickly.

Some of the lightning induced energy will also travel inside AC lines, transmission lines, CAT5 cable, data and audio lines attached to the tower. In order to protect the connected electrical and electronic equipment inside the equipment room from power surges, voltage spikes, and other high transient voltages, surge protectors are installed. These sense the higher voltage level, switch and shunt it to ground thereby protecting the equipment.

Single Point Grounding is a grounding method to ensure that all system related electrical and electronic equipment, waveguides, transmission lines, cable trays and if desired, all other metallic surfaces of an equipment shelter or environment is connected to the same grounding point through individual and direct connections to one single grounding bar.

It is imperative that the building's perimeter ground be part of the tower grounding system that also connects to the internal building Master Ground Bar (MGB) where the AC service entrance ground is also attached. All equipment chassis are grounded to this single point master ground as are all other ground connectors from any other electrical or electronic devices inside the room.

This ensures that the same ground potential is maintained during and after the lightning strike, preventing ground currents from developing.

1.3.2 Site Grounding Systems

Several types of Grounding Systems are applicable to MCTS sites as follows:

- Lightning/Tower Ground;
- Power Ground;
- Building Perimeter Ground;
- Equipment Ground.

1.3.2.1 Lightning/Tower Ground

A lightning or tower ground is a grounding system of cables and ground rods typically laid out in a radial pattern that shunts the lightning induced energy away from equipment and people for quick dissipation of charges. In most cases, the charges are dissipated into the ground (see para 3.1).

1.3.2.2 Power Ground

The site power supply alternating current (AC) return (neutral) is used for the electrical ground and ties all electrical systems to the electrical ground. This ground is often very inductive to high frequency pulses.

1.3.2.3 Building Perimeter Ground

A building perimeter ground, or ring ground, is a buried cable encircling the equipment shelter(s) connected to ground rods as required. The building perimeter ground is also connected to the shelter's structural steel, the MGB, the tower grounding system, any nearby pipes that it crosses any fence posts and other metallic surfaces on site to achieve a single point ground for the site (see para 3.3).

1.3.2.4 Equipment Ground

During a lightning strike, the ground reference level can increase because of the momentary inductance that the site’s grounding system experiences, developing a voltage rise commonly called ground potential rise (GPR). This ground reference can be different from the ground reference other equipment on site is subjected to if connected through wires from a remote source or a poorly grounded electrical system. Interconnected equipment experiencing two or more different ground potentials can be damaged because of the currents that are developed. If the difference in the GPR is high enough, it can lead to fire, cause an explosion of back-up batteries, or equipment failure (see para 3.3).

1.4 CONNECTIONS

There are 4 ways of connecting grounding cables or wires to each other or to other metallic surfaces:

- Exothermic;
- Bolt-on;
- Clamping and crimping;
- Silver soldering.

1.4.1 Exothermic

The preferred way of interconnecting dissimilar metals for best conductivity and corrosion resistance is by cad-welding, thermit connections (exothermic bonding), or brazing. This creates a solid homogenous bond that can then be coated with a moisture resistant compound. Toxic fumes are created when zinc is vapourized and care should be taken not to inhale those fumes during bonding. All other types of connections are much inferior but can be used if exothermic bonding is not possible.

1.4.2 Bolt-on

Provides a stronger mechanical connection than clamping/crimping and is typically used to attach the eye of the cable grounding kit to the tower’s grounding bar. All exterior grounding connections, especially clamped, crimped and bolted should use a moisture repelling compound to prevent water from migrating into the connection, causing oxidization.

1.4.3 Clamping and crimping

Most cable grounding kits are fitted with crimped or clamped terminal eyes that attach to the tower or to cable grounding bars on towers. This is an acceptable practice for attaching lighter gauged grounding straps or wires. Clamping or compression fitted connections should be avoided whenever possible for all major connections of stranded grounding cables of AWG#2 or larger, especially if buried below grade. Galvanized steel also causes a chemical reaction to copper or brass over time, especially when moisture is present. This can be mitigated by the use of stainless steel clamps when connecting to copper grounding cables.

1.4.4 Silver soldering

Thin stranded copper wire typically used for the ground plane of isolated towers makes for a good corrosion resistant connection. Silver soldering this connection creates an even strong mechanical connection that otherwise might melt from the heat conducted through a direct lightning strike.

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Chapter 2 STANDARDS

2.1 LIGHTNING PROTECTION OF TOWERS

This is normally achieved via ground rods and ground plates. Typically copper clad steel rods between 8 -12 feet in length with an O/D of between ¾ inch and 1 inch are preferred. Grounding plates are hot-dipped galvanized steel plates intended for direct burial, and can dissipate twice as many charges as an 8 feet ground rod if installed in a highly conductive environment that allows for quick dissipation of electric charges. If possible, ground rods are installed vertically into the ground to come into contact with the water table or permanently moist soil below.

2.1.1 Guyed Towers

Three AWG#4/0 stranded copper cables shall be attached to the tower base at 120 degree spacing, CAD-welded to the ring conductor around the base of the tower and buried. A AWG#4/0 stranded copper cable shall run from the buried ring conductor to the equipment building and then around the shelter, forming a complete and closed perimeter loop. Care shall be taken to avoid cable bends of 8" (20 cm) or less.

At least 2 separate grounding cables, AWG#4/0 shall be CAD-welded to the buried tower ground ring conductor, each running in an outward direction away from the tower and away from the equipment building a distance of 60 feet (18 m) or more (see Fig 2-1). Copper clad 10 feet long ground rods shall be bonded to the radials every 20 feet (6 m) or as required by soil resistance measurements.

Figure 2-1 shows the base section of a 300 ft guyed communication tower grounded by a single AWG #2 bare stranded copper cables. This is not adequate. This single, light gauge ground cable exhibits high inductance during a lightning pulse that might cause too much energy to be shunted through the transmission lines into the communication room. The high energy pulse could damage or destroy communication equipment which might lead to fire. Instead, the tower base should be grounded with 3 stranded, copper ground cables, AWG #4/0 or with 3 copper straps bonded to the tower base ground ring to reduce the inductance to acceptable levels. The tower base ground ring should be buried below grade by 4 feet where possible. The tower base ground ring is bonded to the perimeter building ground and radials running outwards and away from the tower with ground rods every 20 feet (6 m) or as determined by the site engineer.

Figure 2-1

Guy anchors shall be grounded separately. Two different methods can be employed to offset the effects that the pH of acidic rainwater (pH between 5.5 and 6 typically) has on copper. Acidic water frees ions of copper that wash onto the galvanized guy cables below, breaking down its zinc coating causing the guys to rust.

1) A continuous, tinned stranded AWG#2/0 copper cable shall be attached to the top guy cable above the preformed guy grips with stainless steel clamps or galvanized clamps and attached the same way to each guy cable below (see Fig 2-2). It shall then be buried and bonded to a copper clad 10 feet ground rod below. From there, 2 buried radials shall branch out and away from the anchor with 10 feet ground rods attached every 20 feet (6 m) or as governed by soil resistance (see Fig 2-3).

2) A hot-dipped galvanized guy strand or better shall be attached to the top guy cable above the preformed guy grips with stainless steel clamps or galvanized clamps and attached the same way to each guy cable below. It shall then be connected to an AWG#2/0 stranded copper cable that is buried and attached to a copper clad 10 feet (3.05 m) ground rod below. From there, 2 buried radials branch out and away from the anchor with 10 feet (3.05 m) ground rods attached every 20 feet (6.0 m) or as governed by soil resistance measurements.

Figure 2-2 Individual grounding of guy cables near anchors above the preformed guy grips using stainless steel ice breakers.

Figure 2-3 Ice breakers are mounted above preformed guy grips, preventing ice from pushing down on guy cable out from guy grip. This also provides a corrosion resistant bond of the stranded copper ground cable via stainless steel plates to the hot-dipped galvanized guy cables.

Figures 2-2 and 2-3

2.1.2 Free-Standing or Self-Supporting Towers

Each tower leg of a free-standing tower shall be exothermically bonded to the buried grounding ring around the tower's base with AWG#4/0 stranded copper cable. The tower grounding ring shall also be connected to the building perimeter ground with AWG#4/0 stranded copper cable to form a complete loop. Care shall be taken to avoid cable bends of 8" (20cm) or less.

Three radial ground cables of AWG#4/0 stranded copper cable shall be bonded to the tower ground ring and run in an outward direction away from the tower and away from the equipment building the distance of 60 feet (18 m) or more. Copper clad 10 feet long ground rods shall be bonded to the radials every 20 feet (6 m) or as determined through soil resistance measurements.

The same grounding principle holds true for 4-sided or cylindrical towers, however, one additional radial with ground rods shall be attached to the tower's grounding ring. Except for the ground connection to the building perimeter ground, all other ground radials should point away from the equipment building. This ensures that the same volume of soil does not get saturated from ground rods dissipating electrons from ground rods opposite to each other.

The buried perimeter ground cable shall be interconnected near each corner of the building and at 20 ft (6 m) intervals to a 10 ft copper clad 3/4” ground rod. An additional ground rod is installed and connected to the perimeter ground near the utility entry point and the bulkhead panel, completing the single point ground system.

2.1.3 Isolated Towers (AM Towers)

All towers that act as antennas shall be isolated from ground by placing them on top of insulators. Guyed AM towers shall also have their guy cables isolated from ground. This is accomplished by incorporating insulators into the guy strands. Most insulated towers operate in the Medium Frequency range (MF) between 300 KHZ to 3MHZ with the commercial broadcasting AM band between 540 KHZ to 1,600 KHZ. The transmitted carrier is amplitude modulated (AM).

In order to operate efficiently, all AM towers have to use an extensive radial ground system to contain and propagate the electric field. This RF ground is a grid network of buried copper radials of AWG#1 to AWG#2/0, going outwards from the tower in all directions to a distance of at least the height of the tower. This buried RF ground, if sufficiently complemented with vertically installed ground rods, is the best ground for lightning protection since it will dissipate the energy induced by a lightning strike away from the tower quickly over a large area.

Special provisions have to be made for lightning protection because AM towers are isolated from ground. A spark-gap arrestor across the insulator between the base of the tower and the ground provides this safeguard. The lightning strike induced voltage will travel down the tower, jump across the approximate ½ inch (1.3 cm) gap of the spark-gap arrestor (see Fig 2-4) and dissipates into the radial ground grid typical of AM towers provided it is connected to sufficient ground rods for fast charge dissipation. The size of the gap in the spark-gap arrestor is a function of the effective radiated power (ERP) of the tower and the anticipated energy of a typical lightning strike in that area.

Figure 2-4 shows part of the base section of an old 220 feet (67 m) isolated tower sitting on top of the insulator. The spark gap arrestor has to have its contact balls positioned horizontally to prevent water from shortening the gap.

Figure 2-5 shows isolated guys.

Figures 2-4 and 2-5

Another device that is also employed with isolated towers is a static drain choke/static drain resistor (see Fig 2-5). Thunderstorms are not the only source of a charge build-up on an isolated tower. Cold dry winds, dust storms and snowstorms can also cause a build up of static charges on towers that can damage electronic equipment if not properly dealt with. The static drain choke appears as a high impedance at the operating frequency of radiating towers and bleeds off static charges before they build up. At power line frequencies or DC, it provides a short circuit to ground. A static drain resistor operates on a similar principle except that it always exhibits high resistance at DC or RF and thereby slowly bleeds off any charges before they can build up. Static drain chokes or drain resistors are employed in addition to spark gap arrestors.

Tower lights on AM towers also require special considerations. In this case, the AC fed from the equipment building to the tower is coupled through a large toroidal transformer where the primary winding is isolated from the secondary windings without physical contact through inductive coupling alone. This transformer is located outside, near the base of the tower and the distance between the secondary and primary winding is much larger than the gap of the spark-gap arrestor nearby, ensuring that most of the high energy pulse of a lightning strike will initially be shunted to ground through the spark gap arrestor.

2.1.4 Cantilever or Roof-Top Mounted Towers

These towers, (including masts and antennas) are mounted on the roof of an existing building, typically against the side of the mechanical or elevator penthouse.

The tower/mast shall be connected to bare stranded copper cable, AWG# 2/0 or greater, and be connected to the structural steel of the building where the MGB shall also be attached.

The tower or mast ground cable can also be connected to an existing roof-top grounding system, bonded to a drain pipe that is at ground potential or, if the building has attachment points to concrete encased rebar, connected to the rebar using the “Ufer” grounding method.

The tower can also be grounded by running bare stranded copper cable, AWG#4/0 from the tower to the side of the building, down the exterior wall of the building into the ground below and bonded to several 10 feet (3 m) ground rods spaced at least 20 feet (6 m) apart from each other and if possible, tied into the existing perimeter ground of the building.

Wide copper bands are better conductors because of their low inductance and are the preferred choice where possible. The trade-offs are higher installation cost of copper bands over stranded copper cables and a more unsightly appearance when installed against the outside of a building.

2.2 LIGHTNING PROTECTION OF TOWER MOUNTED EQUIPMENT

2.2.1 Antennas

Most antennas used by the CCG are at ground potential. Antennas shall be mounted with stainless steel, hot-dipped galvanized or aluminum brackets to the tower. If the tower is painted, the paint shall be removed carefully to the zinc finish where the brackets make contact with the tower leg or structural member. This will help to prevent damage to the antenna and its transmission line in case of a lightning strike by maintaining the same ground potential as the tower.

2.2.2 Transmission Lines, Waveguides, and Cable Trays

Size specific transmission line grounding kits are available from manufacturers and shall be used near where the antenna is mounted, every 200 feet (60 m) of a downward run, near the base of the tower, just before the bulkhead panel or cable entry port, and at any point where the cable’s bending radius nears or exceeds 70 degrees.

A Tower Ground Bus Bar (TGB) shall be fastened to the tower just below the area where the transmission lines start their horizontal run across the waveguide bridge, cable tray, or messenger cable to the equipment building. The TGB shall be fastened securely to the tower providing good electrical connection and shall be bonded by CAD-welding to the tower’s ground ring with an AWG#2/0 stranded copper cable. The grounding leads of all transmission line grounding kits shall also be secured to the TGB (see Fig 2-6).

Figure 2-6 TGBs are installed near the cable bridge entrance where the transmission lines leave the tower for their horizontal run across the cable bridge into the communication room.

Figure 2-7 The TGB has to be mounted below the cable grounding kits to ensure that the discharge path of a potential lightning strike will be downwards to the TGB where all cable grounding straps are tight together.

Figures 2-6 and 2-7

Waveguide bridges or cable trays shall be electrically isolated from the tower and shall be bonded to the perimeter ground using AWG# 4/0 stranded copper cable that is exothermically connected to each support mast. An outdoor ground bar shall be installed near the cable entry point, either attached to the building or isolated from the waveguide bridge or cable tray. This external ground bar shall be connected with an AWG#2 stranded copper cable to the perimeter ground system. (see Fig 2-7)

The bulkhead panel is a copper plate that acts as the feed-through entrance panel for the transmission lines into the equipment room. The transmission lines are terminated against the panel with their corresponding surge arrestors attached and from there connect to the transceivers via flexible jumpers. Surge arresters may also be mounted inside the equipment room as long as the grounding straps or cables attached to the surge protectors are less than 24 inch (60 cm) in length and are connected to the MGB. The bulkhead panel shall connect to the perimeter ground with 2 x 3 inch (5 x 7cm) wide copper bands or alternatively with at least 2 lengths of AWG#2/0 stranded copper cable.

Andrews' wall feed-through panels or individual cable entry ports may also be used in conjunction with Harger Entrance Panel Kit or equivalent, to provide proper grounding points to the outside perimeter ground, coaxial cable shields and surge suppressors (see Fig 2-8).

Figure 2-8 shows transmission lines entering the communication shelter through individual Andrews's cable entrance ports. The cable grounding kits are attached to the transmission lines just before they enter into the building and the grounding straps are attached to the outside portion of the Harger Entrance Panel that in turn is grounded through an AWG#4/0 stranded copper cable to the perimeter ground.

Figure 2-8

2.2.3 Tower Lights

All AC cables on towers shall run inside metal conduits or steel-armoured TECK cables. The conduit or TECK cable shall be firmly connected to the structural steel of the tower where the lights are connected, at least every 200 feet (60 m) on a downward run and via flash-guard or similar surge protection near the base of the tower (see Fig 2-9 to 2-11). The AC power line energizing tower lights shall also be protected using metal oxide varistors (MOV) or silicon avalanche diodes (SAD), or other surge protective devices (SPD). All SPDs shall be installed within the equipment room for maximum effectiveness.

Figures 2-9, 2-10 and 2-11

2.2.4 Tower Mounted Electronics

Amplifiers. The AC feed cables that power electronic and amplifiers mounted on a tower are to be connected to the structural steel of the tower identically as specified for tower lights above.

The DC supply voltage required for the operation of a tower mounted amplifier is delivered through the transmission line via DC injection from inside the communication room. Special surge protectors shall be installed on the bulkhead entrance panel or within 24 inch (60 cm) of the MGB or the Harger Entrance panel allowing for DC injection.

Low Power Amplifiers. Low power amplifiers receive their DC supply and operating voltage through the power-over-ethernet (POE) CAT5 cable that also allows bi-directional data transfer.

Special surge arrestors can be installed between the POE injector and the CAT5 cable going up the tower.

2.3 LIGHTNING PROTECTION AND GROUNDING OF BUILDING AND SITES

2.3.1 Building Perimeter Ground

A building perimeter ground shall be a AWG# 4/0 bare, stranded copper cable, that runs buried to a depth of between 12 to 24 inch (30 to 60 cm) around the equipment building and shall be exothermically connected to ¾ inch O/D of 10 feet copper clad ground rods at every corner and every 20 feet (6 m) or as determined by soil resistive measurements. It interconnects via stranded AWG#1/0 to fence posts and other metallic surfaces and it also interconnects to any nearby pipes it crosses. The perimeter ground or ring ground is also connected to the lightning ground of the tower, the structural steel of the building and the MGB (see Fig 2-12). All grounding conductors, rods or radials achieve the highest efficiency when placed in moist soil.

The building perimeter ground shall also be connected to the bulkhead panel by 2x3 inch copper bands or alternatively by 2 runs of bare AWG#2/0 stranded copper cable.

The building perimeter ground shall also be connected to the MGB by bare AWG#2/0 stranded copper cable. It shall not be in contact with any other metal surface or object.

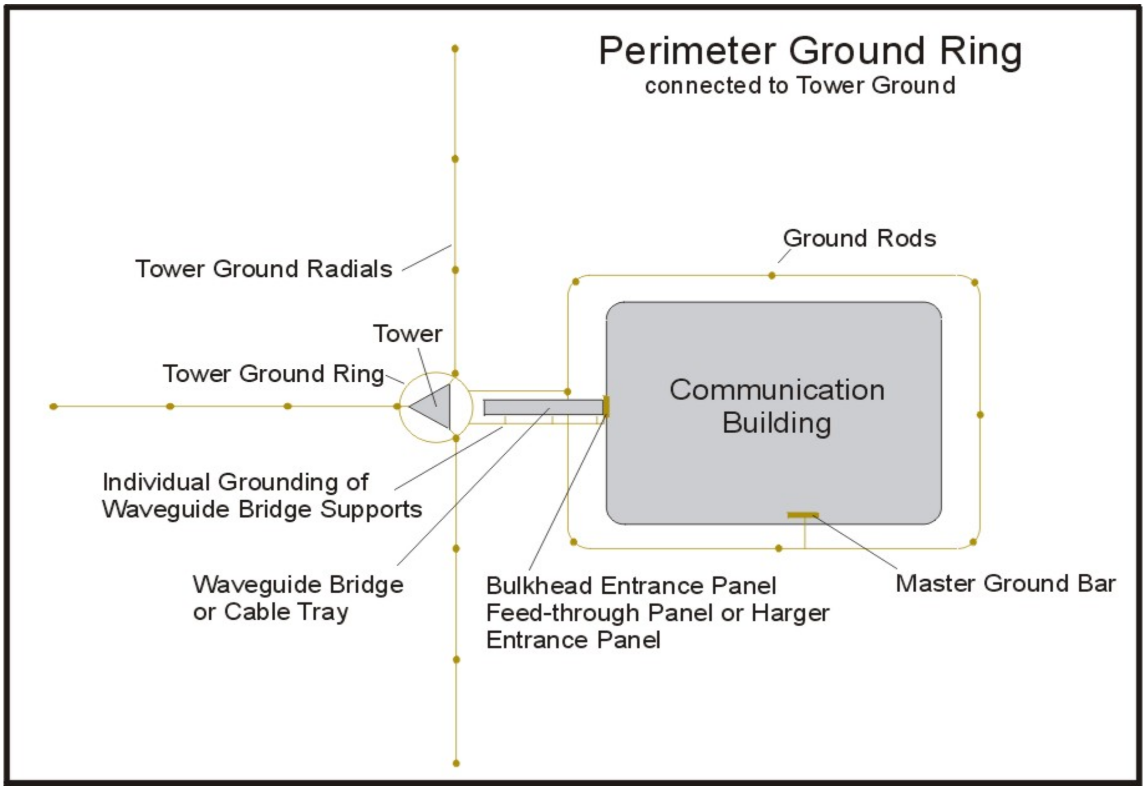

Figure 2-12

2.3.2 Equipment Room Ground

A bulkhead panel shall be installed where the transmission lines enter the building and it shall be bonded to the building's perimeter ground by 2x3 inch copper bands, or alternatively, by 2 runs of bare AWG#2/0 stranded copper cable (see Fig 2-13). If this cannot be done, or is impractical, a separate grounding system with ground rods is to be installed and bonded via copper straps to the bulkhead panel.

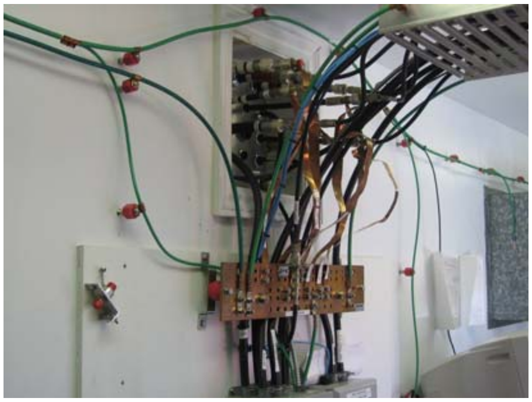

Fig 2-13 shows a Bulkhead Panel with surge suppressors mounted against incoming transmission lines. The Master Ground Bar is mounted below and is connected to the perimeter ground. Copper straps attached to the MGB and to the surge suppressors ensure a low inductance discharge path to the outside ground system.

Figure 2-13

A Master Ground Bar (MGB), a rigid copper bar with multiple attachment points for individual grounding cables to interconnect equipment, racks, shelves, etc in the communications room, shall be installed. In most cases, the MGB is installed against a wall about 12 inches above the floor near the bulkhead panel or AC service entrance and acts as the single reference ground for all ground connections inside the building. The MGB shall be connected to the building perimeter ground by bare AWG#2/0 stranded copper cable. It shall not be in contact with any other metal surface or object.

All equipment inside the equipment room shall be connected to the MGB.

In order to protect electronic equipment from transient voltage spikes and residual energy caused by lightning strikes, transmission lines shall be terminated on bulkhead panel mounted surge protectors or lightning suppressers. The fast response time of surge protectors aid in shortening the center conductor to ground, thereby preventing costly damage to the antenna input/output stage of the transceiver.

Surge suppressers may also be mounted closer to the transceivers inside the equipment room as long as they are connected with green, insulated AWG#6 stranded copper conductors not exceeding a length of 24 inches (60 cm) to the MGB.

Figure 2-14 shows incoming transmission lines being terminated against surge suppressors that are grounded with wide copper bands to the inside part of the Harger Entrance Panel Kit. The brass plate is connected via two threaded rods that run inside PVC conduits through the wall to the outside ground bar that provides cable grounding kit termination. The outside ground plate is connected to the perimeter ground.

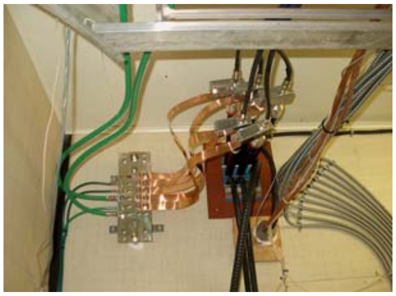

Figure 2-14

Halo Ceiling Ground Ring (see Fig 2-14), a stranded AWG#4/0 copper cable with a black jacket shall be fastened around the room’s wall about 6 inches (15 cm) below the ceiling. This cable shall be attached with copper straps to all non-electronic metal surfaces such as windows, doors, vents, etc. that are **not** connected to the single point ground. The function of the halo ground ring is to reduce the effects of the induced magnetic field following a lightning strike.

2.3.3 Incoming Lines; Power, UPS, Telephone, and Data

Ideally, telephone lines shall enter the building near the MGB and shall be grounded to it. If this is not possible, a telephone copper ground bus bar shall be installed near the telephone line entry point. This secondary bus bar shall be connected to the MGB utilizing a single length green insulated AWG#6 stranded copper cable.

Each telephone line shall be protected by a surge arrestor, MOV/SAD, with its ground connected to the MGB or the telephone bus bar.

Each incoming audio or data line shall be protected by a surge arrestor, MOV/SAD, with its ground connected to the MGB, the telephone bus bar.

The primary power neutral shall be connected at the main service disconnect location to the MGB with green insulated AWG#2/0 stranded copper cable.

The chassis of all emergency generators or other AC powered equipment shall be bonded with a green insulated stranded copper cable to the MGB.

The DC output of the un-interrupted power supply (UPS) shall be protected using MOV/SAD or other devices to shunt high surge currents to ground.

2.3.4 Other Site Grounding Requirements

2.3.4.1 Grounding of Chain-Link Fences

Chain-link fences within 30 feet (9 m) of the building perimeter ground shall be connected to the perimeter ground using AWG#2/0 stranded copper cable (see Fig 2-15). Chain-link fences within 30 feet (9 m) of a tower shall be bonded to the radials or perimeter groundings that are interconnected. Fence posts shall be exothermically connected to the peripheral ground every 100 ft (30 m).

Chain-link fences that are more than 30 feet (9 m) away from the building peripheral ground but less than 50 feet (15 m) beyond the perimeter ground shall be bonded using AWG#6 copper wire attached to the reinforcing wire of the chain link fence and to a 10 feet x ¾ inch ground rod every 150 feet (45 m).

Figure 2-15 Chain-link fence around this communication site is not bonded to the external perimeter ground since it is well beyond the 50 feet (15.24 m) distance of the 340 feet communication tower and the adjacent communication building.

Figure 2-15

Chain link fences that encircle a tower and/or an equipment building within 20 feet (6 m) of the structures shall have their gates grounded and bonded to the gatepost using copper braided straps.

Every gatepost shall be grounded directly to a ground rod or, if within 30 feet (9 m) of the building's perimeter ground, bonded to the perimeter ground.

No chain-link or metallic fences shall be on the active ground plane of an AM site. This is a distance of at least the height of the tower away from the base of the tower. Fences around an active AM site are subject to induced RF currents and unless extremely well grounded can cause severe burns. Fences at AM communication sites shall be grounded every 20 feet (6 m) to a ground rod or as specified by the site engineer.

All chain link or metallic fences shall be exothermically bonded to any metallic structure, pipe, conduit or object within 10 feet (3 m) using AWG#2/0 if below grade or AWG#2 if above grade, stranded copper cable.

2.4 LIGHTNING PROTECTION AND GROUNDING OF ELECTRONIC EQUIPMENT

2.4.1 Electronic Equipment inside Equipment Rooms

Proper surge protectors shall be installed on all incoming transmission lines between the outside cable entry point and the antenna connection of the equipment.

All chassis of all electronic equipment inside the same rack or enclosure shall be connected to the rack(s) or the enclosure's own copper grounding bus bar using green, insulated AWG#6 stranded copper conductors.

Figure 2-16

Figure 2-16 shows equipment racks inside the Canadian Coast Guard's communication building at Cardinal, Ontario. The center rack has a vertical copper ground bus bar that allows attachment provisions for all individual chassis of rack mounted equipment. The bus bar in turn is connected to the MGB.

Copper Ground Bus Bar

Each rack's or metal enclosure's copper bus bar shall be connected to the MGB using green, insulated AWG#2 stranded copper conductors (see Fig 2-16).

Metal cable trays or conduits shall be bonded to a continuous length of AWG#2/0 stranded copper cable that is attached to the MGB. The green jacket of this cable shall be cut at intervals to allow bonding to each individual cable tray section.

Good grounding practices ensures that all grounding connections are as short as possible with few bends, that appropriately large copper conductors are used and that each piece of equipment has its own and direct connection to the MGB.

2.5 SPECIAL GROUNDING CONSIDERATIONS

2.5.1 Grounding Towers and Anchors in Rock

A ring of stranded copper cable AWG# 4/0 shall be placed around the base of the tower. Each tower leg shall be bonded to the conductor ring with AWG#4/0 stranded copper cable. Copper ground radials shall be attached to the base grounding ring running outwards in a star-like pattern for at least 60 feet (18 m) and spaced between 20 to 40 degrees apart or as determined by the site engineer to establish the capacitive coupled discharge system. The radials shall be AWG#2/0 and for better charge dispersion, short, flat, 12 inches (30 cm) long copper straps shall be bonded at right angles to each radial at 2 feet (60 cm) increments (see Fig 2-17).

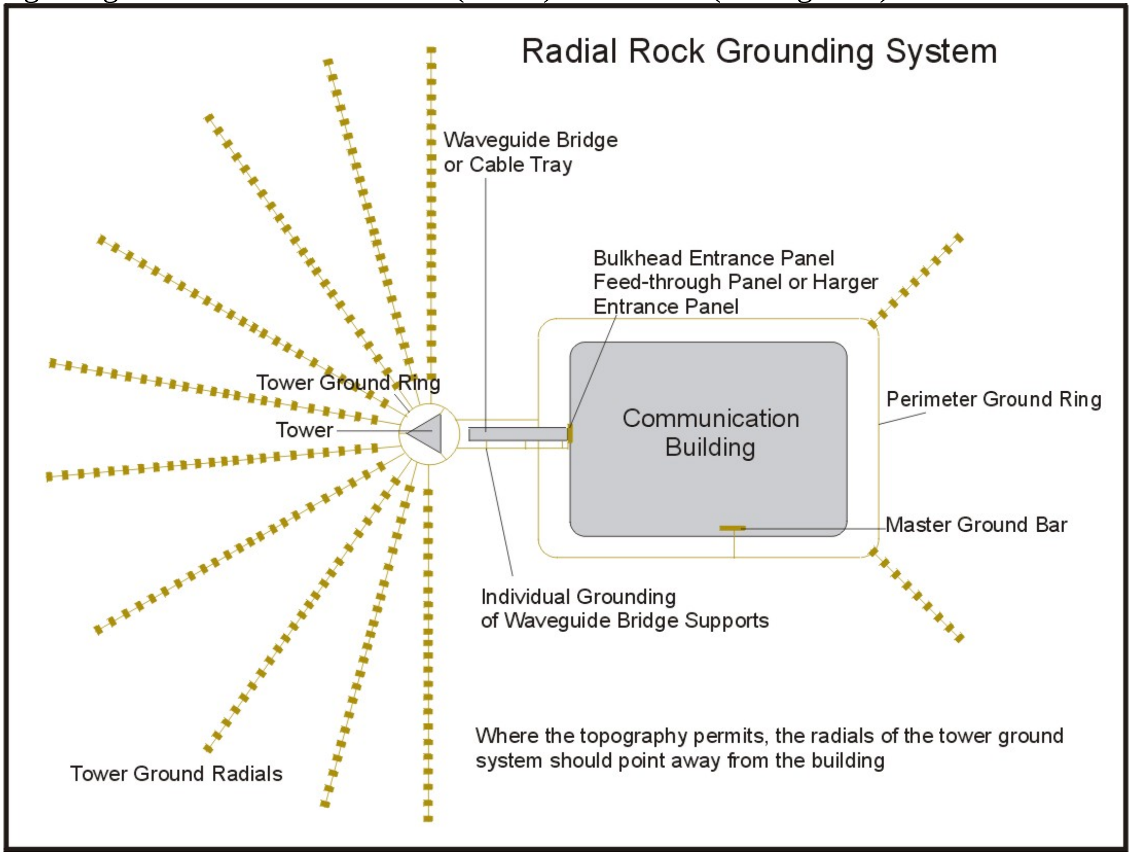

Figure 2-17

The effectiveness of using Bentonite as the filling agent in holes is much disputed. Holes are drilled into the rock some distance apart with a copper grounding rod installed inside. The grounding rods are all connected together and the holes are filled with Bentonite, a form of highly conductive clay that exhibits low pH which helps to minimize the corrosion of copper grounding rods.

Radial grounding can also be improved upon by encasing the radials in Ground Enhancing Materials (GEM) that will bond to the rock.

One continuous AWG#2/0 stranded copper cable shall be attached to the upper guy cable at each anchor and fastened to all guys below using stainless steel clamps so that the ground cables run in an almost vertical downward direction.

The guy ground cable shall be bonded below grade level to a second copper cable so as to create 2 radials that can bypass the anchor in a V-shaped connection and run beyond the anchor for another 60 ft (18 m). The radials shall be AWG#2/0 and for better charge dispersion, short, flat, 12-inch (30 cm) long copper straps shall be bonded at right angles to each radial at 2 feet (60 cm) increments.

2.5.2 Grounding in Permafrost

Permafrost is non-conductive and not unlike grounding on rocky surfaces; fast discharge paths for the lightning induced energy can be difficult to obtain. A surface radial grounding system is often the only way to discharge and dissipate the lightning strike's induced energy.

A ring of stranded copper cable AWG# 4/0 shall be placed around the base of the tower. Each tower leg shall be bonded to this ring with AWG#4/0 cable. Copper ground radials shall be attached to the base grounding ring running outwards in a star-like pattern for at least 60 feet (18 m) and spaced 20 to 40 degrees apart or as determined by the site engineer. The radials should be AWG#2/0 and for better charge dispersion, short, flat, 12 inch (30 cm) copper straps shall be bonded at right angles to each radial at 2 feet (60 cm) increments.

A more effective ground system can be designed if copper bands are used rather than stranded ground conductors.

This "floating" ground shall be bonded to all equipment and metal structures to ensure that the same ground potential is maintained during the lightning strike's discharge.

2.5.3 Grounding in Low-Conductive Soil

When poor soil conditions are suspected, the soil's measurements have to be obtained. A Megger earth tester shall be used to measure the soil's resistivity. Typically, four short copper rods are driven into the ground in a straight-line equal distant from each other. Current is applied to the 2 outermost rods and then measured between the 2 inner rods allowing the soil resistivity to be calculated based on the current flowing through it. In order for the test results to be valid, testing is to be performed under "normal" climatic conditions by personnel familiar with the test equipment and testing procedures.

For communication sites, the resistance of the ground system to ground shall be 5 Ohms or less.

The soil's conductivity can be increased by using Epson salt, Magnesium Sulfate, Copper Sulfate, Rock Salt, or other chemicals. There are chemical ground rods available that also try to retain moisture and then slowly release the saline liquid into the ground increasing its conductivity. Careful consideration should be given regarding the choice of any chemicals used to enhance ground conductivity, since in most cases unwanted side effects are encountered.

12 pounds (5.5 kilograms) of salt should be considered for every 10 feet grounding rod. The salt should be mixed with water so that it can penetrate into the soil below. Magnesium Sulfate is the least damaging to the environment other than specially designed GEMs. Even though salt is readily available, because of its impact on the environment, its corrosive properties and because it has to be replenished at periodic intervals, it is not the best choice.

There is also Ground Enhancing Materials (GEM) available that ensure a more environmentally friendly approach in increasing the soil's conductivity. Some of these general soil enhancement options are listed below with resistivity values.

- **Bentonite:** Conductive clay formed from volcanic ash typical 2.5 ohms per meter. Its moisture content can vary by a large percentage.
- **Carbon-Based Backfill Materials**: 0.1 – 0.5 ohms-per-meter. Its water retention properties are not as good as clay;
- **Clay-Based Backfill Materials (GAF)**: exhibiting high water retention capabilities between 0.2 – 0.8 ohms-per-meter;
- **Conductive Concrete:** 30 – 90 ohms-per-meter. Concrete is affected by ice and corrosion.

Soil resistive values are shown in Annex A.

2.5.4 Grounding in Corrosive Environments

A buffering agent such as Bentonite can be added to and mixed with the soil to help offset the damaging impact a highly corrosive soil might have on a grounding system. In extreme situations, a specially formulated GEM can be used.

Where the air is salty, has a high sulfuric content, or other chemical pollutants that might cause accelerated corrosion, all external grounding connections should be sealed with an anti-corrosion compound and, if possible, sealed air tight to prevent oxidization.

2.5.5 Grounding in Co-locating Environments

The owner of communication site is responsible for the proper grounding of tower and facility. The tenant or co-locator is responsible for the grounding of their own equipment. All incoming transmission lines should connect through a surge protector that is grounded to the bulkhead entrance panel or in its absence, to the internal MGB. Equipment chassis, racks and metal enclosures as well as all data, telephone or audio lines shall be protected and grounded as described in the earlier paragraphs. If the general grounding inside the equipment room appears to be substandard, the site owner shall be requested to address the deficiencies. The installation of a separate grounding system is not an option.

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Chapter 3 INSPECTION AND MAINTENANCE

3.1 NEW INSTALLATIONS

3.1.1 Newly installed lightning protection and grounding systems shall be inspected for the following:

- Check all ground cable connection points of guys and anchors for proper connection and tightness;
- Check all other grounding connections for tightness and anti-corrosion compound (e.g. No-Ox-ID);
- Measure and record ground resistivity (maximum 5 ohms);
- Measure and record bonding resistance (maximum 1 ohm).

3.1.2 The above ground and connection inspection of new installations shall be repeated six months after installation and thereafter in conjunction with the scheduled tower inspections.

3.2 EXISTING INSTALLATIONS

3.2.1 Existing sites shall be inspected in conjunction with the scheduled tower inspection as follows:

- Check all ground cable connection points of guys and anchors for proper connection, tightness, and corrosion. Tighten or replace as required;
- Check all other ground connections for tightness, corrosion and anti-corrosion; compound. Replace as required and re-apply anti-corrosion compound (e.g. No-Ox-ID);
- Measure and record ground resistivity, (maximum 5 ohms), at sites with known poor soil conductivity. For sites with 'normal' soil conditions ground resistivity measurements should be done every five years;
- Measure bonding resistance (maximum 1 ohm).

3.3 CONNECTIVITY MEASUREMENTS

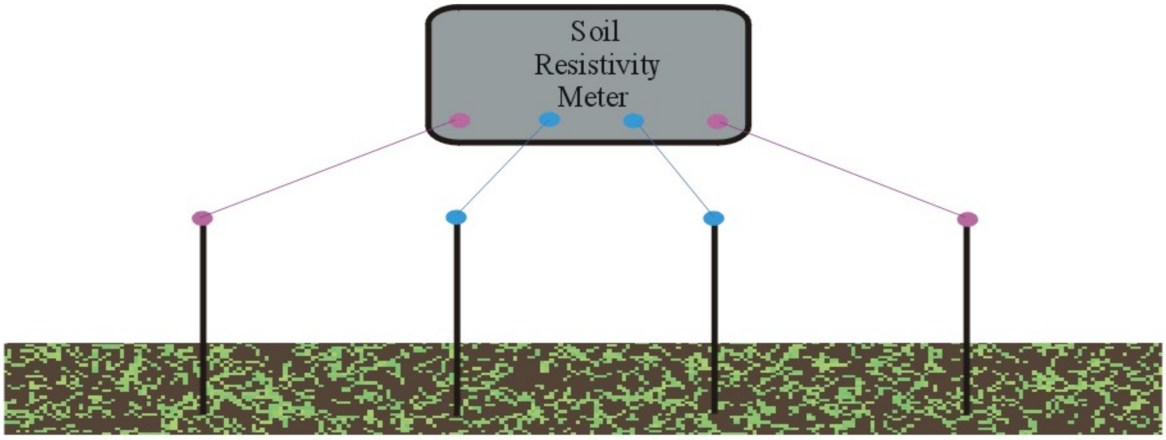
The resistance from each piece of equipment and ground within an equipment room can be checked by using a specially designed clamp-on meter. The resistive value between the MGB and each equipment attachment point should not be greater than 1 ohm.

3.4 TESTING SOIL RESISTIVITY

A periodic testing of the soil's resistivity should be done and, if unusually dry weather conditions prevail, initiated more frequently. The findings of newly conducted soil resistivity measurements should be compared to the original system specification to identify if conductance enhancement material needs to be injected into the soil or if the grounding system has to be upgraded using alternative methods (see Fig 3-1).

The testing of the complete buried ground system with its radials, ground rods and peripheral ground is a complex process that may require excavation to access the copper cables at various locations if corrosion of the grounding system is suspected. The cables may have to be cut at certain locations and replaced if damaged and additional ground rods may have to be installed if the moisture content or conductivity of the soil is reduced. In order to do active ground system measurements, currents have to be induced into the soil at various distances to measure and calculate the performance of the grounding system. This type of measurement and analysis should be done by a qualified technician with experience in measuring soil resistivity and ground systems.

In order to obtain accurate readings of the soil's resistivity, tests have to be conducted at multiple locations at various depths. The most common instrument used to obtain accurate readings is a Soil Resistivity Meter. This measuring equipment typically comes with 4 test leads and test electrodes made from stainless steel. Soil resistivity is measured by injecting current between two test electrodes and measuring the resultant voltage between the second set of electrodes. The results are analyzed, evaluated and recorded.



Voltage is dropped across the 2 outer electrodes and the current is measured between the 2 inner electrodes, establishing the soil's resistivity. Equal spacing between electrodes is important to obtain accurate readings.

Figure 3-1

The Four-Electrode-Method of testing the soil's resistivity as shown above is called the Wenner

4-pin Method. It identifies the average resistivity (ρ) of the soil (electrolyte). The obtained readings are calculated by the test equipment and displayed. In order to avoid erroneous readings caused by polarization of electrodes by DC test currents or because of other fault currents present in the soil, soil resistivity testers employ fast reversing DC measurement technology or use 50 HZ AC line current coupled through isolation transformer or similar technology.

Manufacturers of soil resistivity testers provide detailed information on how their equipment is to be used and how ground resistivity measurements are to be conducted. Additional information on more comprehensive soil resistivity measurement techniques can be found in Motorola's *Standards and Guidelines for Communication Sites R56* under section 4.3 Soil Resistivity Measurements.

Soil Resistive Values in Ω-cm

Soil Composition	Minimum Resistivity	Average Resistivity	Maximum Resistivity
Ashes, cinder, brine, waste	590	2,370	7,000
Clay, shale, gumbo, loam	340	4,060	16,300
Clay, shale, gumbo, loam with portions of sand and gravel	1,020	15,800	135,000
Gravel, sand, stones with little clay or loam	59,000	94,000	458,000

Effect of salt content on the resistivity of sandy loam with a moisture content of 15% by weight at 17°C.

Salt added in % by weight	Resistivity in Ω-cm
0	10,700
0.1	1,800
1.0	460
5	190
10	130
20	100

Effect of temperature on the resistivity of sandy loam with a moisture content of 20% by weight and with salt weighing 5% of moisture.

Temperature in Degrees C	Resistivity in Ω-cm
20	110
10	142
0	190
-5	312
-13	1440

Effect of moisture content by weight.

% Weight	Top Soil	Sandy Loam
0	>1,000,000,000	>1,000,000,000
2.5	250,000	150,000
5	165,000	43,000
10	53,000	18,500
15	19,000	10,500
20	12,000	6,300
30	6,400	4,200

Data obtained from http://www.dranetz-bmi.com/pdf/groundtesting.pdf. “Understanding Ground Resistance Testing Soil Resistivity”.

Annex A SOIL RESISTIVE VALUES

Soil Resistive Values in Ω-cm

Soil Composition	Minimum Resistivity	Average Resistivity	Maximum Resistivity
Ashes, cinder, brine, waste	590	2,370	7,000
Clay, shale, gumbo, loam	340	4,060	16,300
Clay, shale, gumbo, loam with portions of sand and gravel	1,020	15,800	135,000
Gravel, sand, stones with little clay or loam	59,000	94,000	458,000

Effect of salt content on the resistivity of sandy loam with a moisture content of 15% by weight at 17°C.

Salt added in % by weight	Resistivity in Ω-cm
0	10,700
0.1	1,800
1.0	460
5	190
10	130
20	100

Effect of temperature on the resistivity of sandy loam with a moisture content of 20% by weight and with salt weighing 5% of moisture.

Temperature in Degrees C	Resistivity in Ω-cm
20	110
10	142
0	190
-5	312
-13	1440

Effect of moisture content by weight.

% Weight	Top Soil	Sandy Loam
0	>1,000,000,000	>1,000,000,000
2.5	250,000	150,000
5	165,000	43,000
10	53,000	18,500
15	19,000	10,500
20	12,000	6,300
30	6,400	4,200

Data obtained from http://www.dranetz-bmi.com/pdf/groundtesting.pdf. “Understanding Ground Resistance Testing Soil Resistivity”.

Annex B GROUND ENHANCING MATERIALS (GEM)

ERICO’s Ground Enhancing Material (GEM) is a superior conductive material that improves grounding effectiveness, especially in areas of poor conductivity such as rocky ground, areas of moisture variation, and sandy soils.

B.1 FEATURES

- l Effective-typical resistivity 12-18 Ohm cms (20 times lower than bentonite clay)
- Once in its “set” form, maintains constant resistance for the “life” of the ground system
- Performs in all soil conditions even during dry spells
- Permanent - does not dissolve, decompose or leach out with time
- Easily installed in dry form or slurry
- Meets (USA) Environmental Protection Authority requirements for landfill
- Can be installed using Trench or Ground Rod Backfill methods

B.2 APPLICATIONS

GEM is ideal for areas with poor conductivity such as rocky ground, mountain tops, sandy soil and areas of moisture variation.

B.3 MORE INFORMATION

B.3.1 GEM Calculator

Download the latest version of ERICO's GEM Software Calculator (http://www.erico.com/static.asp?id=27). Available in four languages (English, French, German and Spanish), the calculator estimates the amount of GEM required for an installation and converts Metric and Imperial measurement units.

B.3.2 How to Specify

- Ground enhancement material in its set form shall have a resistivity of not more than 20 ohm-cm
- Ground enhancement material must be permanent and maintenance-free (no recharging with salts or chemicals which may be corrosive) and maintain its earth resistance with time.

- It must set up firmly and not dissolve or decompose or otherwise pollute the soil or the local water table.
- The ground enhancement material shall be suitable for installation in a slurry form
- The ground enhancement material shall not depend on the continuous presence of water to maintain its conductivity

B.4 GROUND ENHANCING MATERIAL (GEM) INSTALLATION METHODS

B.4.1 Trench Installation

Estimated linear feet of ground conductor covering with each bag of GEM

Trench Width	**Total Thickness of GEM**			
	2.5cm (1")	5.1cm (2")	7.6cm (3")	10. 2cm (4")
10cm (4")	4.3m (14.0’)	2.1m (7.0’)	1.4m (4.7’)	1.1m (3.5’)
15cm (6")	2.8m (9.3’)	1.4m (4.7’)	0.9m (3.1’)	0.7m (2.3’)
20cm (8")	2.1m (7.0’)	1.1m (3.5’)	0.7m (2.3’)	0.5m (1.8’)
25cm (10")	1.7m 5.6’)	0.9m (2.8’)	0.6m (1.9’)	0.4m (1.4’)
30 cm (12")	1.4m (4.7’)	0.7m (2.3’)	0.5m (1.6’)	0.4m (1.2’)

A 11.1 kg bag of GEM will cover 2.1m (7 linear feet) of conductor length for a 10.2cm - (4-inch) wide, 5.1cm (2-inch) thick covering 2.5cm (1 inch) below and 2.1cm (1 inch) above the conductor), based on 1017 kg /m3 (63.5 lb/cu ft).

B.4.1.1 Method

1) Dig a trench at least 10.2 cm (4 inches) wide x 76.2 cm (30 inches) deep or below the frost line, whichever is deeper. Spread out enough GEM to uniformly cover bottom of trench - about 2.5cm (1 inch) deep.

2) Place copper tape / earth grid conductor on top of GEM.

3) Spread another 3 cm (1 inch) deep layer of GEM around and on top of the conductor so as to completely cover conductor.

4) Carefully cover the GEM with soil to a depth of about 10 cm (4 inches), making sure not to expose the conductor. Tamp down the soil, then fill in the trench.

5) Please note that this is a guide to installation only. Full instructions will be supplied at time of product purchase.

B.4.2 Ground Rod Backfill Installation

**Estimated bags of GEM for backfilling around ground rods
to a density of 1442 kg/m3 (90 lb/cu ft)**

Diameter of hole	**Depth of hole (feet) ***						
	1.8m (6')	**2.1m (7')**	**2.4m (8')**	**2.7m (9')**	**5.2m (17')**	**5.8m (19')**	**6.1m (20')**
7.5cm (3")	2	2	2	2	4	4	4
10.0cm (4")	2	3	3	3	6	7	7
12.5cm (5")	3	4	4	5	9	10	10
15.0cm (6")	5	5	6	7	13	14	15
17.5cm (7")	6	7	8	9	17	19	20
20.0cm (8")	8	9	11	12	22	25	26
22.5cm (9")	10	12	13	15	28	31	32
25.0cm (10")	12	14	16	18	34	38	40

* 2.44m (8 foot) minimum rod length required to be in contact with the soil (or GEM). As per NEC 250-83c.

B.4.2.1 Method

1) Auger a 7.6cm (3 inch) or large diameter hole to a depth of 15.0cm (6 inches) less than the length of the ground rod.

2) Place ground rod into augured hole and drive it using the steel head and hammer approx 30 cms (one foot) into bottom of the hole. The top of the ground rod will be approximately 15.2cm (6 inches) below the level of the grade. At this time, make any connections to ground rod using CADWELD® connections.

3) Pour the appropriate amount of GEM (see below) around the ground rod. To ensure the GEM material completely fills the hole, tamp around the ground rod with a pole.

4) Fill remainder of augured hole with soil removed during auguring. For various augured-hole diameters and depths, see the table above.

Note: *Excess standing water must be removed the hole.*

Note: *When premixing GEM in a slurry form, use a standard cement mixer or hard-mix in a mixing box, wheelbarrow, etc. Use 5.5 to 7.5 litres (1.5 to 2 gallons) of clean water per bag of GEM.*

Note: *This is a guide to installation only. Full instructions will be supplied at time of product purchase.*

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Annex C TERMS AND DEFINITIONS

Bentonite	A ground enhancing material (GEM) of clay with high conductivity.
Bonding	A process of mechanically connecting two or more metal parts together for the purpose of reducing electrical resistance and facilitating the discharge of lightning or electrical fault currents to ground.
Brazing	The joining of two or more metal pieces together with a heated liquefied filler metal whose melting temperature is lower than that of the metals being joined.
Bulkhead panel	A copper panel/plate designed for the attachment of incoming transmission lines.
Cable tray	A support structure for cables and transmission lines.
Effective Radiated Power (ERP)	The actual Radio Frequency power radiated by an antenna.
Exothermic welding	The fusing of two or more metal pieces with a mixture of copper oxide and granular aluminium through a momentary heating process to achieve a molecular bond.
Ground Enhancing Material (GEM)	Conductive and non-acidic material added to the ground/soil to improve its conductivity for the dissipation of lightning induced energy.
Grounding	The process of establishing a connection/path to ground, often referred to as a discharge system, for the dissipation of lightning induced energy or fault currents into the ground.
Ground Potential Rise (GPR)	The voltage rise caused when the ground reference level increases because of the momentary inductance that a grounding system experiences during a lightning strike.
Ground rod	A steel electrode, copper clad or galvanized driven into the ground for the dissipation of the energy induced by a lightning strike.
Inductance	The electrical resistance to alternating current or pulses.

Master Ground Bar (MGB)	A solid copper or brass plate that is used as the single distribution point for ground cables used inside an equipment room.
Metal Oxide Varistor (MOV)	A surge suppressor, often used for higher voltages, which conducts when a pre-set voltage level is exceeded.
Perimeter ground	A grounding system consisting of a buried cable and ground rods that form a closed loop around a building, trailer, or shelter.
Radials	Straight runs of buried copper cable from the base of a tower, or structure, typically with ground rods attached at specified intervals.
Silicon Avalanche Diode (SAD)	A solid state surge suppressor that conducts when a pre-set voltage level is exceeded.
Silver soldering	The joining two or more metal parts with silver as the filler agent. This provides a stronger mechanical connection over regular lead based soldering having a much higher heat resistance.
Spark gap arrestor	A passive, mechanical devise that only allows current to conduct at a pre-set high voltage by arcing across its contacts.
Surge suppressor	A device that shunts transient currents above a pre-set level to ground.
Thermite bonding	The fusing of two or more metal pieces with a mixture of iron oxide powder and granular aluminium through a momentary heating process to achieve a molecular bond.
Toroidal transformer	A transformer with primary windings on a round ring with secondary windings on another ring that is looped through the center of the primary winding ring without making physical contact.
Tower Ground Bar (TGB)	A solid copper or brass bar attached to a tower for the connection of cable grounding straps.
Ufer grounding	A grounding method that uses the rebar and steel embedded in concrete as grounding electrodes for lightning charge dispersion.
Waveguide bridge	A platform, usually made of galvanized steel, that supports transmission lines and other cables

Annex D TEST

- CAN/CSA-C22.2 No. 0.4-04
- CAN/CSA-S37-01
- Canadian Electrical Code
- Canadian Electrical Safety Code
- CCG Tower/Remote Site Groundings General Drawings And Engineering Standards, Newfoundland
- Designing For A Low Resistant Earth Interface (Grounding) by Roy B. Carpenter, Jr. and Roy B. Lanzoni
- General Site Grounding Specification, Canadian Coast Guard, Rev 5, Central & Artic, December 12, 2002
- Grounding Standard for the National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, Standard No. S24.809, Revision of December 22, 2000
- Grounding/Bonding & Lightning Protection For A Typical Cell Site, Rogers Wireless, Issue 3, October 29, 2004
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Annex E TEST 2

The Canadian Electrical Safety Code defines in **Section 10** under **Grounding and Bonding** the various rules, options and requirements that apply to meet code compliance. For supplementary information and details not in this standard, consult the Canadian Electrical Safety Code for more information.

Section 10 – Grounding and Bonding also details and defines the following:

- Artificial Grounding Electrodes
- Equipment Bonding
- Equipment Bonding Conductors
- Grounding and Bonding Conductors
- Grounding Electrodes
- Lightning Arresters
- Lightning Rods
- Methods of Grounding
- Neutral Grounding Device
- Neutral Grounding Device Conductors
- Neutral Grounding Device Warning Signs
- Spacing and Bonding of Electrical, Communication, and Community Antenna Distribution Grounding Systems
- System Grounding Conductors

Appendix G - VHF-DF Servo Antenna Installation Manual

Refer to: http://www.df2100.com/