Appendix D

Structural Analysis Report

CCG
STRUCTURAL ANALYSIS

45.72m GUYED KNOCK DOWN TOWER
OWNED BY CCG

Cuslett, NL

Prepared by:

TEI
119 Springdale St.
St. John's, NL,
Canada

Prepared for:

Aaron Slaney
CCG

Issue Date:	Status:	Project #:	Issued By:	Reviewed By:	Approved By:
April 27, 2018	R0 – Issued to Client	2018-44	JCW	JW	JW

TABLE OF CONTENTS

1.0 Introduction **1**

2.0 Assumptions **2**

3.0 Analysis Results **3**

4.0 Conclusions **4**

5.0 General Notes & Assumptions **5**

Appendix A **7**

Environment Canada Site Specific Wind Data **8**

Appendix B **10**

Tower Profile and Antenna Loading **11**

Appendix C **13**

Graphical Analysis Results **14**

Appendix D **22**

Proposed Antenna Arrangement **23**

1.0 Introduction

As per instructions, we have analyzed the CCG owned 45.72m triangular cross section, guyed all-weld tower. This tower was originally installed at Pearce Peak and is being re-located to the CCG Custlett tower site. The existing tower will be modified by removing all the current torsion resistors at each guy level for re-installation at Cuslett.

The structural analysis was performed to assess whether the tower meets the strength requirements of CSA S37-13 with the addition of proposed antennas as shown on the attached tower profile. This analysis only includes the tower structure. The foundations will be designed at a later date based on loads provided in this report.

Structure Detail

Height:	45.72m
Type:	Guyed Knock Down
Name:	Cuslett, NL
Latitude (N):	46º 58' 27.9"
Longitude (W):	54º 9' 14.8"

Analysis Parameters

Standard:	CSA S37-13
Ice Loading:	35 mm glazed radial
Wind Loading:	866 Pa (Site Specific 1/50yr Wind Data)
Reliability Class:	I
Serviceability Factor:	669 Pa (Site Specific 1/10yr Wind Data)
Loading Combinations:	24 Load Cases (12 bare, 12 iced)

Sources of Information

Tower Drawings:	None
Structural Mapping:	None
Reports:	None
Environmental Data:	Environment Canada Site Specific Wind Data dated April 4, 2018
Correspondence:	Email from Aaron Slaney dated April 10, 2018
RF Design:	Proposed Antenna Arrangement dated March 20, 2018
Geotechnical Report:	None

2.0 Assumptions

Several assumptions were made in order to facilitate our analysis. General assumptions are included in Section 5.0. If you have any knowledge which would indicate they do not accurately represent the existing tower, proposed and existing antenna and transmission line arrangements, or site specific information, we must be notified so that we can make the appropriate changes to our analysis, conclusions and any recommendations.

Project specific assumptions utilized in completing our structural analysis include:

1. The yield strength for the tower legs and diagonals was taken as 350W. Horizontals and all other structural members were taken as 300W.

2. The tower members, connections, and other relevant components are in good condition and are capable of carrying their full design capacity based on a recent visual tower maintenance inspection.

3. Antennas and line loading for inclusion into the modeling programs were retrieved from the proposed antenna arrangement.

4. Bluewave (V) BMY 146Y-4 (Antenna #7) has since been eliminated from the proposed antenna arrangement by the RCMP but is still considered for this analysis.

3.0 Analysis Results

Based on the above information and assumptions, our analysis results indicate that the tower **DOES NOT experience overloads** under the proposed loading in accordance with the strength requirements of CSA S37-13.

Graphical tower loading and capacity results are provided in Appendix C.

Foundations were not evaluated as part of this analysis. Foundations to be designed at a later date based on the following:

- Foundation Base:
  - Axial = 492.2 kN
  - Shear N-S = -26.22 kN
  - Shear E-W = 24.33 kN
  - Moment N-S = 0 kN-m
  - Moment E-W = -0.01 kN-m
  - Torsion = 1.14 kN-m
- Guy Anchors:
  - Level 1 @ 23.2: Tension at Anchor = 117.70 kN
  - Level 2 @ 41.5: Tension at Anchor = 116.10 kN

For your information, we have attached the tower profile and loading chart, as well as graphical analysis results.

4.0 Conclusions

Based on the above information, particulars and assumptions, our analysis results indicate that the tower structure **DOES NOT experience overloads** when assessed in accordance with the strength requirements of CSA S37-13 under Class I Reliability. As a result the tower **is capable of supporting the proposed loading.**

We trust the forgoing is satisfactory. If you have any questions or comments, please contact the undersigned.

Jon Wong, P. Eng.
Structural Engineer
Tiller Engineering Inc.
119 Springdale Street
P.O. Box 403, 50 Hamlyn Road Plaza
St. John's, NL, Canada
A1E 5X7

Phone: (709) 579-6700
Fax: (709) 579-6701
Email: jwong@tei-inc.ca
Web: www.tillerengineering.com
Toll Free: 1-877-907-6700

5.0 General Notes & Assumptions

1. All Results plus Conclusions derived from this analysis report are as accurate as the information provided to Tiller Engineering Inc.

2. All Results plus Conclusions and recommendations are based on analysis results for Reliability Class I. This is the most conservative case whereby the target failure probability is 0.01% over a 50 year period, since any failure would result in unacceptable risk of injury and/or interrupted service.

3. Should the Client wish to accept some measure of risk, Tiller Engineering Inc. can re-evaluate the results, conclusions and recommendations based on either Reliability Class II or III at the Client's request.

4. This analysis is completed in accordance with the strength/safety (Ultimate Limit States-ULS) and antenna service (Serviceability Limit States-SLS) requirements of CSA S37-13.

5. In our analysis, twenty-four (24) load cases are evaluated: twelve (12) wind directions under (a) full design wind pressure without ice and (b) half design wind plus full ice thickness.

6. Our assessment is based on the maximum CSA S37-13 recommended ice thickness. These figures are general in nature and based on Environment Canada data. Site specific ice loading could change considerably. If you have any site specific information which would indicate that greater uniform accumulations of ice are likely to occur, please contact us immediately since this analysis would not be valid.

7. ULS evaluation compares the minimum factored resistance governed by either members or connections with factored loads resulting from wind and/or ice (maximum governing) applied to the structure.

8. SLS evaluation reports deflection of microwave antenna beams as a result of applied service loads, if applicable. Unless specified by the owner, total deflection is compared against antenna manufacturer data for ½ antenna beam width. The owner may also specify operational availability for the analysis, used in calculating service loads (default for our analyses is a serviceability factor of 1).

9. The analysis does not constitute an approval/disapproval of the physical condition of the structure. Unless noted otherwise, Tiller Engineering Inc. assumes the physical condition of the structure does not impair its performance under ULS or SLS. A thorough inspection of the actual tower conditions is recommended by CSA S37-13 prior to any analysis or modifications to the structure. This should be completed by qualified engineering personnel if it has not been done immediately prior to the analysis. Tiller Engineering Inc. cannot comment on any capacity effects due to condition of subsurface foundations unless a thorough on-site evaluation is performed.

10. Azimuths are generally referenced to True North unless otherwise indicated.

11. This report is only valid if antennas and lines are installed as listed above. Any changes should be forwarded to Tiller Engineering Inc.'s attention for further assessment.

12. This tower analysis report is intended to verify the adequacy of the **main** tower structural components. Legs, diagonals and guys were checked and are an indication of the adequacy of the complete tower system.

13. The loading considered in our analysis includes all existing antennas, transmission lines and other appurtenances as shown in Appendix A.

14. The tower and its foundation system have been properly constructed as per the original design drawings and specifications and able to resist the original design loads.

15. The tower members, connections, foundations and other relevant components are in good condition and are capable of carrying their full design capacity.

16. Transmission lines and other linear attachments are assumed to act integral with the tower mast where warranted as per CSA S37-13.

17. New antennas and line loading for inclusion into the modeling programs were provided by CCG.

18. Initial guy tensions assumed to be 10% of breaking strength unless noted.

APPENDIX A

Environment Canada Site Specific Wind Data

Cuslett, NL 45.7m Tower

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

Site Information:

Name: Cuslett, NL
Latitude: 46° 58' 27.9" N
Longitude: 54° 9' 14.8" W
Tower Height (m): 45.7
Elevation MSL (m): 134.5

Results:

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

Q_{nbc} (Pa):	780	$Q_{nbc} = 780(Z/10)^{0.2}$	V_{nbc} = 77.7 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):

$$Q_h = 0.12919 \{[0.1625\, e^{(-0.0025\, z)} + 1.2124\, \ln(z/0.2000) / \ln(z/0.0500)]\, 77.67\}^2\, (z/10)^{0.200}$$

Profile Formula General Form:

$$Q_h = 0.12919 \{[a_1\, e^{(-a2\, z)} + a_3\, \ln(z/z_h) / \ln(z/z_{01})]\, v_{01}\}^2\, (z/10)^{0.200}$$

Site Values of Coefficients:

$$a_1 = 0.1625,\ a_2 = 0.0025,\ a_3 = 1.2124,\ z_h = 0.2000,\ z_{01} = 0.0500,\ v_{01} = 77.67 \text{ mph}$$

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.

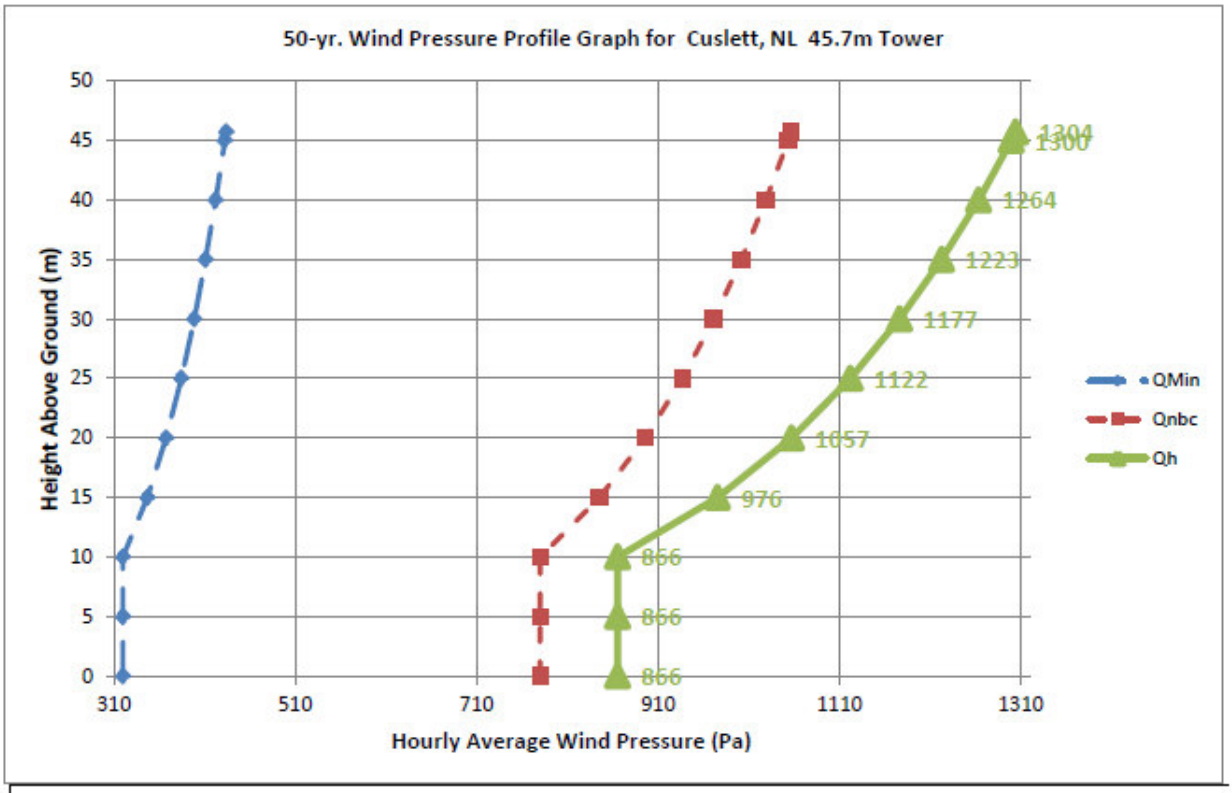
Note: No wind pressure value less than 90% of the value at 10 m should be used for heights less than 10 m a.g.l.

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%].

April 04, 2018

Environment Canada Site Specific Wind Data

Cuslett, NL 45.7m Tower



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.

April 04, 2018

Environment Canada Site Specific Wind Data

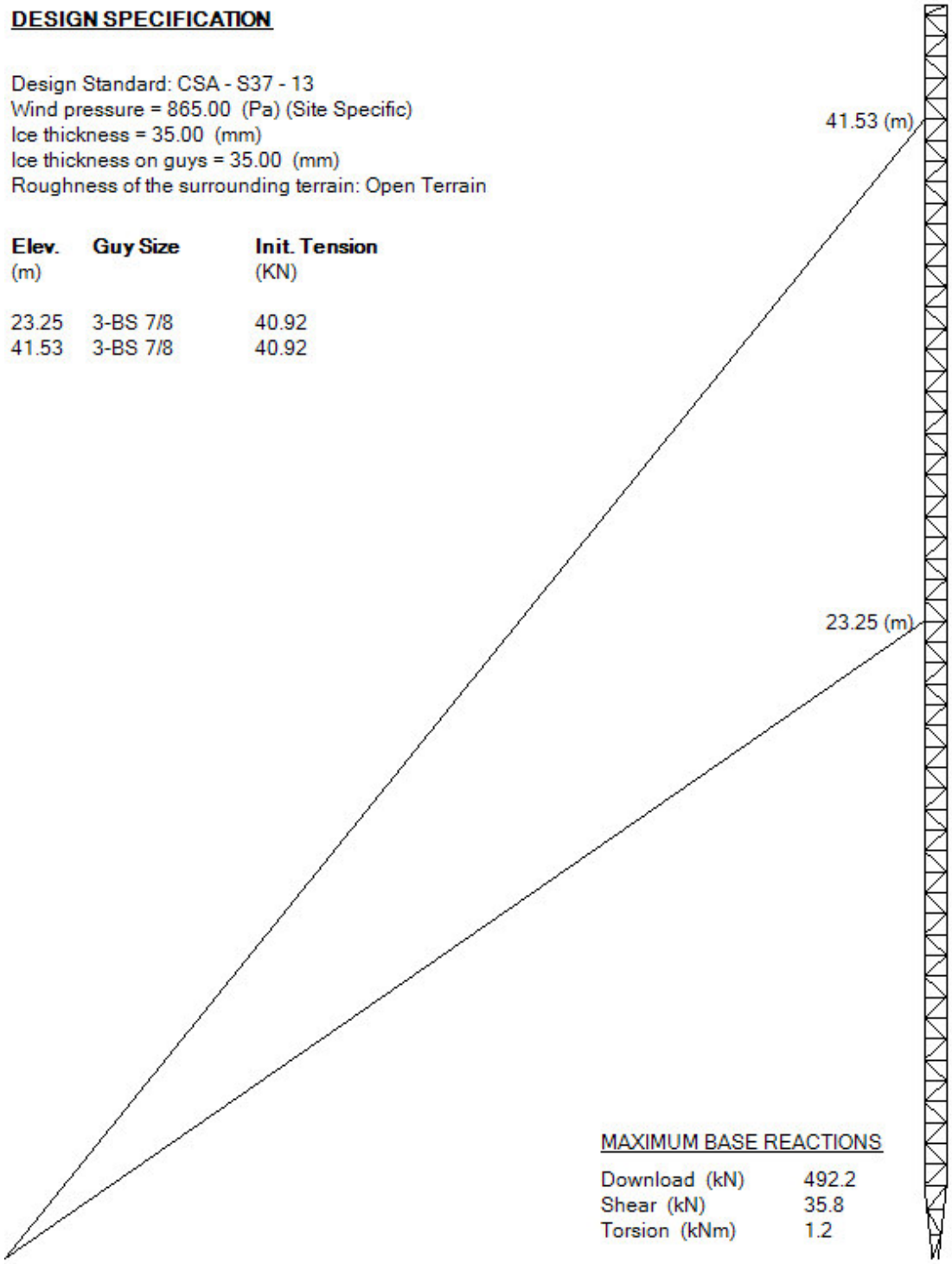
Appendix B

Tower Profile and Antenna Loading

DESIGN SPECIFICATION

Design Standard: CSA - S37 - 13
Wind pressure = 865.00 (Pa) (Site Specific)
Ice thickness = 35.00 (mm)
Ice thickness on guys = 35.00 (mm)
Roughness of the surrounding terrain: Open Terrain

Elev. (m)	Guy Size	Init. Tension (KN)
23.25	3-BS 7/8	40.92
41.53	3-BS 7/8	40.92



Tower Profile

ANTENNA AND TX LINE LOAD:

Ant#	Owner	Antenna Type	Elevation (m)	Azimuth	TX Line / RRUs	Status
1	CCG	SRL-210C-4	45.70	275°	22mm COAXIAL	PLANNED
2	CCG	SRL-210C-2	37.47	150°	13mm COAXIAL	PLANNED
3	CCG	SRL-210C-4	35.95	275°	22mm COAXIAL	PLANNED
4	CCG	SRL-227	35.03	36°	13mm COAXIAL	PLANNED
5	CCG	SRL-210C-4	27.41	275°	22mm COAXIAL	PLANNED
6	CCG	SRL-210C-2	20.56	275°	22mm COAXIAL	PLANNED
7	CCG	BLUEWAVE (V) (BMY 146Y-4)	17.35	44°	13mm COAXIAL	PLANNED
8	CCG	SRL-210C-2	15.57	275°	22mm COAXIAL	PLANNED
9	CCG	SRL-210C-2	10.45	275°	22mm COAXIAL	PLANNED

Note: The related information contained in the above table is the main contributor to the existing structural loading only. It is not intended to be a complete and exact inventory of all tower appurtenances. **BLACK** antennas are existing, **BLUE** are proposed antennas and TX lines, **RED** are to be removed and **GREEN** are future.

Legend: DC (V1) = Old Solution (4) Pair Power (Version 1)
DC (V2) = New Solution (4) Pair Power (Version 2)
FO (V1) = Old Solution (24) Pair Fiber (Version 1)
FO (V2) = New Solution (4) Pair Fiber (Version 2)
FO (V3) = New Solution (6) Pair Fiber (Version 3)

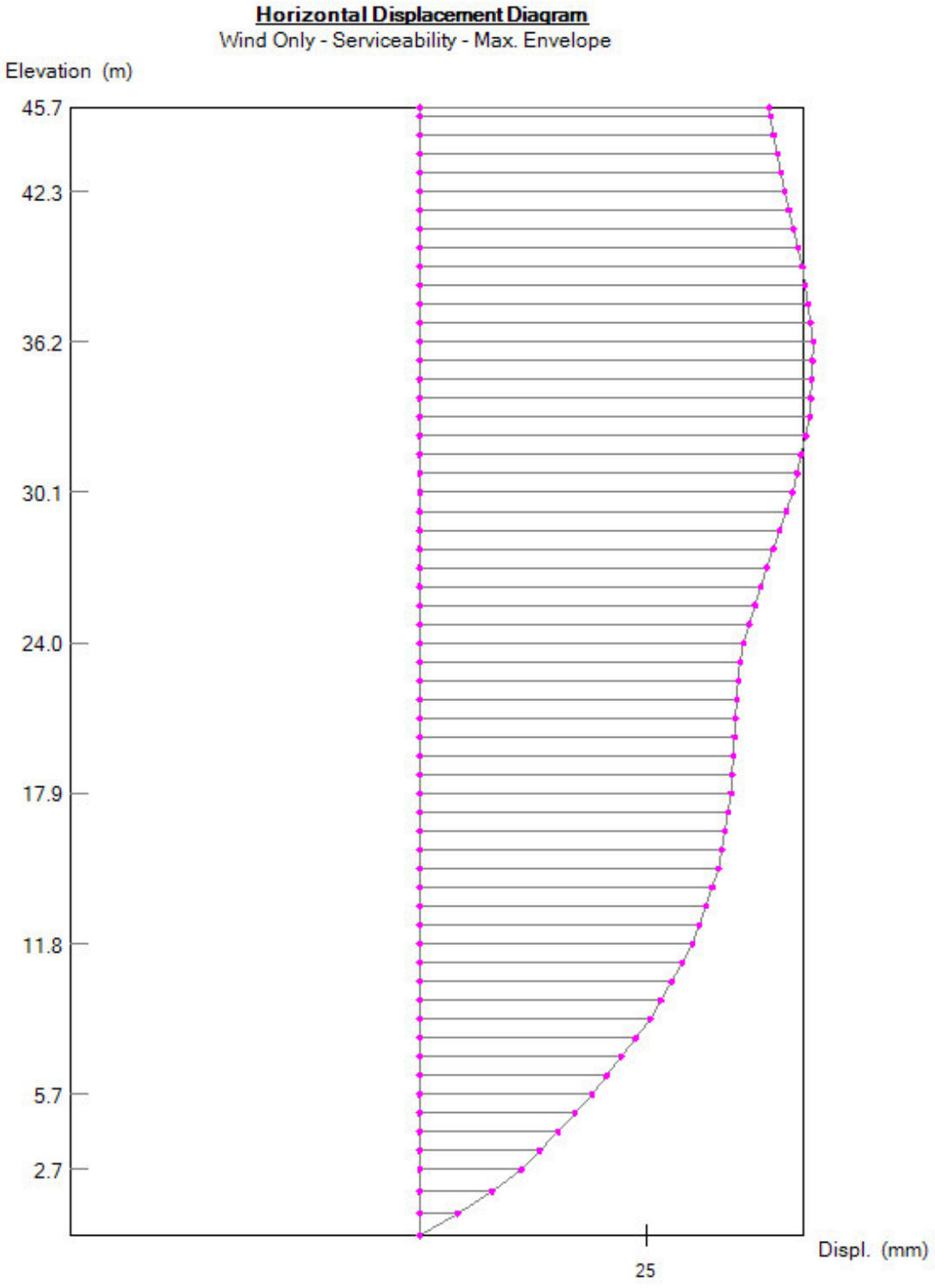
Appendix C

Graphical Analysis Results

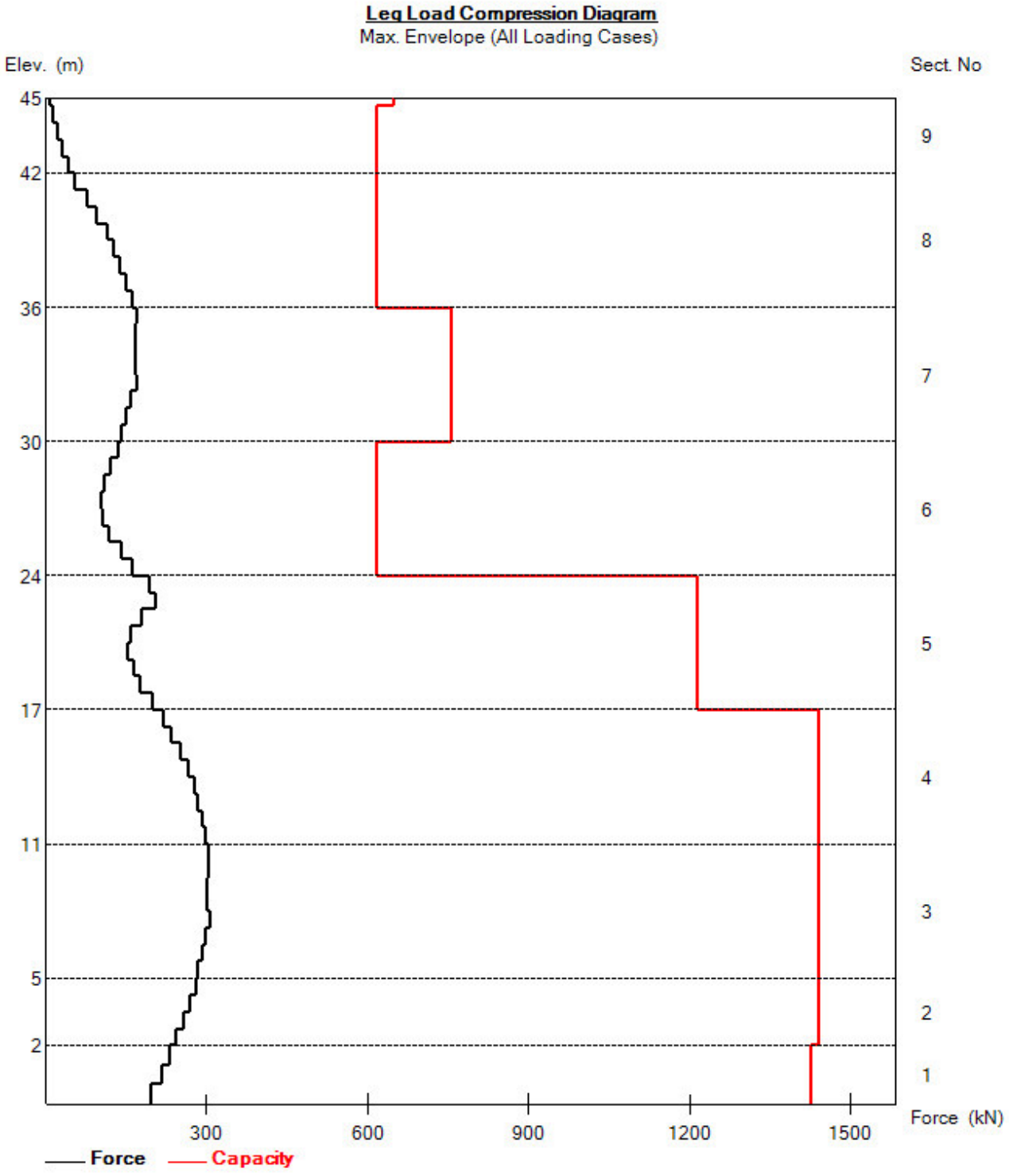
Section A: PROJECT DATA

```
Project Title:      SA+CIP
Customer Name:      CCG
Site:               Cuslett
Contract No.:       2018-44
Revision:           1
Engineer:           J.Wong
Date:               Apr 17 2018
Time:               11:19:27 AM

Design Standard:    CSA-S37-13

GENERAL DESIGN CONDITIONS

Start wind direction:                       0.00 (Deg)
End wind direction:                         330.00 (Deg)
Increment wind direction:                   30.00 (Deg)
Elevation above ground:                     0.00 (m)
Roughness of the surrounding terrain:       Open Terrain
Importance Factor:                          1.00
Serviceability Factor:                      1.00
Gust Factor Cg:                             2.0
Material Density:                           7850.0(kg/m^3)
Young's Modulus:                            199947.6 (MPa)
Poisson Ratio:                              0.30
Weight Multiplier:                          1.00

WIND ONLY CONDITIONS:
Wind pressure:                              865.00 (Pa)
Wind Load Factor:                           1.40
Dead Load Factor:                           1.25
Dead Load Factor for Uplift:                0.85
Dead Load Factor for Guys:                  1.00

WIND AND ICE CONDITIONS:
Wind pressure:                              865.00 (Pa)
Ice thickness:                              35.00 (mm)
Ice density:                                900.00(kg/m^3)
Ice thickness on guys:                      35.00 (mm)
Ice density on guys:                        900.00(kg/m^3)
Wind Load Factor:                           1.40
Dead Load Factor:                           1.25
Ice Load Factor:                            1.45
Dead Load Factor for Guys:                  1.00
Temperature Reduction with Ice: 10.0 (Deg. Celsius)

WIND ONLY SERVICEABILITY CONDITIONS:
Wind pressure:                              668.00 (Pa)
Wind Load Factor:                           1.00
Dead Load Factor:                           1.00
Dead Load Factor for Guys:                  1.00

Site Specific Wind:           Yes

Site specific Wind Pressure Profile Formula Coefficients:
a1:           0.1625
a2:           0.00250
a3:           1.212
Zh:           0.200
Z01:          0.050
V01:          77.670
V01 (10 year):68.270

Additional axial forces in horizontal members at Guy and Torsion Resistor levels due to local effect
of Guys and/or TRs are considered.

Analysis performed using: TowerSoft Finite Element Analysis Program
```

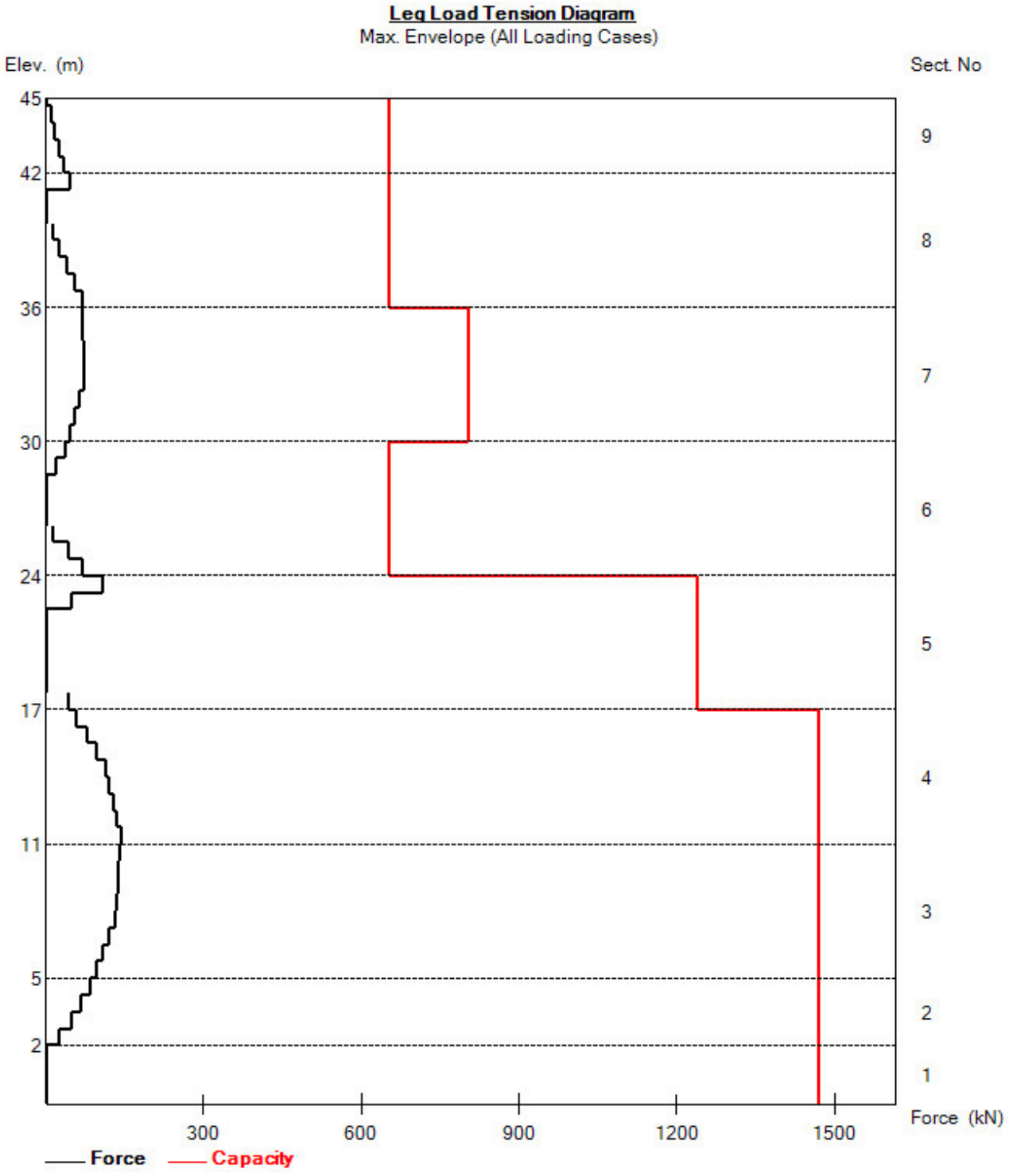
Project Data



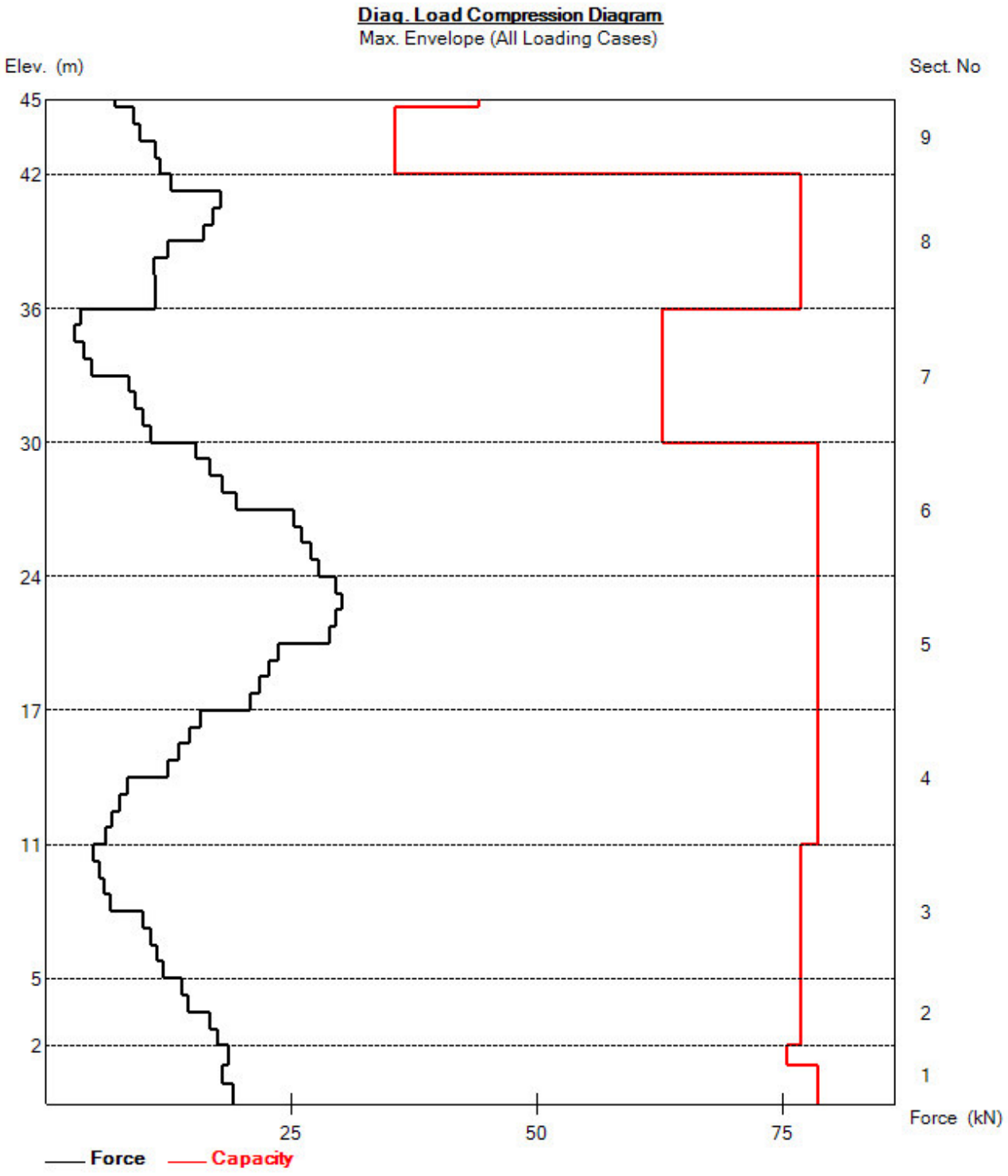
Horizontal Displacement
Under Serviceability Conditions



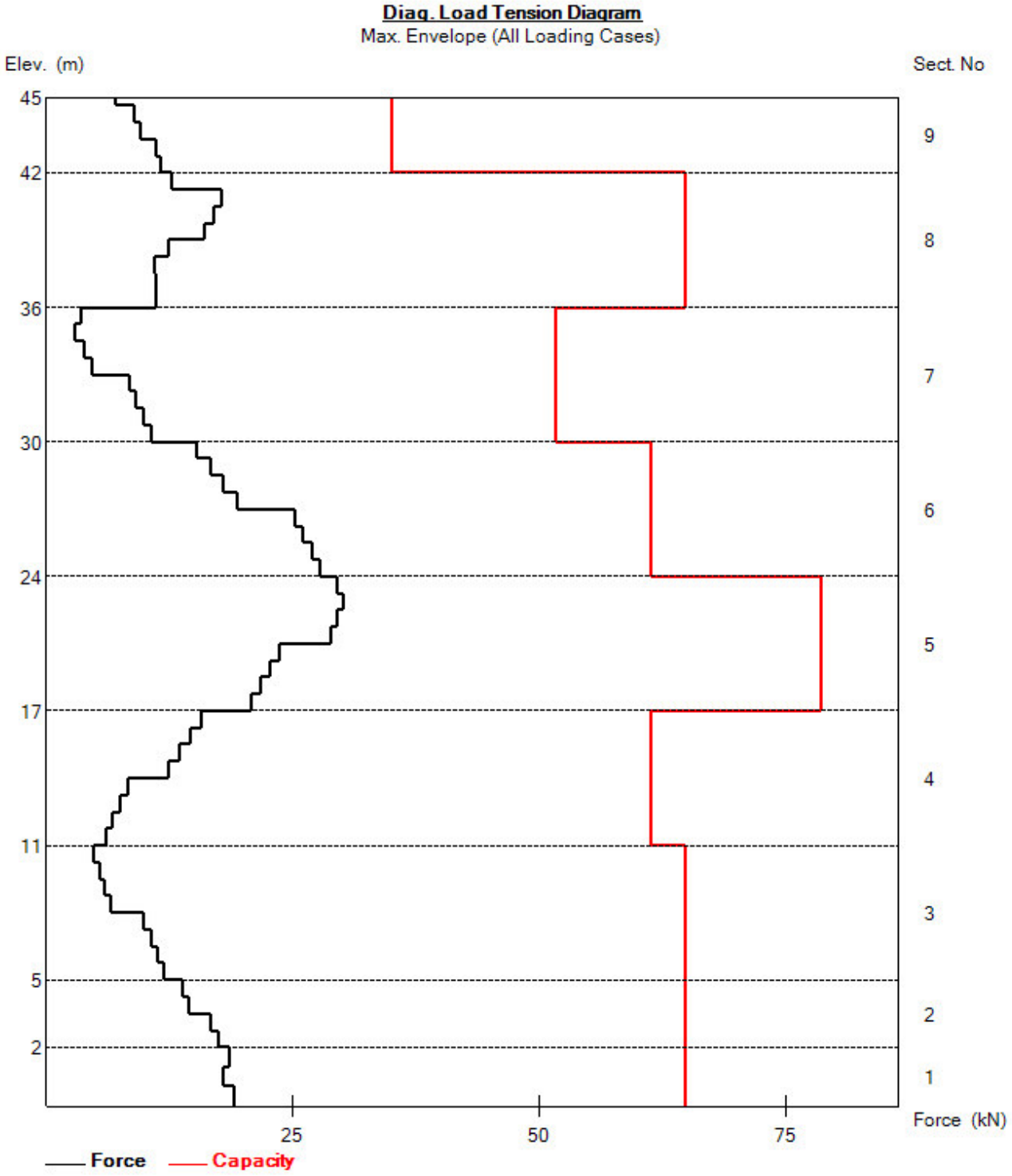
Leg Compression
Class I Reliability



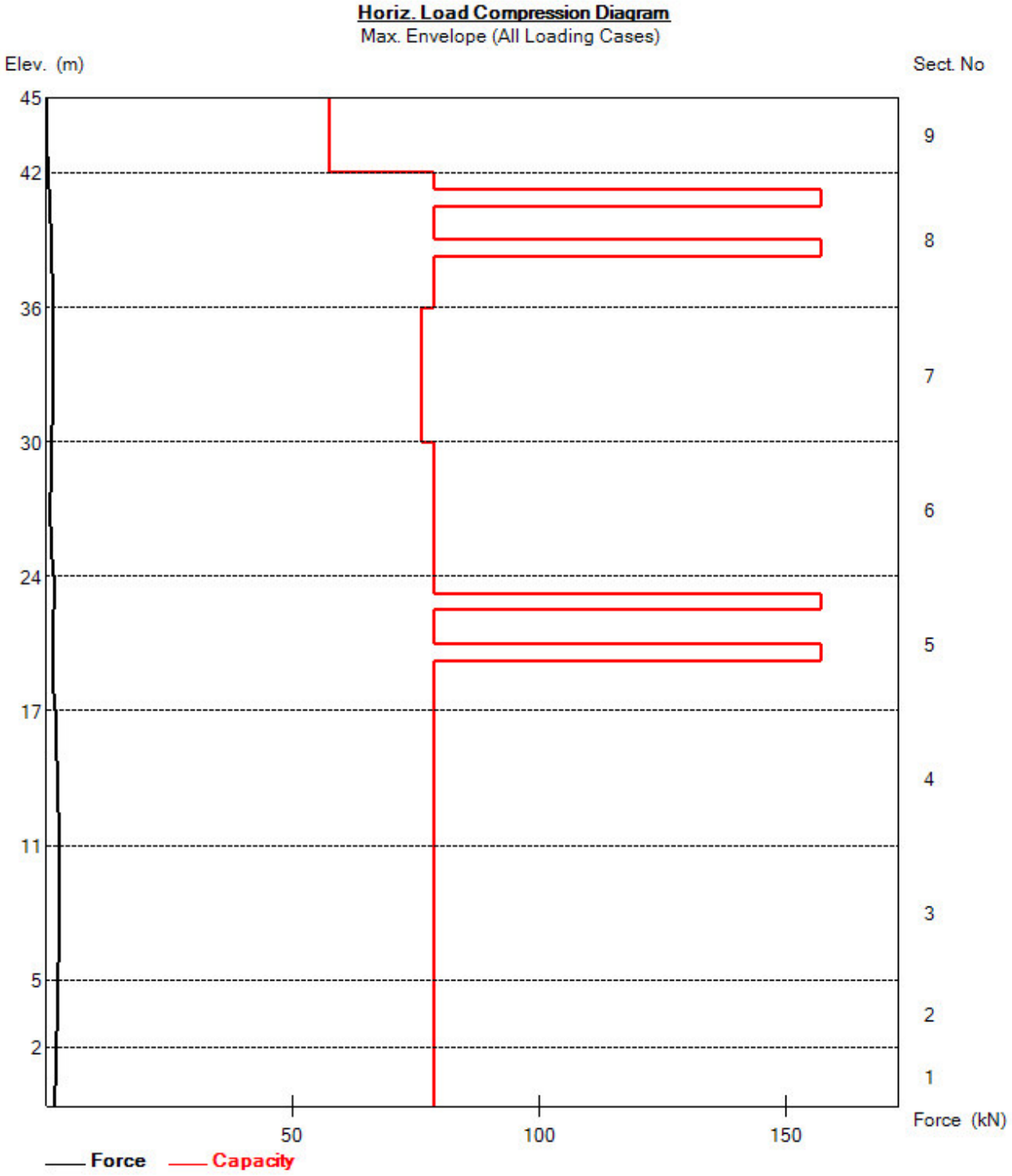
Leg Tensions
Class I Reliability



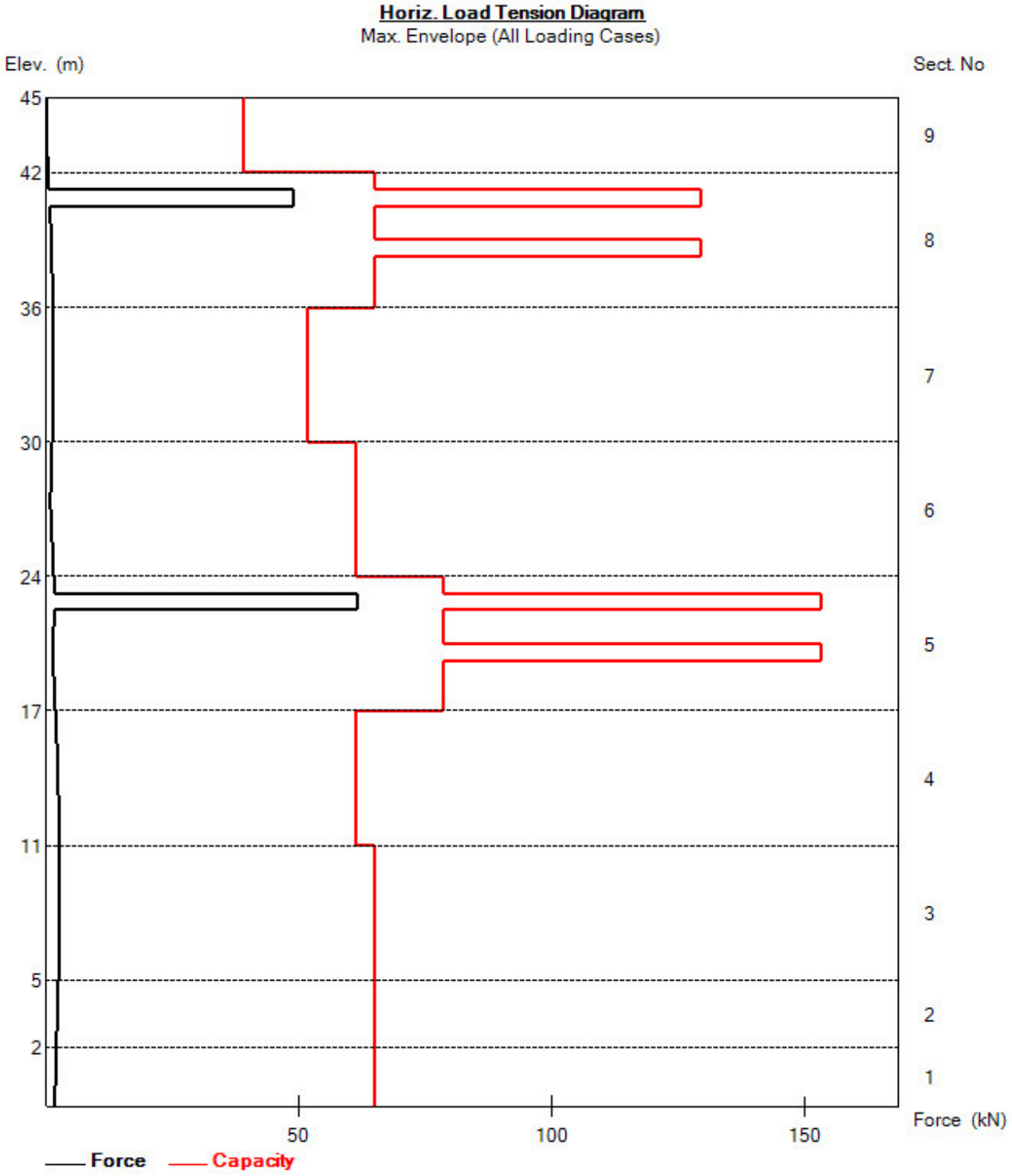
Diagonal Compression
Class I Reliability



Diagonal Tension
Class I Reliability



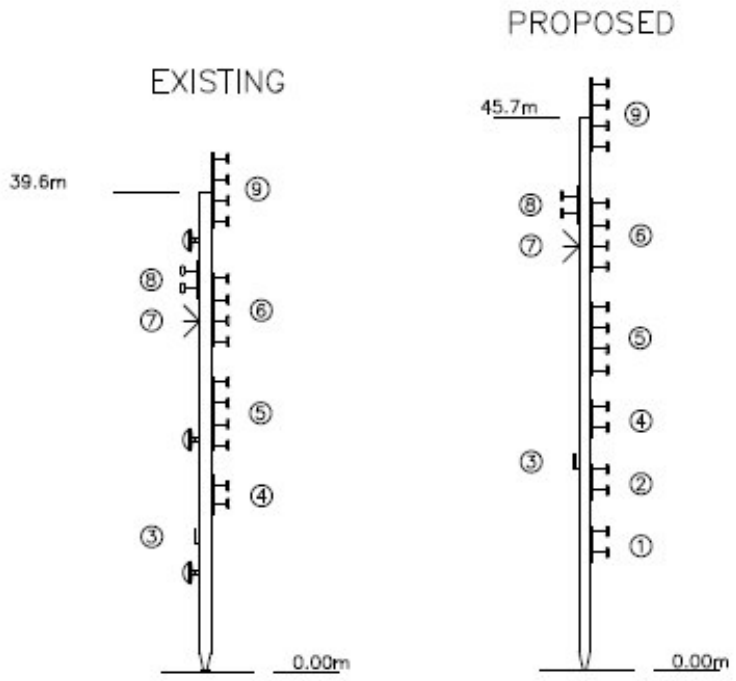
Horizontal Compression
Class I Reliability



Horizontal Tension
Class I Reliability

ANTENNA SYSTEMS

ITEM	TYPE	ELEV. (ANTENNA MID POINT)	AZ.	LOCATION	TX LINE
1	SRL-210C-2	10.45M	275°	LEG 3	22mm COAXIAL
2	SRL-210C-2	15.57M	275°	LEG 3	22mm COAXIAL
3	BLUEWAVE (V) (BWY 146Y-4)	17.35M	44°	LEG 1	13mm COAXIAL
4	SRL-210C-2	20.56M	275°	LEG 3	22mm COAXIAL
5	SRL-210C-4	27.41M	275°	LEG 3	22mm COAXIAL
6	SRL-210C-4	35.95M	275°	LEG 3	22mm COAXIAL
7	SRL-227	35.03	36°	LEG 1	13mm COAXIAL
8	SRL-210C-2	37.47	150°	LEG 2	13mm COAXIAL
9	SRL-210C-4	45.70M	275°	LEG 3	22mm COAXIAL



Fisheries and Oceans Canada / Pêches et Océans Garde côtière

drawing title-dessin titre: PROPOSED ANTENNA ARRANGEMENT

drawn-dessine: R.H.

checked-verifie:

approved-approuve:

site: CUSLETT NEWFOUNDLAND

scale-echelle: N.T.S.

project no.:

date-date: MAR. 20, 2018

drawing no.-no du dessin: CUSLETT_VHF_ANTENNA_LAYOUT.DWG

Proposed Antenna Arrangement