Appendix I

Applicant's Audible Noise and EMF Calculations

Predicted Intensity of Electric Fields (kV/m) at Maximum Operating Voltage
Where Not Paralleling Existing Transmission Lines

Structure Type	Line Voltage	Distance from Project ROW Centerline										
		-300	-200	-100	-50	-25	0	25	50	100	200	300
500 kV Guyed-Delta	550 kV	0.080	0.215	1.330	5.137	6.414	3.071	6.413	5.136	1.329	0.214	0.079
500 kV Guyed-V	550 kV	0.096	0.321	2.325	7.027	5.284	4.907	5.278	7.021	2.320	0.319	0.096
500 kV Self-Supporting	550 kV	0.096	0.321	2.325	7.027	5.284	4.907	5.278	7.021	2.320	0.319	0.096

Predicted Intensity of Electric Fields (kV/m) at Maximum Operating Voltage
Where Parallel to Existing 500 kV Transmission Line (Self-Supporting Tower)

Structure Type	Line Voltage	Distance from Project ROW Centerline									
		-200	-100	-50	-25	0	25	50	100	200	300	400
Project: 500 kV Guyed-Delta Existing: 500 kV Self-Supporting	550 kV 550 kV	0.228	1.359	5.170	6.457	3.100	6.290	4.819	0.838	3.803	1.732	0.249
Project: 500 kV Guyed-V Existing: 500 kV Self-Supporting	550 kV 550 kV	0.342	2.358	7.060	5.322	4.888	5.114	6.702	1.487	3.754	1.756	0.264
Project: 500 kV Self-Supporting Existing: 500 kV Self-Supporting	550 kV 550 kV	0.342	2.358	7.060	5.322	4.888	5.114	6.702	1.487	3.754	1.756	0.264

Predicted Intensity of Electric Fields (kV/m) at Maximum Operating Voltage
Where Parallel to Existing 500 kV Transmission Line (Guyed-Delta Tower)

Structure Type	Line Voltage	Distance from Project ROW Centerline									
		-200	-100	-50	-25	0	25	50	100	200	300	400
Project: 500 kV Guyed-Delta Existing: 500 kV Guyed-Delta	550 kV 550 kV	0.237	1.347	5.149	6.429	3.049	6.287	4.856	0.415	3.842	1.080	0.213
Project: 500 kV Guyed-V Existing: 500 kV Guyed-Delta	550 kV 550 kV	0.327	2.335	7.041	5.319	4.935	5.177	6.760	1.442	3.896	1.092	0.200
Project: 500 kV Self-Supporting Existing: 500 kV Guyed-Delta	550 kV 550 kV	0.327	2.335	7.041	5.319	4.935	5.177	6.760	1.442	3.896	1.092	0.200

Predicted Intensity of Electric Fields (kV/m) at Maximum Operating Voltage
Where Parallel to Existing 230 kV Transmission Line (H-Frame Tower)

Structure Type	Line Voltage	Distance from Project ROW Centerline										
		-300	-200	-100	-50	-25	0	25	50	100	200	300
Project: 500 kV Guyed-Delta Existing: 230 kV H-Frame	550 kV 253 kV	0.080	0.218	1.337	5.146	6.426	3.079	6.377	5.035	0.818	2.495	0.190
Project: 500 kV Guyed-V Existing: 230 kV H-Frame	550 kV 253 kV	0.100	0.327	2.334	7.035	5.295	4.903	5.228	6.914	1.840	2.538	0.221
Project: 500 kV Self-Supporting Existing: 230 kV H-Frame	550 kV 253 kV	0.100	0.327	2.334	7.035	5.295	4.903	5.228	6.914	1.840	2.538	0.221

Predicted Intensity of Electric Fields (kV/m) at Maximum Operating Voltage
Where Parallel to Existing 115 kV Transmission Line (H-Frame Tower)

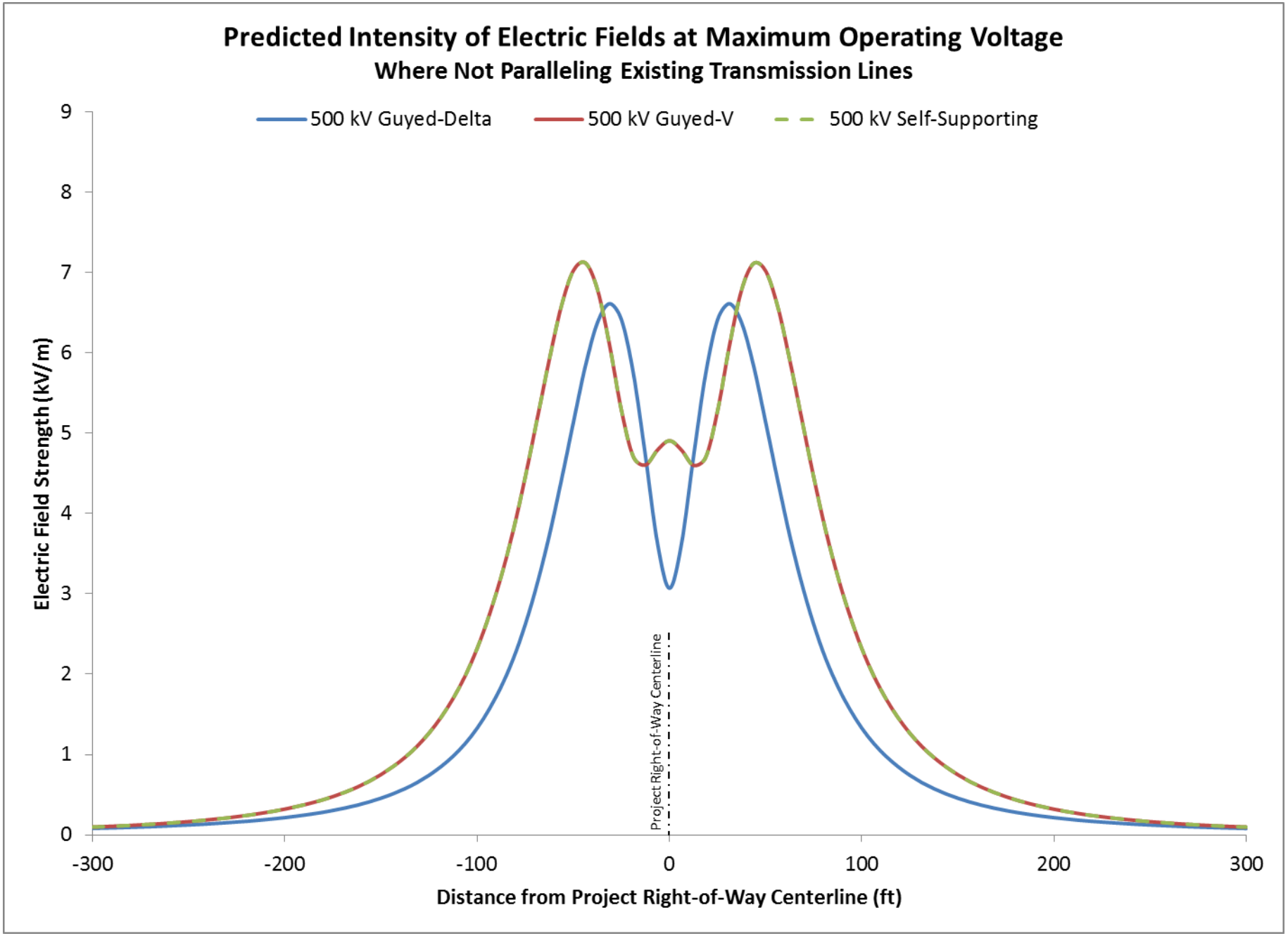
Structure Type	Line Voltage	Distance from Project ROW Centerline										
		-300	-200	-100	-50	-25	0	25	50	100	200	300
Project: 500 kV Guyed-Delta Existing: 115 kV H-Frame	550 kV 127 kV	0.079	0.214	1.329	5.136	6.413	3.073	6.421	5.152	1.388	0.359	0.029
Project: 500 kV Guyed-V Existing: 115 kV H-Frame	550 kV 127 kV	0.096	0.320	2.321	7.021	5.277	4.906	5.287	7.036	2.375	0.369	0.055
Project: 500 kV Self-Supporting Existing: 115 kV H-Frame	550 kV 127 kV	0.096	0.320	2.321	7.021	5.277	4.906	5.287	7.036	2.375	0.369	0.055

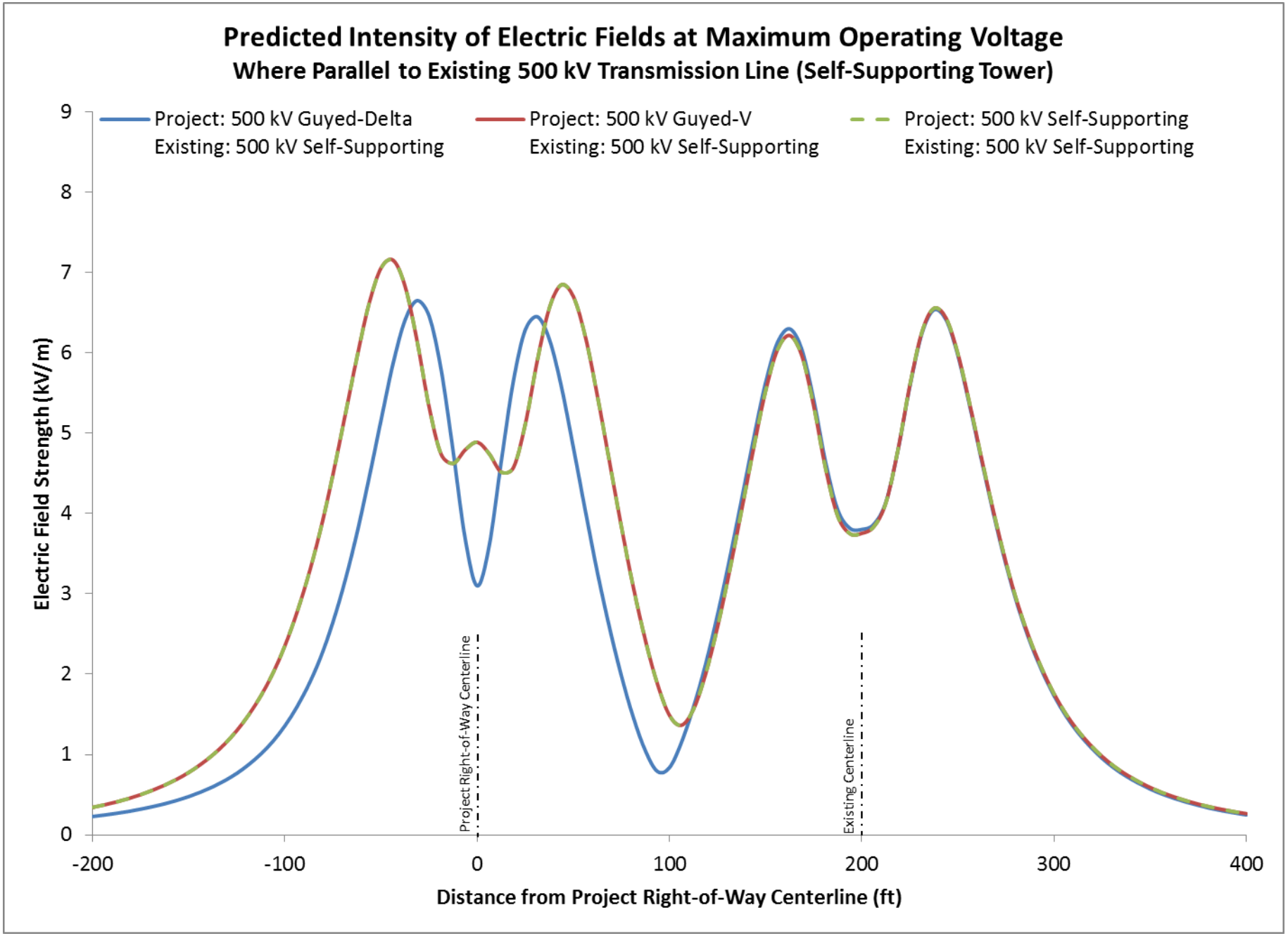
Predicted Intensity of Electric Fields (kV/m) at Maximum Operating Voltage
Where Parallel to Two Existing 115 kV Transmission Lines (H-Frame Towers)

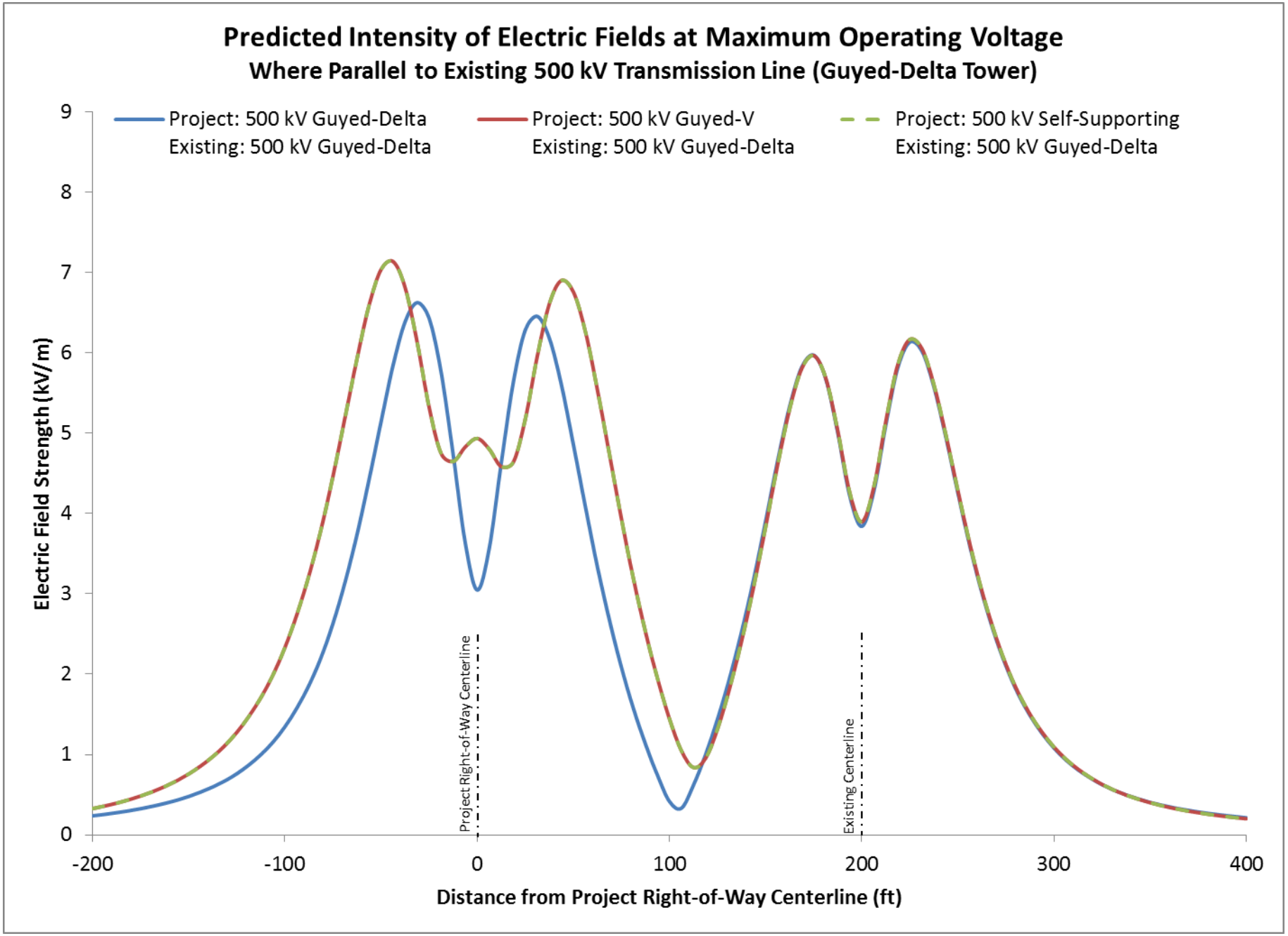
Structure Type	Line Voltage	Distance from Project ROW Centerline										
		-300	-200	-100	-50	-25	0	25	50	100	200	300
Project: 500 kV Guyed-Delta	550 kV											
Existing: 115 kV H-Frame	127 kV	0.079	0.214	1.330	5.137	6.414	3.076	6.432	5.184	1.652	0.846	0.062
Existing: 115 kV H-Frame	127 kV											
Project: 500 kV Guyed-V	550 kV											
Existing: 115 kV H-Frame	127 kV	0.097	0.321	2.322	7.022	5.278	4.906	5.290	7.052	2.582	0.873	0.075
Existing: 115 kV H-Frame	127 kV											
Project: 500 kV Self-Supporting	550 kV											
Existing: 115 kV H-Frame	127 kV	0.097	0.321	2.322	7.022	5.278	4.906	5.290	7.052	2.582	0.873	0.075
Existing: 115 kV H-Frame	127 kV											

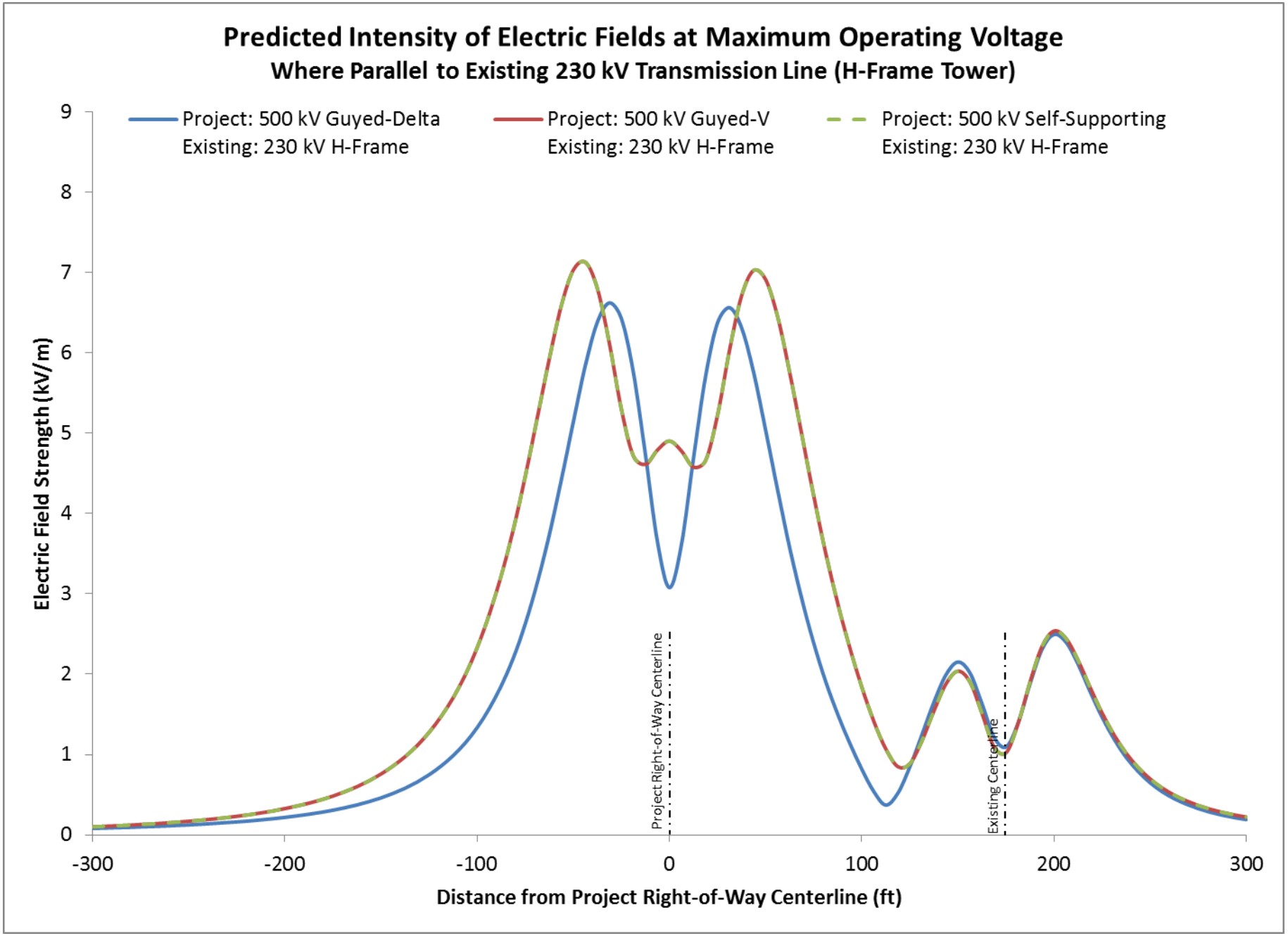
Predicted Intensity of Electric Fields (kV/m) at Maximum Operating Voltage
Where Parallel to Existing 115 kV & 230 kV Transmission Lines (H-Frame Towers)

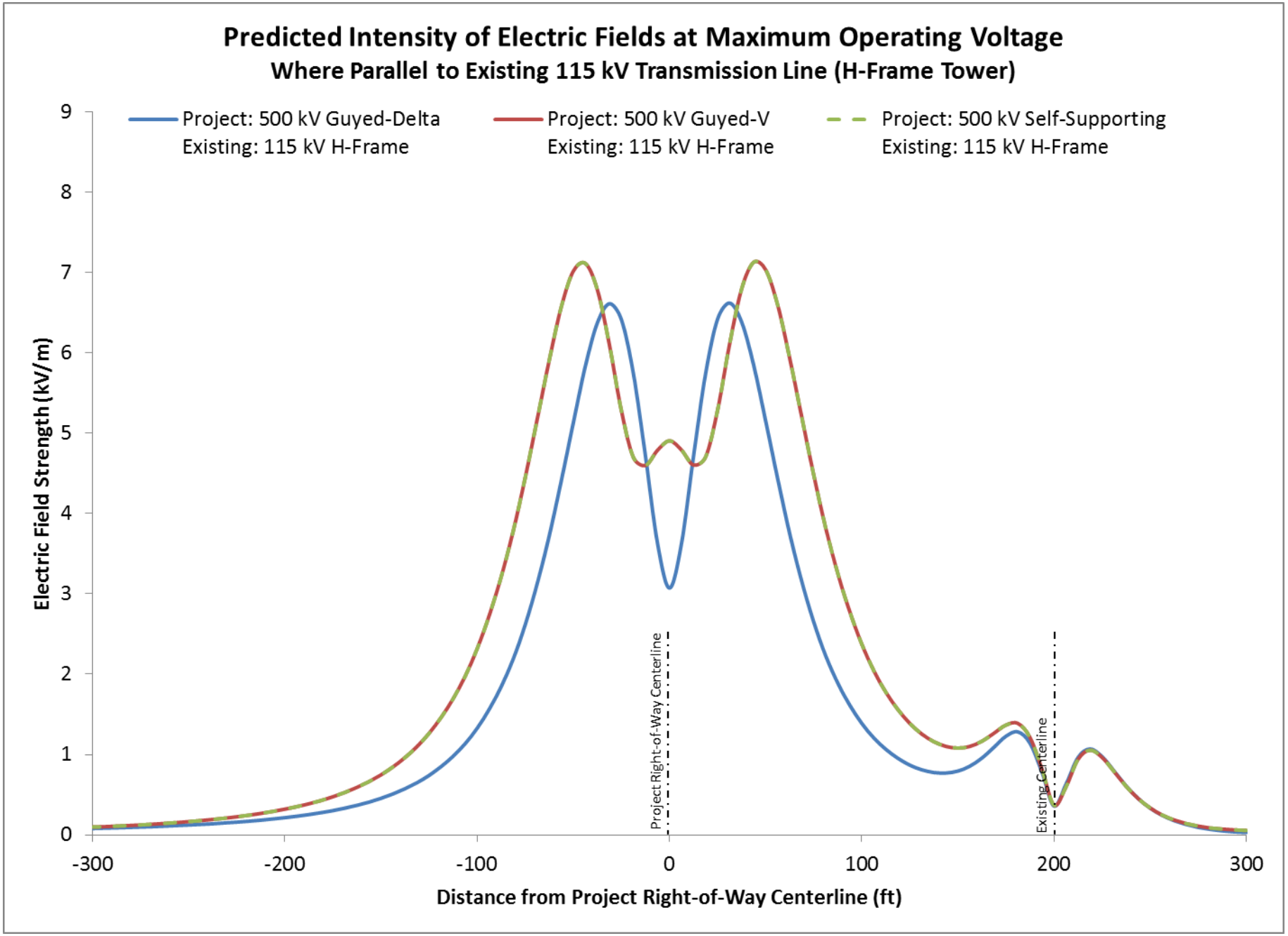
Structure Type	Line Voltage	Distance from Project ROW Centerline										
		-300	-200	-100	-50	-25	0	25	50	100	200	300
Project: 500 kV Guyed-Delta	550 kV											
Existing: 115 kV H-Frame	127 kV	0.080	0.217	1.338	5.147	6.427	3.080	6.375	5.032	0.812	0.292	0.422
Existing: 230 kV H-Frame	253 kV											
Project: 500 kV Guyed-V	550 kV											
Existing: 115 kV H-Frame	127 kV	0.100	0.327	2.332	7.032	5.291	4.904	5.230	6.907	1.785	0.278	0.447
Existing: 230 kV H-Frame	253 kV											
Project: 500 kV Self-Supporting	550 kV											
Existing: 115 kV H-Frame	127 kV	0.100	0.327	2.332	7.032	5.291	4.904	5.230	6.907	1.785	0.278	0.447
Existing: 230 kV H-Frame	253 kV											

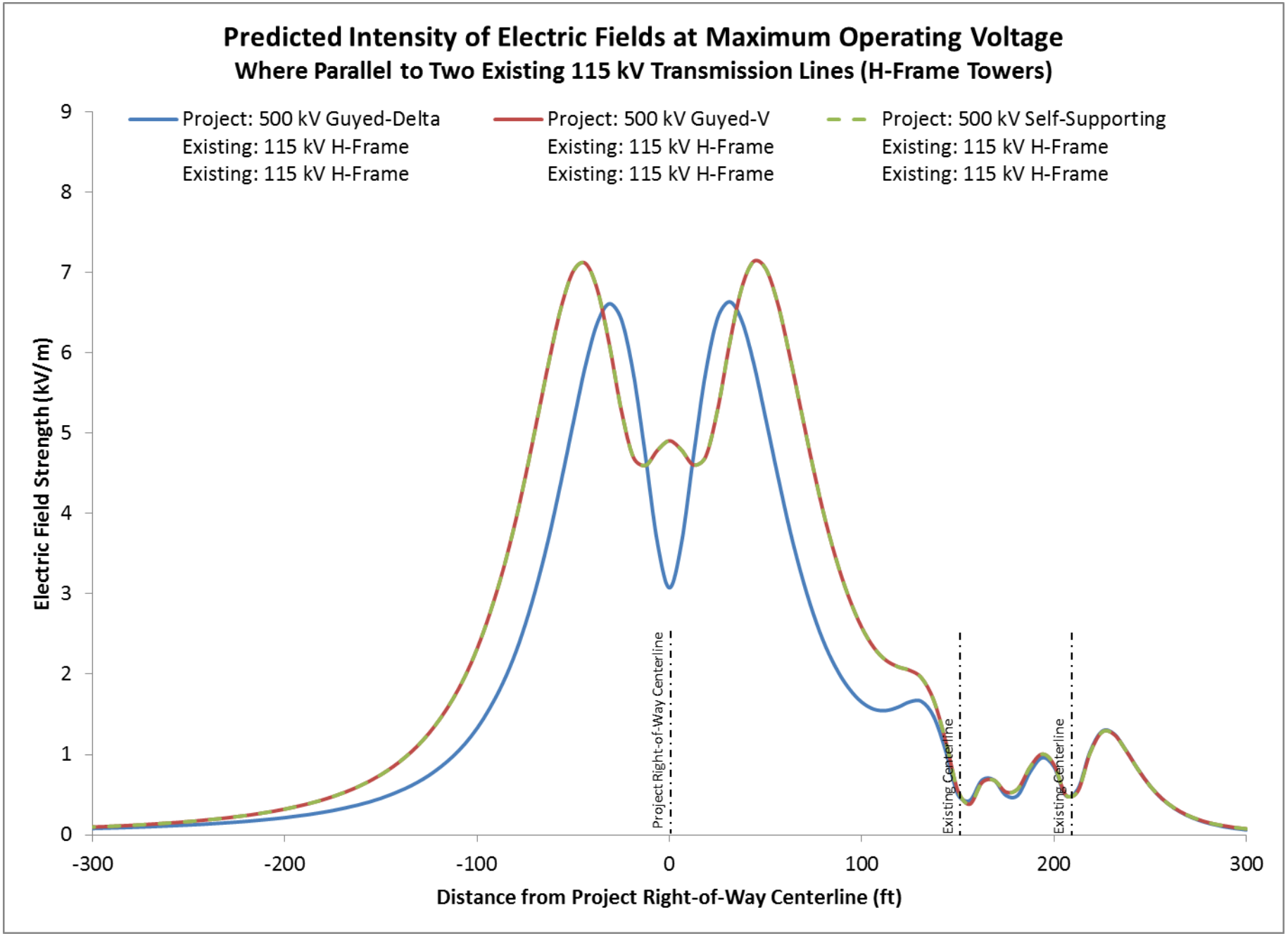

Predicted Intensity of Electric Fields at Maximum Operating Voltage
Where Not Paralleling Existing Transmission Lines
500 kV Guyed-Delta
500 kV Guyed-V
500 kV Self-Supporting
Electric Field Strength (kV/m)
9
8
7
6
5
4
3
2
1
0
-300
-200
-100
0
100
200
300
Project Right-of-Way Centerline
Distance from Project Right-of-Way Centerline (ft)

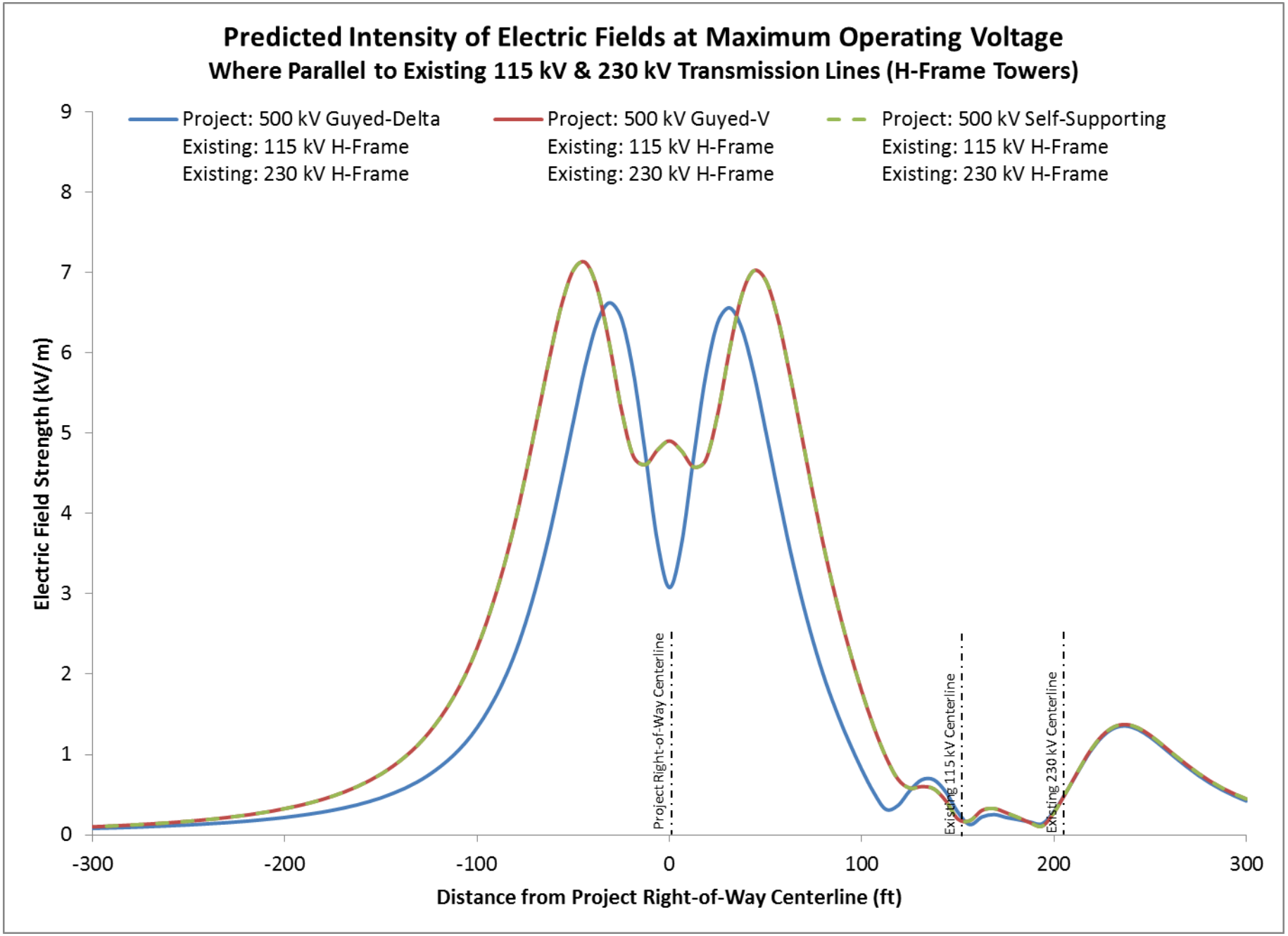

Predicted Intensity of Electric Fields at Maximum Operating Voltage
Where Parallel to Existing 500 kV Transmission Line (Self-Supporting Tower)
Project: 500 kV Guyed-Delta
Existing: 500 kV Self-Supporting
Project: 500 kV Guyed-V
Existing: 500 kV Self-Supporting
Project: 500 kV Self-Supporting
Existing: 500 kV Self-Supporting
Electric Field Strength (kV/m)
0
1
2
3
4
5
6
7
8
9
-200
-100
0
100
200
300
400
Project Right-of-Way Centerline
Existing Centerline
Distance from Project Right-of-Way Centerline (ft)


Predicted Intensity of Electric Fields at Maximum Operating Voltage
Where Parallel to Existing 500 kV Transmission Line (Guyed-Delta Tower)
Project: 500 kV Guyed-Delta
Existing: 500 kV Guyed-Delta
Project: 500 kV Guyed-V
Existing: 500 kV Guyed-Delta
Project: 500 kV Self-Supporting
Existing: 500 kV Guyed-Delta
Electric Field Strength (kV/m)
0
1
2
3
4
5
6
7
8
9
-200
-100
0
100
200
300
400
Project Right-of-Way Centerline
Existing Centerline
Distance from Project Right-of-Way Centerline (ft)


Predicted Intensity of Electric Fields at Maximum Operating Voltage
Where Parallel to Existing 230 kV Transmission Line (H-Frame Tower)
Project: 500 kV Guyed-Delta
Existing: 230 kV H-Frame
Project: 500 kV Guyed-V
Existing: 230 kV H-Frame
Project: 500 kV Self-Supporting
Existing: 230 kV H-Frame
Electric Field Strength (kV/m)
0
1
2
3
4
5
6
7
8
9
-300
-200
-100
0
100
200
300
Distance from Project Right-of-Way Centerline (ft)
Project Right-of-Way Centerline
Existing Centerline


Predicted Intensity of Electric Fields at Maximum Operating Voltage
Where Parallel to Existing 115 kV Transmission Line (H-Frame Tower)
Project: 500 kV Guyed-Delta
Existing: 115 kV H-Frame
Project: 500 kV Guyed-V
Existing: 115 kV H-Frame
Project: 500 kV Self-Supporting
Existing: 115 kV H-Frame
Electric Field Strength (kV/m)
0
1
2
3
4
5
6
7
8
9
-300
-200
-100
0
100
200
300
Distance from Project Right-of-Way Centerline (ft)
Project Right-of-Way Centerline
Existing Centerline


Predicted Intensity of Electric Fields at Maximum Operating Voltage
Where Parallel to Two Existing 115 kV Transmission Lines (H-Frame Towers)
Project: 500 kV Guyed-Delta
Existing: 115 kV H-Frame
Existing: 115 kV H-Frame
Project: 500 kV Guyed-V
Existing: 115 kV H-Frame
Existing: 115 kV H-Frame
Project: 500 kV Self-Supporting
Existing: 115 kV H-Frame
Existing: 115 kV H-Frame
Electric Field Strength (kV/m)
0
1
2
3
4
5
6
7
8
9
-300
-200
-100
0
100
200
300
Distance from Project Right-of-Way Centerline (ft)
Project Right-of-Way Centerline
Existing Centerline
Existing Centerline


Predicted Intensity of Electric Fields at Maximum Operating Voltage
Where Parallel to Existing 115 kV & 230 kV Transmission Lines (H-Frame Towers)
Project: 500 kV Guyed-Delta
Existing: 115 kV H-Frame
Existing: 230 kV H-Frame
Project: 500 kV Guyed-V
Existing: 115 kV H-Frame
Existing: 230 kV H-Frame
Project: 500 kV Self-Supporting
Existing: 115 kV H-Frame
Existing: 230 kV H-Frame
Electric Field Strength (kV/m)
0
1
2
3
4
5
6
7
8
9
-300
-200
-100
0
100
200
300
Distance from Project Right-of-Way Centerline (ft)
Project Right-of-Way Centerline
Existing 115 kV Centerline
Existing 230 kV Centerline

POWER ENGINEERS, INC.

9320 SW BARBUR BOULEVARD
SUITE 200
PORTLAND, OR 97219 USA

PHONE 503-892-6700
FAX 503-892-6799

MEMORANDUM

DATE: August 8, 2013

TO: Larry Henriksen

C: Kurt Bell

FROM: Josh Brown

SUBJECT: 127300 Great Northern Transmission Line Project – EMF and Corona Effects Calculations

MESSAGE

Larry,

Two transmission line configurations for the Great Northern Transmission Line Project (GNTL) were analyzed to determine electric and magnetic field (EMF) and corona effects from the transmission lines. The first set of cases is for a double circuit 345 kV transmission line which was investigated for both single and double circuit operation. The second set of cases is for a single circuit 500 kV transmission line. Included with this memo are Excel files (Field_Plots_345kV_C1-12_08_6_2013.xlsm, Field_Plots_500kV_C1-8_08_6_2013.xlsm) for the 345 kV and 500 kV transmission lines respectively. All values were calculated using BPA's Corona and Field Effects Program (CAFEP), Version 3.0.

DATA INPUT

EMF and corona effects from transmission lines are primarily dependent on the following parameters: conductor geometry, subconductor size/bundling, line phasing (double circuit configuration) current, voltage, and the elevation of the line. Attachments 1 - 4 show the structures analyzed for both the 345 kV and 500 kV transmission lines and includes the span lengths used, conductor types, and phasing (345 kV transmission line only). The 345 kV transmission line cases were analyzed with a maximum operating voltage, 105% of nominal (results in a maximum voltage of 362 kV). The 500 kV transmission line cases were analyzed with a maximum operating voltage, 110% of nominal (results in a maximum voltage of 550 kV). The following environmental factors were used for the investigation:

- Line elevation of 1,200 feet
- Ambient temperature of 30° C
- Latitude of 47°North

Conductor temperatures and sags were calculated based on the currents in Tables 1 and 2 and the span lengths, and environmental factors described above. The temperatures for the conductor sag were calculated using Southwire's SWRate software (Version 3.02). The 345 kV and 500 kV line conductor sags can be found in Attachments 5 and 6 and were calculated using Southwire's SAG10 software (Version 3.10.10).

Tables 1 and 2 identify the data inputs (345 kV and 500 kV configurations respectively) used to calculate the field and corona effects for each case in the included Excel files. The

345 kV analysis was performed using a minimum ground clearance of 30 feet. The 30 foot ground clearance resulted in minimum conductor attachment heights of 69.2 feet and 58.6 feet for the X-7 and X-8 structures respectively. To achieve the guideline of a maximum electric field strength less than 8 kV/m at one meter above the ground surface (required by the State of Minnesota), the attachment points of the 500 kV structures were adjusted by raising the structures approximately two feet. This results in a ground clearance of approximately 40 feet which was needed to achieve the electric field guideline. As a result of the increase in structure heights of approximately two feet, the minimum attachment height increases to 99.5 feet for the 500 kV structures.

Table 1: 345 kV Cases Analyzed

CURRENT	CONDUCTOR TEMP	LINES ENERGIZED	STRUCTURE TYPE	
			X-7	X-8
2,338 A	100° C	1	Case 1	Case 7
2,338 A	100° C	2	Case 2	Case 8
2,040 A	83.8° C	1	Case 3	Case 9
2,040 A	83.8° C	2	Case 4	Case 10
585 A	42.6° C	1	Case 5	Case 11
585 A	42.6° C	2	Case 6	Case 12

Table 2: 500 kV Cases Analyzed

CURRENT	CONDUCTOR TEMP	STRUCTURE TYPE	
		X-2	X-6
3,168 A	75° C	Case 1	Case 5
2,000 A	53.1° C	Case 2	Case 6
1,024 A	43.1° C	Case 3	Case 7
1,506 A	47.2° C	Case 4	Case 8

RESULTS

Results in the Excel files include the following for each case:

- **Magnetic Field** – The reported magnetic field values are the magnetic flux densities at a given point in space reported in units of milligauss. This calculation assumes balanced currents, calculations are performed at the minimum conductor height (mid-span), and is calculated one meter (3.28 feet) above the surface of the earth per IEEE Standard 644-1994 (R2008), IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields From AC Power Lines.
- **Electric Field**- The electric field strength is a measure of the force per unit charge at a given point in space relative to a charged object. It is typically measured in kilovolts per meter (kV/m). Values are calculated at the minimum conductor height (mid-span) at a height of one meter above the ground per IEEE Standard 644-1994 (R2008).
- **Audible Noise (Rain L50)** – Audible noise is measured as an equivalent A-weighted sound-pressure level in decibels (dBA). The L_{50} Audible Noise (Foul Weather) values represent a predicted average (L_{50}) noise levels present when foul weather conditions cause the conductors to become wet. The actual value is expected to be at or below this calculated L_{50} value 50% of the time, and above the

value the other 50% of the time. Values are calculated at a height of five feet above the ground per IEEE Standard 656-1992 (IEEE Standard for the Measurement of Audible Noise From Overhead Transmission Lines).

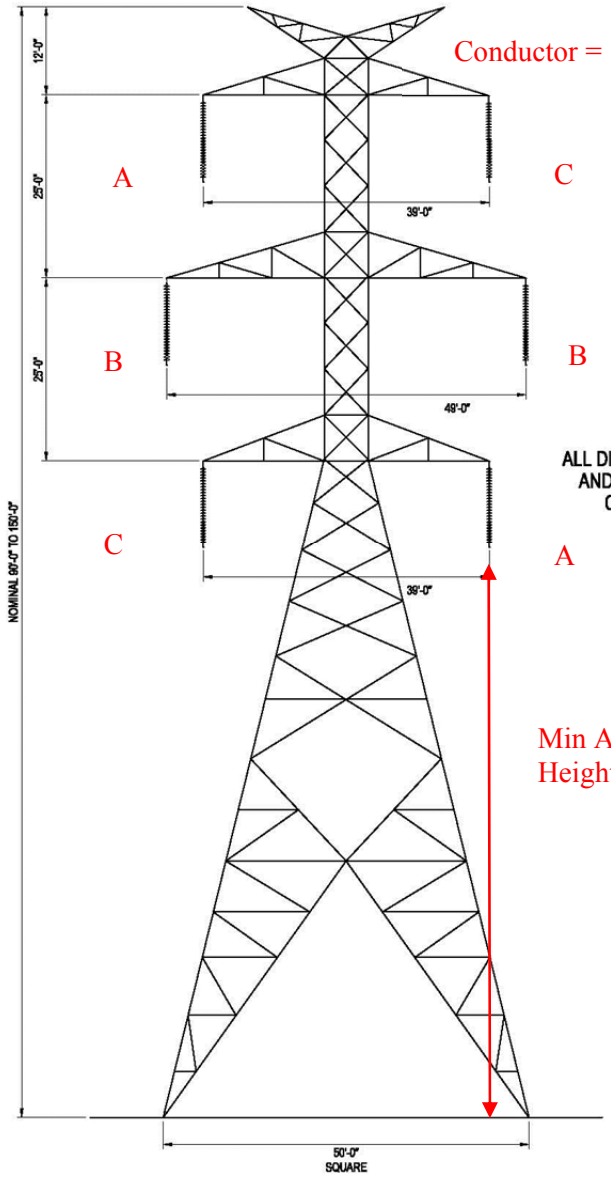
- **Audible Noise (Rain L5)** –The L_5 Audible Noise (Foul Weather) values represent a predicted average (L_5) noise levels present when foul weather conditions cause the conductors to become wet. The actual value is expected to be at or below this calculated L_5 value 95% of the time, and above the value the other 5% of the time.
- **Radio Interference**-Radio interference is the degradation of a radio signal by radio frequency electromagnetic disturbances and is reported as the field strength of the interference. It is often measured in decibels (dB) of one microvolt per meter (μV/m), which is a logarithmic scale. The L_{50} Radio Interference (Fair Weather) values represent the predicted average levels present when conductors are dry. The actual value of radio interference is expected to be at or below this calculated L_{50} value 50% of the time, and above the value the other 50% of the time. Values are calculated at a height of six feet above the ground and at 1 MHz, using the average conductor height to approximate the average values along the entire line. IEEE Standard 430-1986 (IEEE Standard Procedures for the Measurement of Radio Noise from Overhead Power Lines and Substations) suggests that these measurements should be taken no greater than two meters above the surface.
- **Television Interference** - Television interference (TVI) is the degradation of a television signal by television frequency electromagnetic disturbances and is reported as the field strength of the interference. It is often measured in decibels (dB) of one microvolt per meter (μV/m) which is a logarithmic scale. The values are reported for wet conductor conditions, as TVI is negligible during fair weather. Values are calculated at a height of ten meters above the ground per IEEE Standard 430-1986 and FCC measurement guidelines, using the average conductor height to approximate the average values along the entire line. Television signals cover multiple bands and a large range of frequencies. These calculations are made in a dead band (75 MHz) in the lower VHF band (54-88 MHz), and interference effects will decrease moving into the upper VHF (174-216 MHz) and the UHF (470-698 MHz) bands.

If you have you any questions about the analysis performed please give me a call at 503 892-6714.

REV	REVISIONS	DATE	DRN	DSGN	CKD	APPD
D	UPDATED INSULATOR	11/02/12	CM	RB	GK	
C	ISSUED FOR REVIEW	9/20/12	GC	RB	GK	
B	NOTES UPDATED	9/18/12	GC	RB		
A	PRELIMINARY OUTLINE					

Span Length = 1,100 ft

Conductor = Two 954 kcmil Cardinal ACSR, 18 inch bundle spacing



ALL DIMENSIONS ARE APPROXIMATE AND PRELIMINARY. SUBJECT TO CHANGE IN FINAL DESIGN.

Min Attachment Height 69.2 ft

NOTES

1. AVERAGE SPAN: 1,100 FT
   WIND SPAN: 1,250 FT
   WEIGHT SPAN: 1,700 FT

DSGN	RB	9/14/12	
DRN	GC	9/17/12	
CKD			
SCALE:	N.T.S.		

FOR 8.5x11 DWG ONLY

REFERENCE DRAWINGS

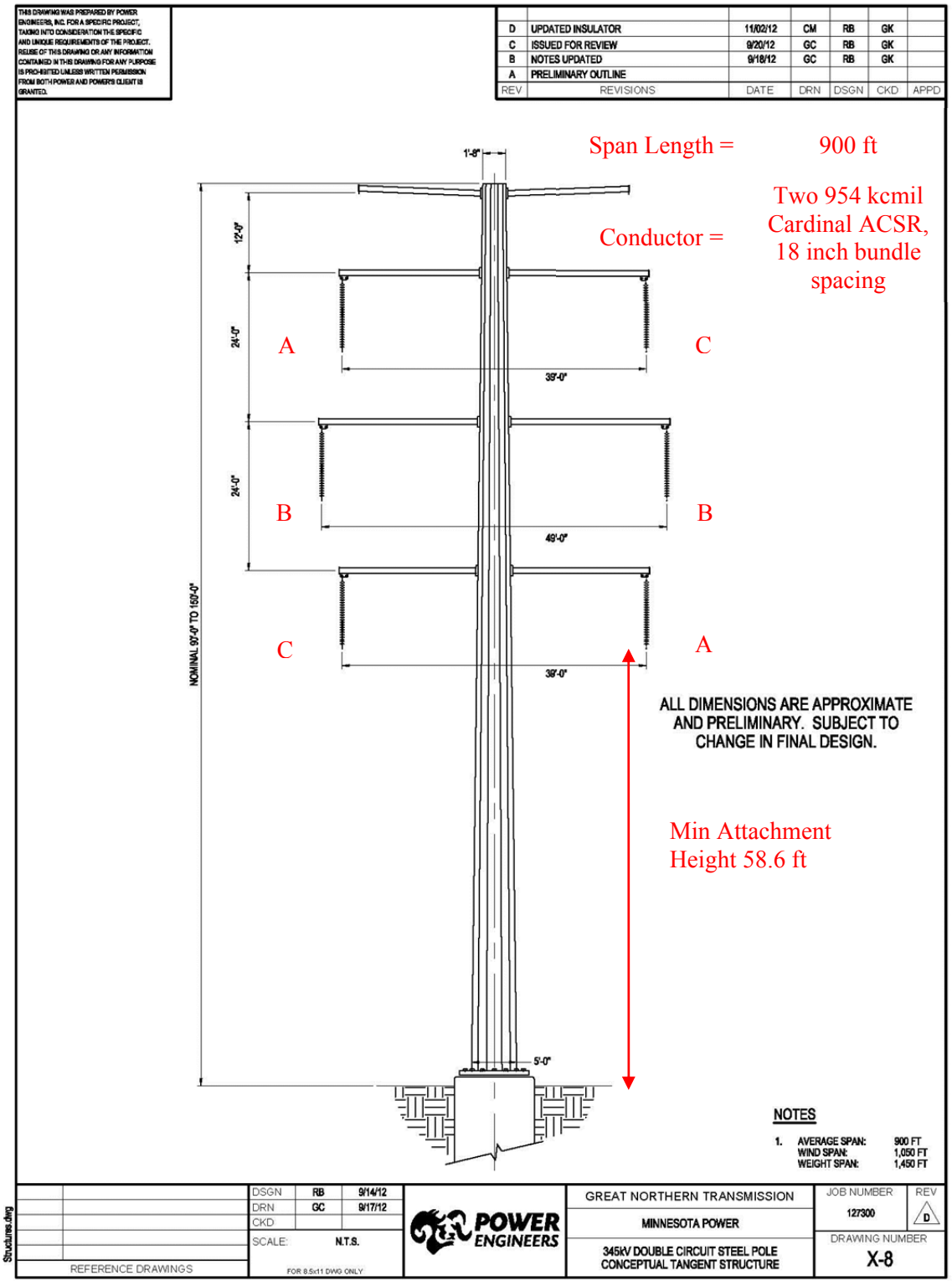
POWER ENGINEERS

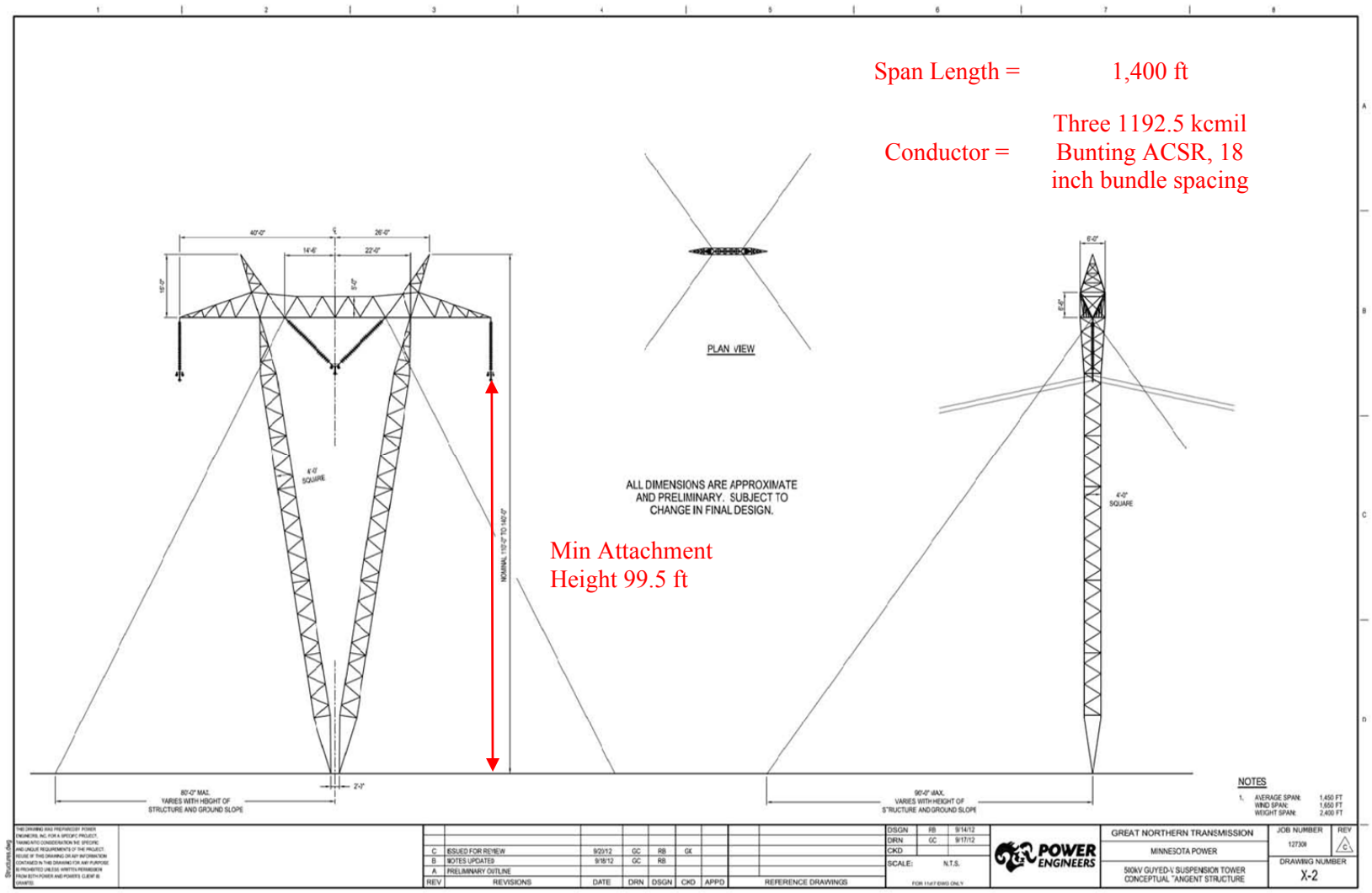
GREAT NORTHERN TRANSMISSION
MINNESOTA POWER
345kV DOUBLE CIRCUIT LATTICE TOWER
CONCEPTUAL TANGENT STRUCTURE

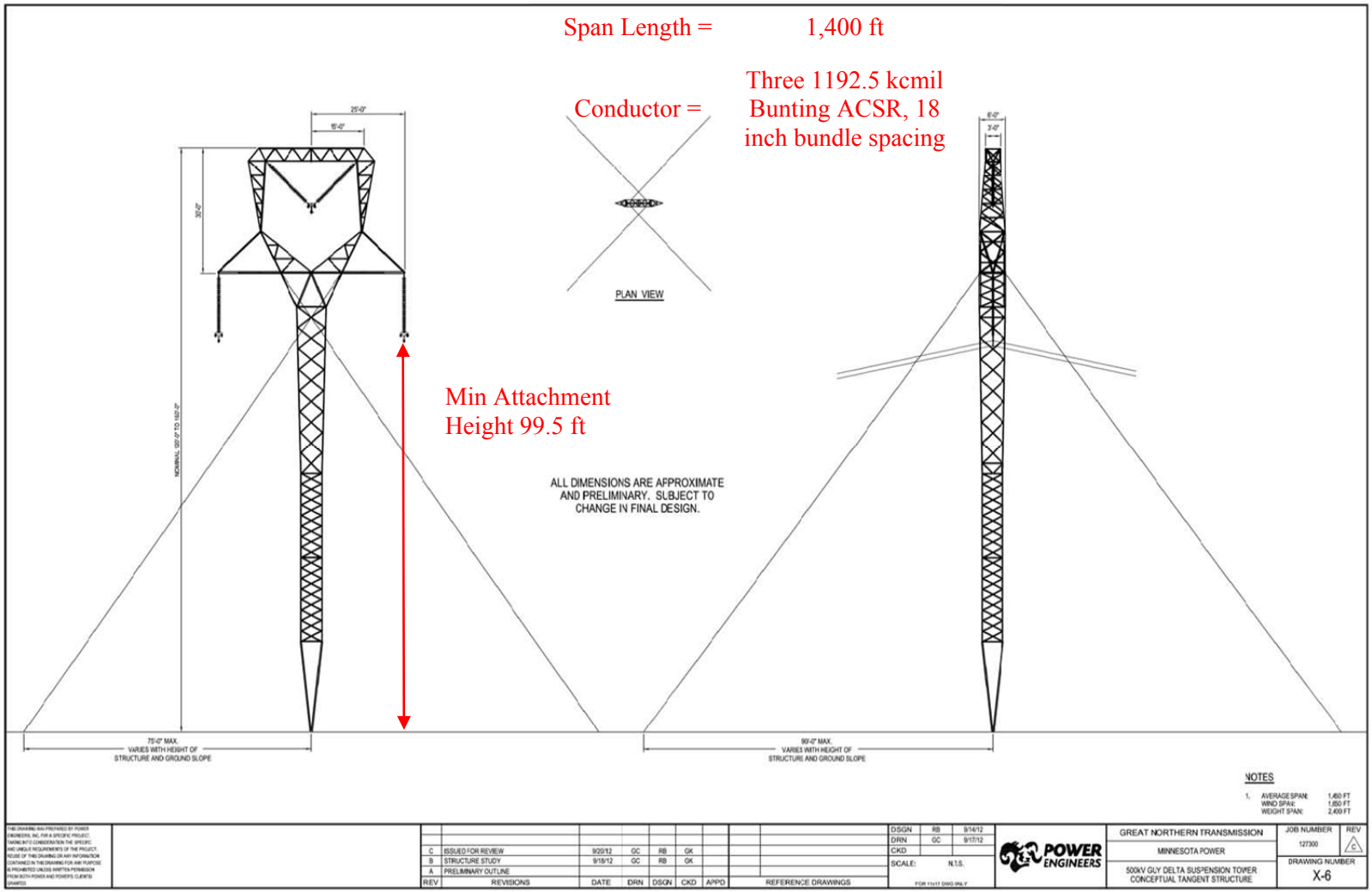
JOB NUMBER 127300 REV D

DRAWING NUMBER X-7

Structures.dwg


THIS DRAWING WAS PREPARED BY POWER ENGINEERS, INC. FOR A SPECIFIC PROJECT, TAKING INTO CONSIDERATION THE SPECIFIC AND UNIQUE REQUIREMENTS OF THE PROJECT. REUSE OF THIS DRAWING OR ANY INFORMATION CONTAINED IN THIS DRAWING FOR ANY PURPOSE IS PROHIBITED UNLESS WRITTEN PERMISSION FROM BOTH POWER AND POWER'S CLIENT IS GRANTED.
D UPDATED INSULATOR 11/02/12 CM RB GK
C ISSUED FOR REVIEW 9/20/12 GC RB GK
B NOTES UPDATED 9/18/12 GC RB GK
A PRELIMINARY OUTLINE
REV REVISIONS DATE DRN DSGN CKD APPD
Span Length = 900 ft
Two 954 kcmil Cardinal ACSR, 18 inch bundle spacing
Conductor =
1'-8"
12'-0"
24'-0"
24'-0"
NOMINAL 90'-0" TO 160'-0"
A
C
B
B
C
A
39'-0"
49'-0"
39'-0"
5'-0"
ALL DIMENSIONS ARE APPROXIMATE AND PRELIMINARY. SUBJECT TO CHANGE IN FINAL DESIGN.
Min Attachment Height 58.6 ft
NOTES
1. AVERAGE SPAN: 900 FT
WIND SPAN: 1,050 FT
WEIGHT SPAN: 1,450 FT
Structures.dwg
REFERENCE DRAWINGS
DSGN RB 9/14/12
DRN GC 9/17/12
CKD
SCALE: N.T.S.
FOR 8.5x11 DWG ONLY
POWER ENGINEERS
GREAT NORTHERN TRANSMISSION
MINNESOTA POWER
345kV DOUBLE CIRCUIT STEEL POLE CONCEPTUAL TANGENT STRUCTURE
JOB NUMBER 127300
REV D
DRAWING NUMBER X-8


Span Length = 1,400 ft
Conductor = Three 1192.5 kcmil Bunting ACSR, 18 inch bundle spacing
PLAN VIEW
ALL DIMENSIONS ARE APPROXIMATE AND PRELIMINARY. SUBJECT TO CHANGE IN FINAL DESIGN.
Min Attachment Height 99.5 ft
NOTES
GREAT NORTHERN TRANSMISSION
MINNESOTA POWER
500kV GUYED-V SUSPENSION TOWER CONCEPTUAL "ANGENT STRUCTURE
DRAWING NUMBER X-2


Span Length = 1,400 ft
Conductor = Three 1192.5 kcmil Bunting ACSR, 18 inch bundle spacing
PLAN VIEW
Min Attachment Height 99.5 ft
ALL DIMENSIONS ARE APPROXIMATE AND PRELIMINARY. SUBJECT TO CHANGE IN FINAL DESIGN.
75'-0" MAX. VARIES WITH HEIGHT OF STRUCTURE AND GROUND SLOPE
90'-0" MAX. VARIES WITH HEIGHT OF STRUCTURE AND GROUND SLOPE
NOTES
1. AVERAGE SPAN: 1,400 FT
WIND SPAN: 1,650 FT
WEIGHT SPAN: 2,400 FT
C ISSUED FOR REVIEW 9/20/12 GC RB GK
B STRUCTURE STUDY 9/18/12 GC RB GK
A PRELIMINARY OUTLINE
REV REVISIONS DATE DRN DSGN CKD APPD
REFERENCE DRAWINGS
DSGN RB 9/14/12
DRN GC 9/17/12
CKD
SCALE: N.T.S.
POWER ENGINEERS
GREAT NORTHERN TRANSMISSION
MINNESOTA POWER
500kV GUY DELTA SUSPENSION TOWER CONCEPTUAL TANGENT STRUCTURE
JOB NUMBER 127300
REV C
DRAWING NUMBER X-6

3.10.10v

Southwire SAG10™

345 kV

7/31/2013

Power Engineers Inc

Minnesota Power
Great Northern Transmission Line
Approximate Sag Calculations

Conductor: 954.0 Kcmil 54/ 7 Stranding ACSR "CARDINAL"

Area = 0.8462 Sq. in Diameter = 1.196 in Weight = 1.229 lb/ft RTS = 33800 lb
Data from Sheet No. 1-SAG
English Units
Limits and Outputs in Average Tensions.

X-7

Span = 1100.0 Feet Special Load Zone
Creep is NOT a Factor Rolled Rod

Design Points Temp °F	Ice in	Wind psf	X lb/ft	Weight lb/ft	Final Sag ft	Final Tension lb	Initial Sag ft	Initial Tension lb
0.0	0.50	4.00	0.30	2.692	33.44	12247	30.01	13638
5.0	0.50	6.40	0.00	2.566	33.33	11627	29.63	13140
32.0	0.50	0.00	0.00	2.284	34.03	10128	28.56	11718
60.0	0.00	57.60	0.00	5.871	43.38	20587	43.38	20587
60.0	0.00	20.70	0.00	2.401	35.95	10148	31.44	11592
60.0	0.00	6.00	0.00	1.367	32.81	6323	26.31	7876
-20.0	0.00	0.00	0.00	1.229	26.87	6935	20.54	9061
0.0	0.00	0.00	0.00	1.229	28.28	6580	21.74	8564
30.0	0.00	0.00	0.00	1.229	30.34	6145*	23.59	7894
60.0	0.00	0.00	0.00	1.229	32.33	5769	25.48	7310
90.0	0.00	0.00	0.00	1.229	34.25	5445	27.32	6805
95.0	0.00	0.00	0.00	1.229	34.57	5398	27.70	6728
97.0	0.00	0.00	0.00	1.229	34.69	5380	27.82	6698
100.0	0.00	0.00	0.00	1.229	34.88	5351	28.01	6653
100.9	0.00	0.00	0.00	1.229	34.93	5342	28.07	6639
103.0	0.00	0.00	0.00	1.229	35.06	5323	28.20	6608
105.0	0.00	0.00	0.00	1.229	35.19	5304	28.33	6579
108.3	0.00	0.00	0.00	1.229	35.38	5274	28.54	6532
108.7	0.00	0.00	0.00	1.229	35.42	5270	28.56	6526
119.9	0.00	0.00	0.00	1.229	36.10	5171	29.26	6378
120.0	0.00	0.00	0.00	1.229	36.11	5170	29.27	6369
129.7	0.00	0.00	0.00	1.229	36.69	5089	29.87	6241
167.0	0.00	0.00	0.00	1.229	37.84	4936	32.17	5798
182.8	0.00	0.00	0.00	1.229	38.31	4876	33.12	5632
212.0	0.00	0.00	0.00	1.229	39.17	4769	34.86	5354
284.0	0.00	0.00	0.00	1.229	40.89	4593	37.84	4936

42.6° C
83.8° C
100° C

* Design Condition

X-8

Span = 900.0 Feet Special Load Zone
Creep is NOT a Factor Rolled Rod

Design Points Temp °F	Ice in	Wind psf	X lb/ft	Weight lb/ft	Final Sag ft	Final Tension lb	Initial Sag ft	Initial Tension lb
0.0	0.50	4.00	0.30	2.692	23.03	11881	20.83	13143
5.0	0.50	6.40	0.00	2.566	22.95	11353	20.53	12624
32.0	0.50	0.00	0.00	2.284	23.60	9825	20.53	11287
60.0	0.00	57.60	0.00	5.871	31.51	12959	31.51	12959
60.0	0.00	20.70	0.00	2.401	25.32	9635	22.14	11011
60.0	0.00	6.00	0.00	1.367	22.57	6147	17.25	7766
-20.0	0.00	0.00	0.00	1.229	17.08	7280	13.04	9531
0.0	0.00	0.00	0.00	1.229	18.29	6779	13.92	8907
30.0	0.00	0.00	0.00	1.229	20.29	6145*	15.51	8032
60.0	0.00	0.00	0.00	1.229	22.14	5634	17.14	7272
90.0	0.00	0.00	0.00	1.229	23.92	5217	18.81	6626
95.0	0.00	0.00	0.00	1.229	24.21	5155	19.09	6529
97.0	0.00	0.00	0.00	1.229	24.32	5131	19.21	6498
100.0	0.00	0.00	0.00	1.229	24.49	5095	19.38	6454
100.9	0.00	0.00	0.00	1.229	24.55	5085	19.43	6417
103.0	0.00	0.00	0.00	1.229	24.67	5060	19.55	6378
105.0	0.00	0.00	0.00	1.229	24.78	5037	19.66	6342
108.3	0.00	0.00	0.00	1.229	24.97	4999	19.84	6283
108.7	0.00	0.00	0.00	1.229	24.99	4995	19.87	6276
119.9	0.00	0.00	0.00	1.229	25.62	4873	20.50	6081
120.0	0.00	0.00	0.00	1.229	25.63	4872	20.50	6081
129.7	0.00	0.00	0.00	1.229	26.16	4772	21.05	5925
162.8	0.00	0.00	0.00	1.229	27.78	4562	22.12	5586
182.8	0.00	0.00	0.00	1.229	27.80	4484	23.98	5203
212.0	0.00	0.00	0.00	1.229	28.56	4374	25.54	4827
284.0	0.00	0.00	0.00	1.229	29.92	4178	28.22	4827

42.6° C
83.8° C
100° C

* Design Condition

3.10.10v

Southwire SAG10™

500 kV

7/31/2013

Power Engineers Inc

Minnesota Power
Great Northern Transmission Line
Approximate Sag Calculations

Conductor: 1192.5 Kcmil 45/ 7 Stranding ACSR "BUNTING"

Area = 1.0010 Sq. in Diameter = 1.382 in Weight = 1.344 lb/ft RTS = 32000 lb
Data from Chart No. 1-857
English Units
Limits and Outputs in Average Tensions.

Span = 1400.0 Feet Special Load Zone
Creep is NOT a Factor Rolled Rod

Design Points					Final		Initial	
Temp °F	Ice in	Wind psf	K lb/ft	Weight lb/ft	Sag ft	Tension lb	Sag ft	Tension lb
0.0	0.50	4.00	0.38	2.881	52.08	13627	44.64	15877
5.0	0.50	6.40	0.00	2.753	52.05	13032	44.20	15323
32.0	0.50	0.00	0.00	2.464	53.06	11445	44.19	13718
60.0	0.00	57.60	0.00	6.392	64.04	24660	64.04	24660
60.0	0.00	28.70	0.00	2.617	55.42	11644	46.74	13720
60.0	0.00	6.00	0.00	1.693	52.05	7068	40.33	9102
-20.0	0.00	0.00	0.00	1.344	45.28	7315	32.87	10041
0.0	0.00	0.00	0.00	1.344	46.85	7060	34.48	8572
30.0	0.00	0.00	0.00	1.344	49.24	6720*	36.92	8944
60.0	0.00	0.00	0.00	1.344	51.56	6421	39.35	8395
90.0	0.00	0.00	0.00	1.344	53.80	6156	41.75	7914
97.0	0.00	0.00	0.00	1.344	54.32	6099	42.31	7811
100.0	0.00	0.00	0.00	1.344	54.54	6075	42.55	7768
100.9	0.00	0.00	0.00	1.344	54.60	6067	42.62	7755
105.3	0.00	0.00	0.00	1.344	55.14	6008	43.20	7651
109.6	0.00	0.00	0.00	1.344	55.72	5999	43.30	7632
117.8	0.00	0.00	0.00	1.344	55.76	5942	43.89	7533
119.9	0.00	0.00	0.00	1.344	55.97	5921	44.11	7494
120.8	0.00	0.00	0.00	1.344	55.98	5920	44.12	7493
127.6	0.00	0.00	0.00	1.344	56.52	5864	44.71	7395
129.7	0.00	0.00	0.00	1.344	56.67	5849	44.87	7368
167.8	0.00	0.00	0.00	1.344	59.26	5597	47.73	6932
212.0	0.00	0.00	0.00	1.344	61.94	5358	51.05	6434

* Design Condition

43.1° C
47.2° C
53.1° C
75° C

Certain information such as the data, opinions or recommendations set forth herein or given by Southwire representatives, is intended as a general guide only. Each installation of overhead electrical conductor, underground electrical conductor, and/or conductor accessories involves special conditions creating problems that require individual solutions and, therefore, the recipient of this information has the sole responsibility in connection with the use of the information. Southwire does not assume any liability in connection with such information.

MEMORANDUM

DATE: March 19, 2014

TO: Larry Henriksen (POWER-HLY)

C: Josh Brown (POWER-PRT)
DMS SR-06/127300.18.01

FROM: Claire Patti (POWER-PRT)

SUBJECT: 127300 Great Northern Transmission Line Project – Magnetic Field Data

MESSAGE

Larry,

Per your request, we have extended the area of analysis for four cases presented in the August 6, 2013 memo (log # 112-1434) for the purpose of determining the distance at which the magnetic field drops below 2mG. In order to maintain the same resolution as the previous results, it was necessary to shift the area of analysis away from the transmission line. The area of analysis begins at the edge of the right-of-way (100 ft from centerline) and extends 700 ft from the centerline of the structure. The data is summarized in the table below and the Excel file included with this memo contains the full results. All values were calculated using BPA's Corona and Field Effects Program (CAFEP), Version 3.0.

Table 1: Magnetic Field Below 2 mG

	STRUCTURE	CURRENT	DISTANCE*
Case 2	X-2	2,000 A	681.2 ft
Case 3	X-2	1,024 A	487.5 ft
Case 6	X-6	2,000 A	537.5 ft
Case 7	X-6	1,024 A	387.5 ft

* Distance from center line of structure.