Electric and Magnetic Field (EMF) Modeling Analysis for the Barnstable Reliability Project

Prepared for

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1 Introduction and Summary

NSTAR Electric Company d/b/a Eversource Energy (Eversource) has proposed to separate the existing overhead 115-kV Line 122 and Line 135 double circuit towers (DCTs) by moving the Line 135 conductors to a new set of support structures within an approximate 3.3-mile stretch of the existing right-of-way (ROW 343) between Shootflying Hill Road and Barnstable Switching Station #958 in Barnstable, Massachusetts. The new support structures will be located in close proximity to the existing DCT structures and will be located on the north side of ROW 343. The Project is known as the Barnstable Reliability Project. Appendix A provides an aerial overview map showing the Project route within existing Eversource ROW 343. This stretch of ROW 343 is currently occupied by two additional 115-kV overhead transmission lines (Line #115 for the entire Project route, and Line #131 for an approximate 0.7-mile segment of the route), as well as by two 23-kV overhead distribution lines (#80 and #84, both present for the entire Project route).

Eversource requested that Gradient perform an independent assessment of the electric and magnetic field (EMF) impacts associated with separating Lines 122 and 135 over approximately 3.3 miles in the Town of Barnstable. For this assessment, EMF impacts were modeled for two representative overhead line cross-sections (Cross-section #1 consisting of a 2.6-mile stretch of ROW 343 between Shootflying Hill Road and National Grid's Merchants Way Substation, and Cross-section #2 consisting of a 0.7-mile stretch of ROW 343 between National Grid's Merchants Way Substation and Eversource's Barnstable Switching Station #958) using projected non-emergency summer peak and normal average transmission line loadings provided by Eversource for the year 2021, which is the expected in-service date for the Project. The only difference between the two cross-sections is the additional presence of the 115-kV Line 131 within Cross-section #2. The 23-kV distribution lines present in the ROW were also included in the EMF modeling using non-emergency summer peak and normal median loadings provided by Eversource. EMF modeling was conducted both for the present-day circuit configuration (referred to as the "Without-Project" case) and for the after-Project circuit configuration (referred to as the "With-Project" case). Appendix B provides cross-section diagrams for both the "Without-Project" and "With-Project" cases.

As described in this report, modeled EMF values both within and at the edges of ROW 343 for each of the two overhead line cross-sections representative of the With-Project circuit configurations and the two sets of load conditions were all well below the health-based guidelines issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for continuous public exposure to EMF (4.2 kilovolts per meter [kV/m] and 2,000 milligauss [mG]; ICNIRP, 2010). Table 1.1, which summarizes the modeled Without-Project and With-Project edge-of-ROW magnetic field results for the two representative overhead line cross-sections (Cross-section #1 – Shootflying Hill Road to National Grid's Merchants Way Substation, and Cross-section #2 – National Grid's Merchants Way Substation to Eversource's Barnstable Switching Station #958) evaluated in the EMF assessment at the two system loads, shows that all modeled edge-of-ROW magnetic field values are very small compared to the ICNIRP health-based guideline of 2,000 mG. As shown in Table 1.1, the Project will result in reduced magnetic fields at the northern ROW edge and a *de minimis* increase in magnetic fields at the southern ROW edge. At both ROW edges, there is a rapid decrease in magnetic fields with lateral distance from the ROW edges.

For electric fields, Table 1.2 shows that there is little to no difference between With-Project and Without-Project modeled edge-of-ROW electric field values at both ROW edges for the two cross-sections, and all modeled edge-of-ROW electric field values remain well below the ICNIRP health-based guideline of 4.2 kV/m.

Table 1.1 Modeled Edge-of-ROW Magnetic Field Values at Two System Loads for Two Representative Overhead Cross-sections of the Barnstable Reliability Project

Load Scenario	Cross-section/Route Segment	Northern Edge-of-ROW Magnetic Fields (mG)		Southern Edge-of-ROW Magnetic Fields (mG)	
		Without-Project	With-Project	Without-Project	With-Project
Non-emergency summer peak	#1: Shootflying Hill Road to National Grid's Merchants Way Substation	39.9	23.8	25.1	25.7
	#2: National Grid's Merchants Way Substation to Eversource's Barnstable Switching Station #958	39.3	23.4	24.3	24.9
Normal (average)	#1: Shootflying Hill Road to National Grid's Merchants Way Substation	22.4	12.2	10.2	10.6
	#2: National Grid's Merchants Way Substation to Eversource's Barnstable Switching Station #958	22.1	12.0	9.8	10.2

Notes:
mG = Milligauss; ROW = Right-of-Way.

Table 1.2 Modeled Edge-of-ROW Electric Field Values for the Barnstable Reliability Project[1]

Cross-section/Route Segment	Northern Edge-of-ROW Electric Fields (kV/m)		Southern Edge-of-ROW Electric Fields (kV/m)	
	Without-Project	With-Project	Without-Project	With-Project
#1: Shootflying Hill Road to National Grid's Merchants Way Substation	0.48	0.43	0.11	0.11
#2: National Grid's Merchants Way Substation to Eversource's Barnstable Switching Station #958	0.48	0.42	0.13	0.13

Notes:
kV/m = Kilovolts Per Meter; ROW = Right-of-Way.
(1) Separate electric field results are not shown for the two load conditions because electric fields have little dependence on load, and are instead dependent on voltage and the spatial configuration of the conductors. There are only minor differences in line voltages for the two loading scenarios (see Table 3.1) that do not result in any significant differences in electric field results. Results are shown for the normal (average) load scenario where line voltages, and thus electric field results are slightly higher as compared to the non-emergency summer peak load scenario.

Section 2 of this report describes the nature of EMF, provides values for EMF levels from common sources, and reports on available EMF exposure guidelines. Section 3 outlines the EMF modeling procedures for calculating electric and magnetic field strengths as a function of lateral distance from an electric transmission (or distribution line) and provides graphical and tabular results for the modeled cross-sections. Section 4 summarizes the conclusions, and the Reference list provides the references cited in this report.

2 Nature of Electric and Magnetic Fields

All matter contain electrically charged particles. Most objects are electrically neutral because positive and negative charges are present in equal numbers. When the balance of electric charges is altered, we experience electrical effects, such as the static electricity attraction between a comb and our hair or drawing sparks after walking on a synthetic rug in the wintertime. Electrical effects occur both in nature and through our society's use of electric power (generation, transmission, consumption).

2.1 Units for EMF Are Kilovolts Per Meter (kV/m) and Milligauss (mG)

The electrical tension on utility power lines is expressed in volts or kilovolts (1 kV = 1,000 V). Voltage is the "pressure" of the electricity and can be envisioned as analogous to the pressure of water in a plumbing system. The existence of a voltage difference between power lines and ground results in an "electric field," usually expressed in units of kilovolts per meter (kV/m). The size of the electric field depends on the voltage, the separation between lines and ground, and other factors (*e.g.*, conductor spacing and phasing).

Power lines also carry an electric current that creates a "magnetic field." The units for electric current are amperes (A) and are a measure of the "flow" of electricity. Electric current can be envisioned as analogous to the flow of water in a plumbing system. The magnetic field produced by an electric current is usually expressed in units of gauss (G) or milligauss (mG) (1 G = 1,000 mG). Another unit for magnetic field levels is the microtesla (μT) (1 μT = 10 mG). The size of the magnetic field depends on the electric current, the distance to the current-carrying conductor, and other factors (*e.g.*, conductor spacing and phasing).

2.2 There Are Many Natural and Man-made Sources of EMF

Everyone experiences a variety of natural and man-made EMF. EMF levels can be slowly varying or steady (often called "direct current" or "DC fields"), or can vary in time (often called "alternating current" or "AC fields"). When the time variation of interest corresponds to that of power line currents (*i.e.*, 60 cycles per second), the fields are called "60-hertz (Hz)" EMF. Man-made magnetic fields are common in everyday life. For example, many childhood toys contain magnets. Such permanent magnets generate strong, steady (DC) magnetic fields. Typical toy magnets (*e.g.*, "refrigerator door" magnets) have fields of 100,000-500,000 mG. On a larger scale, the Earth's core also creates a steady DC magnetic field that can be easily demonstrated with a compass needle. The size of Earth's magnetic field in the northern US is about 550 mG (over 100 times smaller than fields generated by "refrigerator door" magnets).

2.3 Power-frequency EMF Are Found Near Electric Lines and Appliances

Electric power transmission lines, distribution lines, and electrical wiring in buildings carry AC currents and voltages that change size and direction at a frequency of 60 Hz. These 60-Hz currents and voltages create 60-Hz EMF nearby. The size of the magnetic field is proportional to the line current, and the size of the electric field is proportional to the line voltage. The EMF associated with electrical wires and electrical equipment decrease rapidly with increasing distance away from the electrical wires.

When EMFs derive from different wires that are in close proximity, or adjacent to one another, the size of the net EMF produced will be somewhere in the range between the sum of EMF from the individual sources and the difference of the EMF from the individual sources. EMF may partially add, or partially cancel, but generally, because adjacent wires are often carrying current in opposite directions, the EMF produced tends not to be additive.

EMFs in the home arise from electric appliances, indoor wiring, grounding currents on pipes and ground wires, and outdoor distribution or transmission circuits. Inside residences, typical baseline 60-Hz magnetic fields (away from appliances) range from 0.5-5.0 mG.

Higher 60-Hz magnetic field levels are found near operating appliances. For example, can openers, mixers, blenders, refrigerators, fluorescent lamps, electric ranges, clothes washers, toasters, portable heaters, vacuum cleaners, electric tools, and many other appliances generate magnetic fields of size 40-300 mG at distances of 1 foot (NIEHS, 2002). Magnetic fields from personal care appliances held within half a foot (*e.g.*, shavers, hair dryers, massagers) can produce average fields of 600-700 mG. At school and in the workplace, lights, motors, copy machines, vending machines, video-display terminals, electric pencil sharpeners, electric tools, electric heaters, and building wiring are all sources of 60-Hz magnetic fields.

2.4 State, National, and International Guidelines for EMF Are Available

The U.S. has no federal standards limiting occupational or residential exposure to 60-Hz EMF. Table 2.1 shows guidelines suggested by national and international health organizations that are designed to be protective against any adverse health effects. The limit values should not be viewed as demarcation lines between safe and dangerous levels of EMF, but rather, levels that assure safety with an adequate margin of safety to allow for uncertainties in the science. As part of its International EMF Project, the World Health Organization (WHO) has conducted comprehensive reviews of EMF health effects research and existing standards and guidelines, with the WHO website for the International EMF Project (WHO, 2018) noting that, "The main conclusion from the WHO reviews is that EMF exposures below the limits recommended in the ICNIRP international guidelines do not appear to have any known consequence on health."

Table 2.2 lists guidelines that have been adopted by various states in the U.S. State guidelines are not health-effect based and have typically been adopted to maintain the *status quo* for EMF on and near transmission line ROWs.

Table 2.1 60-Hz EMF Guidelines Established by Health and Safety Organizations

Organization	Magnetic Field	Electric Field
American Conference of Governmental and Industrial Hygienists (ACGIH) (occupational)	10,000 mG[1] 1,000 mG[2]	25 kV/m[1] 1 kV/m[2]
International Commission on Non-Ionizing Radiation Protection (ICNIRP) (general public, continuous exposure)	**2,000 mG**	**4.2 kV/m**
Non-Ionizing Radiation (NIR) Committee of the American Industrial Hygiene Assoc. (AIHA) endorsed (in 2003) ICNIRP's occupational EMF levels for workers	4,170 mG	8.3 kV/m
Institute of Electrical and Electronics Engineers (IEEE) Standard C95.6 (general public, continuous exposure)	9,040 mG	5.0 kV/m
UK, National Radiological Protection Board (NRPB) (now the Health Protection Agency [HPA])	2,000 mG	4.2 kV/m
Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (Draft Standard, December 2006[3])	3,000 mG	4.2 kV/m

Notes:
EMF = Electric and Magnetic Field; kV/m = Kilovolts Per Meter; mG = Milligauss; ROW = Right-of-Way.
(1) The ACGIH guidelines for the general worker (ACGIH, 2015, p. 128-131).
(2) The ACGIH guideline for workers with cardiac pacemakers (ACGIH, 2015, p. 128-131).
(3) ARPANSA (2006, 2008).

Table 2.2 State EMF Standards and Guidelines for Transmission Lines

State	Line Voltage (kV)	Electric Field (kV/m)		Magnetic Field (mG)	
		On ROW	Edge ROW	On ROW	Edge ROW
Florida[1]	69-230	8.0	2.0[2]		150
	500	10.0			200, 250[3]
Massachusetts			**1.8**		**85**
Minnesota		8.0			
Montana		7.0[4]	1.0[5]		
New Jersey			3.0		
New York[3]		11.8 11.0[6] 7.0[4]	1.6		200
Oregon		9.0			

Notes:
EMF = Electric and Magnetic Field; kV/m = Kilovolts Per Meter; mG = Milligauss; ROW = Right-of-Way.
Sources: NIEHS (2002); FLDEP (2008); MAEFSB (2010).
(1) Magnetic fields for winter-normal (*i.e.*, at maximum current-carrying capability of the conductors).
(2) Includes the property boundary of a substation.
(3) 500-kV double-circuit lines built on existing ROWs.
(4) Maximum for highway crossings.
(5) May be waived by the landowner.
(6) Maximum for private road crossings.

3 EMF Modeling

3.1 Software Program Used for Modeling EMF for Power Line Cross-sections

The FIELDS computer program, designed by Southern California Edison, was utilized to predict magnetic and electric field strengths from the proposed lines expected to exist 1 meter (~3 feet) above the ground surface per standard industry practices (IEEE Power Engineering Society, 1995a,b). This program operates using Maxwell's equations, which accurately apply the laws of physics as related to electricity and magnetism (EPRI, 1982, 1993). Modeled fields using this program are both precise and accurate for the input data utilized. Results of the model have been checked extensively against each other and against other software (*e.g.*, "CORONA" from the Bonneville Power Administration, US Department of Energy) to ensure that the implementation of the laws of physics are consistent. In these validation tests, program results for EMF were found to be in very good agreement with each other (Mamishev and Russell, 1995).

3.2 Power-line Loads

Magnetic fields produced by the proposed lines were modeled using line loadings communicated by Eversource. The current per phase satisfies the relationship:

(Eq. 3.1)
$$S = \sqrt{3} \times V \times I_{phase}$$

where:

S	=	The power in kilovolt-amps (kVA)
V	=	The line voltage in kilovolts (kV)
I_{phase}	=	The current per phase in amperes (A)

Thus, the current per phase conductor is:

(Eq. 3.2)
$$I_{phase} = \frac{S}{\sqrt{3} \times V}$$

Real power is given in megawatts (MW) (*P*), and apparent power in megavolt-amps (MVA) (*S*).[1] To convert between power quoted in MW to MVA, one must divide by the power factor.

Transmission line electric current and voltage values provided by Eversource are summarized by load scenario in Table 3.1 for the 115-kV circuits present in the ROW 343 cross-sections, while Table 3.2 provides electric current and voltage values for the two 23-kV distribution lines also present in the ROW 343 cross-sections. The same electric current and voltage values were used for both the Without-Project and With-Project circuits.

[1] MVA is apparent power and is the vector sum of real (active) and imaginary (reactive) power. MW and MVA are not the same unless power factor = 1.0, which, in a practical AC circuit, is generally not the case.

Table 3.1 Projected Electric Currents (A) and Voltages (kV) by Load Scenario for 115-kV Transmission Lines in ROW 343 Between Shootflying Hill Road and Barnstable Switching Station #958[1]

Load Scenario	TLine1		TLine2		TLine3		TLine4	
	Electric Current (A)	Electric Voltage (kV)	Electric Current (A)	Electric Voltage (kV)	Electric Current (A)	Electric Voltage (kV)	Electric Current (A)[2]	Electric Voltage (kV)
Non-emergency summer peak 2021 load level	394.6	118.5	515.8	119.0	503.9	119.0	-177.1	118.6
Normal (average) 2021 load level	205.0	120.1	313.7	120.3	306.5	120.3	-90.5	120.5

Notes:
A = Amperes; kV = Kilovolt.
(1) Non-specific identifiers are provided for the transmission lines to protect Critical Energy/Infrastructure Information (CEII).
(2) The negative current indicates current flow is opposite to the direction for the other transmission lines.

Table 3.2 Projected Electric Currents (A) and Voltages (kV) by Load Scenario for the two 23-kV Distribution Lines in ROW 343 Between Shootflying Hill Road and Barnstable Switching Station #958[1]

Load Scenario	DLine1		DLine2	
	Electric Current (A)[1]	Electric Voltage (kV)	Electric Current (A)	Electric Voltage (kV)
Non-emergency summer peak load level	347.7	23.0	163.4	23.0
Normal load level (2016-2018 median)	105.4	23.0	84.2	23.0

Notes:
A = Amperes; kV = Kilovolt.
(1) Non-specific identifiers are provided for the distribution lines to protect Critical Energy/Infrastructure Information (CEII)..

3.3 EMF Modeling for the Without-Project and With-Project Circuits

Gradient modeled electric and magnetic fields expected to exist 1 meter (~3 feet) above the ground surface for two representative ROW overhead line cross-sections with the conductor configurations and phasings for Without-Project and With-Project circuits depicted in the Appendix B cross-section diagrams and the two loading scenarios described above. The EMF modeling included all overhead transmission and distribution lines within the ROW 343 cross-sections due to the potential for the electric and magnetic fields from the non-Project lines to interact with the EMF associated with the separated Line 135 conductors. It was assumed that there are two shield wires for each of the 115-kV transmission lines in the right of way, with the wires being offset 2 feet on either side of the poles for Lines 122, 135, and 131 and being centered on top of the H-frame poles for Line 115. Table 3.3 below summarizes the conductor and shield/neutral wire types and diameters that were provided by Eversource.

Table 3.3 Summary of Conductor and Shield/Neutral Wire Types and Diameters

<table>
<tr><th rowspan="2">Line</th><th colspan="2">Conductor</th><th colspan="2">Shield/Neutral Wire</th></tr>
<tr><th>Type</th><th>Diameter (inches)</th><th>Type</th><th>Diameter (inches)</th></tr>
<tr><td>122</td><td>2338 48/13 ACAR</td><td>1.762</td><td>0.512" OPGW</td><td>0.512</td></tr>
<tr><td>135</td><td>2338 48/13 ACAR</td><td>1.762</td><td>0.512" OPGW</td><td>0.512</td></tr>
<tr><td rowspan="2">131</td><td rowspan="2">795 ACSR 26/7 "Drake"</td><td rowspan="2">1.107</td><td>0.528" OPGW</td><td>0.528</td></tr>
<tr><td>7#9 alumoweld</td><td>0.343</td></tr>
<tr><td rowspan="2">115</td><td rowspan="2">1113 ACSS 45/7 "Bluejay"</td><td rowspan="2">1.258</td><td>0.512" OPGW</td><td>0.512</td></tr>
<tr><td>0.512" OPGW</td><td>0.512</td></tr>
<tr><td>84</td><td>795 acsr 36/1 "Coot"</td><td>1.04</td><td>4/0 acsr neutral</td><td>0.563</td></tr>
<tr><td>80</td><td>795 acsr 36/1 "Coot"</td><td>1.04</td><td>3/0 acsr neutral</td><td>0.502</td></tr>
</table>

For each cross-section, EMF levels were modeled for both Without-Project and With-Project ROW conditions as a function of distance perpendicular to the direction of current flow along a segment of the route where the transmission line runs straight. Variation in the height of the nearby grade along ROW 343 was not accounted for given the general Eversource policy to model EMF for the most conservative location of lowest conductor sag (*i.e.*, closest to the ground surface). Per information provided by Eversource, the height above grade at maximum sag for the lowest conductors for the 115-kV transmission lines was assumed to be 30 feet above the ground for the lowest conductor, while for the two 23-kV distribution lines, heights of 20 feet above the ground were assumed for the two lower conductors. ROW 343 has a consistent width of 270 feet for the Project route, and EMF levels were modeled out an additional 15 feet on either side of the ROW to further illustrate the continuing decline in EMF levels beyond the ROW edges.

3.4 EMF Modeling Results

3.4.1 Magnetic Field Modeling Results for Overhead Line Cross-sections

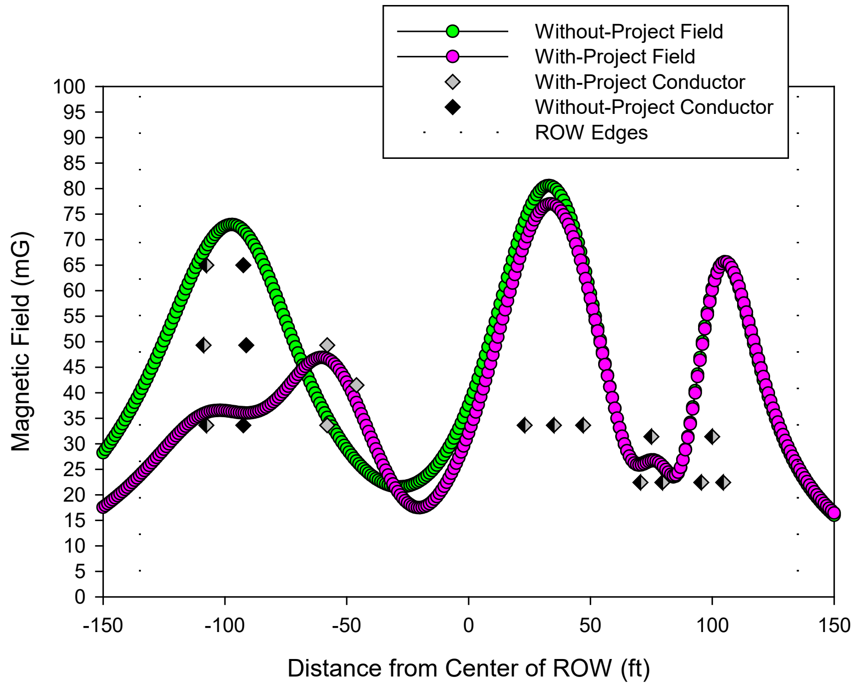
Detailed results of the magnetic field modeling for the Without-Project and With-Project overhead transmission line cross-sections are summarized in Table 3.4 and Figures 3.1 and 3.2. As reflected in this table and the figures, With-Project magnetic field values for the overhead transmission line cross-sections all fall below the ICNIRP health-based guideline for continuous public exposure to magnetic fields (2,000 mG; ICNIRP, 2010), both at the ROW edges and within ROW 343. The table and figures show that the Project will result in little change to the peak within-ROW magnetic fields and magnetic fields at the southern ROW edge as compared to Without-Project values for both load scenarios. Table 3.4 and Figures 3.1 and 3.2 also show that the Project will result in reduced magnetic field levels at the northern ROW edge as compared to Without-Project values for both load scenarios. In addition, the figures demonstrate the rapid decrease in magnetic field levels with distance away from the conductors, with drop-off continuing beyond the ROW edges.

Table 3.4 Summary of Without-Project and With-Project Modeled Peak Edge-of-ROW and Within-ROW Magnetic Field Values by Overhead Cross-section and Load Scenario

Load Scenario	Cross-section/Route Segment	Northern Edge-of-ROW Magnetic Fields (mG)		Southern Edge-of-ROW Magnetic Fields (mG)		Within-ROW Maximum Magnetic Fields (mG)	
		Without-Project	With-Project	Without-Project	With-Project	Without-Project	With-Project
Non-emergency summer peak	#1: Shootflying Hill Road to National Grid's Merchants Way Substation	39.9	23.8	25.1	25.7	80.6	77.0
	#2: National Grid's Merchants Way Substation to Eversource's Barnstable Switching Station #958	39.3	23.4	24.3	24.9	76.5	72.9
Normal (average)	#1: Shootflying Hill Road to National Grid's Merchants Way Substation	22.4	12.2	10.2	10.6	49.7	47.6
	#2: National Grid's Merchants Way Substation to Eversource's Barnstable Switching Station #958	22.1	12.0	9.8	10.2	47.5	45.4

Notes:
mG = Milligauss; ROW = Right-of-Way.

(Panel a)



(Panel b)

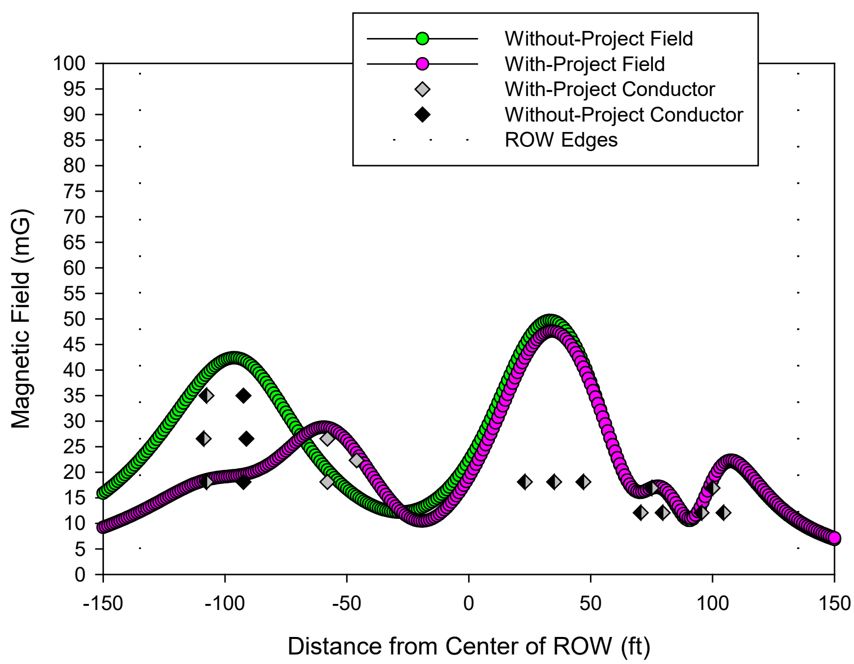
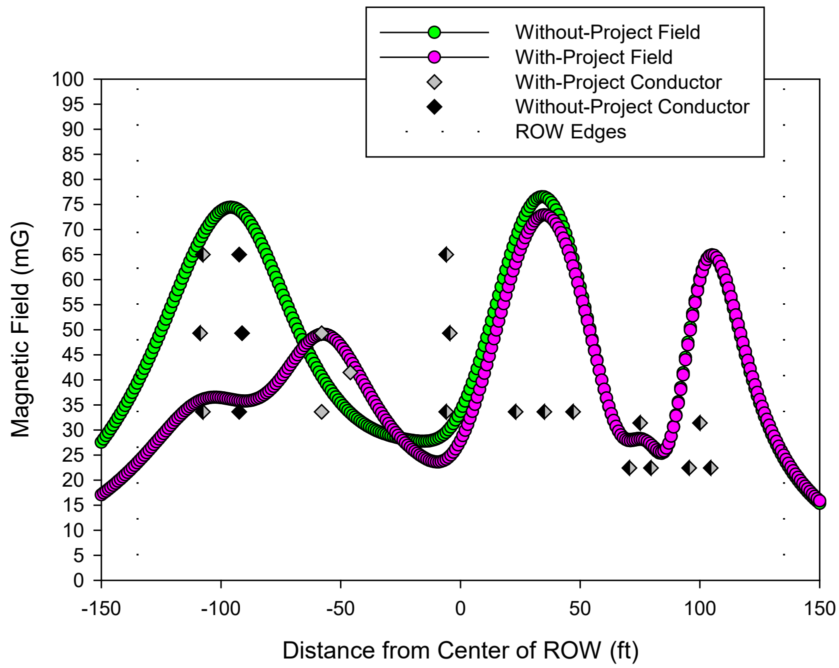


Figure 3.1 Cross-section #1 – Shootflying Hill Road to National Grid's Merchants Way Substation: Without-Project and With-Project Modeled Magnetic Field Values at Projected Non-emergency Summer Peak 2021 Load Levels (Panel a) and Normal (Average) Load Levels (Panel b). The view is to the

east towards Barnstable Switching Station #958, with the cross-section being shown perpendicular to the directions of electric current. The relative locations of the existing and proposed Line 135 115-kV conductors are shown as black and gray diamonds, respectively; while the relative locations of the other 115-kV transmission line conductors and 23-kV distribution line conductors in the ROW that will remain unchanged are shown as black and gray diamonds. The vertical location of the diamonds is illustrative and not to scale. The centerline of the 270-foot-wide ROW has been set at x = 0, and the vertical solid and dashed lines indicate the ROW edges.

(Panel a)



(Panel b)

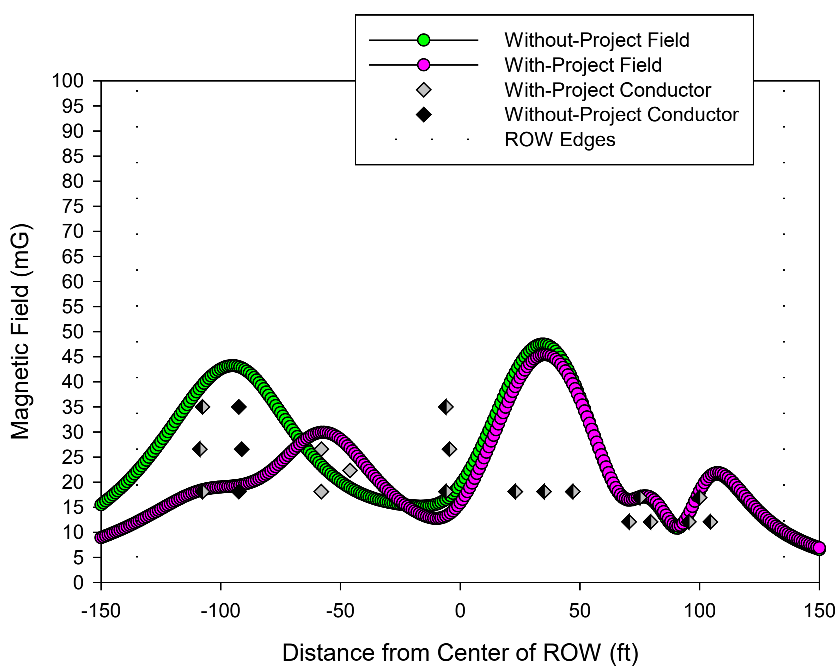


Figure 3.2 Cross-section #2 – National Grid's Merchants Way Substation to Eversource's Barnstable Switching Station #958: Without-Project and With-Project Modeled Magnetic Field Values at Projected Non-emergency Summer Peak 2021 Load Levels (Panel a) and Normal (Average) Load Levels (Panel b).

The view is to the east towards Barnstable Switching Station #958, with the cross-section being shown perpendicular to the directions of electric current. The relative locations of the existing and proposed Line 135 115-kV conductors are shown as black and gray diamonds, respectively; while the relative locations of the other 115-kV transmission line conductors and 23-kV distribution line conductors in the ROW that will remain unchanged are shown as black and gray diamonds. The vertical location of the diamonds is illustrative and not to scale. The centerline of the 270-foot-wide ROW has been set at x = 0, and the vertical solid and dashed lines indicate the ROW edges.

3.4.2 Electric Field Modeling Results for Overhead Line Cross-sections

Because the electric field is dependent on voltage and the spatial configuration of the conductors and has little dependence on load, Figures 3.3 and 3.4 show representative electric field profiles for the two cross-sections. In addition, results of the electric field modeling are summarized in Table 3.5 below.

Table 3.5 Summary of Without-Project and With-Project Modeled Peak Edge-of-ROW and Within-ROW Electric Field Values for the Representative Overhead Line Cross-sections[1]

Cross-section/Route Segment	Northern Edge-of-ROW Electric Fields (kV/m)		Southern Edge-of-ROW Electric Fields (kV/m)		Within-ROW Maximum Electric Fields (kV/m)	
	Without-Project	With-Project	Without-Project	With-Project	Without-Project	With-Project
#1: Shootflying Hill Road to National Grid's Merchants Way Station	0.48	0.43	0.11	0.11	1.57	1.29
#2: National Grid's Merchants Way Station to Eversource's Barnstable Switching Station #958	0.48	0.42	0.13	0.13	1.73	1.71

Notes:
kV/m = Kilovolts Per Meter; ROW = Right-of-Way.
(1) Separate electric field results are not shown for the two load conditions because electric fields have little dependence on load and are instead dependent on voltage and the spatial configuration of the conductors. There are only minor differences in line voltages for the two loading scenarios (see Table 3.1) that do not result in any significant differences in electric field results. Results are shown for the normal (average) load scenario where line voltages, and thus electric field results, are slightly higher as compared to the non-emergency summer peak load scenario.

Similar to the magnetic field results, all modeled With-Project and Without-Project electric field values are well below the ICNIRP health-based guideline of 4.2 kV/m for continuous public exposure to electric fields (ICNIRP, 2010). In addition, Table 3.5 and Figures 3.3 and 3.4 show that there are only small differences in peak within-ROW and ROW-edge electric fields between the With-Project and Without-Project conductor configurations.

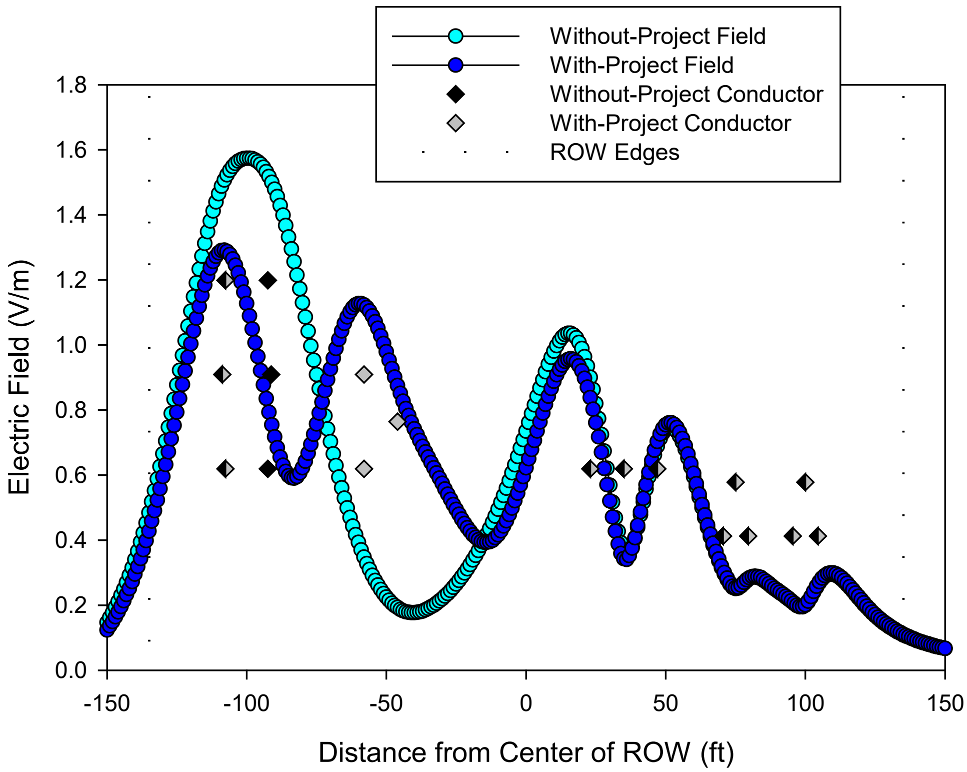


Figure 3.3 Cross-section #1 – Shootflying Hill Road to National Grid's Merchants Way Substation: Without-Project and With-Project Modeled Electric Field Values. The view is to the east towards Barnstable Switching Station #958, with the cross-section being shown perpendicular to the directions of electric current. The relative locations of the existing and proposed Line 135 115-kV conductors are shown as black and gray diamonds, respectively; while the relative locations of the other 115-kV transmission line conductors and 23-kV distribution line conductors in the ROW that will remain unchanged are shown as black and gray diamonds. The vertical location of the diamonds is illustrative and not to scale. The centerline of the 270-foot-wide ROW has been set at x = 0, and the vertical solid and dashed lines indicate the ROW edges.

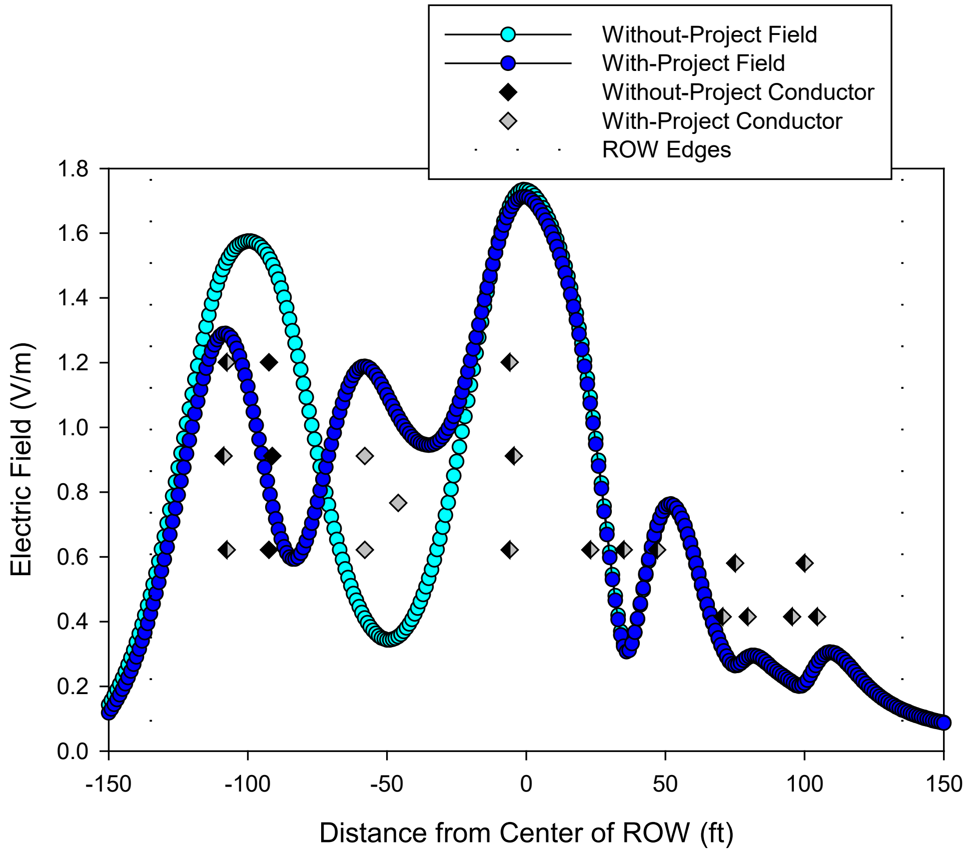


Figure 3.4 Cross-section #2 – National Grid's Merchants Way Substation to Eversource's Barnstable Switching Station #958: Without-Project and With-Project Modeled Electric Field Values. The view is to the east towards Barnstable Switching Station #958, with the cross-section being shown perpendicular to the directions of electric current. The relative locations of the existing and proposed Line 135 115-kV conductors are shown as black and gray diamonds, respectively; while the relative locations of the other 115-kV transmission line conductors and 23-kV distribution line conductors in the ROW that will remain unchanged are shown as black and gray diamonds. The vertical location of the diamonds is illustrative and not to scale. The centerline of the 270-foot-wide ROW has been set at x = 0, and the vertical solid and dashed lines indicate the ROW edges.

4 Conclusions

Using the FIELDS model, Gradient calculated the EMF levels at 1 meter (~3 feet) above the ground surface for representative cross-sections of ROW 343 between the Shootflying Hill Road and Barnstable Switching Station #958 in Barnstable, Massachusetts, where Eversource proposes to separate Lines 122 and 135. Both With-Project and Without-Project circuit configurations were modeled, which included the other existing overhead 115-kV transmission lines (Lines #115 and #131) and 23-kV distribution lines (Lines #80 and #84) also present in the ROW. EMF modeling was performed using projected non-emergency summer peak and normal transmission line loadings provided by Eversource for the year 2021, which is the expected in-service date for the Project. As discussed above, the With-Project maximum modeled electric and magnetic field levels predicted within and at the edges of ROW 343 all fall well below accepted health-based guidelines for allowable public exposure to electric and magnetic fields (4.2 kV/m and 2,000 mG, respectively; ICNIRP, 2010). Moreover, compared to the Without-Project case, With-Project ROW-edge EMF levels were reduced on the northern ROW edge and were only minimally changed on the southern ROW edge.

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Appendix A

Aerial Overview Map Showing the Barnstable Reliability Project Route

Appendix B

Representative Without-Project and With-Project ROW Overhead Line Cross-sections for the Barnstable Reliability Project (view is looking east toward Barnstable Station)