Appendix AG

Eversource/National Grid Merrimack Valley Reliability Project Electric Field, Magnetic Field, Audible Noise, and Radio Noise Modeling in New Hampshire, June 16, 2015

Electrical Engineering and
Computer Science Practice

Exponent®

Eversource / National Grid Merrimack Valley Reliability Project

Electric Field, Magnetic Field, Audible Noise, and Radio Noise Modeling in New Hampshire

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Electric Field, Magnetic Field, Audible Noise, and Radio Noise Modeling in New Hampshire

Prepared for

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Acronyms and Abbreviations

A	Ampere
AAL	Annual average loading
AC	Alternating current
AN	Audible noise
dB	Decibels
dBµV/m	Decibels above 1 microvolt per meter
DC	Direct current
EMF	Electric and magnetic fields
ELF	Extremely low frequency
EPA	Environmental Protection Agency
G	Gauss
Hz	Hertz
ICES	International Committee on Electromagnetic Safety
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
ISO-NE	New England Independent System Operator
kHz	Kilohertz
kV	Kilovolt
kV/m	Kilovolts per meter
L_{50}	Sound level exceeded 50 percent of the time (i.e., median)
L_{dn}	Day-night sound level
L_{eq}	Equivalent sound level
MW	Megawatt
MVAR	Megavolt-ampere reactive
MVRP	Merrimack Valley Reliability Project
mG	Milligauss
MHz	Megahertz
NEP	New England Power Company
PSNH	Public Service Company of New Hampshire
RN	Radio noise

ROW	Right-of-way
V/m	Volts per meter

Limitations

At the request of the Public Service Company of New Hampshire (PSNH), d/b/a Eversource Energy, and the New England Power Company (NEP), d/b/a National Grid, Exponent modeled the levels of electric fields, magnetic fields, audible noise, and radio noise associated with the proposed transmission line, as well as existing and rebuilt transmission and distribution lines along the portions of the proposed route of the Merrimack Valley Reliability Project located in New Hampshire. This report summarizes work performed to date and presents the findings resulting from that work. In the analysis, we have relied on geometry, material data, usage conditions, specifications, and various other types of information provided by the clients. NEP and PSNH have confirmed to Exponent that the data provided to Exponent and summary contained herein is not subject to Critical Energy Infrastructure Information restrictions. We cannot verify the correctness of this data, and rely on the clients for the data's accuracy. Although Exponent has exercised usual and customary care in the conduct of this analysis, the responsibility for the design and operation of the Project remains fully with the clients.

The findings presented herein are made to a reasonable degree of engineering and scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available, through any additional work, or review of additional work performed by others.

The scope of services performed during this investigation may not adequately address the needs of other users of this report outside of the New Hampshire Site Evaluation Committee's permitting process, and any re-use of this report or its findings, conclusions, or recommendations presented herein are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. No guarantee or warranty as to future life or performance of any reviewed condition is expressed or implied.

Executive Summary

The proposed Merrimack Valley Reliability Project (MVRP or Project) includes the construction of a new 345-kilovolt transmission line (designated the 3124 Line) that is planned to run for approximately 24.4 miles from NEP's Tewksbury 22A Substation in Tewksbury, Massachusetts, to PSNH's Scobie Pond Substation in Londonderry, New Hampshire. The portion of the MVRP in New Hampshire is the subject of this report.

Existing and proposed transmission and distribution lines along the proposed route are sources of 60-Hertz electric and magnetic fields (EMF), audible noise (AN), and radio noise (RN). To characterize Project-related changes to EMF, AN, and RN levels, Exponent modeled these aspects of line operation for nine sections of the right-of-way along the Proposed Route in New Hampshire under pre-Project and post-Project configurations and various operating conditions.

EMF levels were compared to authoritative health-based international standards and guidelines developed by the International Commission on Non-Ionizing Radiation Protection and the International Committee for Electromagnetic Safety and were found to be below Basic Restrictions on public exposure (ICES, 2002; ICNIRP, 2010).

AN levels in fair weather in all portions of the Project will be below the Environmental Protection Agency's day-night reference level (USEPA, 1974). This level was identified as an acceptable level to prevent public annoyance and to protect public health and welfare with an adequate margin of safety.

RN levels in fair weather at 50 feet from the outer conductor throughout the route are below the Institute of Electrical and Electronics Engineers' guideline level (IEEE, 1971) for RN from a transmission line.

Note that this Executive Summary does not contain all of Exponent's technical evaluations, analyses, conclusions, and recommendations. Hence, the main body of this report is at all times the controlling document.

Introduction

The proposed Merrimack Valley Reliability Project (MVRP or Project) was developed as a result of a determination by the New England Independent System Operator (ISO-NE) that the current electric transmission system serving southern New Hampshire and northeastern Massachusetts did not meet ISO-NE or Northeast Power Coordinating Council transmission system planning criteria. As a result of the ISO-NE process that made this determination, the New England Power Company (NEP), d/b/a National Grid, and the Public Service Company of New Hampshire (PSNH), d/b/a Eversource Energy, have planned to enhance the electrical transmission infrastructure in southern New Hampshire and northeastern Massachusetts. The MVRP will eliminate potential overloads on several components of the existing transmission system that could be experienced under certain contingency conditions and will provide resiliency and increased flexibility to the system.

The MVRP involves the construction of a new 345-kilovolt (kV) transmission line (designated the 3124 Line) that is planned to run for approximately 24.4 miles from the Tewksbury Substation 22A in Tewksbury, Massachusetts, to the Scobie Pond Substation in Londonderry, New Hampshire, and will pass through the Towns of Tewksbury, Andover, and Dracut in Massachusetts, and through Pelham, Windham, Hudson, and Londonderry in New Hampshire. Since the MVRP is planned to be constructed within existing rights-of-way (ROW), the Project will also include the relocation within the ROW of some existing lines to accommodate the proposed 3124 Line. In all portions of the route where existing lines need to be relocated, the proposed 3124 Line is placed near the center of the ROW, while a lower-voltage line is relocated nearer the ROW edge.[1]

The Project is divided into four segments; Segment 1 is the portion of the Project in Massachusetts, while Segments 2 – 4 are wholly in New Hampshire. The MVRP facilities in Massachusetts (Segment 1) will be constructed, owned, and operated by NEP, as will Segment 2 in New Hampshire. Segments 3 and 4 will be constructed, owned, and operated by PSNH. This

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[1] As discussed in greater detail below, this design helps to minimize the change in Project-related EMF, AN, and RN levels that will be associated with the planned MVRP.

report discusses the facilities that are proposed for the New Hampshire segments only (Segments 2, 3, and 4), and their electrical environment.

Route and Configuration of the Project in New Hampshire

The New Hampshire portion of the Project includes the construction of the new 3124 Line on an existing ROW from the Massachusetts/New Hampshire border at Pelham, New Hampshire, to the Scobie Pond Substation in Londonderry, New Hampshire, a distance of approximately 18 miles. The existing ROW in New Hampshire includes up to nine existing alternating current (AC) transmission or distribution lines, or both, in various sections, although never more than six in any one section. There are two existing 345-kV lines (380 and 326), two 230-kV lines (N-214 and O-215), and five 115-kV lines (Y-151, X-116, Z-119, R-187, and S-188)—as well as two distribution circuits (365 and 32W4) and one ±450 kV direct current (DC) transmission line (451/452). The ROW width in Segments 2 – 4 in New Hampshire varies from approximately 350 feet to 635 feet. In all portions of the route where existing lines need to be relocated, the proposed 3124 Line is placed near the center of the ROW while the lower-voltage (Y-151) line is relocated nearer the ROW edge, a design feature that reduces levels of EMF, AN, and RN at the ROW edge. A table summarizing the route and describing the circuits that are existing (i.e., not changed as part of this proposed Project), rebuilt (moved or rebuilt in a different configuration, or both), and proposed (the 3124 Line) is provided in Appendix C, Table C-1. In order to discuss the various line configurations, each Segment is subdivided into different sections for discussion. Segment 1 (in Massachusetts) is broken down into eight sections (with Section 8 divided into Sections 8a and 8b).[2] Segment 2 (in New Hampshire) is broken down into Sections 8 and 9 (with Section 8 divided into Sections 8b, 8c, and 8d). Segment 3 is comprised of Section 10 and Segment 4 is divided into Sections 11 – 15. A description of each Segment and Section in New Hampshire is as follows:

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[2] Section 8b crosses the Massachusetts/New Hampshire border and is therefore discussed in reports for both states.

Segment 1/Sections 1 through 8a include the portions of the Project located wholly in Massachusetts and, thus, they are not discussed in this report.[3]

Segment 2 includes the portion of the Project that runs from the Massachusetts/New Hampshire border through the Town of Pelham, continuing north for 8.1 miles within the NEP ROW to a location in the Town of Hudson where the PSNH ROW begins to run adjacent to the NEP ROW. Segment 2 is subdivided into Sections 8b, 8c, 8d, and 9.

> ***Sections 8b through 8d*** describe the portions of the Project from the Massachusetts/New Hampshire border that runs for approximately 8 miles to a location just north of Bockes Road in the town of Hudson. Currently, this section of the ROW (350 feet wide) contains three existing overhead transmission lines: O-215, Y-151, and N-214, respectively from west to east. In the proposed configuration, the Y-151 Line will be relocated from near the center of the ROW to approximately 28.5 feet from the western ROW edge and will be constructed on 115-kV delta davit-arm steel structures. In the space vacated by the Y-151 Line, the new 3124 Line will be constructed on 345-kV steel H-frame structures at the center of the 350-foot ROW. Section 8 is subdivided into four portions, 8a, 8b, 8c, and 8d, all with the same physical configuration. Section 8a is located wholly within Massachusetts and is not described here.
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>> ***Section 8b*** (Mile 5.8 to Mile 8.9) describes approximately 3.1 miles of the Project from approximately 0.3 miles south of Methuen Road in Dracut, Massachusetts, to the Pelham Substation in New Hampshire. Approximately 2.4 miles of this ROW section are located in New Hampshire; the remainder is located in Massachusetts.
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>> ***Section 8c*** (Mile 8.9 to Mile 9.6) describes approximately 0.7 miles of the Project from the Pelham Substation to a point just southeast of where Main Street and Bridge Street parallel one another in Pelham. In this section, the physical

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[3] Portions of Section 8b are located in both Massachusetts and New Hampshire.

configuration and phasing of the circuits is the same as in Section 8b, but the loading of the Y-151 Line is higher than in Section 8b.

Section 8d (Mile 9.6 to Mile 14.2) describes approximately 4.6 miles of the Project from a point just southeast of where Main Street and Bridge Street parallel one another in Pelham to a point north of Bockes Road in Hudson where the Y-151 Line diverges from the main ROW. In this section, the physical configuration and loading of the circuits is the same as in Section 8c, but the phasing of the Y-151 Line is different than in Section 8c.

Section 9 (Mile 14.2 to Mile 14.6) describes approximately 0.4 miles of the Project from a point north of Bockes Road in Hudson where the Y-151 Line diverges from the main ROW until the Project transitions to PSNH ownership in Hudson, just south of Wiley Hill Road. Currently, this section of the ROW contains two existing overhead transmission lines: O-215 and N-214, from west to east, respectively, separated by a distance of approximately 183 feet. In this section there is sufficient clearance within the ROW to construct the new 3124 Line without relocating any existing lines. In the proposed configuration, the new 3124 Line will be constructed on 345-kV steel H-frame structures at the center of the 350-foot ROW.

Segment 3/Section 10 (Mile 14.6 to Mile 18.5) runs from just south of Wiley Hill Road in Hudson (the point of ownership transition from NEP to PSNH) to a point in Londonderry where the new 3124 Line will change direction (turning to the northeast) toward Scobie Pond. The combined PSNH/NEP ROW in this section is approximately 567 feet wide and currently contains transmission lines 326, N-214, 451/452 (a DC transmission line), and O-215, respectively from west to east. The new 3124 Line will be constructed on steel H-frame structures, approximately 85 feet from the east ROW edge that has not previously been cleared.

Segment 4 of the Project begins from the point that the PSNH ROW diverges from the NEP ROW and continues to Scobie Pond Substation. This Segment of the Project is 5.9 miles long and located entirely within the Town of Londonderry. In the proposed configuration of all portions of the ROW along this Segment, the 3124 Line will be constructed on steel H-frame structures approximately 100 feet from the existing 326 Line. Segment 4 is subdivided into Sections 11 through 15.

Section 11 (Mile 18.5 to Mile 20.5) runs northeast from the point where the PSNH ROW diverges from running parallel with the NEP ROW and continues approximately 1.9 miles to a point just west of High Range Road. The ROW in this section is approximately 460 feet wide and currently contains transmission lines 380, 326, Z-119, and X-116, respectively from west to east. The distance between the existing 326 and Z-119 Lines is approximately 187.5 feet, including a portion near the center of the ROW that is not currently cleared. In the proposed configuration this portion of the ROW will be cleared and the 3124 Line will be constructed on steel H-frame structures approximately 100 feet from the existing 326 Line.

Section 12 (Mile 20.5 to Mile 21.6) turns and runs east from the point just west of High Range Road to a location just west of Mammoth Road (a distance of approximately 1.1 miles), adjacent to the existing Mammoth Road Substation. At this junction the Z-119 Line crosses the X-116 Line and the S-188 Line (from Mammoth Road Substation) joins the ROW, north of the X-116 Line. The ROW in this section is approximately 635-feet wide and currently contains transmission lines 380, 326, S-188, X-116, and Z-119, respectively from north to south. Similar to Section 11, there is a relatively large distance (170 feet) between the 326 and S-188 Lines including a portion near the center of the ROW that is not currently cleared. In the proposed configuration this portion of the ROW will be cleared and the 3124 Line will be constructed on steel H-frame structures approximately 100 feet from the existing 326 Line.

Section 13 (Mile 21.6 to Mile 23.0) continues east from the Mammoth Road Substation, across Mammoth Road and then turns and runs northeast to Trolley Car Path (just west of Interstate 93), a distance of approximately 1.4 miles. At the Mammoth Road Substation, the S-188 Line leaves the 535-foot wide ROW and the R-187 Line (from Scobie Pond Substation) joins the ROW. The ROW currently contains transmission lines 380, 326, R-187, and X-116, Z-119, respectively from north to south. A 34-kV distribution circuit (365) is also present on the ROW, approximately 25 feet from the southern ROW edge. Similar to Section 12, a distance of 170 feet currently separates the 326 and R-187 Lines including a portion near the center of the ROW that is not currently cleared. In the proposed configuration, this portion of the ROW will be cleared and the 3124 Line will be constructed on steel H-frame structures approximately 100 feet from the existing 326 Line.

Section 14 (Mile 23.0 to Mile 23.8) continues approximately 0.8 miles northeast from Trolley Car Path (where the existing 365 distribution circuit leaves the ROW) across Interstate 93 to a point just west of Rockingham Road. The existing configuration is identical to that of Section 13 (Lines 380, 326, R-187, X-116, and Z-119, respectively from north to south), except that the existing distribution circuit is no longer on the ROW. In the proposed configuration, this portion of the ROW will be cleared and the 3124 Line will be constructed on steel H-frame structures approximately 100 feet from the existing 326 Line.

Section 15 (Mile 23.8 to Mile 24.4) covers the final distance of less than 0.6 miles, from a point west of Rockingham Road where an existing 12-kV distribution circuit (32W4) joins the ROW to the Scobie Pond Substation. The existing configuration is identical to that of Section 14 (Lines 380, 326, R-187, X-116, and Z-119, respectively from north to south), except that the existing 32W4 distribution circuit is located a distance of approximately 29 feet from the southern ROW edge. In the proposed configuration this portion of the ROW will be cleared and the 3124 Line will be constructed on steel H-frame structures approximately 100 feet from the existing 326 Line.

Figure 1 depicts the proposed route of the Project, showing Segments 2 through 4 from the Massachusetts border to the Scobie Pond Substation in Londonderry, as well as the representative sections of these Segments where EMF, AN, and RN were modeled for this report.

A schematic diagram showing the 3124 Line and other transmission lines in various sections of the ROW in Segments 2 through 4 is depicted in Figure 2. Additional information regarding many of the details of the various transmission lines is summarized in Appendix C. Table C-1 provides a summary of the lines present on each of the Sections along with an indication of whether they are existing, relocated, or proposed. Appendix C, Table-C-2 provides a summary of the loading for each line in each of the different ROW Sections and Figure C-1 depicts the new structures proposed for use in various voltages and in various portions of the route.

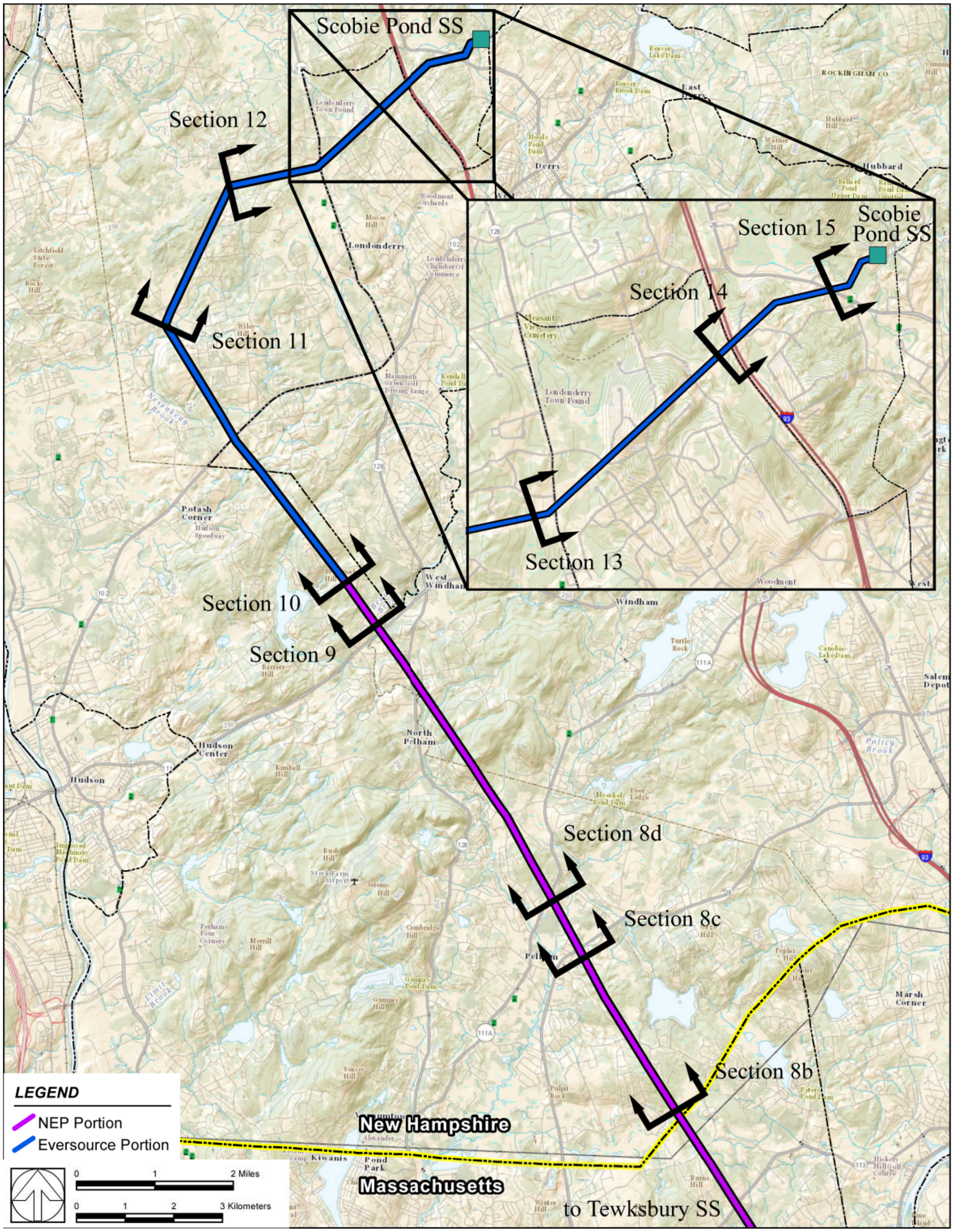

Figure 1. Proposed route of MVRP in New Hampshire showing the locations of modeling Sections 8b through 15 (Segments 2 through 4).

Direction of arrows shows the view of modeling cross sections

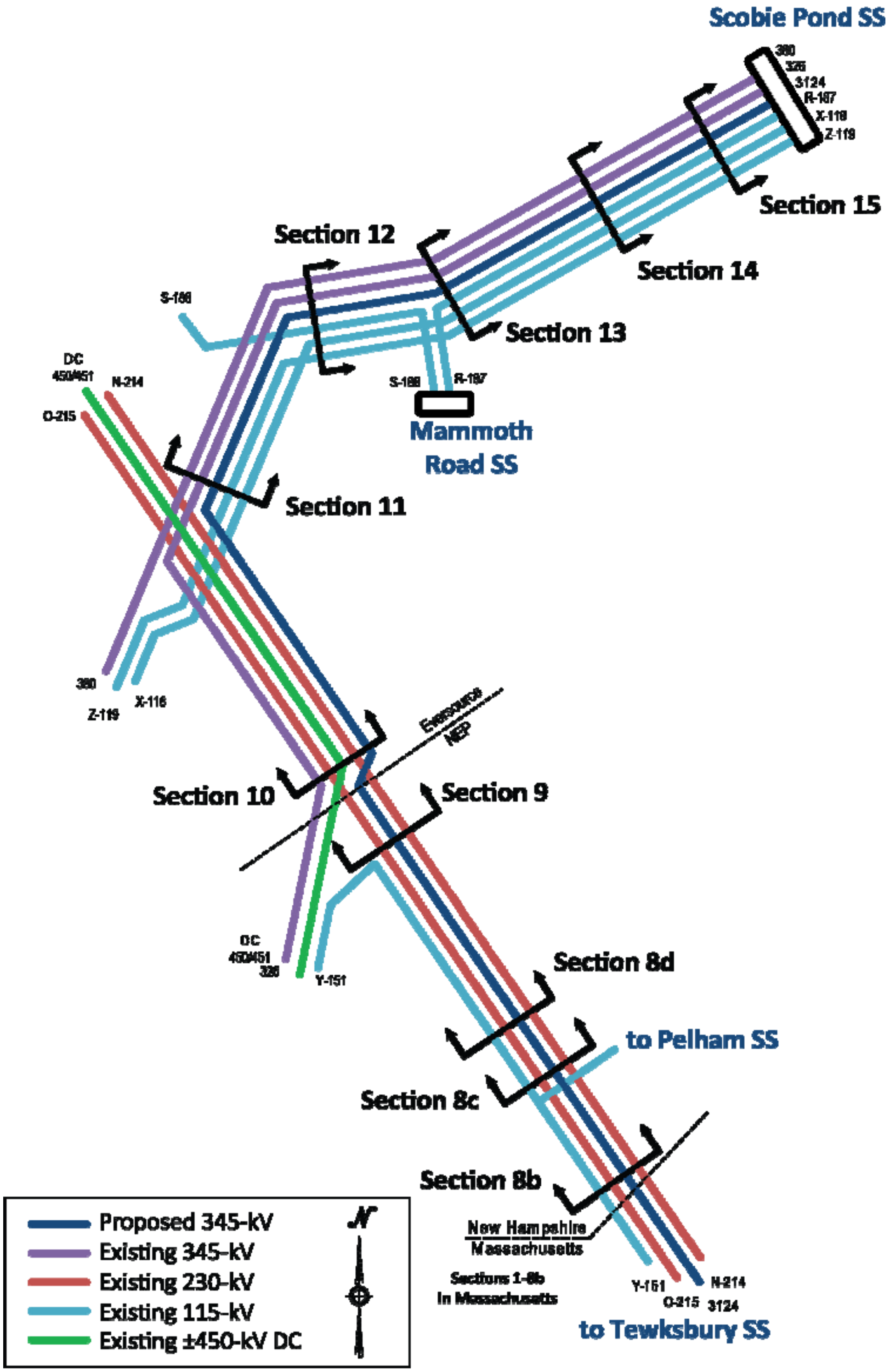

Figure 2. Schematic diagram of MVRP in New Hampshire (Segments 2 through 4) showing the locations of modeling Sections 8b through 15.

Note distribution circuits are not shown and Section lengths are not to scale.

Electrical Environment

The existing and proposed circuits along the route of the proposed MVRP are sources of 60-Hz EMF and corona phenomena such as AN and RN. To characterize the potential effect of the proposed construction on the existing levels of EMF, AN, and RN, Exponent modeled the levels of these parameters under existing and proposed conditions. The following is a brief description of these phenomena.

Electric and Magnetic Fields

Any source of electricity, such as transmission lines, distribution lines, household appliances, and equipment in our homes and workplaces, produces both electric and magnetic fields. Most electricity in North America is transmitted as AC at a frequency of 60 Hz (i.e., it changes direction and magnitude in a continuous cycle that repeats 60 times per second). The fields from these AC sources are commonly referred to as power-frequency or extremely low frequency (ELF) EMF.[4]

Electric Fields

Electric fields are created by voltage on the conductors of transmission lines. The strength of Project-related electric fields in this report is expressed in units of kilovolts per meter (kV/m), which is equal to 1,000 volts per meter (V/m). Most objects are conductive—including fences, shrubbery, and buildings—and thus they block electric fields.[5] In general, the intensity of an electric field diminishes with increasing distance from the source and in the case of transmission lines that decrease is typically in proportion to the square of the distance from the lines, so the electric-field level decreases rapidly with distance. The electric-field level increases as the voltage increases, and even if an appliance or electrical device is turned off, if the voltage is still present on the conductors, an electric field will be present.

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[4] The electric and magnetic fields described in this report are quasi-static ELF (non-propagating) fields, not to be confused with electromagnetic fields.

[5] Electric fields will penetrate a small distance into conductive objects; that depth depends on the frequency of the field and the conductivity of the material.

Magnetic Fields

Magnetic fields are created by current that flows in transmission line conductors. The strength of Project-related magnetic fields in this report is expressed as magnetic flux density in units of milligauss (mG), where 1 Gauss (G) = 1,000 mG. Magnetic fields, unlike electric fields, are not blocked by conductive objects; however, similar to electric fields, the intensity of magnetic fields diminishes with increasing distance from the source. In the case of transmission lines, magnetic fields also generally decrease with distance from the lines in proportion to the square of that distance.

Magnetic fields differ from electric fields because they depend on the current flowing through a conductor, rather than voltage, so if an appliance or electrical device is turned off, magnetic fields are not present even if it is still connected to the power source. Since current—expressed in units of amperes (A)—generates magnetic fields around transmission-line conductors, measurements or calculations of the magnetic field present only a snapshot at one moment of time because the current flow varies depending upon the patterns of power demand on the bulk transmission system. Power demand on a given day, throughout a week, or over the course of months and years can vary, so the magnetic field produced by the transmission line can also vary. Therefore, current flow is often expressed as annual average load (AAL), which is a good prediction of the magnetic field on any randomly selected day of the year, and also as annual peak load (the highest magnetic-field level that might occur for a few hours or days during the year). The forecasted AAL is used for modeling magnetic fields, while annual peak load is also calculated for reference.

Corona

When the electric field at a localized portion of the conductor surface exceeds the breakdown strength of air a process known as corona discharge occurs. During a corona discharge, a tiny amount of energy is released in the form of conductor vibration, light, AN, and RN. Corona activity depends on a number of factors: line voltage, conductor size, conductor geometry, altitude, irregularities on the line, and weather conditions. Both AN and RN from AC transmission lines are most pronounced during foul weather and increase with increasing altitude above sea level. Transmission lines are designed to be free of corona under ideal conditions (i.e., smooth conductors with no irregularities); therefore corona from AC transmission lines is less frequent during fair-weather conditions, and is typically a foul-weather phenomenon because the rain drops (or other forms of precipitation) themselves form protrusions that produce corona through the resulting localized electric-field enhancements.

Audible Noise

This phenomenon is a direct result of corona on AC transmission lines and is typically heard as a hissing, crackling sound that may be accompanied by a hum (120 Hz) during heavy corona activity in foul weather. The sound level from AN is measured in decibels (dB) referenced to 20 micropascals, which is approximately the pressure threshold of human hearing at 1 kilohertz (kHz) and is 0 decibels on the A-weighted scale (dBA).

The range of audible frequencies for the human ear is from approximately 20 Hz to 20 kHz, with peak sensitivity near 1 kHz. The change in sensitivity of the human ear with frequency is reflected in measurements by weighting the contribution of sound at different frequencies. Sound at low frequencies, such as 20 Hz, or high frequencies, such as 20 kHz, —where the ear is less sensitive—is given much less weight than at frequencies near 1 kHz, where the ear is most sensitive. The weighting of sound over the frequency spectrum to account for the sensitivity of the human ear is called the *A-weighted sound level* and the level is denoted by dB-A. AN levels that are commonly encountered can vary widely from a 20 to 30 dB to well over 100 dB. Several commonly encountered AN sources and the associated levels are listed in Table 1. The AN due to a transmission line is most pronounced directly underneath the line conductors, and decreases with distance from the transmission line.

Table 1. Commonly encountered acoustic sources and AN levels

Source	A-weighted sound level (dB-A)
Auto horn	110
Inside subway	95
Traffic	75
Conversation	65
Office	55
Living Room	45
Library	35
Bedroom	24

Corona-generated AN varies in time. In order to account for fluctuating sound levels, statistical descriptors, called exceedance levels (L-Levels) are used to describe environmental noise and refer to the A-weighted sound level that is exceeded for a specified percentage of the time. The L_5 exceedance level, for example, refers to the noise level that is exceeded 5 percent of the time; while L_{50} refers to the sound level exceeded 50 percent of the time. Sound-level measurements in this report are expressed in the L_{50} level (median level).

Radio Noise

The same corona phenomena on transmission line conductors that produces AN also generates RN. The RN from transmission line corona can result in broadband radiofrequency fields that can affect signal reception (particularly at frequencies near 1 megahertz [MHz]).[6] Like AN, RN is also affected by altitude and weather conditions.

RN levels in this report are expressed as dB above 1 microvolt per meter (dBμV/m) to describe the electric field intensity incident upon a reference antenna at 500 kHz as recommended by the Institute of Electrical and Electronics Engineers (IEEE) (IEEE 1971, 1986). In order to account

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[6] The magnitude of RN from a transmission line decreases rapidly with increasing frequency

for fluctuating noise levels, statistical descriptors are used to describe RN. RN levels in this report are expressed as 50 percent exceedance values (median or L_{50} values).[7]

While RN from a transmission line may exist at frequencies from 100 kHz to above 1,000 MHz, devices that operate at low frequencies are more susceptible to interference from RN, such as an amplitude-modulated commercial radio station that operates at 520 kHz to 1,720 kHz. In comparison, a frequency-modulated radio station that operates at approximately 88 MHz to 108 MHz generally is not affected by RN due to the method of modulation and because the frequency of operation is much higher than the frequencies where transmission line corona produces its greatest levels of RN.

RN can potentially interfere with the video portion of analog television signals. This is not of particular concern for the majority of television stations in the United States due to frequencies of television broadcasts and since the switchover from analog to digital broadcasting began in 1996 under the Digital Television Transition Act. Under this act, full-power television stations received an additional broadcast channel to run digital and analog broadcasts simultaneously. The deadline for full-power television stations to switch to digital was June 12, 2009, and the deadline for low-power television stations to switch to digital is September 1, 2015, after which RN is not expected to affect television reception.[8]

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[7] RN can also be generated by gap discharges, more common in distribution lines, in which discharges can occur where small gaps develop between metallic line hardware, such as insulators, clamps, or brackets. Gap discharges are less common on higher-voltage lines, and can be mitigated through the use of hardware designed to eliminate gap-type phenomena.

[8] http://www.fcc.gov/digital-television

Assessment Criteria

Electric and Magnetic Fields

Neither the federal government nor the state of New Hampshire has enacted standards for magnetic fields or electric fields from transmission lines or other sources at power frequencies. Some other states have statutes or guidelines that apply to fields produced by new transmission lines, but are not health-based guidelines. For example, New York and Florida have limits on EMF that were designed to limit fields from new transmission lines to levels produced by existing transmission lines, i.e., to maintain the *status quo* (FDER 1989; FDEP 1996; NYPSC 1978; NYPSC 1990).

Levels of EMF can also be assessed in terms of standards and guidelines developed by scientific and health agencies. Two authoritative international agencies that have published limits of exposure to 60-Hz EMF include the International Committee on Electromagnetic Safety (ICES) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The assessment levels set by these organizations are summarized in Table 2 below.[9]

Corona Phenomena

Levels of AN and RN from AC transmission lines are compared to guidelines developed by other governmental and professional organizations such as the US Environmental Protection Agency (USEPA) and the IEEE. The guideline levels for these phenomena are also summarized in Table 2.

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[9] ICNIRP and ICES exposure limits are based on internal doses (physical quantities inside the human body directly related to observed health effects) that should not be exceeded; these limits are called Basic Restrictions. Since internal doses are difficult to measure, Reference Levels or Maximum Permissible Exposures are also set for environmental exposures (2,000 mG and 4.2 kV/m for ICNIRP; 9,040 mG and 10 kV/m within the ROW for ICES). If Reference Levels or Maximum Permissible Exposures are not exceeded, it guarantees that the Basic Restrictions are also met. If environmental exposures, however, exceed the Reference Levels that does not mean that the Basic Restriction is exceeded; rather it means that additional dosimetric determination is needed, such as that performed in conjunction with Kavet et al. (2012).

Audible Noise

The EPA has established a guideline of 55 dBA for annual average day-night level (L_{dn}) in outdoor areas (USEPA, 1974). In computing this value, a 10-dB correction (penalty) is added to nighttime noise between 10:00 PM and 7:00 AM. Outdoor noise generally does not contribute to indoor levels, which are dominated by activities within a building or residence (USEPA, 1974).

Radio Noise

There are no regulations related to RN from transmission lines or related facilities in New Hampshire, nor does the federal government regulate RN from transmission lines. Typically, transmission-line operators look to the IEEE Radio Noise Design Guide (IEEE, 1971) to identify the acceptable level of average fair-weather RN. This design guide references a 61 dBµV/m level, measured at a frequency of 500 kHz and at a distance of 50 feet from the outside conductor, which has historically been found to be acceptable for other AC transmission lines.[10]

Summary of Assessment Criteria

The reference and threshold values listed in Table 2 are used as criteria for the evaluation of potential line designs and their potential effects on the electrical environment around transmission lines.

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[10] If the reception of a radio broadcast signal at a particular location is compromised by the installation of transmission lines, the effect can be mitigated by use of a directional antenna, relocation of an existing antenna, or other solutions (USDOE, 1977; USDOE, 1980; Loftness et al., 1981).

Table 2. Environmental assessment: Basic Restrictions on EMF exposure at 60 Hz and guidelines for AN and RN relevant to AC transmission lines

Electrical Parameter	Limit	Agency providing guideline (year)	Comment
Electric field	36.4 kV/m*	ICNIRP (2010)	General public exposure
	26.8 kV/m*	ICES (2002)	General public exposure
Magnetic field	12.4 G*	ICNIRP (2010)	General public exposure
	9.15 G*	ICES (2002)	
Audible noise	55 dBA†	EPA (1974)	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use
Radio noise	61 (dBμV/m)‡	IEEE (1971)	Measured at 15 meters (~50 feet) horizontally from the conductor in fair weather

* Health-based limits on fields, computed from Kavet et al. (2012) at 60 Hz.

† A 10 dB penalty is imposed during nighttime hours.

‡ The 1 MHz measurement frequency in IEEE (1971) was changed to 500 kHz by IEEE Radio Noise Measurement Standard 430-1986. The guideline has therefore been adjusted for frequency (calculations performed at 500 kHz) and receiver (-2 dB for 9 kHz bandwidth receiver) to update the guideline to present methods of measurement and calculation (500 kHz with CISPR receiver).

Methods

Calculations of EMF, AN, and RN

Based upon information provided by PSNH and NEP, Exponent has performed calculations of AC electric fields, magnetic fields, AN, and RN using computer algorithms developed for AC transmission lines by the Bonneville Power Administration (BPA), an agency of the U.S. Department of Energy (BPA, 1991). The inputs to the program include data regarding voltage, current flow, phasing, and conductor configurations.

In the model, simplifying assumptions are made in order to make the calculations more tractable for a large number of transmission line conductors and to yield conservative values. Each conductor is modeled as infinite in length at a fixed height above a flat earth (also assumed infinite in extent) and is assumed to be parallel to all other conductors. For EMF calculations, the conductor height above ground is taken at the point of lowest sag to ensure that the presented values are representative of the highest field levels that may be encountered beneath the line.[11] Although these assumptions simplify the calculations, they do not decrease the accuracy of the model and have been shown to accurately predict electric-field and magnetic-field levels measured near transmission lines (Chartier and Dickson, 1990; Perrin et al., 1991). Both electric- and magnetic-fields are calculated at a height of 1 meter (3.28 feet) above ground and are reported as the root mean square value of the field in accordance with IEEE Std. C95.3.1-2010 and IEEE Std. 644-2008.

The BPA computer algorithms also calculate AN and RN from AC transmission lines based upon empirical formulae developed from measurements made near high-voltage AC transmission lines (Chartier and Stearns, 1981; Chartier, 1983). These formulae for corona-generated AN and RN have also been compared to measurements throughout the United States and are shown to be accurate for replicating measured results (IEEE Committee Report, 1982; Olsen et al., 1992). The AN was calculated at a height of 1.5 meters (5 feet) above ground,

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[11] There are variations in the transmission line clearance height above ground due to the sag of the transmission lines over variable-height terrain, but EMF levels beneath the transmission lines will be lower where the clearance of the lines above ground is higher.

corresponding roughly to ear level, and results are reported in units of dBA. Calculations of RN were made assuming a receiving antenna height of 1 meter (3.28 feet) above ground and a frequency of 500 kHz in accordance with IEEE Std. 430-1986 and are reported in units of dBµV/m.

Calculations in Section 10

In Section 10 of the proposed route, there is an existing ±450-kV DC transmission line on the ROW. The electrical environment associated with a DC transmission line is characterized by DC electric fields, DC magnetic fields, and corona phenomena. DC electric fields and magnetic fields vary little over time, and thus have a frequency of ~0 Hz.[12] The static fields from a DC transmission line do not induce internal electric fields in a conductive object or body and do not contribute to the EMF effects from AC transmission lines and thus are considered and reported separately from AC fields from AC lines. The DC electric field and magnetic field from the ±450-kV DC line are not expected to change as a result of the Project and so are not discussed further in this report. The AN and RN from the DC transmission line, however, will add to the AN and RN from other lines (including the proposed 3132 Line) and so the combined contribution of the DC line as well as all existing and proposed AC lines was evaluated for the AN and RN.

The BPA algorithms used for calculations of EMF, AN, and RN for AC transmission lines are not suitable for calculations of DC transmission lines. Therefore, for Section 10 of the proposed line, calculations of AN and RN were performed using formulae developed at the Electric Power Research Institute's (EPRI) High Voltage Transmission Research Center and formalized in the EPRI TL Workstation (EPRI 1990, 1991). Measurements from reduced scale DC models and full scale DC test lines in the northeastern United States form the developmental basis for these algorithms (Comber, 1982; Johnson, 1983, 1988; EPRI, 1990).

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[12] Electric and magnetic fields associated with the operation of a DC transmission line are referred to as DC electric and magnetic fields or static electric and magnetic fields.

Similar to the other Sections, in Section 10 AN was calculated at a height of 5 feet, corresponding roughly to ear level, and RN was calculated for an antenna measurement height of 1 meter and frequency of 500 kHz, according to IEEE Std. 430-1986.[13]

Modeling Configurations

Data for modeling the transmission lines provided by PSNH and NEP included conductor configurations and loadings of the existing and proposed transmission lines.

Conductor Height

As described above, the modeling was performed assuming that the conductor is straight and flat at a fixed height above ground. This height above ground, however, changes with electrical current; as the current increases the temperature of the conductors also increases. This increased temperature leads to increased sag of the transmission lines and hence the minimum conductor height (the height used for modeling) above ground decreases. It is important to note that the conductors of the new transmission line (and other existing lines) have been selected such that their ampacity (current-carrying capacity) is far higher than what is expected during annual peak loading. Therefore, even under annual peak loading scenarios the height of the conductors will be very similar to that during AAL. Nevertheless, the height of transmission lines above ground was modeled at two heights in order to estimate the most conservative (highest) EMF levels associated with the Project—at average height, when modeling AAL, and at minimum height when modeling annual peak loading.[14]

Loading Scenarios for Magnetic Field Modeling

The magnitude of the magnetic field is proportional to the loading of the transmission lines and so was modeled for five separate scenarios:

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[13] The IEEE design guideline value for RN was extrapolated to 500 kHz for comparison to calculated values (IEEE, 1971).

[14] Average height is meant as sag for annual average load conditions and therefore conductor height above ground during these conditions. Minimum height is meant as maximum sag and therefore minimum conductor height above ground.

1. Pre-Project annual average loading (AAL) with conductors at average conductor height;
2. Pre-Project annual peak (2018) loading, with conductors at minimum conductor height;
3. Post-Project AAL with conductors at average conductor height;
4. Post-Project annual peak (2018) loading, with conductors at minimum conductor height; and
5. Post-Project annual peak (2023) loading, with conductors at minimum conductor height.

The loading of each modeled transmission line under each of the above loading scenarios is shown in Appendix C, Table C-2. The actual loading will vary based upon demand and so will vary throughout the course of the year, and even during different times of the day. The modeling scenarios of greatest interest, therefore, are those that are likely to apply on any particular day of the year. The scenario most likely to represent this is the AAL scenario in the pre-Project and post-Project configurations. These two scenarios are therefore presented in graphical figures (shown in Appendix B, Figures B-1 to B-10) and detailed analyses, while the annual peak load scenarios are presented only in tabular form (Appendix A, Table A-1).

Electric Field Modeling Scenarios

The electric-field level is determined primarily by the voltage, conductor spacing, and height above ground, not current flow. The transmission line voltage level is quite constant but, as described above, the conductor height above ground may vary with loading and thus indirectly affect the electric-field level. To evaluate this potential variation, electric-field calculations were performed for the same two modeling heights as for magnetic-field calculations. Electric-fields (assuming a 5% overvoltage condition for all AC conductors) are therefore reported for four scenarios:

1. Pre-Project configuration at average conductor height;
2. Pre-Project configuration at minimum conductor height;
3. Post-Project configuration at average conductor height; and
4. Post-Project configuration at minimum conductor height.

Similar to the magnetic-field calculations, the calculations of greatest interest are those that are likely to apply on any particular day of the year. The scenario most likely to represent the transmission lines (either in their pre-Project or post-Project configuration) is the average height scenario. The electric-field level at average height for both pre-Project and post-Project configurations is therefore presented in graphical figures (shown in Appendix B, Figures B-11 to B-20) and detailed analyses, while the minimum height scenarios are presented only in tabular form (Appendix A, Table A-2).

Audible Noise and Radio Noise Modeling Scenarios

AN and RN calculations are performed assuming the conductors are located at a single height above ground. In contrast to EMF calculations, which are performed assuming a midspan height, AN and RN levels at any particular location near the line will have contributions from corona activity all along the line and so are modeled at a height that accounts for the change in line height along the line consistent with past work (e.g., Chartier and Stearns, 1981). The modeling height used to represent this scenario (and used in all calculations herein) was calculated by adding one-third of the sag of the line to the midspan height at AAL.

As discussed above, a far more dominant factor for AN and RN is the weather. In foul weather levels of AN and RN from AC lines can be much higher than in fair weather. Levels of AN and RN were therefore evaluated at a single conductor height, as follows:

1. Pre-Project, fair weather;
2. Pre-Project, foul weather;
3. Post-Project fair weather; and
4. Post-Project foul weather.

The calculated AN and RN levels are summarized in tabular form (Appendix A, Tables A-3 and A-4, respectively) and in graphs (shown in Appendix B, Figures B-21 to B-30 for AN and Figures B-31 to B-40 for RN).

Phase Optimization

Where two AC transmission line circuits are located on the same ROW, the specific arrangement of the conductors of each circuit will have an effect on the calculated levels of electric fields, magnetic fields, AN, and RN. Exponent performed a phase-optimization analysis to evaluate the effect of line phasing on the magnetic-field level at the edges of the ROW.[15] In a phase optimization analysis, all possible phasing configurations of the new and reconfigured AC lines for a cross section are analyzed to identify the particular phasing that reduces the highest AC magnetic-field level at either ROW edge to a minimum level considering the magnetic-field contributions of all the AC lines on the ROW.[16] Phase optimization is one of the ways to minimize EMF levels consistent with recommendations to apply low cost measures (WHO, 2007). PSNH and NEP used the results of the phasing analysis and their assessment of the constructability of phase configurations to select the phasing of the new and rebuilt lines. The same phasing is not optimal in every section and the aggregate optimal phasing was determined by calculating a single phasing for post-Project AAL, which results in the minimum aggregate magnetic field at the edge of the ROW across all sections. When all sections are considered together, the aggregate optimal phasing of the 3124 Line (as depicted in Figures in Appendix B) is designated as C-B-A from west to east.[17]

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[15] In sections where no existing lines are rebuilt to accommodate the new 3124 Line (Sections 9 through 15), there are six phasing options. In Sections 8b through 8d the new 3124 Line and the existing Y-151 Line that is proposed to be rebuilt results in 36 phasing options.

[16] There is a tradeoff between minimizing the magnetic field at the ROW edge and the highest magnetic-field level on the ROW. There is also a tradeoff between minimizing the magnetic field and minimizing AN and RN.

[17] Other rebuilt lines were also analyzed to determine the aggregate optimal phasing in the sections in which they are planned to be rebuilt. These results are presented in more detail below in the Modeling Results section of the report.

Modeling Results

In all portions of the route where existing lines need to be relocated, the proposed 3124 Line is placed near the center of the ROW while a lower-voltage line is relocated nearer the ROW edge. This design decision to construct the proposed 3124 Line away from the ROW edges along the majority of the route combined with the use of optimal phasing of the proposed and rebuilt transmission lines results in minimal Project-related changes to EMF, AN, and RN levels at the ROW edge as described below in more detail.[18]

Since there were a large number of configurations modeled, summary tables depicting the values of each modeled parameter at specific locations on the ROW are presented in Appendix A, Tables A-1 through A-4. Graphs showing the calculated profiles are provided in Appendix B, for the magnetic field (Figures B-1 through B-10), electric field (Figures B-11 through B-20), AN (Figures B-21 through B-30), and RN (Figures B-31 through B-40).

Phase Optimization

Each of the proposed cross sections has at least two AC transmission lines and so they were analyzed to assess the potential magnetic-field reduction that could be achieved by phase optimization. PSNH and NEP used the results of the phasing analysis and their assessment of the constructability of phase configurations to select the phasing of the new and rebuilt lines.

The phasing of the 3124 Line was constrained to stay the same throughout the route (as well as in Segment 1 in Massachusetts, not discussed herein). Likewise, the phasing of the Y-151 Line was constrained to keep the same phasing in Sections 8b through 8d (as well as 8a, not discussed herein). The difference between optimal phasing and the phasing selected by PSNH and NEP for construction is indicated in Table 3, which shows that the selected phasing is within 5.5 mG of the optimal phasing in all cross sections.

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[18] For RN levels, the location where compliance with the guideline is assessed is 50 feet from the outside conductor, not the ROW edge.

Table 3. Optimization summary by route section

Section Number	Lines Optimized	# of Options Evaluated	Difference from Optimal
Section 8b	3124, Y-151	36	4.5 mG
Section 8c	3124, Y-151	36	2.0 mG
Section 8d	3124, Y-151	36	2.0 mG
Section 9	3124	6	5.5 mG
Section 10	3124	6	0*
Section 11	3124	6	0*
Section 12	3124	6	0*
Section 13	3124	6	0*
Section 14	3124	6	0*
Section 15	3124	6	0*

*The aggregate-optimal phasing of the 3124 line is also optimal in each of these sections.

Magnetic Fields

Calculated magnetic-field values for all sections are summarized in Appendix A, Table A-1, and plotted in graphs shown in Appendix B, Figures B-1 to B-10. The magnetic-field levels as a result of the Project operating at AAL are discussed below since these values are more informative for assessing exposures than magnetic-field levels at annual peak loading, which might apply only for a few hours or days in a year.

The highest magnetic field on the ROW under AAL conditions is calculated to decrease from approximately 151 mG in the pre-Project configuration (Section 10) to approximately 124 mG in the post-Project configuration (also Section 10).[19] The magnetic-field level is calculated to increase by up to 41 mG in some sections and decrease by more than 26 mG in other sections.

At the edge of ROW, the highest magnetic field on any section of the route is 29 mG in the pre-Project configuration and decreases by approximately 5 mG to approximately 24 mG in the post-Project configuration (both ROW edge maxima are in Sections 13 through 15).[20]

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[19] At annual peak loading the highest pre-Project magnetic-field level is approximately 311 mG (in Section 8c) and approximately 316 mG in the post-Project configuration (in Section 11).

[20] Similarly, the highest edge of ROW magnetic-field level at annual peak loading is calculated to decrease from approximately 109 mG to 82 mG (in Section 7).

Elsewhere, at the edges of the ROW where the pre-Project magnetic field is much lower, the magnetic field is calculated to increase at the most by 7.8 mG (east edge of Section 10).

Electric Fields

Calculated electric-field values for all sections are summarized in Appendix A, Table A-2, and plotted in graphs shown in Appendix B, Figures B-11 through B-20. For average conductor height, the highest calculated electric field on the ROW increases from approximately 5.2 kV/m in the pre-Project configuration to approximately 6.6 kV/m in the post-Project configuration. This peak electric field occurs in Sections 10 through 15 and is somewhat lower (approximately 4.3 kV/m) in other sections.[21] In all sections, the peak electric field occurs near the center of the ROW.

In Section 10, where the 3124 Line is proposed to be constructed approximately 85 feet from the eastern ROW edge, the edge of the ROW electric-field level is calculated to increase from approximately 0.1 kV/m to 1.2 kV/m. The electric field is slightly higher (approximately 1.3 kV/m) on the northwest ROW edge in Sections 13 through 15, but this is due to the existing 345-kV line and is relatively unchanged from pre-Project conditions.

Corona Phenomena

In contrast to EMF, which are vector quantities (with both magnitude and direction) and can therefore be reduced by a field in the opposite direction, AN and RN are scalar quantities (with only a magnitude and no direction) and the introduction of a new source (e.g., the proposed 3124 Line) will generally increase AN and RN levels on the ROW.

Audible Noise

Calculated AN levels for all sections are depicted in Appendix B, Figures B-20 to B-30, and are summarized in Appendix A, Table A-3. For the majority of the Project, the highest fair weather AN level is approximately 23 dBA (Sections 11 and 13 through 15). The maximum increase in

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[21] When the electric field is modeled at minimum height, the highest pre-Project field level is approximately 6.6 kV/m and increases to approximately 8 kV/m in the post-Project configuration. Complete tabular results are provided in Appendix B, Table B-2.

AN is approximately 2 dB, but is lower (e.g., 0-1 dB) in most locations. In Section 10, the fair weather AN is higher due to the presence of the DC line and is approximately 39 dBA at the ROW edge in both pre-Project and post-Project configurations. In foul weather, the AN from the AC lines would be approximately 25 dB higher than the calculated fair weather AN levels in all route sections.[22] To add this noise level to the ambient noise, it is first necessary to convert dB to sound pressure levels, add the two sound pressure levels together, and then convert back to dB. For example, if the ambient sound level is 40 dBA and the noise from the transmission line is also 40 dBA, then the total noise level will be approximately 43 dBA, which is 3 dB higher. This 3 dB change in the AN level is the 'just-noticeable-difference' necessary for the human ear to be able to detect a change in the AN level (Hansen, 2001). On the other hand, if the ambient sound level is 50 dBA and the contribution from the line is 40 dB, the total noise level will be 50.3 dBA. The increase in AN due to the contribution of the transmission line noise would be masked by the ambient noise and would not produce a noticeable difference.

Radio Noise

The RN levels calculated for all sections are depicted in Appendix B, Figures B-31 to B-40, and are summarized in Appendix A, Table A-4. The highest RN level at a distance of 50 feet from the outside conductor is approximately 44 dBμV/m in Sections 11 through 15 for both pre-Project and post-Project configurations. In foul weather, RN from AC lines would be approximately 17 dB higher in all route sections.[23]

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[22] For DC lines, AN levels are typically 6 dB lower during foul weather than in fair weather.

[23] For DC lines, RN levels are typically 6 dB lower in foul weather than in fair weather.

Comparison to Environmental Criteria and Discussion

Electric and Magnetic Fields

As described above, neither the federal government, nor the state of New Hampshire has standards for EMF. Therefore standards and guidelines developed by scientific and health agencies to protect health and safety that are based on reviews and evaluations of relevant health research were used as criteria for assessment of potential environmental effects. The calculated EMF values of all post-Project scenarios are below exposure levels that would cause the Basic Restrictions published by ICNIRP and ICES to be exceeded. The highest calculated AC magnetic-field level on the ROW along any portion of the route at AAL is 124 mG, more than 70 times lower than the exposure calculated to produce an internal electric field equal to the ICES Basic Restriction. In addition, the highest electric-field level calculated at average height is 6.6 kV/m, more than four times lower than the exposure level calculated to equal the Basic Restriction in either the ICNIRP or ICES guidelines.[24]

Audible Noise

The EPA guideline value for the annual average L_{dn} AN level in outdoor areas is 55 dBA (USEPA, 1974). In computing this value, a 10-dB correction (penalty) is added to night-time noise between the hours of 10:00 PM and 7:00 AM. The highest Post-Project median fair weather (L_{50}) AN level anywhere along the edge of the proposed route is 39 dBA (in Section 10). This is the most relevant condition for the evaluation of potential disturbance to the surrounding population because people are more likely to be outdoors in fair weather.

In foul weather, the highest level of AN at the ROW edge is 48 dBA (in Sections 11 and 13 through 15). This maximum level can be evaluated directly against the EPA guideline by estimating how often foul weather occurs and comparing this data to previous research, summarized in Table 4 which shows the difference between the L_{50} values and L_{dn} values, based upon different foul weather occurrence rates. Hourly precipitation data from the National

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[24] Under annual peak-loading conditions the highest electric field and magnetic field levels are 8.6 kV/m and 316 mG, respectively.

Climatic Data Center between December 31, 2008 and December 31, 2013 was used to assess the foul weather occurrence rate along the Project route.[25] The closest station with hourly precipitation data available is located in Durham, NH (NCDC Weather station COOP: 272174) which indicated precipitation of at least 1/10th of an inch occurred approximately 4% of the time. Based on the 4% foul weather occurrence rate reported by the Durham, NH, the L_{dn} level would be approximately 44 dBA.

More detailed weather information that includes the occurrence of even trace amounts of precipitation is available from Albany, NY[26] or Hartford CT[27] weather stations and indicates that the foul weather occurrence rate of 4% may be higher if smaller amounts of precipitation are included (e.g., considering trace amounts of precipitation, the foul weather rate would be 18% as reported by the Albany, NY site). Using this higher occurrence rate, which considers even trace amounts of precipitation, the resulting L_{dn} for MVRP is 49 dBA, which is still below the EPA L_{dn} guideline limit of 55 dBA.

Table 4. Correction factors to obtain equivalent sound levels (L_{eq}) and day-night sound level (L_{dn}) from median (L_{50}) foul weather transmission line sound level

	L_{dn}-L_{50} foul weather	
% Foul weather	**40 dBA ambient**	**No ambient**
0	-7.6	-17.6
1	-6.6	-12.0
5	-4.0	-6.0
10	-2.0	-2.9
18*	+0.5*	-0.2*
100	+6.7	+6.7

Source: Dietrich (1982)
* Interpolated from data in Dietrich (1982)

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[25] http://www.ncdc.noaa.gov/cdo-web/datasets. The most recent data available was December 31, 2013, and approximately 5 years of data were evaluated to determine this foul weather occurrence rate.

[26] NCDC Weather station COOP:300042 at the international airport in Albany, NY recorded at least 1/100th inch of precipitation in approximately 8% of the hours and 'trace' precipitation in an additional approximately 10% of the hours.

[27] NCDC Weather station COOP:063456 at the international airport in Hartford, CT recorded at least 1/100th inch of precipitation in approximately 8% of the hours and 'trace' precipitation in an additional approximately 7% of the hours.

In addition, the wind and rain that typically occur during foul weather are themselves likely to generate levels of AN (41-63 dBA) that are similar to or exceed the levels of AN from the transmission lines. The AN from the foul weather itself would therefore likely mask the noise from the transmission lines during these conditions (Miller, 1978).

Radio Noise

The state of New Hampshire has not enacted a limit for RN. Likewise, the Federal Communication Commission (FCC) Rules and Regulations (2010) contain no guideline for RN from transmission lines. Power transmission lines fall into the FCC category of "incidental radiator," which is defined as "a device that generates radio frequency energy during the course of its operation although the device is not intentionally designed to generate or emit radio frequency energy." Operation of an incidental radiator "is subject to the conditions that no harmful interference is caused and that interference must be accepted that may be caused by the operation of an authorized radio station, by another intentional or unintentional radiator, by industrial, scientific and medical (ISM) equipment, or by an incidental radiator." Section 15.1(m) of the FCC regulations defines "harmful interference" as "any emission, radiation or induction that endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radio communications service operating in accordance with this Chapter."

Historically, transmission lines have not had difficulty in operating under the FCC rules, since most sources of "harmful interference" from transmission lines in fair weather are due to gap-type discharges that can be identified and repaired (USDOE, 1980). Residences very near transmission lines, however, may be affected by corona-type RN in foul weather. For this reason, the IEEE Radio Noise Design Guide (IEEE, 1971) identifies an acceptable level of average fair-weather RN of 61 dBμV/m at 50 feet (15 meters) from the outside conductor.[28] As discussed above and shown in full detail in Appendix A, Table A-4, the highest fair-weather RN values at 50 feet from the outer conductor in the proposed configuration is 44 dBμV/m

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[28] The 1 MHz measurement frequency in IEEE (1971) was changed to 500 kHz by IEEE Radio Noise Measurement Standard 430-1986. The guideline has therefore been adjusted for frequency (calculations performed at 500 kHz) and receiver (-2 dB for 9 kHz bandwidth receiver) to update guideline to present methods of measurement and calculation (500 kHz with CISPR receiver).

(Sections 11 through 15). Therefore all calculated RN levels are far below the recommended level in all proposed cross sections.

Comparisons of Calculated Values to Environmental Criteria for Alternating Current Lines

A summary of the calculated values of EMF, AN, and RN are provided in Table 5, along with a direct comparison to the environmental levels (repeated from Table 2).

Table 5. Comparison of calculations for the proposed Project to environmental assessment criteria for AC electric field, magnetic field, audible noise, and radio noise

Environmental Assessment Criteria

	Magnetic Field (mG)		Electric Field (kV/m)		Fair Weather Audible Noise (dBA)	Fair Weather Radio Noise (dBμV/m)
Agency	ICNIRP (2010)	ICES (2002)	ICNIRP (2010)	ICES (2002)	EPA (1974)	IEEE (1971)
Limit	12,420*	9,150*	36.4*	26.8*	55[‡]	61[§]

Calculations for the Proposed Project

	Magnetic Field (mG)		Electric Field (kV/m)		Fair Weather Audible Noise (dBA)	Fair Weather Radio Noise (dBμV/m)
Section Number	ROW Edge[†]	Max on ROW[†]	ROW Edge[†]	Max on ROW[†]	ROW Edge	50 feet from conductor
Section 8b	**7.4** (31)	**75** (281)	**0.6** (0.9)	**4.3** (6.5)	20	41
Section 8c	**9.0** (42)	**75** (281)	**0.6** (0.9)	**4.3** (6.5)	20	41
Section 8d	**8.5** (38)	**75** (281)	**0.5** (0.7)	**4.3** (6.5)	20	41
Section 9	**8.6** (29)	**75** (281)	**0.6** (0.5)	**4.3** (6.5)	20	41
Section 10	**14** (44)	**124** (306)	**1.2** (1.1)	**6.6** (8.5)	39	42
Section 11	**23** (36)	**119** (316)	**1.2** (1.2)	**6.6** (8.6)	23	44
Section 12	**5.6** (12)	**120** (316)	**0.2** (0.2)	**6.6** (8.6)	20	44
Section 13	**24** (32)	**120** (313)	**1.3** (1.2)	**6.6** (8.6)	23	44
Section 14	**24** (32)	**120** (313)	**1.3** (1.2)	**6.6** (8.6)	23	44
Section 15	**24** (32)	**120** (313)	**1.3** (1.2)	**6.6** (8.6)	23	44

[*] Computed from Kavet et al. (2012) at 60 Hz.

[†] The calculated EMF values are presented for two scenarios (i) for AAL and average conductor height (shown in bold) and (ii) for annual peak loading and minimum conductor height (shown in parentheses)

[‡] Ldn level. A10 dB penalty is assessed during nighttime from 10pm to 7am.

[§] The 1 MHz measurement frequency in IEEE (1971) was changed to 500 kHz by IEEE Radio Noise Measurement Standard 430 -1986. The guideline has therefore been adjusted for frequency (calculations performed at 500 kHz) and receiver (-2 dB for 9 kHz bandwidth receiver) to update guideline to present methods of measurement and calculation (500 kHz with CISPR receiver).

Summary

This report summarizes calculations of the EMF, AN, and RN associated with existing and proposed transmission lines on the planned route of the 3124 Line between the Massachusetts/New Hampshire state line and the Scobie Pond Substation in Londonderry, New Hampshire. These calculations have been performed using methods that are accepted within the scientific and engineering community and which previously have been found to match well with measurements. These calculations have been compared to applicable standards or guidelines and found to be below recommended limits used to assess potential adverse impacts to environmental and public health.

Electric and magnetic fields: The highest EMF levels calculated on the ROW, both during AAL (6.6 kV/m; 124 mG) as well as at annual peak loading (8.6 kV/m, 316 mG) along any portion of the route are below the exposures calculated to induce electric fields in tissue equal to the ICES and ICNIRP Basic Restrictions on exposure, which are 26.8 kV/m and 9.15 G (for ICES) and 36.4 kV/m and 12.4 G (for ICNIRP). EMF levels at the ROW edges are either below pre-Project levels, or are negligibly higher. The highest EMF levels at the edge of the ROW in any section (1.3 kV/m and 24 mG for AAL and 1.2 kV/m and 44 mG for annual peak loading) are also far below the ICES and ICNIRP Basic Restrictions.

Audible Noise: The highest edge of ROW AN along the proposed route of the 3124 Line in New Hampshire due to the transmission lines is 39 dBA in fair weather and below the EPA guideline even when considering an ambient noise level of 40 dBA. In foul weather, the highest AN level would be approximately 48 dBA; however the wind and rain that typically occur during foul weather are themselves likely to generate ambient levels of AN (41-63 dBA) that are similar to or exceed the levels of AN from the transmission line and would likely mask the noise from the transmission lines during these conditions (Miller, 1978).

Radio Noise: The highest fair-weather RN value at 50 feet from the outer conductor anywhere along the route of the proposed 3124 Line (44 dBμV/m) is well below the IEEE guideline level of 61 dBμV/m.

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Appendix A

Summary Tables of Calculated EMF, AN, and RN in New Hampshire

- Electric-field levels were calculated for four scenarios:
    1. Pre-Project configuration at average conductor height
    2. Post-Project configuration at average conductor height
    3. Pre-Project configuration at minimum conductor height
    4. Post-Project configuration at minimum conductor height
- Magnetic-field levels were calculated for five scenarios:
    1. Pre-Project configuration at average conductor height and existing AAL
    2. Post-Project configuration at average conductor height and proposed AAL
    3. Pre-Project configuration at minimum conductor height and existing 2018 annual peak loading
    4. Post-Project configuration at minimum conductor height and proposed 2018 annual peak loading
    5. Post-Project configuration at minimum conductor height and proposed 2023 annual peak loading
- AN and RN were calculated for four scenarios, all at average height and 1/3 sag:
    1. Pre-Project fair weather
    2. Pre-Project foul weather
    3. Post-Project fair weather
    4. Post-Project foul weather

Table A-1. Magnetic field levels (mG) at AAL and annual peak loading.

Section Number	Condition	Distance from Centerline of ROW -ROW Edge -100 ft	-ROW Edge	Max on ROW	+ROW Edge	+ROW Edge +100 ft
8b	Pre-Project AAL	1.4	6.2	52	5.5	1.3
	Pre-Project annual peak (2018)	4.7	21	297	26	5.5
	Post-Project AAL	2.4	7.4	75	7.4	2.4
	Post-Project annual peak (2018)	6.1	29	278	28	7.3
	Post-Project annual peak (2023)	6.2	31	281	28	7.4
8c	Pre-Project AAL	1.4	6.2	71	5.5	1.4
	Pre-Project annual peak (2018)	4.8	21	311	26	5.5
	Post-Project AAL	2.3	9.0	75	7.4	2.4
	Post-Project annual peak (2018)	6.2	39	278	28	7.2
	Post-Project annual peak (2023)	6.2	41	281	28	7.4
8d	Pre-Project AAL	1.9	7.3	60	6.6	1.8
	Pre-Project annual peak (2018)	6.5	25	285	30	7.3
	Post-Project AAL	2.3	8.5	75	7.4	2.4
	Post-Project annual peak (2018)	6.1	36	278	28	7.2
	Post-Project annual peak (2023)	6.2	38	281	28	7.4
9	Pre-Project AAL	1.6	6.5	34	5.7	1.4
	Pre-Project annual peak (2018)	5.3	23	292	28	6.1
	Post-Project AAL	2.6	8.6	75	7.4	2.4
	Post-Project annual peak (2018)	7.3	27	278	28	7.4
	Post-Project annual peak (2023)	7.5	28	280	29	7.6
10	Pre-Project AAL	0.7	5.3	151	6.0	2.4
	Pre-Project annual peak (2018)	4.2	20	261	5.6	1.9
	Post-Project AAL	1.2	5.8	124	14	2.1
	Post-Project annual peak (2018)	5.5	22	289	42	8.8
	Post-Project annual peak (2023)	5.4	22	306	44	9.2

Section Number	Condition	Distance from Centerline of ROW				
		-ROW Edge -100 ft	-ROW Edge	Max on ROW	+ROW Edge	+ROW Edge +100 ft
11	Pre-Project AAL	7.6	28	139	10	2.1
	Pre-Project annual peak (2018)	11	44	234	30	3.0
	Post-Project AAL	5.6	23	119	11	1.3
	Post-Project annual peak (2018)	6.1	32	300	35	4.9
	Post-Project annual peak (2023)	6.1	31	316	36	5.1
12	Pre-Project AAL	3.5	7.6	140	3.3	1.1
	Pre-Project annual peak (2018)	5.1	11	233	7.3	1.7
	Post-Project AAL	2.4	5.6	120	4.7	0.9
	Post-Project annual peak (2018)	2.5	6.4	300	11	2.5
	Post-Project annual peak (2023)	2.4	6.3	316	11	2.7
13	Pre-Project AAL	7.6	29	140	11	0.8
	Pre-Project annual peak (2018)	11	44	234	20	1.7
	Post-Project AAL	5.6	24	120	13	1.2
	Post-Project annual peak (2018)	6.1	32	296	23	4.0
	Post-Project annual peak (2023)	6.0	32	313	24	4.2
14	Pre-Project AAL	7.7	29	140	3.1	1.3
	Pre-Project annual peak (2018)	11	44	234	8.7	1.6
	Post-Project AAL	5.7	24	120	4.5	1.0
	Post-Project annual peak (2018)	6.1	32	296	13	3.2
	Post-Project annual peak (2023)	6.1	32	313	13	3.4
15	Pre-Project AAL	7.6	29	140	7.5	0.9
	Pre-Project annual peak (2018)	11	44	234	15	1.6
	Post-Project AAL	5.6	24	120	9.1	1.1
	Post-Project annual peak (2018)	6.1	32	296	19	3.8
	Post-Project annual peak (2023)	6.0	32	313	20	4.0

Table A-2. Electric-field levels (kV/m) at average and minimum conductor height

		Distance from Centerline of ROW				
Section Number	**Condition**	**-ROW Edge -100 ft**	**-ROW Edge**	**Max on ROW**	**+ROW Edge**	**+ROW Edge +100 ft**
8b	Pre-Project (average height)	0.1	0.5	2.7	0.5	0.1
	Pre-Project (minimum height)	0.0	0.4	6.5	0.4	0.0
	Post-Project (average height)	0.1	0.6	4.3	0.5	0.1
	Post-Project (minimum height)	0.1	0.9	6.5	0.4	0.0
8c	Pre-Project (average height)	0.1	0.5	2.7	0.5	0.1
	Pre-Project (minimum height)	0.0	0.4	6.5	0.4	0.0
	Post-Project (average height)	0.1	0.6	4.3	0.5	0.1
	Post-Project (minimum height)	0.1	0.9	6.5	0.4	0.0
8d	Pre-Project (average height)	0.1	0.5	2.7	0.5	0.1
	Pre-Project (minimum height)	0.0	0.4	6.4	0.4	0.0
	Post-Project (average height)	0.1	0.5	4.3	0.5	0.1
	Post-Project (minimum height)	0.1	0.7	6.5	0.4	0.0
9	Pre-Project (average height)	0.1	0.5	2.6	0.5	0.1
	Pre-Project (minimum height)	0.0	0.4	6.4	0.4	0.0
	Post-Project (average height)	0.1	0.6	4.3	0.5	0.1
	Post-Project (minimum height)	0.1	0.5	6.5	0.4	0.0
10	Pre-Project (average height)	0.1	0.6	5.2	0.1	0.0
	Pre-Project (minimum height)	0.1	0.5	7.3	0.1	0.0
	Post-Project (average height)	0.1	0.6	6.6	1.2	0.1
	Post-Project (minimum height)	0.1	0.5	8.5	1.1	0.1
11	Pre-Project (average height)	0.2	1.2	5.0	0.5	0.0
	Pre-Project (minimum height)	0.1	1.2	7.1	0.5	0.0
	Post-Project (average height)	0.2	1.2	6.6	0.4	0.0
	Post-Project (minimum height)	0.1	1.2	8.6	0.5	0.0

Section Number	Condition	Distance from Centerline of ROW				
		-ROW Edge -100 ft	-ROW Edge	Max on ROW	+ROW Edge	+ROW Edge +100 ft
12	Pre-Project (average height)	0.1	0.2	5.0	0.1	0.0
	Pre-Project (minimum height)	0.0	0.1	7.1	0.1	0.0
	Post-Project (average height)	0.1	0.2	6.6	0.2	0.0
	Post-Project (minimum height)	0.0	0.1	8.6	0.2	0.0
13	Pre-Project (average height)	0.2	1.3	5.0	0.2	0.0
	Pre-Project (minimum height)	0.1	1.2	7.1	0.2	0.0
	Post-Project (average height)	0.2	1.3	6.6	0.2	0.0
	Post-Project (minimum height)	0.1	1.2	8.6	0.2	0.0
14	Pre-Project (average height)	0.2	1.3	5.0	0.1	0.0
	Pre-Project (minimum height)	0.1	1.2	7.1	0.1	0.0
	Post-Project (average height)	0.2	1.3	6.6	0.1	0.0
	Post-Project (minimum height)	0.1	1.2	8.6	0.1	0.0
15	Pre-Project (average height)	0.2	1.3	5.0	0.1	0.0
	Pre-Project (minimum height)	0.1	1.2	7.1	0.1	0.0
	Post-Project (average height)	0.2	1.3	6.6	0.1	0.0
	Post-Project (minimum height)	0.1	1.2	8.6	0.1	0.0

Table A-3. Median audible noise levels due to the lines in fair and foul weather (dBA)

Section Number	Condition	Distance from Centerline of ROW -ROW Edge -100 ft	-ROW Edge	Max on ROW	+ROW Edge	+ROW Edge +100 ft
8b	Pre-Project in fair weather	15	18	22	18	15
	Pre-Project in foul weather	40	43	47	43	40
	Post-Project in fair weather	17	20	24	20	17
	Post-Project in foul weather	42	45	49	45	42
8c	Pre-Project in fair weather	15	18	22	18	15
	Pre-Project in foul weather	40	43	47	43	40
	Post-Project in fair weather	17	20	24	20	17
	Post-Project in foul weather	42	45	49	45	42
8d	Pre-Project in fair weather	15	18	22	18	15
	Pre-Project in foul weather	40	43	47	43	40
	Post-Project in fair weather	17	20	24	20	17
	Post-Project in foul weather	42	45	49	45	42
9	Pre-Project in fair weather	15	18	22	18	15
	Pre-Project in foul weather	40	43	47	43	40
	Post-Project in fair weather	17	20	24	20	17
	Post-Project in foul weather	42	45	49	45	42
10*	Pre-Project in fair weather	36	39	43	36	34
	Pre-Project in foul weather	44	47	51	45	42
	Post-Project in fair weather	36	39	43	37	34
	Post-Project in foul weather	44	47	51	45	43
11	Pre-Project in fair weather	20	23	27	18	17
	Pre-Project in foul weather	45	48	52	43	42
	Post-Project in fair weather	20	23	27	19	17
	Post-Project in foul weather	45	48	52	44	42

Section Number	Condition	Distance from Centerline of ROW -ROW Edge -100 ft	-ROW Edge	Max on ROW	+ROW Edge	+ROW Edge +100 ft
12	Pre-Project in fair weather	18	20	27	17	16
	Pre-Project in foul weather	43	45	52	42	41
	Post-Project in fair weather	18	20	27	17	16
	Post-Project in foul weather	43	45	52	42	41
13	Pre-Project in fair weather	20	23	27	17	16
	Pre-Project in foul weather	45	48	52	42	41
	Post-Project in fair weather	20	23	27	17	16
	Post-Project in foul weather	45	48	52	42	41
14	Pre-Project in fair weather	20	23	27	17	16
	Pre-Project in foul weather	45	48	52	42	41
	Post-Project in fair weather	20	23	27	17	16
	Post-Project in foul weather	45	48	52	42	41
15	Pre-Project in fair weather	20	23	27	17	16
	Pre-Project in foul weather	45	48	52	42	41
	Post-Project in fair weather	20	23	27	17	16
	Post-Project in foul weather	45	48	52	42	41

* In Segment 10, all calculations of AN and RN are made with the EPRI/HVTRC method to account for the existing DC line in this segment.

Table A-4. Median radio noise levels due to lines in fair and foul weather (dBA)

		Distance from Centerline of ROW				
Section Number	Condition	-50 ft from outside conductor†	-ROW Edge	Max on ROW	+ROW Edge	+50 ft from outside conductor†
8b	Pre-Project in fair weather	41	39	55	39	41
	Pre-Project in foul weather	58	56	72	56	58
	Post-Project in fair weather	34	39	55	39	41
	Post-Project in foul weather	51	56	72	56	58
8c	Pre-Project in fair weather	41	39	55	39	41
	Pre-Project in foul weather	58	56	72	56	58
	Post-Project in fair weather	34	39	55	39	41
	Post-Project in foul weather	51	56	72	56	58
8d	Pre-Project in fair weather	41	39	55	39	41
	Pre-Project in foul weather	58	56	72	56	58
	Post-Project in fair weather	34	39	55	39	41
	Post-Project in foul weather	51	56	72	56	58
9	Pre-Project in fair weather	41	39	55	39	41
	Pre-Project in foul weather	58	56	72	56	58
	Post-Project in fair weather	41	38	55	39	41
	Post-Project in foul weather	58	55	72	56	58
10*	Pre-Project in fair weather	42	39	64	27	47
	Pre-Project in foul weather	61	58	78	44	64
	Post-Project in fair weather	41	39	64	40	42
	Post-Project in foul weather	60	58	77	57	59
11	Pre-Project in fair weather	44	42	58	26	25
	Pre-Project in foul weather	61	59	75	43	42
	Post-Project in fair weather	44	42	58	26	25
	Post-Project in foul weather	61	59	75	43	42

		Distance from Centerline of ROW				
Section Number	**Condition**	**-50 ft from outside conductor†**	**-ROW Edge**	**Max on ROW**	**+ROW Edge**	**+50 ft from outside conductor†**
12	Pre-Project in fair weather	44	31	58	22	23
	Pre-Project in foul weather	61	48	75	39	40
	Post-Project in fair weather	44	31	58	23	23
	Post-Project in foul weather	61	48	75	40	40
13	Pre-Project in fair weather	44	42	58	22	23
	Pre-Project in foul weather	61	59	75	39	40
	Post-Project in fair weather	44	43	58	23	23
	Post-Project in foul weather	61	60	75	40	40
14	Pre-Project in fair weather	44	42	58	22	23
	Pre-Project in foul weather	61	59	75	39	40
	Post-Project in fair weather	44	43	58	23	23
	Post-Project in foul weather	61	60	75	40	40
15	Pre-Project in fair weather	44	43	58	23	23
	Pre-Project in foul weather	61	60	75	40	40
	Post-Project in fair weather	44	43	58	23	23
	Post-Project in foul weather	61	60	75	40	40

* In Segment 10, all calculations of AN and RN are made with the EPRI/HVTRC method to account for the existing DC line in this segment.

† The distance of ±50 feet from the outside conductor will change from section to section and also from pre-Project to post-Project configurations. The RN values listed in this column therefore are not always positioned at the same location for pre-Project and post-Project conditions

Appendix B

Graphical Profiles of Calculated EMF, AN, and RN in New Hampshire

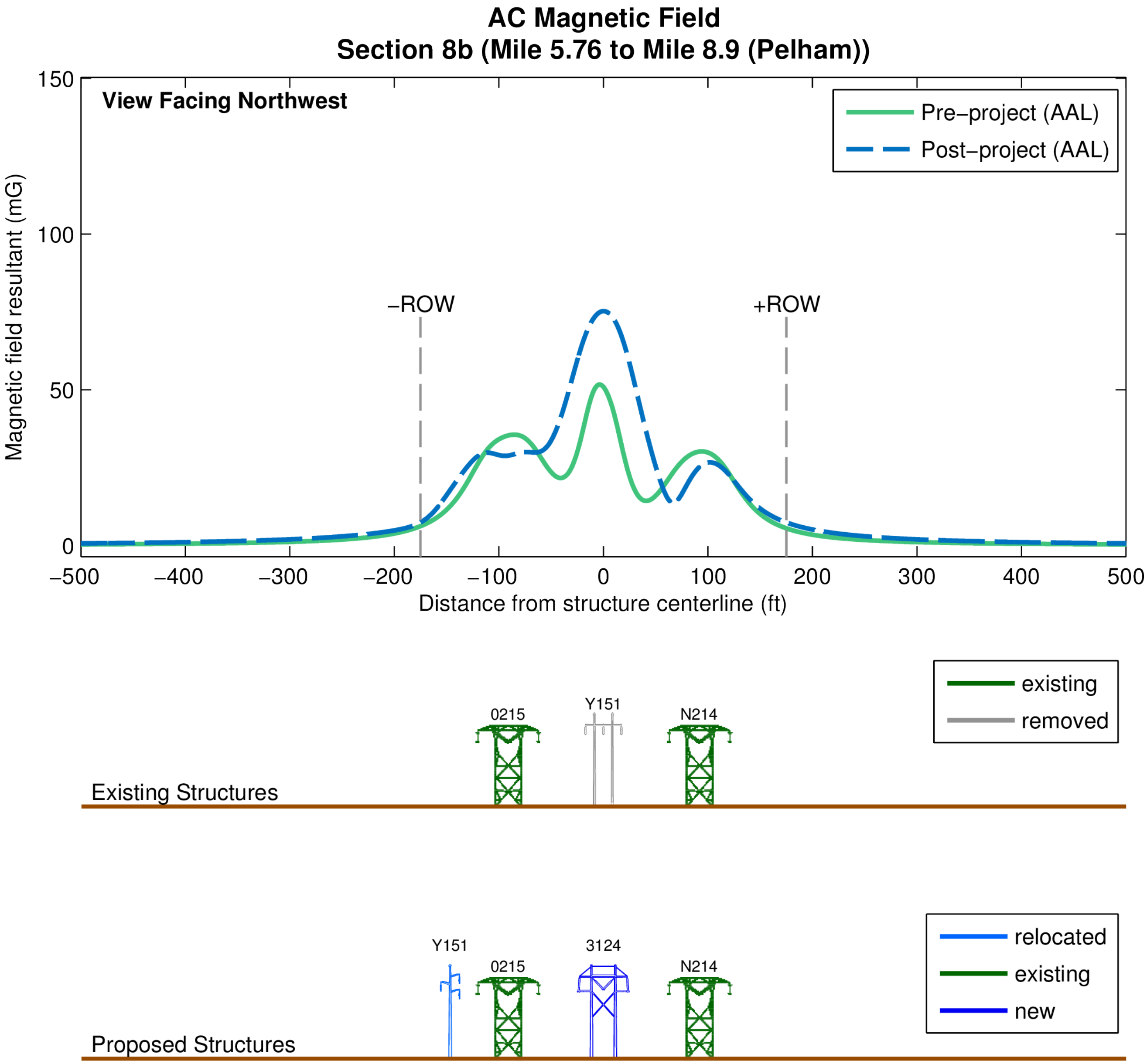

Figure B-1. AC magnetic field profile along Section 8b (Mile 5.76 to Mile 8.9 (Pelham)).

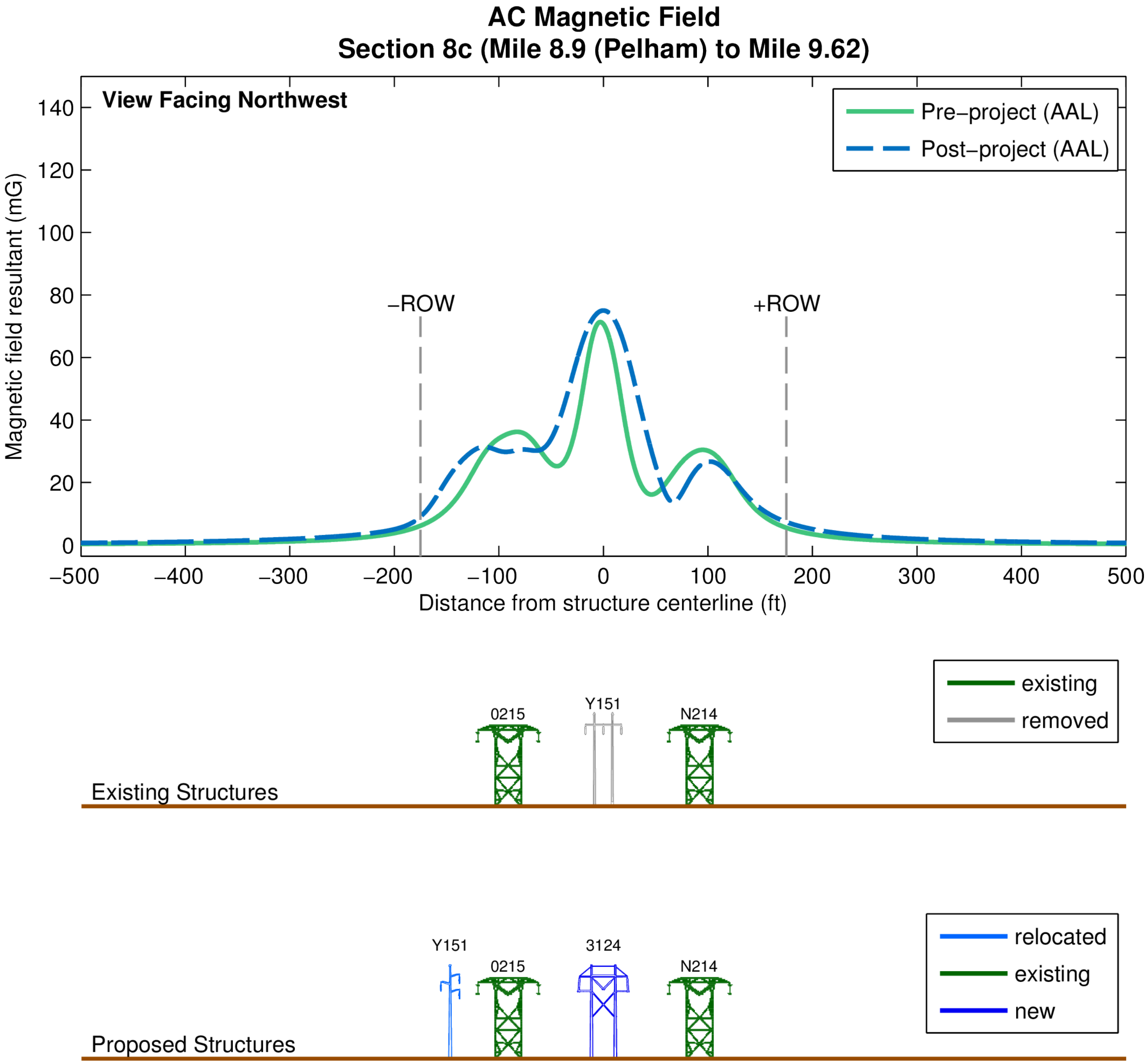

Figure B-2. AC magnetic field profile along Section 8c (Mile 8.9 (Pelham) to Mile 9.62).

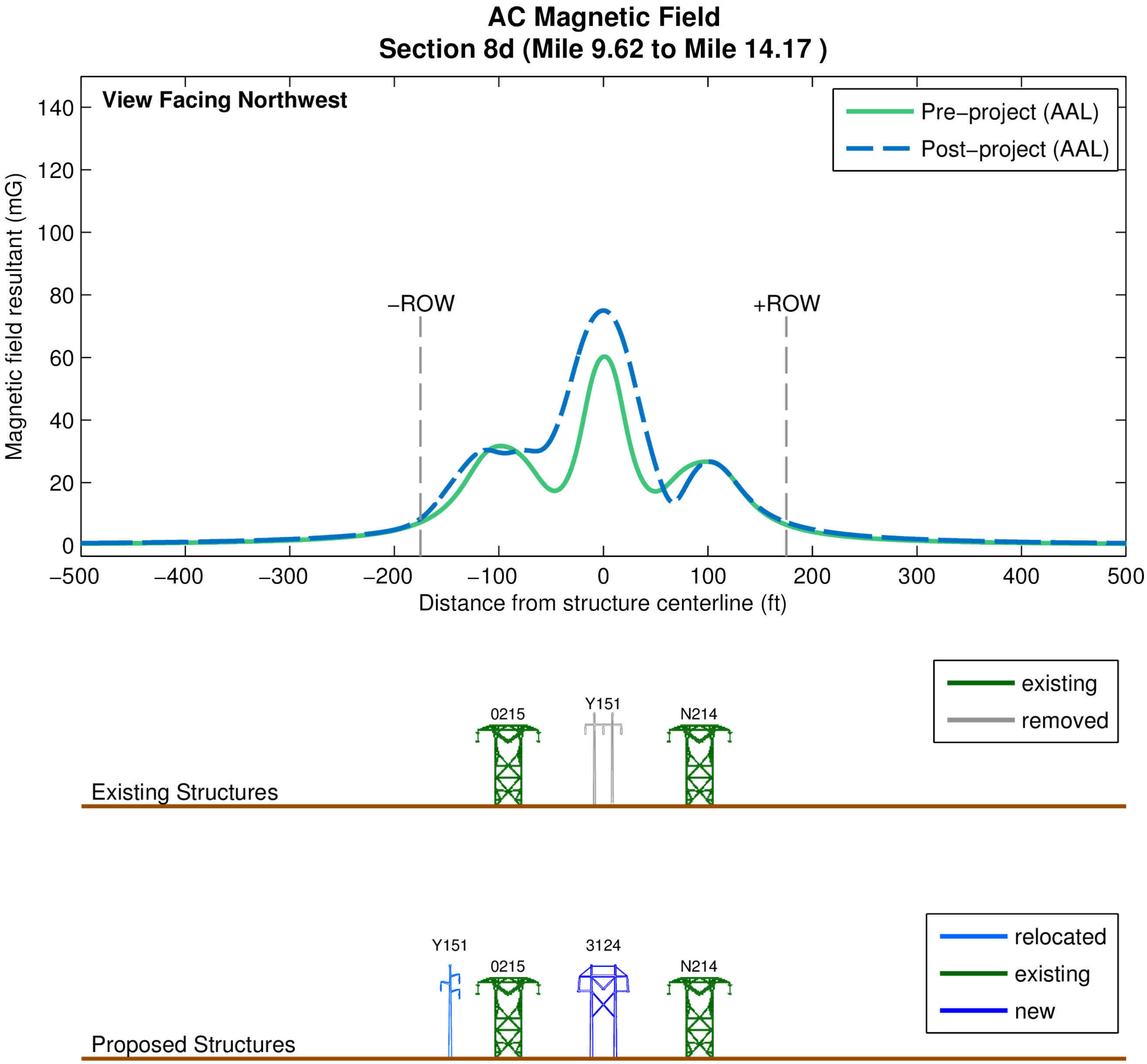

Figure B-3. AC magnetic field profile along Section 8d (Mile 9.62 to Mile 14.17).

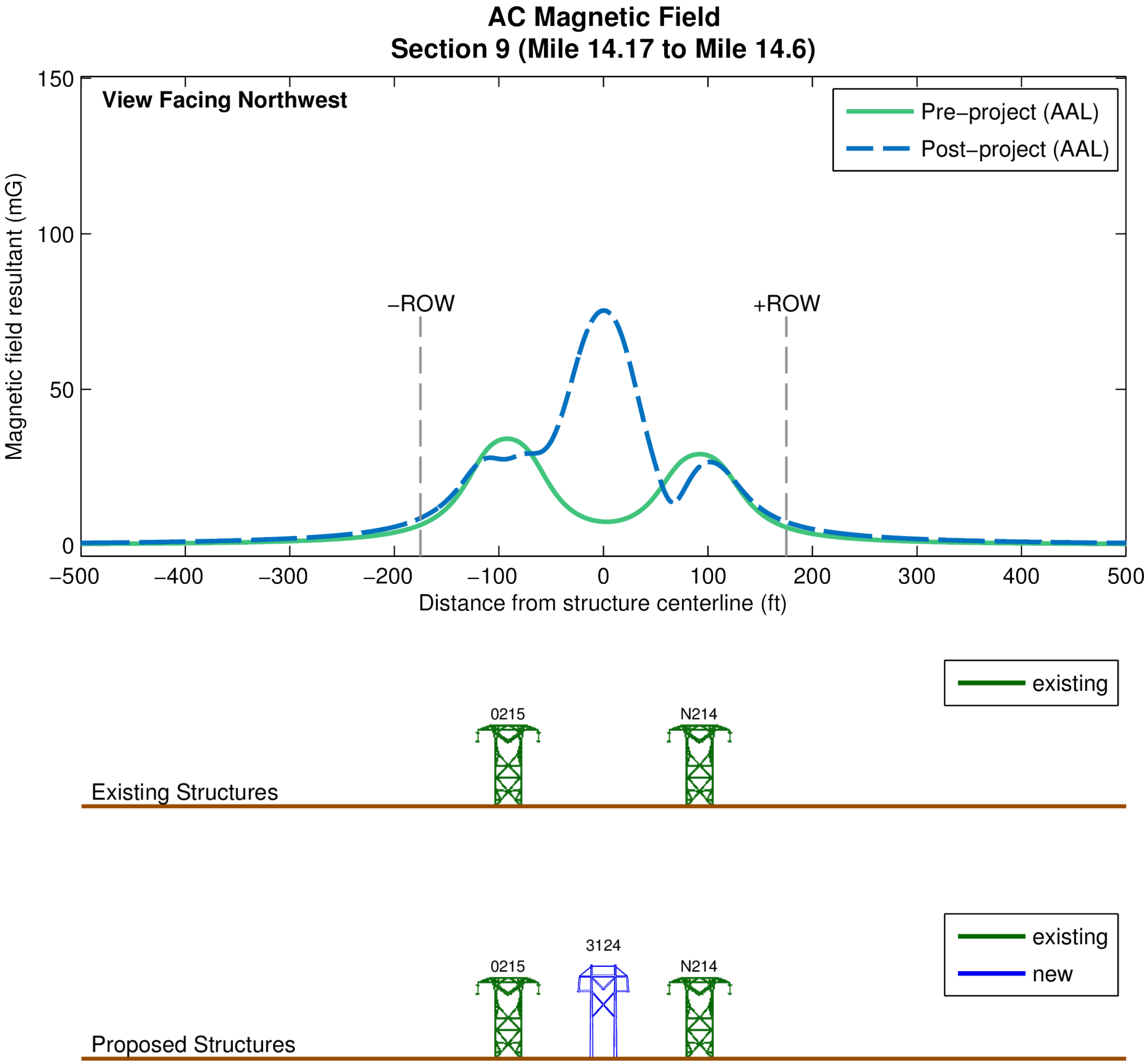

Figure B-4. AC magnetic field profile along Section 9 (Mile 14.17 to Mile 14.6).

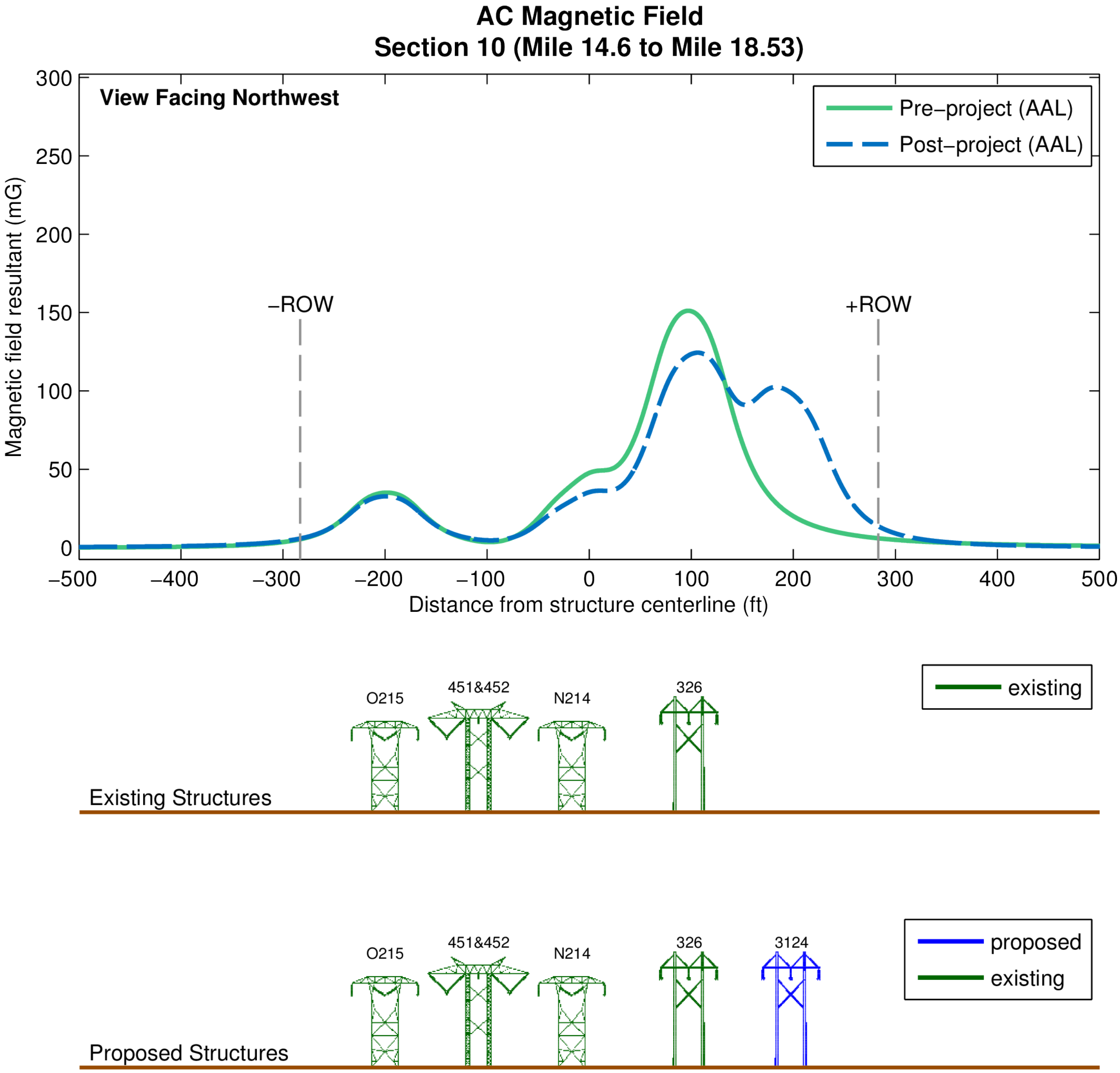

Figure B-5. AC magnetic field profile along Section 10 (Mile 14.6 to Mile 18.53).

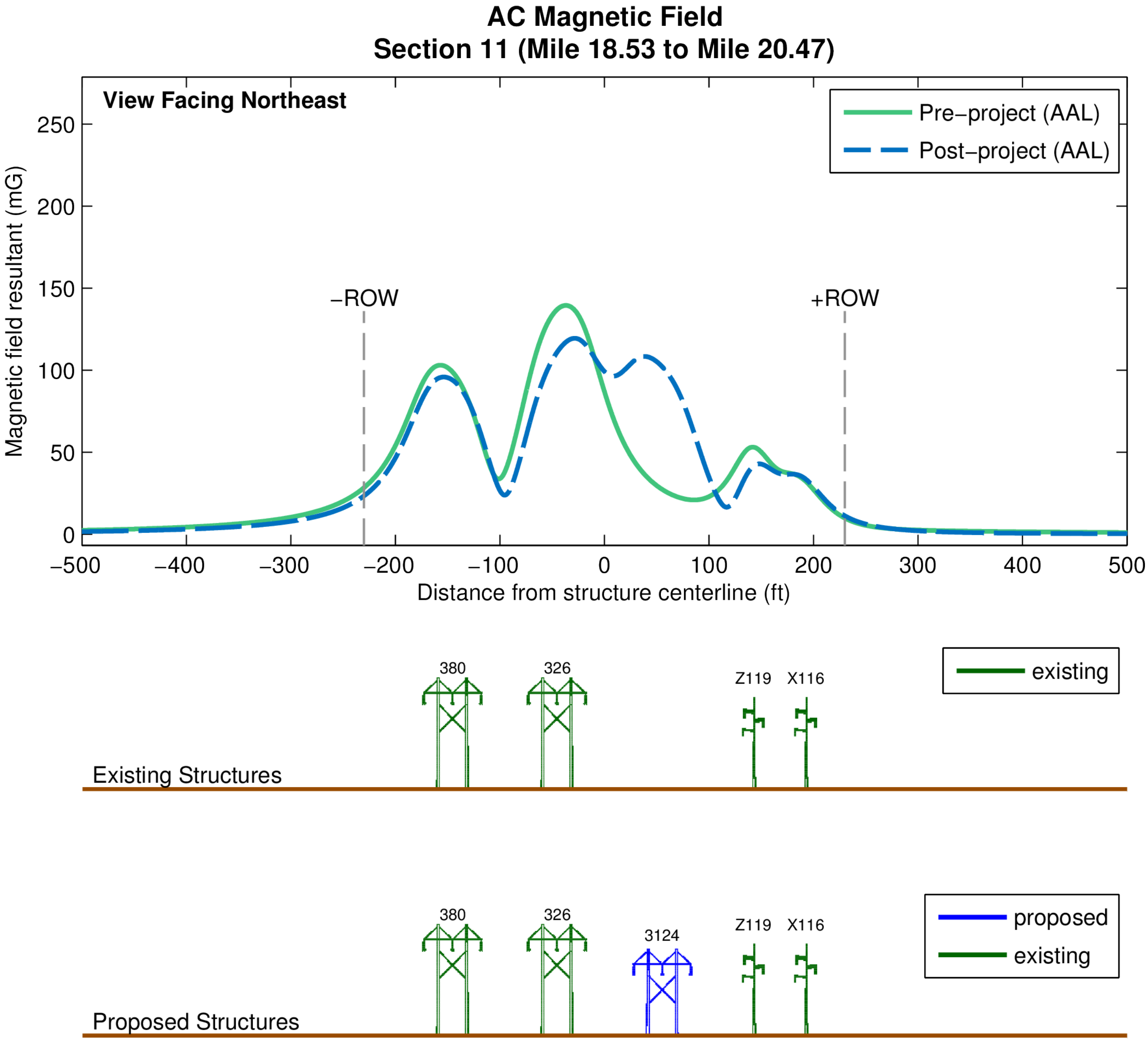

Figure B-6. AC magnetic field profile along Section 11 (Mile 18.53 to Mile 20.47).

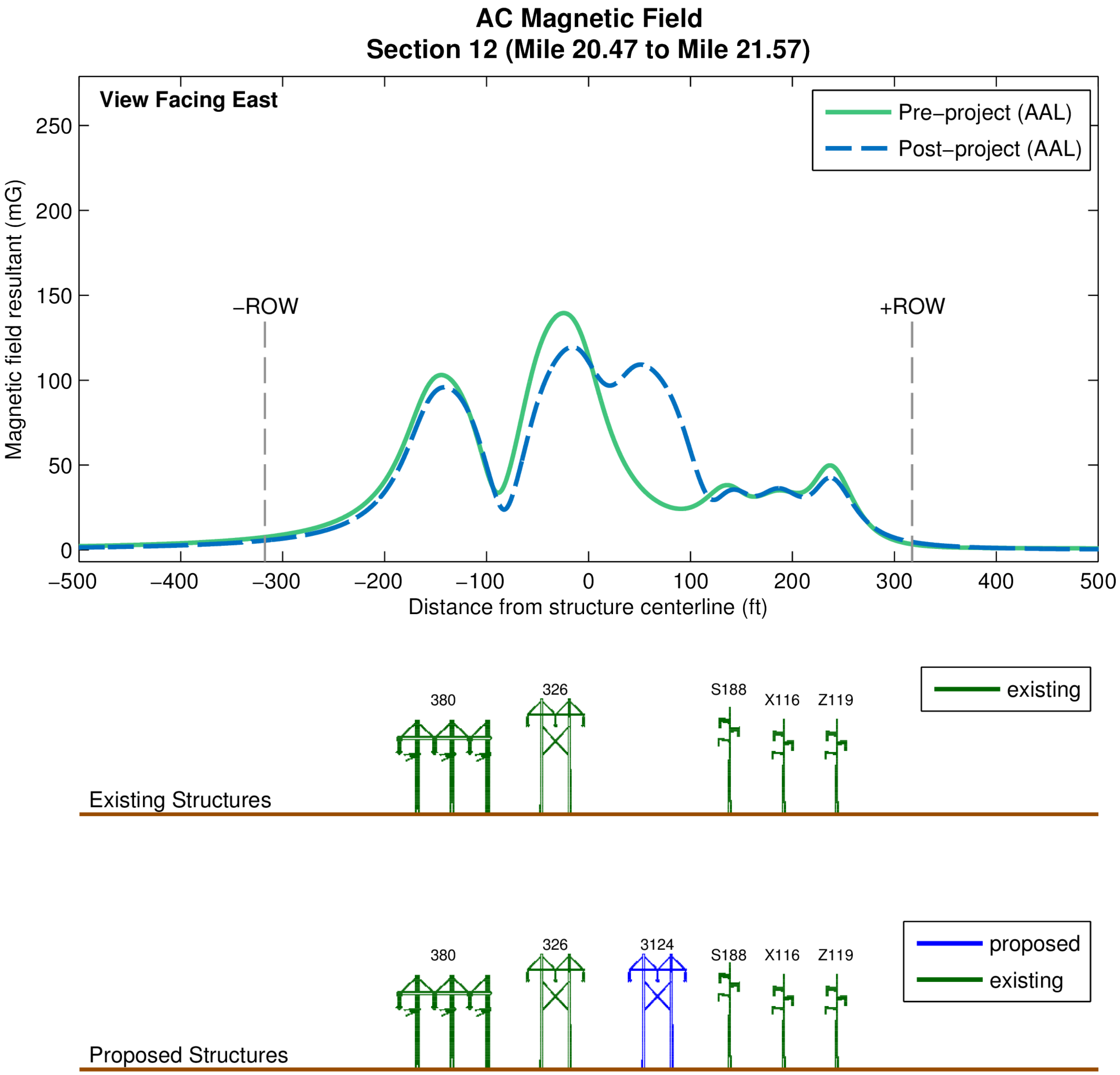

Figure B-7. AC magnetic field profile along Section 12 (Mile 20.47 to Mile 21.57).

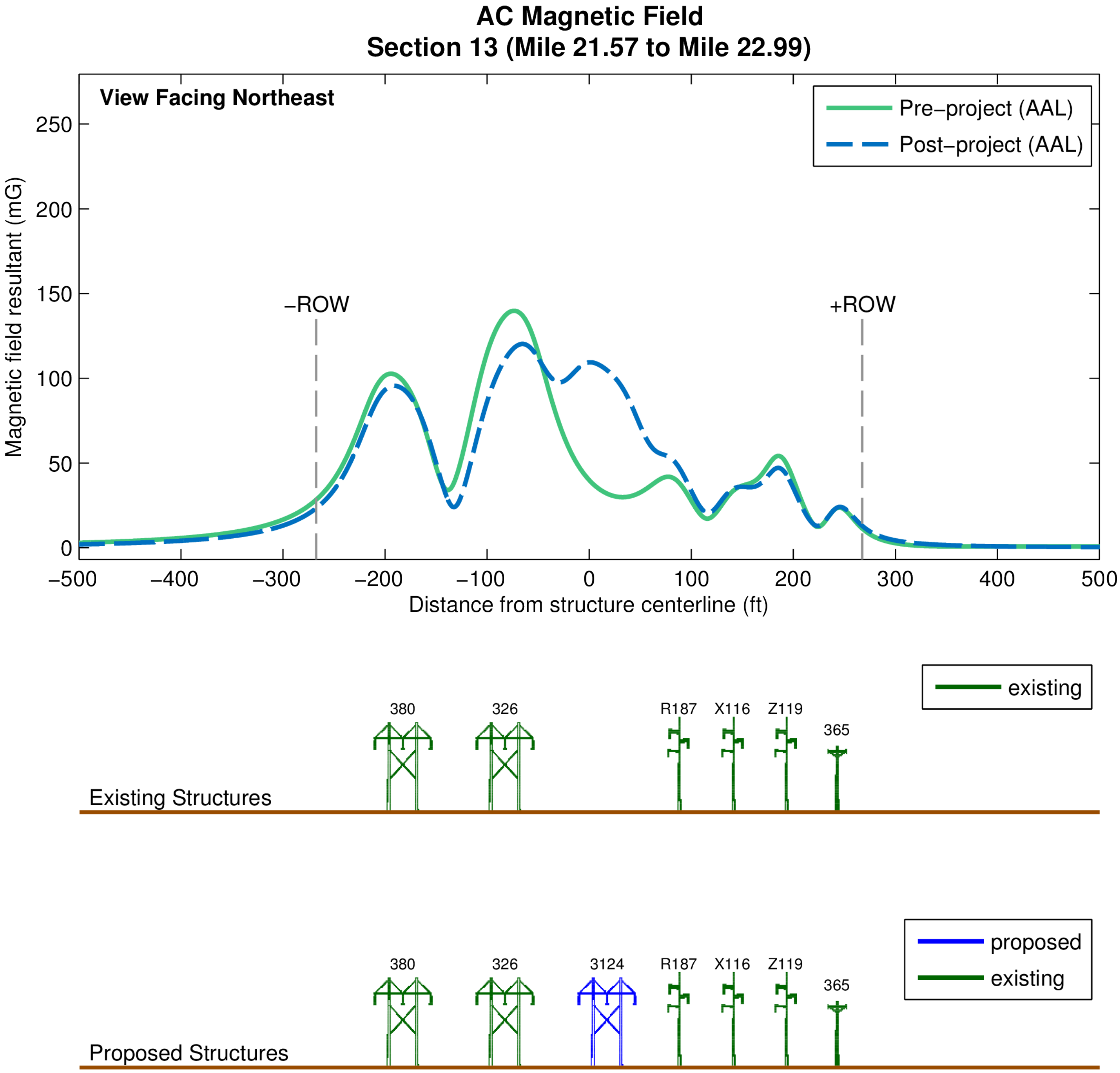

Figure B-8. AC magnetic field profile along Section 13 (Mile 21.57 to Mile 22.99).

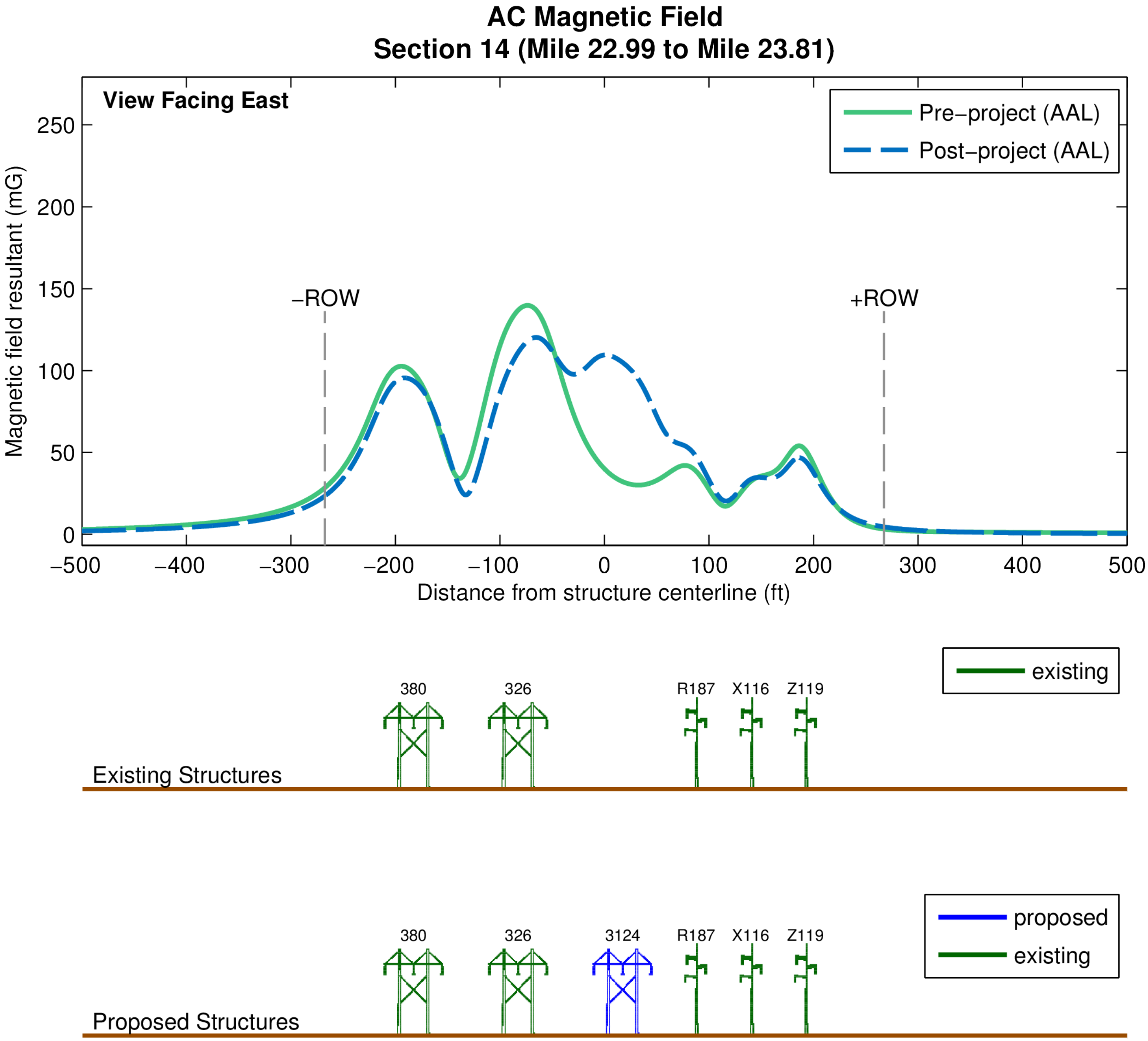

Figure B-9. AC magnetic field profile along Section 14 (Mile 22.99 to Mile 23.81).

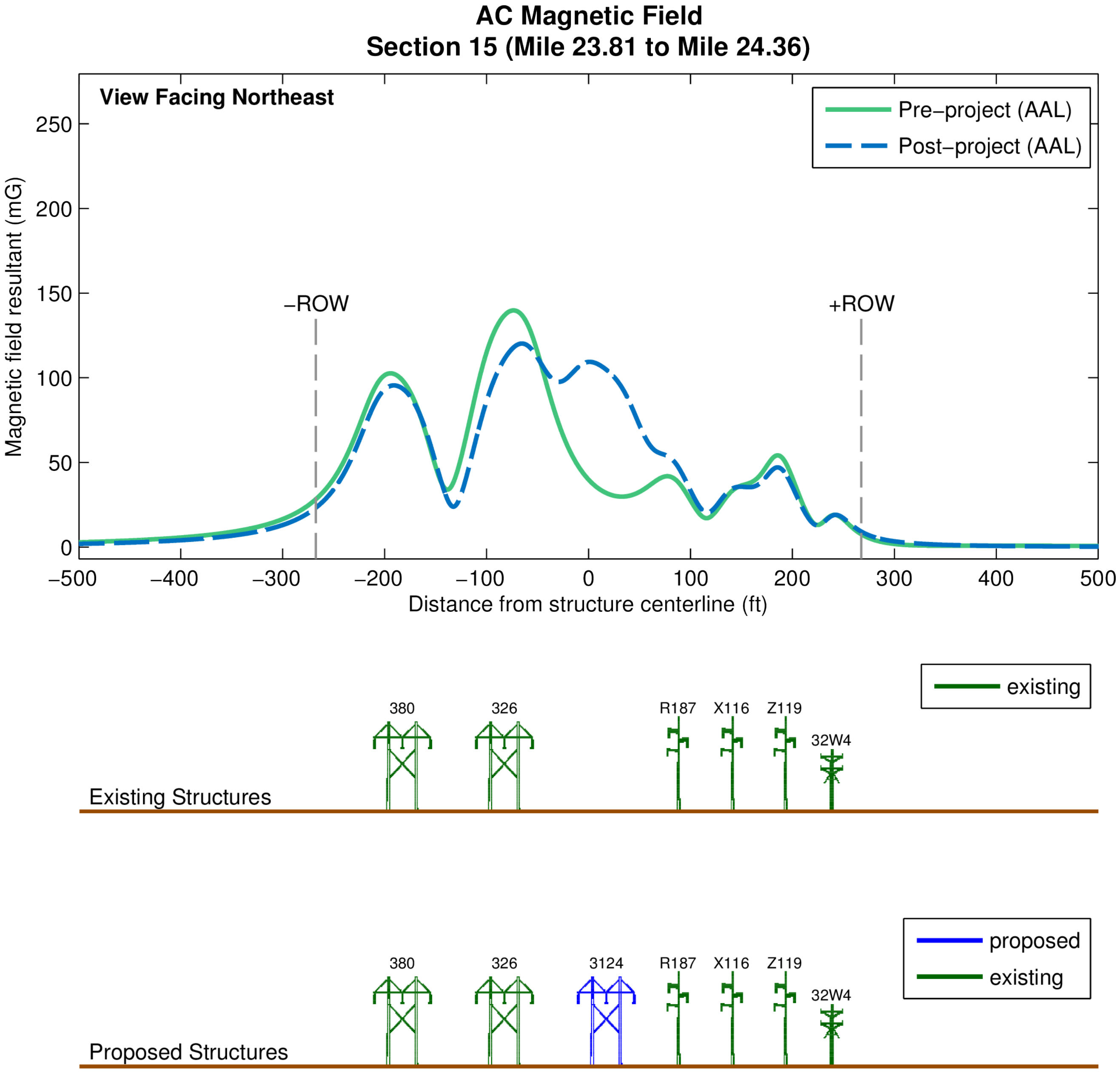

Figure B-10. AC magnetic field profile along Section 15 (Mile 23.81 to Mile 24.36).

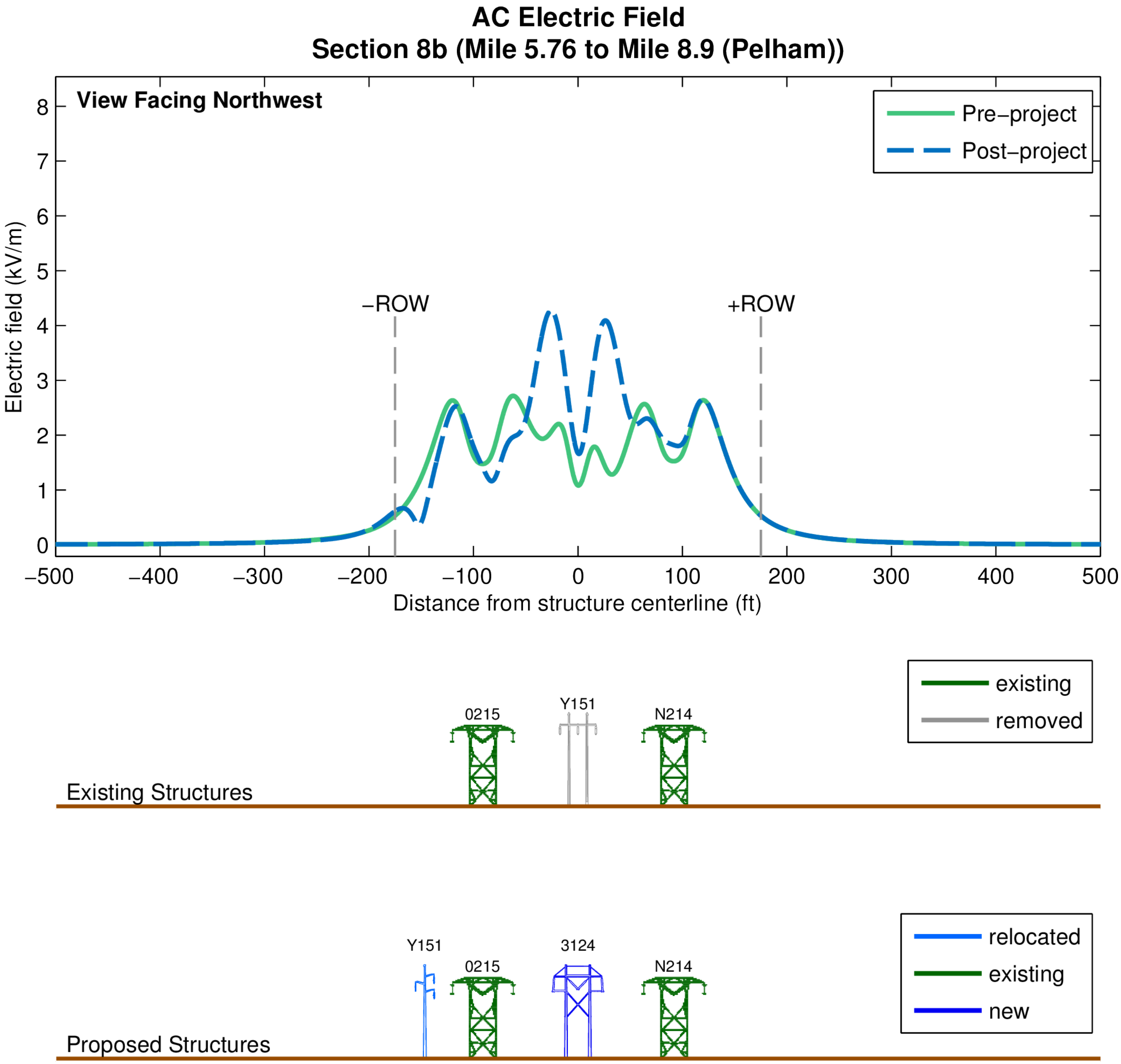

Figure B-11. AC electric field profile along Section 8b (Mile 5.76 to Mile 8.9 (Pelham)).

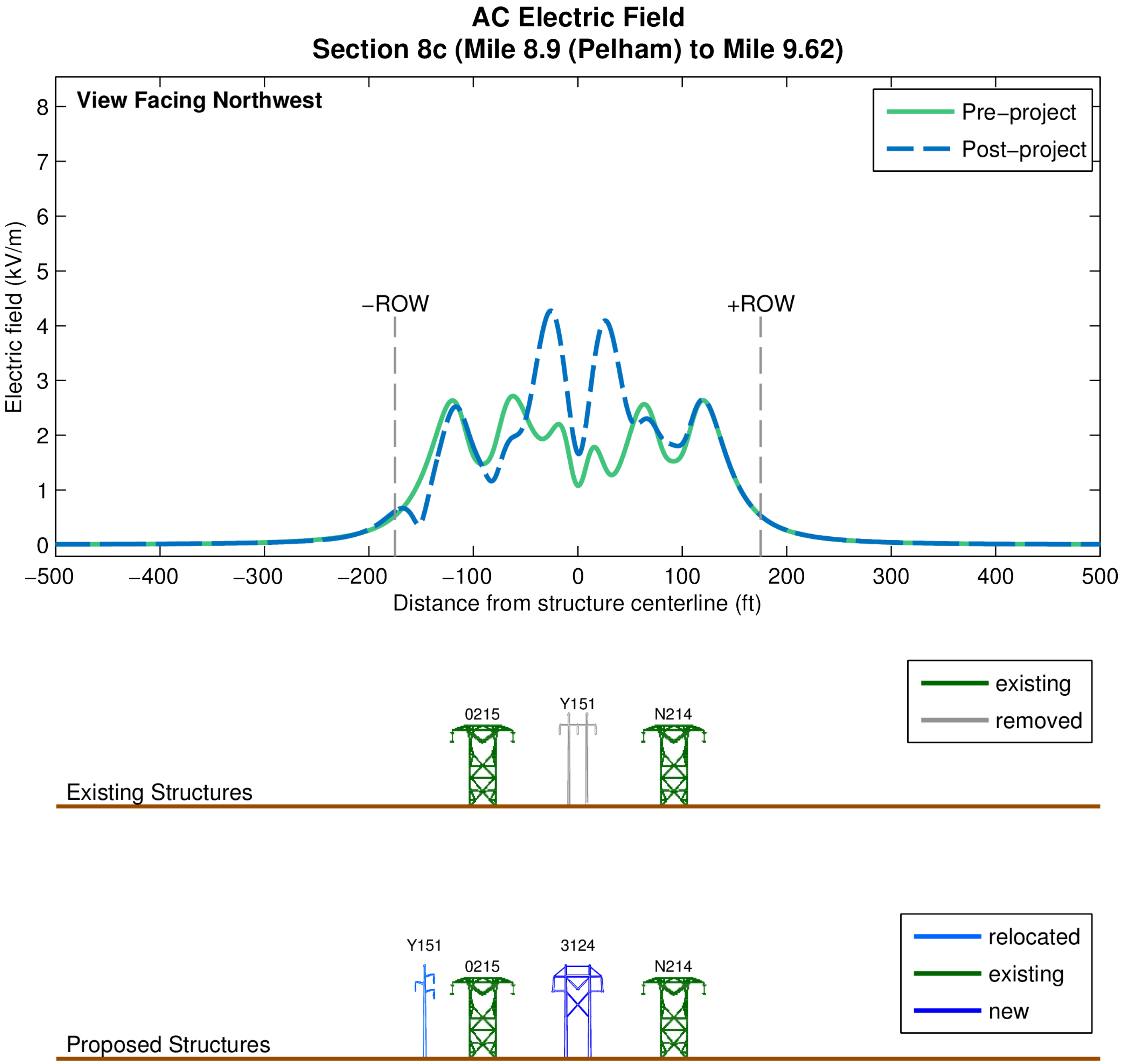

Figure B-12. AC electric field profile along Section 8c (Mile 8.9 (Pelham) to Mile 9.62).

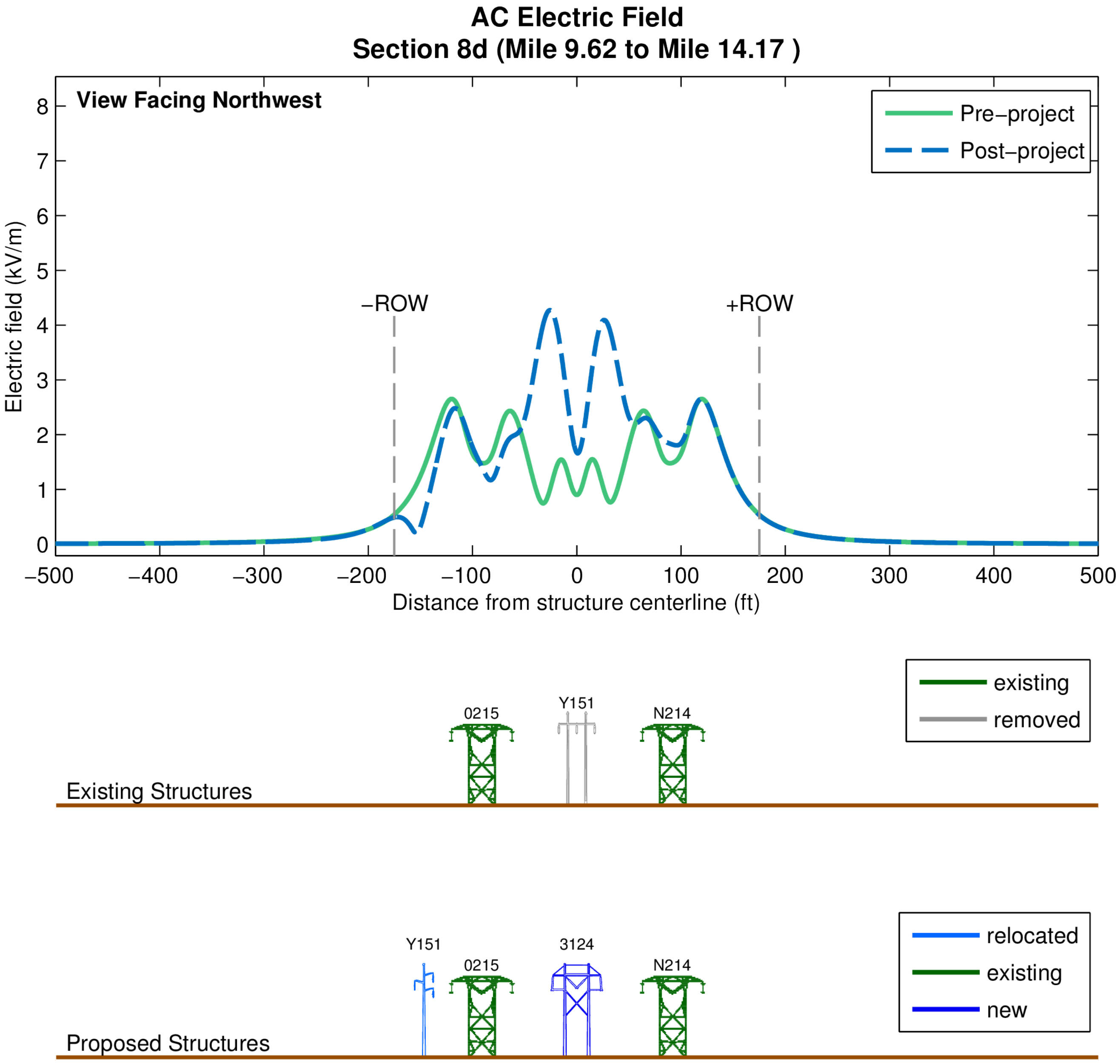

Figure B-13. AC electric field profile along Section 8d (Mile 9.62 to Mile 14.17).

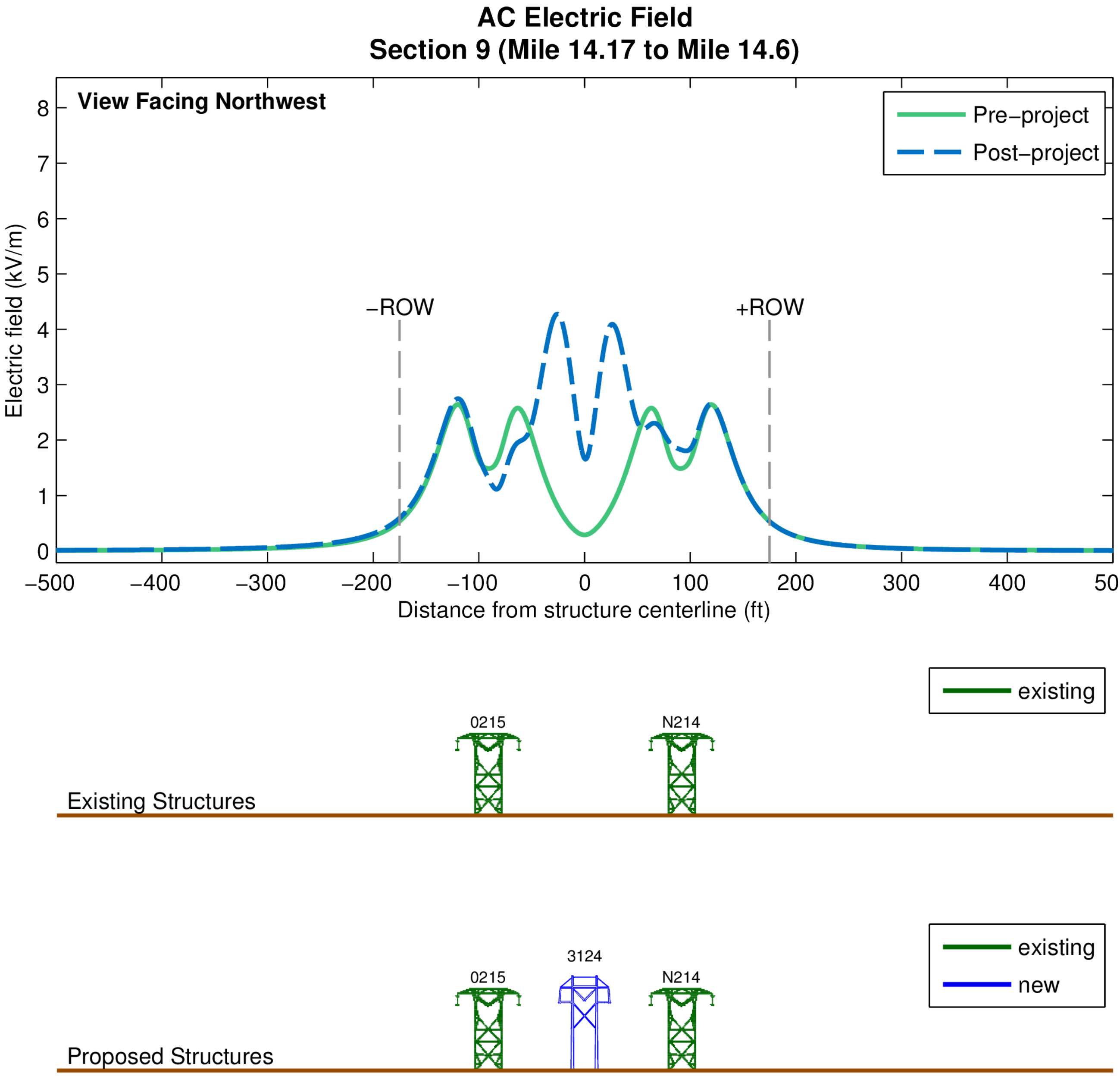

Figure B-14. AC electric field profile along Section 9 (Mile 14.17 to Mile 14.6).

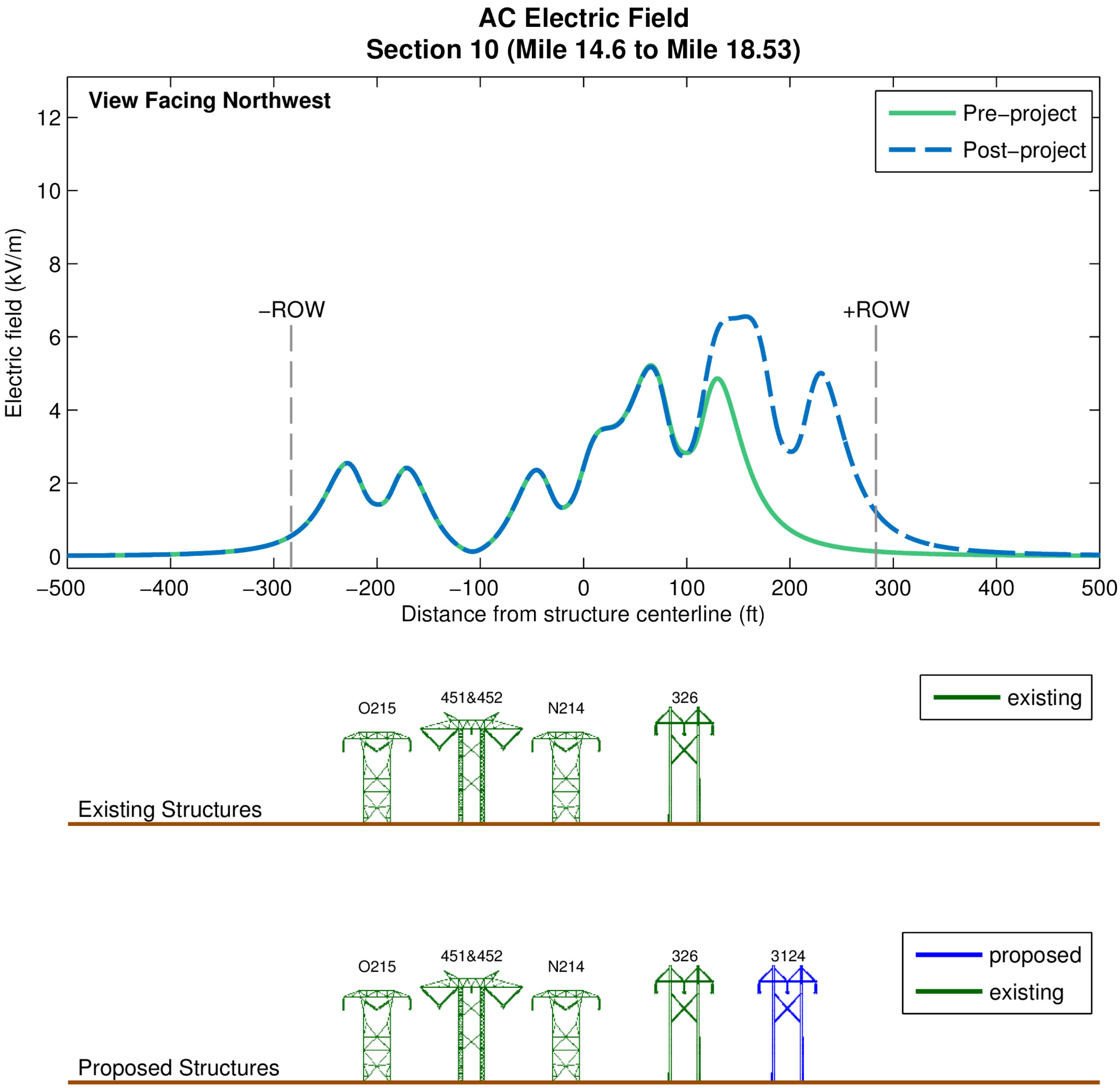

Figure B-15. AC electric field profile along Section 10 (Mile 14.6 to Mile 18.53).

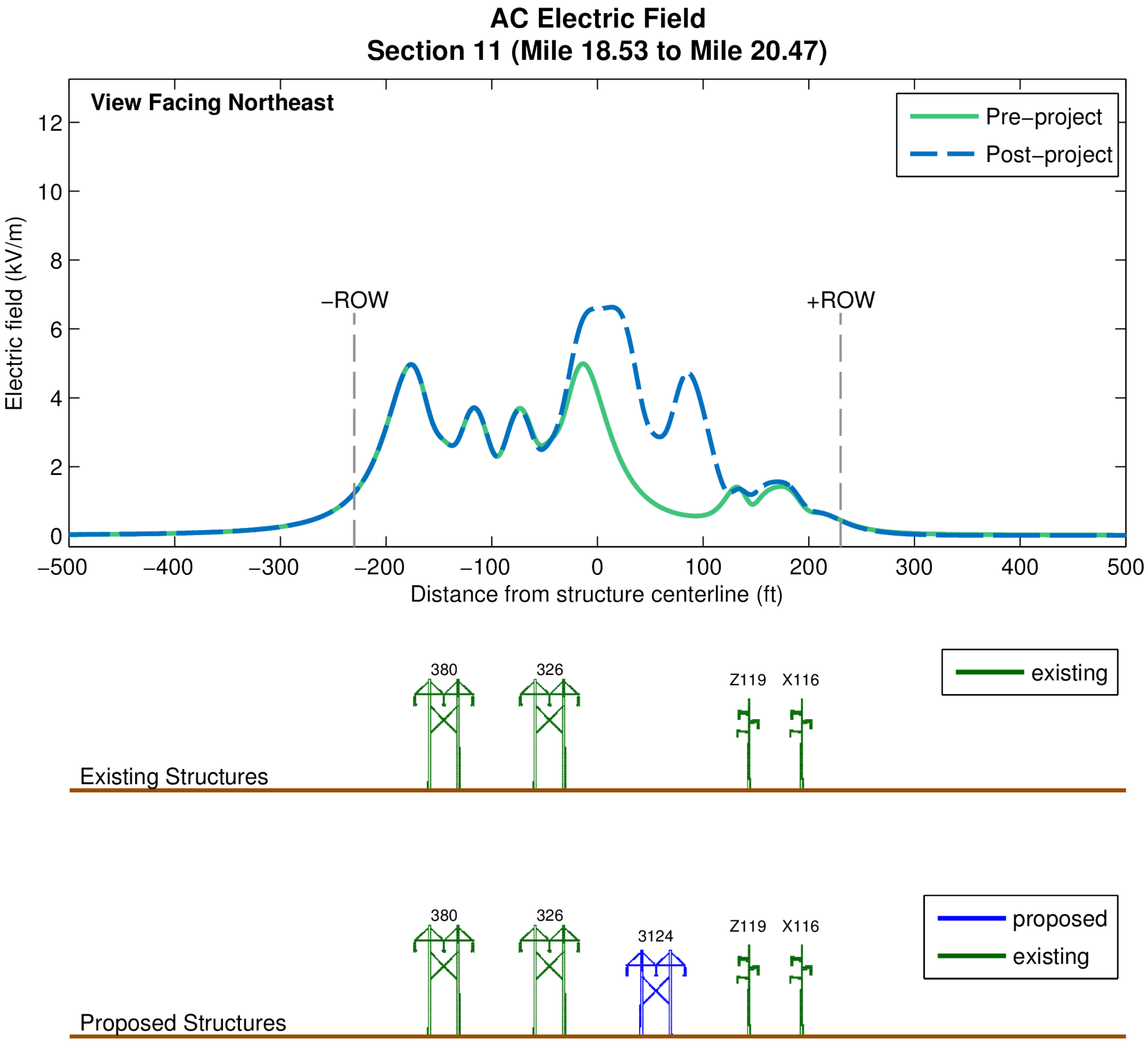

Figure B-16. AC electric field profile along Section 11 (Mile 18.53 to Mile 20.47).

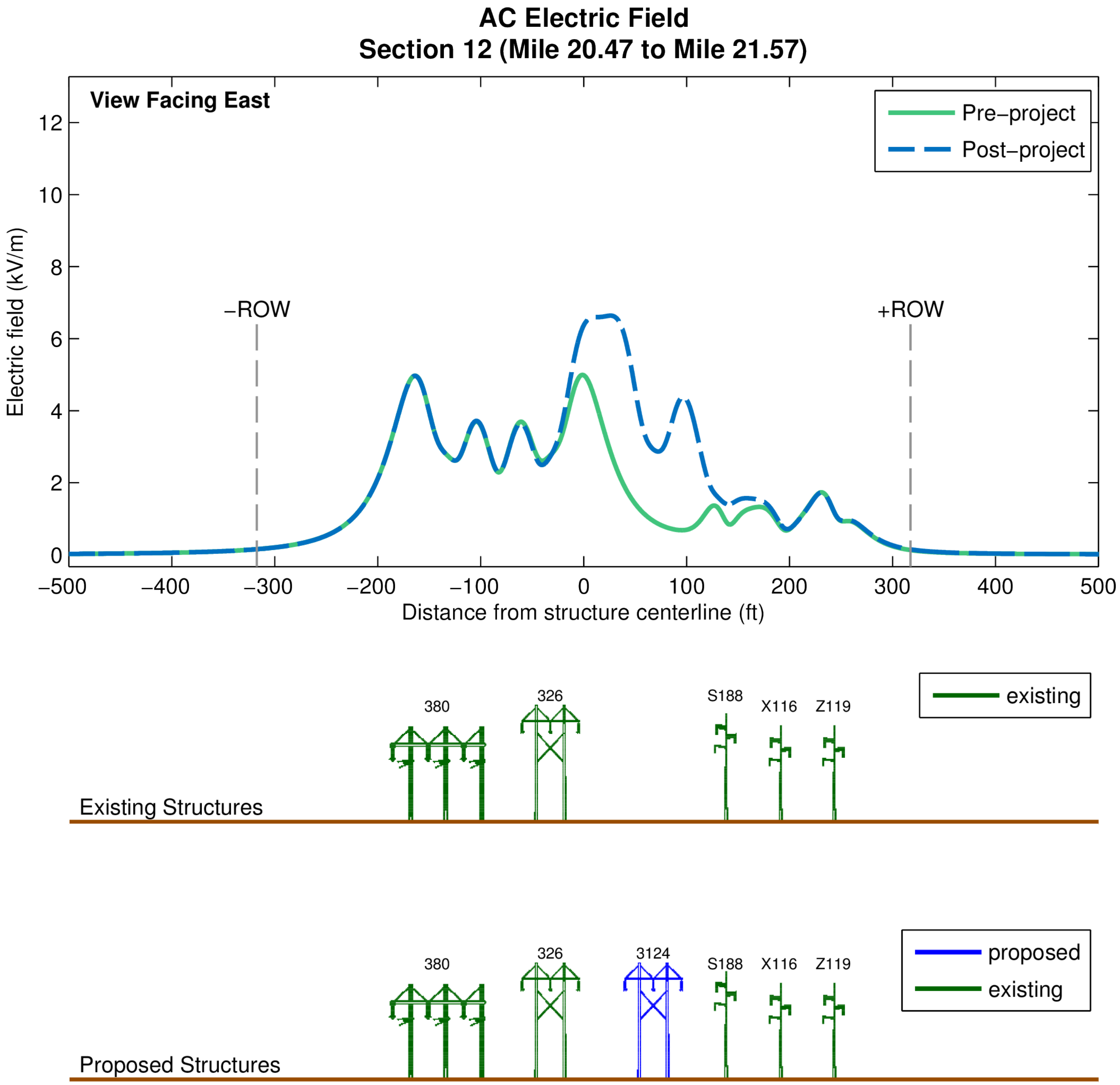

Figure B-17. AC electric field profile along Section 12 (Mile 20.47 to Mile 21.57).

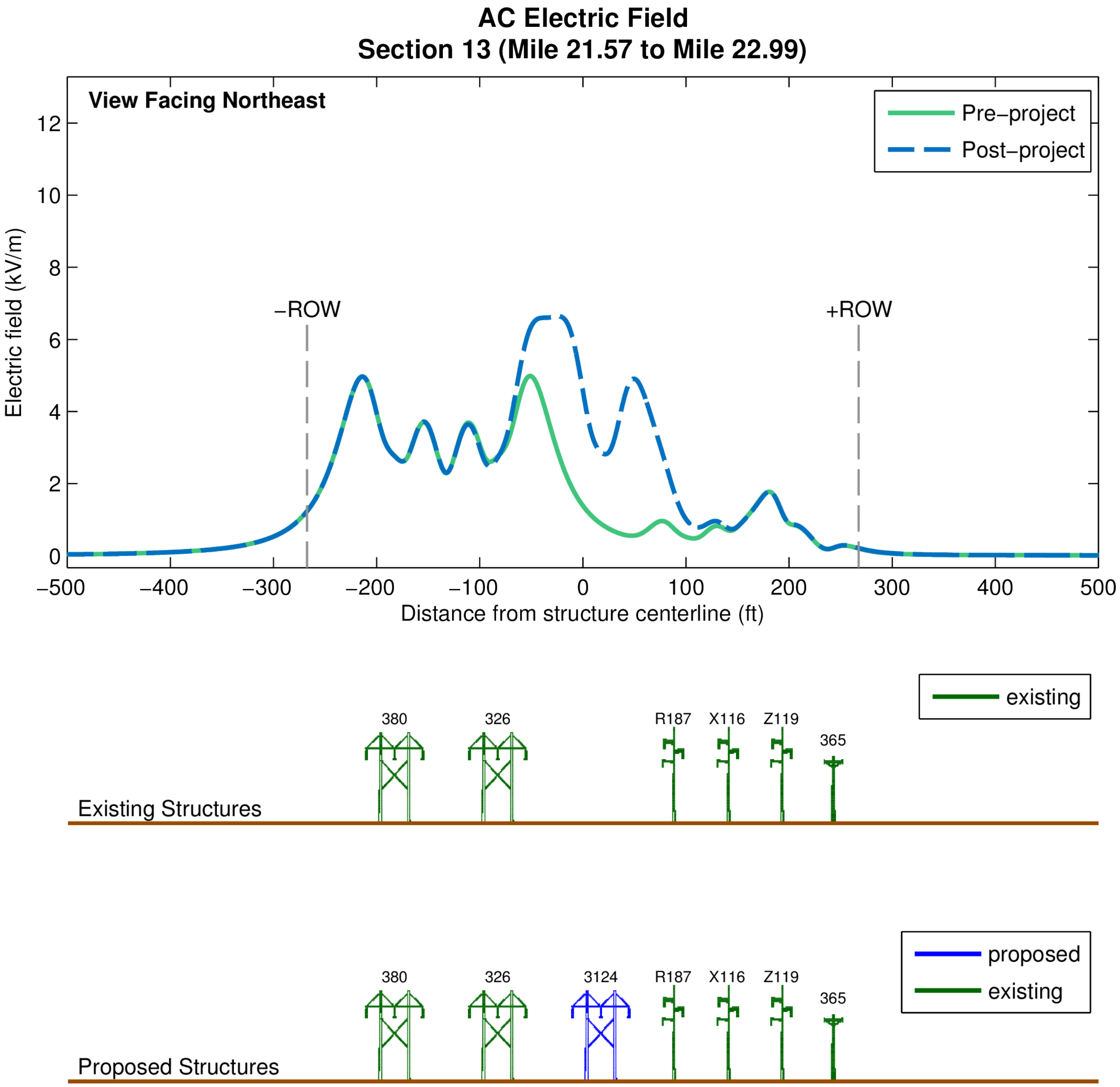

Figure B-18. AC electric field profile along Section 13 (Mile 21.57 to Mile 22.99).

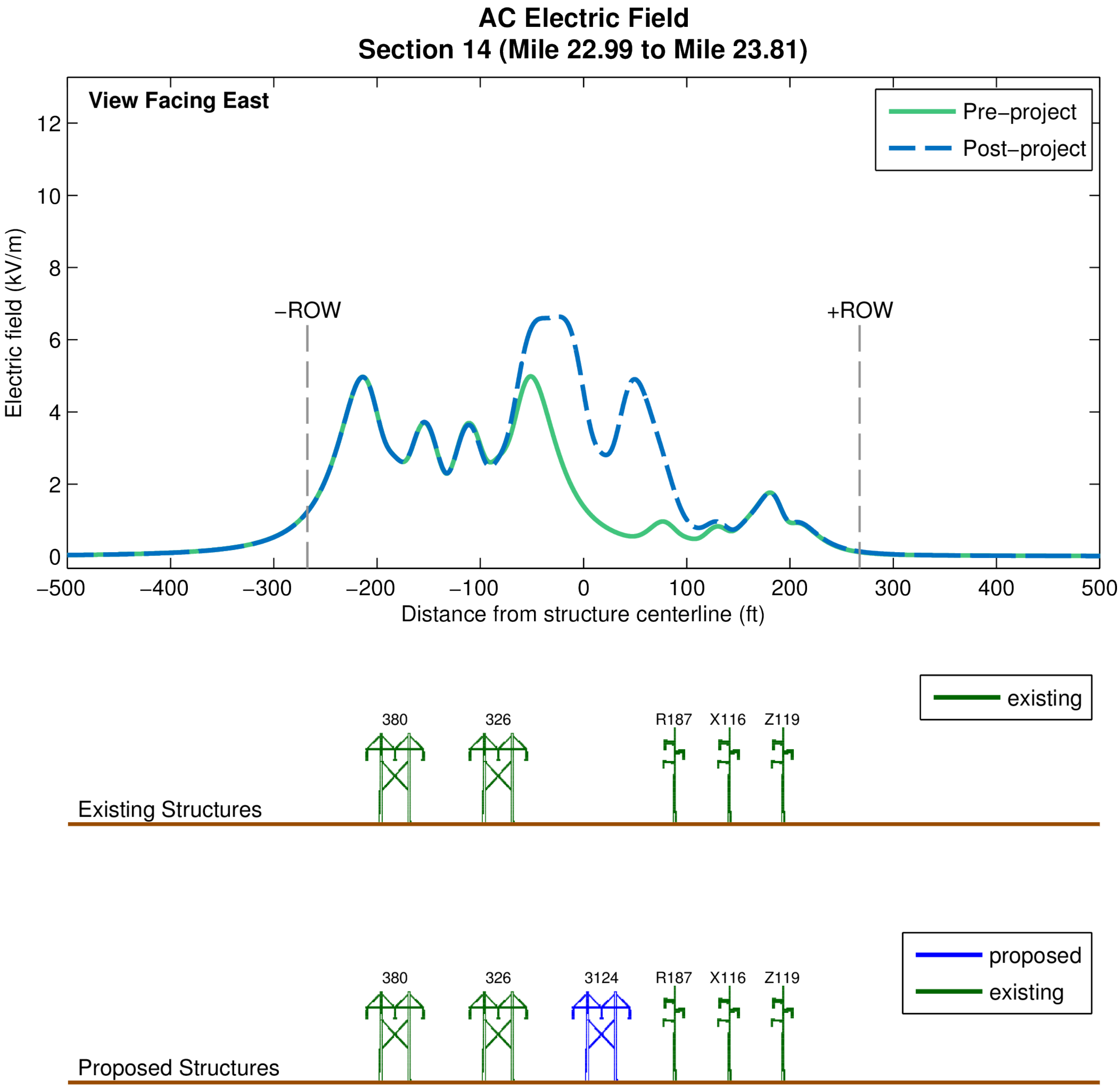

Figure B-19. AC electric field profile along Section 14 (Mile 22.99 to Mile 23.81).

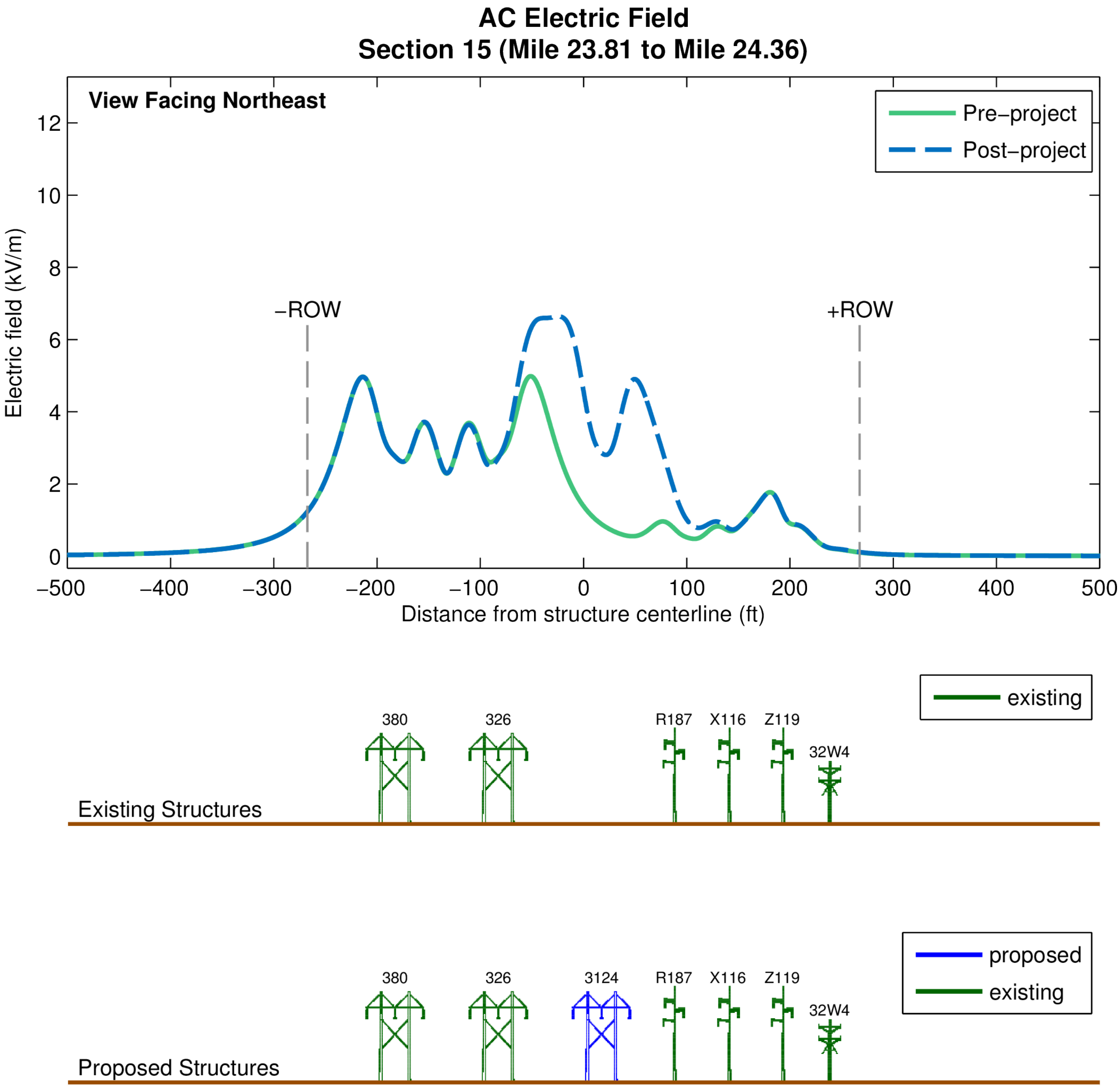

Figure B-20. AC electric field profile along Section 15 (Mile 23.81 to Mile 24.36).

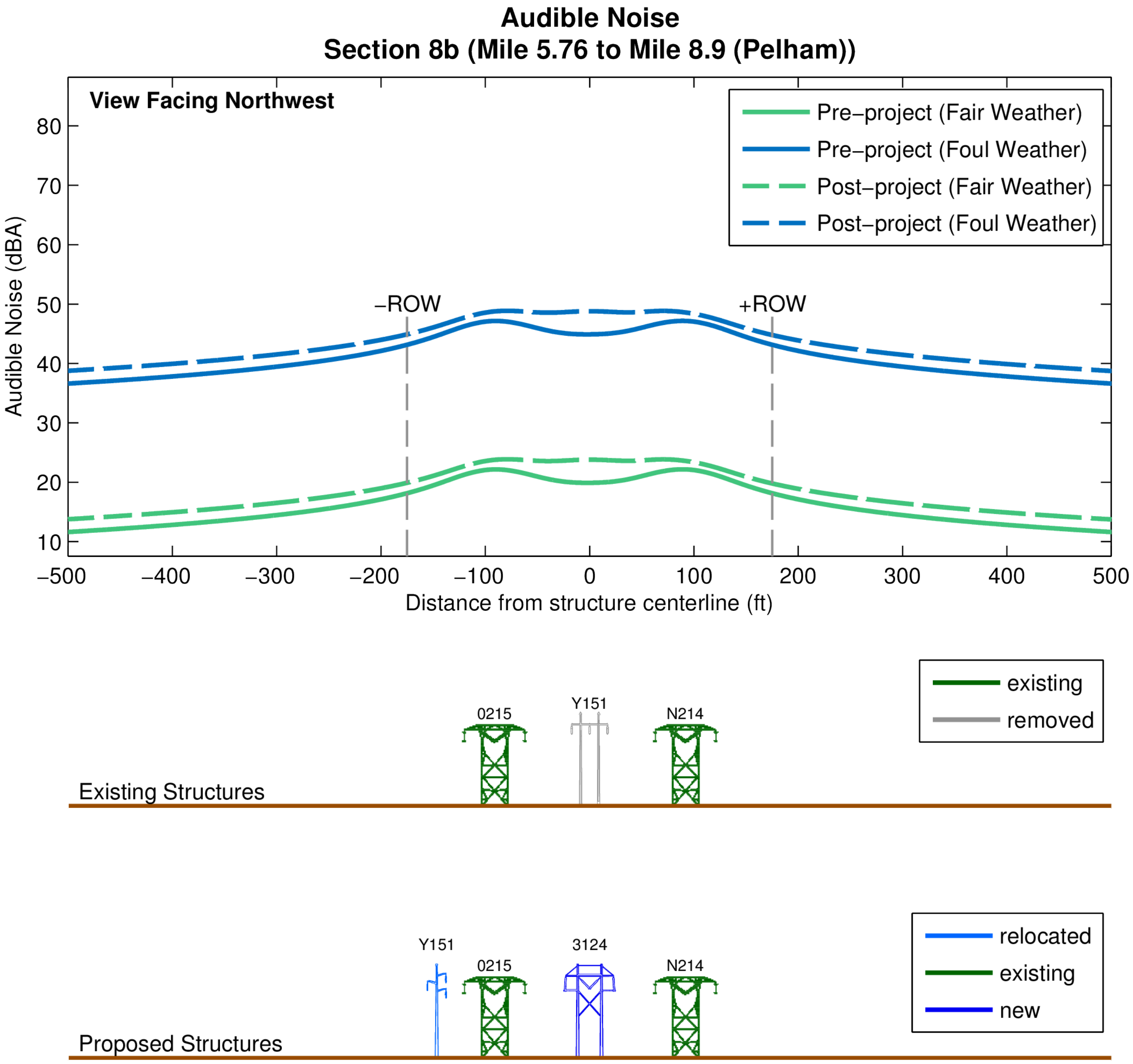

Figure B-21. Audible noise profile along Section 8b (Mile 5.76 to Mile 8.9 (Pelham)).

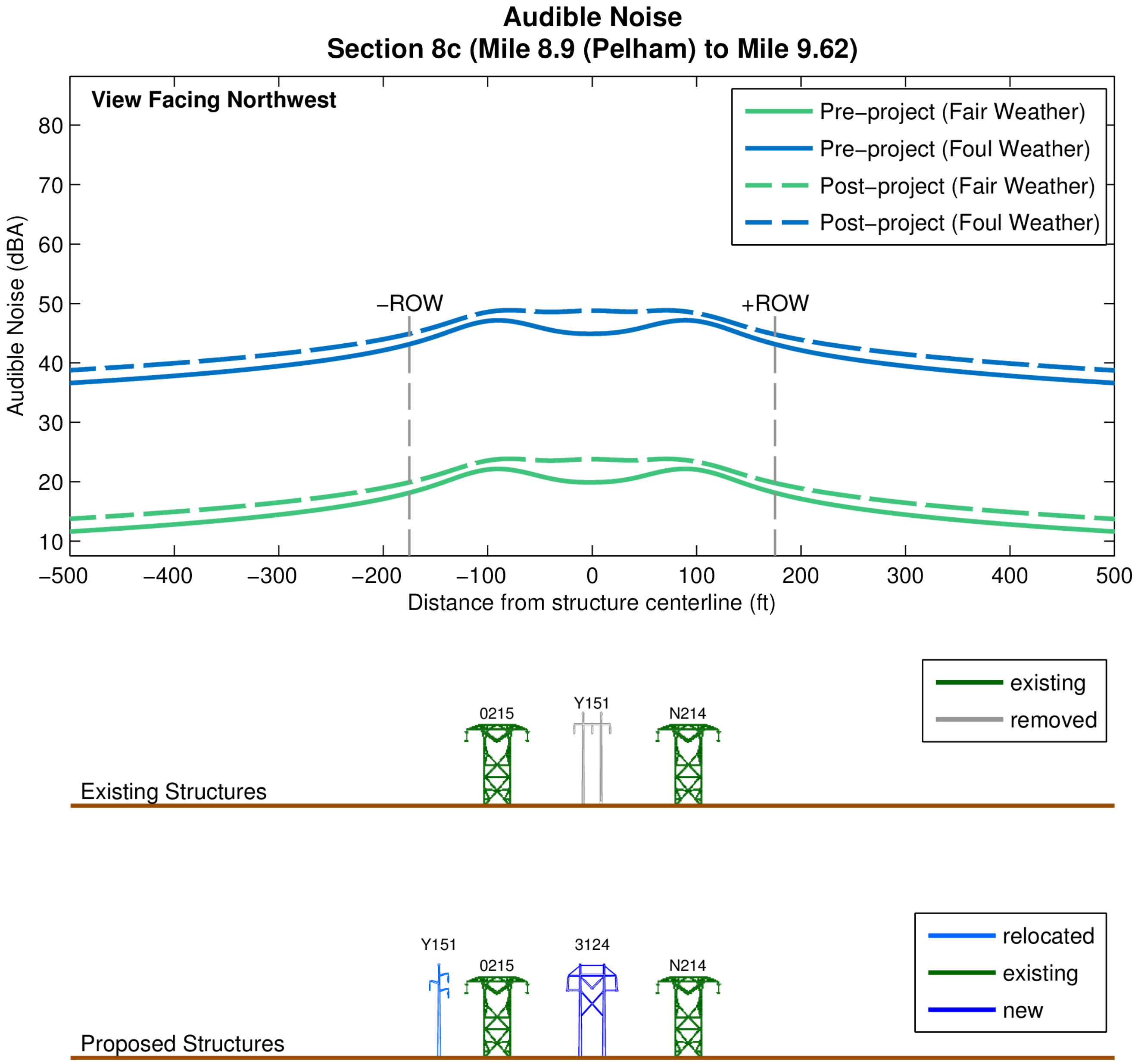

Figure B-22. Audible noise profile along Section 8c (Mile 8.9 (Pelham) to Mile 9.62).

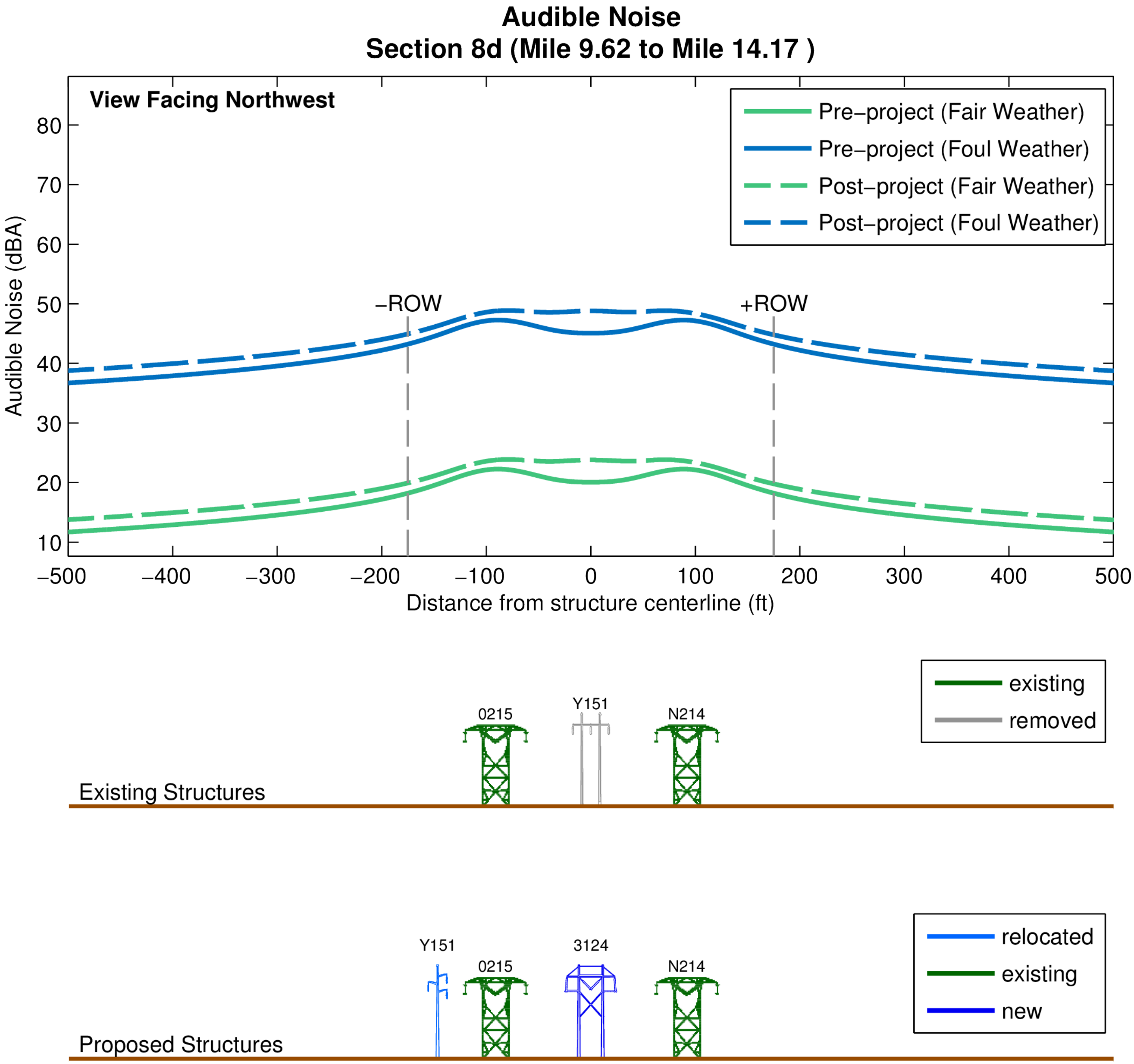

Figure B-23. Audible noise profile along Section 8d (Mile 9.62 to Mile 14.17).

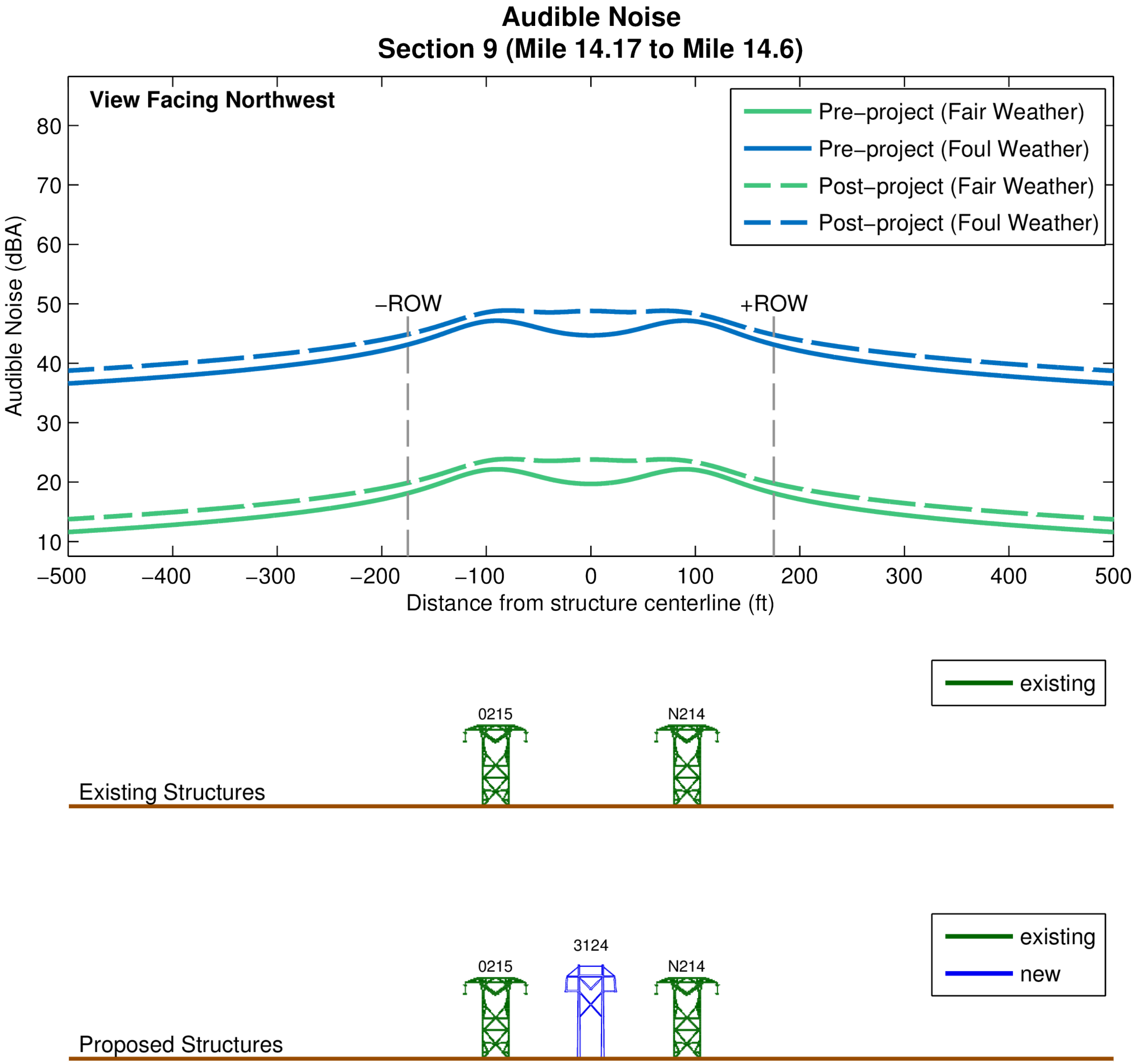

Figure B-24. Audible noise profile along Section 9 (Mile 14.17 to Mile 14.6).

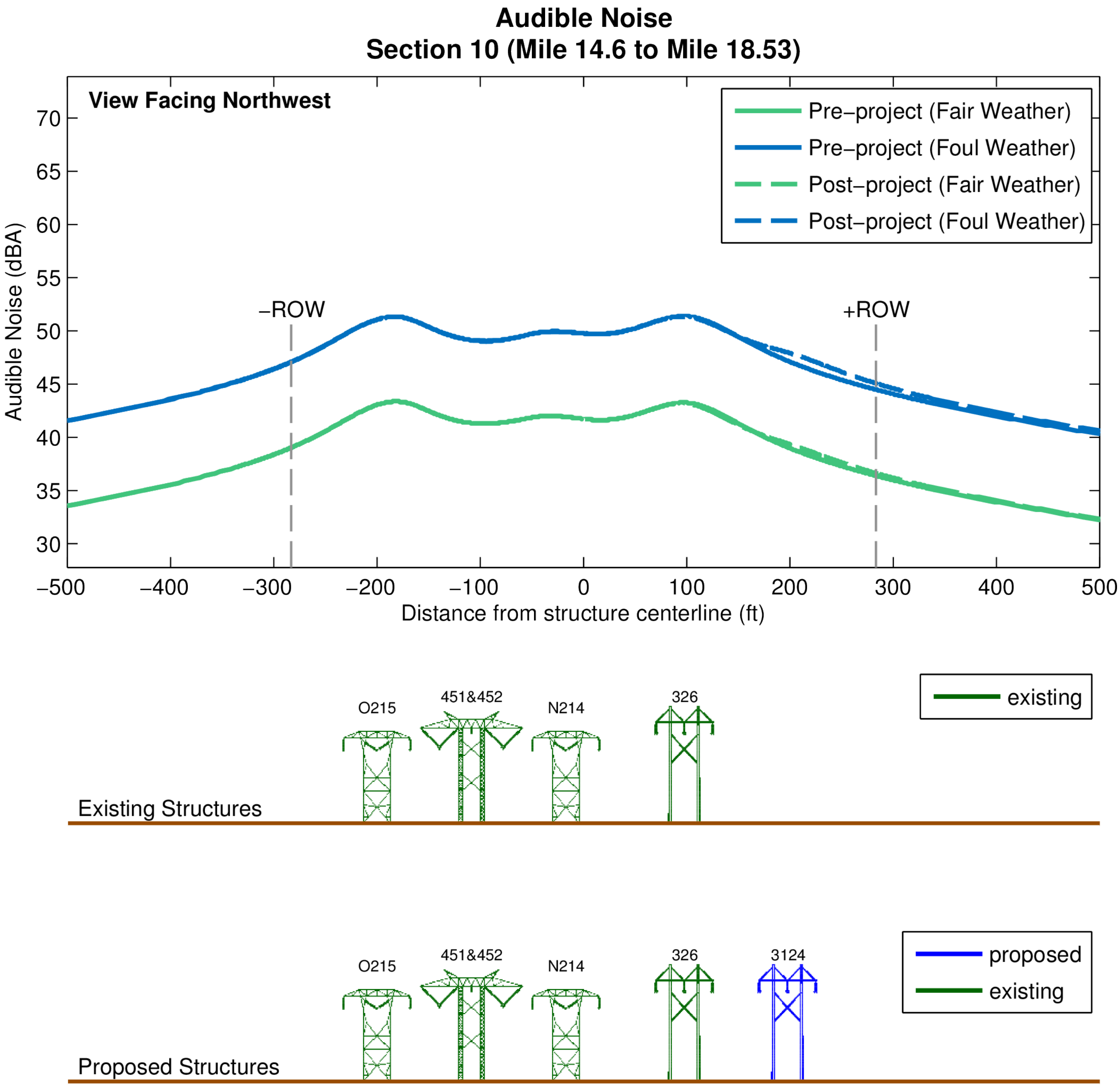

Figure B-25. Audible noise profile along Section 10 (Mile 14.6 to Mile 18.53).

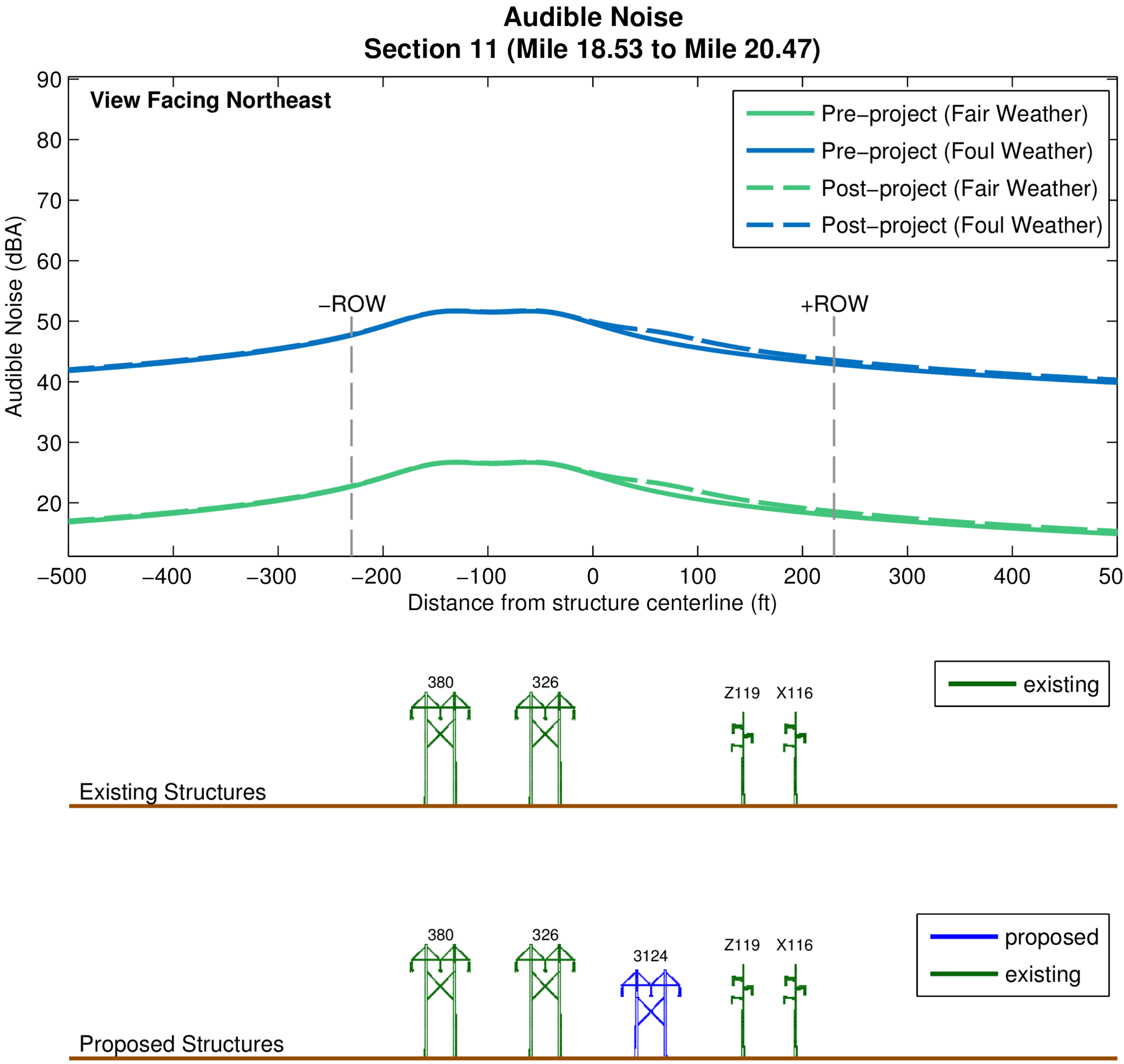

Figure B-26. Audible noise profile along Section 11 (Mile 18.53 to Mile 20.47).

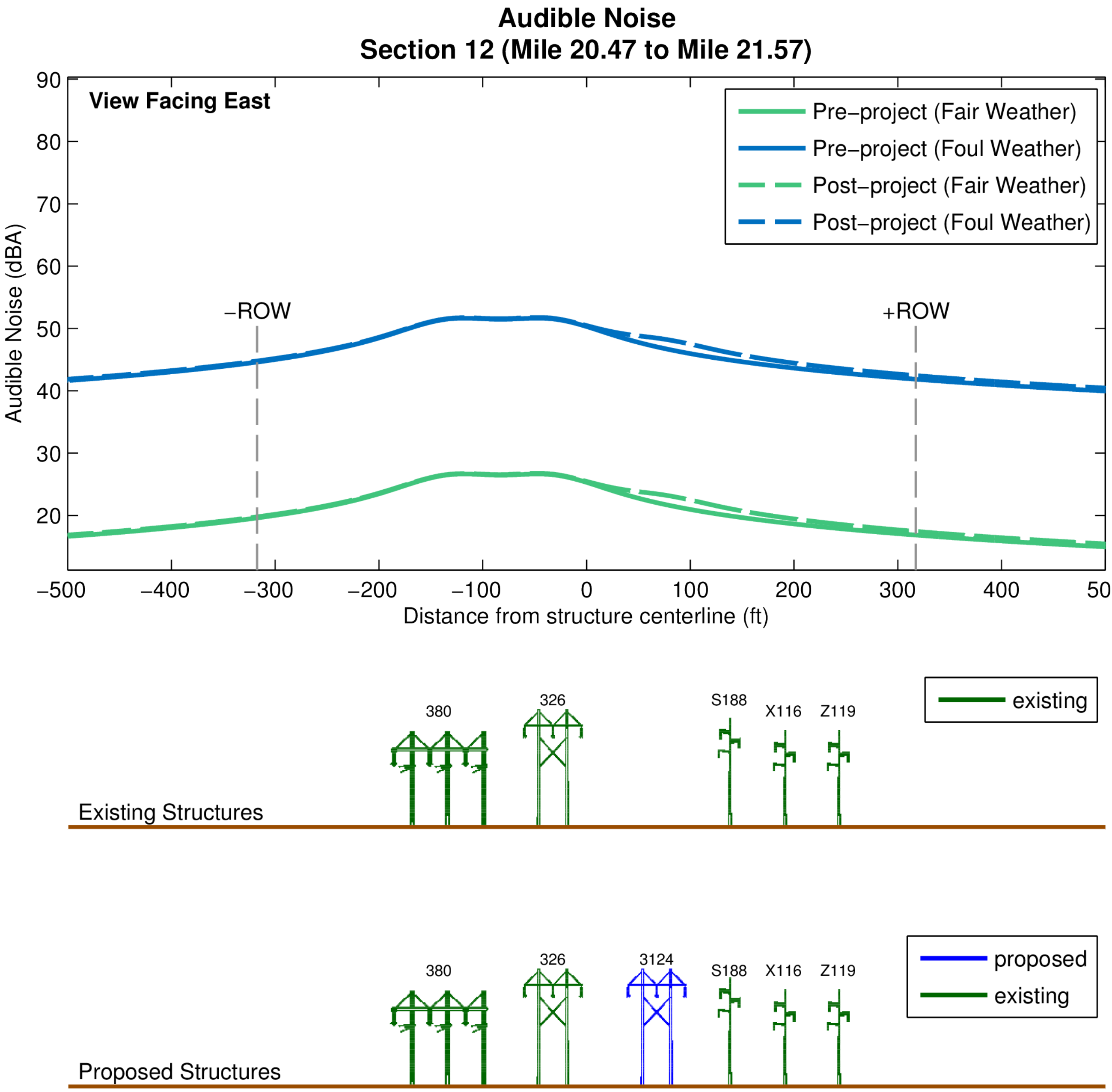

Figure B-27. Audible noise profile along Section 12 (Mile 20.47 to Mile 21.57).

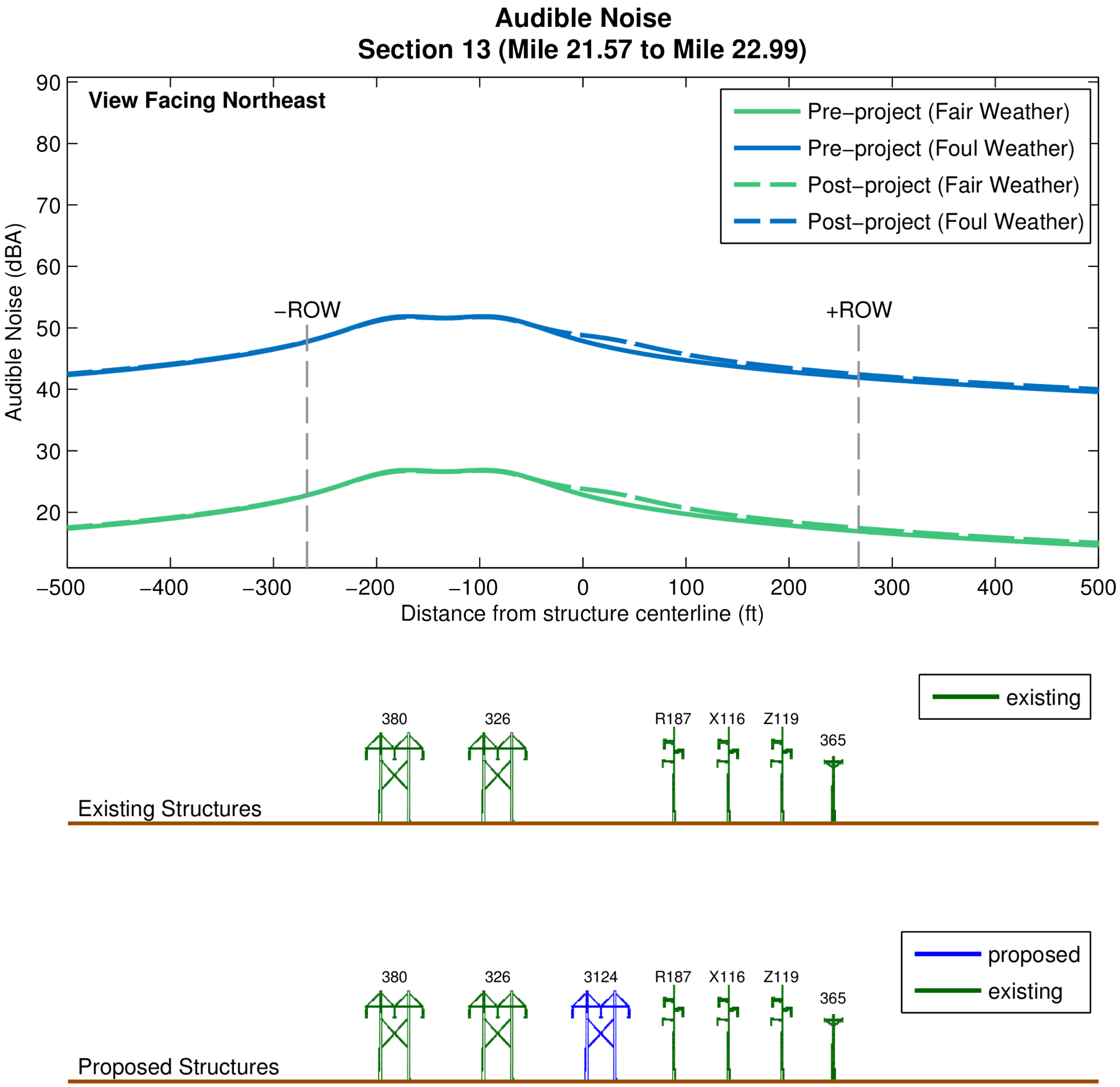

Figure B-28. Audible noise profile along Section 13 (Mile 21.57 to Mile 22.99).

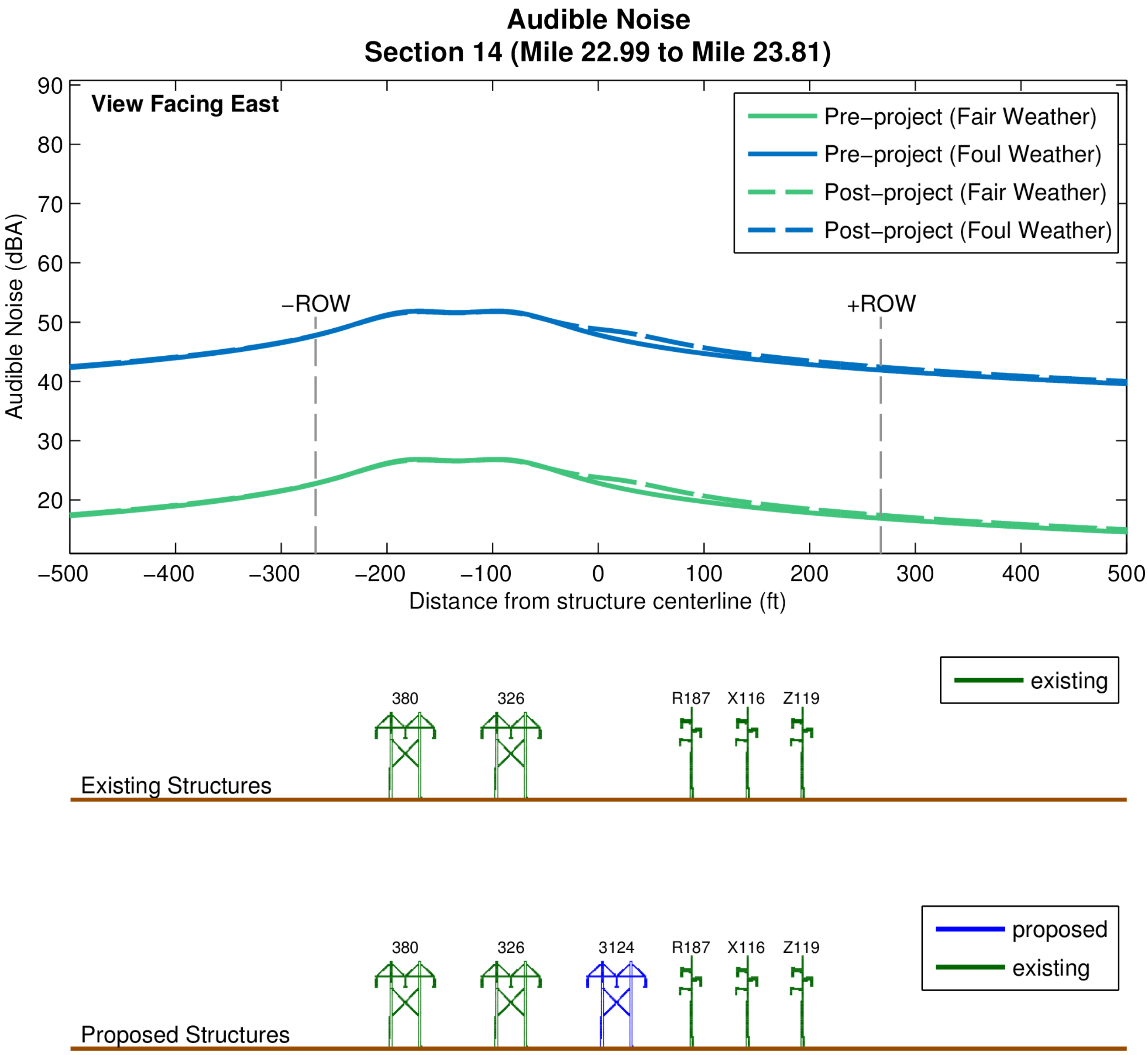

Figure B-29. Audible noise profile along Section 14 (Mile 22.99 to Mile 23.81).

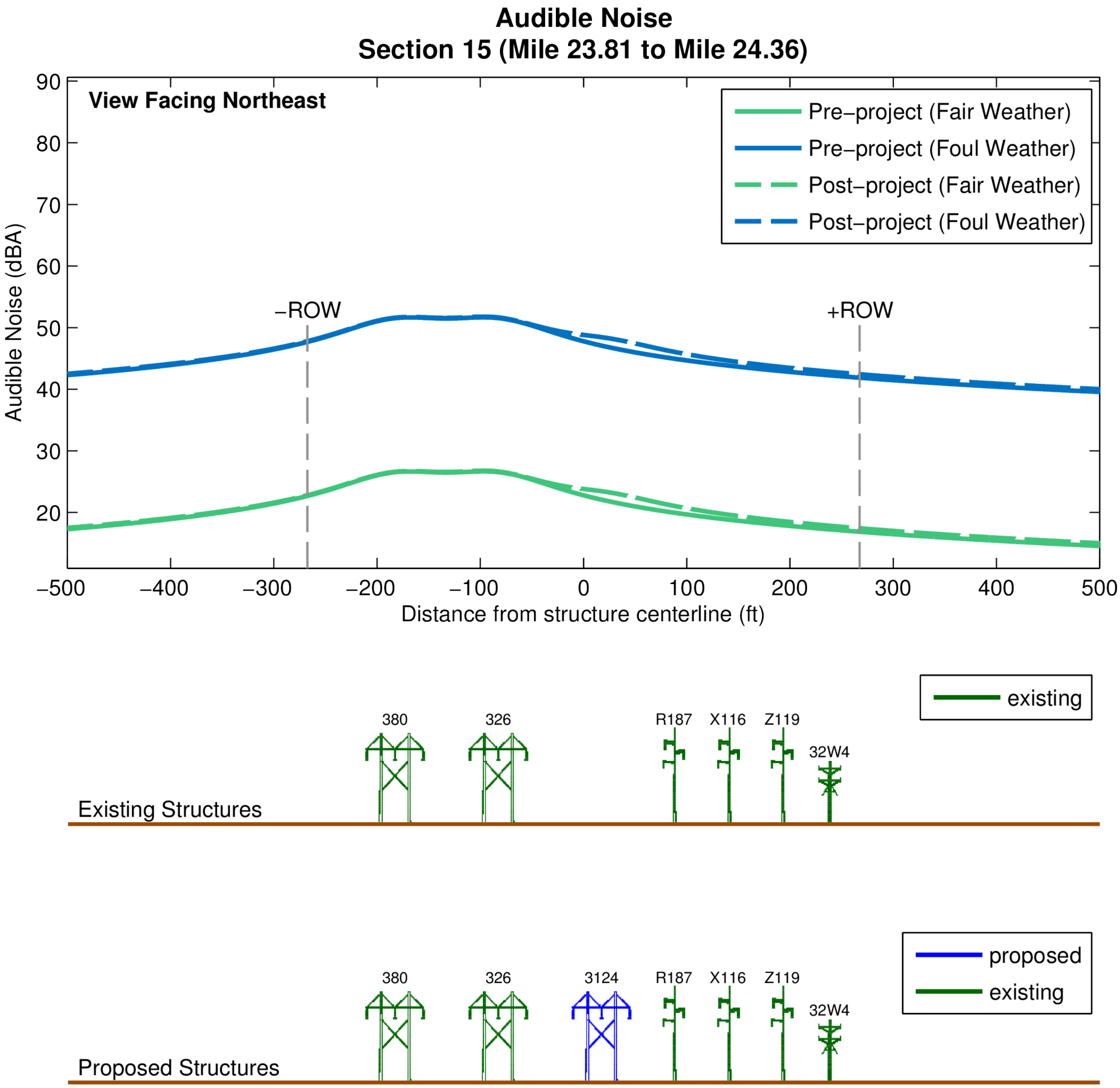

Figure B-30. Audible noise profile along Section 15 (Mile 23.81 to Mile 24.36).

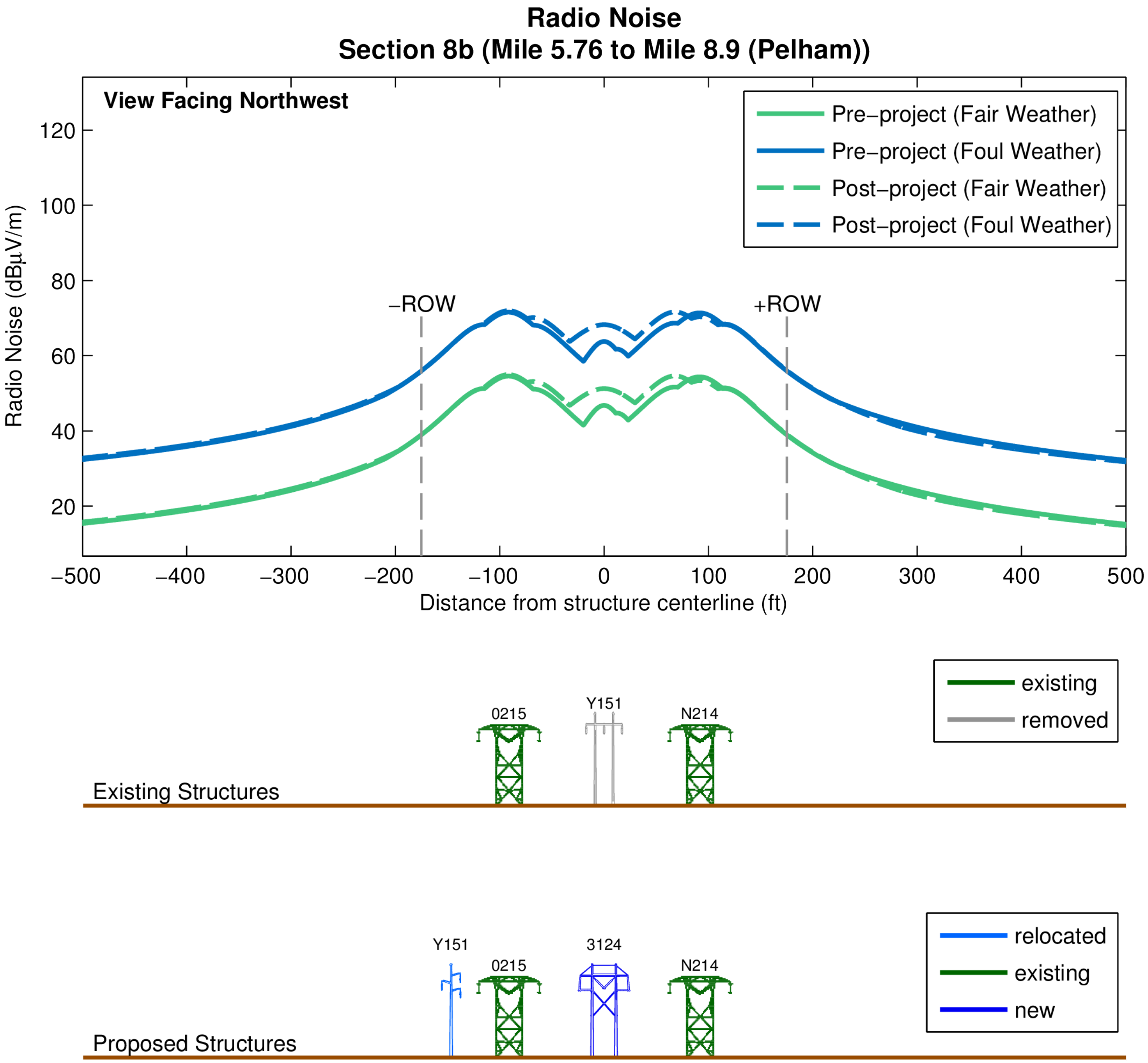

Figure B-31. Radio noise profile along Section 8b (Mile 5.76 to Mile 8.9 (Pelham)).

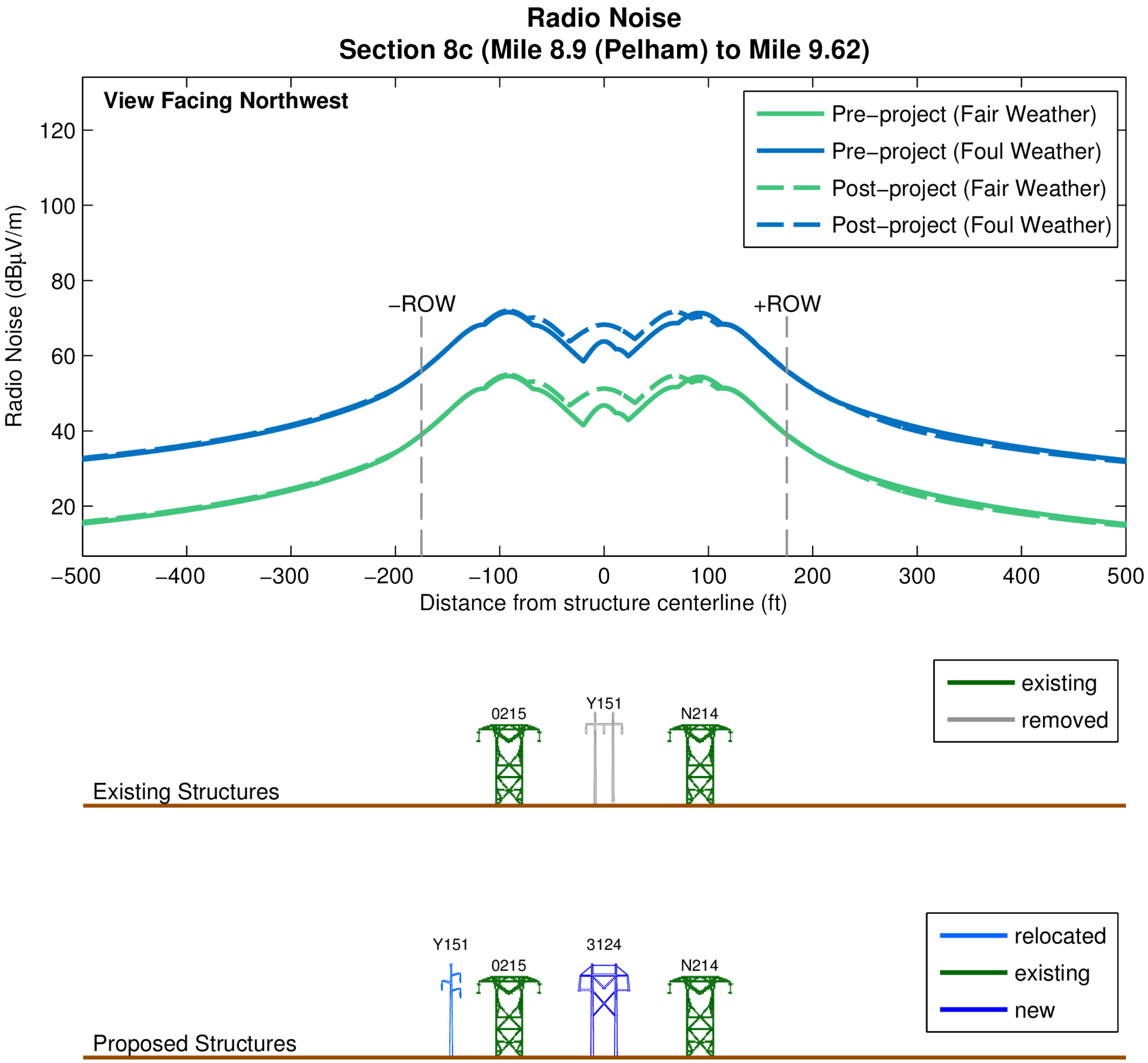

Figure B-32. Radio noise profile along Section 8c (Mile 8.9 (Pelham) to Mile 9.62).

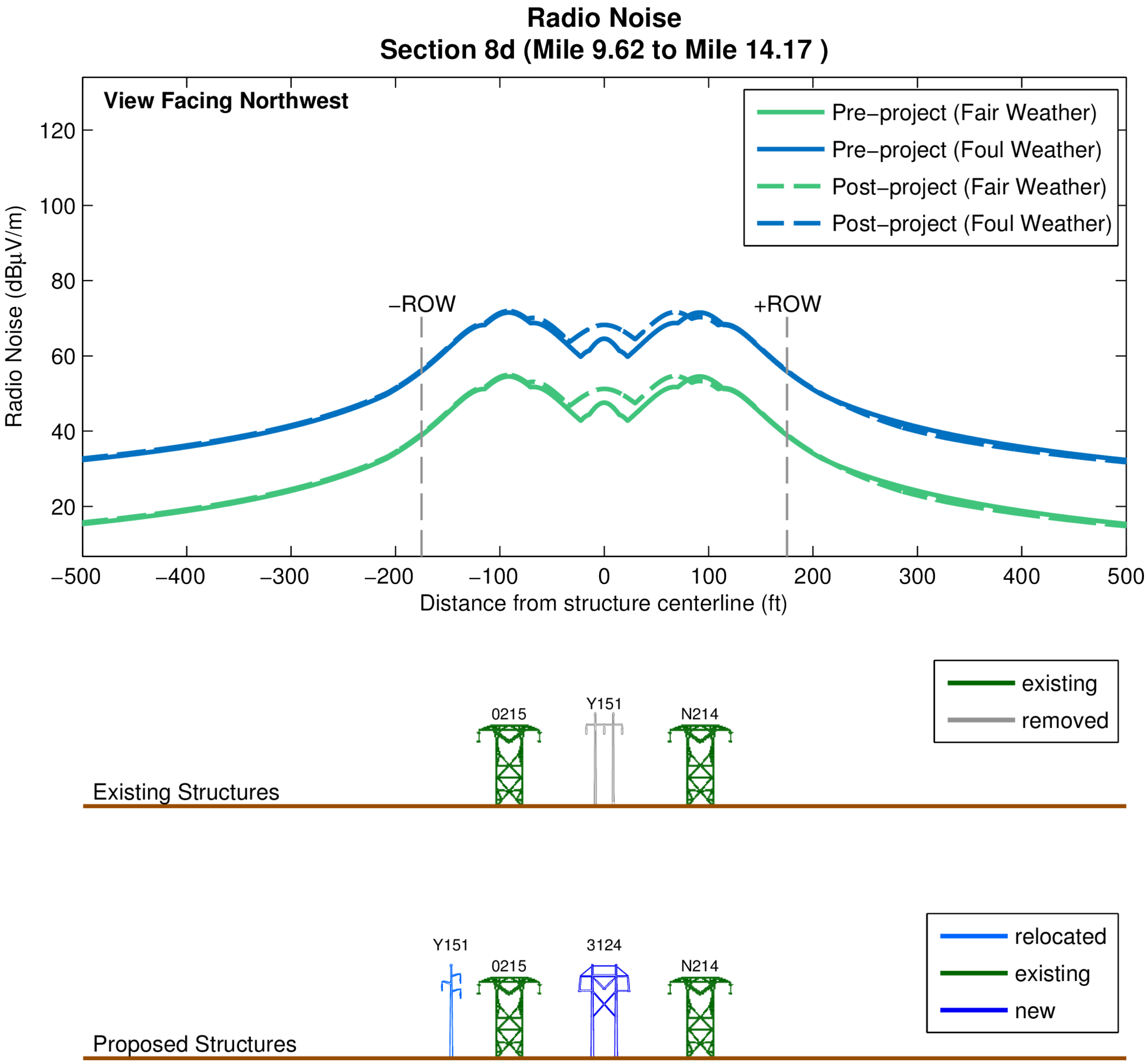

Figure B-33. Radio noise profile along Section 8d (Mile 9.62 to Mile 14.17).

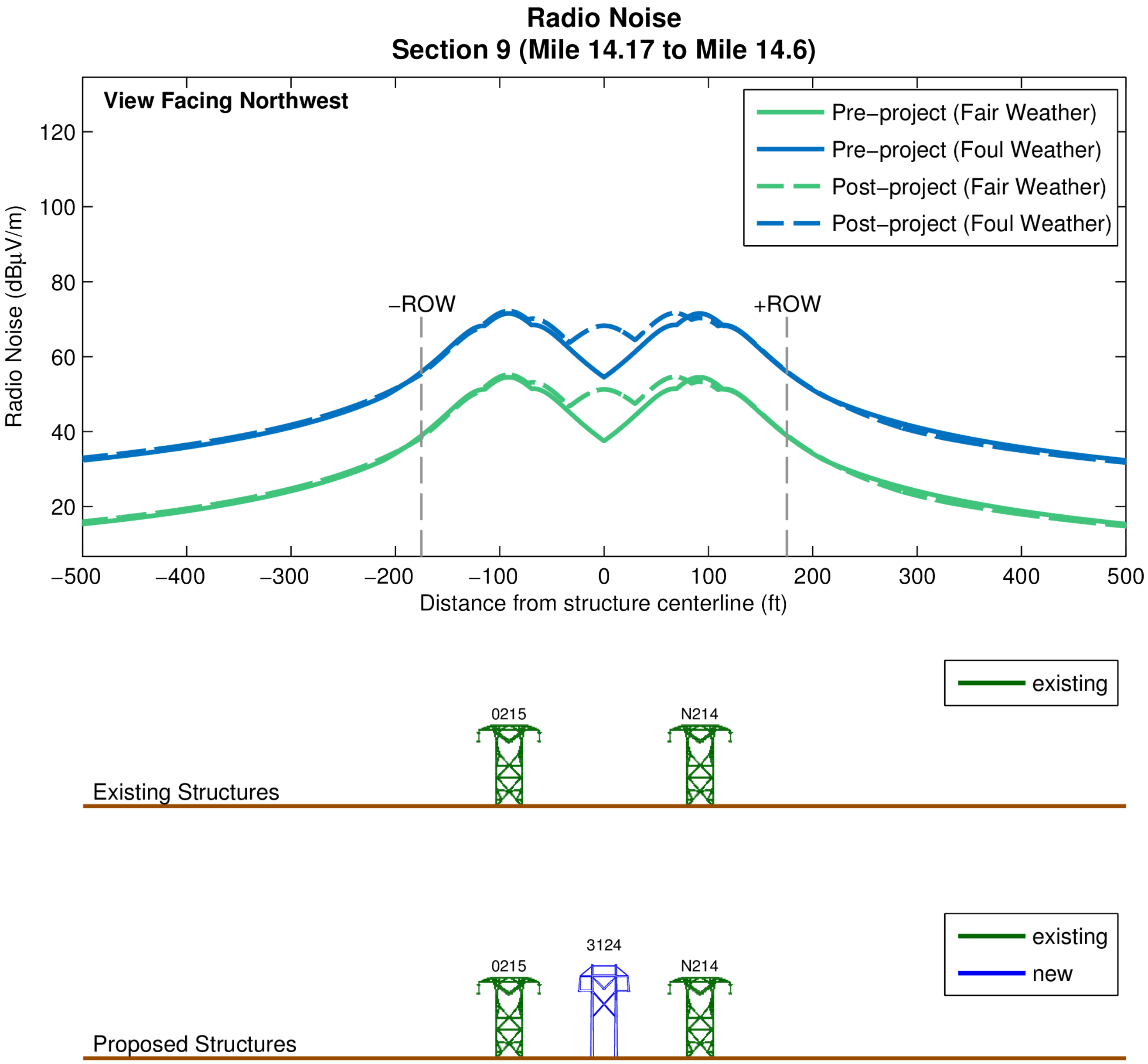

Figure B-34. Radio noise profile along Section 9 (Mile 14.17 to Mile 14.6).

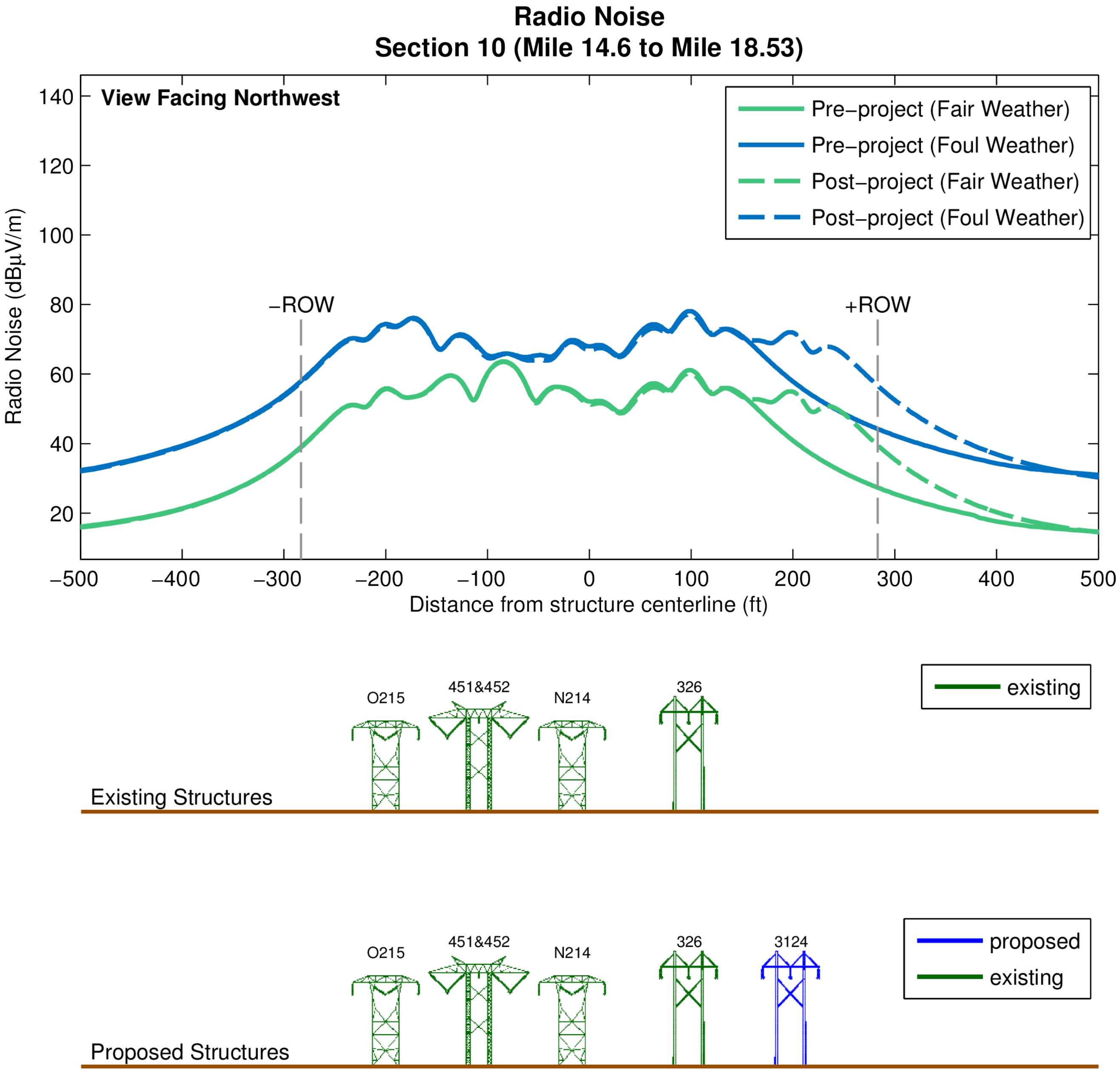

Figure B-35. Radio noise profile along Section 10 (Mile 14.6 to Mile 18.53).

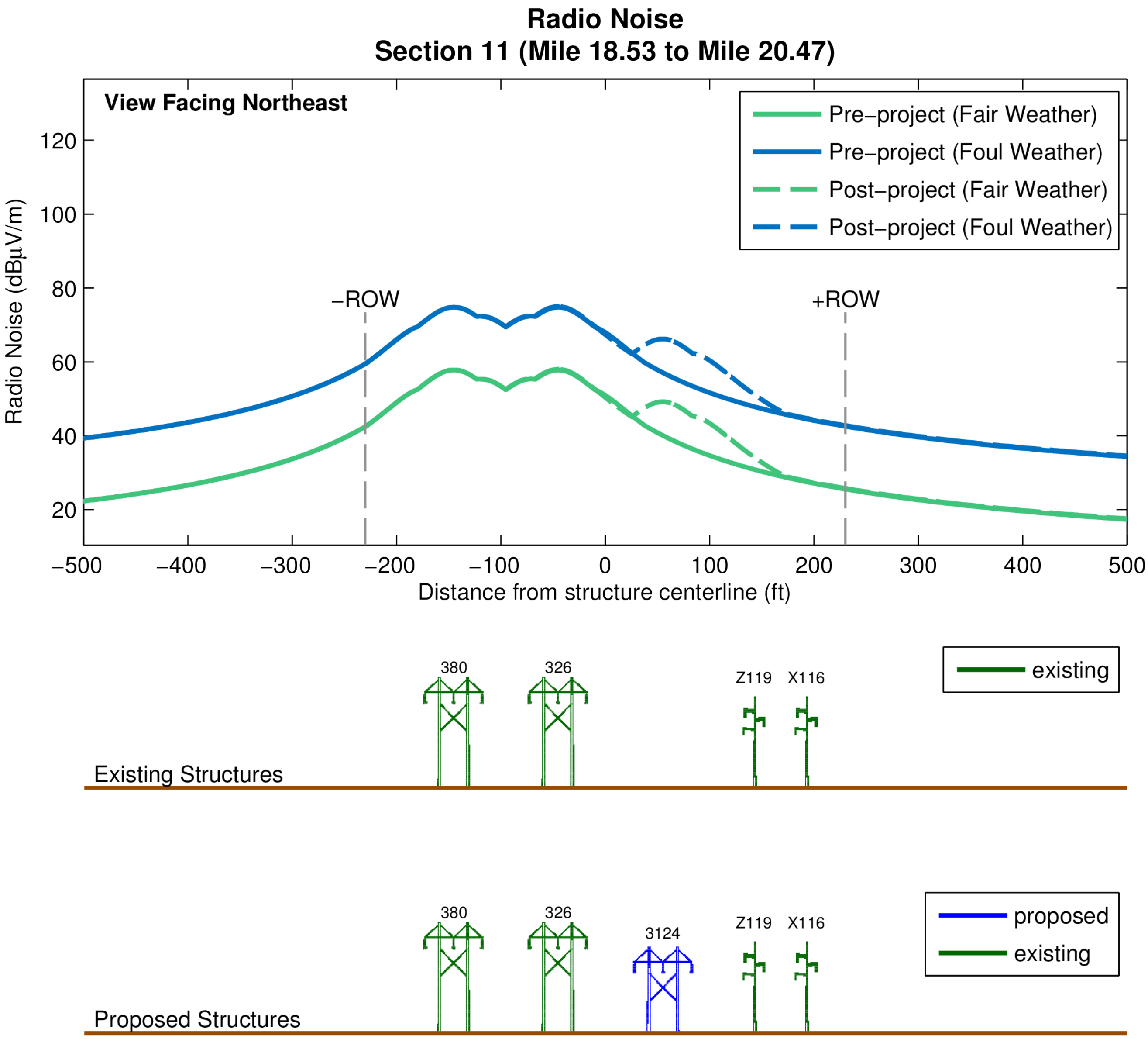

Figure B-36. Radio noise profile along Section 11 (Mile 18.53 to Mile 20.47).

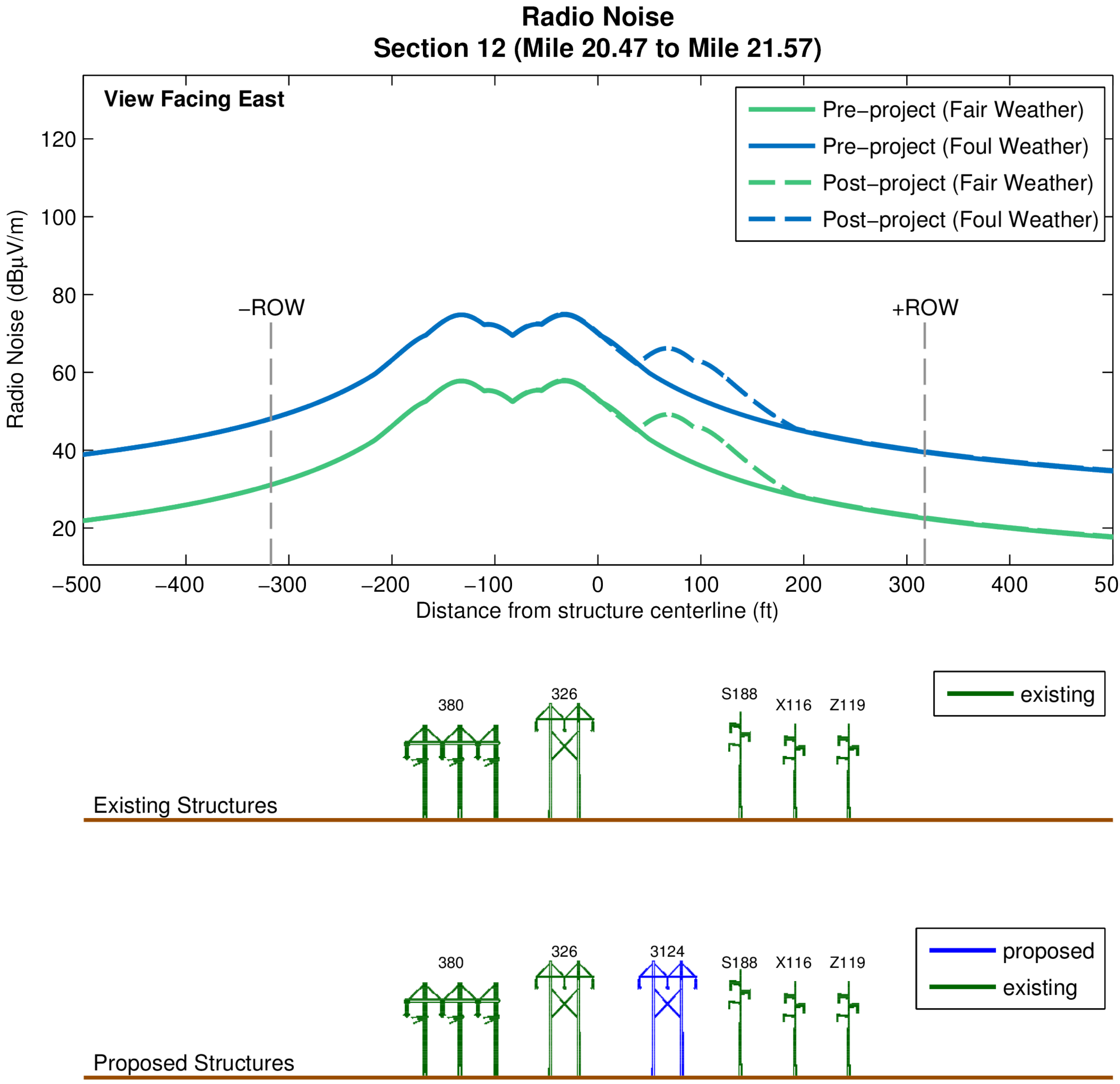

Figure B-37. Radio noise profile along Section 12 (Mile 20.47 to Mile 21.57).

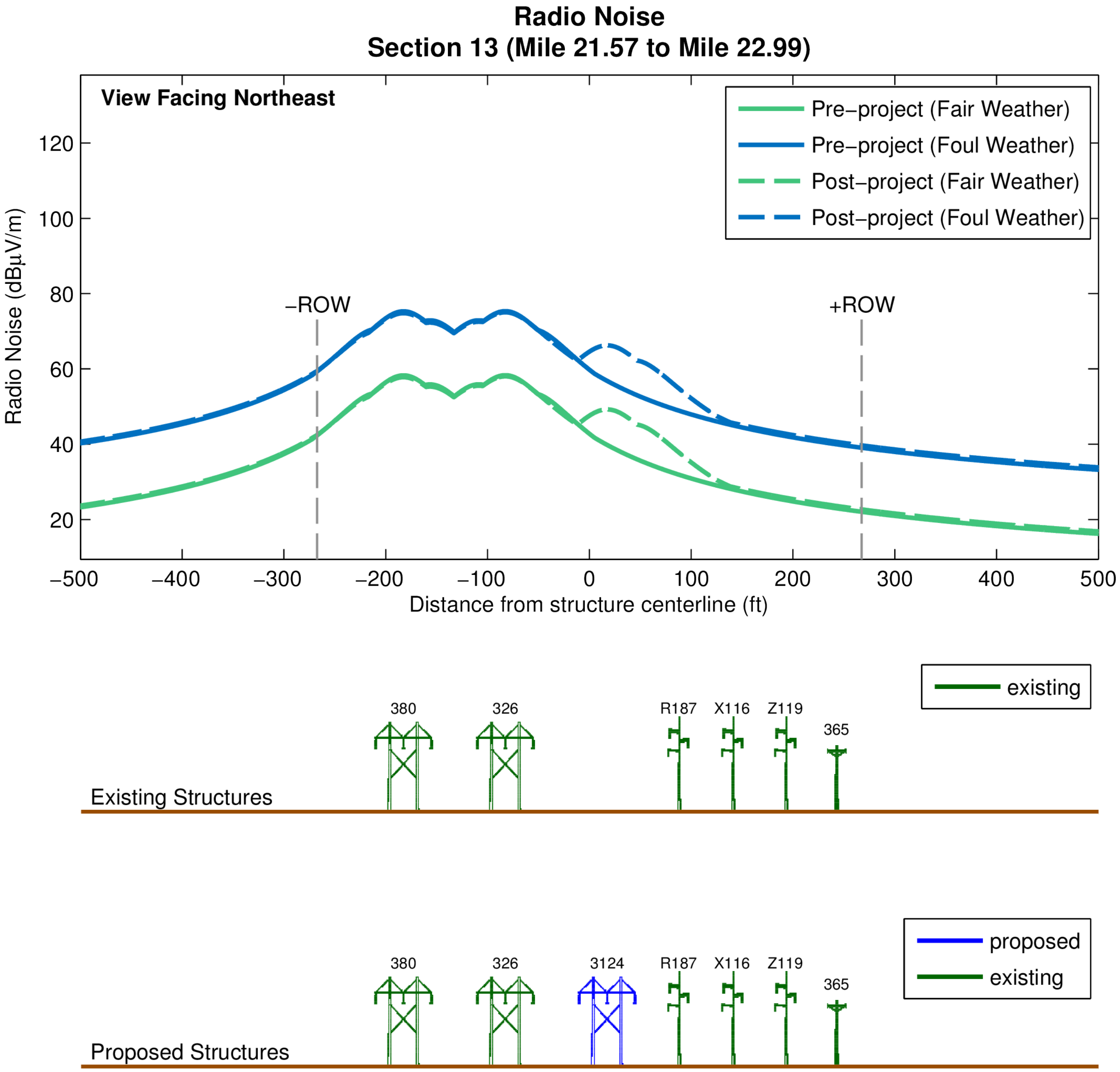

Figure B-38. Radio noise profile along Section 13 (Mile 21.57 to Mile 22.99).

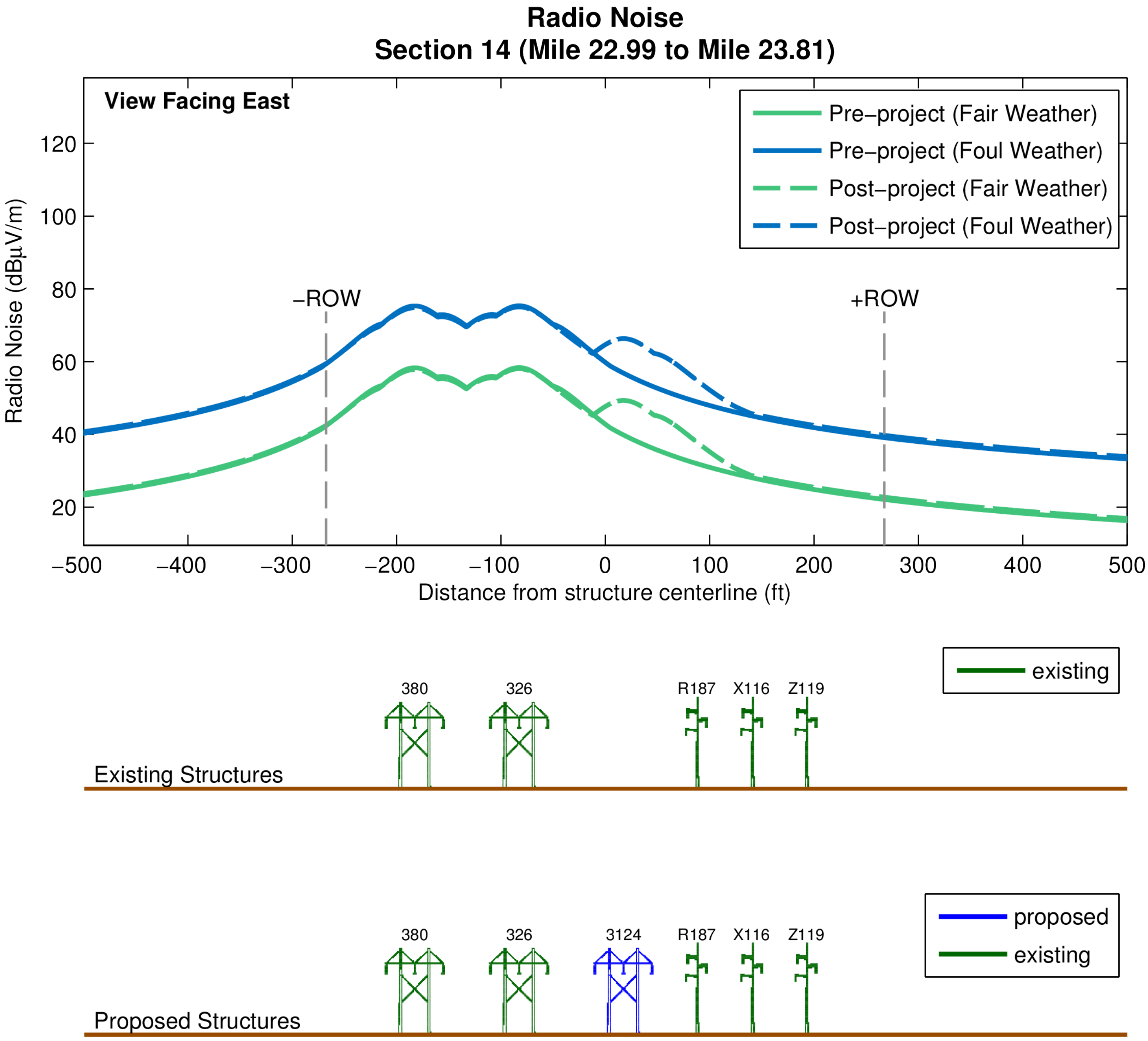

Figure B-39. Radio noise profile along Section 14 (Mile 22.99 to Mile 23.81).

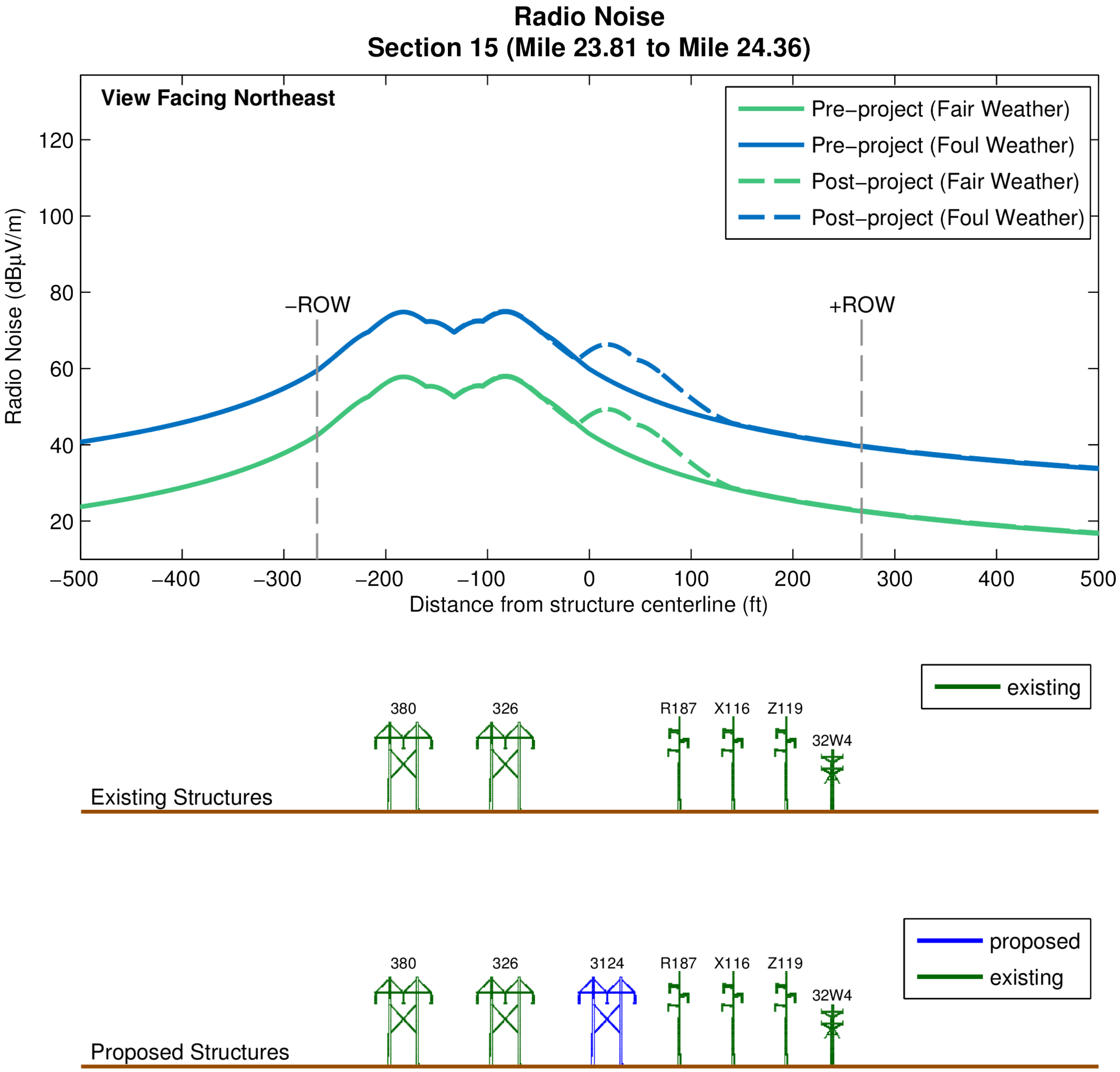

Figure B-40. Radio noise profile along Section 15 (Mile 23.81 to Mile 24.36).

Appendix C

Summary of ROW Configurations by Section Number with Circuit Loading and New Structure Diagrams

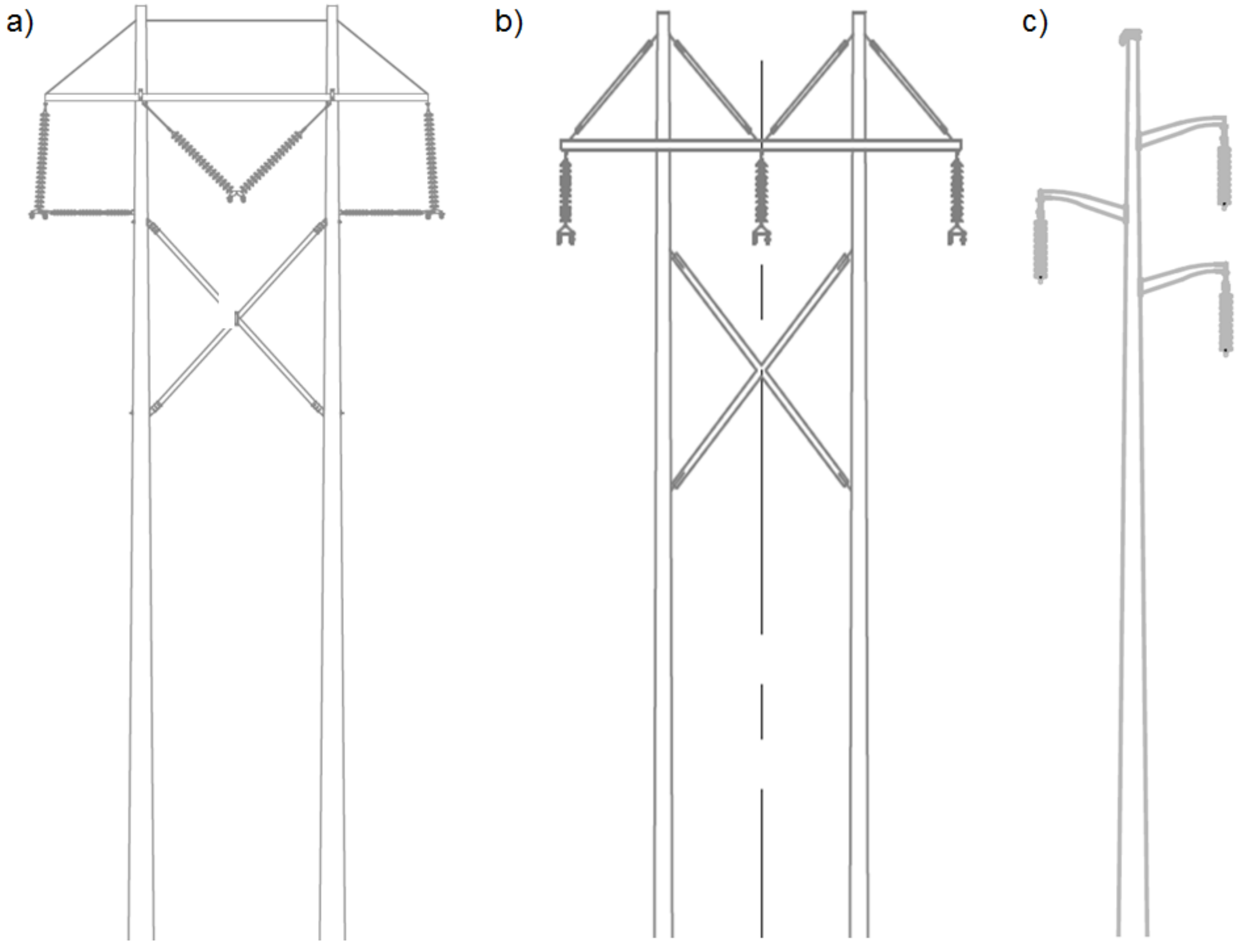

Figure C-1. Schematic of proposed structures for the proposed route. Steel H-frame structures for the proposed 3124 Line in NEP portions of the route (a); in PSNH portions of the route (b); and steel delta davit structures for the proposed rebuild of the Y-151 Line in Section 8 (c).

Table C-1. Summary of ROW configuration by section number

		Transmission Line Number												
		Transmission Lines										Distribution		DC
Section Number	Section Description	3124 (345 kV)	380 (345 kV)	326 (345 kV)	N-214 (230 kV)	O-215 (230 kV)	Y-151 (115 kV)	X-116 (115 kV)	Z-119 (115 kV)	R-187 (115 kV)	S-188 (115 kV)	365 (34.1 kV)	32W4 (12.7 kV)	451/452 (±450 kV)
8b	Mile 5.76 to Mile 8.9 (Pelham)	P	-	-	E	E	R	-	-	-	-	-	-	-
8c	Mile 8.9 (Pelham) to Mile 9.62	P	-	-	E	E	R	-	-	-	-	-	-	-
8d	Mile 9.62 to Mile 14.17	P	-	-	E	E	R	-	-	-	-	-	-	-
9	Mile 14.17 to Mile 14.6	P	-	-	E	E	-	-	-	-	-	-	-	
10	NGRID Interconnect to Str 236 at NGrid ROW	P	-	E	E	E	-	-	-	-	-	-	-	E
11	Str 236 at NGrid ROW to Str 255 at High Range Road	P	E	E	-	-	-	E	E	-	-	-	-	-
12	Str 255 at High Range Road to Mammoth Road S/S	P	E	E	-	-	-	E	E	-	E	-	-	-
13	Mammoth Rd S/S to Str 276	P	E	E	-	-	-	E	E	E	-	E	-	-
14	Str 276 to departure of 34.5 kV	P	E	E	-	-	-	E	E	E	-	-	-	-
15	departure of 34.5 kV to Str 286	P	E	E	-	-	-	E	E	E	-	-	E	-

P = proposed,
E = existing (not changed by project),
R = existing line, rebuilt to accommodate project

Table C-2. Loading summary of all modeled transmission lines

			Pre-Project				Post-Project					
			AAL		Annual Peak (2018)		AAL		Annual Peak (2018)		Annual Peak (2023)	
Line Name	Section Number	Voltage (kV)	MW	MVAR	MW	MVAR	MW	MVAR	MW	MVAR	MW	MVAR
3124	10-15	345	n/a	n/a	n/a	n/a	261.0	-66.4	616.6	-112.2	652.6	-114.1
326	10-15	345	447.2	-90.2	543.1	-107.3	335.6	-75.3	280.5	-83.7	298.5	-87.5
380	11-15	345	347.9	-9.6	536.0	-29.5	314.7	-4.8	457.8	-23.8	454.1	-22.1
N214	8b-10	230	51.2	-23.3	254.0	1.2	42.9	-22.0	233.9	1.2	235.7	4.8
O215	8b-10	230	64.9	-6.4	199.1	6.9	62.7	-6.1	193.7	5.9	192.3	9.7
R187	13-15	115	69.1	7.8	-14.7	33.7	66.7	8.2	-20.5	40.9	-16.6	35.8
S188	12	115	39.3	1.5	-75.8	18.3	37.0	2.0	-81.6	25.4	-79.2	19.8
X116	11-15	115	53.8	-8.7	127.6	23.4	48.4	-7.9	114.9	23.1	118.7	24.6
Y151	8b	115	27.5	-6.4	99.8	-13.1	12.5	-2.7	65.0	-5.2	70.3	-6.8
Y151	8c-8d	115	40.2	-5.5	126.6	-4.9	25.2	-2.1	91.4	0.7	97.4	-0.3
Z119	11-15	115	53.8	-8.7	127.7	23.4	48.5	-7.9	115.0	23.1	118.8	24.6
365	13	34.1	12.9	0.0	19.6	0.4	14.0	0.0	19.6	0.4	21.5	1.0
32W4	10	12.7	3.6	0.0	5.4	-0.2	3.9	0.0	5.4	-0.2	5.9	-0.2
451&452	10	±450 kV DC	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a