3.21 ELECTRICAL ENVIRONMENT

This section provides a description of the electrical environment of the existing and proposed transmission lines. The predicted levels of electric and magnetic fields, audible noise, and radio noise are calculated for the Proposed Route and Route Alternatives. Potential induced or stray voltages from the transmission lines are discussed, as are potential impacts on equipment used near the lines such as satellite receivers, GPS units, and cell phones.

3.21.1 Affected Environment

This section discusses those aspects of the environment that could be impacted by the Project. It starts with a discussion of the Analysis Area considered, identifies the issues that have driven the analysis, and characterizes the existing conditions across the Proposed Route and Route Alternatives in Wyoming, Nevada, and Idaho.

3.21.1.1 Analysis Area

The affected environment includes the area of land directly under and adjacent to the proposed transmission lines and alternatives. By design, expected levels of electric and magnetic field, audible noise, and radio noise would be at or below accepted guidelines at the edge of the proposed ROWs (in the range of 60 to 150 feet from the centerline of the ROW for the proposed line designs). For informational purposes, profiles of these levels are calculated and plotted out to a distance of 300 feet beyond either side of the centerlines of the Proposed Route and Route Alternatives.

3.21.1.2 Issues to be Analyzed

Issues often associated with the electrical environment of proposed transmission projects that were considered consist of the following:

- Whether voltage on the conductors of the transmission lines would build up, for example in large vehicles or pivot irrigation systems, and produce nuisance shocks, or lead to fuel ignition;
- Whether EMF associated with transmission lines would cause health effects;
- Whether the audible noise during operations would be loud enough to be annoying or interfere with normal communication;
- Whether stray voltage would be a concern in the context of animal care where unwanted voltage on feeders, watering stations, or equipment such as milking machines, can lead to reduced food or water intake; and
- Whether services such as GPS receivers, satellite dish receivers, cell phones, AM/FM radio, television, and internet would be disrupted.

3.21.1.3 Regulatory Framework

Applicable guidelines or regulations at the federal, state, or local level that may apply to the electric and magnetic fields, audible noise, or radio noise of the proposed transmission lines are discussed in this section.

Electric and Magnetic Fields

No federal regulations or guidelines apply directly to the electric and magnetic field levels for the lines in Wyoming, Nevada, and Idaho proposed for the Gateway West Project. The federal government performed an extensive review of field related issues in the 1990s that resulted in the decision that regulatory actions were not warranted (NIEHS 1999).

Although there are no federal regulations on low frequency electric and magnetic fields in the United States, recommendations and guidelines exist within the international community. Table 3.21-1 lists electric and magnetic field guidelines recommended by the European Union, the International Committee on Electromagnetic Safety, and the International Commission on Non-Ionizing Radiation Protection, an affiliate of the World Health Organization (ICES 2002; ICNIRP 1998). Table 3.21-2 lists electric and magnetic field level regulations that have been set in other states.

Table 3.21-1. International Guidelines for AC Electric and Magnetic Field Levels

Agency	Location	Electric Field	Magnetic Field
European Union General Public Exposure	Edge of ROW	4.2 kilovolt per meter (kV/m)	0.833 G
International Committee on Electromagnetic Safety (ICES) Occupational Exposure [1/]	Within ROW	10 kV/m	27.1 G
General Public Exposure	Edge of ROW	5 kV/m	9.04 G
International Commission on Non-Ionizing Radiation Protection (ICNIRP) Occupational Exposure	Within ROW	8.3 kV/m	4.17 G
General Public Exposure	Edge of ROW	4.2 kV/m	0.833 G

1/ 20 kV/m in controlled occupation setting
Magnetic fields are measured in Gauss (G) and milligauss (mG). Please note that 1 G = 1,000 mG.

Table 3.21-2. State Regulated AC Electric and Magnetic Field Levels

State	Location	Electric Field	Magnetic Field
Florida			
500-kV Lines	Within ROW	10 kV/m	NA
- single circuit	Edge of ROW	2 kV/m	200 mG
- double circuit		2 kV/m	250 mG
230 kV or less	Within ROW	8 kV/m	NA
	Edge of ROW	2 kV/m	150 mG
Minnesota	Within ROW	8 kV/m	NA
Montana	Within ROW – road crossing	7 kV/m	NA
	Edge of ROW	1 kV/m [1/]	NA

Table 3.21-2. State Regulated AC Electric and Magnetic Field Levels (continued)

State	Location	Electric Field	Magnetic Field
New Jersey	Within ROW Edge of ROW	NA 3 kV/m	NA NA
New York	Within ROW – open Within ROW – public road Edge of ROW	11.8 kV/m 7 kV/m 1.6 kV/m	NA NA 200 mG
North Dakota	Within ROW Edge of ROW	9 kV/m NA	NA NA
Oregon	Within ROW Edge of ROW	9 kV/m NA	NA NA

1/ Can be waived by landowner.
NA = Not Applicable. No requirements.

Seven states have adopted limits for electric field strength either at the edge or within the ROW of the transmission line corridor. Only Florida and New York currently limit magnetic fields levels from transmission lines. The magnetic field levels set in those two states only apply at the edge of the ROW and were based on an objective of preventing field levels from increasing beyond levels currently experienced by the public.

Audible Noise

There are no federal regulatory requirements for the audible noise level from transmission lines. The USEPA has audible noise guidelines developed for the protection of public health and welfare that are widely accepted by state and local governments for the long-term exposure to environmental noise (USEPA 1974). The USEPA employs the equivalent sound level (L_{eq}) and day-night sound level (L_{dn}) metrics in its guidelines. The L_{eq} is the energy averaged sound level over a specified time, whereas the L_{dn} is a 24-hour average sound level that includes a 10 dBA penalty to sound levels during nighttime hours (10:00 pm – 7:00 am). The USEPA guideline lists an L_{dn} of 55 dBA to protect the public from interference to activity or annoyance outdoors in residential areas.

Table 3.21-3 provides a summary of the USEPA audible noise guidelines.

Neither Idaho, Nevada, nor Wyoming has environmental noise regulations with dBA limits applicable to the Gateway West Project.

Table 3.21-3. Summary of USEPA Guidelines for Audible Noise

Location	Level	Concern
All public accessible areas with prolonged exposure	70 A-weighted decibels (dBA) $L_{eq(24h)}$	Protection for safety/hearing loss
Outdoor at residential structures or other noise sensitive areas where large amounts of time spent	55 dBA L_{dn}	Protection against annoyance and activity interference
Outdoor areas where limited amounts of time are spent (parks, school yards, golf courses, etc.)	55 dBA $L_{eq(24h)}$	
Indoor residential	45 dBA L_{dn}	
Indoor non-residential	45 dBA $L_{eq(24h)}$	

Radio Noise

Neither Idaho, Nevada, nor Wyoming nor any other state has limits for either radio interference or television interference. Electromagnetic interference from power transmission systems in the United States is governed by the Federal Communication Commission (FCC) Rules and Regulations (FCC 1988). A power transmission line is categorized by the FCC as an "incidental radiation device." It is defined as "a device that radiates radio frequency energy during the course of its operation although the device is not intentionally designed to generate radio frequency energy." Such a device "shall be operated so that the radio frequency energy that is emitted does not cause harmful interference. In the event that harmful interference is caused, the operator of the device shall promptly take steps to eliminate the harmful interference." In this case, "harmful interference" is defined as "any emission, radiation or induction which endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radio communication service operating in accordance with this chapter" (FCC 1988).

Complaints related to corona-generated interference are infrequent. The advent of cable or satellite television with the move to digital broadcast television in June 2009 also reduces the possibility of corona-generated interference. Cable, satellite, and digital broadcast are generally not subject to corona-generated interference. Electric power companies have been able to work quite well under the present FCC rule because harmful interference can generally be eliminated or effectively mitigated.

3.21.1.4 Methods

Algorithms developed by BPA that have been validated and used by engineers and scientists for many years were used to calculate the expected levels of electric field, magnetic field, audible noise, and radio noise that may be produced by the proposed Gateway West transmission lines. These calculation techniques are contained in the CAFÉ (Corona and Field Effects) program from BPA (n.d.). The inputs to the model are line voltage, load flow (current), and the physical dimensions of the line (conductor diameter, spacing, and height). The electric and magnetic field values were calculated at a reference height of one meter above ground. For modeling purposes, it was assumed that the maximum voltage of the 500-kV circuits was 10 percent above the nominal 500-kV value and voltage of the lower voltage 230-kV circuits was 5 percent above the nominal value. Proposed and alternative ROW dimensions, location of existing and proposed lines, and electrical loading were provided by the Proponents.

Table 3.21-4 lists the Gateway West proposed design line segments with the characteristics and the peak loadings used for calculation of the magnetic fields. In some cases such as Segment 1W and a portion of Segments 1E, 2, 4, 5, 8, and 9, the proposed transmission line runs in parallel with other lines but at a separation of at least 1,500 feet[1]. Although the lines would be in parallel, this separation distance is great enough that the electric and magnetic fields and audible and radio noise levels from the

[1] The proposed single-circuit 500-kV line between Cedar Hill and Hemingway and for one alternative would parallel but be offset 175 feet from an existing 138 kV line. In this case the peak electric and magnetic fields would be due primarily to the 500-kV line due to the large difference in line voltage and design.

Table 3.21-4. Line Segments

Segment Designation	Connecting Point A – Point B	Line Description	Line Status	Type	Peak Loading
1E (1-2)	Windstar – Aeolus	Single Circuit – 230 kV	New	H-frame pole	280 MW
1W(a) (1-2)	Windstar – Aeolus	Single Circuit – 230 kV	New and Rebuilt	H-frame pole	318 MW
1W(c) (1-2)	Dave Johnston – Aeolus	Single Circuit – 230 kV	New and Rebuilt	H-frame pole	327 MW
2 (2-3)	Aeolus – Creston	Double Circuit 500/230 kV	New	Dbl Circuit lattice tower	1,500 MW/ 350 MW
3 (3-4)	Creston – Bridger	Double Circuit 500/230 kV	New	Dbl Circuit lattice tower	1,500 MW/ 350 MW
4 (4-5)	Bridger – Populus	Double Circuit 500/500 kV	New	Dbl Circuit lattice tower	1,500 MW/ 1,500 MW
5 (5-6)	Populus – Borah	Single Circuit – 500 kV	New	Lattice Tower	1,500 MW
6 (6-8)	Borah – Midpoint	Single Circuit – 500 kV	No construction	Lattice tower	1,500 MW
7 (5-9)	Populus – Cedar Hill	Single Circuit – 500 kV	New	Lattice tower	1,500 MW
8 (8-10)	Midpoint – Hemingway	Single Circuit – 500 kV	New	Lattice tower	1,500 MW
9 (9-10)	Cedar Hill – Hemingway	Single Circuit – 500 kV	New	Lattice tower	1,500 MW
10 (8-9)	Midpoint – Cedar Hill	Single Circuit – 500 kV	New	Lattice tower	1,500 MW

lines would not be affected by the presence of the other line and thus can be treated and shown separately. This is illustrated in Figure 3.21-1 and Figure 3.21-2.

Figure 3.21-1 illustrates the electric field profile for Segment 1W, which has two parallel transmission lines (1W[a] and 1W[c], both of which require a reconstruction of an existing 230-kV line as well as the construction of a new line for portions of their length). Segments 1W(a) and 1W(c) are 1,500 feet from each other. Both lines have been considered in the calculation of the electric field profile across the distance of 1,500 feet plus 500 feet on either side of the lines for a total plot width of 2,500 feet.

Figure 3.21-2 is a plot of the electric field over the same distance but the electric field has been calculated individually for each line as if it was the only line present and then plotted on the graph. As can be seen by comparing Figure 3.21-1 and Figure 3.21-2, there is little if any difference in the plots for the two cases when the lines are separated by 1,500 feet. Comparisons for magnetic field, audible noise, and radio noise show similar results when the transmission lines are separated by 1,500 feet.

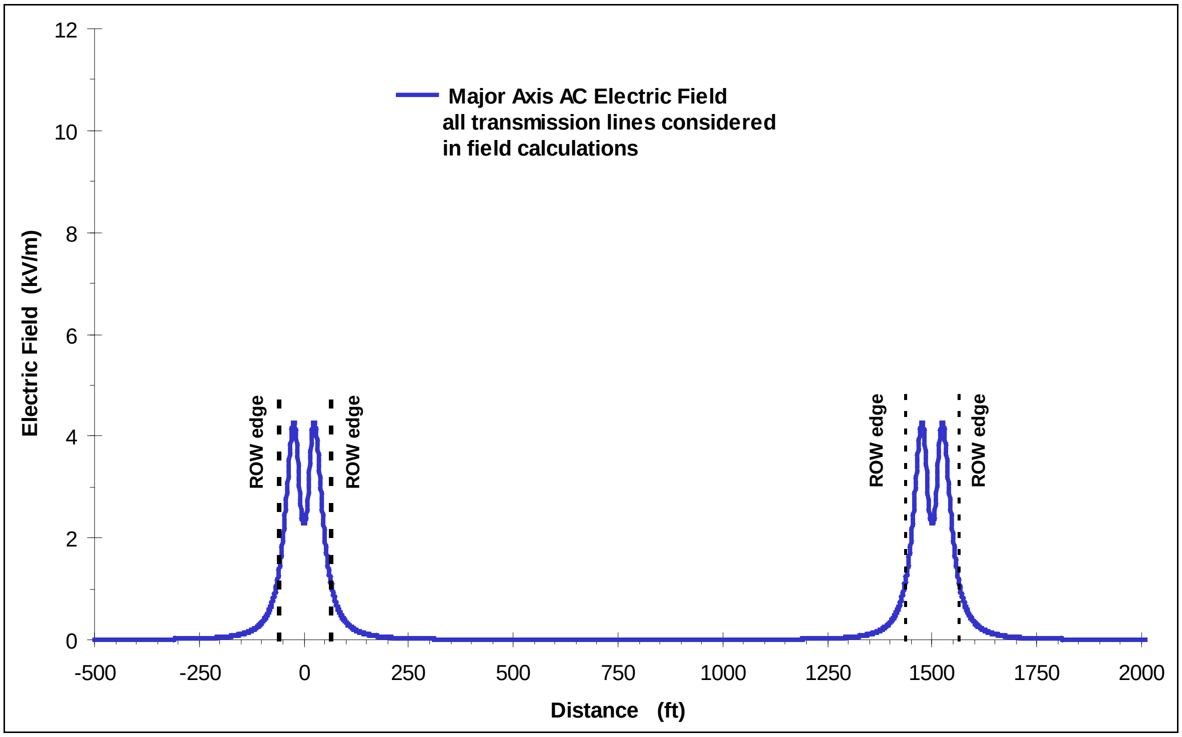

Figure 3.21-1. Plot of the Electric Field for Segment 1W Considering Two Parallel Lines 1W(a) and 1W(c) Separated from Each Other by 1,500 Feet in the Electric Field Calculations

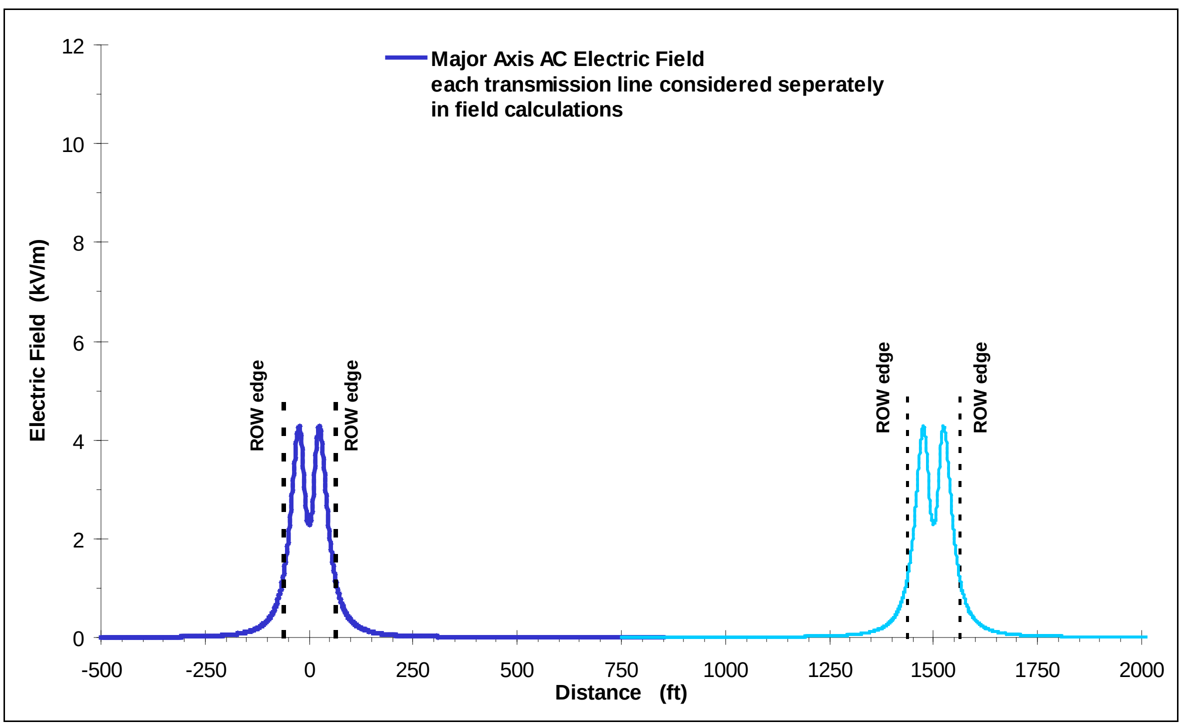

Figure 3.21-2. Plot of the Electric Field for Segment 1W Calculating the Electric Fields Separately for each of the Two Parallel Lines 1W(a) and 1W(c)

A 35-mile segment of the Segment 1W corridor would have a third 230-kV line (Segment 1E) parallel but separated by 1,500 feet. Similar to two 230-kV lines separated by 1,500 feet, a third line would result in little difference for the magnetic field, audible noise, and radio noise.

Existing Conditions

Existing levels of audible noise, radio noise, and electric and magnetic field are generally at ambient levels since there are no existing high-voltage transmission lines near the proposed Gateway West facilities (due to the required 1,500 feet of separation). Exceptions occur where existing and proposed transmission lines converge on substations and the short segment of 138-kV line paralleled on Segment 9. See Table 3.21-5 for a list of existing ambient levels of audible noise, radio noise, and electric and magnetic field.

Table 3.21-5. Existing Ambient Levels

Electric Field (kV/m)	Magnetic Field (mG)	Audible Noise (dBA in rain)	Radio Noise dB (1μV/m in rain)
0.1 kV/m to 10 kV/m Earth's static field	500 to 600 mG Earth's static field	30 to 55 dBA depending on terrain, vegetation, and wind and rain intensity	30 to 45 dB(1μV/m) depending on season and atmospheric activity

Existing electric and magnetic fields are essentially the static natural electric field of the earth, which is due to atmospheric conditions and can range from a few hundred volts/meter to kilovolts/meter, and the natural magnetic field of the earth, which is in the range of 500 milligauss (mG) to 600 mG; however, both of the fields are essentially static or slowly varying instead of oscillating 60 times per second like AC electric and magnetic field associated with a typical AC powerline. Much of the area crossed is open range and cultivated fields. Smaller areas of desert, forest, and scattered residential conditions also occur. Existing general levels of audible noise levels are at ambient conditions that range from 20 to 40 dBA due to air movement through brush and trees depending on local terrain and vegetation conditions (see Section 3.23 for more discussion of noise). Local individual sources such as animal calls or human activity can produce audible noise levels exceeding 60 dBA. Existing ambient levels of radio noise are due to atmospheric activity and are at approximately 30 to 40 dB (1 microvolt per meter [μV/m]) at 1 megahertz (MHz) depending on season and the amount of storm activity.

Electric and Magnetic Fields

Electric and magnetic fields are associated with the operation of AC powerlines or devices supplied with AC electricity. Electric and magnetic fields are sometimes referred to as EMF. These fields describe properties of a location or point in space and its electrical environment, including the forces that would be experienced by a charged body in that space by virtue of its charge or the movement of charges. The voltage, which is the "pressure," produces an electric field that moves the electricity through wires. The current produces a magnetic field, which is a measure of how much electricity is flowing. Thus, wherever there is electric current flowing (including through any type of wiring), there is both an electric and a magnetic field.

The standard unit for measuring the strength of an electric field is volts per meter (V/m). The unit in which magnetic field levels are measured is mG. Electric and magnetic fields are characterized by the frequency at which their direction and magnitude oscillate each second. The fields produced by the use of electricity oscillate at a frequency of 60 cycles per second, or 60 hertz (Hz). Electric and magnetic fields collectively are sometimes referred to as EMF although the term EMF is often used in reference to just the magnetic field.

Typical sources of these fields include powerlines (both transmission and distribution lines), home and office appliances, tools, building wiring, and currents flowing on water pipes. The importance of these sources to overall exposure varies considerably. For example, if a residence is very close, such as within 50 feet to a transmission line or even a distribution line (which runs near most everyone's residence), these sources could be the dominant, but not necessarily the only, source of magnetic fields in the home. Depending on the circumstances, other sources may be of equal or greater importance. For example, a random survey of 1,000 residences in the United States reported that currents flowing on water pipes and on other components of house grounding systems are twice as likely as outside powerlines to be the source of the highest magnetic fields measured in homes (Zaffanella 1993).

Electric-field levels depend primarily on the line’s voltage; the higher the voltage on the line, the higher the electric field levels associated with that line. Little variation is expected with electric field levels from a powerline because a line’s voltage does not vary significantly. Conducting objects including fences, shrubbery, and buildings easily block electric fields. Magnetic-field levels depend primarily on the current, or load, flowing on the line; as electricity demand increases and the current on the line increases, the magnetic field levels associated with the line generally increase. The transmission of electric power at a higher voltage (e.g., at 500 kV) reduces the current flow on the line to a level below that required to transport the same amount of power over lower-voltage lines. Both electric and magnetic field levels decrease rapidly with distance from a distribution or transmission line.

Audible and Radio Noise

Audible and radio noise occur when the 60 Hz electric fields at the surface of powerline conductors are large enough to cause a local breakdown in the insulating properties of the air. This electrical breakdown of the air or ionization of the air, at the surface of the conductor is called corona. Corona is a small “spark” or electrical breakdown in the air surrounding the conductor. This small “spark” into the air produces audible and radio noise. If there is sufficient corona activity, audible noise and radio/television noise can be noticeable within a few hundred feet of the transmission line, and small amounts of ozone and nitrous oxide can be released. These effects are most pronounced directly underneath the line conductors, and decrease with distance from the transmission line.

Corona activity depends on a number of factors such as altitude, line voltage, conductor size, conductor geometry, and weather conditions. The breakdown strength of air is 30 kV per centimeter at sea level and decreases with increasing altitude. For a particular altitude, conductor size and line voltage are taken into consideration when designing a transmission line so that the electric fields at the conductor surface do not exceed the breakdown potential of air. However, for lines with a voltage equal to or greater than typically 345 kV, any irregularities on the conductor surface (e.g., nicks, water droplets, or debris) may create points where the electric field is intensified sufficiently to produce corona. In inclement weather, moisture such as raindrops or snowflakes accumulating on the conductor surface would also act as points for corona inception. Corona activity is, therefore, most likely to occur on high-voltage transmission lines at higher altitudes during inclement weather if it occurs. High-voltage transmission lines are designed to avoid corona levels that would be likely to cause electronic or audible interference. These factors can be addressed and mitigated if necessary through design choices for the transmission line such as conductor size and bundling as well as general geometry of the transmission.

Audible Noise – The air breakdown, or small spark caused by corona at the surface of a transmission line conductor, is accompanied by a snapping sound. If there is sufficient corona activity on a high-voltage line, many small snaps from corona sources along a conductor may be sufficient, in combination, to produce discernible audible noise or crackle at the edge of the ROW. At lower system voltages (voltages below 230 kV), audible noise from the transmission-line conductors is typically not formally evaluated because of the very low levels of corona activity and correspondingly low occurrence of corona effects. For lines at higher voltages (345 kV and above) with higher conductor-surface gradients, corona activity is more likely and audible noise more frequent, particularly in inclement weather, and is therefore taken into account in the design of the transmission line.

Sound intensity is measured in decibels referenced to 20 micropascals, which is approximately the pressure threshold of human hearing at 1 kilohertz (kHz). 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. The weighting of sound over the frequency spectrum to account for the sensitivity of the human ear is called the A-weighted sound level. When the A-weighting scale is applied to a sound-pressure measurement, the level is often reported as dBA.

The sound intensity of typical human speech is approximately 60 to 70 dBA, and background levels of noise in rural environments are about 30 to 40 dBA. Specific identifiable noises such as birdcalls, neighborhood activity, and traffic can produce background audible noise levels of 50 to 70 dBA or higher.

Radio Noise – The impulsive corona currents cause wide-band electric and magnetic “noise” fields. This radio noise spans the frequency spectrum from below 100 kHz to approximately 1,000 MHz. Inclement weather and high altitude increase radio noise levels. This noise from transmission lines can produce interference to an AM signal such as a commercial AM radio audio signal (i.e., radio noise) or the video portion of a TV station (i.e., TV noise). FM radio stations and the audio portion of a TV station signal (which is also frequency modulated) are generally not affected by noise from a transmission line. Radio noise is measured in units of dB based on its field strength referenced to a signal level of 1 μV/m (IEEE 1986). Like audible noise, since it is due to corona activity, radio noise is more likely for lines at higher voltages (345 kV and above) with higher conductor-surface gradients, particularly at higher altitudes and in inclement weather. Radio noise performance is considered in the design of higher voltage lines at 345 kV and above.

<u>Other Conditions</u>

Electromagnetic Interference to GPS, Satellite Receivers, Cell Phones, and Community Communication Systems – GPS units, satellite receivers, cell phones, and community communication systems typically operate at high frequencies in the tens to hundreds of megahertz or even into the gigahertz range. These systems also often use FM or digital coding of the signals so that they are relatively immune to the electromagnetic interference from transmission line corona.

GPS units are used in a wide range of activities including several important agricultural activities in the study area such as monitoring pivot irrigation, tracking wheeled and tracked equipment movements during farming operation, and checking the orientation of aerial spraying aircraft. GPS units operate in the frequency range of 1.2 to 1.6 gigahertz. Tests with satellite receivers operate at frequencies from 3.4 gigahertz to 7 gigahertz and have shown no effect from transmission lines unless the receiver was trying to view the satellite through the transmission tower or the conductor bundle of the transmission line. Repositioning the receiver by a few feet was sufficient to eliminate the obstruction and reduced signal. Mobile phones operate in the radiofrequency range of about 800 million Hz, 1,900 million Hz, or higher frequencies. A million hertz is 1 MHz. Electric and magnetic fields at these high frequencies have very different physical characteristics from 60 Hz power frequency electric and magnetic fields. Due to the frequencies used by these devices and the modulation and processing techniques used, interference effects are unlikely.

Modern farming equipment uses GPS to guide tractors used for planting, cultivation, and harvesting. Modern guidance systems have an accuracy of 1 to 2 inches. Comments from local farmers indicate that powerlines can interfere with these GPS guidance systems, make them far less accurate, being off from 1½ to 4½ feet. If so, inefficiencies could result in wasted fuel, increased labor costs, and under- or over-fertilizing resulting in reduced productivity.

The Proponents report that they do not specifically track reports of interference with GPS tractor navigation systems; however, in the Magic Valley area of Idaho these systems are widely used and there are several existing transmission lines up to 500 kV crossing the area. They report that over the last 10 years they have not been contacted about interference with tractor GPS navigation systems. Users of these systems have expressed concerns about the possibility of interference, but no specific examples have been reported (IPC 2010).

It should be noted that GPS accuracy can be impacted by many factors including atmospheric conditions; satellite constellation and geometry; the design, quality, and position of the GPS antennas and receivers; signal interference; and “multipath.” Of these, a transmission line and its structures could conceivably contribute to signal interference and multipath.

Signal interference occurs when other signals at the same frequency as the satellite signal are present. Multipath occurs when objects such as buildings or parts of the tractor itself reflect the GPS satellite signal so that the satellite signal arrives at the receiver later than it would have if it had followed a straight line from the satellite. A study commissioned by the Electric Power Research Institute found that signal interference is "unlikely" based on the design of GPS receivers and their ability to separate the GPS signal from background noise (Silva and Olsen 2002). Another study compared the accuracy of real-time kinematic GPS receivers at different locations with respect to transmission lines and towers (Gibblings et al. 2001). This study concluded that multipath from transmission towers could result in GPS system initialization errors (i.e., the system reports the wrong starting location) 1.1 percent to 2.3 percent of the time. This study also reported that the GPS system software was able to identify and correct these initialization errors within the normal startup time. This study reported initialization errors due to electromagnetic interference from energized overhead transmission lines when the GPS receiver was located outside the vehicle, but concluded that "most, if not all of this effect can be eliminated by shielding the receiver and cables." Placing the receiver inside the vehicle used in the study significantly reduced the initialization errors.

Field Induction (induced currents and nuisance shocks) – The electric fields associated with a transmission line can induce small electric currents in metallic objects adjacent to or under transmission lines. Metallic roofs, vehicles, equipment, and fences are examples of objects that can develop a small electric charge when in proximity to high-voltage transmission lines. The amount of induced charge depends on the characteristics and size of the object, its grounding, and the electric field strength. An electric current can flow when an object has an induced charge and a path to ground. The amount of current flow is determined by the impedance of the object to ground and the voltage induced between the object and ground. The amount of induced current that can flow is important for evaluating the potential for nuisance shocks to people and the possibility of other effects such as fuel ignition.

The threshold of perception is approximately 1 mA for humans (Dalziel and Mansfield 1950). If the current is increased sufficiently beyond a person's perception threshold, it can become bothersome and possibly startling. Larger currents can cause the muscles of the arm and hand to involuntarily contract so that a person cannot let go of an object. The value at which 99.5 percent of men, women, and children can still let go of an object is approximately 9, 6, and 5 mA, respectively. Transmission lines are designed such that the maximum amount of current induced on the largest metallic object normally expected under the line would be less than 5 mA.

In the process of establishing contact with a vehicle or metallic object under a transmission line, a small arc may occur. This is often called a nuisance shock since it can be annoying. Nuisance shocks and induced currents can be eliminated by proper grounding of the object, shielding it from electric fields, or positioning it farther from the transmission line.

Idaho Power has received reports of shocks from fences near transmission lines. In these cases, the fences were electric fences that were insulated from the earth. Persons working on the insulated fence wire could in some instances experience a shock when they contacted the fence wire. This phenomenon is due to the fact that the fence wire is insulated from the earth, while being surrounded by an electric field.

Similar shocks can be experienced when contacting vehicles or irrigation pivots located close to a transmission line. The shock is similar to a static shock. The NESC addresses this issue, limiting the steady-state current that can flow between an object and the earth near a transmission line to 5 mA. This is considered to be a safe level. In the cases reported to Idaho Power, engineers have responded by checking the voltage at the fence or other objects to ensure that the 5 mA limit is not exceeded, and then providing suggestions to the customer on ways to eliminate the issue while working on their equipment. This issue is well understood and can be mitigated with proper grounding of the equipment or structure. The transmission line clearances are designed to prevent the 5 mA limit described above from being exceeded at objects such as vehicles with rubber tires that would be difficult to ground.

Stray Voltage –.Stray voltage refers to a phenomenon that is primarily of concern in wet environments usually involved with an AC distribution system. Transmission lines such as the one proposed are not normally associated with the phenomenon of stray voltage because the transmission line is a balanced, three-phase line without any direct electrical connection to end-user facilities.

In the Gateway West study area, wet environments may include dairy barns or feedlots. Stray voltage issues may occur when an animal makes contact with a metal object that is at a different potential from another point in contact with the animal (i.e., the nearby ground or earth potential). This may occur when there is poor grounding or bonding of the metal object to the earth and the electrical ground. For example, faulty or improperly wired motorized appliances, portable electric heaters, and fluorescent lights can lead to stray voltage issues. Metallic fences or large metallic object that are adjacent to, run parallel, or pass under the proposed Gateway West transmission lines may develop a different potential than the surrounding ground if not properly grounded; however, this is easily resolved by grounding the object.

Grounding practices required by the National Electric Code for dairies and similar agricultural facilities are specifically designed to prevent stray voltage issues from impacting these facilities. The Proponents expect to continue to receive and respond to questions about stray voltage and transmission lines and have programs in place to provide on-site testing and education to address these concerns.

Cardiac Pacemakers – Electric and magnetic fields from a variety of sources, including some industrial equipment, automobile ignition wiring, anti-theft devices in stores, magnetic resonance imaging machines, slot machines, cell phones, and certain medical procedures (e.g., radiation therapy, electrocautery, and defibrillation), have been reported to affect the operation of implanted cardiac pacemakers and defibrillators. In theory, pacemaker interference from the electric fields associated with high-voltage transmission lines might be possible depending upon the type of pacemaker, the person's location and orientation under the conductors of the transmission line, and the voltage and design of the transmission line. The manufacturers of pacemakers have designed their devices in various ways to minimize potential interference from external sources, including powerline EMF. For example, the increasingly prevalent bipolar pacemaker models are virtually immune to interference. Medtronic, a leading producer of pacemakers, notifies users of its products to limit their exposure to power frequency fields to below 6 kilovolts per meter (kV/m) and 1,000 mG to protect against possible electrical interference (Medtronic 2006).

Electrolysis – Electrolysis is a process in which DC voltage is deliberately applied from an external power source to combinations of materials and electrolytes to produce an otherwise non-spontaneous electrochemical reaction or to accelerate a spontaneous electrochemical reaction. For example, electrolysis is used in some metal plating processes and to separate hydrogen and oxygen from water. The transmission system operates using AC voltage and current, which does not produce or accelerate these reactions. Based on the concern raised (see Section 3.21.1.2), it is likely that the commenter is referring to galvanic corrosion, which is a spontaneous electrochemical reaction. Galvanic corrosion may occur when a single material such as an aluminum pipe is placed in different electrolytes along its length, or when different materials such as brass and galvanized steel are physically in contact with each other and are placed in a single electrolyte such as condensation on a cold water pipe and its associated valves. This process will occur whether or not a transmission line is present and is not influenced by the presence of the AC electrical system.

DC voltage is deliberately applied to many underground metallic pipelines to counter the effects of galvanic corrosion. These galvanic protection systems can produce DC voltages between different points on nearby metallic structures, which can accelerate the galvanic corrosion reaction in these structures as described above. Utility transmission towers do not utilize these active galvanic corrosion suppression systems; however, in some instances pipeline ROWs are located close to a transmission line ROW, which may give the impression that accelerated galvanic corrosion is due to the presence of the transmission line.

3.21.2 Direct and Indirect Effects

This section is organized to present first construction, then operation, followed by decommissioning effects from the proposed Project. Route Alternatives are analyzed in detail below in Section 3.21.2.3. There is a Design Variation involving use of two single-circuit structures proposed by the Proponents for Segments 2, 3, and 4 (see Section 2.2 for details), which is analyzed below in Section 3.21.2.4. The Proponents have also proposed a Schedule Variation, analyzed in Section 3.21.2.6, in which one of the two single circuits to be constructed in Segments 2, 3, and 4 and a portion of Segment 1W would be built on an extended schedule with construction beginning approximately 2.5 years after completion of the initial construction.

Mitigation measures or EPMs are presented in detail within this section only if it is the first time they have been discussed in Chapter 3; all other measures are referenced or summarized. A comprehensive list of all Proponent-proposed EPMs and Agency-required mitigation measures can be found in Table 2.7-1 of Chapter 2.

Plan Amendments

Proposed amendments are summarized in Table 2.2-1 of Chapter 2 and detailed in Appendices F and G. Amendments are needed to permit the Project to cross various areas of BLM-managed and NFS lands. Effects described for areas requiring an amendment in order for the Project to be built would only occur if the amendment were approved. Amendments that later land management designations could change future use of these areas. No amendments specific to the electrical environment are proposed for the Project and no impacts to the electrical environment resulting from approving the amendments beyond the impacts of the project are anticipated.

3.21.2.1 No Action Alternative

Under the No Action Alternative, the proposed Project would not be constructed or operated. No Project-related changes in the electrical environment would occur.

3.21.2.2 Effects Common to All Action Alternatives

Electric and Magnetic Fields

Electric Field

During construction of the proposed transmission line, the electric field levels would be at background or ambient levels since the proposed lines would not be energized and are not near pre-existing transmission lines along most of the Proposed Route. Once the lines are energized, the AC electric field levels would increase.

The various segments of the Gateway West Project, as proposed, consist of three line structures: a 230-kV H-frame structure (Appendix B, Figure B-1); a 500-kV single-circuit lattice structure (Figure B-2); and a 500-kV double-circuit lattice structure (Figure B-3). The 500-kV double-circuit lattice structure is further distinguished by its application with either two 500-kV circuits, as designed, or with a 500-kV circuit and the second circuit operated at 230-kV. The conductor location, spacing, and type for the 230-kV circuit on the structure would be physically designed as though for a 500-kV circuit, allowing its operating voltage to be increased to 500-kV at some future point as growth demanded, but for the present time would be operated at 230 kV. Please note that when multiple circuits exist in close proximity (such as with two adjacent structures or with a double-circuit structure) the particular phasing of the conductor bundles in relation to each other will affect the resulting levels of electric field, magnetic field, audible noise, and radio noise and the phasing of all conductor bundles of all the circuits will have to be factored in the calculations. The phase of a particular conductor bundle is indicated as either A, B, or C and the order and phasing of the conductor bundles of a circuit that are used to calculate the electrical levels are indicated as ABC. ABC for a single horizontal circuit indicates that the left conductor bundle is phase A, the middle conductor is phase B, and the right conductor bundle is phase C. CAB would indicate that the left conductor bundle is phase C, the middle conductor bundle is phase A, and the right conductor bundle is phase B.

The major-axis electric field profiles at midspan were calculated at a 1 meter height above ground (IEEE 1994) for these four line types and are plotted in Figure 3.21-3 through Figure 3.21-6. The electric field was calculated at the point of minimum

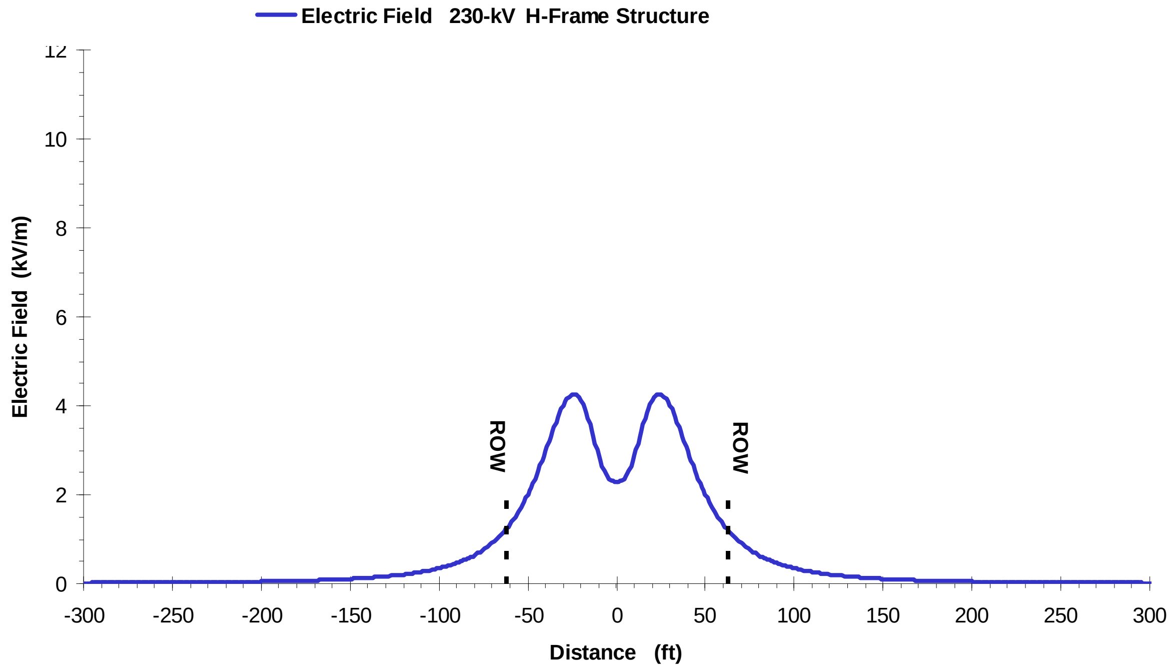

Figure 3.21-3. Electric Field Profile at Midspan for 230-kV H-frame Structure.
Note: Major axis electric field calculated at standard height of 1 meter.

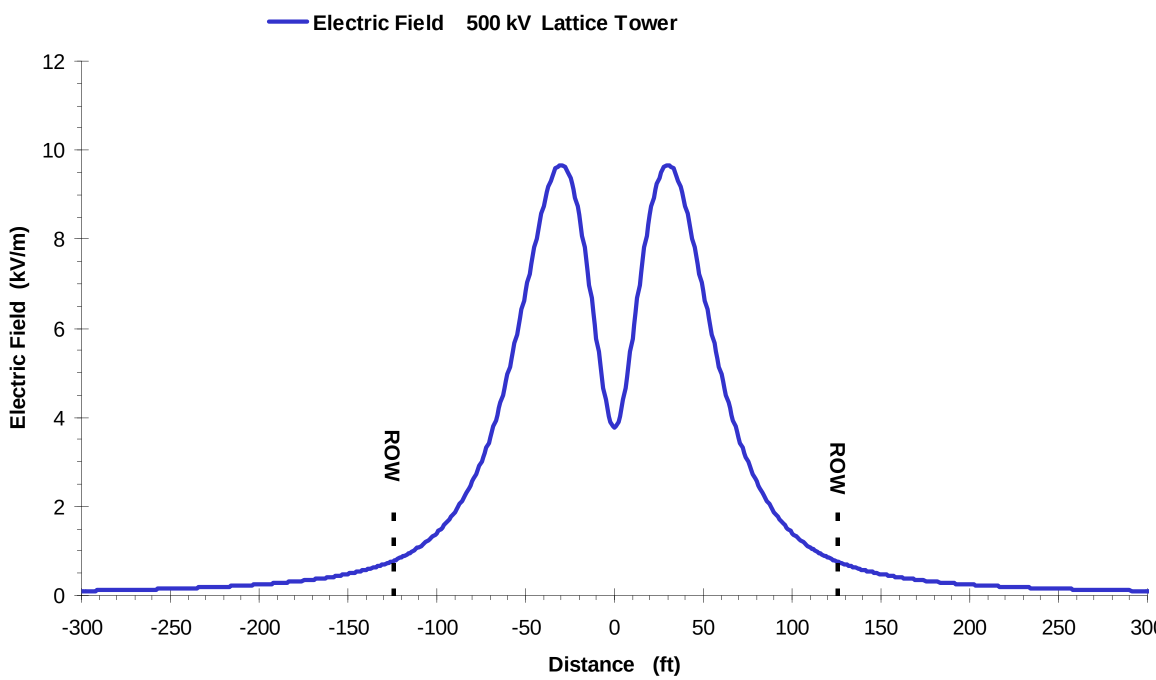

Figure 3.21-4. Electric Field Profile at Midspan for Single-Circuit 500-kV Lattice Structure
Note: Major Axis electric field calculated at standard height of 1 meter above ground.

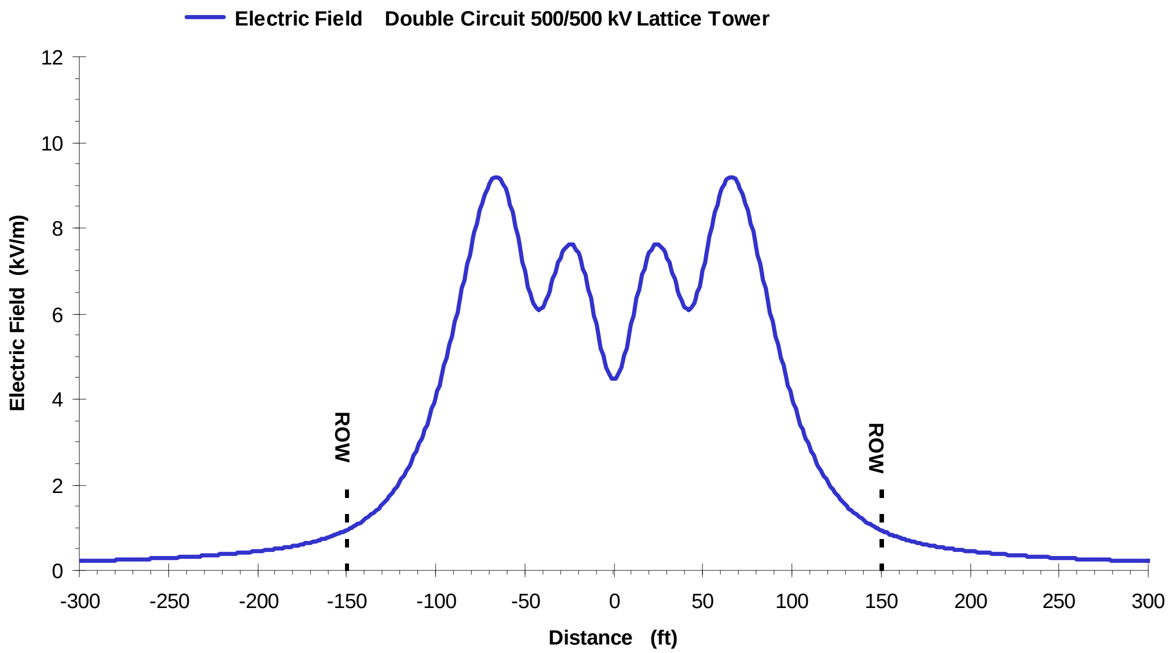

Figure 3.21-5. Electric Field Profile at Midspan for Double-Circuit 500-kV Lattice Structure with two 500-kV Circuits

Note: Conductor phasing from left to right is ABC-ABC. Major Axis electric field calculated at standard height of 1 meter above ground.

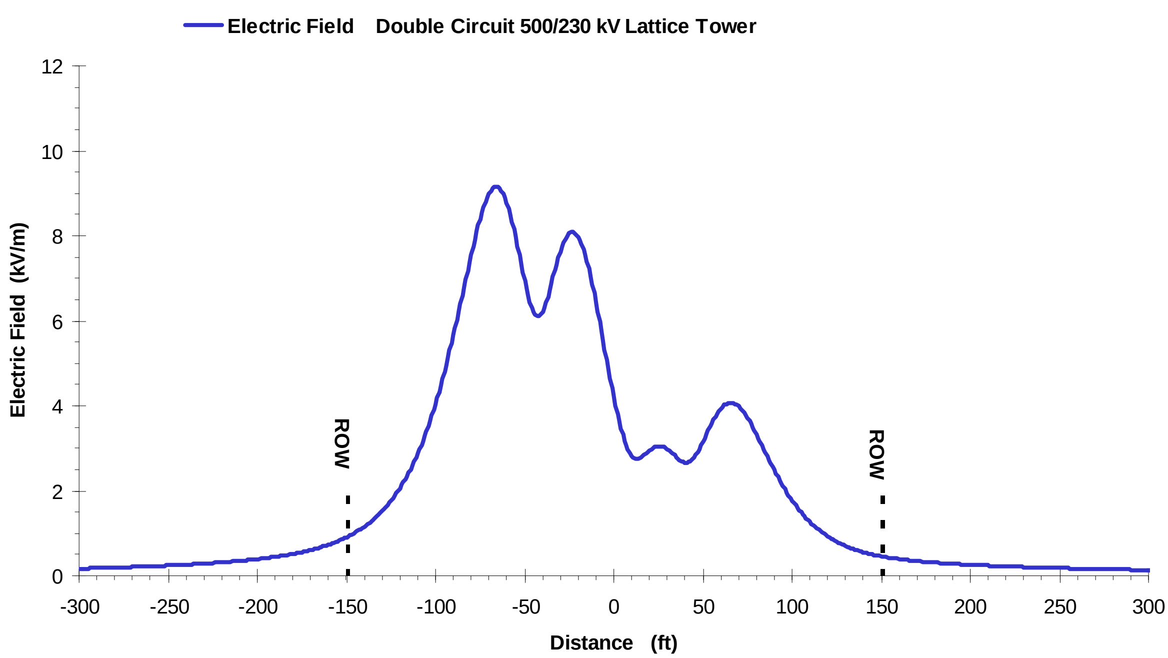

Figure 3.21-6. Electric Field Profile at Midspan for Double-Circuit 500-kV Lattice Structure with a 500-kV Circuit and a 230-kV Circuit

Note: Conductor phasing from left to right is ABC-ABC. Major Axis electric field calculated at standard height of 1 meter above ground.

clearance between the lowest conductor and ground. This occurs at midspan for level terrain. The conductor height used for the 500-kV lines was 35 feet and 28 feet was used for the 230-kV lines (Appendix B, Section 1.1.2). The line height above ground increases as one moves from midspan back toward the tower, which results in lower electric fields under the line. The electric field was calculated with a 10 percent overvoltage for 500-kV lines and a 5 percent overvoltage on 230-kV lines.

The electric fields at the edges of the ROWs and the highest electric field found within the ROW for each of the line segments in the Gateway West Project are listed in Table 3.21-6. The largest electric field calculated at the edge of the ROW was 1.23 kV/m. This level was found along the 230-kV line segments that had ROW widths of 125 feet. Electric fields of 0.94 kV/m or less were found at the ROW edge of the line segments with double-circuit 500-kV structures. Fields of 0.77 kV/m were found at the ROW edge of the single-circuit 500-kV line segments (Segments 5 through 10). The highest electric field found within the ROW was 9.67 kV/m for the single-circuit 500-kV segments (Segments 5 through 10). Slightly lower electric fields (approximately 9.2 kV/m) were found within the ROW for the segments with double-circuit 500-kV structures (Segment 2 and 3 with 500-kV and 230-kV circuits and Segment 4 containing two 500-kV circuits).

Table 3.21-6. Electric Fields

Segment	ROW Width (ft)	South/East ROW Edge (kV/m)	Maximum within ROW (kV/m)	North/West ROW Edge (kV/m)
Segment 1E (230 kV)	125	1.23	4.26	1.23
Segment 1W				
Line 1W(a) (230 kV)	125	1.23	4.26	1.23
Line 1W(c) (230 kV)	125	1.23	4.26	1.23
Segment 2 (500/230 kV)	300	0.91	9.15	0.46
Segment 3 (500/230 kV)	300	0.91	9.15	0.46
Segment 4 (500/500 kV)	300	0.94	9.19	0.94
Segment 5 (500 kV)	250	0.77	9.67	0.77
Segment 6 (500 kV)	250	0.77	9.67	0.77
Segment 7 (500 kV)	250	0.77	9.67	0.77
Segment 8 (500 kV)	250	0.77	9.67	0.77
Segment 9 (500 kV)	250	0.77	9.67	0.77
Segment 10 (500 kV)	250	0.77	9.67	0.77

Major Single Axis Electric Field at standard height of 1 meter.
Ground Clearance: 35 feet for 500-kV lines; 28 feet for 230-kV lines.
Electric fields are calculated at a standard height of 1 meter above ground.
Field levels along the route are within state requirements.

Magnetic Field

The magnetic field levels during the construction phase of the proposed Project would be at background or ambient levels since the proposed lines would not yet be energized except for portions of Segment 1W(a) and 1W(c). For 1W(a) and 1W(c), the portion of these routes that would consist of an existing 230-kV line would be rebuilt as part of the Project. Once the lines are energized, the AC magnetic fields would increase to those described in Table 3.21-7. The major-axis magnetic field profiles at midspan (point of closest approach of conductors to ground) were calculated for the four line types and are plotted in Figures 3.21-7 through 3.21-10. The magnetic fields at the edges of the

Table 3.21-7. Magnetic Fields (Peak Loading)

Segment	ROW Width (ft)	South/East ROW Edge (mG)	Maximum within ROW (mG)	North/West ROW Edge (mG)
Segment 1E (230 kV)	125	41	171	41
Segment 1W				
Line 1W(a) (230 kV)	125	47	194	47
Line 1W(c) (230 kV)	125	47	196	47
Segment 2 (500/230 kV)	300	48	258	32
Segment 3 (500/230 kV)	300	48	258	32
Segment 4 (500/500 kV)	300	53	249	53
Segment 5 (500 kV)	250	37	311	37
Segment 6 (500 kV)	250	37	311	37
Segment 7 (500 kV)	250	37	311	37
Segment 8 (500 kV)	250	37	311	37
Segment 9 (500 kV)	250	37	311	37
Segment 10 (500 kV)	250	37	311	37

Major Single Axis Magnetic Field at standard height of 1 meter.
Peak Loading on 500-kV circuits is 1,500 MW (0.95 load factor assumed).
Peak Loading on 230-kV circuits: 350 MW for Segment 2 and 3.
Segment 1E: 280 MW
Segment 1W(a): 318 MW
Segment 1W(c): 327 MW
Typical loading used as 70 percent of peak load. Magnetic field level for typical load taken as 70 percent of Magnetic Field under peak load conditions.

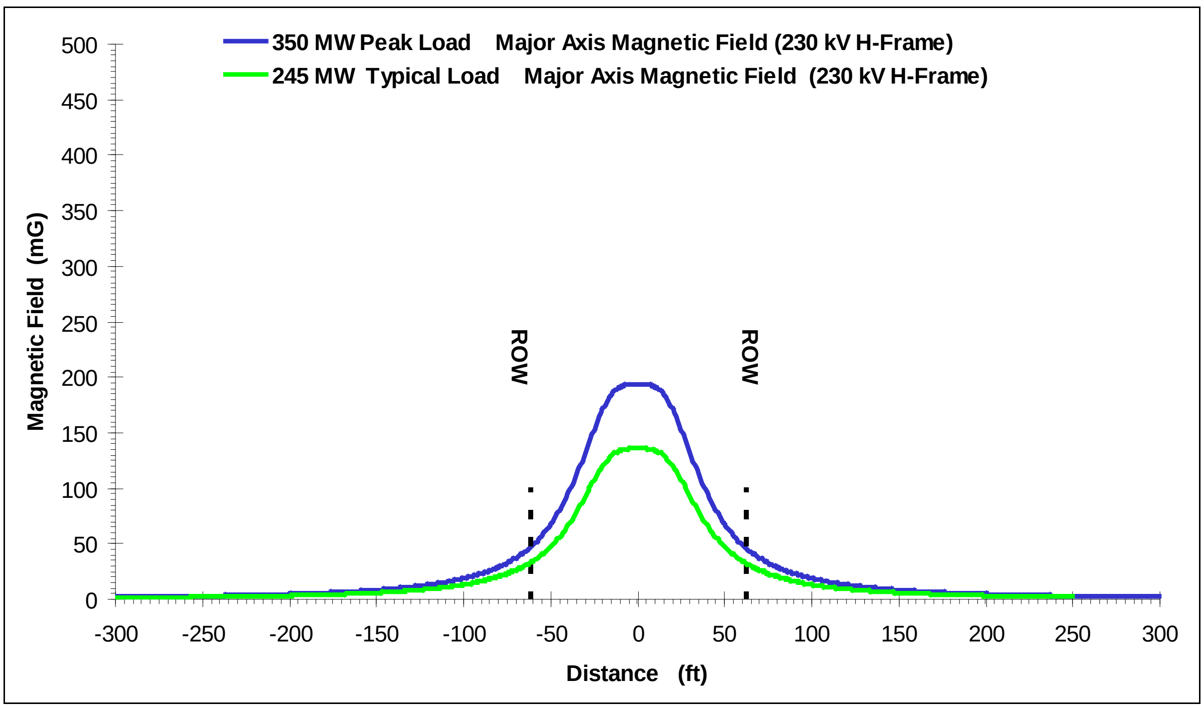

Figure 3.21-7. Magnetic Field Profile at Midspan for 230-kV H-frame Structure
Note: Magnetic field plotted for peak load of 350 MW and typical load of 245 MW. Major Axis magnetic field calculated at standard height of 1 meter.

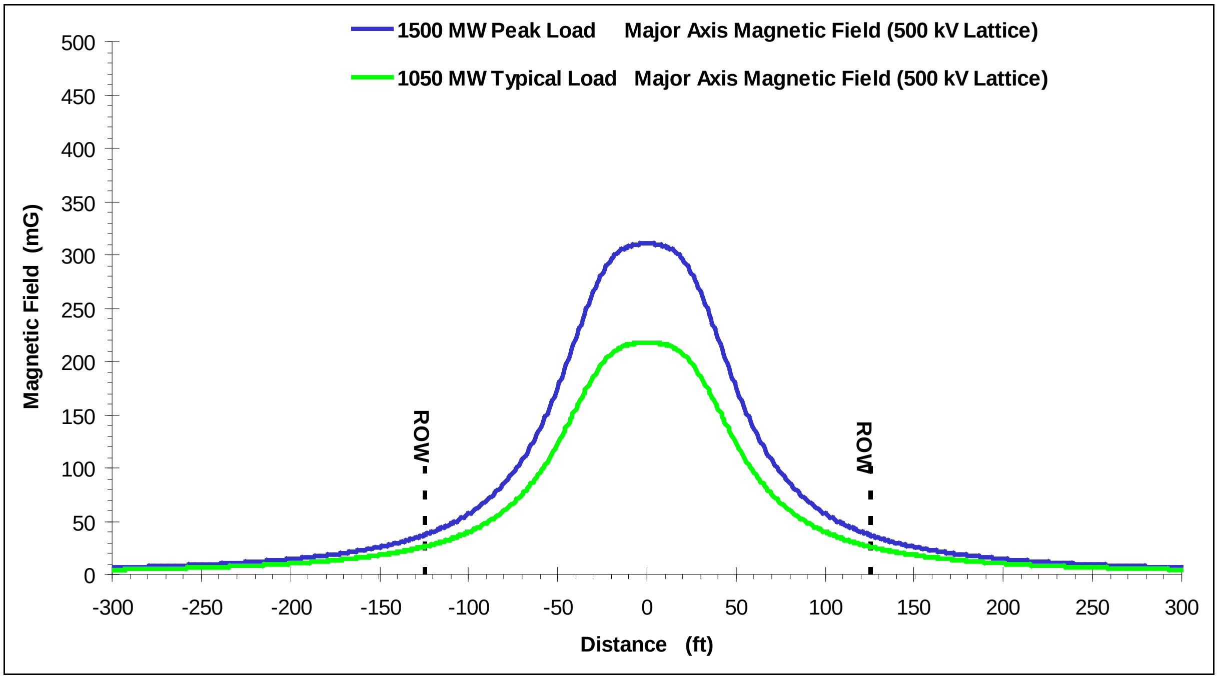

Figure 3.21-8. Magnetic Field Profile at Midspan for 500-kV Lattice Structure

Note: Major Axis magnetic field calculated at standard height of 1 meter.

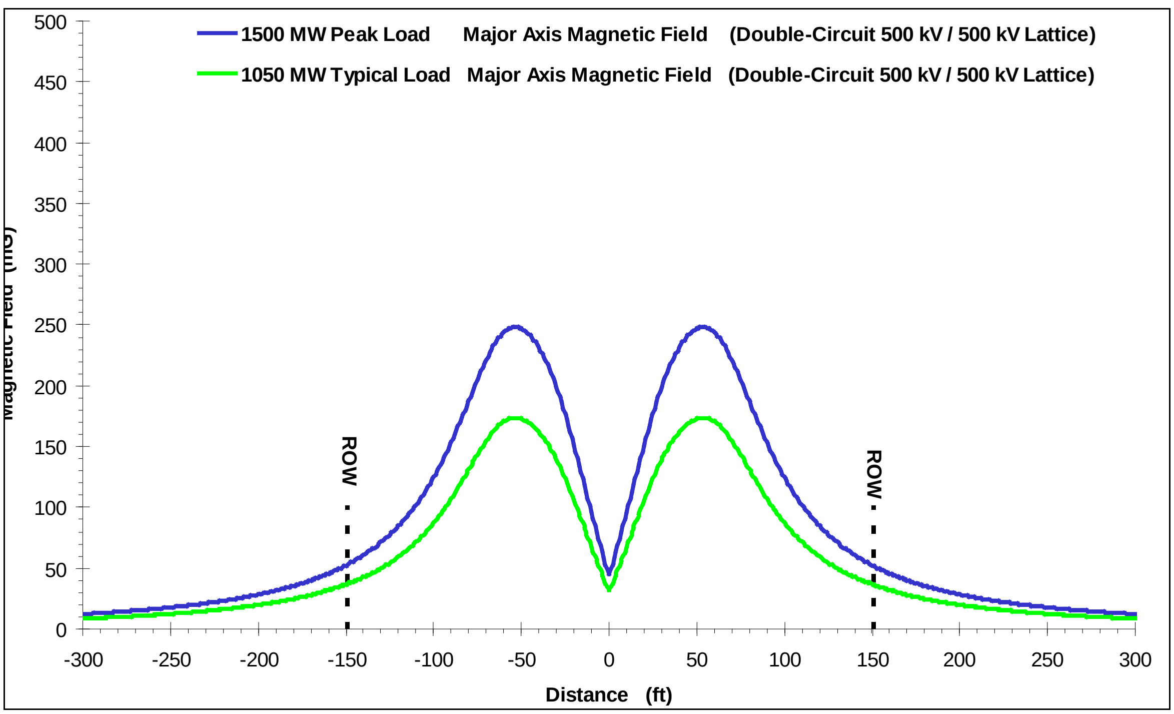

Figure 3.21-9. Magnetic Field Profile at Midspan for Double-Circuit 500-kV Lattice Structure with Two 500-kV Circuits

Note: Major Axis Magnetic Field Calculated at Standard Height of 1 Meter. Conductor Phasing from Left to Right is ABC-ABC.

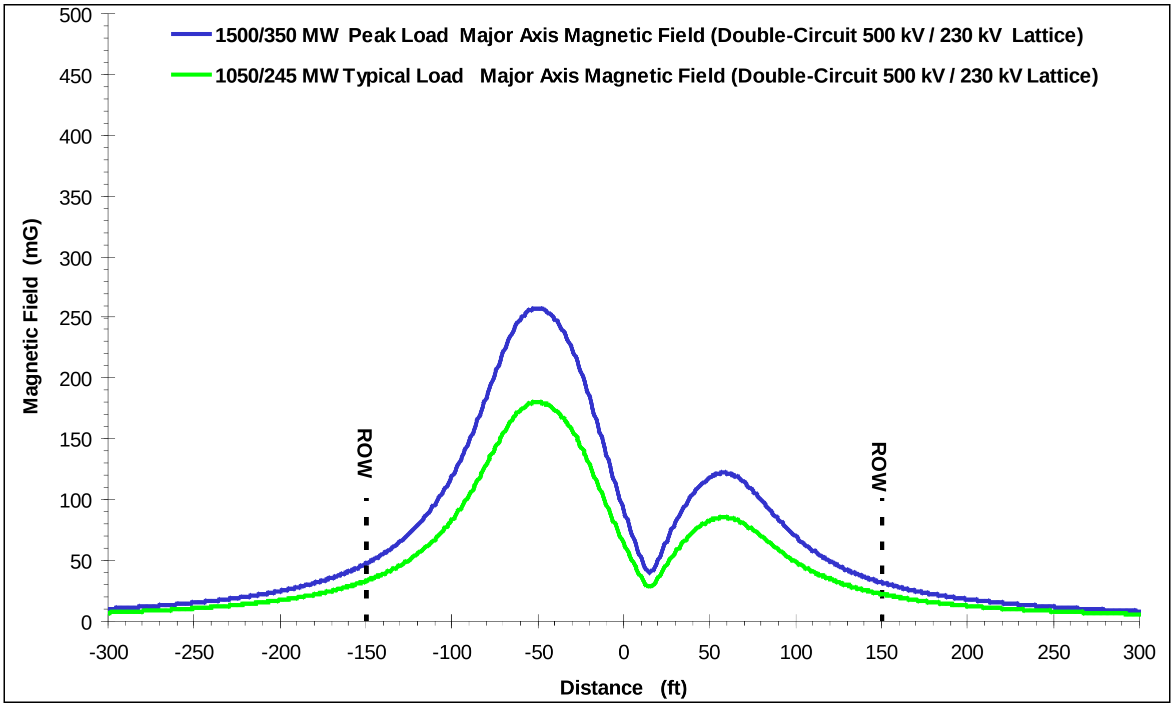

Figure 3.21-10. Magnetic Field Profile at Midspan for Double-Circuit 500-kV Lattice Structure with a 500-kV Circuit and a 230-kV Circuit

Note: Major Axis Magnetic Field Calculated at Standard Height of 1 meter. Conductor Phasing from Left to Right is ABC-ABC.

ROWs and the highest magnetic field found within the ROW for each of the Line Segments in the Gateway West Project are listed in Table 3.21-6. The largest magnetic field calculated at the edge of the ROW was 53 mG. This level was found along Segment 4 with the double-circuit 500-kV lines. The highest magnetic field found within the ROW was 311 mG for the ROWs containing the single-circuit 500-kV line (Segments 5 through 10).

Electric and Magnetic Field Effects

The interaction of electric and magnetic fields with humans or animals near or underneath high-voltage lines can be categorized as short-term or long-term effects. Short-term effects can generally be perceived and may be considered a nuisance, such as induced currents or shocks. Long-term effects for EMF generally relate to health concerns.

Short-Term Effects

Short-Term Electric Field Effects

Short-term electric field effects involve potentials and currents that may be induced on objects such as conductive roofs or buildings, fences, vehicles, or agricultural equipment near high-voltage lines. These potentials and currents may result in perceptible shocks or current flow if sufficiently large. The magnitude of induced currents and potentials on objects or equipment under the proposed lines would depend on the magnitude of the electric field, the size and shape of the object, and the object's connection (resistance) to ground. Grounding the object would reduce the induced potential to essentially zero and eliminate the object as a source of shocks or currents. Objects that are not grounded or poorly grounded may be a source of currents or shocks.

Fences or metal objects that are within the ROW should be grounded. Grounding would eliminate induced currents or potentials on these objects as a concern. Unlike fences or buildings, mobile equipment such as vehicles and agricultural machinery cannot be permanently grounded. The NESC requires that for high-voltage powerlines, such as the 230-kV and 500-kV lines proposed for the Gateway West Project, sufficient conductor clearance to ground be maintained to limit the short-circuit current induced in the largest anticipated vehicle under the line to 5 mA or less (NESC 2007). If necessary, this can be accomplished at locations where large vehicles are anticipated by increasing the line height, providing shielding of the electric field, or by limiting access.

The relation between short-circuit current and electric field for several vehicles and agriculture related pieces of equipment has been measured and is listed in Table 3.21-8 (EPRI 1982).

Table 3.21-8. Induced Current Factors

Object	**I_{sc}/E (mA/kV)**
Car L 4.6 m x W 1.78 m x 1.37 m	0.088
Pickup Truck L 5.2 m x W 2.0 m x H 1.7m	0.11
Tractor-Semitrailer (40-foot trailer) L 15.75 m x W 2.4 m x H 3.7m	0.64
Farm Tractor pulling Crop Wagon Tractor L 3.7 m x W 1.95 m x H 1.5 m Crop Wagon L 5.65 m x W 2.11 m x H 2.5 m Total Length 9.55 m	0.30

I_{sc} = short-circuit current
E = AC electric field
mA/kV = milliampere per kilovolt

Multiplying the factors listed in Table 3.21-8 by the electric field yields the short-circuit current expected under conditions that are expected to produce the greatest magnitude short-circuit currents. The highest electric field calculated within the ROW for the proposed Gateway West lines was 9.67 kV/m. The vehicles and equipment listed in Table 3.21-8 would have short-circuit currents that are less than the 5 mA current required by the NESC except for the tractor-semitrailer where the induced current would be 6.2 mA if the entire length of the tractor-semitrailer were in a 9.67 kV/m electric field (e.g., parallel to the line). Tractor-semitrailers would generally not be anticipated under the line except at line road crossings. At locations where large vehicles are anticipated, the line height would be increased if necessary (or the line design altered) so that the line complies with the NESC 5 mA safety requirement.

Although transmission lines are designed to limit induced currents on objects underneath the lines to a safe level (5 mA or less), this level of current or the contact electric shock may still occur and be perceived when an object is contacted. This may be considered a nuisance depending on the magnitude of the current or shock. The peak electric field found under the 500-kV lines is sufficient that currents and potentials induced on vehicles and farm equipment operated within the ROW might be perceived. Most of the area under the lines has lower fields and only a small area under the 500-kV lines where the conductors come closest to ground near midspan would be likely to induce perceivable currents or potentials on conductive objects such as vehicles or farm equipment. Ground cover and vegetation in contact with the equipment would partially ground it and further reduce the likelihood of perceivable currents or potentials. Perceived currents or potentials on vehicles or farm equipment can be mitigated if they occur by using a ground strap on the vehicle or equipment or if the vehicle or equipment avoids stopping while under the lines. Since a spark and current may occur between objects under the line if the objects are not properly connected and grounded, refueling a vehicle while it is under the line should be avoided.

Direct perception of the electric field has been reported in the instance of raising the back of the hand overhead toward a transmission line. The perception, which was due to movement of the hair on the back of the hand, occurred for a median electric field of 7 kV/m (EPRI 1982). For the proposed 500-kV lines, the electric field in a limited area of the ROW under the conductors near midspan would exceed the reported perception levels.

The electric fields from the proposed 230-kV and 500-kV lines for the Gateway West Project are comparable to those for other 230-kV and 500-kV lines. Electric field impacts can be reduced or eliminated by grounding practices and adherence to the NESC. In practice, unintentional grounding and shielding by vegetation and nearby objects would reduce the levels of induced current and shocks that have been considered for adverse safety conditions.

Short-Term Magnetic Field Effects

Magnetic fields associated with transmission lines can induce voltage and current in long conducting objects that are parallel to the transmission line. As with electric-field induction, these induced voltages and currents are a potential source of shocks. A fence, irrigation pipe, pipeline, electrical distribution line, or telephone line forms a conducting loop when it is grounded at both ends. The earth forms the other portion of the loop. The magnetic field from a transmission line can induce a current to flow in such a loop if it is oriented parallel to the line. If only one end of a fence is grounded (possible loop), then an induced voltage appears across the open end of the loop. The possibility for a shock exists if a person closes the loop at the open end by contacting both the ground and the conductor. The magnitude of this potential shock depends on the following factors: the magnitude of the magnetic field; the length of the object (the longer the object, the larger the induced voltage); the orientation of the object to the transmission line (parallel as opposed to perpendicular; no induction occurs on perpendicular loops); and the amount of electrical resistance in the loop (high resistance limits the current flow).

Magnetically induced currents from powerlines have been investigated for many years. Mitigating measures have been developed and are available. Studies of gas pipelines near transmission lines have developed prediction methods and mitigation techniques for induced voltages on pipelines (Dabkowski and Taflove 1979; Taflove and Dabkowski 1979). Similar techniques and procedures are available for irrigation pipes and fences. Grounding policies employed by utilities for long fences reduce the potential magnitude of magnetically induced voltage and currents.

Magnetic fields can cause distortion of the image on older style video display terminals and computer monitors (cathode-ray tubes). The threshold magnetic field for interference depends on the type and size of monitor and the frequency of the magnetic field. Interference has been observed for certain monitors at fields at or below 10 mG (Baishiki et al. 1990; Banfai et al. 2000). The problem typically arises when cathode-ray tube computer monitors are in use near electrical distribution or transmission facilities in large office buildings. This is becoming less of a concern with the advent of flat screen monitors, such as used in laptop computers. Flat screen monitors are not susceptible to AC magnetic fields. Some specialized equipment (for instance, certain medical equipment such as a magnetic resonance imaging machine or test equipment such as a scanning electron microscope) may be sensitive to even lower levels of magnetic field. However, equipment that is very sensitive to magnetic fields typically has shielding and is installed in a protected environment, to shield them from the magnetic fields of 1 to 10 mG or higher that can be found in buildings due to their wiring, lights, and other equipment. Mitigation methods for magnetic fields are available and involve grounding practices, shielding, device geometry, and distance.

Long-Term Effects

For more than 30 years, questions have been asked about the potential effect of EMF from powerlines on people. Early studies focused on electric fields. Magnetic fields began receiving increased attention in the late 1970s. A substantial amount of research has been conducted in the United States and around the world over the past several decades examining whether exposures to power frequency EMF have health or environmental effects.

Epidemiology studies have addressed many of the issues raised about EMF and health. Multidisciplinary reviews express the consensus in the scientific community that the epidemiologic evidence is insufficient to demonstrate a causal relationship between extremely low frequency (ELF; pertaining to power frequency) EMF and any health effect (NIEHS 1998, 1999; HCN 2001; NRPB 2001, 2004; IARC 2002; HCN 2004).

Several organizations responsible for health decisions including national and international organizations have convened groups of scientists to review the body of EMF research. These expert groups, including the National Institute of Environmental Health Sciences, the International Agency for Research on Cancer, the National Radiological Protection Board of Great Britain, and the Health Council of the Netherlands, have included dozens of scientists with diverse skills that reflect the different research approaches required to answer questions about health. Their conclusions are listed in Table 3.21-9.

The assessments by International Agency for Research on Cancer, the National Institute of Environmental Health Sciences, the National Academy of Science, the National Radiological Protection Board of Great Britain, and the Health Council of the

Table 3.21-9. EMF Conclusions of Multidisciplinary Review Groups

Organization	Conclusions
National Institute of Environmental Health Sciences (NIEHS 1999)	"The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic Lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects have been reported. No indication of increased leukemias in experimental animals has been observed. The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given the weak magnitude of these increased risks, some other factor or common source of error could explain these findings. However, no consistent explanation other than exposure to ELF-EMF has been identified. Epidemiological studies have serious limitations in their ability to demonstrate a cause and effect relationship whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to ELF-EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but it cannot completely discount the epidemiological findings. The NIEHS concludes that ELF-EMF exposure cannot be recognized at this time as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In my opinion, the conclusion of this report is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers or noncancer health outcomes provide sufficient evidence of a risk to currently warrant concern."
National Academy of Sciences (NAS 1999)	"An earlier Research Council assessment of the available body of information on biologic effects of power-frequency magnetic fields (NRC 1997 http://www.nap.edu/catalog.php?record id=5155#toc) led to the conclusion 'that the current body of evidence does not show that exposure to these fields presents a human health hazard. Specifically, no conclusive and consistent evidence shows that exposure to residential electric and magnetic fields produces cancer, adverse neurobehavioral effects, or reproductive and developmental effects'. The new, largely unpublished contributions of the EMF-RAPID program are consistent with that conclusion. We conclude that no finding from the EMF-RAPID program alters the conclusions of the previous NRC review on the Possible Effects of Electromagnetic Fields on Biologic Systems (NRC 1997). In view of the negative outcomes of EMFRAPID replication studies, it now appears even less likely that MFs [magnetic fields] in the normal domestic or occupational environment produce important health effects, including cancer."

Table 3.21-9. EMF Conclusions of Multidisciplinary Review Groups (continued)

Organization	Conclusions
National Radiological Protection Board of Great Britain (NRPB 2001) (NRPB 2004)	"Laboratory experiments have provided no good evidence that extremely low frequency [ELF] electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggests that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK [or in the US]." "Because of the uncertainty… and in absence of a 'dose-response' relationship, NRPB has concluded that the data concerning childhood leukemia cannot be used to derive quantitative guidance on restricting exposure."
Health Council of the Netherlands (HCN 2001) (HCN 2004)	"Because the association is only weak and without a reasonable biological explanation, it is not unlikely that it [an association between ELF exposure and childhood leukemia] could also be explained by chance… The committee therefore sees no reason to modify its earlier conclusion that the association is not likely to be indicative of a causal relationship." "The Committee, like the IARC itself, points out that there is no evidence to support the existence of a causal relationship here. Nor has research yet uncovered any evidence that a causal relationship might exist."
International Agency for Research on Cancer (IARC 2002)	"Studies in experimental animals have not shown consistent carcinogenic or co-carcinogenic effects of exposures to ELF [extremely low frequency] magnetic fields, and no scientific explanation has been established for the observed association of increased childhood leukemia risk with increasing residential ELF magnetic field exposure." IARC categorized EMF as a "possible carcinogen" for exposures at high levels, based on the meta-analysis of studies of statistical links with childhood leukemia at levels above 3-4 mG.

Netherlands agree that there is little evidence to suggest EMF is associated with adverse health effects, including most forms of adult and childhood cancer, heart disease, Alzheimer's disease, depression, and reproductive effects. However, all of the assessments concluded that epidemiology studies *in total* suggest an association between magnetic fields at higher time-weighted average exposure levels (greater than 4 mG) and childhood leukemia. Nevertheless, all agree that the experimental laboratory data do not support a *causal* link between EMF and any adverse health effect, including leukemia, and have not concluded that EMF is, in fact, the cause of any disease.

The exposure of animals to electric and magnetic fields has also been investigated for over 30 years. Vegetation in the form of grasses, shrubs, and small trees largely shields small ground-dwelling species such as mice, rabbits, foxes, and snakes from electric fields. Species that live underground, such as moles, woodchucks, and worms, are further shielded from electric fields by the soil; aquatic species are shielded from electric fields by water. Large species such as deer and domestic livestock have greater potential exposures to electric fields since they can stand taller than the surrounding vegetation. However, the duration of exposure for deer and other large animals is limited to foraging bouts or the time it takes them to cross under the line. All species would be exposed to higher magnetic fields under or near a transmission line than elsewhere, because vegetation and soil do not provide shielding from this aspect of the transmission-line electrical environment.

Field studies have been performed to monitor the behavior of large mammals in the vicinity of high-voltage transmission lines. No effects of electric or magnetic fields were evident in two studies from the northern U.S. on big game species, such as deer and elk, exposed to a 500-kV transmission line (Goodwin 1975; Picton et al. 1985).

Much larger populations of animals that might spend time near a transmission line are livestock that graze under or near transmission lines. To provide a more sensitive and reliable test for adverse effects than informal observation, scientists have studied animals continuously exposed to fields from high-voltage lines in relatively controlled conditions. For example, grazing animals such as cows and sheep have been exposed to high-voltage transmission lines and their reproductive performance examined (Lee et al. 1996). No adverse effects were found among cattle exposed to a 500-kV direct-current overhead transmission line over one or more successive breeding events (Angell et al. 1990). Compared to unexposed animals in a similar environment, the exposure to 50 Hz fields did not affect reproductive functions or pregnancy of cows (Algers and Hennichs 1985; Algers and Hultgren 1987). Sheep and cattle exposed to EMF from transmission lines exceeding 500 kV were examined and no effect was found on the levels of hormones in the blood, weight gain, onset of puberty, or behavior (Stormshak et al. 1992; Lee et al. 1993; Lee et al. 1995; Thompson et al. 1995; Burchard et al. 1998; Burchard et al. 2004).

Greenberg et al. (1981) studied honeybee colonies placed near 765-kV transmission lines. They found that hives exposed to AC electric fields of 7 kV/m had decreased hive weight, abnormal amounts of propolis (a resinous material) at hive entrances, increased mortality and irritability, loss of the queen in some hives, and a decrease in the hive's overall survival compared to hives that were not exposed. Placing the hive farther from the line, shielding the hive, or using hives without metallic parts eliminates this problem.

Numerous studies have been carried out to assess the effect of exposure of plants to transmission-line electric and magnetic fields. These studies have involved both forest species and agriculture crops. Researchers have found no adverse effects on plant responses, including seed germination, seedling emergence, seedling growth, leaf area per plant, flowering, seed production, germination of the seeds, longevity, and biomass production (Lee et al. 1996).

Electric and Magnetic Field Summary

The EMF for the proposed lines meets international, federal, and Wyoming, Nevada, and Idaho guidelines. The electric fields calculated at the edge of the ROW for the 500-kV lines are less than 1 kV/m for the 500-kV line and less than 1.25 kV/m for the 230-kV lines (see Section 3.21.1.3 for the respective international, federal, and state guidelines). The electric fields at the edges of the ROWs and the highest electric field found within the ROW for each of the line segments in the Gateway West Project are listed in Table 3.21-6. The largest electric field calculated at the edge of the ROW was 1.23 kV/m. This level was found along the 230-kV line segments that had ROW widths of 125 feet. Electric fields of 0.94 kV/m or less were found at the ROW edge of the line segments with double-circuit 500-kV structures. Fields of 0.77 kV/m were found at the ROW edge of the single-circuit 500-kV line segments (Segments 5 through 10). The highest electric field found within the ROW was 9.67 kV/m for the single-circuit 500-kV segments (Segments 5 through 10). Slightly lower electric fields (approximately 9.2 kV/m) were found within the ROW for the segments with double-circuit 500-kV structures (Segments 2 and 3 with 500-kV and 230-kV circuits and Segment 4 containing two 500-kV circuits). Segments 2 through 10 have peak electric fields ranging from 9.15 kV/m to 9.67 kV/m, while the 230-kV lines in Segment 1 peak at 4.26 kV/m (Table 3.21-6).

The magnetic fields calculated at the edge of the ROW for the 500-kV lines are 53 mG or less and 47 mG or less for the 230-kV lines (Table 3.21-7). For magnetic fields within the ROW, the 500-kV line segments (Table 3.21-7: Segments 2 through 10) have peak magnetic fields ranging from 249 to 311 mG. Segments 1E, 1W(a), and 1W(c) have peak magnetic fields ranging from 171 to 196 mG.

Mitigation techniques such as grounding practices and shielding exist to address any short-term effects that might be reported. The scientific consensus is that there is little evidence suggesting that EMF is associated with adverse health effects, and no exposure standards have been recommended.

Audible Noise

Audible noise levels from the transmission line itself would not occur until the line is energized. During construction audible noise related to the line would consist of construction noise and be limited to localized areas that have active construction activities. Once the lines are energized, the AC audible noise would vary depending on the weather conditions, with foul weather producing increased levels of audible noise. Two-hundred thirty (230)-kV lines contribute little or no audible noise in fair weather and, although their audible noise may increase in foul weather, it is less than the audible noise produced by rain and wind.

The audible noise profiles in fair and foul weather at midspan were calculated for the four line types and are plotted in Figures 3.21-11 through 3.21-14. The audible noise levels at the edges of the ROWs and the highest levels found within the ROW for each of the line segments in Gateway West are listed in Table 3.21-10 for foul weather conditions and Table 3.21-11 for fair weather conditions.

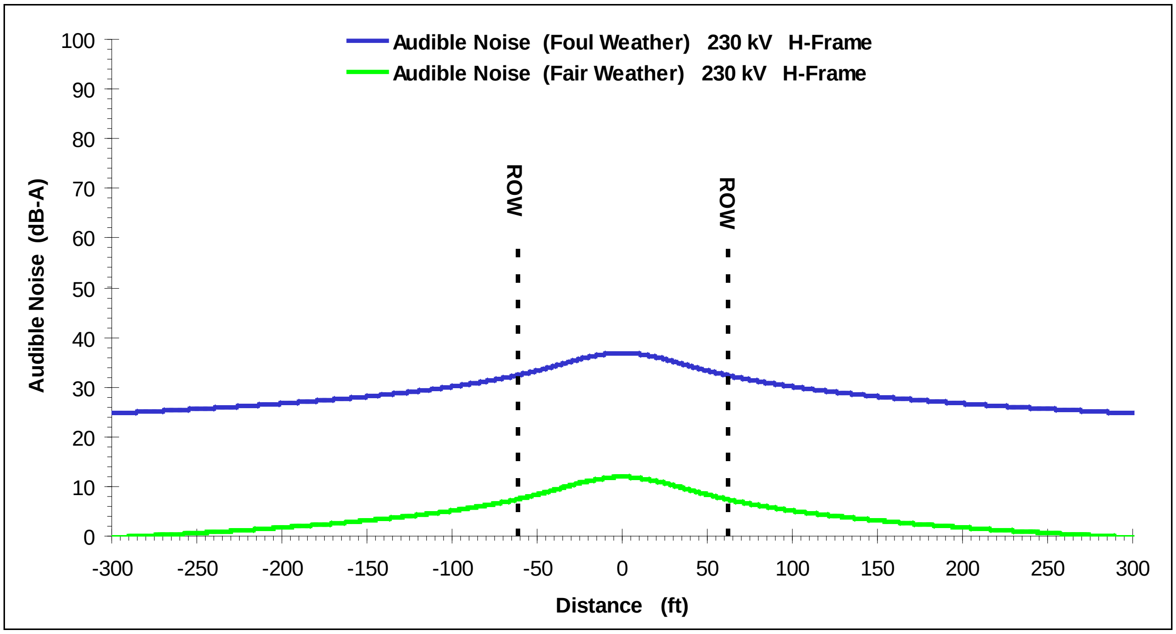

Figure 3.21-11. Audible Noise Profile at Midspan for Single-Circuit 230-kV H-frame Structure

Note: Audible noise profile calculated for fair and foul weather conditions. Conductor phasing from left to right is ABC.

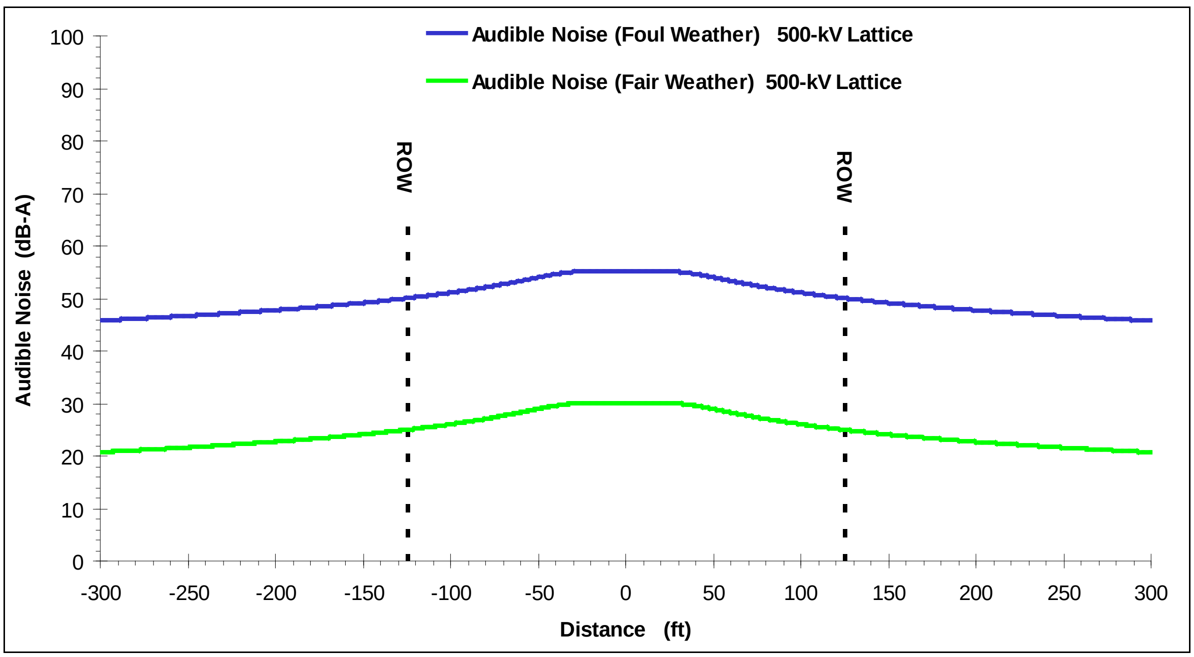

Figure 3.21-12. Audible Noise Profile at Midspan for Single-Circuit 500-kV Lattice Structure

Note: Audible noise profile calculated for fair and foul weather conditions. Conductor phasing from left to right is ABC.

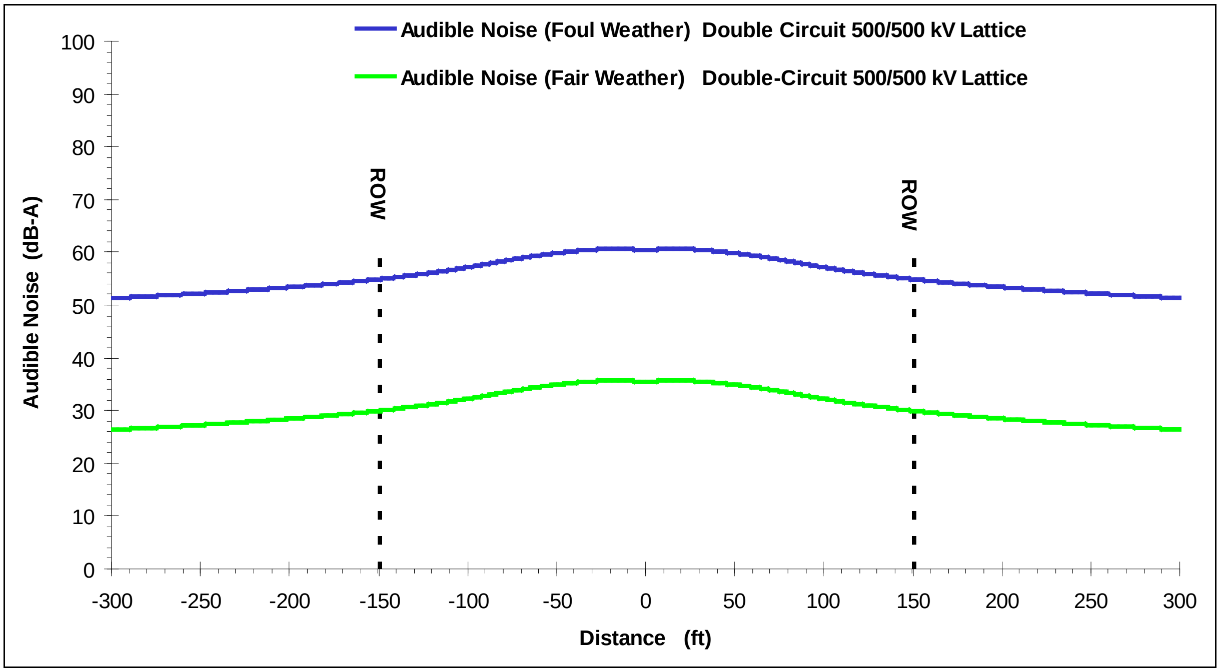

Figure 3.21-13. Audible Noise Profile at Midspan for Double-Circuit 500-kV Lattice Structure with Two 500-kV Circuits

Note: Audible noise profile calculated for fair and foul weather conditions. Conductor phasing from left to right is ABC-ABC.

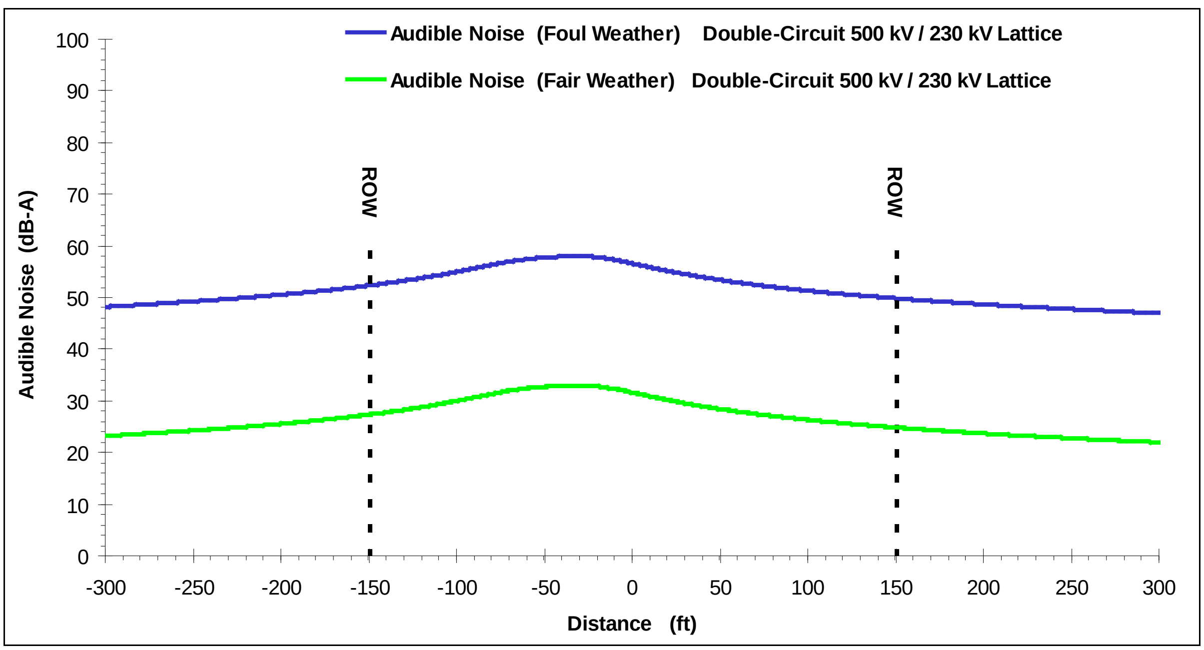

Figure 3.21-14. Audible Noise Profile at Midspan for Double-Circuit 500-kV Lattice Structure with a 500-kV Circuit and a 230-kV Circuit

Note: Audible noise profile calculated for fair and foul weather conditions. Conductor phasing from left to right is ABC-ABC.

Table 3.21-10. Audible Noise in Foul Weather

Segment	ROW Width (feet)	South/East ROW Edge (dBA)	Maximum within ROW (dBA)	North/West ROW Edge (dBA)
Segment 1E (230 kV)	125	32	37	32
Segment 1W				
Line 1W(a) (230 kV)	125	32	37	32
Line 1W(c) (230 kV)	125	32	37	32
Segment 2 (500/230 kV)	300	52	58	50
Segment 3 (500/230 kV)	300	52	58	50
Segment 4 (500/500 kV)	300	55	61	55
Segment 5 (500 kV)	250	50	55	50
Segment 6 (500 kV)	250	50	55	50
Segment 7 (500 kV)	250	50	55	50
Segment 8 (500 kV)	250	50	55	50
Segment 9 (500 kV)	250	50	55	50
Segment 10 (500 kV)	250	50	55	50

Median audible noise in foul weather measured in dB with A weighting referenced to 20 microPascals.
A weighting chosen to match response of human ear.
Altitude of 7,000 feet (audible noise would be less for altitude lower than 7,000 feet).

Table 3.21-11. Audible Noise in Fair Weather

Segment	ROW Width (ft)	South/East ROW Edge (dBA)	Maximum within ROW (dBA)	North/West ROW Edge (dBA)
Segment 1E (230 kV)	125	7	12	7
Segment 1W				
Line 1W(a) (230 kV)	125	7	12	7
Line 1W(c) (230 kV)	125	7	12	7
Segment 2 (500/230 kV)	300	27	33	25
Segment 3 (500/230 kV)	300	27	33	25
Segment 4 (500/500 kV)	300	30	36	30
Segment 5 (500 kV)	250	25	30	25
Segment 6 (500 kV)	250	25	30	25
Segment 7 (500 kV)	250	25	30	25
Segment 8 (500 kV)	250	25	30	25
Segment 9 (500 kV)	250	25	30	25
Segment 10 (500 kV)	250	25	30	25

Median audible noise in foul weather measured in dB referenced to 20 microPascals with A weighting.
A weighting chosen to match response of human ear.
Altitude of 7,000 feet (audible noise would be less for altitude lower than 7,000 feet).

Audible noise levels for foul weather conditions calculated at the edge of the ROW for the line segments ranged from 32 dBA to 55 dBA. Fifty-five dBA in foul weather was only found for the edges of the ROW of Segment 4 that has the double-circuit 500-kV lines. The audible noise levels in fair weather were less than in foul weather and ranged from 7 dBA to 30 dBA at the edge of the ROW. The audible noise levels would depend on the altitude of the line, with the noise increasing with the altitude. An altitude of 7,000 feet was used for all audible noise calculations. This is the highest estimated altitude expected along the line route thus producing the largest levels of audible noise. Line segments at lower altitudes would have lower levels of audible noise.

Table 3.21-12 lists common sources of audible noise and the associated sound level in dBA. Conversation is carried out at sound level of approximately 60 to 70 dBA. Traffic and equipment noise can range from 70 dBA to above 100 dBA; well in excess of the audible noise levels expected from the proposed Gateway West transmission lines. The levels found at the edge of the ROW during fair weather (30 dBA or less – Table 3.21-11) are similar to the noise levels found in a library or a bedroom at night and are likely to be masked by ambient audible noise levels from vegetation movement in breezes and animal and insect activity. Higher levels of audible noise may occur during foul weather but these levels are still at or below the level of conversational speech, and the audible noise from rain and wind during foul weather would help mask these levels.

Table 3.21-12. Common Audible Noise Levels

Sound Level (dBA)	Condition	Sound Level (dBA)	Condition
140 ---	Threshold of Pain	70 ---	
			Conversational Speech
130 ---		60 ---	
	Pneumatic Chipper		Business Office
120 ---		50 ---	
	Automobile Horn (40 feet away)		Suburban Living Room
110 ---		40 ---	
			Library
100 ---		30 ---	
	Inside New York Subway		Bedroom at Night
90 ---		20 ---	
	Inside Bus		Broadcast Studio
80 ---		10 ---	
	Average Traffic on Street Corner		
70 ---		0 ---	Threshold of Hearing

The audible noise levels from the proposed Gateway West lines are similar to the audible noise levels of other 230 and 500-kV lines. The levels of audible noise expected at the edge of the ROW during fair or foul weather for the proposed Gateway West transmission lines meet codified federal and state audible noise levels for Wyoming, Nevada, and Idaho.

Radio Noise

Radio noise from the proposed transmission lines would not occur until the lines are actually energized. During the construction phase there would be no radio noise from the lines since the conductors do not have voltage on them. Once the lines are energized, the AC radio noise would vary depending on the weather conditions with foul weather producing higher levels of radio noise than fair weather.

Portions of Segments 1W(a) and 1W(c) (230 kV) would consist of a rebuild of an existing 230-kV line. The radio noise levels associated with these portions of Segment

1W(a) and 1W(c) would be low because 230-kV lines have low levels of radio noise that are similar or below existing ambient radio noise levels due to atmospheric conditions.

The radio noise profiles in fair and foul weather at midspan were calculated for the four line types and are plotted in Figure 3.21-15 through Figure 3.21-18. The radio noise levels at the edges of the ROWs and the highest levels found within the ROW for each of the line segments in the Gateway West Project are listed in Table 3.21-13 for foul weather conditions and Table 3.21-14 for fair weather conditions.

Radio noise levels for foul weather conditions calculated at the edge of the ROWs for the line segments ranged from 42 dB (1 μV/m) to 58 dB (1 μV/m). Fifty-eight dB (1 μV/m) in foul weather was only found for the edges of the ROW of Segment 4 that has the double-circuit 500-kV lines. The radio noise levels in fair weather were less than in foul weather and ranged from 25 dB (1 μV/m) to 41 dB (1 μV/m) at the edge of the ROW.

The radio noise levels at the edge of the ROW in fair weather ranged from 25 dB (1 μV/m) for the 230-kV line segments to 41 dB (1 μV/m) or less for the line segments containing 500-kV lines. The Institute of Electrical and Electronic Engineers (IEEE) Radio Noise Design Guide (1986) identifies an acceptable fair-weather radio noise level of 40 dB at 100 feet from the outside conductor of a line. The fair weather radio noise at the edge of the ROW for the Segments 2 through 4 is calculated to be 41 dB; however, the proposed edge of ROW for Segments 2 through 4 containing the double-circuit 500-kV structures is less than 100 feet from the outside conductors. For these segments, the ROW edge is at approximately 88 feet from the outside conductor. When the location is increased to 100 feet from the outside conductor the fair weather radio noise decreases to below 40 dB and does meet the guideline. The 41 dB at the edge of the ROW is also calculated for an altitude of 7,000 feet. Lower altitudes will produce lower levels of radio noise. For line Segments 2 through 4 at 6,000 feet altitude or below, the fair weather radio noise decreases to below 40 dB meeting the IEEE Radio Noise Design Guideline even at the reduced distance of the edge of the ROW. Levels during foul weather would generally be 16 to 22 dB higher than in fair weather conditions though increased atmospheric radio noise would mask a portion of this increase.

The radio noise levels from the proposed lines are comparable to those of other 230-kV and 500-kV lines. There are no state limits for radio noise and no set federal limits. Radio noise is governed by the FCC under the general rule (47 CFR Part 15) that states “that the radio frequency energy that is emitted does not cause harmful interference. In the event that harmful interference is caused, the operator of the device shall promptly take steps to eliminate the harmful interference.” Power utilities have been able to work well under the FCC rule because the lines are designed to avoid complaints and mitigation methods exist to address specific complaints if they occur.

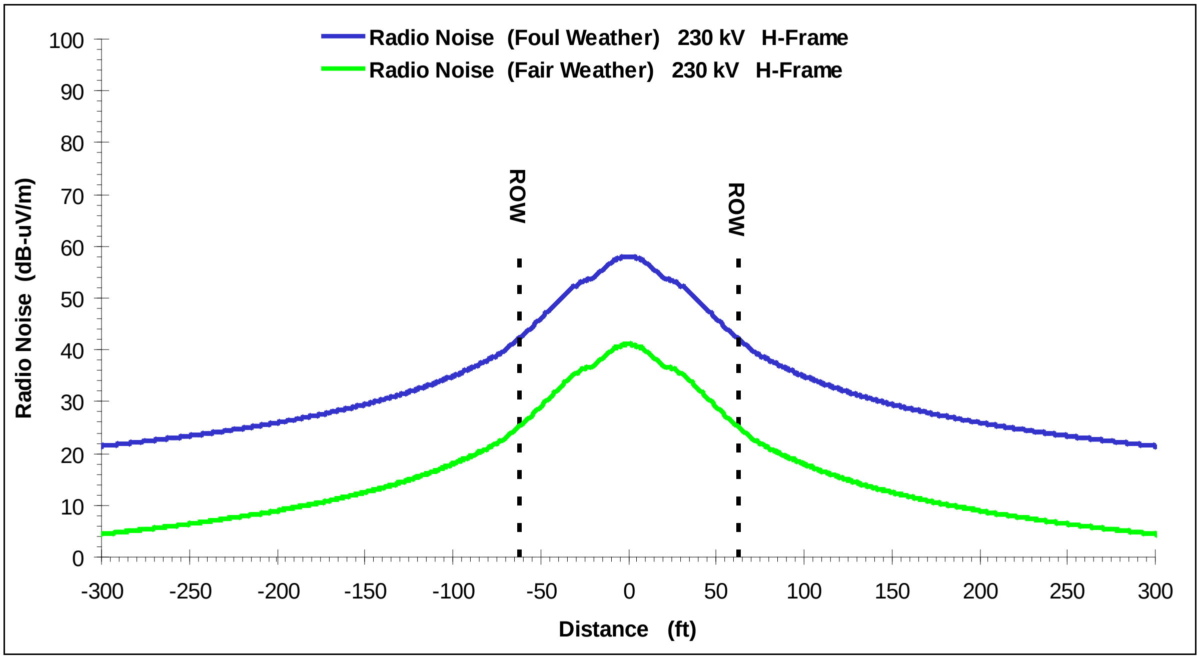

Figure 3.21-15. Radio Noise Profile at Midspan for Single-Circuit 230-kV H-frame Structure

Note: Radio noise profile calculated for fair and foul weather conditions. Conductor phasing from left to right is ABC.

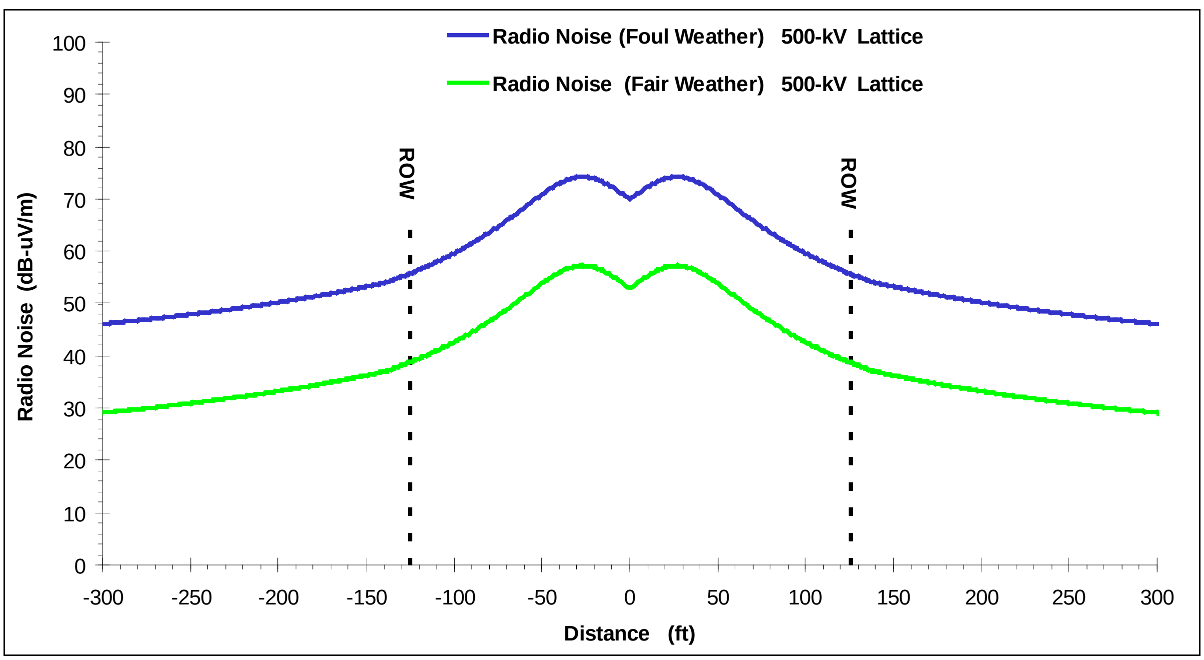

Figure 3.21-16. Radio Noise Profile at Midspan for Single-Circuit 500-kV Lattice Structure

Note: Radio noise profile calculated for fair and foul weather conditions. Conductor phasing from left to right is ABC.

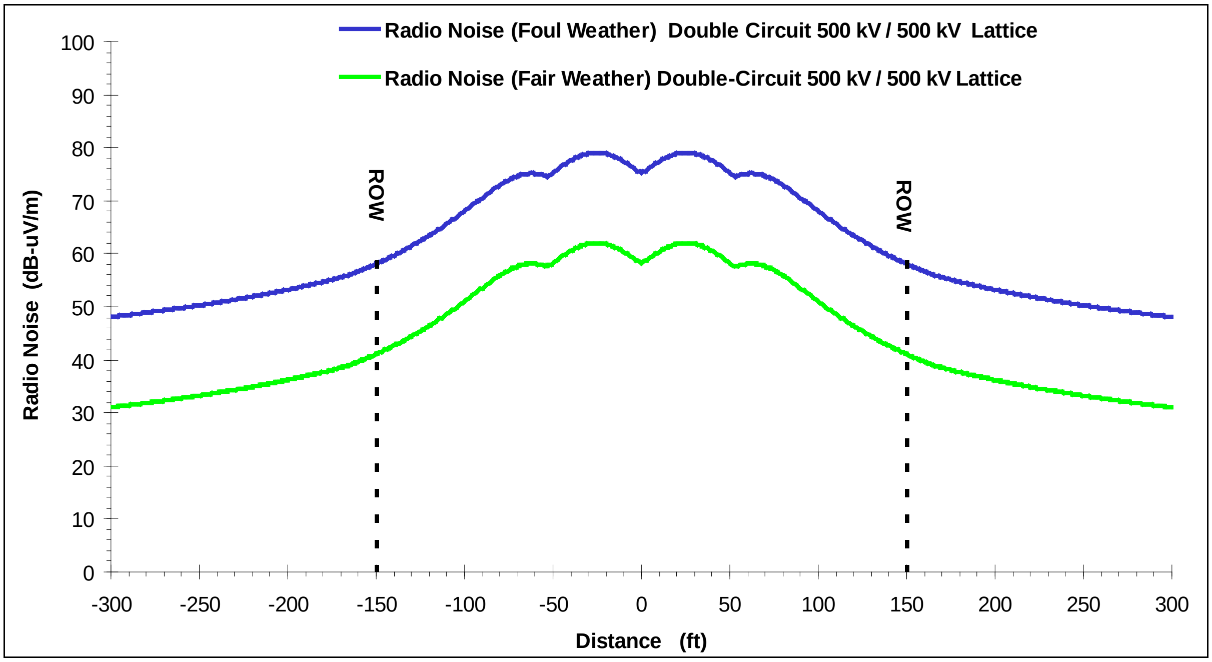

Figure 3.21-17. Radio Noise Profile at Midspan for Double-Circuit 500-kV Lattice Structure with Two 500-kV Circuits

Note: Radio noise profile calculated for fair and foul weather conditions. Conductor phasing from left to right is ABC-ABC.

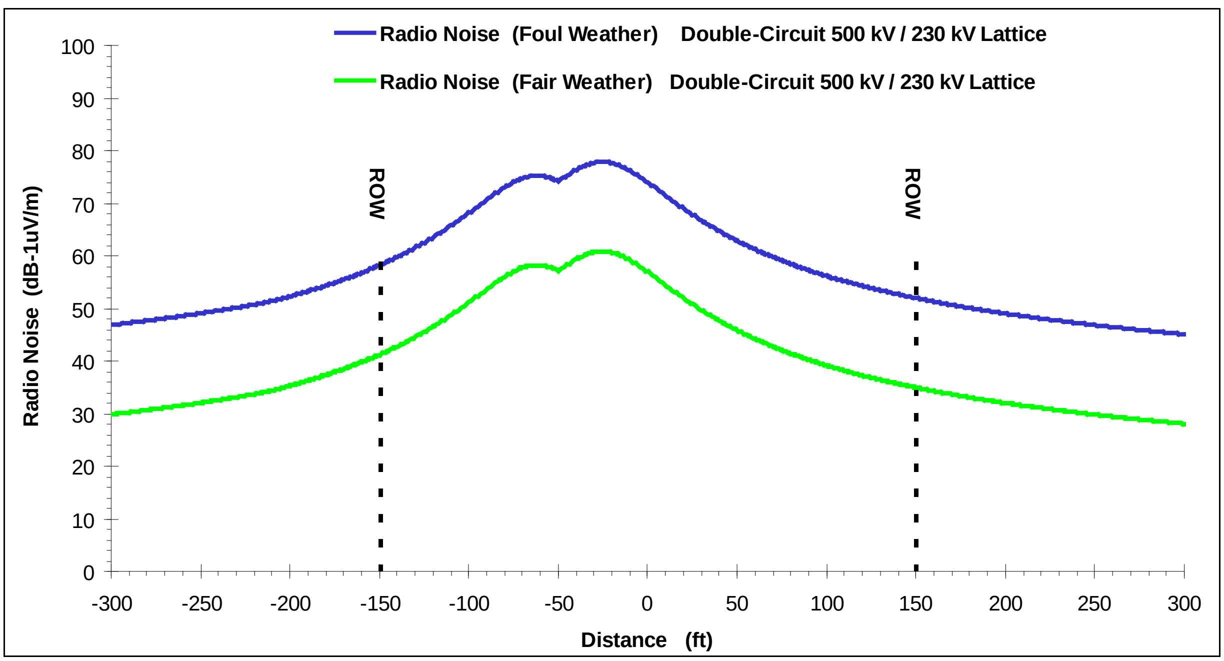

Figure 3.21-18. Radio Noise Profile at Midspan for Double-Circuit 500-kV Lattice Structure with a 500-kV Circuit and a 230-kV Circuit

Note: Radio noise profile calculated for fair and foul weather conditions. Conductor phasing from left to right is ABC-ABC.

Table 3.21-13. Radio Noise in Foul Weather

Segment	ROW Width (ft)	South/East ROW Edge (dB)	Maximum within ROW (dB)	North/West ROW Edge (dB)
Segment 1E (230 kV)	125	42	58	42
Segment 1W				
Line 1W(a) (230 kV)	125	42	58	42
Line 1W(c) (230 kV)	125	42	58	42
Segment 2 (500/230 kV)	300	58	78	52
Segment 3 (500/230 kV)	300	58	78	52
Segment 4 (500/500 kV)	300	58	79	58
Segment 5 (500 kV)	250	56	74	56
Segment 6 (500 kV)	250	56	74	56
Segment 7 (500 kV)	250	56	74	56
Segment 8 (500 kV)	250	56	74	56
Segment 9 (500 kV)	250	56	74	56
Segment 10 (500 kV)	250	56	74	56

Median radio noise measured in dB referenced to 1 μV/m.
Altitude of 7,000 feet (radio noise would be less for altitude lower than 7,000 feet).

Table 3.21-14. Radio Noise in Fair Weather

Segment	ROW Width (ft)	South/East ROW Edge (dB)	Maximum within ROW (dB)	North/West ROW Edge (dB)
Segment 1E (230 kV)	125	25	41	25
Segment 1W				
Line 1W(a) (230 kV)	125	25	41	25
Line 1W(c) (230 kV)	125	25	41	25
Segment 2 (500/230 kV)	300	41	61	35
Segment 3 (500/230 kV)	300	41	61	35
Segment 4 (500/500 kV)	300	41	62	41
Segment 5 (500 kV)	250	39	57	39
Segment 6 (500 kV)	250	39	57	39
Segment 7 (500 kV)	250	39	57	39
Segment 8 (500 kV)	250	39	57	39
Segment 9 (500 kV)	250	39	57	39
Segment 10 (500 kV)	250	39	57	39

Median radio noise measured in dB referenced to 1 μV/m.
Altitude of 7,000 feet (radio noise would be less for altitude lower than 7,000 feet)

Other Effects

Other effects from the proposed Gateway West transmission lines may include visible corona, ozone, field induction, stray voltage, and interference with electronic devices such as GPS systems, cell phones, or satellite receivers. These effects would be localized to the area of the transmission line if they occur. These factors are generally due to the field strength at the surface of the conductor (visible corona, ozone, and interference with electronic devices) or the field strength at ground level (field induction and stray voltage).

The following mitigation measures are recommended by the Agencies for reducing impacts.

EE-1 During final design, limit the conductor surface gradient in order to meet the IEEE Radio Noise Guideline.

EE-2 During construction, identify objects such as fences, metal buildings, pipelines, and other metal objects within or near the proposed ROW that have the possibility for induced potentials and currents and implement electrical grounding of these objects according to the utility's and National Electric Code standards.

EE-3 During final design and construction, identify areas where large equipment is anticipated and provide sufficient conductor clearance to ground to meet the NESC 5 mA rule or limit size or access of large equipment.

Visible Corona – Corona is sometimes visible as a faint bluish glow near the conductors on high-voltage lines. Any corona on the conductors would be visible only under the darkest conditions and after the eyes had time to dark adapt. It is unlikely it would be noticed or affect the local environment.

Ozone – Small amounts of ozone and other oxidants can be produced around the conductors when there is corona present. Ozone accounts for the majority of the oxidants with nitrous oxide accounting for the remainder. Ozone is a naturally occurring part of the air with levels of 10 to 30 parts per billion (ppb) at night in rural settings, increasing during daylight to approximately 70 to 100 ppb. Ozone levels exceeding 100 ppb can be found in urban areas and cities. Ozone is also produced by many common appliances such as copy machines, battery chargers, air fresheners, and welding equipment. The ozone levels from a 500-kV line are at the single digit parts per billion level or below. The ozone from the high-voltage lines is at the limit of ozone detection equipment and well below even the fluctuations of ambient levels and would not affect the ambient air quality.

Field Induction (induced currents and potentials/nuisance shocks) – Induced potentials and currents are present under high-voltage lines due to the electric fields. Grounding of fences and large metal structures under or near the lines would eliminate these objects as sources of potentials or currents. Agricultural activities can occur near or under transmission lines. However, mobile objects like vehicles or pieces of farm equipment cannot be grounded permanently and thus can develop a potential and currents while under or near the transmission line. A tractor pulling a wagon under the double-circuit 500-kV line of Segment 4 at the point of highest electric field (9.67 kV/m) can develop a current of 2.9 mA (Table 3.21-8). A pickup truck at the same location can develop a current of 1 mA. These are currents that are likely to be perceived. The actual currents would likely be much lower due to the line height being higher and inadvertent grounding of the vehicle by field vegetation and non-ideal insulation by the tires. Placing a ground strap on vehicles or equipment would help ground the vehicle, mitigating induced currents or potentials. Dragging a log chain from large equipment that passes under high-voltage lines can be used to provide grounding. Simply avoiding stopping to enter or exit vehicles while under high-voltage lines is another common sense way to avoid concern with induced potentials or currents.

Stray Voltage – Stray voltage or current is a problem whereby currents or potentials on conductive objects and metal work can come in contact and flow through humans or animals. Stray voltage is often a concern involving the farm electrical system and the local utility distribution system where a potential is developed on the grounded neutral system of the farm or utility. If an animal or human comes in contact with metal equipment that is at a different potential than the ground on which they are standing, a current may flow through the animal, or person, to ground and the potential be detected. Usually if this potential difference exists, it is too small to generate any physical or behavioral changes. In the case of nearby transmission lines, fences or piping that pass under or near the transmission line and connect back to a farm can be the source of currents and potentials on the farm. Stray voltage may be the result of corrosion or broken ground connections. Good grounding practices would reduce or eliminate this concern. The Proponents maintain programs for on-site investigation of stray voltage concerns.

Cardiac Pacemakers – Concern has focused on potential interference to cardiac pacemakers and defibrillators. A cardiac pacemaker monitors the electrical activity of the heart. If the heart fails to beat, the pacemaker administers a small stimulus to trigger the “missing” beats. An implanted cardiac defibrillator similarly monitors the electrical activity of the heart but is designed to block disorganized contractions of the heart (arrhythmias) by administering a strong electrical shock to restore normal heart rhythms. Exposure to electric and magnetic fields could affect the function of these devices if induced signals on sensing leads are interpreted as natural cardiac activity (Griffin 1986; CCOHS 1988; Barold et al. 1991). However, the opportunities for exposure and interference from powerlines are lower than for contact with ordinary household appliances.

Due to recent design improvements, many pacemakers in use would not be particularly susceptible to electrical fields. There remains a small possibility that some pacemakers, particularly those of older designs, and with single-lead electrodes, may sense potentials induced on the electrodes and leads of the pacemaker and provide unnecessary stimulation to the heart.

There are two general types of pacemakers: asynchronous and synchronous. The asynchronous pacemaker pulses at a predetermined rate. It is practically immune to interference because it has no sensing circuitry and is not exceptionally complex. The synchronous pacemaker, on the other hand, pulses only when its sensing circuitry determines that pacing is necessary. Interference resulting from transmission line electric or magnetic fields can cause a spurious signal in the pacemaker’s sensing circuitry. However, when these pacemakers detect a spurious signal, such as a 60 Hz signal, they are programmed to revert to an asynchronous or fixed pacing mode of operation and return to synchronous operation within a specified time after the signal is no longer detected. The potential for pacer interference depends on the manufacturer, model, and implantation method, among other factors. Studies have determined thresholds for interference of the most sensitive units to be about 2,000 to 12,000 mG for magnetic fields and about 1.5 to 2.0 kV/m for electric fields. The magnetic fields from the transmission lines are well below these values, even for the peak magnetic field of 311 mG found on the ROW (Table 3.21-7). The electric fields expected at the edges of the ROW (1.23 kV/m or less) are below the threshold level of 1.5 kV/m for the most sensitive pacemaker. The proposed transmission lines would not have an effect on pacemakers outside the ROW.

Cardiovascular specialists do not consider prolonged asynchronous pacing to be a problem. Periods of operation in this mode are commonly induced by cardiologists to check pacemaker performance. Although the electric field within areas of the transmission line ROW may affect the operation of some models of pacemakers by causing them to revert to asynchronous pacing, this would only be for short duration while walking under the transmission lines and is not considered harmful. The vehicle compartment of a car or truck or the cab of agricultural equipment (combine or tractor) shields the occupant from the electric field and thus there would not be an effect on a pacemaker while in a vehicle or cab while under the transmission line. Pacemakers in areas outside the transmission line ROW would not be affected. Before walking under the conductors of a high-voltage transmission line on the ROW, those with pacemakers or defibrillators should check with their physician if they have concerns.

GPS, Satellite Receivers, and Cell Phones – Corona-generated radio interference may cause disruption on AM communications bands in addition to AM radio such as the citizen’s band and some mobile bands. However, mobile-radio communications are not susceptible to transmission-line interference because they are generally FM. Similarly, cellular telephones operate at a frequency of 900 MHz or higher, which is well above the frequency where corona-generated radio noise is prevalent. GPS systems operate at a frequency of 1.57 gigahertz and have been shown to be unaffected by radio noise from high-voltage transmission lines (Silva and Olsen 2002). Satellite receivers operate at even higher frequencies in the 3 to 6 gigahertz band. For these higher frequency devices, the receiver has to be essentially looking directly at the conductor before it may be affected (Chartier et al. 1986). In the unlikely event that interference occurs with these or other communications, mitigation would be easily achieved with the techniques used for AM radio interference such as a slight antenna relocation or orientation. As digital signal processing has been integrated into these communication systems, the potential interference impact of corona-generated radio noise has decreased.

Decommissioning

Upon decommissioning, the Project would be de-energized. This would result in no current and no voltage on the transmission lines. There would be no physical changes in the lines or structures that would occur associated with de-energization. Once de-energized there would not be any short-term or long-term impacts from the lines.

3.21.2.3 Proposed Route and Alternatives by Segment

For a given overhead line design and ROW width, there is no strong geographical or route preference driven by the electrical environment. Expected levels of electric field, magnetic field, audible noise, and radio noise found at the edge of the transmission corridor meet or are below accepted federal and state guidelines. The expected impacts of the electrical environment would be similar for the Route Alternatives.

3.21.2.4 Design Variation

An alternate design is proposed for Segments 2, 3, and 4 that would replace the double-circuit single structure with two single-circuit structures. The width of the ROW would also be increased by 50 feet, from 300 feet for the proposed double-circuit single structure to 350 feet with a separation between the two single-circuit structures of 175 feet (Figure 3.21-19). The other line segments would remain the same.

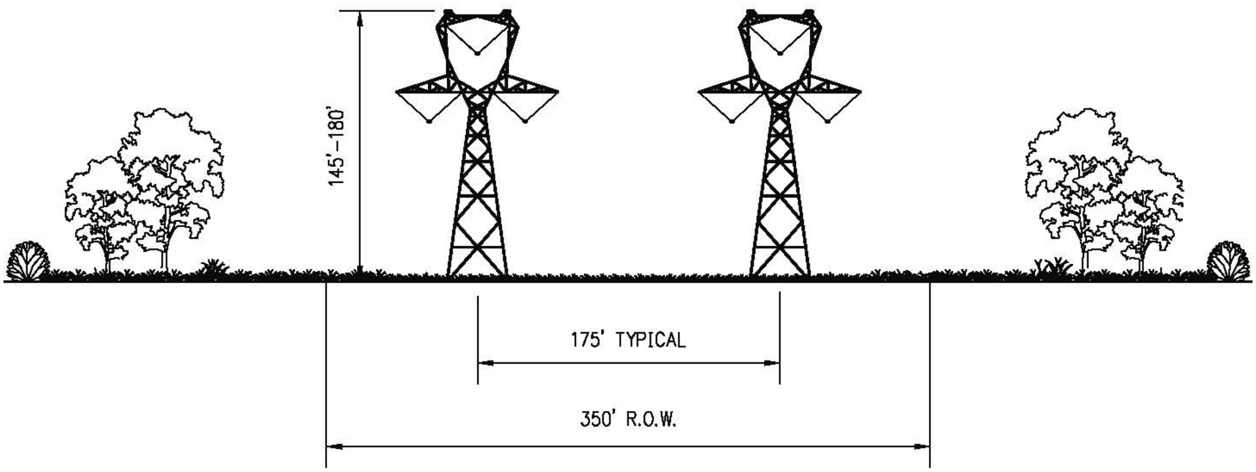

Figure 3.21-19. Proposed Design Variation for Two 500-kV Single Circuits

The different geometry used for the two 3-phase circuits in the alternate design changes the expected electrical environment for Segments 2, 3, and 4. The electric and magnetic fields, audible noise levels, and radio noise levels expected for this alternative are presented below.

Electric and Magnetic Fields

Electric Field – The electric field was calculated at a standard height of 1 m above ground at midspan where the conductors have their closest approach to ground. The electric field values at the edge of the ROW and at the peak of the profile within the ROW are listed in Table 3.21-15 for the design variation of Segments 2, 3, and 4. Plots of the electric field profiles are shown in Figure 3.21-20 and Figure 3.21-21 for Segments 2, 3, and 4 and Segments 2 and 3 under the final and initial energization plans. The Design Variation configuration using two single-circuit structures results in a slightly higher peak electric field of 9.69 kV/m within the ROW versus the 9.19 kV/m calculated for the Proposed Action single double-circuit structure, with both circuits energized at 500 kV. Higher electric fields are found at the edges of the ROW for the Design Variation versus the Proposed Action with both circuits energized at 500 kV.

Table 3.21-15. Electric Fields: Two Single-Circuit 500-kV Structures Alternative

Segment	ROW Width (ft)	South/East ROW Edge (kV/m)	Maximum within ROW (kV/m)	North/West ROW Edge (kV/m)
Initial Energization				
Segment 2 (230 kV/500 kV)	350	2.03	9.68	0.91
Segment 3 (230 kV/500 kV)	350	2.03	9.68	0.91
Final Energization				
Segments 2, 3, and 4 (500 kV/500 kV)	350	2.04	9.69	2.04

Major Single Axis Electric Field at standard height of 1 meter.
Ground Clearance: 35 feet for 500-kV lines.
Electric fields are calculated at a standard height of 1 meter above ground.

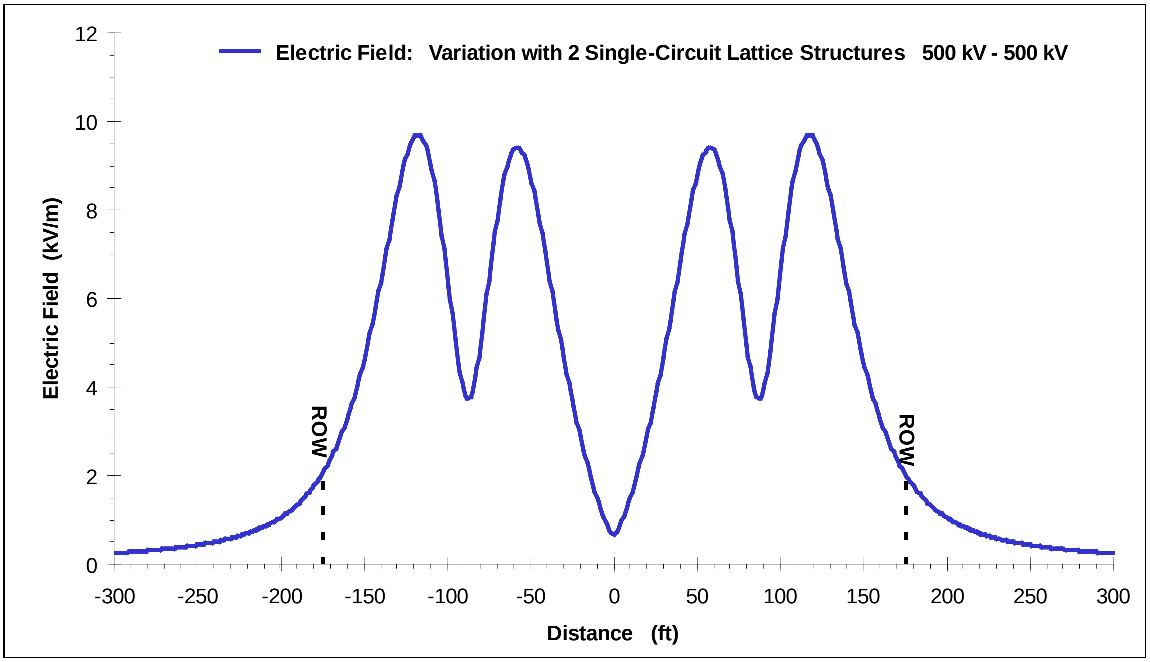

Figure 3.21-20. Electric Field Profile at Midspan for Two Single-Circuit 500-kV Lattice Tower Structures Both Energized at 500 kV (Segments 2, 3, and 4 under final energization plan)

Note: Major Axis electric field calculated at standard height of 1 meter. Conductor phasing from left to right is ABC-ABC.

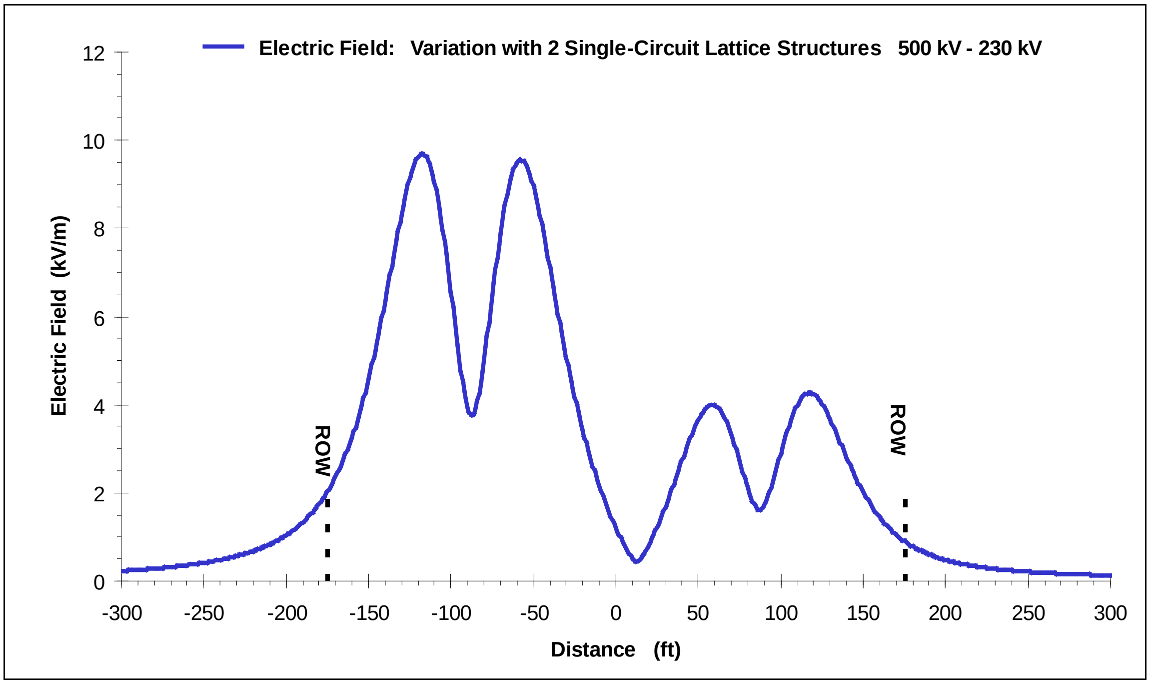

Figure 3.21-21. Electric Field Profile at Midspan for Two Single-Circuit 500-kV Lattice Tower Structures

Note: One circuit is energized at 500 kV while the other circuit is energized at only 230 kV (Segments 2 and 3 under initial energization plan). Major Axis electric field calculated at standard height of 1 meter. Conductor phasing from left to right is ABC-ABC.

Magnetic Field – The magnetic field was calculated at a standard height of 1 meter above ground at midspan where the conductors have their closest approach to ground. The magnetic field values at the edge of the ROW and at the peak of the profile within the ROW are listed in Table 3.21-16 for the alternate Segments 2, 3, and 4. Plots of the magnetic field profiles are shown in Figure 3.21-22 and Figure 3.21-23 for Segment 4 and Segments 2 and 3. The Design Variation using two single-circuit structures results in a higher peak magnetic field of 303 mG within the ROW of Segment 2 and 3 versus the 258 mG calculated for the proposed double-circuit structure. The peak magnetic field in the design variation of Segments 2, 3, and 4 for the final energization plan is 296 mG. Higher magnetic fields are found at the edges of the ROW for the design variation versus the proposed configuration (Table 3.21-16 versus Table 3.21-7).

Table 3.21-16. Magnetic Fields: Two Single-Circuit 500-kV Structures Alternative

Segment	ROW Width (ft)	South/East ROW Edge (mG)	Maximum within ROW (mG)	North/West ROW Edge (mG)
Initial Energization Plan				
Segment 2 (230 kV/500 kV)	350	77	303	44
Segment 3 (230 kV/500 kV)	350	77	303	44
Final Energization Plan				
Segments 2, 3, and 4 (500 kV/500 kV)	350	80	296	80

Major Single Axis Magnetic Field at standard height of 1 meter.
Peak Loading on 500-kV circuits is 1,500 MW (0.95 load factor assumed).
Typical loading used as 70 percent of peak load.
Magnetic field level for typical load taken as 70 percent of magnetic field under peak load conditions.

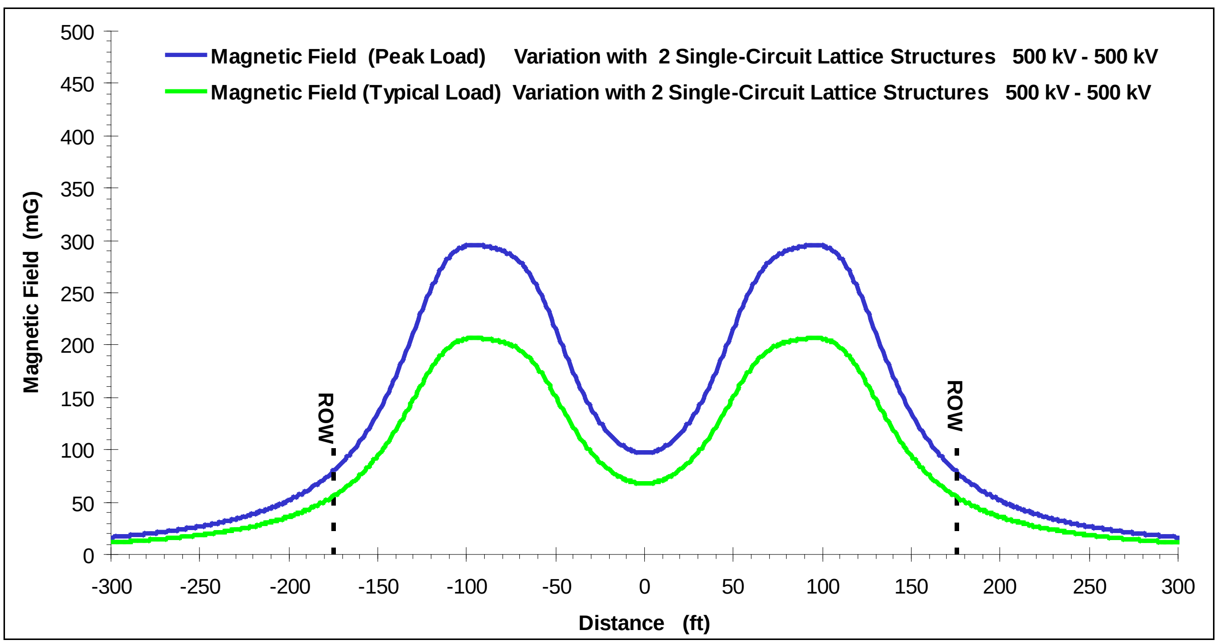

Figure 3.21-22. Magnetic Field Profile at Midspan for Two Single-Circuit 500-kV Lattice Structures

Note: Both circuits are energized at 500 kV. (Segments 2, 3, and 4 under final energization plan). Major Axis magnetic field calculated at standard height of 1 meter. Conductor phasing from left to right is ABC-ABC.

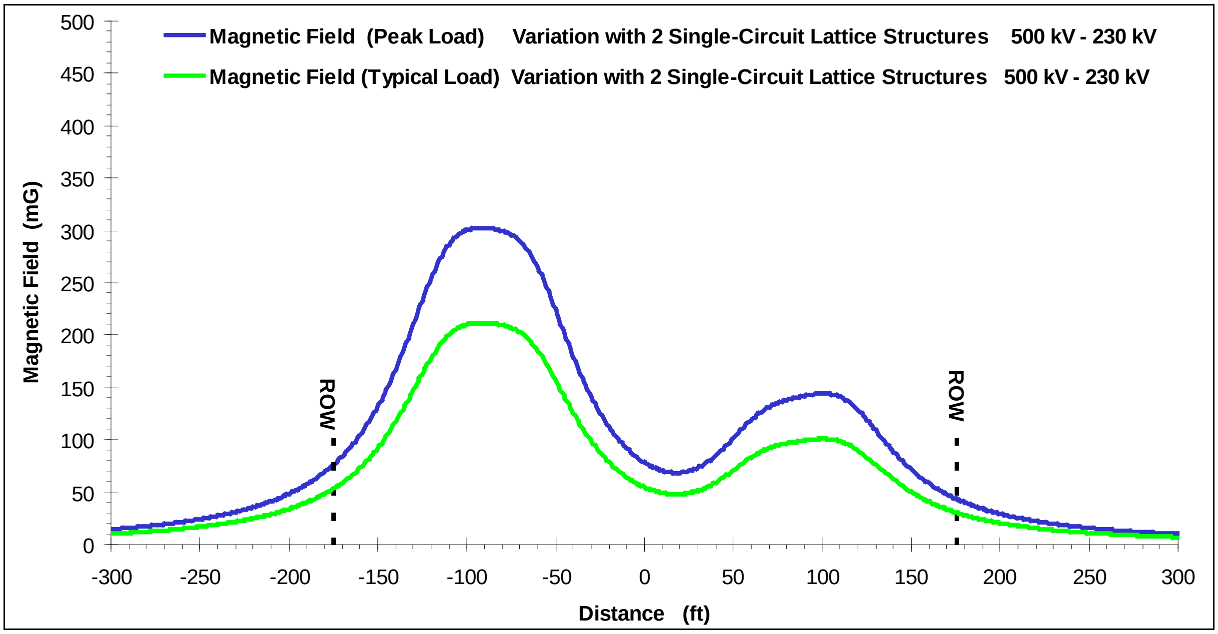

Figure 3.21-23. Magnetic Field Profile at Midspan for Two Single-Circuit 500-kV Lattice Structures

Note: One circuit is energized at 500 kV while the other circuit is energized at only 230 kV (Segments 2 and 3 under initial energization plan). Major Axis magnetic field calculated at standard height of 1 meter. Conductor phasing from left to right is ABC-ABC.

Audible Noise

The audible noise was calculated at a height of 1.5 meters above ground at midspan for the alternate design of two single-circuit structures on Segments 2, 3, and 4. The audible noise values at the edge of the ROW and at the peak of the profile within the ROW are listed in Table 3.21-17 for the Design Variation. Plots of the audible noise profiles are shown in Figure 3.21-24 and Figure 3.21-25 for final and initial energization plans. The Design Variation results in a slightly lower audible noise peak of 56 dBA within the ROW of Segment 2, 3, and 4 for the final energization plan versus the 61 dBA calculated for the Proposed Action single double-circuit structure. Similar or slightly lower audible noise levels are found at the edges of the ROW for the alternate configuration versus the proposed configuration (Table 3.21-17 versus Table 3.21-10).

Table 3.21-17. Audible Noise (Foul Weather): Two Single-Circuit 500-kV Structures Alternative

Segment	ROW Width (ft)	South/East ROW Edge (dBA)	Maximum within ROW (dBA)	North/West ROW Edge (dBA)
Initial Energization Plan				
Segment 2 (230 kV/500 kV)	350	52	55	47
Segment 3 (230 kV/500 kV)	350	52	55	47
Final Energization Plan				
Segments 2, 3, and 4 (500 kV/500 kV)	350	53	56	53

Notes:
Median Audible noise in foul weather measured in dB with A weighting referenced to 20 microPascals.
A weighting chosen to match response of human ear.
Altitude of 7,000 feet (audible noise would be less for altitude lower than 7,000 feet).

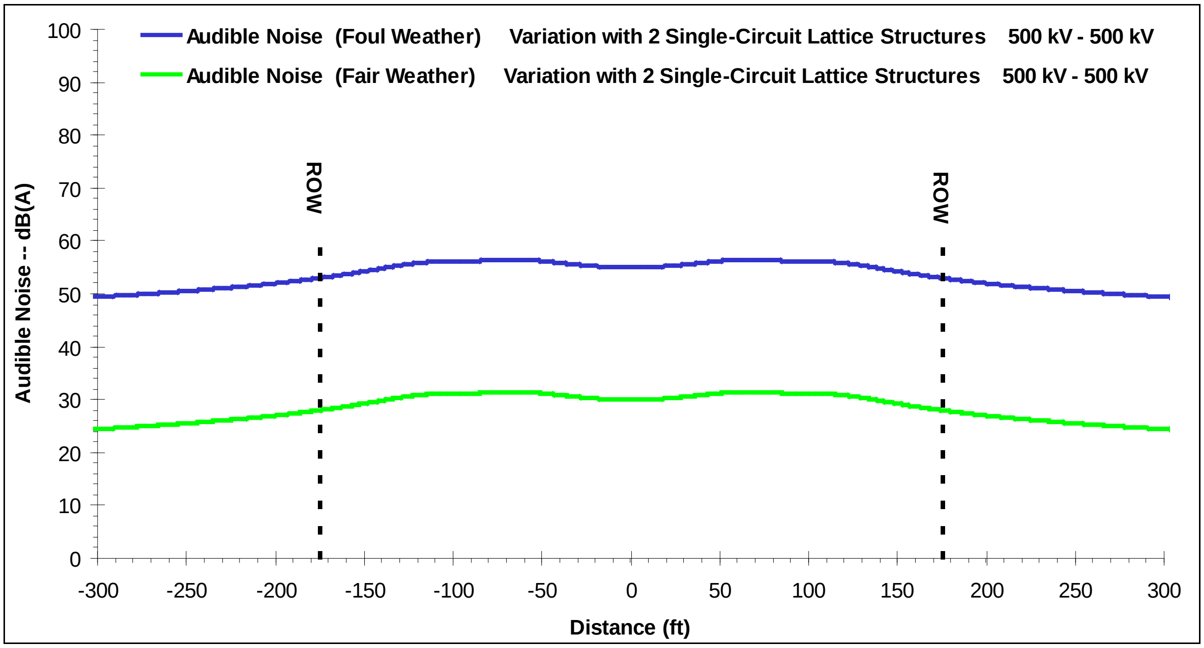

Figure 3.21-24. Audible Noise Profile at Midspan for two Single-Circuit 500-kV Lattice Structures

Note: Both circuits are energized at 500 kV (Segments 2, 3, and 4 under final energization plan). Audible noise profile calculated for fair and foul weather conditions.

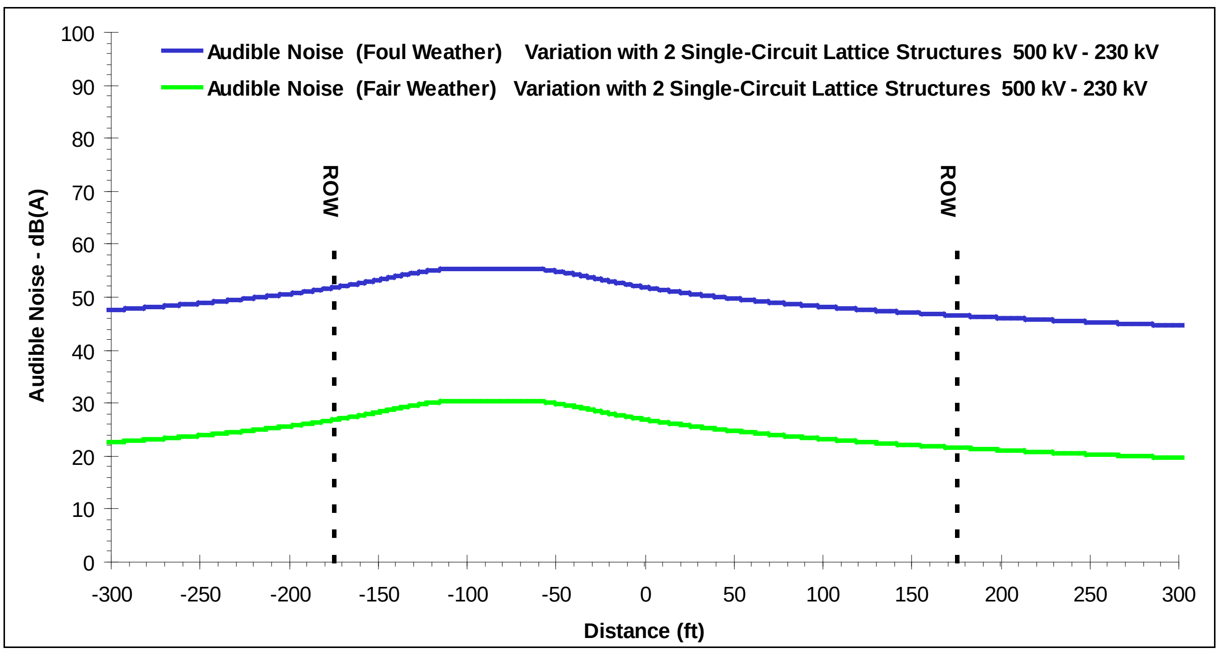

Figure 3.21-25. Audible Noise Profile at Midspan for two Single-Circuit 500-kV Lattice Structures

Note: One circuit is energized at 500 kV while the other circuit is energized at only 230 kV (Segments 2 and 3 under initial energization plan). Audible noise profile calculated for fair and foul weather conditions.

Calculated fair weather audible noise values at the edge of the ROW and at the peak of the profile within the ROW are listed in Table 3.21-18 for the design variation structures on Segments 2, 3, and 4. The Design Variation configuration using two single-circuit structures results in a lower fair weather audible noise peak of 31 dBA within the ROW of Segment 4 versus the 36 dBA calculated for the proposed double-circuit structure. Similar or slightly lower fair weather audible noise levels are also found at the edges of the ROW for the Design Variation configuration versus the proposed configuration (Table 3.21-18 versus Table 3.21-11). The audible noise levels at the edge of ROW during both foul and fair weather are below federal and state guidelines. The audible noise levels for the Design Variation are only 2 to 3 dBA lower at the edge of the ROW than the proposed design. Fluctuations in measured audible noise levels often exceed this. This difference would likely be unnoticed.

Table 3.21-18. Audible Noise (Fair Weather): Two Single-Circuit 500-kV Structures Alternative

Segment	ROW Width (ft)	South/East ROW Edge (dBA)	Maximum within ROW (dBA)	North/West ROW Edge (dBA)
Initial Energization Plan				
Segment 2 (230 kV/500 kV)	350	27	30	22
Segment 3 (230 kV/500 kV)	350	27	30	22
Final Energization Plan				
Segments 2, 3, and 4 (500 kV/500 kV)	350	28	31	28

Median Audible noise in foul weather measured in dB referenced to 20 microPascals with A weighting.
A weighting chosen to match response of human ear.
Altitude of 7,000 feet (audible noise would be less for altitude lower than 7,000 feet).

Radio Noise

Radio noise was calculated at a height of 3 meters above ground at midspan for the Design Variation of two single-circuit structures on Segments 2, 3, and 4. The radio noise values at the edge of the ROW and at the peak of the profile within the ROW are listed in Table 3.21-19 for the Design Variation on Segments 2, 3, and 4. Plots of the radio noise profiles are shown in Figure 3.21-26 and Figure 3.21-27 for the final and initial energization plans. The Design Variation using two single-circuit structures

Table 3.21-19. Radio Noise (Foul Weather): Two Single-Circuit 500-kV Structures Alternative

Segment	ROW Width (ft)	South/East ROW Edge (dB)	Maximum within ROW (dB)	North/West ROW Edge (dB)
Initial Energization Plan				
Segment 2 (230 kV/500 kV)	350	62	74	47
Segment 3 (230 kV/500 kV)	350	62	74	47
Final Energization Plan				
Segments 2, 3, and 4 (500 kV/500 kV)	350	62	75	62

Median radio noise measured in dB referenced to 1 µV/m.
Altitude of 7,000 feet (radio noise would be less for altitude lower than 7,000 feet)

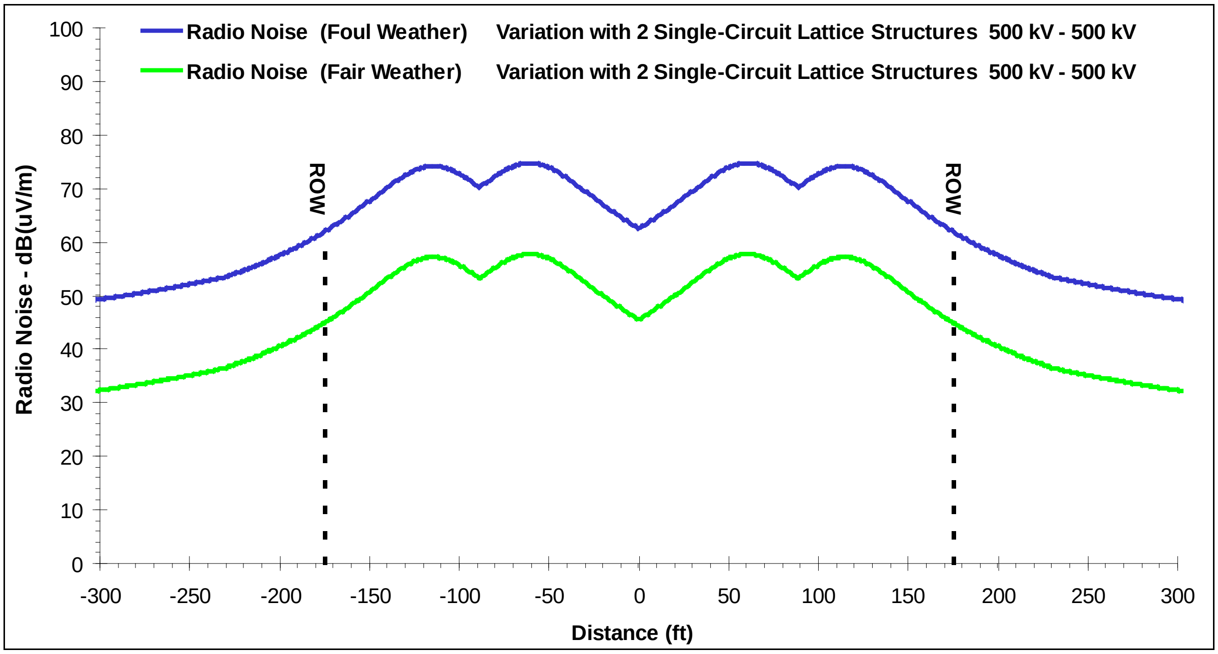

Figure 3.21-26. Radio Noise Profile at Midspan for Two Single-Circuit 500-kV Lattice Structures both Energized at 500 kV

Note: Radio noise profile calculated for fair and foul weather conditions.

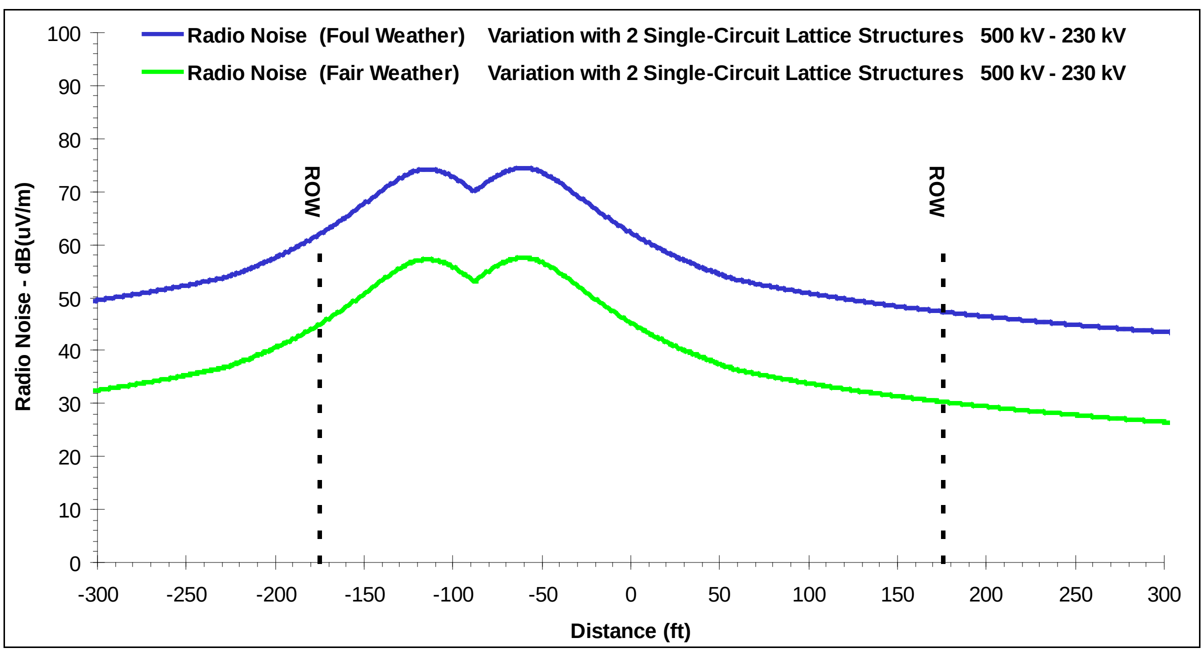

Figure 3.21-27. Radio Noise Profile at Midspan for Two Single-Circuit 500-kV Lattice Structures

Note: One circuit is energized at 500 kV while the other circuit is energized at only 230 kV (Segments 2 and 3). Radio noise profile calculated for fair and foul weather conditions.

results in a slightly lower radio noise peak of 76 dB (1 µV/m) within the Design Variation ROW of Segments 2, 3, and 4 versus the 79 dB (1 µV/m) calculated for the Proposed Action single double-circuit structure.

Higher radio noise levels are found at the edges of the ROW for the Design Variation versus the Proposed Action (Table 3.21-19 versus Table 3.21-13).

Calculated fair weather radio noise values at the edge of the ROW and at the peak of the profile within the ROW are listed in Table 3.21-20 for the Design Variation on Segments 2, 3, and 4. The Design Variation using two single-circuit structures results in a slightly lower fair weather radio noise peak of 58 dB (1 µV/m) within the ROW of Segments 2, 3, and 4 versus the 62 dB (1 µV/m) calculated for the Proposed Action single double-circuit structure. Higher fair weather radio noise levels are found at the edges of the ROW for the Design Variation versus the Proposed Action (Table 3.21-20 versus Table 3.21-14). The Design Variation meets the IEEE Radio Noise Guidelines of 40 dB (1 µV/m) for fair weather at 100 feet from the nearest conductor. The ROW edge is approximately 60 feet from the nearest conductor for the Design Variation. The radio noise levels for the Design Variation at the edge of the ROW are 4 to 5 dB (1 µV/m) higher than the Proposed Action design. Fluctuations in measured radio noise levels often exceed this.

Table 3.21-20. Radio Noise (Fair Weather): Two Single-Circuit 500-kV Structures Alternative

Segment	ROW Width (ft)	South/East ROW Edge (dB)	Maximum within ROW (dB)	North/West ROW Edge (dB)
Initial Energization Plan				
Segment 2 (230 kV/500 kV)	350	45	57	30
Segment 3 (230 kV/500 kV)	350	45	57	30
Final Energization Plan				
Segments 2, 3, and 4 (500 kV/500 kV)	350	45	58	45

Median radio noise measured in dB referenced to 1 µV/m.
Altitude of 7,000 feet (radio noise would be less for altitude lower than 7,000 feet).

Summary

The Design Variation would consist of constructing two single-circuit lines in Segments 2 through 4 instead of a single double-circuit line. The disturbance footprint of the two single-circuit towers is greater than that of the double-circuit tower, in part because the requested ROW would be wider, but also because helicopter-assisted construction could be implemented in these areas due to the lighter weight of the towers, which would require additional fly yards. The additional ROW space and the fly yards would cause additional temporary disturbance during construction. Across Segments 2, 3, and 4, the additional disturbance of the single-circuit tower alternative ranges from 25 to 30 percent greater than the comparable portions of the double-circuit tower disturbance under the proposed design. The two single circuits require more ground disturbance, but would be designed and constructed to the same standards as the Proposed Action.

The Design Variation requires 50 feet more ROW width and results in higher electric and magnetic fields but slightly lower audible noise levels and radio noise levels within the ROW. The differences in levels at the edge of the ROW, either up or down, would probably not be perceived. The increase in the peak electric field with the Design Variation could result in higher line heights being required at road crossings where large semi-trailer trucks are anticipated than for the proposed design.

3.21.2.5 Structure Variation

The proposed guyed Structure Variation would add four guy wires about 140 feet long from a point about 100 feet up in each tower to four guy anchors spaced in a square around the tower (Appendix B, Figure B-6). This would not change the amount of disturbance during construction or operation appreciably. The conductors would be at about the same spacing and distance above ground on cross-arms approximately the same height as for the self-supporting lattice towers. Therefore, there would be no appreciable difference in the electrical environment from the use of this Structure Variation when compared to the use of self-supporting lattice towers.

3.21.2.6 Schedule Variation

The Schedule Variation uses the two single-circuit design variation described above but extends construction over a longer timeframe. Initially only one of the eventual two single-circuit lines would be constructed with the second to be constructed at a later date. The Schedule Variation proposes that the first single-circuit transmission line in Segments 2, 3, and 4 would be built as soon as a ROW grant is issued, but that the second line would not begin construction until late 2018. This would mean nearly 2 years between the end of construction for the first line and beginning of construction for the second line. Any staging areas and fly yards that had been used for the first stage would have been revegetated after construction was complete and would have to be cleared again. There would be two sets of construction disturbances adding movement, noise, and dust to the area of construction in two instances in any given area.

The Schedule Variation assumes that two single circuits for Segments 2, 3, and 4 are operated at 500 kV at the time they are installed. The result, after the second 500-kV circuit is built, would produce no different effects than the final energization plan for the Design Variation. During the time between the in-service date of the first 500-kV line and the in-service date of the second 500-kV line, the EMF, audible noise, and radio noise levels found within the ROW of Segment 4 and at its edges would be different than the levels discussed in Section 3.21.2.4 although they would fall within the same general range of the levels previously discussed.

3.21.3 Mitigation Measures

The Agencies have identified the following mitigation measures as a means for reducing impacts. They recommend that the Proponents incorporate these measures into their EPMs and apply them Project-wide.

- EE-1 During final design, limit the conductor surface gradient in order to meet the IEEE Radio Noise Guideline.
- EE-2 During construction, identify objects such as fences, metal buildings, pipelines, and other metal objects within or near the proposed ROW that have the possibility for induced potentials and currents and implement

electrical grounding of these objects according to the utility's and National Electric Code standards.

EE-3 During final design and construction, identify areas where large equipment is anticipated and provide sufficient conductor clearance to ground to meet the NESC 5 mA rule or limit size or access of large equipment.