Docket No. ______
Exh. TDI-KK-2

REPORT

NEW ENGLAND CLEAN POWER LINK PROJECT– NOISE IMPACT ASSESSMENT FOR CONVERTER STATION

RSG
the science of insight

11.26.2014

PREPARED FOR:
TDI NEW ENGLAND

SUBMITTED BY:
KEN KALISKI, P.E., INCE BD. CERT.,
SENIOR DIRECTOR

55 Railroad Row
White River Junction, VT 05001
802.295.4999
www.rsginc.com

NEW ENGLAND CLEAN POWER LINK PROJECT– NOISE IMPACT ASSESSMENT FOR CONVERTER STATION

PREPARED FOR:
TDI NEW ENGLAND

CONTENTS

INTRODUCTION

TDI New England is proposing an underwater/underground HVDC transmission line from the Canadian border to a proposed converter station, located in Ludlow, Vermont. In preparation for the Section 248 proceedings, TDI New England retained RSG to conduct a noise impact assessment of the operation of the proposed converter station to determine sound impacts on residences in the surrounding area. Included in this report are:

- Description of the Project;
- Sound level regulations, precedents, and Project goals;
- Background sound level monitoring procedures and results;
- Sound propagation modeling procedures and results;
- Conclusions.

A primer describing acoustical terminology used in this report is included as a separate exhibit.

1.0 PROJECT DESCRIPTION

Champlain VT, LLC, d/b/a TDI New England (TDI-NE) is proposing the New England Clean Power Link project (NECPL or Project). The NECPL is a high-voltage direct current (HVDC) electric transmission line that will provide electricity generated by renewable energy sources in Canada to the New England electric grid. The line will run from the Canadian border at Alburgh, Vermont to Ludlow, Vermont along underwater and underground routes.

The transmission line will be comprised of two approximately 5" diameter cables – one positively charged and the other negatively charged – and will be solid-state dielectric and thus contain no fluids or gases. The nominal operating voltage of the line will be approximately 300 to 320 kV, and the system will be capable of delivering 1,000 megawatts (MW) of electricity.

The proposed underwater portion of the transmission line, approximately 98 miles in length, will be buried to a target depth of three to four feet in the bed of Lake Champlain except at water depths of greater than 150 feet where the cables will be placed on the bottom and self-burial of the cables in sediment will occur. In areas where there are obstacles to burial (e.g. existing infrastructure, bedrock), protective coverings will be installed.

The overland portion of the transmission line, approximately 56 miles in length, will be buried approximately four feet underground within existing public (state and town) road rights-of-way (ROWs).[1] The cables will be installed within a railroad ROW for approximately 3.5 miles in the towns of Shrewsbury and Wallingford. Very short sections of the route at the Lake Champlain entry and exit points, as well as at the converter site in Ludlow, will be located on private land that is controlled by TDI-NE.

In Ludlow, the HVDC line will terminate at a converter station that will convert the electrical power from direct current (DC) to alternating current (AC). An underground AC transmission line will then run to the existing 345 kV Coolidge Substation in Cavendish, Vermont located approximately 0.3 miles to the south, that is owned and operated by the Vermont Electric Power Company (VELCO).

The converter station is situated off of Nelson Road, along the side of a hill with Twenty Mile Stream Road to the east, Nelson Road to the west, and the intersection between Nelson Road and the closest road (Barker Road) at the south. (Figure 1).

Twenty Mile Stream Road is located approximately 2,360 feet (720 meters) to the east. Chapman Road is located approximately 1,770 feet (540 meters) to the northeast. VELCO's Coolidge substation is located approximately 1,080 feet (330 meters) to the southeast.

The closest residences to the south, east, north, and northwest are located approximately 1,120 feet (340 meters), 1,770 feet (540 meters), 2,130 feet (650 meters), and 1,540 feet (470 meters) away, respectively.

---

[1] The only potential areas where underground burial may not occur is at two stream/river crossings in Ludlow where the cables may be placed in conduit and attached to a bridge or culvert headwall.

The Converter Station site is shown in Figure 2. The Converter Building, which is the largest structure on the site, is approximately 165 feet in width by 325 feet in length. It will house the necessary electrical equipment that converts DC from the HVDC line to AC power. The building includes a Reactor Area, Valve Area, DC Area and Control Area. These contain electrical equipment such as reactors, arrestors, current transformers, current transducers, disconnect switches, direct voltage dividers, capacitors, reactors, arrestors, insulated gate bipolar transistor valves, and electrical control and protection equipment, (cabinets, computers, etc.)

Some of this equipment generates noise. The noise will be contained, to a large extent, by the walls of the structure (see Section 4 of this report.)

Exterior to the Converter Building will be the AC Yard. The noise-generating equipment here will be three, single-phase 350MVA 345kV/420kV power transformers and valve coolers (these are a system designed to dissipate the power losses generated in the converter valves). The fans from the valve coolers generate sound. At various locations around the building, there will be standard commercial HVAC units used to cool the building. The sound from the transformers is expected to be of a constant level, but the cooling fans on the transformers, valve coolers, and building HVAC will operate at loads relative to line power load and ambient temperature.

There will be a stand-by diesel generator system to supply power to essential loads in case the primary auxiliary supply is unavailable. The diesel generator will emit sound, which will be partially controlled by an enclosure. It will only be run for emergency power and periodic exercising.

There are no other operational components of the Project along the transmission line route that will generate noise.

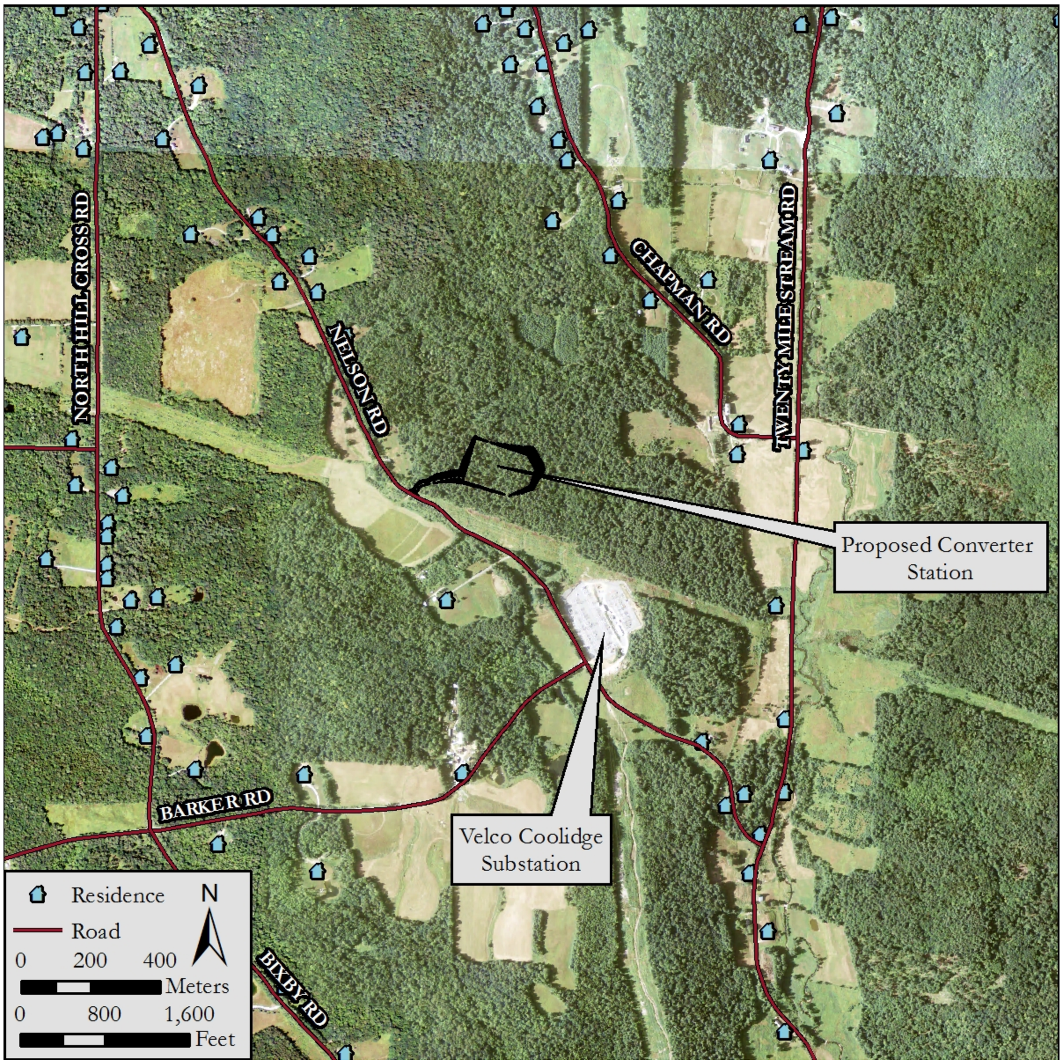

FIGURE 1: AREA MAP

FIGURE 2: SCHEMATIC LAYOUT OF THE PROPOSED SITE

2.0 SOUND LEVEL REGULATIONS, PRECEDENTS, AND CONVERTER STATION NOISE GOALS

The NECPL is being reviewed by the Public Service Board under Section 248 of Title 30. As such, noise limits contained within municipal zoning ordinances do not apply to the Project.

There are no Vermont statutes or regulations that establish quantitative noise standards applicable to this project. We are not aware of any quantitative noise standards that have been established for substations in other PSB decisions.

The PSB has established noise standards, in a different context, for wind generation projects. Kingdom Community Wind and Georgia Mountain Community Wind have CPG conditions limiting them to 45 dBA outdoors and 30 dBA indoors (1-hour Leq) as measured at residences.

In addition, the PSB is currently undergoing a review of its approach to noise regulation for generation and transmission facilities (Docket 8167). In opening that Docket, the PSB stated,

> In reviewing Section 248 applications the Board has endeavored to impose, where needed, sound limitations on projects that are intended to protect the public health and safety, consistent with the best scientific information available at the time. To a large extent, the Board has employed a standard based upon noise guidelines developed by the World Health Organization. However, even with these restrictions placed on several recently constructed facilities, the Board has received complaints regarding sounds produced by the operation of some facilities. These complaints have raised questions about whether the limitations that the Board has previously adopted are adequate.

It is our understanding that most of the Board's investigation in Docket 8167 has focused on noise from wind projects rather than other types of facilities.

Nonetheless, in light of the PSB's concerns, we have recommended and TDI-NE has agreed to noise goals for the NECPL's converter station that are more conservative (i.e. lower than) the noise limits for wind projects, and that are based on available scientific information on noise impacts for similar types of sound such as those from a substation. The project-specific noise goals are based on the World Health Organization Nighttime Noise Guidelines for Europe and portions of ANSI S12.9 Part 4, as discussed below.

2.1 | WHO NOISE GUIDELINES

The United Nation's World Health Organization (WHO) has published "Guidelines for Community Noise" (1999) which uses the most current research on the health impacts of noise to develop guideline sound levels for communities. The foreword of the report states, "The scope of WHO's effort to derive guidelines for community noise is to consolidate actual scientific knowledge on the health impacts of community noise and to provide guidance to environmental health authorities and professionals trying to protect people from the harmful effects of noise in non-industrial environments."

The WHO guidelines suggest a daytime and nighttime protective noise level. During the day, the levels are 55 dBA $Leq_{(16)}$, which is an average over a 16-hour day, to protect against serious annoyance and 50 dBA $Leq_{(16)}$ to protect against moderate annoyance.

During the night, the WHO recommends limits of 45 dBA $Leq_{(8)}$ (8-hour Leq) and an instantaneous maximum of 60 dBA LAf_{max} (fast response maximum). These are to be measured outside the bedroom window. A sound level inside the bedroom that is protective of sleep is 30 dBA $Leq_{(8)}$. Given their assumption that the outside to inside transmission loss is 15 dB with windows open, so long as the sound levels outside of the house remain at or below 45 dBA, sound levels in the bedroom will remain below 30 dBA. Given the climate in this region, this is essentially a summertime standard, since residents are less likely to have their windows open during other times of the year. By closing windows, an additional ~10 dB of sound attenuation will result.

In October 2009, WHO Europe conducted an updated literature review and developed guidelines for nighttime noise in Europe. They expanded on the 1999 WHO guidelines by adding an *annual average* nighttime guideline level to protect against adverse effects on sleep disturbance. This guideline is 40 dB L_{night}, outside, assuming windows are partially open all year. This guideline was established based on research on the effects of traffic, rail, and aircraft noise. Because there is no tonality associated with those broadband noise sources, no tonality adjustment was recommended.

2.2 | ANSI S12.9 SOUND STANDARDS

ANSI S12.9 Part 4, American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 4: Noise Assessment and Prediction of Long-Term Community Response" is used to establish a noise standard based on long-term exposure to sound. The standard is based on an annual average day/night sound level.

To calculate the day/night average sound level, adjustments are made to account for various characteristics of the sound that may make it more or less annoying. Such characteristics include impulsivity, rapid onset rate, tonality, aircraft sound, and time of day and week.

The two adjustments that could apply to the NECPL include nighttime operation and tonality. That is, the operation is expected to be 24 hours per day/7 days per week (although not constantly at the maximum sound pressure level). In addition, certain components, particularly sources inside the control building and the transformers (without fans) are expected to be tonal. ANSI S12.9 Part 4 recommends that sound spectra that are tonal be given a 5 dB adjustment to compensate for the increased annoyance of tonal sounds. In addition, sound that occurs at night is further adjusted by 10 dB. This highlights an important difference between the ANSI S12.9 standard and WHO Europe guideline, in that the ANSI standard is an annual average sound level, which is why there is a specific nighttime adjustment, while the WHO Europe guideline is an annual average *nighttime* sound level, which means that the nighttime aspect is inherent in the guideline level.

ANSI S12.9 Part 5 contains the "Sound level descriptors for determination of compatible land use." Under this standard, day-night sound levels under 55 dBA are compatible with urban/suburban single-family residences with extensive outdoor use. Levels between 55 and 60 dBA Ldn are "marginally compatible". Under this standard, an annual average of 45 dBA would be compatible for broadband sound sources at night, and 40 dBA for tonal sound sources that operate during the night (i.e., by subtracting the 5 dB and 10 dB adjustments noted above).

2.3 | NOISE THRESHOLD GOALS FOR THE NECPL'S CONVERTER STATION

The sound sources at the Project's converter station will be continuous and operate at night and during the day. Some sound sources will be tonal. Under both the WHO Europe guidelines and ANSI S12.9, the appropriate noise threshold goal would be 40 dBA (annual average Leq).

As a more conservative approach for this project, we have recommended and TDI-NE has agreed to use the ANSI S12.9 Part 4 tonal adjustment with the WHO Europe guideline. This would result in a noise threshold goal of 40 dBA L_{night} for broadband and 35 dBA L_{night} for tonal sound.[2]

For the purposes of this analysis, we make a further conservative assumption that the sound sources would run at the maximum sound level all year. As a result, the maximum one-hour sound emissions would be the same as the annual average. Given that the noise goals are based on protection against sleep disturbance, they would apply only to areas of frequent human use around residences, and would not apply to areas that have transient uses such as driveways, trails, farm fields, and parking areas.

[2] While not directly applicable, as discussed above, we note that the NECPL noise goals are more stringent than the Town of Ludlow's noise limits. Under the Ludlow zoning limits, a project cannot exceed 65 dBA more than 8 hours per 24 hours and not to exceed 70 dBA at residential property lines. These zoning limits are substantially less restrictive than the NECPL goal of 35 dBA L_{night}.

3.0 BACKGROUND SOUND LEVEL MONITORING

To characterize the existing acoustical environment of the surrounding area, RSG conducted background sound level measurements with leaf-off conditions in October 2014. The purpose of background sound level measurements is to characterize the existing soundscape in an area, allowing identification of existing sound sources as well as their relative contributions to the soundscape. In this case, contributions from VELCO's Coolidge substation are of interest due to its proximity to the Converter Station and the potential similarity of sound emission characteristics between the two.

3.1 | LOCATIONS

Three monitoring locations were chosen surrounding the location of the proposed converter station, where monitoring was performed over a period of seven days. The three locations were chosen to represent soundscapes in different directions relative to the Project. Monitor locations are shown in Figure 3.

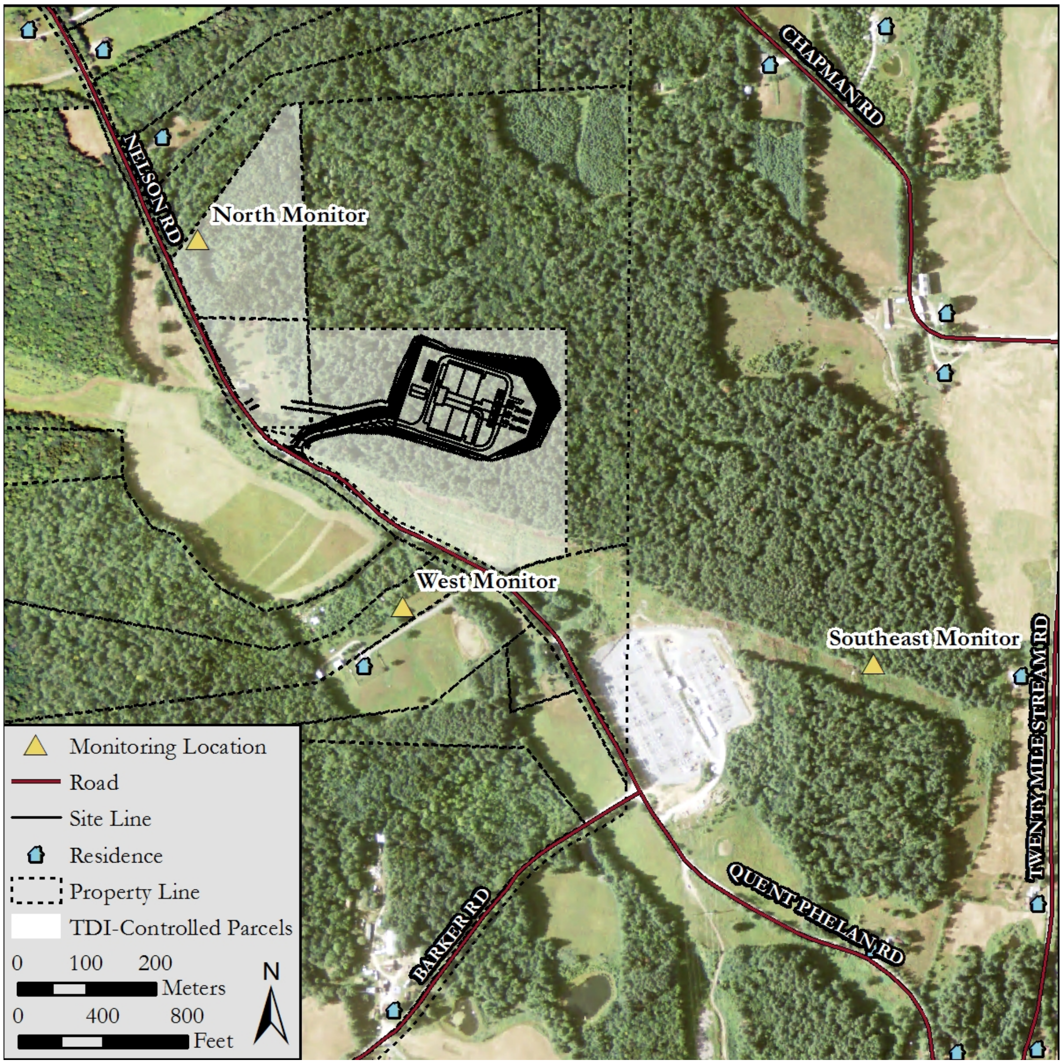

FIGURE 3: BACKGROUND SOUND LEVEL MONITORING LOCATIONS

MONITOR A – NORTH MONITOR

Monitor A was chosen to represent the soundscape at residences to the north/northwest of the proposed project and is shown in Figure 4. Monitor A was located in a stand of coniferous trees, located just north of a small clearing and approximately 1,115 feet (340 meters) northwest of the converter site. Nelson Road was located approximately 160 feet (50 meters) to the west of the monitor, and the closest residence north of the Project was located approximately 520 feet (160 meters) to the northwest.

FIGURE 4: PICTURE OF THE NORTH MONITOR

MONITOR B – WEST MONITOR

The West Monitor was chosen to represent soundscapes of the closest residences located south and west of the project. A picture of the monitor is shown in Figure 5. The monitor was positioned in a field located approximately 260 feet (80 meters) northeast and downhill of the residence. Nelson Road was located approximately 330 feet (100 meters) to the north and lower than the monitor. VELCO's Coolidge substation was located approximately 950 feet (290 meters) to the southeast. The proposed project would be located approximately 790 feet (240 meters) to the north.

FIGURE 5: PICTURE OF THE WEST MONITOR

MONITOR C – SOUTHEAST MONITOR

The Southeast Monitor was chosen to represent residential soundscapes to the southeast of the Project. A picture of the monitor is shown in Figure 6. The monitor was positioned next to the power cut in a mixed vegetation forested area. Twenty Mile Stream Road was located approximately 850 feet (260 meters) to the east, with the closest residence located approximately 690 feet (210 meters) to the east. The intersection between Chapman Road and Twenty Mile Stream Road was located approximately 1,770 feet (540 meters) to the northeast. VELCO's Coolidge substation was located approximately 620 feet (190 meters) to the west, and the proposed converter station would be located approximately 1,970 feet (600 meters) to the northwest. The monitor was well downhill of the VELCO Coolidge substation, below several steep ledges.

FIGURE 6: PICTURE OF THE SOUTHEAST MONITOR

3.2 | PROCEDURES

Long term monitoring was carried out using ANSI/IEC Type 1 integrating sound pressure level meters, logging 1/3 octave band sound pressure levels once each second, along with overall A-weighted equivalent levels. Each meter was calibrated before and after measurements with a Larson Davis CAL200 calibrator, emitting a 94 dB 1 kHz tone. Microphones were mounted on wooden stakes at a height of approximately 1.5 meters (5 feet) above ground level and were covered with 7-inch hydrophobic windscreens to minimize wind-caused noise. Audio recorders were attached to each sound level meter to aid in sound source identification and sound source characterization. An anemometer, mounted approximately 1.5 meters (5 feet) above ground level, was located at Monitor B to measure wind speed.

3.3 | RESULTS

Monitoring was carried out from October 24 to October 31, 2014. Temperatures during this period ranged from 0 to 17 °C (32 to 62 °F)[3] and winds ranged from calm to 6 m/s (calm to 13 mph). Light precipitation occurred during isolated hours of October 25, October 26, October 28, and October 29. Periods with wind speeds greater than 5 m/s or precipitation

[3] Temperature and precipitation data were obtained from the www.wunderground.com Springfield, VT station.

were removed from the data, as the high wind speeds and patter of rain on the wind screen are recorded by the sound level meter in excess of the actual ambient sound level.

MONITOR A - NORTH

Overall sound level results are shown in Table 1 and time history results are shown in Figure 7. The daytime equivalent average sound level (Leq) is 38 dBA and the nighttime Leq is 33 dBA. The daytime bottom 10th percentile sound level (L90) is 25 dBA and the nighttime L90 is 20 dBA. This is the quietest of the three monitoring sites, though it exhibits similar sound level patterns as the other sites. There is no single dominating sound source, frequent sound sources include car pass-bys on Quent Phelan/Nelson Road, foliage noise caused by wind, and airplane over-flights. These sound sources are all intermittent sound sources, which contributes to the frequently large difference between the Leq and L90. There is no diurnal pattern to sound levels at this site.

Transformer noise is frequently exhibited by a 120 Hz tone (in the 125 Hz 1/3 octave band), or a tone at twice the line frequency. A spectrum of a quiet nighttime period, shown in Figure 8, does not show a prominent 125 Hz 1/3 octave band, so transformer noise from the VELCO Coolidge substation is rarely audible.

TABLE 1: OVERALL MONITORING RESULTS – NORTH MONITOR

Period	Sound Pressure Level (dBA)			
	Leq	L90	L50	L10
Overall	36	21	29	39
Day	38	25	32	41
Night	33	20	26	37

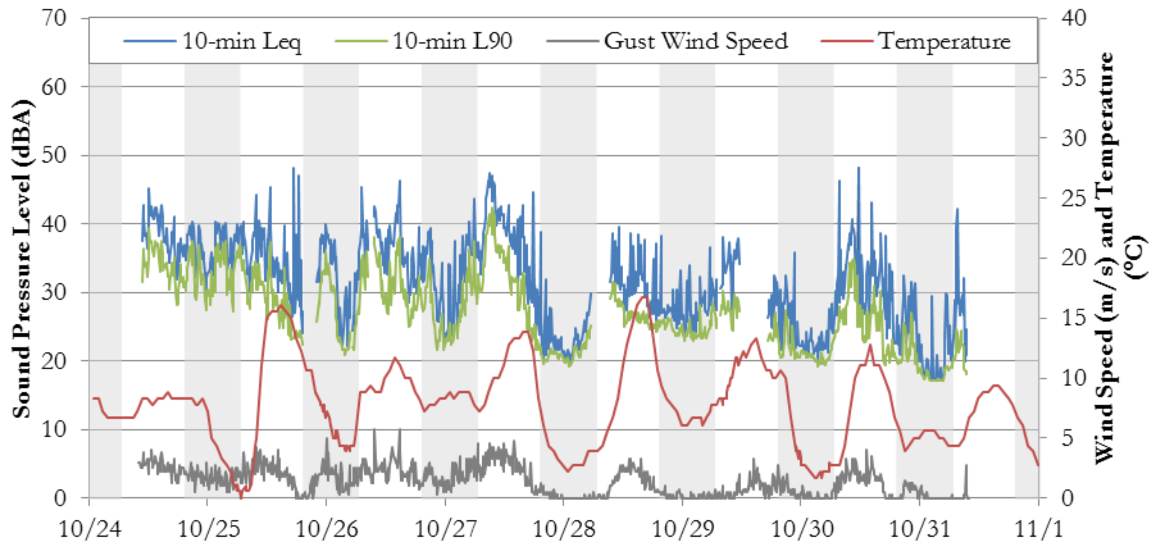

FIGURE 7: BACKGROUND SOUND LEVEL MONITORING TIME HISTORY RESULTS – NORTH MONITOR

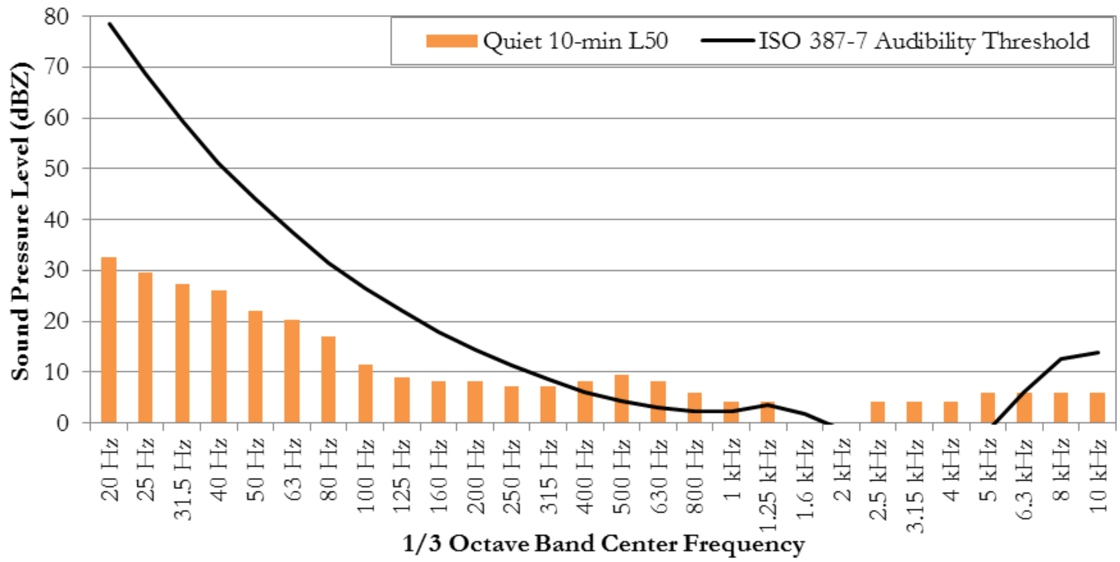

FIGURE 8: QUIET NIGHTTIME MONITORING PERIOD SPECTRUM AT THE NORTH MONITOR[4]

MONITOR B - WEST

Overall sound level results are shown in Table 2 and time history results are shown in Figure 9. The daytime Leq is 46 dBA and the nighttime Leq is 33 dBA. The daytime L90 is 29 dBA and the nighttime L90 is 26 dBA. The soundscape at the West Monitor includes sound from vehicle passbys on Quent Phelan/Nelson Road and the residence's driveway, along with the occasional airplane overflight. During the monitoring period, bird calls were frequent and yard maintenance equipment noise was occasionally present. Like the North Monitor, all major sound sources are intermittent, contributing to the frequently large difference between the Leq and L90. The only diurnal sound level pattern is the decreased nighttime difference between the Leq and L90. This is due to nighttime decreases in traffic and bird activity.

A spectrum of the quietest measured 10-minute nighttime L50, is shown in Figure 10. The 125 Hz 1/3 octave band is prominent at this location, and the audio recordings indicate that the VELCO Coolidge substation is audible during certain quiet times.

TABLE 2: OVERALL MONITORING RESULTS – WEST MONITOR

Period	Sound Pressure Level (dBA)			
	Leq	L90	L50	L10
Overall	43	27	32	40
Day	46	29	35	43
Night	33	26	30	36

[4] Sound pressure levels in several 1/3 octave bands were below 0 dB, so a different period was chosen where fewer 1/3 octave band sound pressure levels are 0 dB.

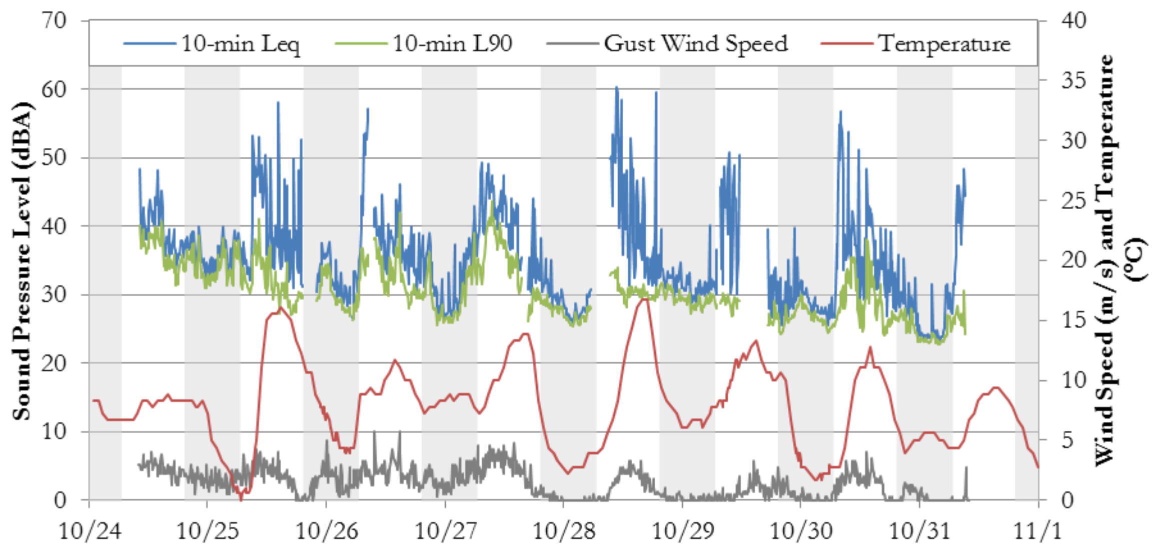

FIGURE 9: BACKGROUND SOUND LEVEL MONITORING TIME HISTORY RESULTS – WEST MONITOR

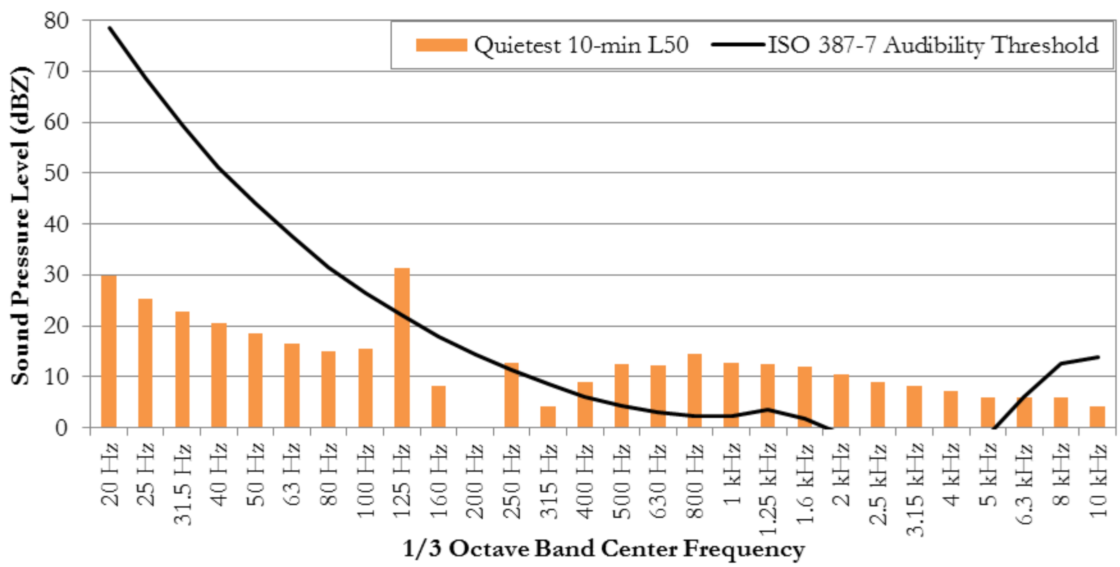

FIGURE 10: QUIETEST NIGHTTIME MONITORING PERIOD SPECTRUM AT THE WEST MONITOR

MONITOR C - SOUTHEAST

Overall sound level results are shown in Table 3 and time history results are shown in Figure 11 for the Southeast Monitor. The daytime Leq is 38 dBA and the nighttime Leq is 31 dBA. The daytime L90 is 27 dBA and the nighttime L90 is 24 dBA.

Sound sources here include bird calls, airplane over-flights, distant car pass-bys, substation noise, and wind-caused foliage noise. The only diurnal sound level pattern is a slight nighttime difference decrease between the Leq and L90. This is due to nighttime decreases in traffic and decreased bird activity.

A spectrum of the quietest measured 10-minute nighttime L50, is shown in Figure 12. The 125 Hz 1/3 octave band is slightly prominent at this location, but, it is below the human audibility threshold. However, harmonics of 120 Hz above 240 Hz (250 Hz 1/3 octave band) may be audible at times.

TABLE 3: OVERALL MONITORING RESULTS – SOUTHEAST MONITOR

Period	Sound Pressure Level (dBA)			
	Leq	L90	L50	L10
Overall	35	25	30	38
Day	38	27	33	40
Night	31	24	28	34

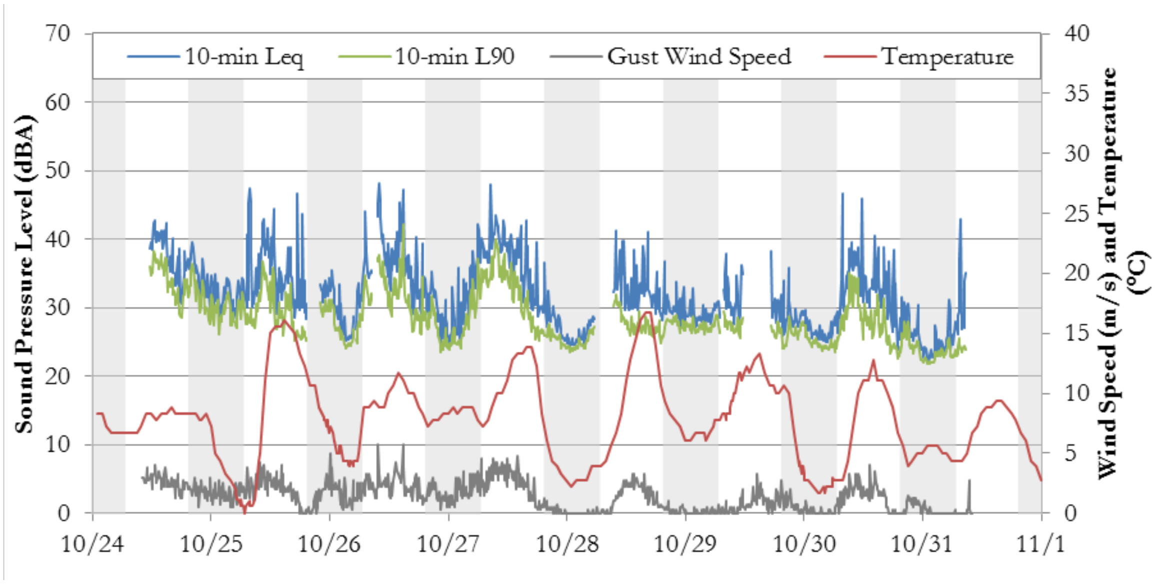

FIGURE 11: BACKGROUND SOUND LEVEL MONITORING TIME HISTORY RESULTS – SOUTHEAST MONITOR

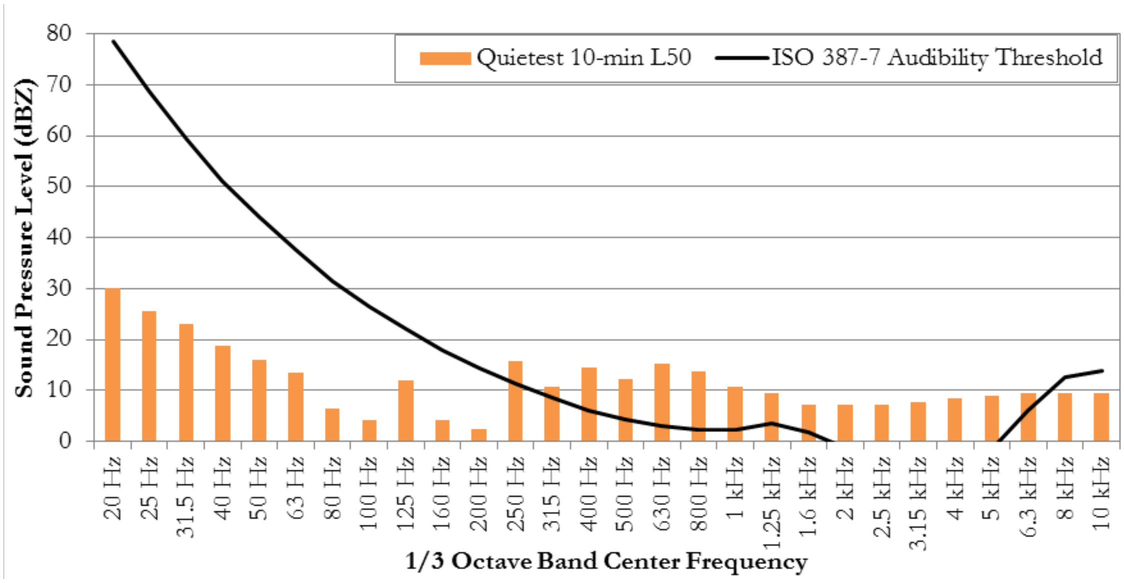

FIGURE 12: QUIETEST NIGHTTIME MONITORING PERIOD SPECTRUM AT THE SOUTHEAST MONITOR

4.0 SOUND PROPAGATION MODELING

4.1 | PROCEDURES

Modeling for the project was performed in accordance with the standard ISO 9613-2, "Acoustics – Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation." The ISO standard states,

> This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level … under meteorological conditions favorable to propagation from sources of known sound emissions. These conditions are for downwind propagation … or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night.

The model takes into account source sound power levels, surface reflection and absorption, atmospheric absorption, geometric divergence, meteorological conditions, walls, barriers, berms, and terrain. The acoustical modeling software used here was CadnaA® V4.4, from Datakustik GmbH. CadnaA® is a widely accepted acoustical propagation modeling tool, used by many noise control professionals in the United States and internationally. ISO 9613-2 also assumes downwind sound propagation between every source and every receiver.

Model input parameters are listed in Appendix A, and modeled sound powers are shown in Table 4. For each piece of equipment, the sound power is given for each individual unit. For the Converter Station Building, the unit of sound intensity in this case is the sound pressure level per square meter of surface.

The converter building was modeled by putting the conversion equipment (valve units, phase reactors, and smoothing reactors) inside of a 21- gauge steel building and then modeling the sound that would penetrate the building walls. In Appendix A the "Converter Building Roof" and "Converter Building Walls" reflect the results of this combination. Other sound sources (transformers, valve cooling towers, transformer cooling fans, and air conditioning units) were modeled outside the building using sound power levels obtained from similar projects and/or information from equipment manufacturers.

The project area was modeled with mixed ground (G=0.5) throughout the project area, G=0.6 within the project fence-line, and G=0 on the project driveway. The extent of modeled foliage is shown in Figure 13.

A 20-meter by 20-meter grid of 1.5 meter (5 foot) high receivers was set up in the model, covering approximately 16 sq. km. (6.2 sq. mi.) in and around the project area. The entire model was laid over the USGS Digital Terrain Model to give accurate elevations throughout.

A total of 146 discrete receivers were included in the model at a 4 meter (13 foot) height, representing residences near the project.

TABLE 4: EQUIPMENT SOUND POWER

Sound Power ID	Sound Emissions Type	Quantity Modeled	1/1 Octave Band Sound Power (dBZ)									Sum (dBA)	Sum (dBZ)
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Cooling Fan Bank	Sound Power	11	78	96	91	88	88	84	81	72	62	89	98
Transformer	Sound Power	3	89	89	106	103	102	84	79	83	75	101	106
Transformer Fans	Sound Power	3	79	96	92	89	89	84	82	72	62	90	99
AC Unit	Sound Power	2	67	72	70	69	71	68	61	58	59	72	78
Valve Unit	Sound Power	19	78	79	82	80	80	77	76	73	71	83	88
Phase Reactor	Sound Power	6	68	68	85	82	81	63	58	62	54	80	88
Smoothing Reactor	Sound Power	2	68	68	84	82	81	63	58	62	54	80	88
Converter Building	Sound Intensity	1	57	52	56	50	48	37	34	27	18	48	61

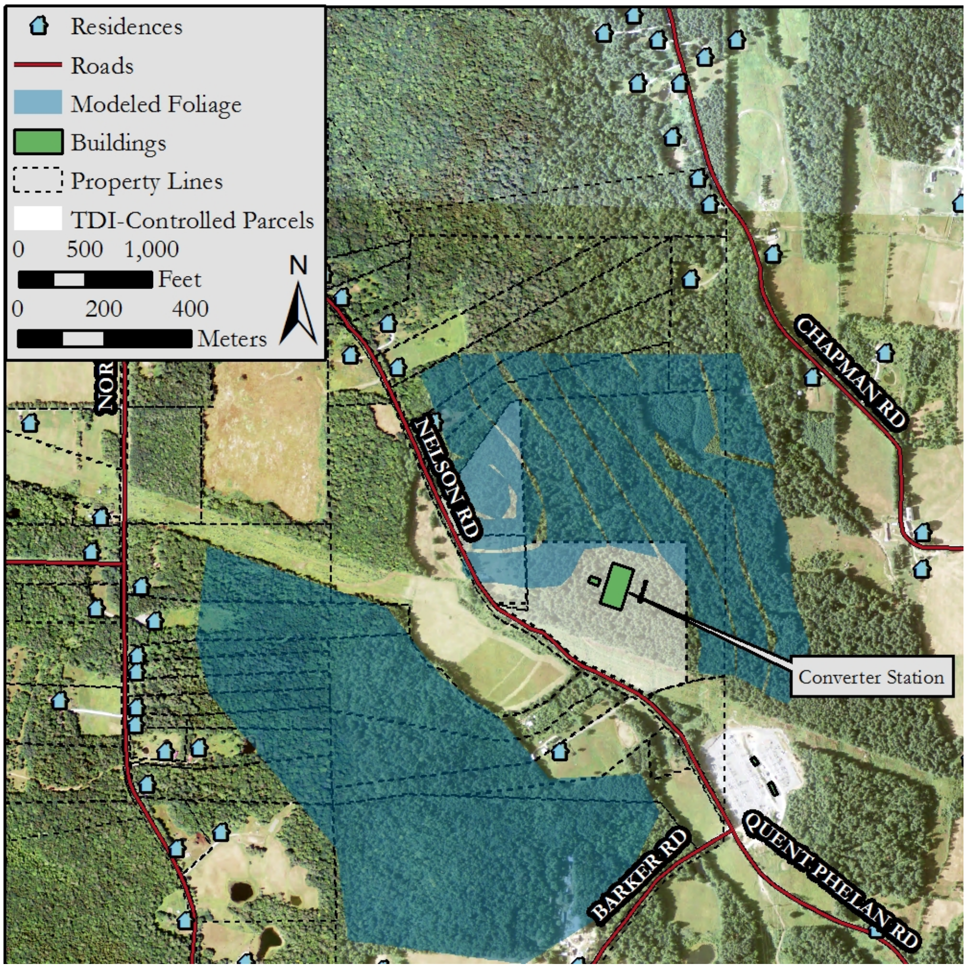

FIGURE 13: MODELED FOLIAGE[5]

[5] Not all foliage present at the site was modeled. For foliage to be acoustically modeled, there must be greater than 100 horizontal meters of continuous foliage present.

4.2 | RESULTS

OVERALL SOUND LEVELS

The sound level results for the only receivers expected to have maximum sound levels above 30 dBA ($Leq_{(1\text{-}hour)}$) are shown in Table 5. Residence locations and results for all residences are found in Appendix B. As shown, the noise goal of 35 dBA is met at all residences.

TABLE 5: MAXIMUM $LEQ_{(1\text{-}HOUR)}$ AT RESIDENCES

Residence ID	Sound Pressure Level (dBA)
31	34.7
30	34.6
5	34.3
40	34.0
43	33.5
19	33.3
32	32.3
46	31.7
24	31.6
51	31.2
28	30.6
26	30.4
23	30.1
54	30.0

To obtain these results, a single configuration was modeled for the proposed converter station. This configuration, including modeled sound contours, is shown in Figure 14. The modeled results include the valve cooling fan towers with noise mitigation sufficient to bring the total valve cooling fan sound power (all eleven towers) down to 100 dBA.[6] The sound power for the project transformers assumes sand-filled braces are used to stiffen the tank, which results in an approximate 2 dB reduction below the NEMA TR-1 standard sound levels for transformers of this size. Absorptive sound barriers in strategic locations are recommended to be used for noise mitigation, as needed. The barriers used for modeling were based on the specifications from an Acoustiblok Industrial absorptive barrier.[7] These mitigation measures, including barrier height and location, may change as final equipment selections are made.

[6] Since an equipment supplier has not yet been selected, specific noise mitigation measures are not being proposed. Rather sound power specifications are being developed so as to meet the noise threshold goals.

[7] RSG does not endorse, sell, or distribute products from any acoustical manufacturer. Product recommendations made in this report are based on acoustical performance only.

Figure 15 shows the Project sound contours in the surrounding neighborhood. The highest Project sound pressure level is 34.7 (rounded to 35) dBA, at the closest residence to the east.

TONALITY

Where transformer noise is dominant, sound emitted by the converter station is expected to be tonal. Figure 16 shows a modeled spectrum at the worst-case residence without the transformer fans or the valve cooling towers running. In that case, there is a tonal prominence in the 125 Hz 1/3 octave band. The second spectrum shown in that figure is the *lowest* monitored 10-minute L50 spectrum at the southeast monitor. Project sound emissions are above monitored levels in the 80 Hz, 100 Hz, 125 Hz, 250 Hz, 315 Hz, and 400 Hz 1/3 octave bands. Consequently, tonal prominence may be audible. Figure 17 shows tonal prominence of each 1/3 octave band of the modeled spectrum, compared with the American National Standards Institute (ANSI) 12.9 Part 4 tonality criteria. These two graphics show that project sound levels may be tonal and audible at this residence when there is no contribution from the valve cooling fans or other broadband masking sound. The 35 dBA L_{night} noise goal includes a 5 dB tonality adjustment, so the Project noise goal is still met.

Figure 18 shows the modeled spectrum of the Project with fans on. As expected, there is reduced tonal prominence with this configuration. During quiet periods, the Project is expected to be audible between 50 and 800 Hz at this location, but Figure 19 confirms the spectrum is not tonal under ANSI 12.9 Part 4.

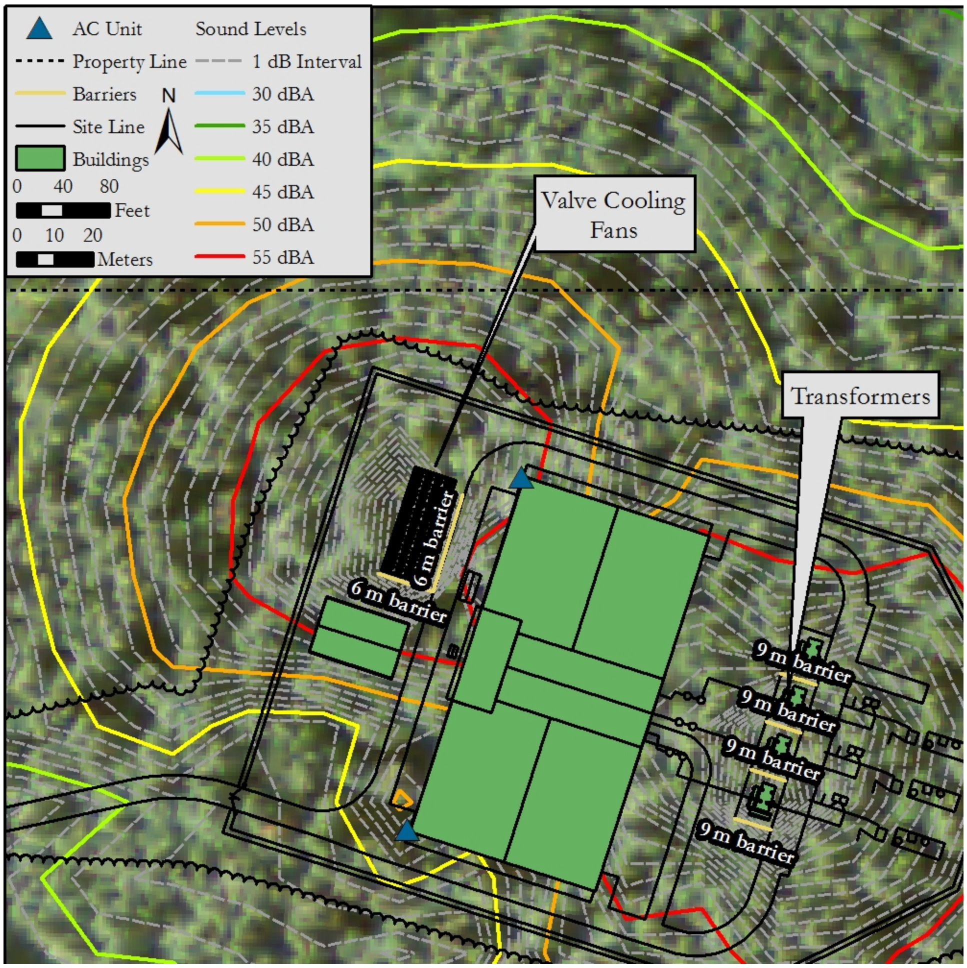

FIGURE 14: SOUND PROPAGATION MODELING – CLOSE-UP VIEW

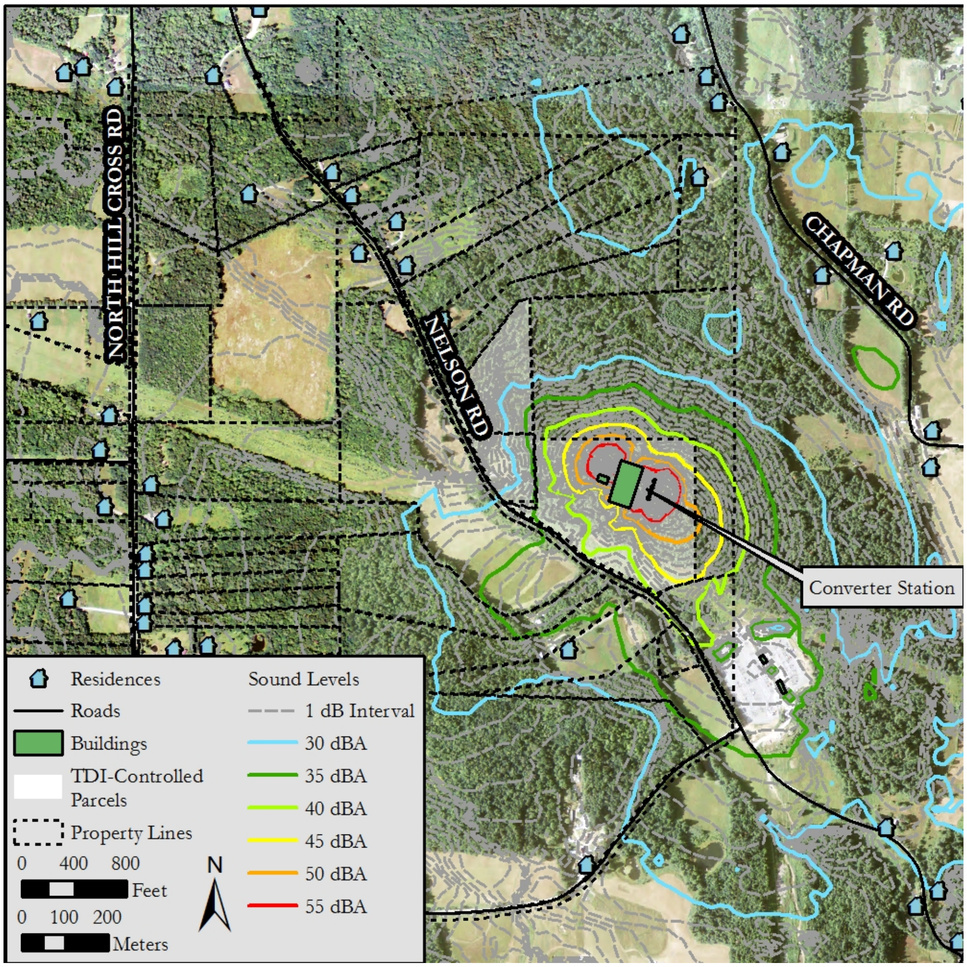

FIGURE 15: SOUND PROPAGATION MODELING RESULTS

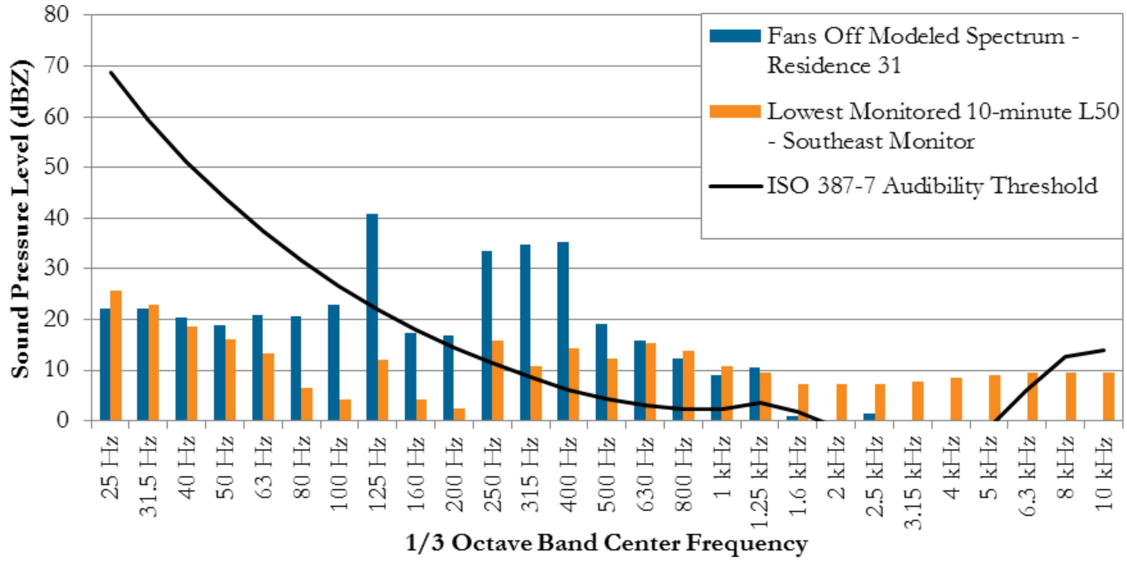

FIGURE 16: MODELED FANS OFF[8] 1/3 OCTAVE BAND SPECTRUM AT THE CLOSEST RESIDENCE TO THE EAST (RESIDENCE 31) COMPARED WITH THE LOWEST MONITORED 10-MINUTE L50 AT THE SOUTHEAST MONITOR

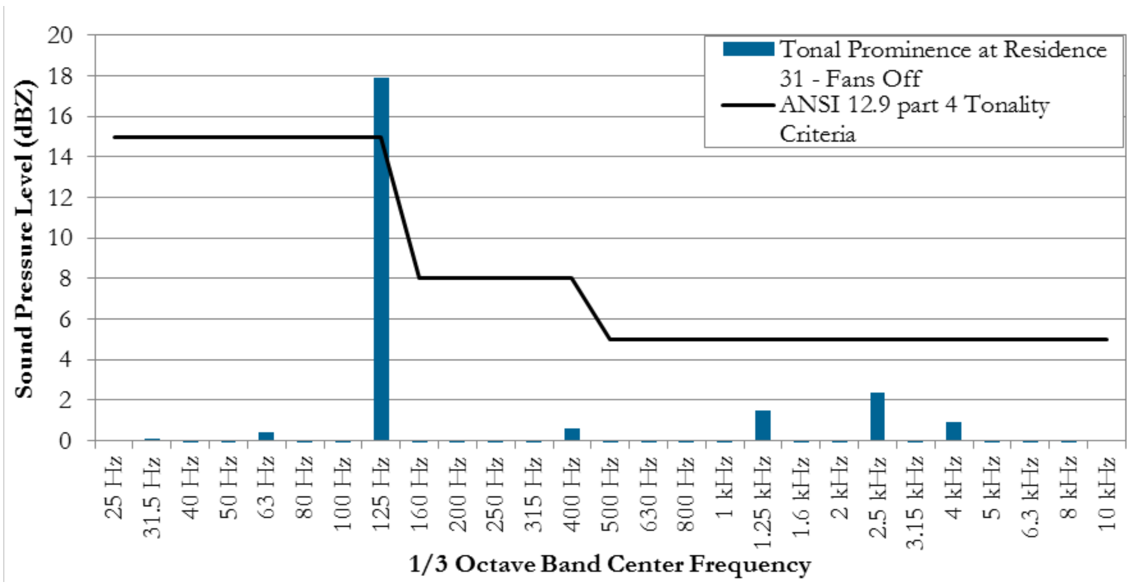

FIGURE 17: MODELED FANS OFF TONAL PROMINENCE AT RESIDENCE 31 COMPARED WITH ANSI 12.9 PART 4 TONALITY CRITERIA

---

[8] Fans are broadband noise, so the most tonal condition for the Project is when the valve cooling towers and the transformer fan banks are not operating.

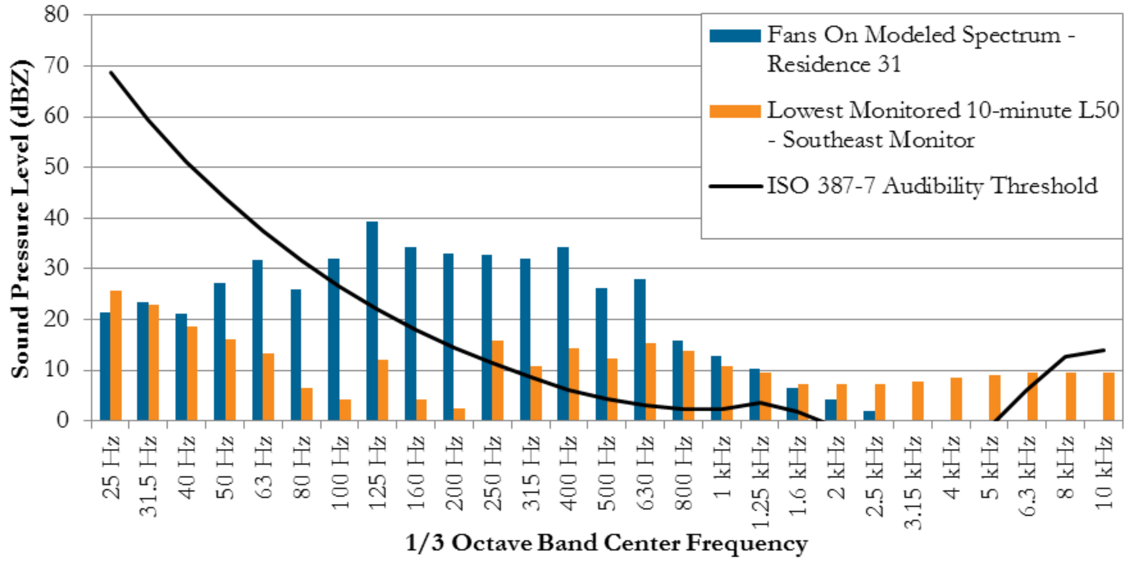

FIGURE 18: MODELED FANS ON 1/3 OCTAVE BAND SPECTRUM AT THE CLOSEST RESIDENCE TO THE EAST (RESIDENCE 31) COMPARED WITH THE LOWEST MONITORED L50 AT THE SOUTHEAST MONITOR

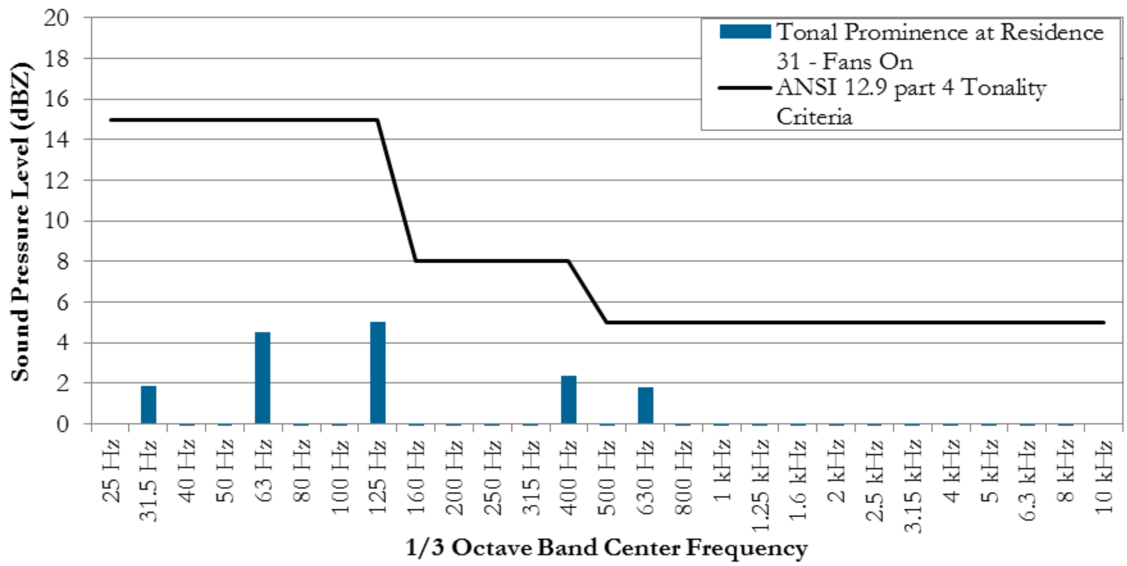

FIGURE 19: MODELED FANS ON TONAL PROMINENCE AT RESIDENCE 31 COMPARED WITH ANSI 12.9 PART 4 TONALITY CRITERIA

5.0 RECOMMENDATIONS

Our recommendations to control noise from the operation of the Converter Station are outlined below:

Because the Converter Station is not at the final design stage, which occurs after permits have been received, the mitigation measures used in the modeling (see section 4.2) may or may not be needed to meet the noise goals. However, some elements of mitigation can be considered, as discussed in section 4.2 above and described in the list below.

1) Periodic exercising of the diesel generator should be scheduled during weekdays, to the extent possible.
2) Noise reduction on the transformers is limited due to their large size.
    a. Filling the tank braces with sand to increase the wall stiffness may be possible and should be considered.
    b. Transformer cooling fans should be specified as "low-noise" to the extent they are available.
    c. Fire walls between transformers should be lined with or made of sound absorbing material.
    d. Fire walls or similar barrier should be placed at the outside of the first and last transformer to limit sound transmission to the west and east.
    e. The distance between the transformer wall and fire wall should be such that it will avoid constructive interference at 120 Hz.
3) The valve cooling fans should be designed to not exceed a total sound power of 100 dBA (or lower if possible). Consideration should be given of:
    a. Installing low noise fans
    b. Increasing the number of individual units to lower the load on any one unit (thereby lowering maximum fan speeds)
    c. Controlling fan speed with variable frequency drives (VFDs).
4) The Converter Station bid documents should specify the noise goal of 35 dBA L_{night}, to include the combined noise impacts from all site sources, including the converter building.

6.0 CONCLUSIONS

This study evaluates the noise impacts of a proposed HVDC converter station, to be located in Ludlow, Vermont. To investigate sound emissions from the converter station, RSG measured background sound pressure levels at three locations surrounding the site and then modeled sound emissions from the proposed converter station using a combination of data from similar projects, manufacturer information, and RSG-measured data. Results are as follows:

- RSG's recommended and TDI-NE's accepted noise goal for the converter station is not to exceed 35 dBA L_{night} for tonal sound and 40 dBA L_{night} for broadband sound. This limit is lower than the World Health Organization Nighttime Noise Guidelines for Europe of 40 dBA L_{night} and ANSI S12.9 guidelines of 40 dBA $Leq_{(annual)}$, and accounts for the continuous nature of the sound source, its operation during the night, and its potential tonality.
- Background sound level monitoring was performed at three locations, located northwest and southeast of the proposed project for a period of one week to establish existing sound levels and characterize the existing soundscape.
    - At the North Monitor, the nighttime equivalent average sound pressure level (Leq) and 10^{th} percentile level (L90) was 33 dBA and 20 dBA, respectively. Dominant sound sources included car pass-bys and airplane over-flights. Sounds characteristic of the existing VELCO Coolidge substation were not readily observed.
    - At the West Monitor, the nighttime Leq and L90 were 33 dBA and 26 dBA, respectively. Sound sources included car pass-bys, airplane overflights, birds, and yard maintenance equipment. During some periods, transformer noise from VELCO's Coolidge substation was evident during portions of a quiet night.
    - At the Southeast Monitor the nighttime Leq and L90 were 31 and 24 dBA, respectively. Sound sources included airplane overflights and occasional car passbys. The spectra for the VELCO substation sound was evident during the quietest nighttime periods, but the levels were in the low 20 dB range.
- Sound propagation modeling was performed using the ISO 9613-2 algorithm, as implemented in Datakustik's Cadna/A modeling software package.
    - With noise mitigation on the project transformers and valve cooling towers, along with strategic placement of noise walls, the highest modeled sound pressure level at a residence did not exceed 35 dBA, meeting the converter station noise goal.
    - This Project has not undergone final design. As a result, the mitigation used in the modeling may or may not be required to meet the converter station

noise goal at the closest residence. Mitigation options are discussed in Section 5 of this report. The specific mitigation measures incorporated into the Project will be selected during final design.

Based upon modeling of the converter station with a goal of meeting both WHO nighttime noise guidelines for Europe and ANSI S12.9 standards, and using additional conservative assumptions to account for the potential of tonal sound sources, the Project will not exceed the noise goal of 35 dBA L night. Thus, we conclude that there will be no undue adverse impact due to noise.

APPENDIX A: MODELING INPUTS

TABLE A 1: MODELING PARAMETERS

Parameter	Settings
Atmospheric Conditions	Temperature: 10° C and Relative Humidity: 70%
Reflections	2nd Order
Grid Receiver Height	1.5 meters
Ground Absorption	0.0 on Paved Roads; 0.6 within Converter Station and Substation Yards; and 0.5 Elsewhere
Maximum Search Radius	4 km
Foliage Attenuation	Yes, 10 meter Height

TABLE A 2: POINT SOURCE INFORMATION

Source	Modeled Sound Power (dBA)	Sound Power Name	Relative Height (m)	Coordinates (Vermont State Plane NAD 83)		
				X (m)	Y (m)	Z (m)
Converter AC Unit	72	AC Unit	1	486682	103633	428
Converter AC Unit	72	AC Unit	1	486712	103726	428

TABLE A 3: LINE SOURCE INFORMATION

Source	Total Modeled Sound Power (dBA)	Sound Power Name	Relative Height (m)
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4
Valve Cooling Fan Bank	90	Cooling Fan Bank	4

TABLE A 4: AREA SOURCE INFORMATION

Source	Total Modeled Sound Power (dBA)	Sound Power ID	Height (m)
Converter Building Roof	79	Converter Building	15
Transformer	98	Transformer	5
Transformer Fan Banks	87	Transformer Fans	5
Transformer	98	Transformer	5
Transformer	98	Transformer	5
Transformer Fan Banks	87	Transformer Fans	5
Transformer Fan Banks	87	Transformer Fans	5

TABLE A 5: VERTICAL AREA SOURCE INFORMATION

Source	Total Modeled Sound Power (dBA)	Sound Power ID	Total Height (m)
Converter Building Walls	78	Converter Building	16
Transformer	98	Transformer	5
Transformer	98	Transformer	5
Transformer Fan Banks	87	Transformer Fans	5
Transformer Fan Banks	87	Transformer Fans	5
Transformer	98	Transformer	5
Transformer Fan Banks	87	Transformer Fans	5

APPENDIX B: RECEIVER INFORMATION

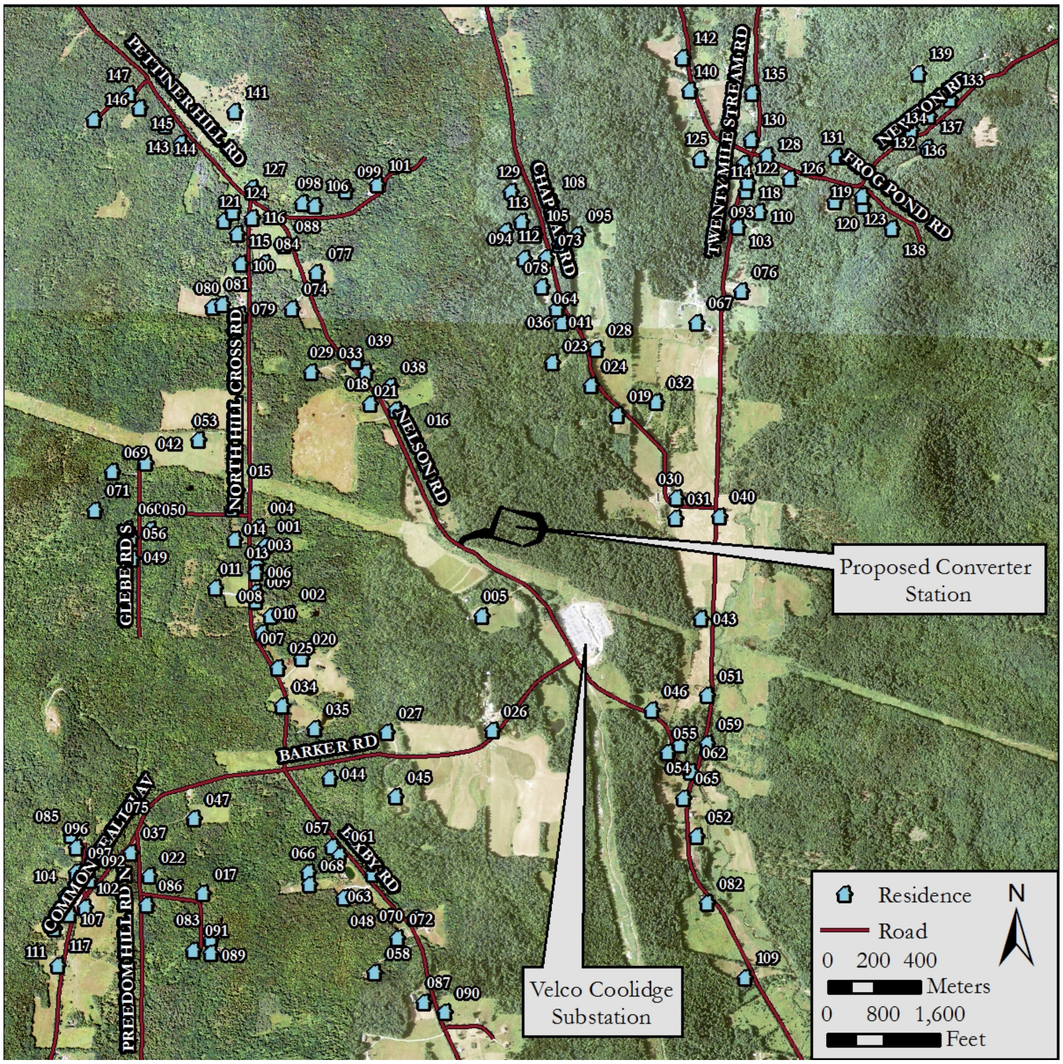

FIGURE B 1: RECEIVER LOCATIONS

TABLE B 1: DISCRETE RECEIVER RESULTS

Residence ID	Sound Pressure Level (dBA)	Relative Height (m)	Coordinates (Vermont State Plane NAD83)		
			X (m)	Y (m)	Z (m)
1	27	4	485655	103591	496
2	27	4	485756	103298	483
3	27	4	485613	103512	495
4	27	4	485624	103672	500
5	34	4	486591	103289	426
6	27	4	485611	103392	493
7	27	4	485678	103289	487
8	27	4	485611	103475	494
9	26	4	485610	103351	493
10	26	4	485637	103213	487
11	25	4	485435	103408	504
13	26	4	485518	103620	503
14	26	4	485508	103752	507
15	26	4	485530	103832	508
16	20	4	486301	104051	453
17	19	4	485383	102087	505
18	25	4	486108	104207	463
19	33	4	487178	104156	389
20	24	4	485808	103103	471
21	27	4	486216	104178	455
22	17	4	485151	102164	508
23	30	4	486895	104383	408
24	32	4	487062	104285	396
25	23	4	485706	103064	476
26	30	4	486635	102791	427
27	19	4	486180	102784	445
28	31	4	487085	104441	405
29	24	4	485852	104344	482
30	35	4	487433	103797	363
31	35	4	487430	103711	363
32	32	4	487345	104212	377
33	27	4	486089	104342	464
34	23	4	485724	102897	471
35	23	4	485865	102800	460
36	30	4	486939	104557	418
37	17	4	485071	102264	503
38	27	4	486193	104280	452
39	27	4	486046	104394	467
40	34	4	487620	103719	358

Residence ID	Sound Pressure Level (dBA)	Relative Height (m)	Coordinates (Vermont State Plane NAD83)		
			X (m)	Y (m)	Z (m)
41	29	4	486913	104616	419
42	24	4	485136	103950	535
43	34	4	487540	103274	356
44	20	4	485931	102585	456
45	18	4	486217	102505	439
46	32	4	487326	102879	368
47	19	4	485345	102410	488
48	20	4	485991	102067	467
49	16	4	485075	103534	507
50	19	4	485156	103663	515
51	31	4	487565	102945	357
52	26	4	487519	102334	358
53	25	4	485365	104049	526
54	30	4	487448	102731	364
55	30	4	487396	102696	360
56	17	4	485072	103625	510
57	17	4	485943	102290	454
58	19	4	486125	101745	466
59	29	4	487564	102736	353
60	16	4	485054	103666	510
61	17	4	485974	102251	455
62	28	4	487495	102613	353
63	18	4	486120	102173	448
64	27	4	486851	104713	422
65	28	4	487464	102500	359
66	18	4	485840	102179	469
67	27	4	487522	104558	374
68	17	4	485844	102126	470
69	23	4	484992	103911	536
70	21	4	486299	101980	440
71	18	4	484913	103746	520
72	20	4	486226	101893	453
73	26	4	486869	104837	431
74	25	4	485769	104619	490
75	16	4	484994	102375	494
76	26	4	487715	104693	375
77	25	4	485875	104774	481
78	26	4	486927	104896	433
79	24	4	485542	104591	505
80	23	4	485425	104625	512

Residence ID	Sound Pressure Level (dBA)	Relative Height (m)	Coordinates (Vermont State Plane NAD83)		
			X (m)	Y (m)	Z (m)
81	24	4	485468	104638	511
82	24	4	487566	102045	357
83	13	4	485415	101887	504
84	24	4	485648	104815	503
85	10	4	484810	102339	470
86	13	4	485139	102038	505
87	19	4	486339	101617	440
88	24	4	485733	104892	499
89	11	4	485415	101827	497
90	18	4	486429	101572	431
91	11	4	485342	101841	496
92	13	4	484891	102145	496
93	24	4	487615	104950	377
94	26	4	486772	104836	431
95	23	4	487001	104935	427
96	11	4	484832	102284	475
97	8	4	484835	102177	482
98	24	4	485815	105075	506
99	24	4	486001	105126	504
100	24	4	485547	104813	508
101	24	4	486136	105153	491
102	12	4	484874	102026	494
103	24	4	487700	104970	378
104	9	4	484786	102079	484
105	26	4	486818	104936	438
106	24	4	485868	105064	505
107	11	4	484804	101996	488
108	25	4	486891	105080	438
109	21	4	487731	101722	351
110	24	4	487792	105037	388
111	10	4	484738	101935	480
112	25	4	486695	104951	439
113	26	4	486763	104994	444
114	23	4	487732	105128	381
115	23	4	485530	104943	509
116	23	4	485595	105009	507
117	10	4	484752	101777	475
118	23	4	487741	105166	381
119	25	4	488241	105065	431
120	23	4	488120	105083	419

Residence ID	Sound Pressure Level (dBA)	Relative Height (m)	Coordinates (Vermont State Plane NAD83)		
			X (m)	Y (m)	Z (m)
121	22	4	485476	104997	511
122	22	4	487727	105246	378
123	24	4	488237	105104	434
124	22	4	485514	105036	508
125	20	4	487535	105266	382
126	23	4	487923	105182	400
127	22	4	485597	105139	507
128	22	4	487823	105281	386
129	25	4	486717	105125	455
130	21	4	487757	105350	382
131	22	4	488127	105275	415
132	23	4	488518	105314	457
133	22	4	488619	105523	470
134	24	4	488370	105358	444
135	20	4	487759	105550	381
136	23	4	488451	105390	453
137	23	4	488526	105452	459
138	21	4	488365	104965	447
139	22	4	488481	105635	456
140	16	4	487490	105562	383
141	16	4	485519	105471	524
142	15	4	487460	105704	388
143	15	4	485286	105335	506
144	14	4	485217	105408	499
145	11	4	485108	105485	486
146	7	4	484909	105437	456
147	9	4	485063	105547	476