Ross County Solar

Exhibit Q

Noise Assessment

Case No. 20-1380-EL-BGN

ROSS COUNTY SOLAR, LLC

ROSS COUNTY SOLAR NOISE ASSESSMENT

Noise Assessment | October 8, 2020


PREPARED FOR:
ROSS COUNTY SOLAR, LLC

SUBMITTED BY:
RSG

IN COOPERATION WITH:
EDR

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

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Ross County Solar ("Project") is a photovoltaic power facility proposed in Ross County in south central Ohio. The project is proposed to have a nameplate capacity of up to 120 MW. As part of the Ohio Power Siting Board (OPSB) permitting process, RSG was hired by Ross County Solar, LLC to perform a Noise Assessment of existing acoustical conditions in the area and sound emissions of the primary sound-producing project components, namely inverters and transformers. This report of the assessment includes:

- A project description;
- Sound level limits applicable to the Project;
- Sound level monitoring procedures and results;
- Operational sound propagation modeling procedures and results;
- Construction noise modeling; and
- Results.

A primer of acoustical terminology used in this report can be found in Appendix A.

2.0 PROJECT DESCRIPTION

The Project is proposed to be located in the western part of Ross County, Ohio just southeast of Greenfield. The Project will be bounded on the east by Ohio Route 41 (OH-41) and on the west by Rapid Forge Road (County Road 1). The Project extends from about 290 meters (951 feet) north of Moxley Road on the south end to approximately 180 meters (590 feet) south of Rapid Forge Road (County Road 41A) on the north end. The total Project encompasses approximately 1400 acres of land ("Project Area"). The edge of Greenfield, Ohio is approximately 1 kilometer (3,280 feet) northwest of the closest Project parcel.

The area is primarily agricultural with scatted residences and farmsteads throughout. A total of 205 receptors are included in this assessment, and the closest receptors are shown along with Project elements in Figure 1.

The primary operational sound sources include 37 inverter skids spread throughout the Project area and two main high-voltage transformers (125 MVA each). Each inverter skid includes an inverter and medium-voltage transformer. Noise emissions from all of these sources are analyzed in this assessment. Typical operations of the Project include transformers and inverters operating during the day, and only transformers operating at night. However, the inverters may operate sometimes at night for MVAR control. As such, it has been assumed for this assessment that all sources could operate at night.

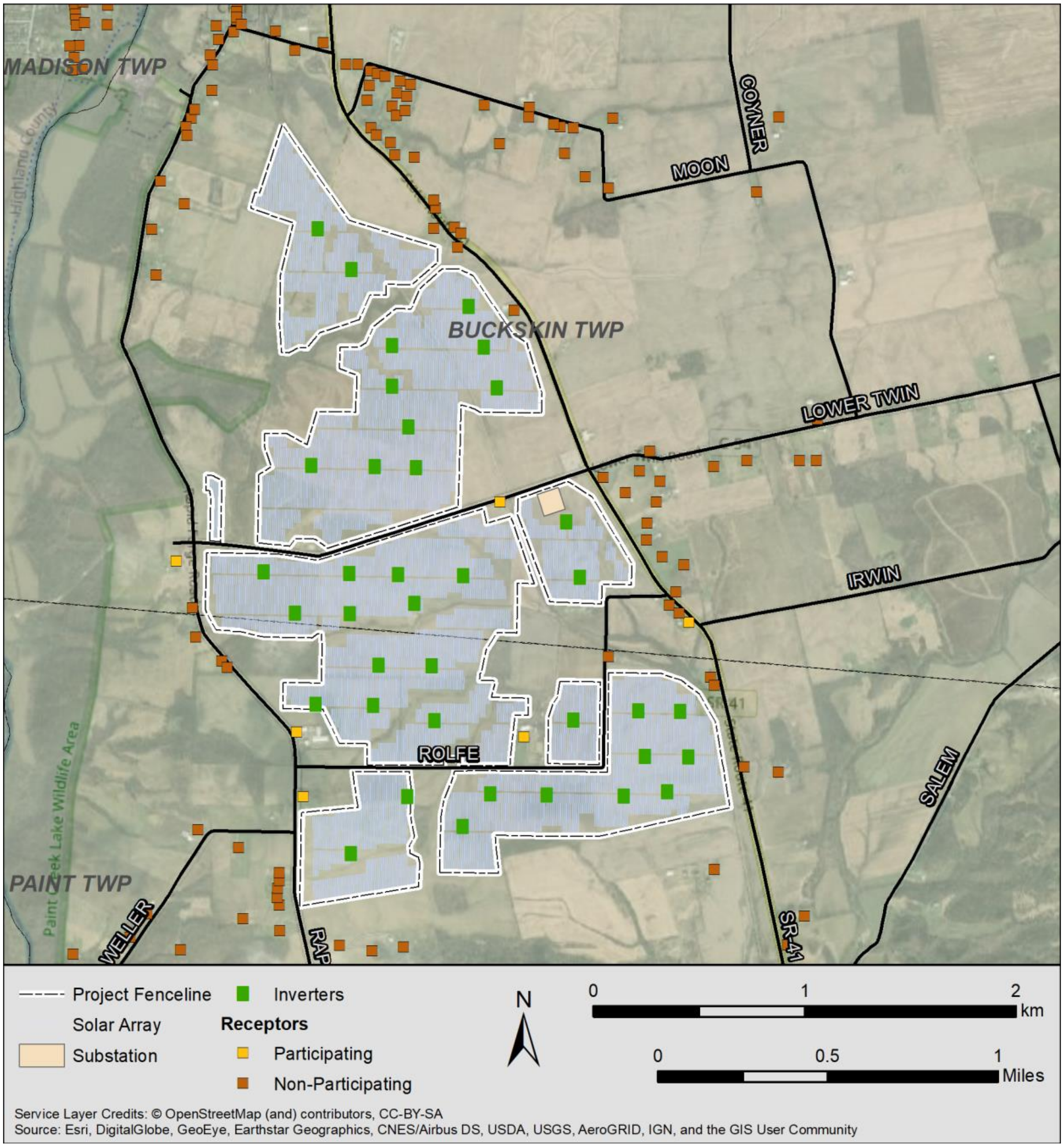

FIGURE 1: PROJECT AREA MAP

3.0 APPLICABLE SOUND LEVEL LIMITS

State noise policy applicable to this Project can be found in Ohio Administrative Code ("OAC") Chapter 4906-4-08(A), which is reproduced below. This Section requires that information on noise be provided including:

- Projected sound levels at the nearest property boundary due to construction;
- Projected sound levels at the nearest property boundary due to operation;
- Descriptions of mitigation measures; and
- A preconstruction background sound level study.

Although there is a specific sound level limit for wind power projects within the OAC, there is not one for solar power projects. The design goal for non-participating sensitive receptors used in this assessment of the Project is the measured ambient sound level plus 5 dB for daytime and nighttime periods. That is, the design goal during the daytime is the measured daytime ambient sound level plus 5 dB, and the nighttime design goal will be the measured nighttime ambient sound level plus 5 dB.

Based on the background sound monitoring conducted at three locations throughout the Project Area (see Section 4.0), the average existing daytime and nighttime equivalent continuous sound levels (L_{eq}) in the area are 44 dBA and 39 dBA, respectively. This sets the daytime design goal at 49 dBA and the nighttime design goal at 44 dBA.

4.0 SOUND LEVEL MONITORING

4.1 PROCEDURES

Background sound levels were measured at three locations around the Project Area. A map showing all three monitor locations is provided in Figure 2. Continuous monitoring was conducted for a week period from June 25 to July 2.

Equipment

Sound levels at each location were measured using a Cesva SC 310 sound level meter, which is an ANSI/IEC Class 1 instrument. All meters logged A-weighted and 1/3 octave band equivalent continuous sound levels once each second. Each sound level meter was attached to external audio recorders (Roland R-05) to aid in source identification and soundscape characterization.

Each sound level meter's microphone was mounted on a wooden stake at a height of approximately 1.5 meters (5 feet) and covered with a seven-inch weather-resistant windscreen. The windscreen reduces the influence of wind-induced self-noise on the measurements. The sound level meters were field-calibrated before and after each measurement period.

Wind data was logged at each site using an ONSET anemometer which recorded average wind speed and wind gust speed data once per minute and was installed at microphone height (1.5 meters). Other meteorological data was taken from the National Weather Service ASOS station at the Washington Court House in Washington, OH (I23).

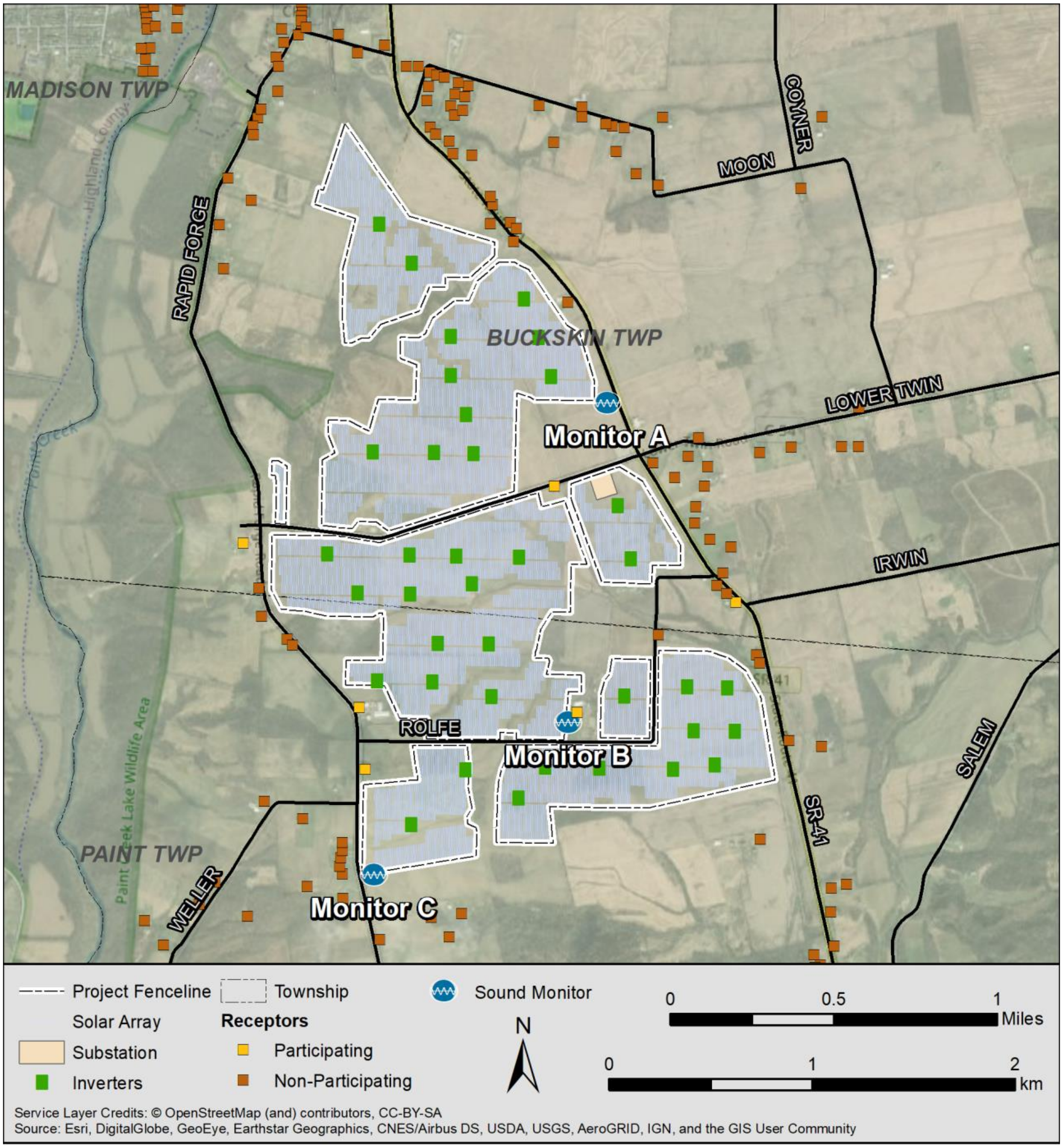

FIGURE 2: MAP OF MONITOR LOCATIONS

Location Descriptions

Monitor A

Monitor A was located on the edge between two fields just west of OH-41 and north of the existing substation on Lower Twin Road. The monitor was setback approximately 50 meters (164 feet) west of OH-41 and measured a soundscape that is representative of residences on the eastern edge of the Project Area along OH-41. It was approximately 185 meters (213 feet) northeast of the residence and 83 meters (607 feet) north of the existing substation and 345 meters (1,132 feet) north of the proposed substation. A photograph of the monitor is shown in Figure 3, and a map of the monitor location is provided in Figure 4.

FIGURE 3: PHOTOGRAPH OF MONITOR A LOOKING EAST

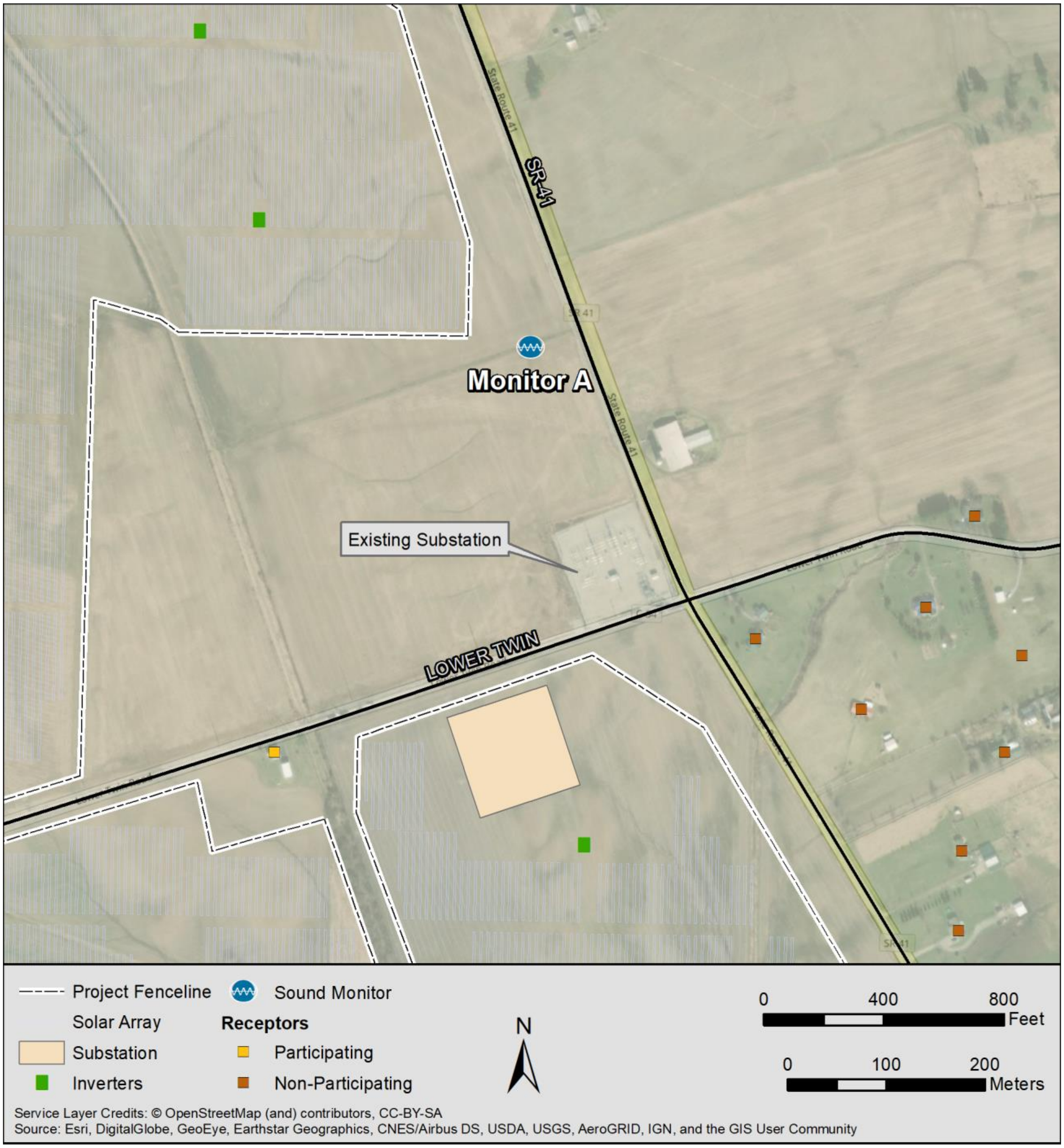

FIGURE 4: MAP OF MONITOR A LOCATION

Monitor B

Monitor B was located near a participating residence on Rolfe Road and was setback approximately 85 meters (279 feet) north of the road. It was located 55 meters (180 feet) southwest of the residence. Monitor B is representative of residences in the middle of the Project Area that are setback further from OH-41. A photograph of the monitor is shown in Figure 5 and a map of the monitor location is provided in Figure 6.

FIGURE 5: PHOTOGRAPH OF MONITOR B LOOKING SOUTH

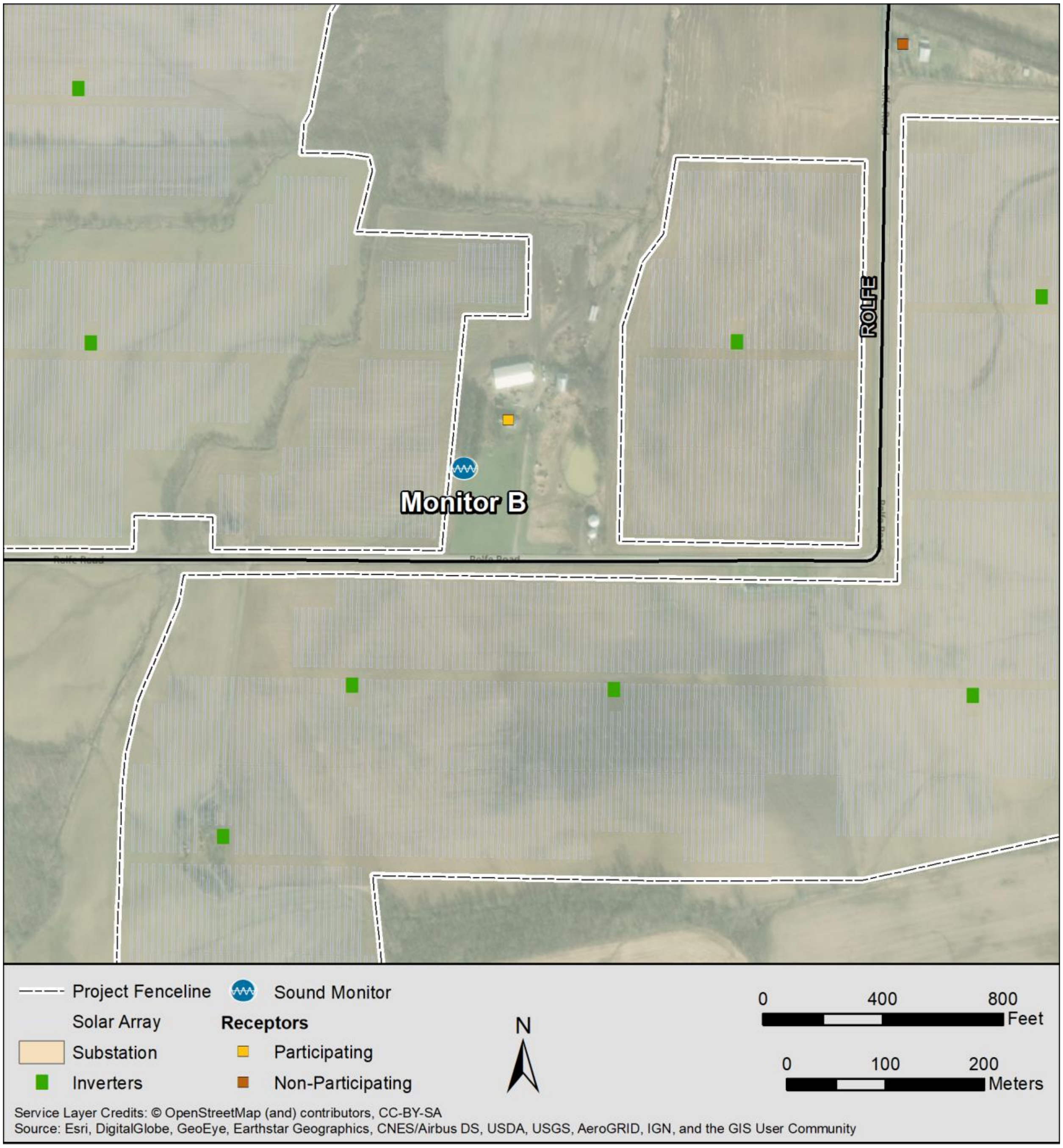

FIGURE 6: MAP OF MONITOR B LOCATION

Monitor C

Monitor C was located on a fenceline between two meadows in the southwest corner of the Project Area approximately 355 meters south of the intersection of Rapid Forge Road and Weller Lane. It was setback approximately 67 meters (220 feet) east of Rapid Forge Road. In the area, there are nonparticipating residences on the west side of Rapid Forge Road between 150 and 220 meters (492 to 721 feet) from the monitor location. Monitor C is representative of residences along Rapid Forge Road. A photograph of the monitor is shown in Figure 7, and a map of the monitor location is provided in Figure 8.

FIGURE 7: PHOTOGRAPH OF MONITOR C LOOKING WEST

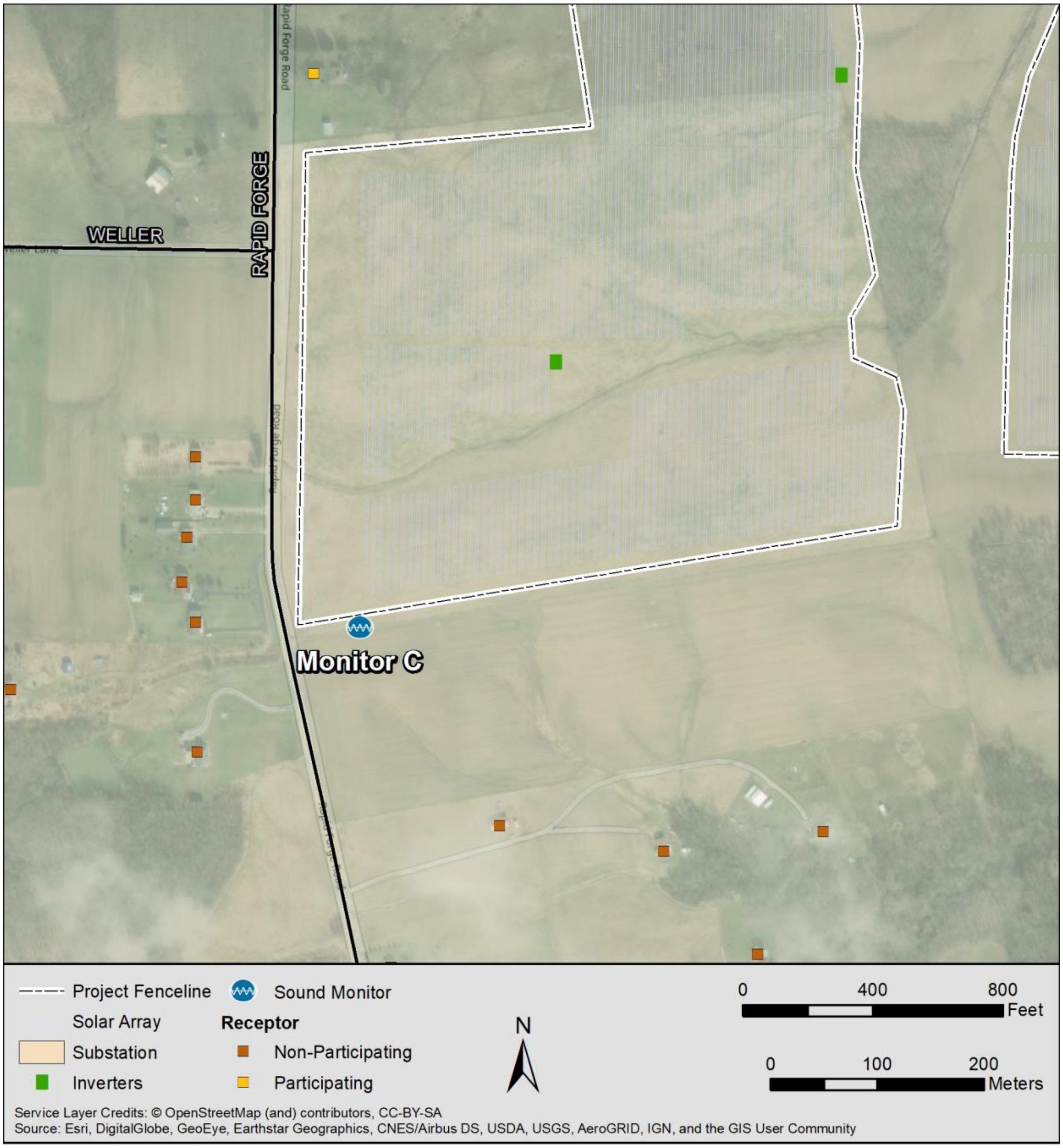

FIGURE 8: MAP OF MONITOR C LOCATION

Data Process

Following the collection of the meters, data was downloaded, processed, and summarized into 10-minute, overall day, overall night, and full monitoring-period length durations. For each 10-minute period, equivalent average (L_{eq}), upper 10th percentile (L_{10}), median (L_{50}), and lower 10th percentile (L_{90}) sound levels were also calculated.

During analysis, sound level data was removed from the dataset to maintain the integrity of the background sound levels during the periods that would cause false sound level readings or artificially high levels. These periods include:

- Wind speeds above 5 m/s (11 mph);
- Precipitation and thunderstorm events;
- Anomalous events; or
- Equipment interactions by RSG staff, other people, or animals.

Precipitation events were obtained from nearby airport data and were corroborated through both analysis of sound level spectrograms and from the audio recordings. There were only a couple brief periods of rain: one on June 26 and another on June 29.

Notable anomalous events that were removed from the dataset include a low flying military aircraft, animal interaction with the monitor, and lawn equipment operating in proximity to the monitors.

4.2 BACKGROUND SOUND LEVEL SUMMARY

An overall summary of the monitor results is provided in this Section, followed by time-history graphs for each monitor in Section 4.3. Sound levels for each location are summarized into daytime, nighttime, and entire period levels in Table 1. It includes equivalent continuous average (L_{eq}), upper 10th percentile (L_{10}), median (L_{50}), and lower 10th percentile (L_{90}) sound levels. The nighttime L_{eq} across the Project Area is 39 dBA, and the daytime L_{eq} across the Project Area is 44 dBA. As discussed in Section 3.0, this sets the nighttime project design goal at 44 dBA and the daytime project design goal at 49 dBA.

TABLE 1: SUMMARY OF BACKGROUND SOUND LEVELS[1]

Site	Sound Pressure Level (dBA)			
	L_{eq}	L_{90}	L_{50}	L_{10}
Overall				
A	48	25	33	49
B	38	27	31	40
C	40	21	29	41
Day				
A	50	28	36	50
B	40	28	32	42
C	41	24	31	43
Daytime Average	44			
Daytime Limit	49			
Night				
A	46	24	30	45
B	35	26	29	37
C	37	19	25	36
Nighttime Average	39			
Nighttime Limit	44			

4.3 MONITOR RESULTS BY LOCATION

For display purposes, the one second data that was collected is displayed in 10-minute summarized values in the time history-graphs to show overall trends. Sound levels are plotted along with ambient temperature and wind speed to show relating trends. Time periods during which data was removed for the sound level summary presented in Section 4.2 are indicated with color-coded markers. Sound level data during periods when the entire 10-minute interval was excluded for wind, rain, or anomalies are still present in these graphs as lighter colors, with the darker colors representing 10-minute intervals where there were no data exclusions or only partial data exclusions.[2] The duration of each time history graph is one week, and each graph exhibits day/night shading where night is defined as 22:00 to 7:00 and shaded grey.

[1] High frequency biogenic sound was filtered out of the data during periods where it was present using an ANS weighting (defined in ANSI S12.100, “Methods to Define and Measure the Residual Sound in Protected Natural and Quiet Residential Areas”) which simply discounts sound levels above the 1 kHz 1/1/ octave band, the frequency range in which the biogenic sounds occur.

[2] For some 10-minute periods, shorter durations within the 10-minutes are excluded due to wind, rain, or anomalies, but the rest of the 10-minute interval is still used in the summary. These periods are shown in the darker colors (Leq and L90) as only some of the 10-minute period was excluded.

Monitor A

Background sound level monitoring results for Monitor A are shown in Figure 9 and Figure 10 . Background sound levels were driven by traffic noise from OH-41, biogenic sounds such as bird calls, and geophonic sounds such as wind passing over foliage. Secondary sources of sound included occasional aircraft flyovers and distant agricultural operations.

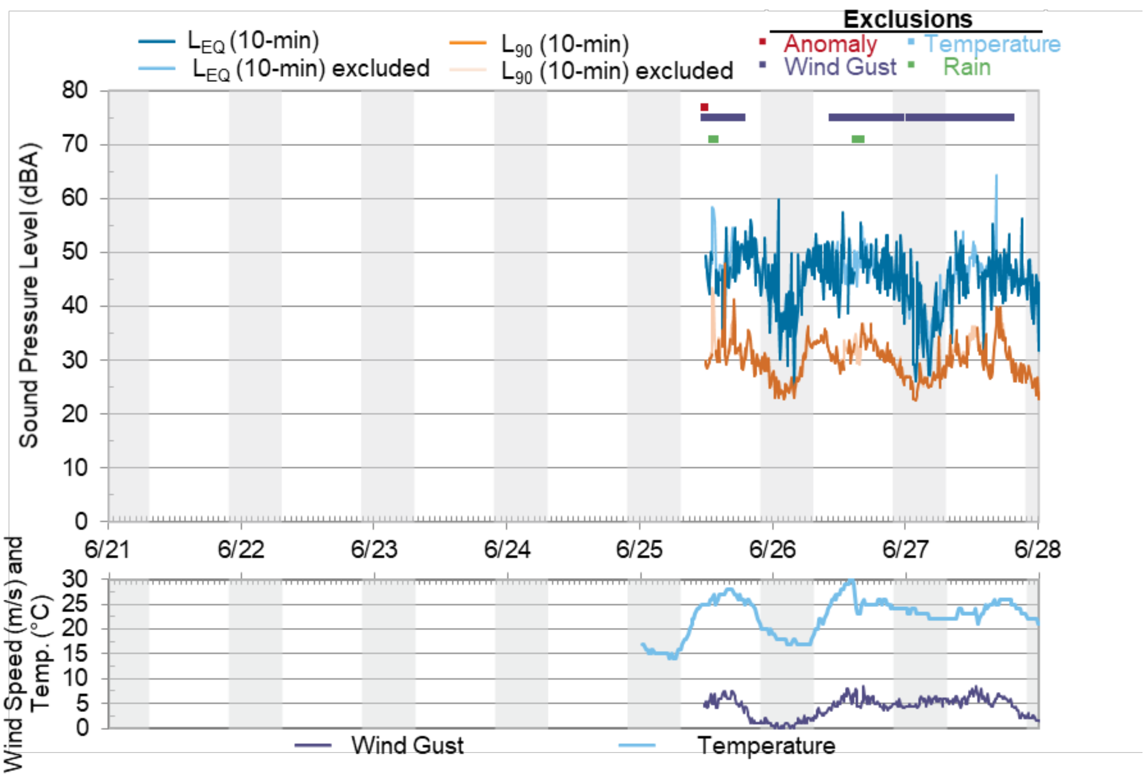

FIGURE 9: SOUND PRESSURE LEVELS OVER TIME - MONITOR A, JUNE 25 TO JUNE 28

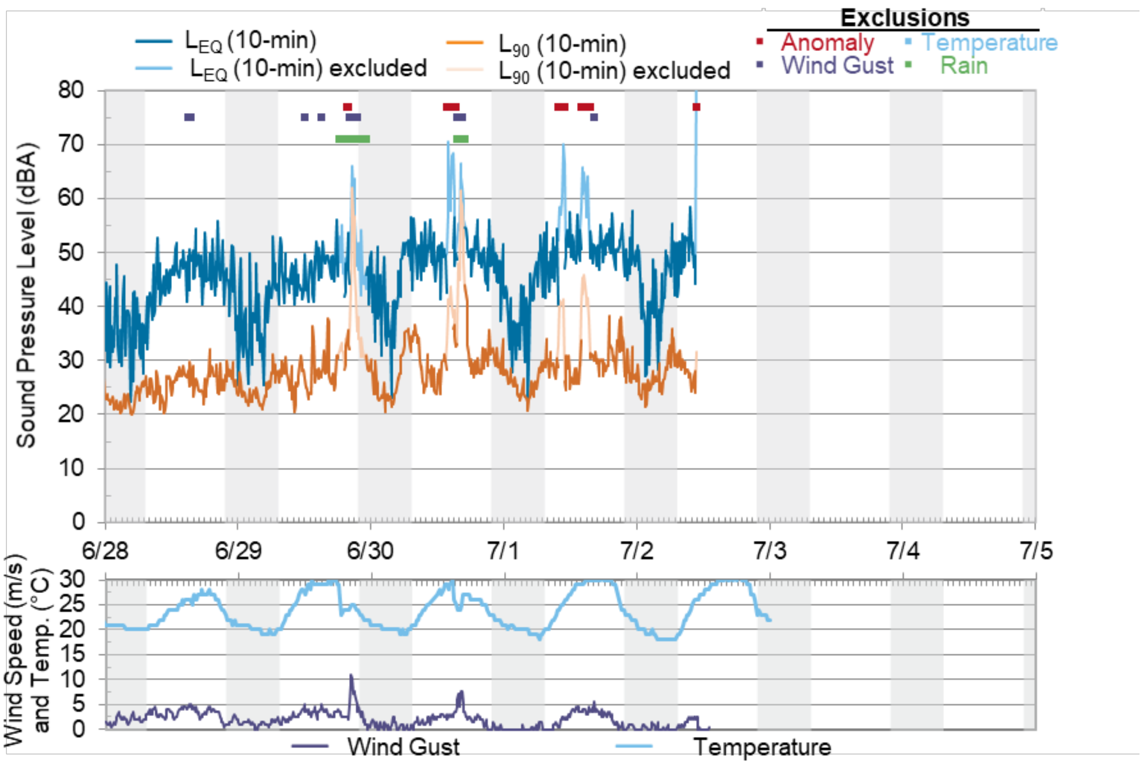

FIGURE 10: SOUND PRESSURE LEVELS OVER TIME - MONITOR A, JUNE 28 TO JULY 2

Monitor B

Background sound level monitoring results for Monitor B are shown in Figure 11 and Figure 12. Monitor B was at the quietest site with very little traffic noise. Background sound levels were driven primarily by geophonic sounds such as wind passing over foliage and biogenic sounds. There were also occasional residential activities, aircraft flyovers, and agricultural sounds.

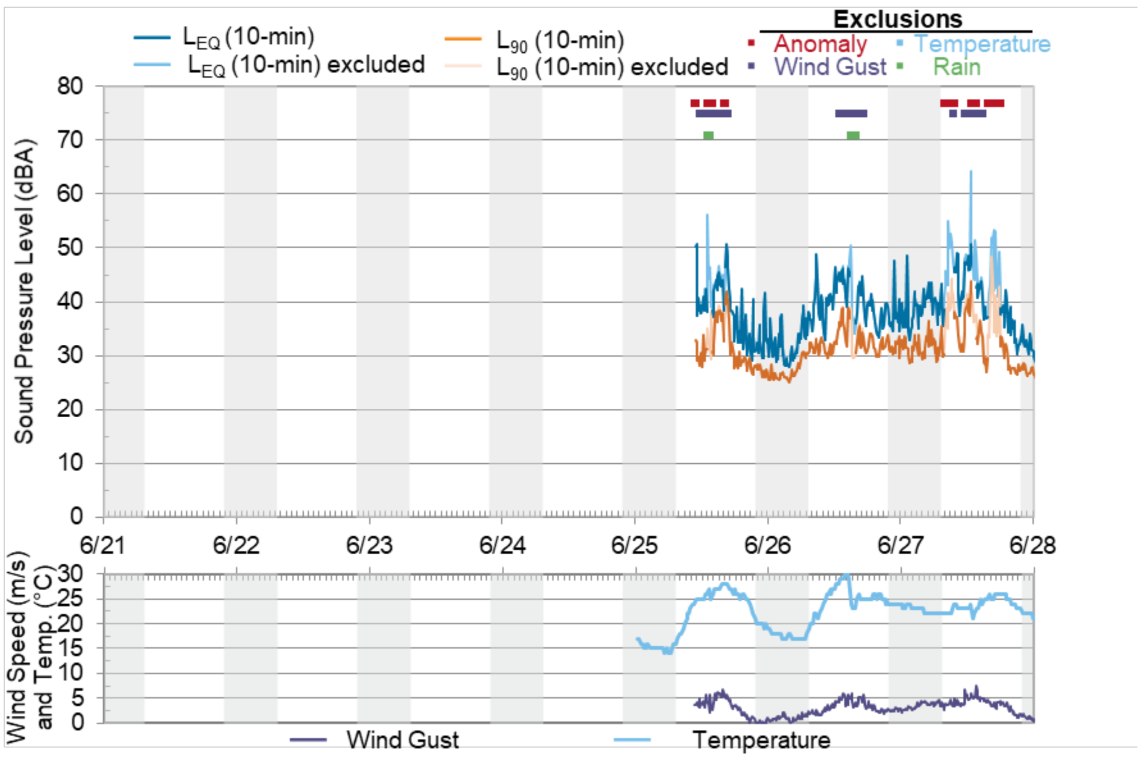

FIGURE 11: SOUND PRESSURE LEVELS OVER TIME - MONITOR B, JUNE 25 TO JUNE 28

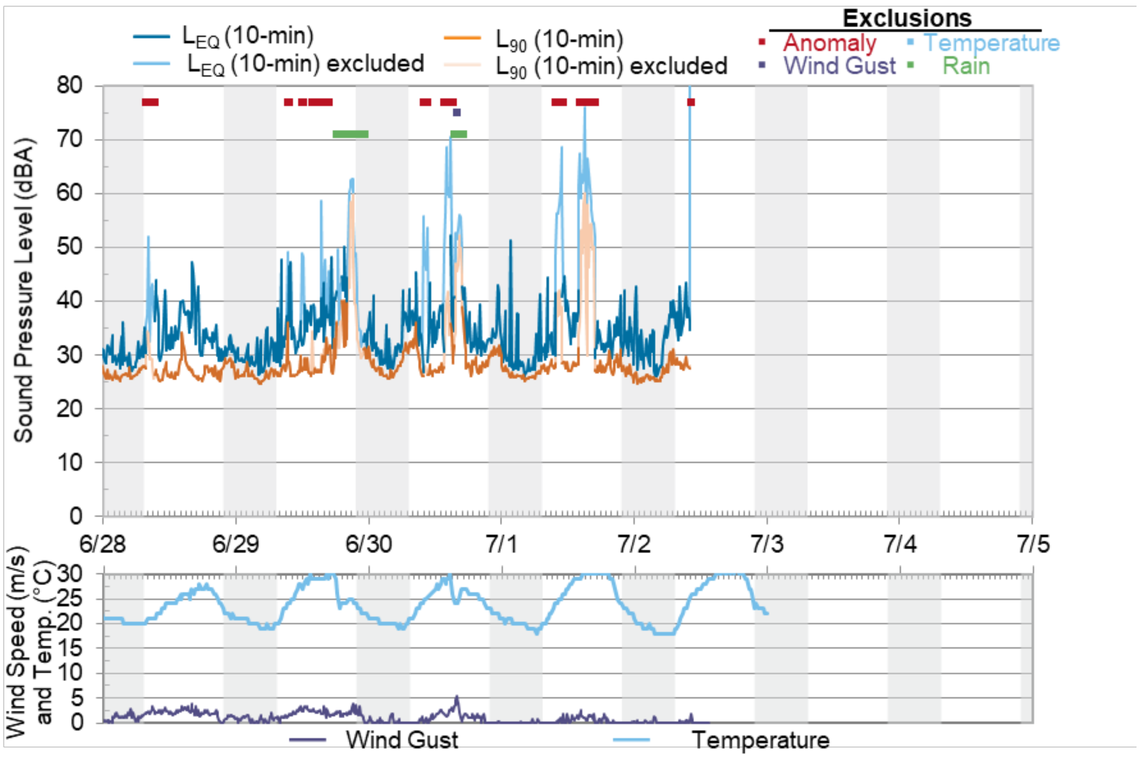

FIGURE 12: SOUND PRESSURE LEVELS OVER TIME - MONITOR B, JUNE 28 TO JULY 2

Monitor C

Background sound level monitoring results for Monitor C are shown in Figure 13 and Figure 14. Sound levels were driven by geophonic sounds, biogenic sounds, and occasional local traffic. Secondary sources of sound included occasional aircraft flyovers and residential activities.

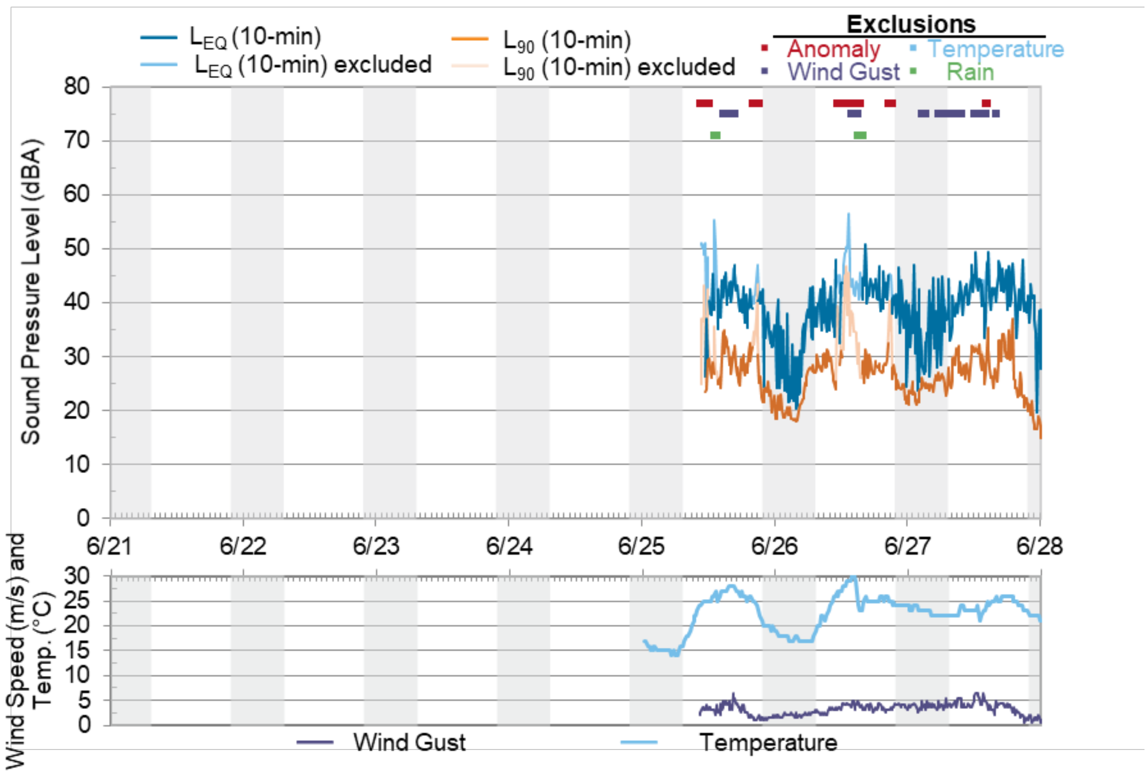

FIGURE 13: SOUND PRESSURE LEVELS OVER TIME - MONITOR C, JUNE 25 TO JUNE 28

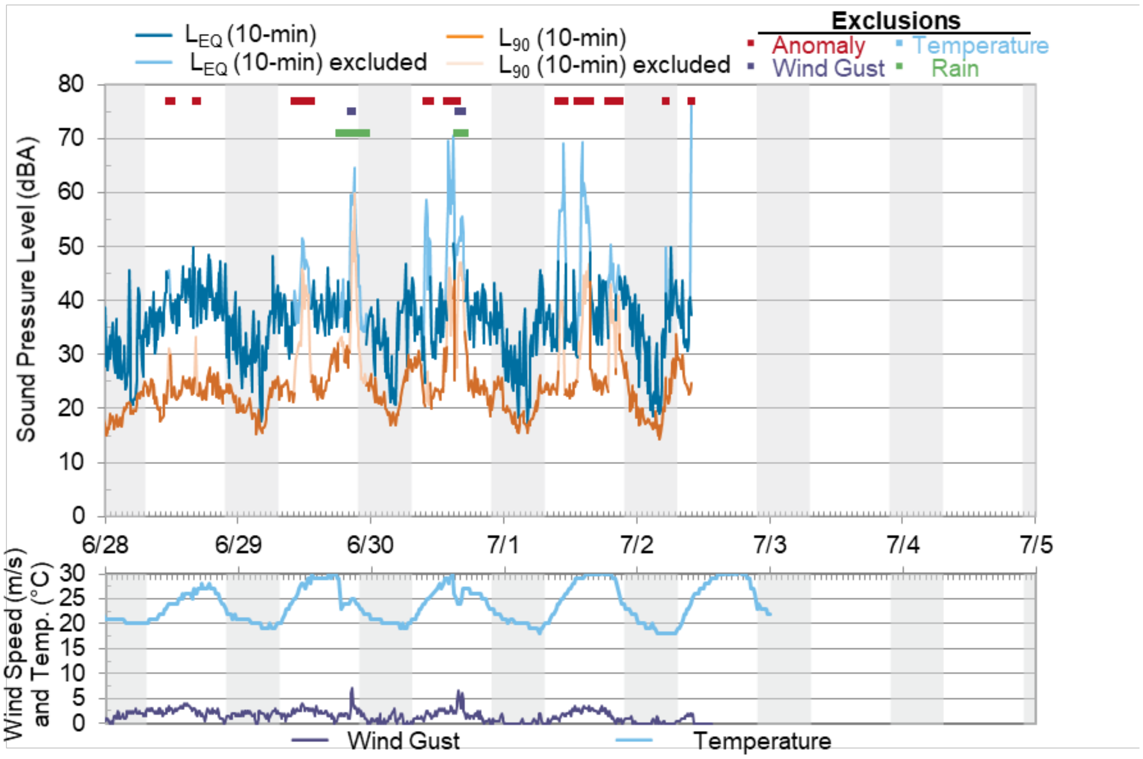

FIGURE 14: SOUND PRESSURE LEVELS OVER TIME - MONITOR C, JUNE 28 TO JULY 2

5.0 SOUND PROPAGATION MODELING

5.1 PROCEDURES

Modeling for the Project was 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, 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, consequently, all wind directions, including the prevailing wind directions, are taken into account.

Model input parameters are listed in Appendix B including the modeled sound power spectra for each source. A few different inverters are currently being considered for the Project. This assessment provides the model result from the inverter which has the highest sound emissions of the inverters under consideration. In addition to the inverters, the model also includes the two proposed substation transformers with cooling fans operating (ONAF).

A total of 209 discrete receivers were placed at residences, churches, commercial and industrial properties, and government locations surrounding the Project Area at a height of 4 meters (13 feet) above ground level. In addition, a grid of receivers spaced 10 meters by 10 meters was setup at a height of 4 meters above ground covering approximately 21 sq. km. (8 sq. mi.) around the Project Area.

Mitigation that has been incorporated into the Project and this sound propagation modeling includes specification of substation transformers that are 3 dB below NEMA TR-1 sound levels and inverter setback distances that allow for the sound to attenuate below the project design goal before propagating to nearby residences.

5.2 MODEL RESULTS

A summary of the sound propagation model results is provided in Table 2, and Appendix C provides a list of the calculated overall sound pressure levels at each discrete receiver. As shown in Table 2, all residences are projected at 42 dBA or less which is below the nighttime project design goal of 44 dBA.

TABLE 2: SUMMARY OF MODELED SOUND PRESSURE LEVELS (dBA)

	AVG	MIN	MAX
Non-participating Residence	26	19	40
Participating Residence	37	33	42

A map of projected sound levels throughout the Project Area is provided in Figure 15.

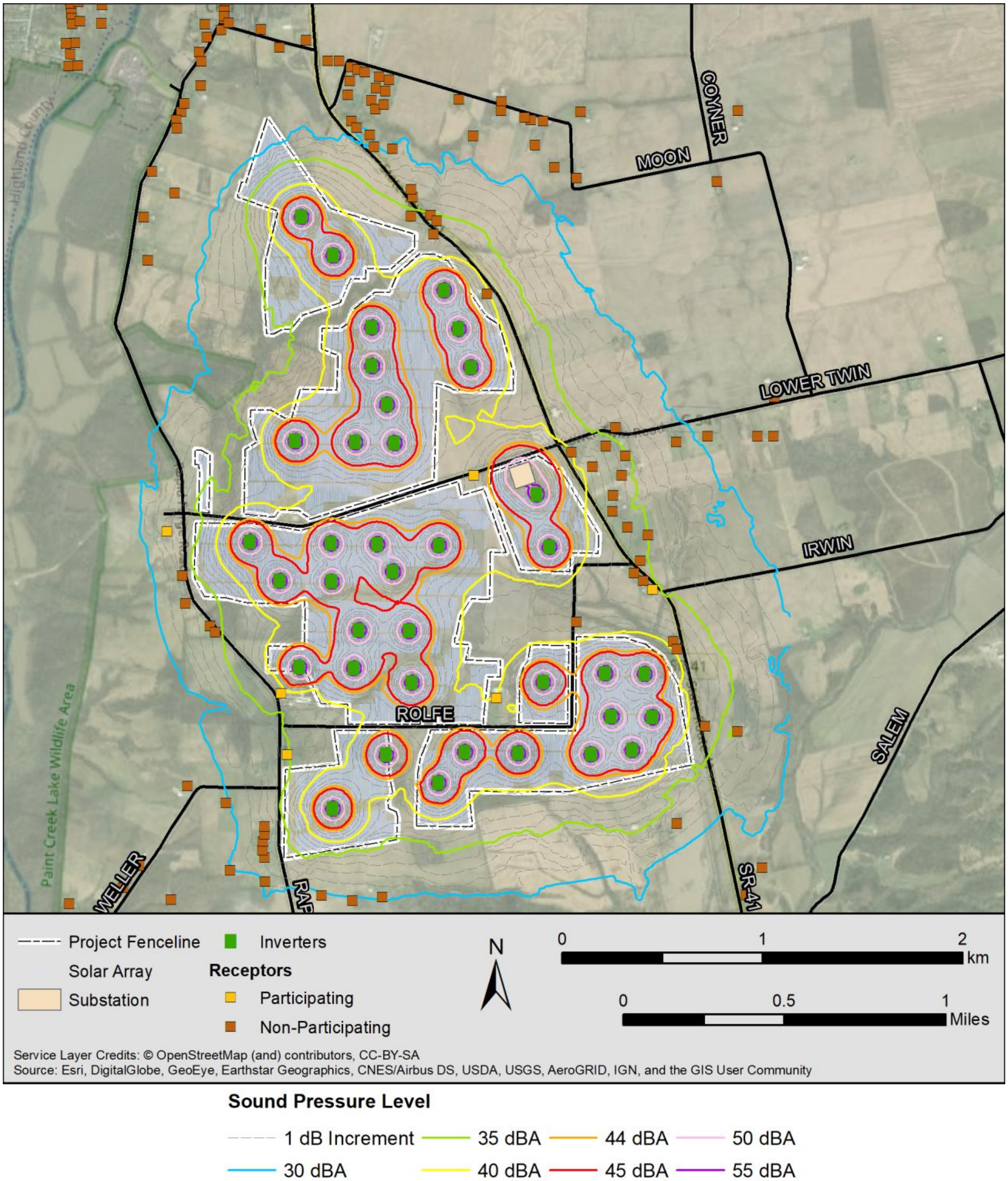

FIGURE 15: SOUND PROPAGATION MODEL RESULTS

6.0 CONSTRUCTION NOISE

Construction activities include road construction, substation construction, trenching, inverter installation, piling and racking. In any given area, construction will be relatively short in duration, particularly for road construction, trenching, piling, and racking. Construction of substations typically lasts longer than these other activities. Road construction would take place within and adjacent to the solar arrays. Trenching would take place along the underground collection line routes. Inverter installation would take place at each inverter pad location. And piling and racking will take place throughout the solar arrays.

Construction that involves increasing sound above ambient levels will take place between 7 AM and 7 PM or dusk, whichever is later. Pile driving will be limited to the hours of 8 AM to 7 PM, Monday through Friday. Construction equipment will be fitted with exhaust systems and mufflers to reduce exhaust noise. In addition, the material staging areas will be located away from sensitive receptors when feasible. To the extent possible, circular vehicular movements will be established to minimize the use of back alarms.

Equipment used for each activity will vary. Some of the louder pieces of equipment[3] are shown in Table 3 along with the approximate maximum sound pressure levels at 15 meters (50 feet) and 91 meters (300 feet) the closest distance between a nonparticipating residence and a solar array where racking and piling will take place.

In addition to the sources in Table 3, horizontal directional drilling (HDD) will also be used during construction. The HDD will be located just south of Rolfe Road in the southern portion of the Project Area and will be over 610 meters (2,000 feet) from the closest nonparticipating receptor. The maximum sound pressure level from the HDD is 87 dBA at 15 meters and 49 dBA at 610 meters.

[3] Sound source information was obtained from FHWA’s Roadway Construction Noise Model and manufacturer data.

TABLE 3: MAXIMUM SOUND LEVELS FROM VARIOUS TYPES OF CONSTRUCTION EQUIPMENT ASSUMING NO ATTENUATION FROM TREES OR TERRAIN

Equipment	Maximum Sound Pressure Level at 91 meters (300 feet) (dBA)[4]	Maximum Sound Pressure Level at 15 meters (50 feet) (dBA)
Excavator	62	85
Dozer	62	85
Grader	62	85
Roller	62	85
Dump Truck	61	84
Concrete Mixing Truck	62	85
Concrete Pumper Truck	59	82
Man-lift	62	85
Flatbed Truck	61	84
Large Crane	62	85
Small Crane	60	83
Trencher	60	83
Compactor	57	80
Forklift	62	85
Boom Truck	61	84
HDD	68	87
Small Pile Driver	61	84

[4] Assumes hard ground around construction site, and ISO 9613-2 propagation with no vegetation reduction. Actual sound levels will likely be lower given the prevalence of vegetation and soft ground around the site.

7.0 CONCLUSIONS

RSG conducted a sound level assessment of the Project that included background sound level monitoring of the existing environment in and around the Project Area and sound propagation modeling to predict operational sound levels at nearby residences.

Summary and conclusions are as follows:

1. Sound sources in the existing soundscape include traffic noise from both local and through traffic, aircraft overflights, and biogenic and geophonic sounds.
    a. Background sound levels were highest at Monitor A due to traffic noise from OH-41. Monitors B and C logged lower sound levels than Montior A as they were located near more rural roads.
    b. The average daytime L_{eq} across the Project Area was 44 dBA.
    c. The average nighttime L_{eq} across the Project Area was 39 dBA.
2. A project design goal of 5 dB above existing L_{eq} was established, creating a daytime goal of 49 dBA and a nighttime goal of 44 dBA for non-participating residences.
3. While the Project transformers are typically the only sources that operate at night from a solar project, there may be times that the inverters for this Project will operate at night for MVAR control. As such, this assessment conservatively assumed
    a. All inverters would operate at night;
    b. Substation transformers would operate in stage two cooling (ONAF) at night; and
    c. Evaluated the projected sound levels from those sources against the nighttime goal of 44 dBA.
4. Sound propagation modeling was conducted in accordance with ISO 9613-2 at 205 receptors throughout the Project Area, using the inverter with the highest sound emissions under consideration.
5. Model results are summarized in Section 5.2, and provided in tabular format in Appendix C. All receptors are less than 44 dBA, meeting the nighttime design goal.
6. Sound levels due to construction are summarized in 6.0.

APPENDIX A. ACOUSTICS PRIMER

Expressing Sound in Decibel Levels

The varying air pressure that constitutes sound can be characterized in many different ways. The human ear is the basis for the metrics that are used in acoustics. Normal human hearing is sensitive to sound fluctuations over an enormous range of pressures, from about 20 micropascals (the "threshold of audibility") to about 20 pascals (the "threshold of pain").[5] This factor of one million in sound pressure difference is challenging to convey in engineering units. Instead, sound pressure is converted to sound "levels" in units of "decibels" (dB, named after Alexander Graham Bell). Once a measured sound is converted to dB, it is denoted as a level with the letter "L".

The conversion from sound pressure in pascals to sound level in dB is a four-step process. First, the sound wave's measured amplitude is squared and the mean is taken. Second, a ratio is taken between the mean square sound pressure and the square of the threshold of audibility (20 micropascals). Third, using the logarithm function, the ratio is converted to factors of 10. The final result is multiplied by 10 to give the decibel level. By this decibel scale, sound levels range from 0 dB at the threshold of audibility to 120 dB at the threshold of pain.

Typical sound sources, and their sound pressure levels, are listed on the scale in Figure 16.

Human Response to Sound Levels: Apparent Loudness

For every 20 dB increase in sound level, the sound pressure increases by a *factor* of 10; the sound *level* range from 0 dB to 120 dB covers 6 factors of 10, or one million, in sound *pressure*. However, for an increase of 10 dB in sound *level* as measured by a meter, humans perceive an approximate doubling of apparent loudness: to the human ear, a sound level of 70 dB sounds about "twice as loud" as a sound level of 60 dB. Smaller changes in sound level, less than 3 dB up or down, are generally not perceptible.

[5] The pascal is a measure of pressure in the metric system. In Imperial units, they are themselves very small: one pascal is only 145 millionths of a pound per square inch (psi). The sound pressure at the threshold of audibility is only 3 one-billionths of one psi: at the threshold of pain, it is about 3 one-thousandths of one psi.

FIGURE 16: A SCALE OF SOUND PRESSURE LEVELS FOR TYPICAL SOUND SOURCES

Frequency Spectrum of Sound

The “frequency” of a sound is the rate at which it fluctuates in time, expressed in Hertz (Hz), or cycles per second. Very few sounds occur at only one frequency: most sound contains energy at many different frequencies, and it can be broken down into different frequency divisions, or bands. These bands are similar to musical pitches, from low tones to high tones. The most common division is the standard octave band. An octave is the range of frequencies whose upper frequency limit is twice its lower frequency limit, exactly like an octave in music. An octave band is identified by its center frequency: each successive band’s center frequency is twice as high (one octave) as the previous band. For example, the 500 Hz octave band includes all sound whose frequencies range between 354 Hz (Hertz, or cycles per second) and 707 Hz. The next band is centered at 1,000 Hz with a range between 707 Hz and 1,414 Hz. The range of human hearing is divided into 10 standard octave bands: 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1,000 Hz, 2,000 Hz, 4,000 Hz, 8,000 Hz, and 16,000 Hz. For analyses that require finer frequency detail, each octave-band can be subdivided. A commonly-used subdivision creates three smaller bands within each octave band, or so-called 1/3-octave bands.

Human Response to Frequency: Weighting of Sound Levels

The human ear is not equally sensitive to sounds of all frequencies. Sounds at some frequencies seem louder than others, despite having the same decibel level as measured by a sound level meter. In particular, human hearing is much more sensitive to medium pitches (from about 500 Hz to about 4,000 Hz) than to very low or very high pitches. For example, a tone measuring 80 dB at 500 Hz (a medium pitch) sounds quite a bit louder than a tone measuring 80 dB at 60 Hz (a very low pitch). The frequency response of normal human hearing ranges from 20 Hz to 20,000 Hz. Below 20 Hz, sound pressure fluctuations are not “heard”, but sometimes can be “felt”. This is known as “infrasound”. Likewise, above 20,000 Hz, sound can no longer be heard by humans; this is known as “ultrasound”. As humans age, they tend to lose the ability to hear higher frequencies first; many adults do not hear very well above about 16,000 Hz. Most natural and man-made sound occurs in the range from about 40 Hz to about 4,000 Hz. Some insects and birdsongs reach to about 8,000 Hz.

To adjust measured sound pressure levels so that they mimic human hearing response, sound level meters apply filters, known as “frequency weightings”, to the signals. There are several defined weighting scales, including “A”, “B”, “C”, “D”, “G”, and “Z”. The most common weighting scale used in environmental noise analysis and regulation is A-weighting. This weighting represents the sensitivity of the human ear to sounds of low to moderate level. It attenuates sounds with frequencies below 1000 Hz and above 4000 Hz; it amplifies very slightly sounds between 1000 Hz and 4000 Hz, where the human ear is particularly sensitive. The C-weighting scale is sometimes used to describe louder sounds. The B- and D- scales are seldom used. All of these frequency weighting scales are normalized to the average human hearing response at

1000 Hz: at this frequency, the filters neither attenuate nor amplify. When a reported sound level has been filtered using a frequency weighting, the letter is appended to "dB". For example, sound with A-weighting is usually denoted "dBA". When no filtering is applied, the level is denoted "dB" or "dBZ". The letter is also appended as a subscript to the level indicator "L", for example "L_A" for A-weighted levels.

Time Response of Sound Level Meters

Because sound levels can vary greatly from one moment to the next, the time over which sound is measured can influence the value of the levels reported. Often, sound is measured in real time, as it fluctuates. In this case, acousticians apply a so-called "time response" to the sound level meter, and this time response is often part of regulations for measuring sound. If the sound level is varying slowly, over a few seconds, "Slow" time response is applied, with a time constant of one second. If the sound level is varying quickly (for example, if brief events are mixed into the overall sound), "Fast" time response can be applied, with a time constant of one-eighth of a second.[6] The time response setting for a sound level measurement is indicated with the subscript "S" for Slow and "F" for Fast: L_S or L_F. A sound level meter set to Fast time response will indicate higher sound levels than one set to Slow time response when brief events are mixed into the overall sound, because it can respond more quickly.

In some cases, the maximum sound level that can be generated by a source is of concern. Likewise, the minimum sound level occurring during a monitoring period may be required. To measure these, the sound level meter can be set to capture and hold the highest and lowest levels measured during a given monitoring period. This is represented by the subscript "max", denoted as "L_{max}". One can define a "max" level with Fast response L_{Fmax} (1/8-second time constant), Slow time response L_{Smax} (1-second time constant), or Continuous Equivalent level over a specified time period L_{EQmax}.

Accounting for Changes in Sound Over Time

A sound level meter's time response settings are useful for continuous monitoring. However, they are less useful in summarizing sound levels over longer periods. To do so, acousticians apply simple statistics to the measured sound levels, resulting in a set of defined types of sound level related to averages over time. An example is shown in Figure 17. The sound level at each instant of time is the grey trace going from left to right. Over the total time it was measured (1 hour in the figure), the sound energy spends certain fractions of time near various levels, ranging from the minimum (about 27 dB in the figure) to the maximum (about 65 dB in the figure). The simplest descriptor is the average sound level, known as the Equivalent Continuous

[6] There is a third time response defined by standards, the "Impulse" response. This response was defined to enable use of older, analog meters when measuring very brief sounds; it is no longer in common use.

Sound Level. Statistical levels are used to determine for what percentage of time the sound is louder than any given level. These levels are described in the following sections.

Equivalent Continuous Sound Level - L_{eq}

One straightforward, common way of describing sound levels is in terms of the Continuous Equivalent Sound Level, or L_{EQ}. The L_{EQ} is the average sound pressure level over a defined period of time, such as one hour or one day. L_{EQ} is the most commonly used descriptor in noise standards and regulations. L_{EQ} is representative of the overall sound to which a person is exposed. Because of the logarithmic calculation of decibels, L_{EQ} tends to favor higher sound levels: loud and infrequent sources have a larger impact on the resulting average sound level than quieter but more frequent sounds. For example, in Figure 17, even though the sound levels spends most of the time near about 34 dBA, the L_{EQ} is 41 dBA, having been "inflated" by the maximum level of 65 dBA and other occasional spikes over the course of the hour.

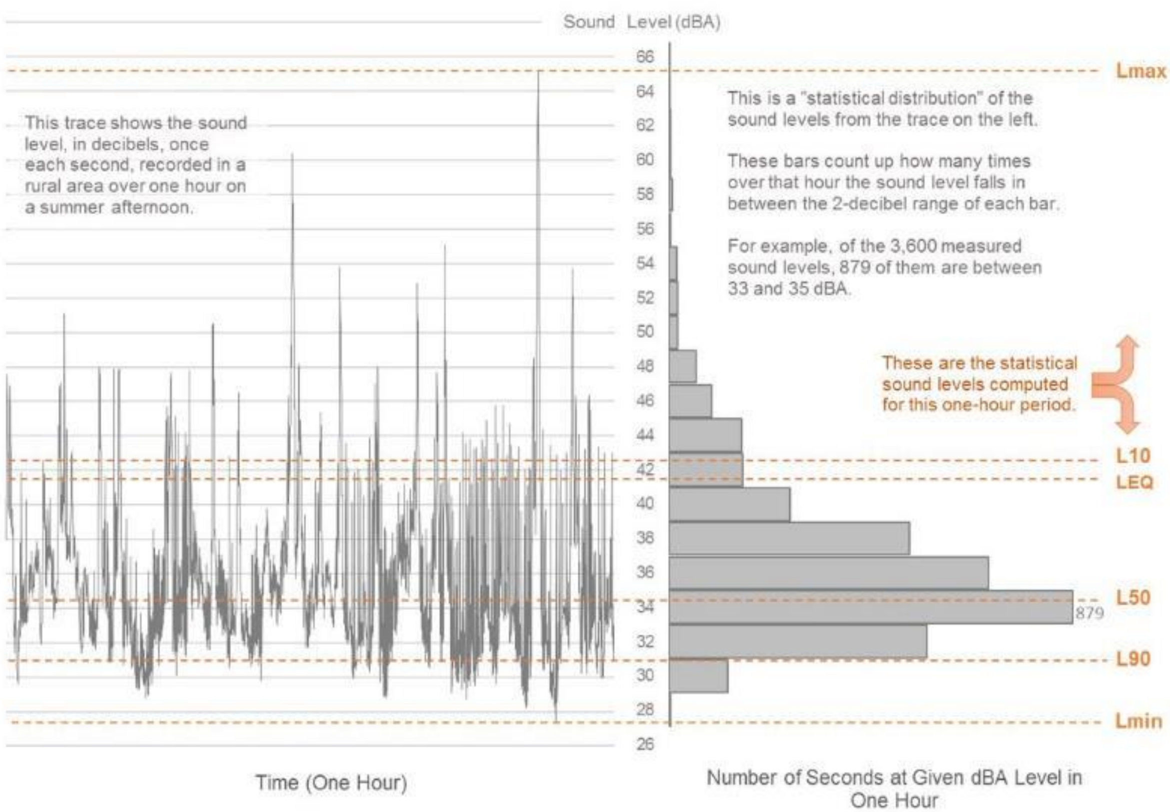

FIGURE 17: EXAMPLE OF DESCRIPTIVE TERMS OF SOUND MEASUREMENT OVER TIME

Percentile Sound Levels – L_n

Percentile sound levels describe the statistical distribution of sound levels over time. "L_N" is the level above which the sound spends "N" percent of the time. For example, L_{90} (sometimes called the "residual base level") is the sound level exceeded 90% of the time: the sound is louder than L_{90} most of the time. L_{10} is the sound level that is exceeded only 10% of the time. L_{50} (the "median level") is exceeded 50% of the time: half of the time the sound is louder than L_{50}, and half the time it is quieter than L_{50}. Note that L_{50} (median) and L_{EQ} (mean) are not always the same, for reasons described in the previous section.

L_{90} is often a good representation of the "ambient sound" in an area. This is the sound that persists for longer periods, and below which the overall sound level seldom falls. It tends to filter out other short-term environmental sounds that aren't part of the source being investigated. L_{10} represents the higher, but less frequent, sound levels. These could include such events as barking dogs, vehicles driving by and aircraft flying overhead, gusts of wind, and work operations. L_{90} represents the background sound that is present when these event sounds are excluded.

Note that if one sound source is very constant and dominates the soundscape in an area, all of the descriptive sound levels mentioned here tend toward the same value. It is when the sound is varying widely from one moment to the next that the statistical descriptors are useful.

APPENDIX B. MODEL INPUT DATA

TABLE 4: MODEL PARAMETER SETTINGS

Model Parameter	Setting
Atmospheric Absorption	Based on 10°C and 70% RH
Foliage	No Foliage Attenuation
Ground Absorption	ISO 9613-2 spectral, G=0 on concrete equipment pads, G=0.6 at substation, and G=1 elsewhere
Receiver Height	4 meters for sound level isolines and 4.0 meters discrete receptors
Search Radius	10,000 meters from each source

TABLE 5: MODELED SOUND POWER SPECTRA, dBZ UNLESS OTHERWISE NOTED

Source	Octave Band Center Frequency (Hz)									Overall Sound Power Level		Reference
	31.5	63	125	250	500	1000	2000	4000	8000	dBA	dBZ	
Substation Transformer ONAF	88	85	96	98	97	85	75	73	69	96	102	Calculated from Ross County Solar provided specs[7]
Representative Inverter	86	90	100	98	94	90	88	91	82	98	103	Manufacturer test data

TABLE 6: SOURCE INPUT DATA

Source	Overall Sound Power Level (dBA)	Relative Height (m)	Coordinates UTM NAD83 Z17N		Absolute Elevation (m)
			X (m)	Y (m)	
Inverter Skid	97.6	1.9	295990.7	4356689.6	274.1
Inverter Skid	97.6	1.9	296148.7	4356496.3	272.6
Inverter Skid	97.6	1.9	296702.5	4356322.3	275.2
Inverter Skid	97.6	1.9	296775.9	4356130.4	275.3
Inverter Skid	97.6	1.9	296342.6	4355944.3	271.8
Inverter Skid	97.6	1.9	296341.7	4356137.6	271.8
Inverter Skid	97.6	1.9	296836.0	4355938.8	275.4
Inverter Skid	97.6	1.9	296417.5	4355752.4	273.4

[7] Spectrum based on RSG measurements of similarly sized transformer

Source	Overall Sound Power Level (dBA)	Relative Height (m)	Coordinates UTM NAD83 Z17N		Absolute Elevation (m)
			X (m)	Y (m)	
Inverter Skid	97.6	1.9	296259.8	4355564.4	274.5
Inverter Skid	97.6	1.9	296454.8	4355561.1	275.0
Inverter Skid	97.6	1.9	295958.5	4355569.4	279.1
Inverter Skid	97.6	1.9	297165.3	4355304.8	273.9
Inverter Skid	97.6	1.9	297229.3	4355041.5	273.7
Inverter Skid	97.6	1.9	296677.4	4355050.6	271.9
Inverter Skid	97.6	1.9	296137.9	4355059.6	283.5
Inverter Skid	97.6	1.9	295732.5	4355066.3	286.6
Inverter Skid	97.6	1.9	295881.7	4354873.2	285.0
Inverter Skid	97.6	1.9	296276.8	4354626.5	282.0
Inverter Skid	97.6	1.9	296529.2	4354622.3	277.5
Inverter Skid	97.6	1.9	296251.7	4354436.3	284.0
Inverter Skid	97.6	1.9	296541.7	4354364.0	280.7
Inverter Skid	97.6	1.9	297197.8	4354365.2	275.2
Inverter Skid	97.6	1.9	297506.9	4354410.7	275.5
Inverter Skid	97.6	1.9	297538.4	4354195.1	276.9
Inverter Skid	97.6	1.9	297742.4	4354191.7	272.4
Inverter Skid	97.6	1.9	296806.6	4354016.6	288.1
Inverter Skid	97.6	1.9	296675.8	4353863.0	289.3
Inverter Skid	97.6	1.9	296413.6	4354003.4	289.3
Inverter Skid	97.6	1.9	296146.3	4353734.5	298.7
Inverter Skid	97.6	1.9	297437.3	4354006.2	278.9
Inverter Skid	97.6	1.9	297073.0	4354012.2	276.6
Inverter Skid	97.6	1.9	296369.4	4355055.7	279.0
Inverter Skid	97.6	1.9	297704.2	4354407.5	269.5
Inverter Skid	97.6	1.9	295979.9	4354440.8	289.6
Inverter Skid	97.6	1.9	297641.9	4354027.2	276.0
Inverter Skid	97.6	1.9	296141.4	4354868.9	279.3
Inverter Skid	97.6	1.9	296446.5	4354918.3	278.3
Sub Transformer	95.8	3.2	297087.1	4355410.4	274.9
Sub Transformer	95.8	3.2	297095.1	4355391.5	274.4

APPENDIX C. MODEL RESULTS FOR EACH RECEPTOR

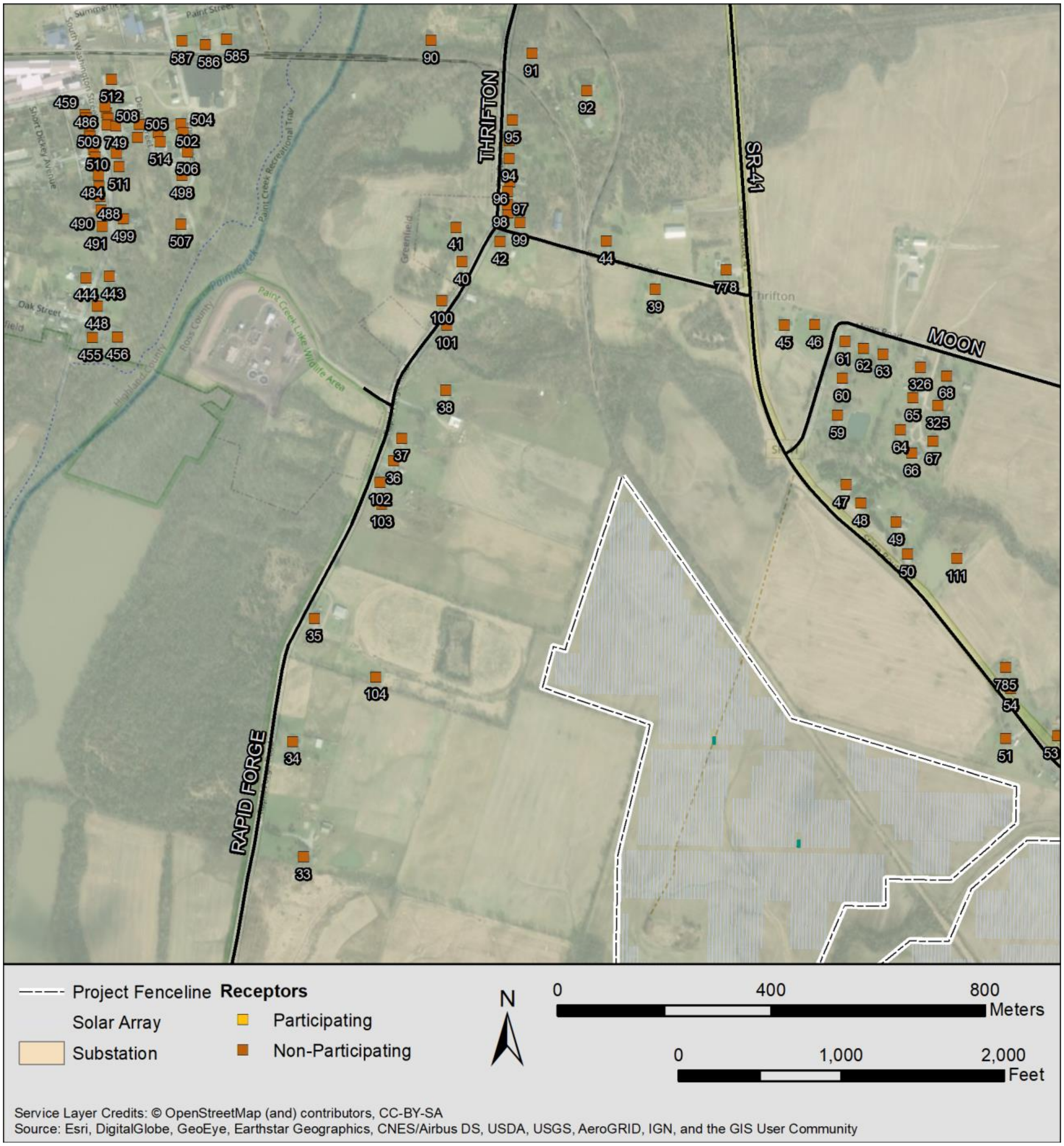

FIGURE 18: MAP OF RECEIVER IDS - NORTHWESTERN AREA

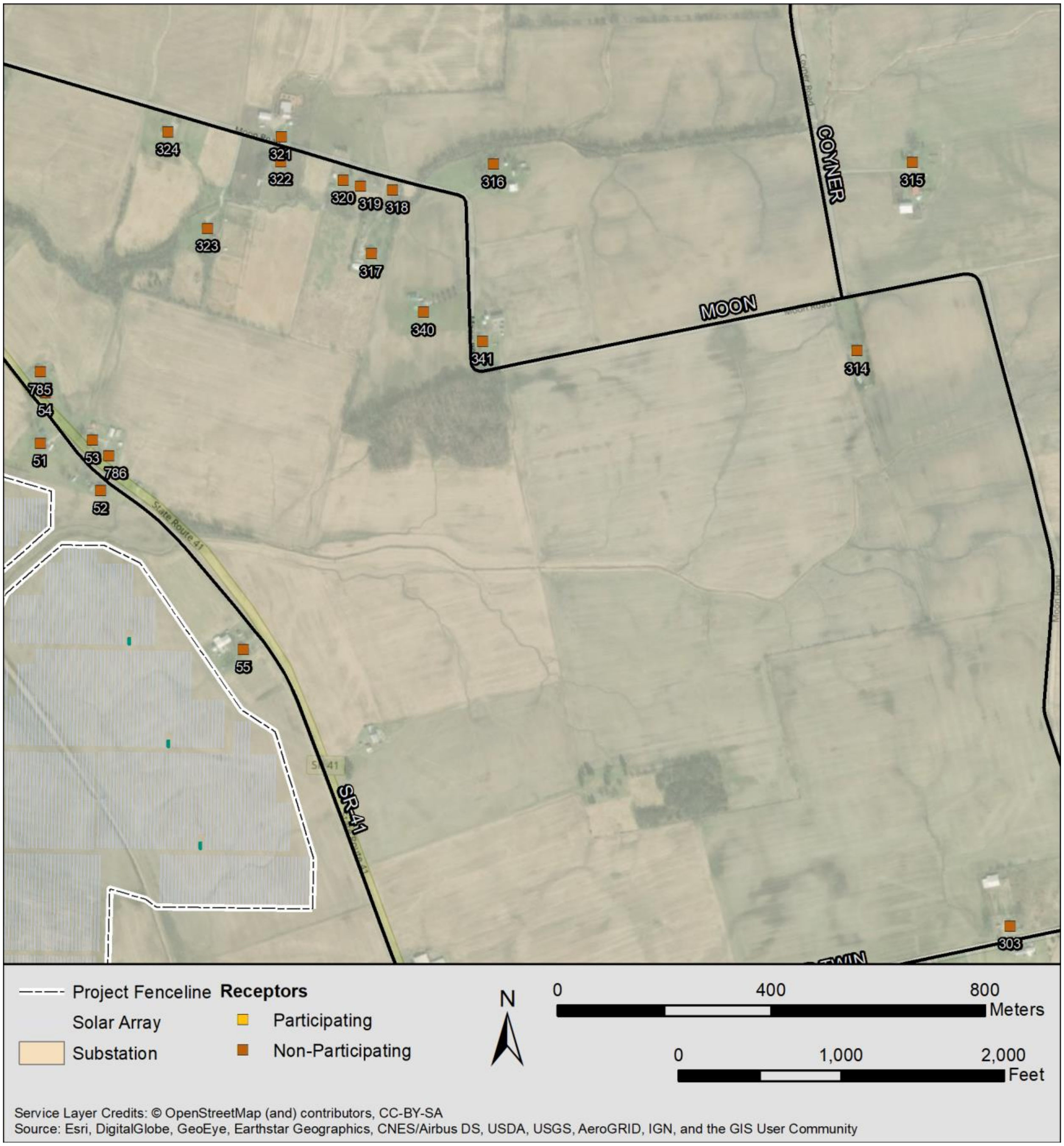

FIGURE 19: MAP OF RECEIVER IDS - NORTHEASTERN AREA

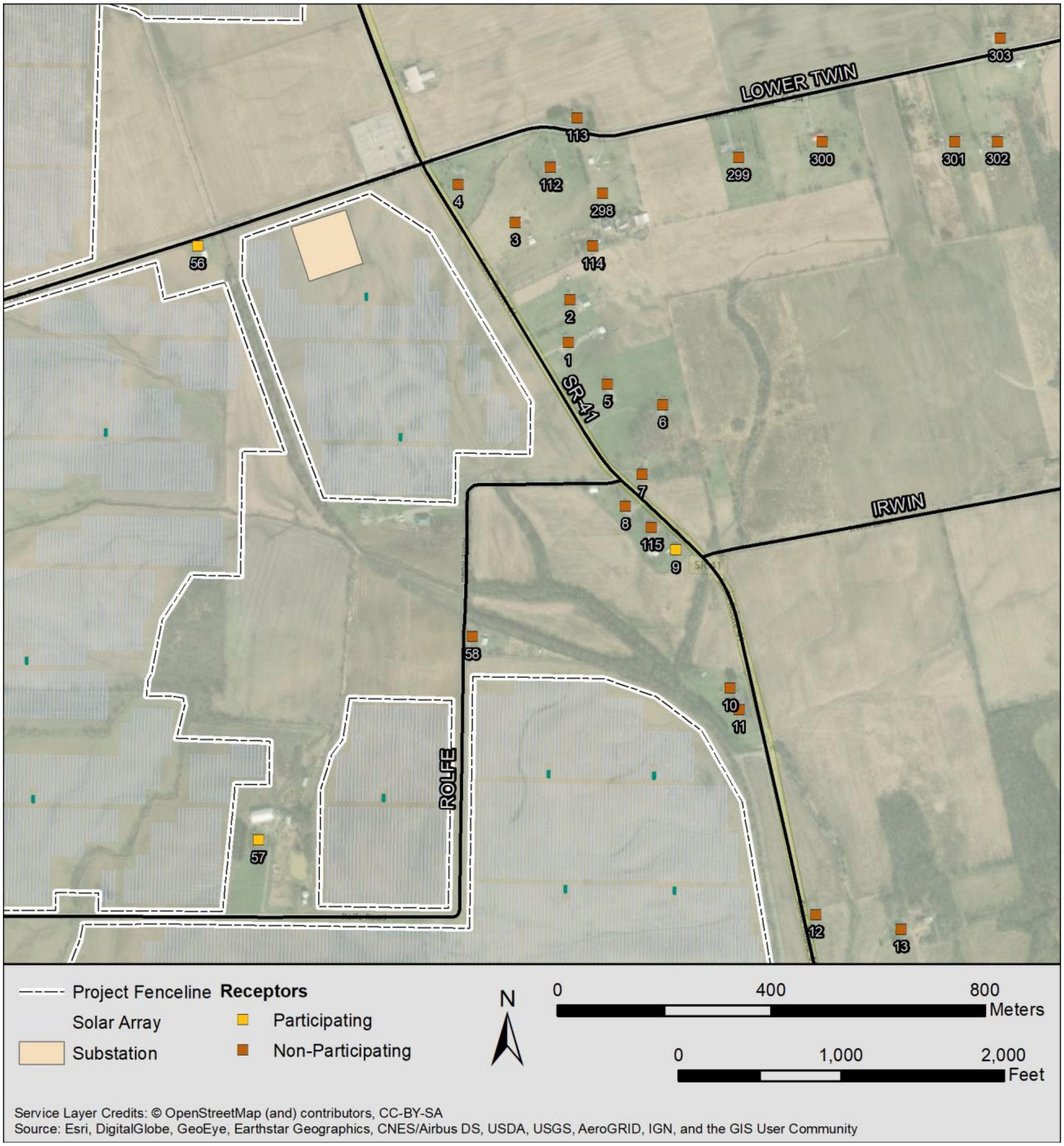

FIGURE 20: MAP OF RECEIVER IDS - EASTERN AREA

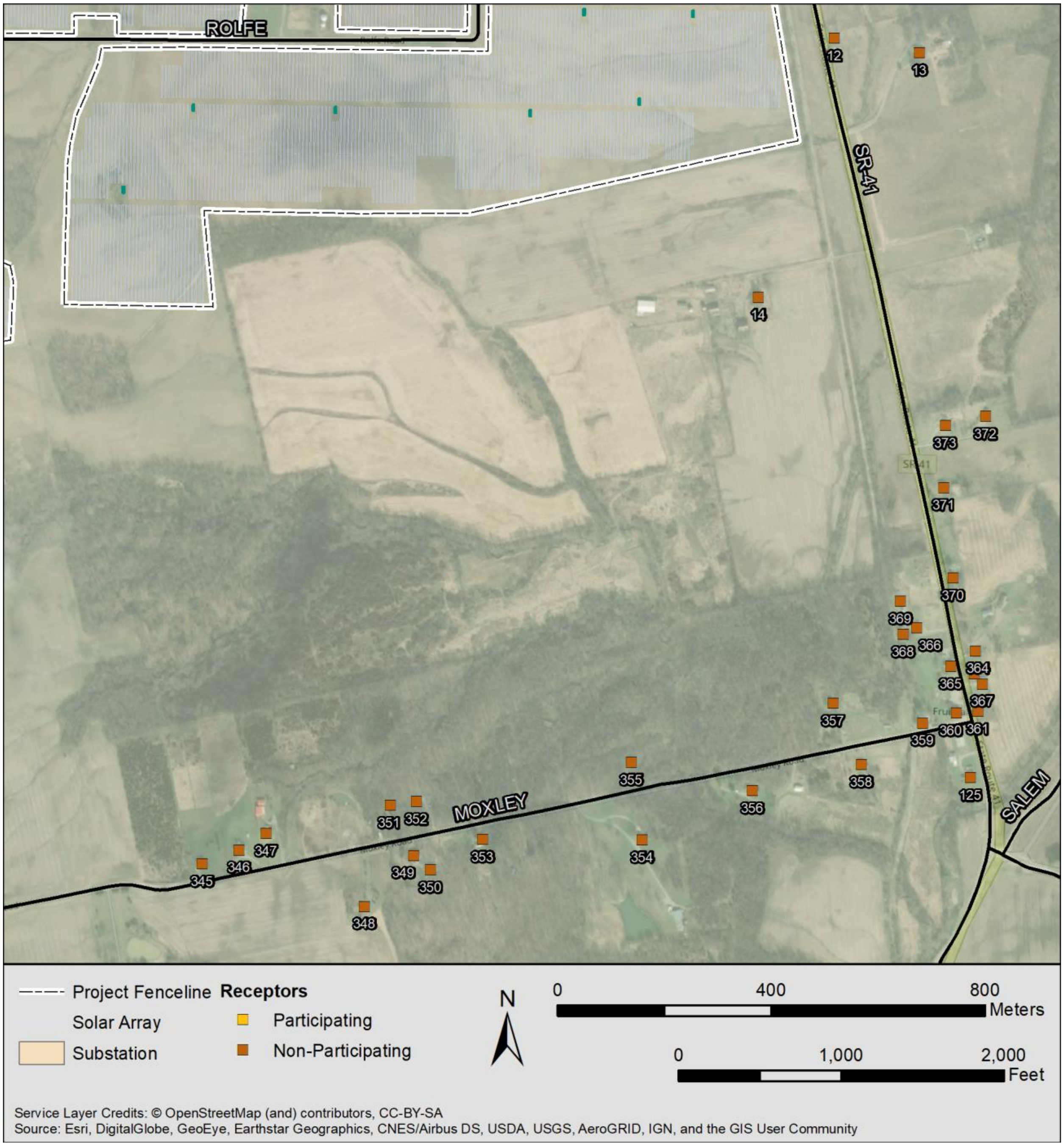

FIGURE 21: MAP OF RECEIVER IDS - SOUTHEASTERN AREA

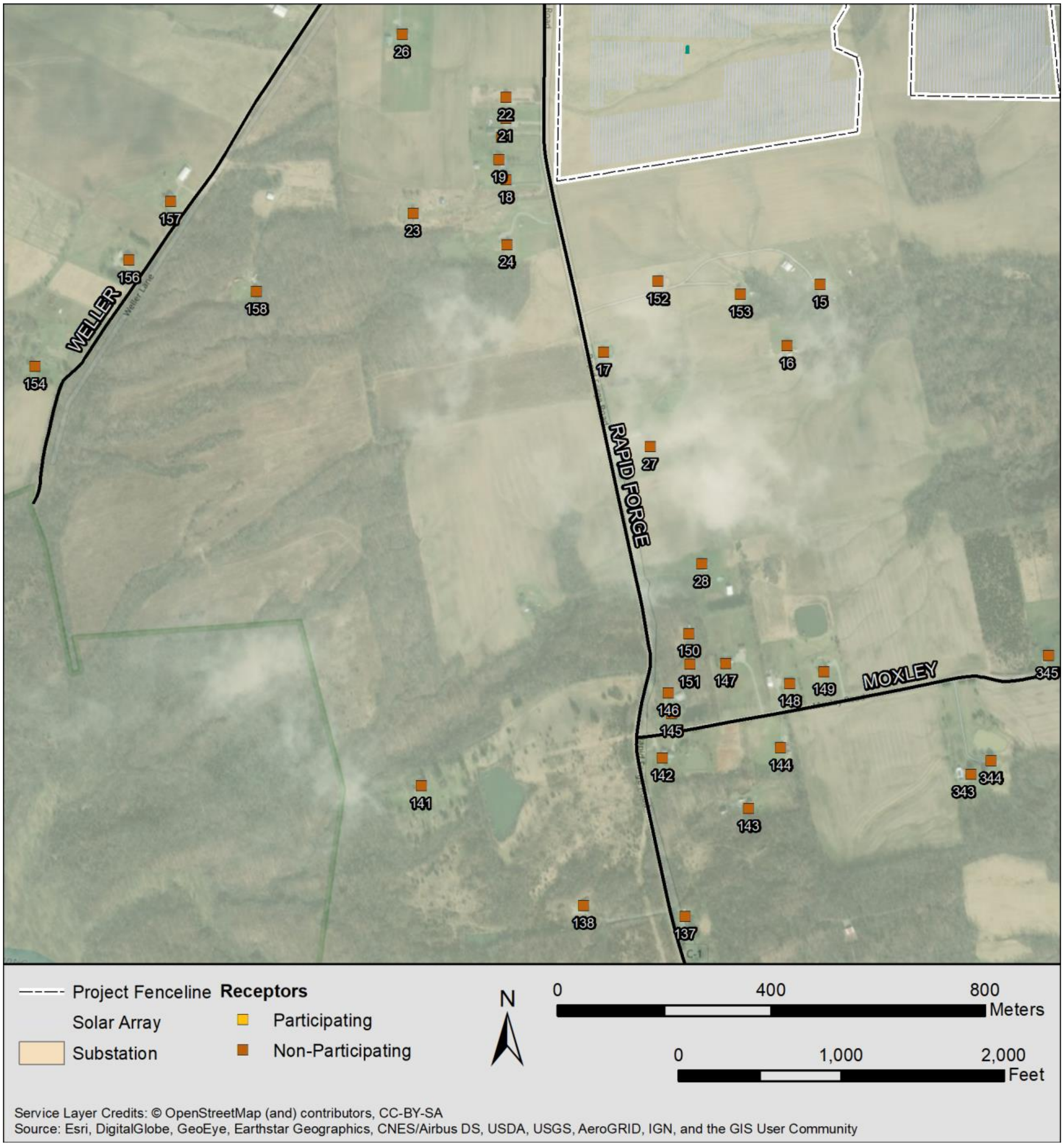

FIGURE 22: MAP OF RECEIVER IDS - SOUTHWESTERN AREA

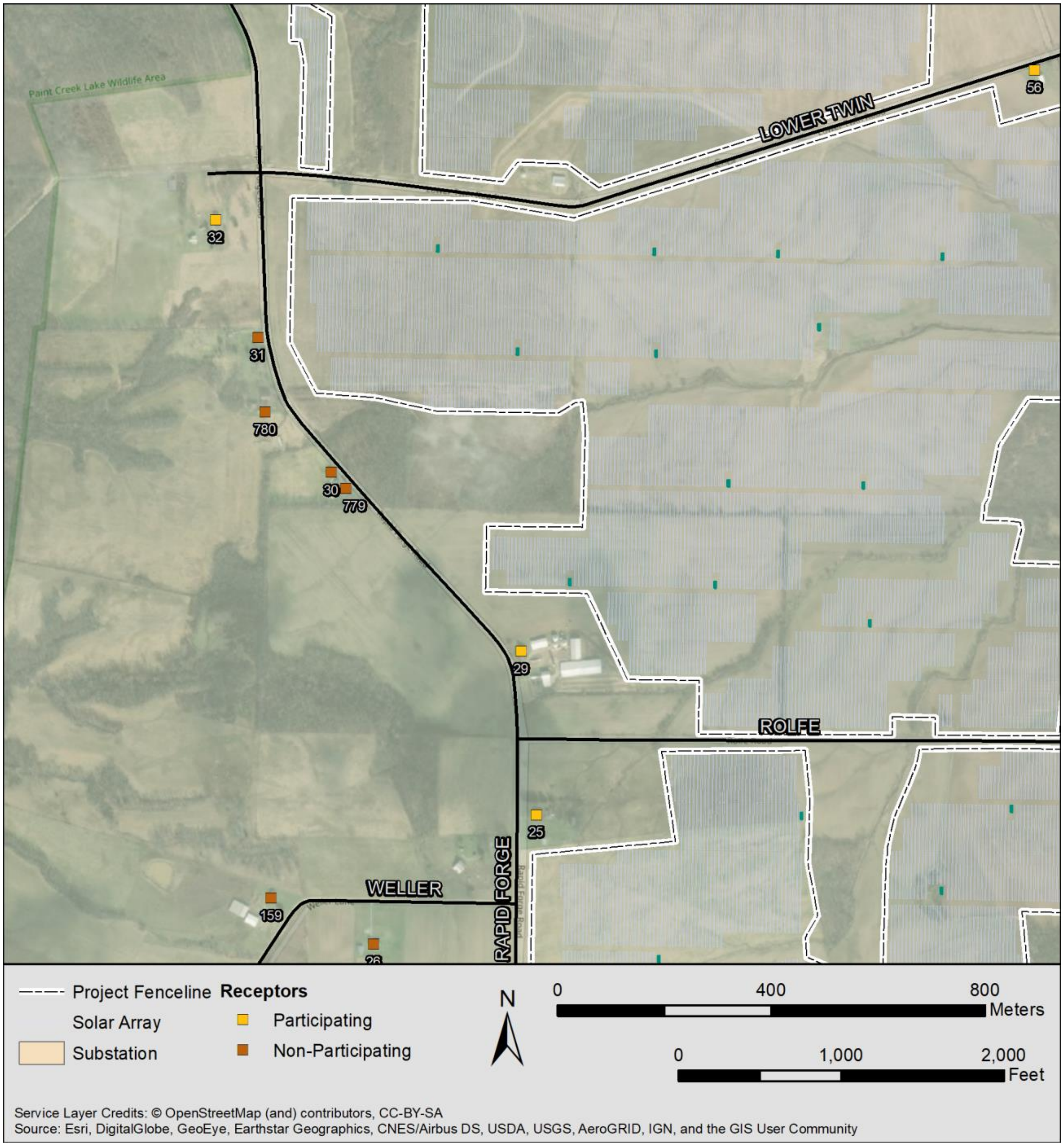

FIGURE 23: MAP OF RECEIVER IDS - WESTERN AREA

TABLE 7: MODEL RESULTS & RECEIVER COORDINATES

Receiver ID	Participation Status	Modeled Sound Pressure Level (dBA)	Relative Height (m)	Coordinates UTM NAD83 Z17N		Absolute Elevation (m)
				X (m)	Y (m)	
1	NonParticipating	37	4	297544	4355218	276
2	NonParticipating	37	4	297547	4355298	277
3	NonParticipating	39	4	297445	4355443	278
4	NonParticipating	40	4	297338	4355514	278
5	NonParticipating	36	4	297618	4355139	276
6	NonParticipating	35	4	297720	4355101	278
7	NonParticipating	36	4	297682	4354971	275
8	NonParticipating	36	4	297651	4354911	274
9	Participating	36	4	297745	4354830	274
10	NonParticipating	39	4	297847	4354571	268
11	NonParticipating	39	4	297864	4354530	267
12	NonParticipating	37	4	298007	4354147	266
13	NonParticipating	35	4	298167	4354119	276
14	NonParticipating	33	4	297865	4353660	275
15	NonParticipating	30	4	296395	4353294	298
16	NonParticipating	29	4	296333	4353180	298
17	NonParticipating	28	4	295990	4353168	308
18	NonParticipating	32	4	295807	4353491	315
19	NonParticipating	32	4	295794	4353528	314
20	NonParticipating	32	4	295799	4353570	311
21	NonParticipating	32	4	295807	4353606	310
22	NonParticipating	32	4	295807	4353645	308
23	NonParticipating	30	4	295634	4353428	322
24	NonParticipating	31	4	295809	4353369	322
25	Participating	35	4	295918	4354005	301
26	NonParticipating	30	4	295613	4353763	309
27	NonParticipating	27	4	296077	4352991	309
28	NonParticipating	26	4	296173	4352771	313
29	Participating	39	4	295889	4354311	298
30	NonParticipating	34	4	295534	4354646	293
31	NonParticipating	33	4	295396	4354899	291
32	Participating	33	4	295317	4355119	293
33	NonParticipating	28	4	295222	4356471	280
34	NonParticipating	26	4	295202	4356687	278
35	NonParticipating	26	4	295243	4356917	277

Receiver ID	Participation Status	Modeled Sound Pressure Level (dBA)	Relative Height (m)	Coordinates UTM NAD83 Z17N X (m)	Coordinates UTM NAD83 Z17N Y (m)	Absolute Elevation (m)
36	NonParticipating	25	4	295391	4357213	272
37	NonParticipating	24	4	295406	4357255	271
38	NonParticipating	24	4	295488	4357345	270
39	NonParticipating	26	4	295880	4357534	274
40	NonParticipating	23	4	295519	4357586	274
41	NonParticipating	23	4	295508	4357650	275
42	NonParticipating	23	4	295590	4357623	274
43	NonParticipating	23	4	295605	4357677	275
44	NonParticipating	23	4	295789	4357624	272
45	NonParticipating	27	4	296122	4357467	277
46	NonParticipating	26	4	296179	4357468	277
47	NonParticipating	29	4	296239	4357168	275
48	NonParticipating	30	4	296266	4357134	276
49	NonParticipating	30	4	296332	4357098	275
50	NonParticipating	30	4	296353	4357038	275
51	NonParticipating	36	4	296537	4356692	277
52	NonParticipating	37	4	296650	4356604	276
53	NonParticipating	35	4	296634	4356698	278
54	NonParticipating	34	4	296546	4356787	278
55	NonParticipating	40	4	296917	4356306	278
56	Participating	42	4	296850	4355399	276
57	Participating	41	4	296964	4354286	279
58	NonParticipating	39	4	297365	4354667	274
59	NonParticipating	27	4	296222	4357298	272
60	NonParticipating	27	4	296231	4357367	275
61	NonParticipating	26	4	296237	4357437	276
62	NonParticipating	26	4	296271	4357424	275
63	NonParticipating	26	4	296308	4357413	274
64	NonParticipating	27	4	296340	4357271	275
65	NonParticipating	27	4	296363	4357331	275
66	NonParticipating	28	4	296361	4357227	275
67	NonParticipating	28	4	296400	4357249	276
68	NonParticipating	28	4	296427	4357372	277
90	NonParticipating	20	4	295461	4358000	265
91	NonParticipating	21	4	295650	4357976	273
92	NonParticipating	21	4	295753	4357906	270

Receiver ID	Participation Status	Modeled Sound Pressure Level (dBA)	Relative Height (m)	Coordinates UTM NAD83 Z17N X (m)	Y (m)	Absolute Elevation (m)
93	NonParticipating	22	4	295608	4357812	274
94	NonParticipating	22	4	295607	4357779	275
95	NonParticipating	21	4	295614	4357851	273
96	NonParticipating	22	4	295608	4357736	275
97	NonParticipating	23	4	295604	4357717	275
98	NonParticipating	23	4	295604	4357692	275
99	NonParticipating	23	4	295627	4357659	273
100	NonParticipating	23	4	295481	4357513	268
101	NonParticipating	23	4	295491	4357467	266
102	NonParticipating	25	4	295365	4357173	272
103	NonParticipating	25	4	295369	4357132	273
104	NonParticipating	28	4	295357	4356808	280
111	NonParticipating	31	4	296446	4357030	276
112	NonParticipating	37	4	297511	4355546	281
113	NonParticipating	34	4	297560	4355638	281
114	NonParticipating	36	4	297590	4355399	278
115	NonParticipating	36	4	297699	4354871	274
125	NonParticipating	22	4	298262	4352761	260
137	NonParticipating	21	4	296143	4352111	301
138	NonParticipating	21	4	295952	4352131	294
141	NonParticipating	21	4	295649	4352356	288
142	NonParticipating	22	4	296099	4352408	305
143	NonParticipating	22	4	296261	4352313	302
144	NonParticipating	23	4	296321	4352427	307
145	NonParticipating	23	4	296117	4352491	310
146	NonParticipating	23	4	296111	4352529	312
147	NonParticipating	25	4	296219	4352585	316
148	NonParticipating	24	4	296338	4352547	311
149	NonParticipating	25	4	296403	4352569	308
150	NonParticipating	25	4	296149	4352641	315
151	NonParticipating	24	4	296151	4352584	315
152	NonParticipating	30	4	296092	4353300	302
153	NonParticipating	30	4	296246	4353276	297
154	NonParticipating	22	4	294926	4353141	281
155	NonParticipating	22	4	294831	4353259	285
156	NonParticipating	24	4	295101	4353341	292

Receiver ID	Participation Status	Modeled Sound Pressure Level (dBA)	Relative Height (m)	Coordinates UTM NAD83 Z17N X (m)	Coordinates UTM NAD83 Z17N Y (m)	Absolute Elevation (m)
157	NonParticipating	25	4	295179	4353450	297
158	NonParticipating	24	4	295340	4353281	299
159	NonParticipating	28	4	295421	4353849	301
298	NonParticipating	35	4	297608	4355497	281
299	NonParticipating	31	4	297863	4355564	283
300	NonParticipating	30	4	298019	4355593	282
301	NonParticipating	28	4	298267	4355594	282
302	NonParticipating	27	4	298348	4355594	281
303	NonParticipating	26	4	298353	4355788	282
314	NonParticipating	24	4	298066	4356865	285
315	NonParticipating	22	4	298169	4357218	286
316	NonParticipating	25	4	297385	4357215	279
317	NonParticipating	27	4	297156	4357047	278
318	NonParticipating	25	4	297196	4357167	276
319	NonParticipating	26	4	297136	4357173	277
320	NonParticipating	26	4	297104	4357185	277
321	NonParticipating	26	4	296988	4357266	278
322	NonParticipating	26	4	296987	4357220	277
323	NonParticipating	27	4	296849	4357094	275
324	NonParticipating	27	4	296776	4357276	277
325	NonParticipating	28	4	296410	4357317	276
326	NonParticipating	26	4	296378	4357388	276
340	NonParticipating	29	4	297255	4356938	282
341	NonParticipating	28	4	297365	4356883	282
343	NonParticipating	23	4	296677	4352377	303
344	NonParticipating	23	4	296715	4352403	301
345	NonParticipating	25	4	296823	4352600	299
346	NonParticipating	25	4	296893	4352626	297
347	NonParticipating	26	4	296944	4352657	295
348	NonParticipating	25	4	297127	4352520	303
349	NonParticipating	25	4	297220	4352615	305
350	NonParticipating	25	4	297251	4352589	307
351	NonParticipating	26	4	297176	4352709	294
352	NonParticipating	26	4	297225	4352717	294
353	NonParticipating	26	4	297349	4352646	307
354	NonParticipating	24	4	297647	4352644	285

Receiver ID	Participation Status	Modeled Sound Pressure Level (dBA)	Relative Height (m)	Coordinates UTM NAD83 Z17N X (m)	Y (m)	Absolute Elevation (m)
355	NonParticipating	25	4	297627	4352790	278
356	NonParticipating	23	4	297854	4352737	263
357	NonParticipating	24	4	298005	4352900	272
358	NonParticipating	23	4	298058	4352785	271
359	NonParticipating	23	4	298173	4352863	261
360	NonParticipating	23	4	298236	4352882	262
361	NonParticipating	23	4	298276	4352886	262
362	NonParticipating	23	4	298275	4352905	262
363	NonParticipating	24	4	298269	4352956	264
364	NonParticipating	24	4	298272	4352999	266
365	NonParticipating	24	4	298226	4352969	264
366	NonParticipating	24	4	298162	4353042	264
367	NonParticipating	23	4	298285	4352937	263
368	NonParticipating	25	4	298137	4353030	263
369	NonParticipating	25	4	298132	4353091	265
370	NonParticipating	26	4	298229	4353135	277
371	NonParticipating	28	4	298213	4353304	275
372	NonParticipating	26	4	298291	4353438	269
373	NonParticipating	27	4	298216	4353421	272
443	NonParticipating	20	4	294858	4357559	270
444	NonParticipating	20	4	294814	4357556	270
448	NonParticipating	20	4	294836	4357502	270
455	NonParticipating	21	4	294827	4357443	269
456	NonParticipating	21	4	294874	4357444	265
459	NonParticipating	19	4	294813	4357861	273
460	NonParticipating	19	4	294853	4357864	273
463	NonParticipating	19	4	294814	4357855	273
464	NonParticipating	19	4	294821	4357831	273
466	NonParticipating	19	4	294823	4357820	273
468	NonParticipating	19	4	294829	4357796	273
471	NonParticipating	19	4	294836	4357765	273
475	NonParticipating	20	4	294840	4357726	273
484	NonParticipating	20	4	294838	4357747	273
486	NonParticipating	19	4	294850	4357876	274
488	NonParticipating	20	4	294841	4357708	273
490	NonParticipating	20	4	294843	4357682	272

Receiver ID	Participation Status	Modeled Sound Pressure Level (dBA)	Relative Height (m)	Coordinates UTM NAD83 Z17N		Absolute Elevation (m)
				X (m)	Y (m)	
491	NonParticipating	20	4	294845	4357652	270
492	NonParticipating	19	4	294832	4357782	273
498	NonParticipating	20	4	294994	4357747	269
499	NonParticipating	20	4	294885	4357666	273
501	NonParticipating	19	4	294915	4357843	272
502	NonParticipating	20	4	294993	4357843	271
503	NonParticipating	20	4	294950	4357828	272
504	NonParticipating	20	4	294997	4357828	271
505	NonParticipating	19	4	294911	4357819	271
506	NonParticipating	20	4	295005	4357792	269
507	NonParticipating	20	4	294993	4357656	263
508	NonParticipating	19	4	294856	4357854	273
509	NonParticipating	19	4	294854	4357842	273
510	NonParticipating	19	4	294872	4357789	272
511	NonParticipating	20	4	294877	4357764	272
512	NonParticipating	19	4	294863	4357927	275
514	NonParticipating	20	4	294954	4357810	270
585	NonParticipating	19	4	295078	4358003	272
586	NonParticipating	19	4	295039	4357992	273
587	NonParticipating	19	4	294995	4358000	274
749	NonParticipating	19	4	294871	4357840	273
778	NonParticipating	25	4	296014	4357571	274
779	NonParticipating	34	4	295560	4354616	294
780	NonParticipating	32	4	295409	4354760	291
785	NonParticipating	34	4	296537	4356826	278
786	NonParticipating	36	4	296665	4356669	278

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