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# CROWNED RIDGE WIND II – NOISE COMPLAINT MONITORING 2022

March 2023

Prepared for Xcel Energy

**Report Title**:

Crowned Ridge Wind II – Noise Complaint Monitoring 2022

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**Report Prepared for**:

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**CROWNED RIDGE WIND II – NOISE COMPLAINT MONITORING 2022**
**March 2023**

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# EXECUTIVE SUMMARY

A sound monitoring study for Crowned Ridge Wind II (the "Project") in Codington, Deuel, and Grant Counties in South Dakota was performed in response to noise complaints. The assessment includes:

- Monitoring at three complaint sites within the Project area for at least 20 days in November and December 2022;
- Consideration of turbine operation, meteorology, and sound levels over the entire monitoring period;
- Noise compliance analysis focused on periods surrounding wind turbine shutdowns; and
- A comparison of the results with expected wind turbine-only sound levels.

The study focuses on determining the Project's compliance with noise limits defined in the Project's operation permit[1] (the "Permit") at residences that registered noise complaints. This study is a follow-up to the Post-Construction Noise Compliance Study[2] completed in Spring 2021. The sound limit of 45 dBA is assessed as the 10-minute turbine-only equivalent average sound level ($L_{eq10\text{-}minute}$) during target operational conditions in which wind turbines were within 1 dB of the maximum manufacturer-rated sound level emission.

For the compliance analysis, wind turbine-only sound levels were evaluated through a deterministic shutdown method at each monitor: the background sound level (sound levels without wind turbines operating) was assessed directly by shutting down nearby wind turbines for 10 to 20 minutes four times each day (one around midday and three at night). Turbine-only levels (10-minute $L_{eq}$) were evaluated for the hour prior and hour after each shutdown.

A total of one-hundred shutdowns were realized for the study. About half of the evaluation periods surrounding wind turbine shutdowns were qualified as target evaluation periods and about 200 10-minute periods were explicitly evaluated at each monitor. Average wind-turbine only sound levels during the target conditions were below 40 dBA for all monitors. However, periods of elevated sound levels at all monitors were observed in which wind turbine-only sound levels at all monitors were at or within 1 dB of the 45 dBA limit. The elevated sound levels were found to be attributable to amplitude modulated wind turbine noise. These periods with elevated sound levels were found to occur during periods of high wind shear (high wind aloft compared to low ground level winds), which is one of the known causes of amplitude modulation. Although the presence of amplitude modulation was seen to increase the sound level over typical operation conditions (including those observed in the Post-Con Study), the wind turbine-only contribution to total sound was not found to be above 45 dBA. As a result, this complaint monitoring study concludes that the Project complies with the noise limits in the Project permit.

[1] Wind energy permit EL19-027, South Dakota Public Utility Commission
[2] EL19-027: 8/06/21 - Post Construction Noise Compliance Report

# 1.0 INTRODUCTION

This study evaluates the Crowned Ridge II Wind Farm's adherence to applicable noise limits at three complainant locations during November and December 2022.

## 1.1 PROJECT DESCRIPTION

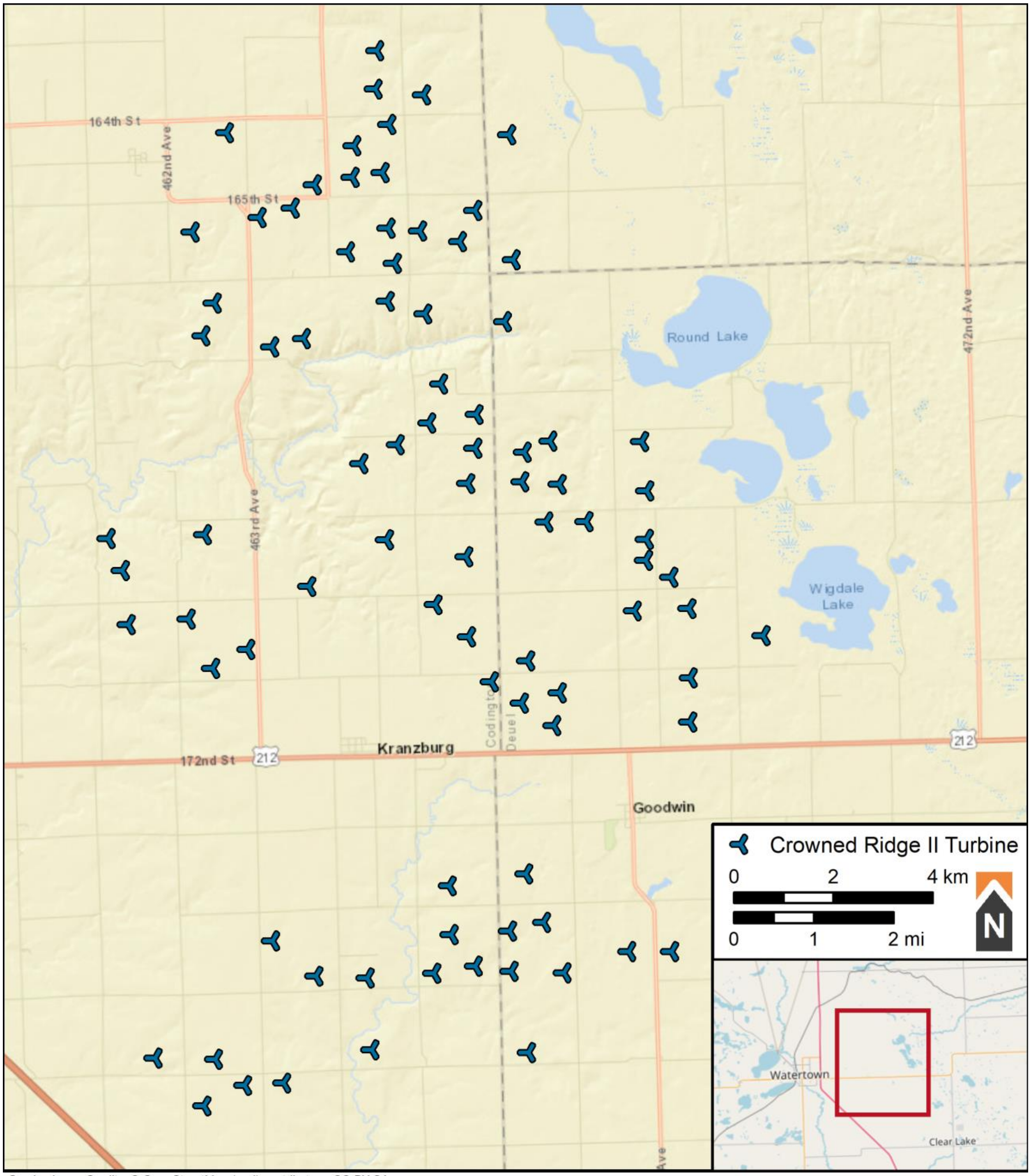
The Crowned Ridge II Wind Farm in Codington, Deuel, and Grant Counties in South Dakota was permitted for construction and operation in April 2020 and commenced commercial operation in December 2020.

The 200 MW project consists of eighty-eight (88) wind turbines: nine (9) GE 2.1-116 and seventy-nine (79) GE 2.3-116 wind turbines. The hub height of the GE 2.1-116 is 80 meters above ground level while the hubs of the GE 2.3-116 models are 90 meters above ground level. Both wind turbine models have 116-meter rotor diameters. All wind turbines have low noise trailing edges (LNTE) installed on the blades.

### Project Area Description

The region surrounding the Project is a working landscape, composed primarily of grain and beef cattle operations, residential homesteads, and other wind projects. The Project spans an area about 7 to 20 kilometers (4.4 to 12.4 miles) east of Watertown, SD around the towns of Waverly, Kranzburg, and Goodwin. It is bordered on the east by a string of lakes including Crooked Lake, Round Lake, and Wigdale Lake. Most of the project is located north of US Highway 212, which bisects the Project east to west. Other wind turbine projects operating in the area include Crowned Ridge I, to the north, and Deuel Harvest wind, to the east.

A map of the Project and surrounding area is provided in Figure 1.




Service Layer Credits: © OpenStreetMap (and) contributors, CC-BY-SA

**FIGURE 1: MAP OF THE CROWNED RIDGE II WIND FARM AND THE SURROUNDING AREA**

## 1.2 NOISE COMPLAINTS

Noise complaints following the commercial operation of the Project prompted the South Dakota Public Utility Commission ("SD PUC") to initiate a post-construction sound monitoring study. The study was commissioned to determine if the sound levels attributable to the Project at surrounding residences complied with the applicable noise standards. The basic methodology and conditions for the study were stipulated in a Permit issued by the SD PUC and additional SD PUC guidance.

The Post-Construction Noise Study ("Post-Con Study") was completed in May/June 2021 and submitted to the SD PUC docket in August 2021. It concluded that the Project was compliant with the Permit conditions. No formal actions were taken on Post-Con Study data or conclusions. New noise complaints from residences included in the Post-Con Study were received in August 2022 and discussed at the SD PUC meeting on August 30, 2022. At the meeting, Xcel agreed to the SD PUC's request to perform a second noise study in the late fall to address concerns of the residents that the Project was louder during that season. Prior to deploying the 2022 study, a Complaint Sound Monitoring Protocol[3] (the "Protocol") was submitted following review and subsequent approval of the outlined methodology in accordance with the Permit.

## 1.3 NOISE COMPLIANCE

### Permit Conditions

The South Dakota counties of Codington, Deuel, and Grant each have their own specific ordinances regulating the sound generated by wind turbines. The most stringent limit (Grant County) of 45 dBA at 25 feet from the structure was adopted as a condition in the Permit; sound levels for participating residences up to 50 dBA are permitted. The Permit specifies that the 10-minute equivalent average sound level ($L_{eq10min}$) be used to evaluate the wind turbine-only contribution to sound level at the assessment location. Table 1 provides the results of previous inquiries into sound levels attributable to the Project, including the Pre-Construction Study[4] and Post-Con Study at the complaint locations under consideration in this study.

A primer on acoustics and the terminology used in this report is provided in Appendix A, including a section specifically about wind turbine noise.

**TABLE 1: WIND TURBINE SOUND LEVELS MODELED IN PRE-CONSTRUCTION AND MEASURED FROM THE 2021 POST-CONSTRUCTION STUDY**

| MONITOR | MODELED (PRE-CONSTRUCTION) | MAXIMUM CALCULATED $L_{EQ}$ (POST-CONSTRUCTION) |
|---|---|---|
| | Turbine-Only | Turbine-Only |
| LT2 | 42.4 | 42.6 |
| LT3 | 41.4 | 40.3 |
| LT6 | 41.7 | 44.3 |

[3] EL19-027: RSG - 10/25/22 - Complaint Sound Monitoring Protocol
[4] EL19-027. Rebuttal Testimony of Jay Haley - Corrected Exhibit JH-R-1 - 01/24/20

## Compliance Assessment

### *Methodology*

Wind turbine shutdowns provide an in-situ measurement of background sound that allow for the turbine only sound to be calculated from the total (turbine + background) sound by quantifying the background sound immediately before or after a period of turbine operation at the same location. The primary purpose of establishing background sound levels for each turbine operation period is to separate total sound (wind turbine + background) into its constituent components (turbine-only sound and background sound). The background sound level measured during a turbine shutdown is utilized to represent the background sound level of all other sources of sound during turbine operation. To determine the sound contributed by only the wind turbine, background sound levels are logarithmically subtracted from total sound levels on a 1/3 octave band basis, as described in ANSI S12.9 Part 3 Section 7.

### *Approach*

All Project wind turbines within 2.8 kilometers (1.75 miles) of a monitor location were shut down during the study period (so that the blades ceased rotating) based on the schedule provided in Table 2. To provide temporal variation in the periods assessed, three nighttime shutdowns and one daytime shutdown are specified. Generally, wind turbine shutdowns are best performed at night to limit background sound levels associated with anthropogenic activity and to allow for atmospheric conditions that are most conducive to sound propagation (i.e., a temperature inversion and higher wind shear).

Within each identified shutdown and operation time interval, measured 1-second $L_{eq}$ sound levels were aggregated into 10-minute periods. Six 10-minute periods before and after each shutdown were analyzed independently to determine the $L_{eq}$ for each discrete turbine operation period on a 1/3 octave band basis. The middle 10-minutes of the turbine-off period was classified as the background sound level ($L_{eq}$) corresponding to the surrounding turbine operation periods.

**TABLE 2. SUGGESTED DAILY SHUTDOWNS SCHEDULE (24-HOUR TIME)**[5]

| | SHUTDOWN 1 | SHUTDOWN 2 | SHUTDOWN 3 | SHUTDOWN 4 |
|---|---|---|---|---|
| **Shutdown Time** | 01:30 | 04:00 | 13:00 | 23:00 |
| **Startup Time** | 01:50 | 04:20 | 13:20 | 23:20 |

[5] While the turbines are shut down completely for 10 minutes, 20-minute periods are provided in this table to allow for spin-down and spin-up.

### *Target Evaluation Conditions*

The Permit stipulates the following two conditions for a period to qualify for a compliance assessment:

1) The closest five wind turbines are operating.
2) The closet wind turbine is operating within 1 dB of maximum sound power emission.

According to manufacturer documentation, both wind turbines reach maximum power production at 11 m/s hub-height wind speed. Maximum sound output is achieved at 10 m/s hub-height wind speed. At 85% of maximum power, corresponding to 9 m/s hub height wind speed, both wind turbine models are at least 1 dB below maximum sound power level. At 33% of maximum power production, the GE wind turbines are about 10 dB below their maximum sound power level.

As such, evaluation periods for noise compliance considered in this study consist of:

- 10-minute periods in the hour before and hour after a turbine shutdown
- the closest five turbines operating at 33% maximum power production or more, and
- the closest turbine operating at 85% of its maximum power production or more.

### *Valid Compliance Periods*

Periods with 10-minute sound levels above the standard and meeting the target compliance conditions were reviewed. Periods meeting the criteria for target evaluation periods were assessed for transient background noise. Data contaminated with transient sound sources such as motor vehicles, aircraft, or excessive wind, was excluded from the analysis (see Section 3.2). Acoustically valid periods that meet the target compliance conditions are referred to as Valid Compliance Periods. Valid Compliance Periods are 10-minute equivalent sound level ($L_{eq}$) that are representative of measured wind turbine sound level.

# 2.0 MONITOR LOCATIONS

The three monitor locations described in this report are referred to as LT2, LT3 and LT6 and are referenced with the modeling receptor ID assigned in the Pre-Con Study. The Monitor ID is the same as those assigned in the 2021 Post-Construction Noise Compliance Report.

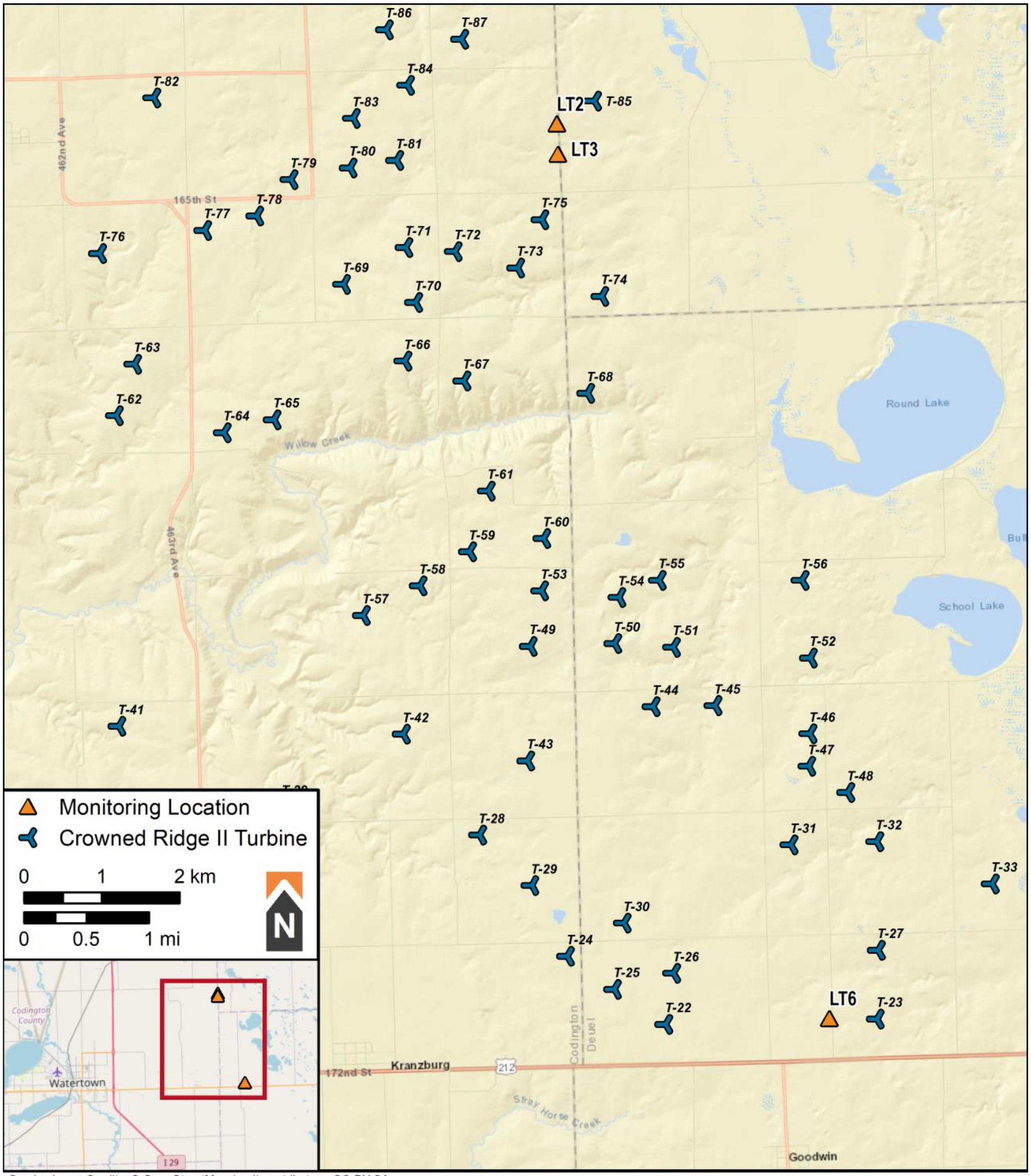
Complaint monitoring was completed at the three monitoring sites listed in this section from November 18th to December 8th, 2021. The monitoring was extended an additional ten days (until December 18th) at two sites (LT2 and LT6) due to monitoring system power failures and complainant requests, respectively.

The geographic locations of the monitor locations used in this study, as well the modeled sound levels for the residence closest to each monitoring location, as defined in the Pre-Con Study,[6] are provided in Table 3, with modeled sound levels[4] and coordinates provided. The table provides predicted wind turbine-only sound levels for the Project, as well as for the cumulative impact of the Project and the surrounding wind projects. The Permit specified that wind turbine noise should be assessed within 25 feet of the corresponding residence. This distance was realized at each monitor.

**TABLE 3: MONITORING LOCATIONS**

| MONITOR | TYPE | RECEPTOR ID | PROJECT PARTICIPANT? | MODELED SOUND LEVEL (dBA) | LONGITUDE | LATITUDE |
|---|---|---|---|---|---|---|
| LT2 | Primary | CR2-C132-NP | No | 42.4 | -96.8829 | 44.99933 |
| LT3 | Primary | CR2-C79-NP | No | 41.4 | -96.8831 | 44.99555 |
| LT6 | Primary | CR2-D221-NP | No | 41.7 | -96.8425 | 44.89467 |

[6] EL19-027. Rebuttal Testimony of Jay Haley - Corrected Exhibit JH-R-1 - 01/24/20. “Proposed Array””



Service Layer Credits: © OpenStreetMap (and) contributors, CC-BY-SA

**FIGURE 2: CROWNED RIDGE II SOUND MONITOR MAP**

## 2.1 LT2 (CR2-C132-NP)

The LT2 monitoring location is adjacent to a residence on 466th Avenue in the northeastern portion of the project. Formal complaints related to wind turbine noise were registered by the residence adjacent to the monitor, particularly related to the nearest turbine, T-85, which is located 560 meters (1840 feet) to the northeast of the monitoring location. A map showing the monitoring location with respect to nearby turbines and local roads is provided in Figure 3.

The sound monitor was placed 7.6 meters (25 feet) northeast of the residence and 17 meters (56 feet) from 466th Avenue. Photographs of the monitor setup are shown in Figures 4 and 5.

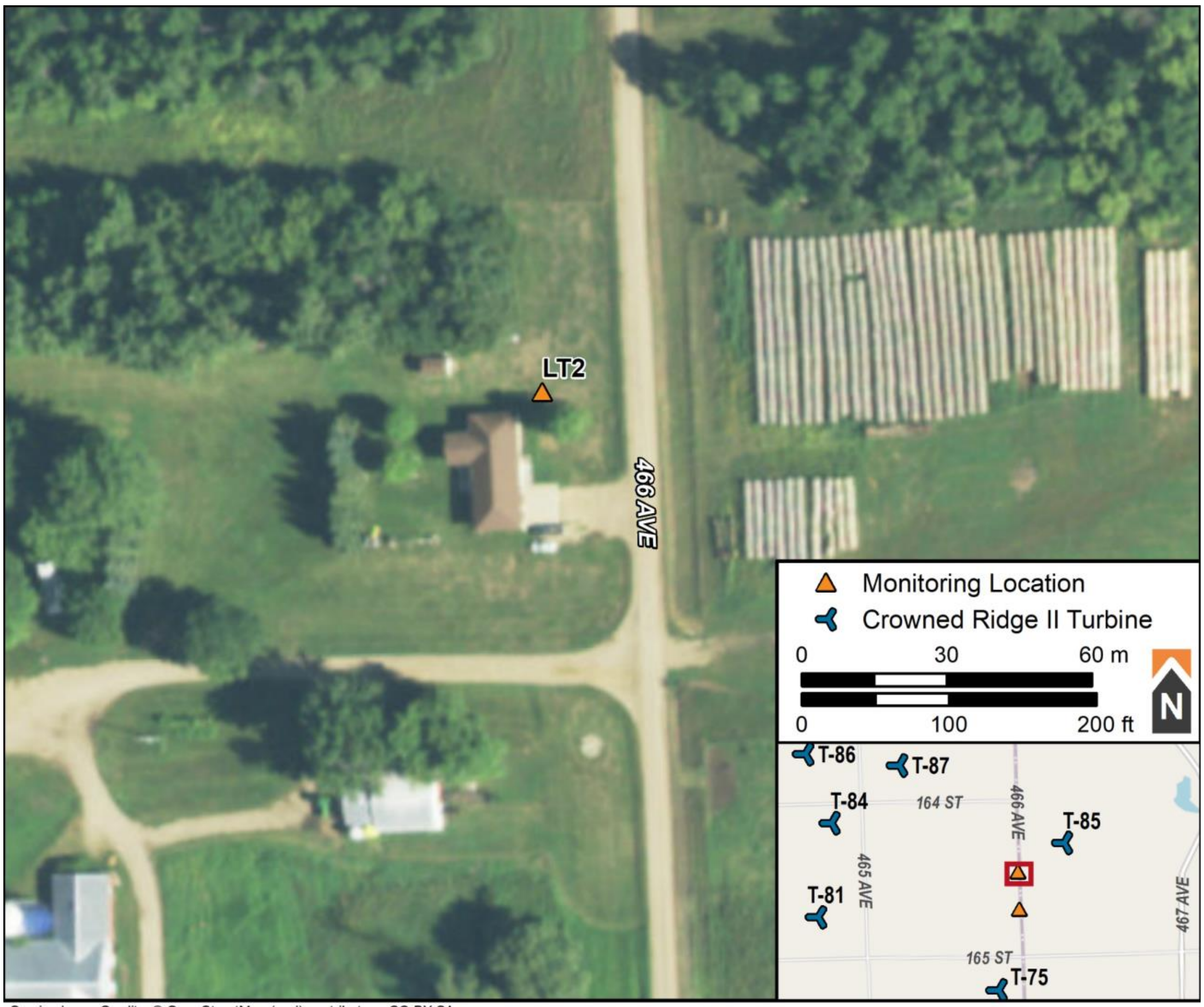



**FIGURE 3: MAP OF LT2 MONITORING LOCATION**

**FIGURE 4: PICTURE OF LT2 DURING COMPLAINT MONITORING, FACING EAST**

**FIGURE 5: PICTURE OF LT2 DURING COMPLAINT MONITORING, FACING SOUTH**

## 2.2 LT3 (CR2-C79-NP)

The LT3 monitoring location is in the northeast portion of the Project, approximately 390 meters (1280 feet) south of LT2 along 466th Avenue.

The closest wind turbine to LT3 is T-85, about 825 meters to the northeast. The next closest turbine, T-75, is located about 870 meters to the south-southwest. Aerial imagery depicting the monitor location and a map of the area surrounding LT3 is provided in Figure 6. The monitor was placed 7.6 meters (25 feet) east of the residence. Photographs of the monitoring setup are provided in Figures 7 and 8.


**FIGURE 6: MAP OF LT3 MONITORING LOCATION**

**FIGURE 7: PICTURE OF LT3 DURING COMPLAINT MONITORING, FACING NORTHEAST**

**FIGURE 8: PICTURE OF LT3 DURING COMPLAINT MONITORING, FACING SOUTH**

## 2.3 LT6 (CR-D221-NP)

The LT6 monitor location is in the front yard of a residence on 468th Avenue in the southwestern portion of the project. The monitor was placed about 28 meters (92 feet) west of 468th Avenue, 530 meters (1,740 feet) north of US Highway 212, and about 1 km (0.63 miles) north-northeast of Goodwin.

A map of the monitor location and surrounding area is shown in Figure 9. The closest wind turbine, T-23 is 600 meters (1,969 feet) to the east of the monitoring location. The microphone was placed 7.6 meters (25 feet) east-southeast of the residence.

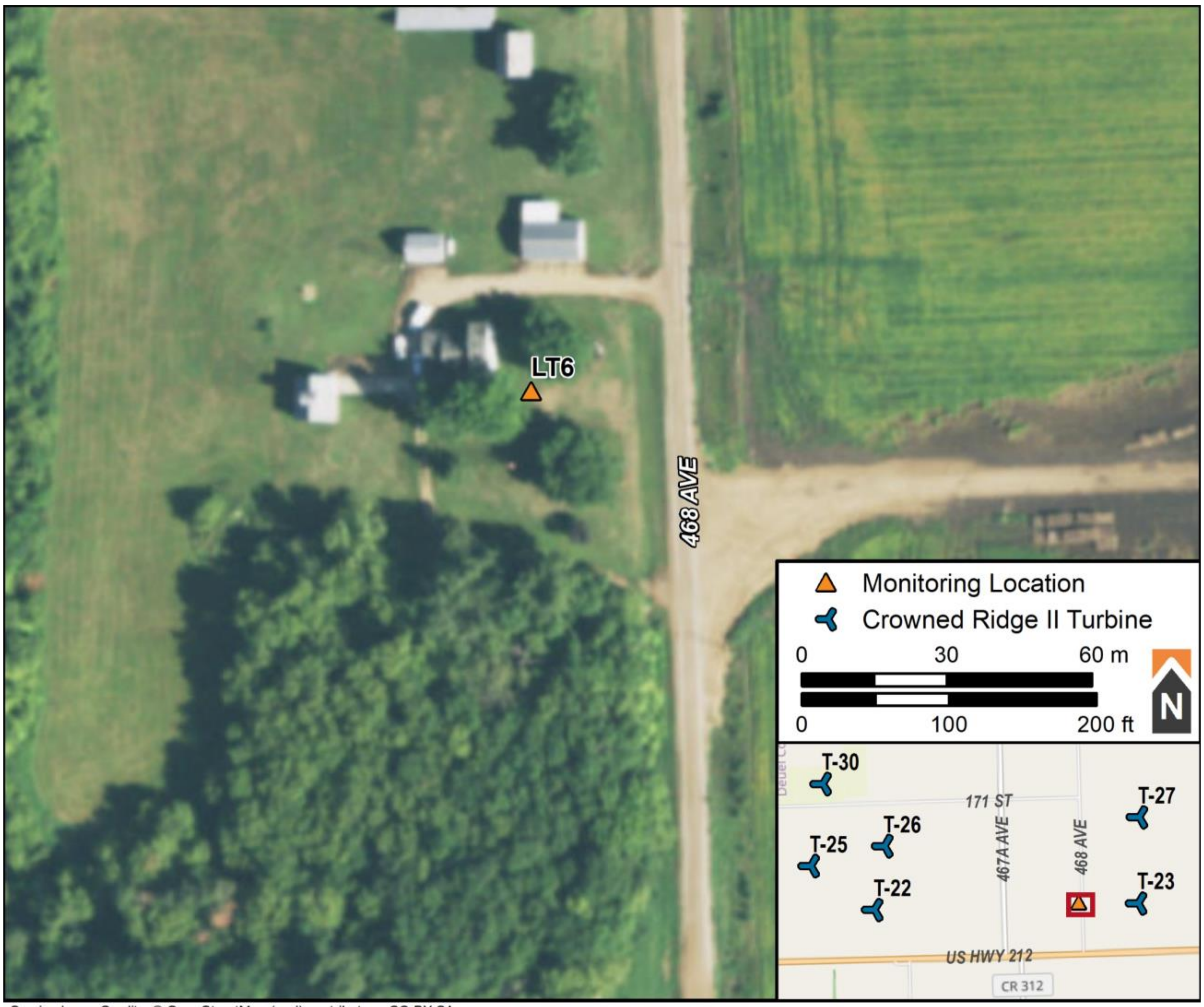



**FIGURE 9: MAP OF LT6 MONITORING LOCATION**

**FIGURE 10: PICTURE OF LT6 DURING COMPLAINT MONITORING, FACING EAST**

**FIGURE 11: PICTURE OF LT6 DURING COMPLAINT MONITORING, FACING NORTH**

# 3.0 DATA COLLECTION AND PROCESSING

## 3.1 DATA ACQUISITION

Several sources of data were leveraged for this study, including 1/3 octave band sound levels, ground-level wind speed and temperature, hub-height wind speed and direction, and meteorological data for the region.

### Sound Level Monitoring Station Detail

Under the direction of RSG, the sound level monitoring stations were deployed by ESI Engineering on November 18, 2022. Sound level data were collected using ANSI/IEC Type 1 Cesva SC310 and Svantek SV979 sound level meters ("SLM"). The SLMs continuously logged overall and 1/3-octave band sound levels once each second. The Cesva SC310 meters were connected to Edirol R-09HR or R-05 audio recorders, recording audio data at a 128 kbps in *.mp3 format. The Svantek SV979 sound level meters internally recorded continuous audio files in 24-bit *.wav format at a 12 kHz sample rate.

The microphone of each sound level meter was mounted on a wooden stake at a height of approximately 1.2 m (4 ft) and protected by an ACO-Pacific hydrophobic windscreen 17 cm (7 in) in diameter. Before and after measurement periods, sound level meters were calibrated with a Larson Davis CAL200 calibrator. All equipment was lab-calibrated within 1 year of the measurement campaign. Field calibrations between monitoring checkups differed 0.5 dB or less and thus no corrections were made to the data for calibration drift. Table 4 lists the models and spectral specifications of each sound level meter.

For the first two monitoring periods at LT2, a Vaisala WXT-530 LT2 collected wind speed, wind direction, relative humidity, temperature, and precipitation once each minute connected to the SV979 as the data logger. Otherwise, an Onset HOBO anemometer was deployed in conjunction with each sound level monitoring station and the average wind speed and maximum gust speed was logged once per minute.

At LT2, the study was extended for a third week due to equipment power failure during the second monitoring period. The same sound level meter was deployed at LT2 for the third week with a different power system. An Onset HOBO meteorological station recorded wind speed, wind direction, relative humidity, temperature was installed at LT2 for the third monitoring period.

At LT6, the monitoring was also extended for a third week to study the effect of the specific location of the monitoring location. Data from the third monitoring period is included herein but the comparison to the nearby alternative monitor location is detailed in a separate forthcoming report. The same equipment was used at LT6 for all three monitoring periods.

**TABLE 4: SOUND LEVEL METER SPECIFICATIONS**

| Monitor | Manufacturer | Model | SN | 1/3 Octave Band Frequency Range |
|---|---|---|---|---|
| LT2 | Cesva | SV979 | 35868 | 5 Hz to 20 kHz |
| LT3 | Cesva | SV977 | 97548 | 5 Hz to 20 kHz |
| LT6 | Cesva | SC310 | T235260 | 10 Hz to 20 kHz |

## Meteorological Data

### *Automated Surface Observation Station*

Beyond the site-specific meteorological data described in the previous section, the Automated Surface Observation Station ("ASOS") at the Watertown Regional Airport (KATY) in Watertown, SD provided regional meteorological data. The KATY ASOS station[7] is located about 14 km (8.75 mi) west of the nearest Project wind turbine.

### *Wind Turbine Operation Data*

Xcel Energy provided SCADA that included hub-height wind speed, nacelle direction, and power production in 10-minute intervals. This study utilizes the hub-height wind speed and power production for each turbine.

Hub-height wind direction from Project SCADA data was inaccurate. However, a Project meteorological tower ("Met Tower") located in the northern portion of the Project (between T-78 and T-79) logged wind speed, direction, and other meteorological parameters. Wind direction measured at 6 meters on the Met Tower was utilized throughout the study. The regional wind direction and ground-level wind direction measured were in basic agreement with the wind direction provided by the Met Tower.

# 3.2 SOUND LEVEL DATA PROCESSING

All logged one-second $L_{eq}$ sound levels were imported into R[8], an Open-Source computing language, for processing and data analysis. The outputs from this analysis are provided as plots and tables throughout this report.

Data were aggregated in 10-minute periods and the equivalent continuous sound levels were calculated from the valid (non-excluded) data from the measured 1-second sound level data. If more than half of samples in an aggregation period were excluded (regardless of the exclusion type), valid acoustical data representing the given period could not be calculated.[9]

[7] Latitude/Longitude: 44.913972 N, 97.154722 W

[8] https://www.r-project.org/about.html

[9] ANSI S12.9 Part 3: Quantities and Procedures for Description and Measurement of Environmental Sound - Part 3: Short-Term Measurements with an Observer Present

## Data Exclusions

For each monitoring location, pre-processing of the data was carried out to exclude acoustically invalid periods during which any of the following occurred:

- **Anomaly**: outliers in the sound level data
  - Site setup and microphone calibration and "additional anomalous sounds" [10] that interfered with the measurement of wind turbine noise during evaluation periods.
  - The last four days of monitoring at LT6 when the wind screen had been knocked off by a tree branch. The tree branch broke off a nearby tree following a significant ice storm.
- **Precipitation**: rain, snow, and ice events
  - Periods with precipitation were identified through data collected from a rain indicator at LT2 and regional meteorological data. Specific time periods of precipitation were pinpointed through inspection of acoustic data.[11]
- **High Wind**: average 10-minute wind speeds above 5 m/s (11.2 mph)[12]
  - Periods were programmatically excluded according to the measurements of ground-level wind gust speed collected by an anemometer at each respective monitoring location (all monitoring locations included an anemometer).
- **Wind Induced Noise**: excessive wind gusts
  - Excessive wind was identified by manually reviewing 1-second 1/3 octave band sound levels for notable random (i.e., not periodic) variations in broadband sound due to sporadic wind gusts and wind-dominated sound.
  - Periods that were observed to be clearly dominated by wind were excluded.

## Data Exceptions

As noted in the Protocol, periods with relative humidity and temperatures outside the Class 1 equipment specifications[13] were retained as acoustically valid data. Wind-turbine only results calculated outside of this range are noted, where applicable. Relative humidity and temperature were measured at LT2. When those data were not available (i.e., the power system for the monitor had failed), regional data from KATY was backfilled for continuity.

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[10] Transient noise sources that occurred during the turbine-on period that were not present in the turbine off period (or the opposite – sounds in a turbine-off period that were not present in turbine-on period)

[11]Note that data are excluded for any period of precipitation, regardless of the rain rate, because of the self-noise induced on the microphone windscreen by droplets or hailstone.

[12] Permit Condition 26e,ii.

[13] Class 1 accuracy of the sound level meters instruments are specified up 90% relative humidity and down to temperatures of 10˚C (-14 ˚F)

# 4.0 OVERALL MONITORING PERIOD RESULTS

This section provides the overall results of all monitored data, including regional weather patterns, wind turbine operational characteristics, and sound levels.

## 4.1 REGIONAL METEOROLOGY

Regional meteorological conditions over the course of the complaint monitoring period are plotted in Figure 12. The vertical lines on the figure delineate the three monitoring periods. The third monitoring period is only applicable to LT2 and LT6. Nighttime periods (10 PM to 7 AM) are indicated with the vertical gray shading.

The top pane displays temperature (in dark blue) and cloud cover (shading from yellow purple). Temperature ranged from -23 ˚C to 10 ˚C. The temperature threshold (-10 C) is shown on the plot and periods below the threshold are highlighted for reference. The first pane also includes percent cloud cover, which was estimated from ASOS observations. Cloud cover logged and computed at the regional ASOS station is reported categorically (CLR = clear, FEW = few, SCT = scattered, BKN = broken, OVC = overcast). These reported data were converted to quantitative ranges of percent of sky cover using values from the Automated Surface Observing System (ASOS) User's Guide (Table 3).[14] Lighter colors toward the bottom of the pane indicate minimal cloud cover (i.e., clear skies), while darker colors toward the top indicate overcast conditions.

The second pane displays relatively humidity (in purple) and rain rate in millimeters per hour (light blue). Relatively humidity was highest at night and during periods of high cloud cover and precipitation. The Class 1 SLM relative humidity threshold (90%) is indicated on the plot; periods above the threshold are highlighted. Precipitation was minimal during the first two monitoring periods. During the third monitoring period, starting on December 12, a severe storm covered the area in substantial ice and snow.

The third pane shows average wind speed (in miles per hour) and direction measured at 10 m (33 ft) above ground level. Regional wind direction is represented in two different ways in the bottom pane. First, the arrows are overlaid on the mean wind speed to indicate the direction that the wind was blowing: the convention is that the arrow at the mean wind speed points in the direction that the wind was blowing, (e.g., ">" would represent winds out of the west blowing to the east). Second, the orange points correspond to the cardinal direction on the y-axis to represent the wind direction.[15]

[14] https://www.weather.gov/media/asos/aum-toc.pdf
[15] The point-based representation provides a finer resolution than the arrows but the point-based method suffers from the inherent discontinuity of North (0 degrees) at the bottom of the plot and North (360 degrees) at the top of the plot.

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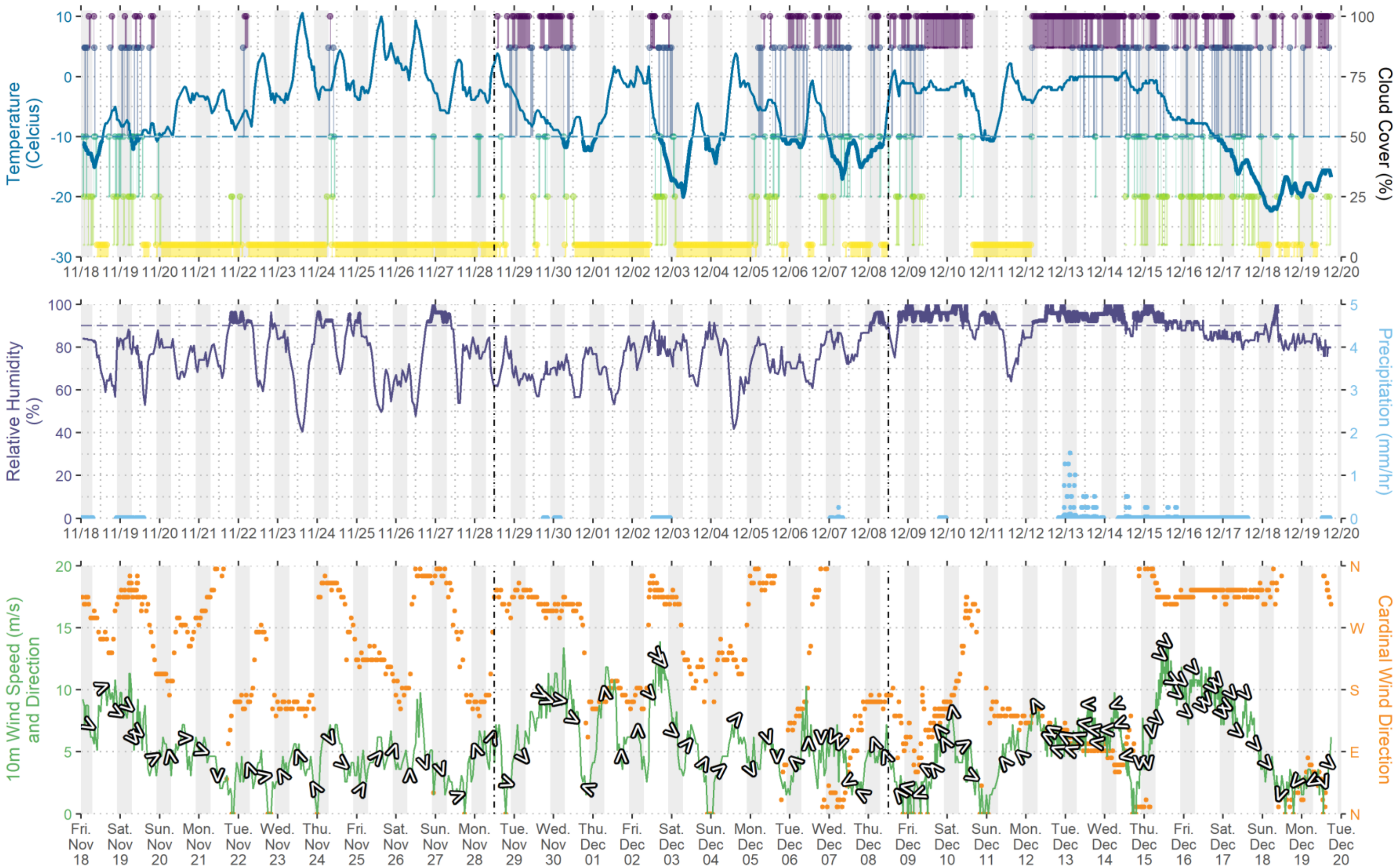


**FIGURE 12. REGIONAL METEOROLOGY FROM KATY IN WATERTOWN, SD.**

*The two vertical lines denote the transitions between the three monitoring periods.*

*Horizontal dashed lines denote Class 1 sound level meter atmospheric condition limits, periods in outside of the respective limits are bolded.*

## 4.2 WIND TURBINE PRODUCTION

The average wind turbine power production and hub-height wind speed for all three monitoring periods is plotted in Figure 13 for all 20 turbines within 2.8 km (1.75 miles) of the monitoring locations.

Wind turbine power production and hub-height wind speed are separated into parallel panes in each figure. Nighttime periods (10 PM to 7 AM) are indicated with the vertical gray shading. The vertical dashed lines delineate the three distinct monitoring periods.

The first pane of the plot shows wind turbine power production. The 10-minute power production data collected by the Project's SCADA system was scaled to the percentage of its maximum power output. In this way, the GE 2.1-116 (with a maximum power output of 2.1 MW) and the GE 2.3-116 (with a maximum power output of 2.3 MW) can be aggregated together on the same scale. For readability on the plot, the scaled 10-minute data power production data was then aggregated into one-hour averages for each turbine. These hourly values were than averaged across all 20 wind turbines included in the study. The horizontal dotted line at 85% of maximum power production represents the wind turbine power production associated with sound emissions within 1 dB of maximum sound power output: the target compliance condition (see Section 1.3).

The second pane of the plot shows hub height wind speed and wind direction for the complete monitoring study. Wind speed is shown as the mean of all 20 study turbines; the range of measured values at the 55 turbines is represented by the light gray shading that follows the wind speed line. The wind direction data are plotted in an identical manner to those of Figure 12: using arrows pointing in the direction that the wind was blowing overlaid on the mean hourly wind speed and the orange dots (corresponding to the y-axis on the right) that represent the cardinal direction of the wind for that hour. The horizontal dotted line at 9 m/s (20.1 mph) represents the hub-height wind speed at which rated maximum sound power is achieved (according to manufacturer specifications). From the figure, it can be observed that when the power production is above 85% of maximum output, measured hub height wind speeds were most often above 9 m/s.

The first two monitoring periods experienced considerable wind and power production on most nights. The mean power production often exceeded the 85% threshold for maximum sound power production between November 18 and December 05. The third monitoring period was hampered by a couple days of low winds followed by extreme weather starting on December 12$^{th}$.

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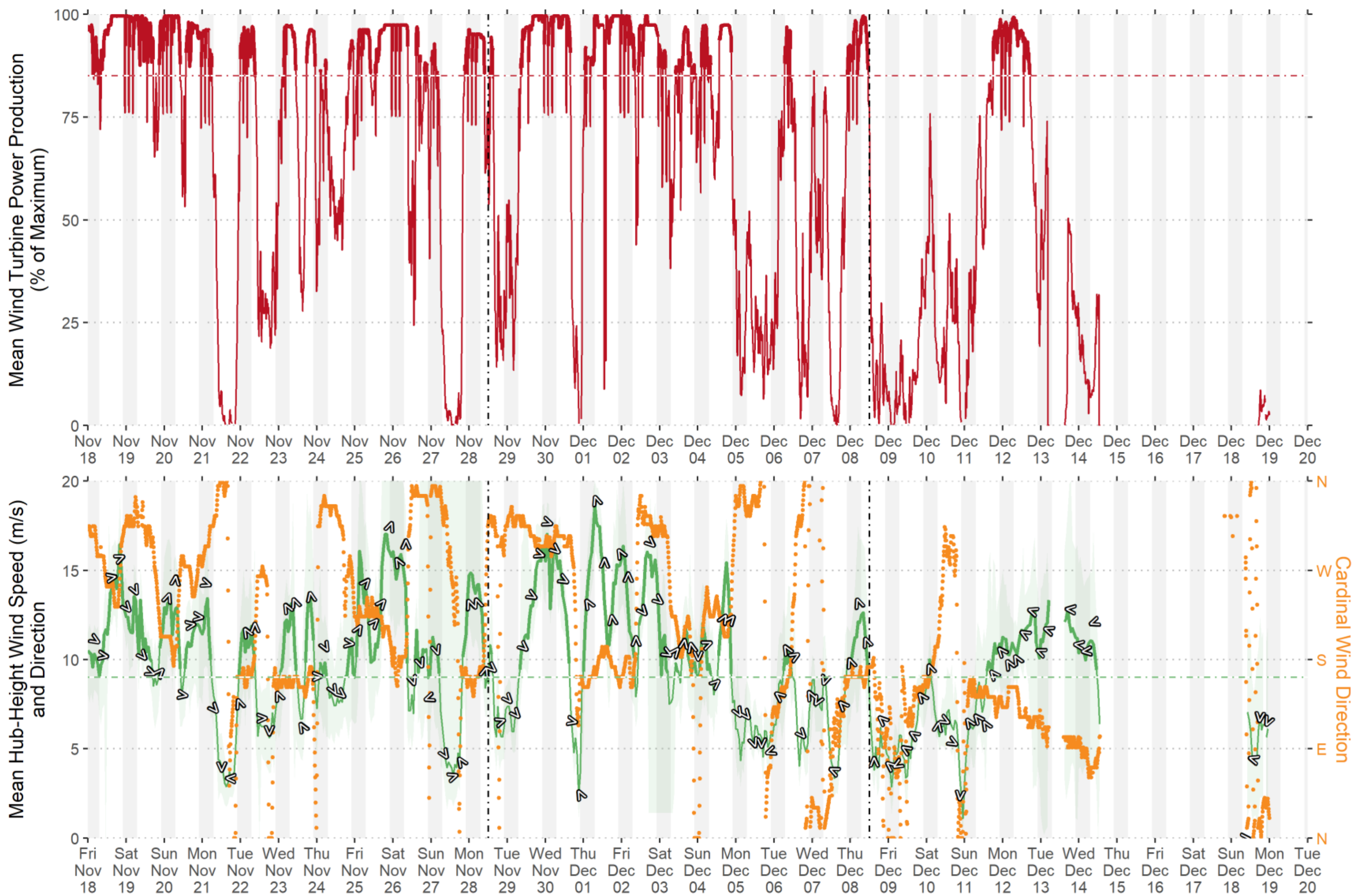


**FIGURE 13: WIND TURBINE SCADA DATA: POWER PRODUCTION, HUB HEIGHT WIND SPEED AND WIND DIRECTION (1-HOUR)**

## 4.3 MONITORING STATION RESULTS

This section provides an overview of the monitoring results. The time history plots portray the results of the full monitoring period, leveraging all available data (wind turbine power production, sound, and wind), lending context to the compliance results.

### Overview

The first monitoring period spanned from November 18 to 28. The second monitoring period spanned from November 28 to December 8. An intermittent power failure of the sound level meter at LT2 led to data loss at the LT2 monitoring station, most notably during the second monitoring period. To collect the sufficient data (at least 14 days), monitoring and recurring shutdowns were extended at LT2 through December 19, 2022. Monitoring at LT6 was also extended through this date at the request of the complainant (and subsequently relayed by SD PUC staff and reiterated by their noise consultant)[16] to study the influence of the specific monitoring location. The sound level monitors detailed in this study were sited as described in the Permit and the Protocol, which were the same locations as the Post-Con Study. Results from the third monitoring period at LT6 are included herein but the comparative results for LT6 and the alternate location are discussed in a separate [forthcoming] report.

Note that ANSI S12.9-2013/Part 3, Section 6.3(b) does not recommend utilizing sound level data with any winds above 5 m/s (e.g. 1-minute gusts). As a result, the data contains a great deal of direct wind-generated pseudo-sound. Wind-caused pseudo-sound is an artifact of the wind interaction with the microphone and is not sound that would actually be experienced by a listener.

### Time History Plots

#### *Description*

Each figure combines three panes of relevant data, including wind turbine power production, sound levels, and meteorology. Time runs consecutively along the x-axis (from left to right). The labeled dates represent the beginning of each day; dotted vertical lines through each plot delineate midnight and noon. Nighttime periods (10 PM to 7 AM) are indicated in each pane by vertical grey shading. All data collected are presented by monitoring period for each monitor.

The top pane shows the 10-minute wind turbine power production in percentage of maximum output. Production from the closest turbine is displayed in red and the range of the other turbines within 1.75 miles is shown as the light red shading outlined in black. Turbine shutdowns on nights with full power production are visible as nearly vertical red lines.

The middle pane provides the aggregated (10-minute) overall sound levels and wind results. The solid dark grey line is the 10-minute A-weighted Leq. The shading surrounding the sound level traces represent the range of statistical sound levels for each 10-minute period ($L_{10}$ to $L_{90}$).

[16] Emails from Public Liaison Officer (Brian Rinker) and SD PUC Staff Noise Consultant (David Hessler), November 22, 2022.

Periods when the $L_{eq}$ lines are blank indicate exclusions. The cause of the exclusion is denoted by the colored points (yellow, blue, pink, and red) corresponding to the type of exclusion (i.e., anomaly, precipitation, high wind, wind-induced noise, respectively). Note that the "raw" $L_{10}$ and $L_{90}$ range are still plotted during excluded periods for context and continuity. Average and gust wind at ground-level, along with hub height wind speed are plotted as 10-minute data in miles per hour. The horizontal red dashed line corresponds to wind speed exclusion threshold of 11.2 mph (5 m/s).

The third pane provides regional precipitation, relative humidity, and temperature for the monitoring period. The light blue shading denotes periods when precipitation was measured regionally. Relative humidity and temperature presented was measured at LT2. When data were unavailable, data from the nearby ASOS station were utilized to fill in the missing data. The relative humidity (90%) and temperature (10˚C/-14˚F) thresholds for Class 1 sound level meter operation are indicated as dashed horizontal lines on the plot; periods that do not comply with Class 1 environmental conditions are bolded.

### *LT2*

Time history results at LT2 are plotted in Figures 14, 15, and 16 for the first, second, and third monitoring periods, respectively.

The correlation between wind and sound level at LT2 is particularly apparent in the first monitoring period (Figure 14). Following the first two nights that were dominated by direct wind noise, shutdowns are visible in the overall 10-minute data on most evenings. Spikes in daytime sound level were most often from nearby anthropogenic activity (vehicles or aircraft). At night, during periods of full wind turbine power production, the sound levels can generally be seen to be nearly 40 dBA and drops to 30 dBA or below during the shutdowns. Additionally, interruptions in data logging due to intermittent power failures are evident in the first period on night ending November 21, the morning of November 23, and the morning of November 26th. It was determined that these power failures, and the terminal failure in the second monitoring period (Figure 15) were caused by excessive consumptive load of the sound level meter and its peripheral equipment. Although the power system was charged by a small interconnected solar panel on sunny days, the power generation could not keep up with the unexpected increase in power draw from the monitoring station. The issue was not discovered until after the first checkup on November 28. As a result, the sound level meter failed during the second monitoring period and was then redeployed with a more reliable power system for the third monitoring period (Figure 16). Despite these issues, 171 valid compliance periods were recorded at LT2 (159 in the first monitoring period).

High winds in the first several days of the second monitoring period (Figure 15) precluded much useful information to be extracted from the second monitoring period at LT2. The third monitoring period (Figure 16) achieved conditions aligning with the target evaluation periods only during the day of December 8 and the night ending on December 12 before excessive winds prevailed (nine total 10-minute valid compliance periods in the third monitoring period).

### *LT3*

The time history results for LT3 are provided in Figure 17 (first monitoring period) and Figure 18 (second monitoring period).

The soundscape at LT3 was dominated by an intermittently operated heating system, farm operations, wind turbine noise, and wind. The sound level from the heating system at the monitor was about 45 dBA. Extensive exclusions of the heating system operating at night were necessary to allow the recorded sound level data to be utilized in the study. Periods with the heating system excluded are evident by the lack of spikes in the black $L_{eq}$ trace at night compared to other time periods.

During the first monitoring periods (Figure 17), shutdowns are visible in the 10-minute time history data on most nights, with total sound levels typically between 35 and 40 dBA when wind turbines were operating at full capacity and background sound levels below 30 dBA. The correlation of hub height wind speed to sound level is most notable on November 25 and November 26. Periods of elevated sound levels due to wind were common the first several days and nights of the second monitoring period (Figure 18). Shutdowns are most evident on the nights ending on December 4 and December 8. A total of 191 valid compliance periods were recorded at LT3 (141 in the first monitoring period).

### *LT6*

Time history results for LT6 are presented in Figures 19, 20, and 21 for the first, second, and third monitoring periods, respectively.

At LT6, traffic on US Highway 212 is evident, particularly during the day, as a major sound source at the monitor due to the consistent difference of 10 dB or more between the $L_{10}$ and $L_{90}$. Large differences between these metrics indicates that sporadic (i.e., transient) sources of sound are common on the soundscape. Due to traffic noise, daytime shutdowns were typically masked by consistent traffic. Shutdowns were reviewed extensively, with vehicular traffic and excessive wind excluded during periods of high wind turbine production as encountered.

Shutdowns are clearly observable on most nights during the first monitoring period (Figure 19), with the highest total sound levels approaching 45 dBA on the nights ending on November 20 and November 26. In the second monitoring period (Figure 20), no average 10-minute wind speeds above 5 m/s were observed but gusty ground level wind speeds and strong winds aloft were notably correlated with sound levels at LT6. Due to the periods excessive wind, wind turbine shutdowns are observable on the nights ending on December 2 (total sound level approaching 45 dBA) and December 4 (less than 40 dBA total). The third monitoring period (Figure 21) saw target wind turbine operation conditions on the night ending on December 10 and December 12. The severe snow and ice storm that began on December 12 left the wind turbines shut down and resulted in a tree branch falling and knocking off the microphone’s wind screen on December 15. The second half of the third monitoring period was acoustically invalid. A total of 208 valid compliance periods were recorded at LT6 (163 in the first monitoring period).

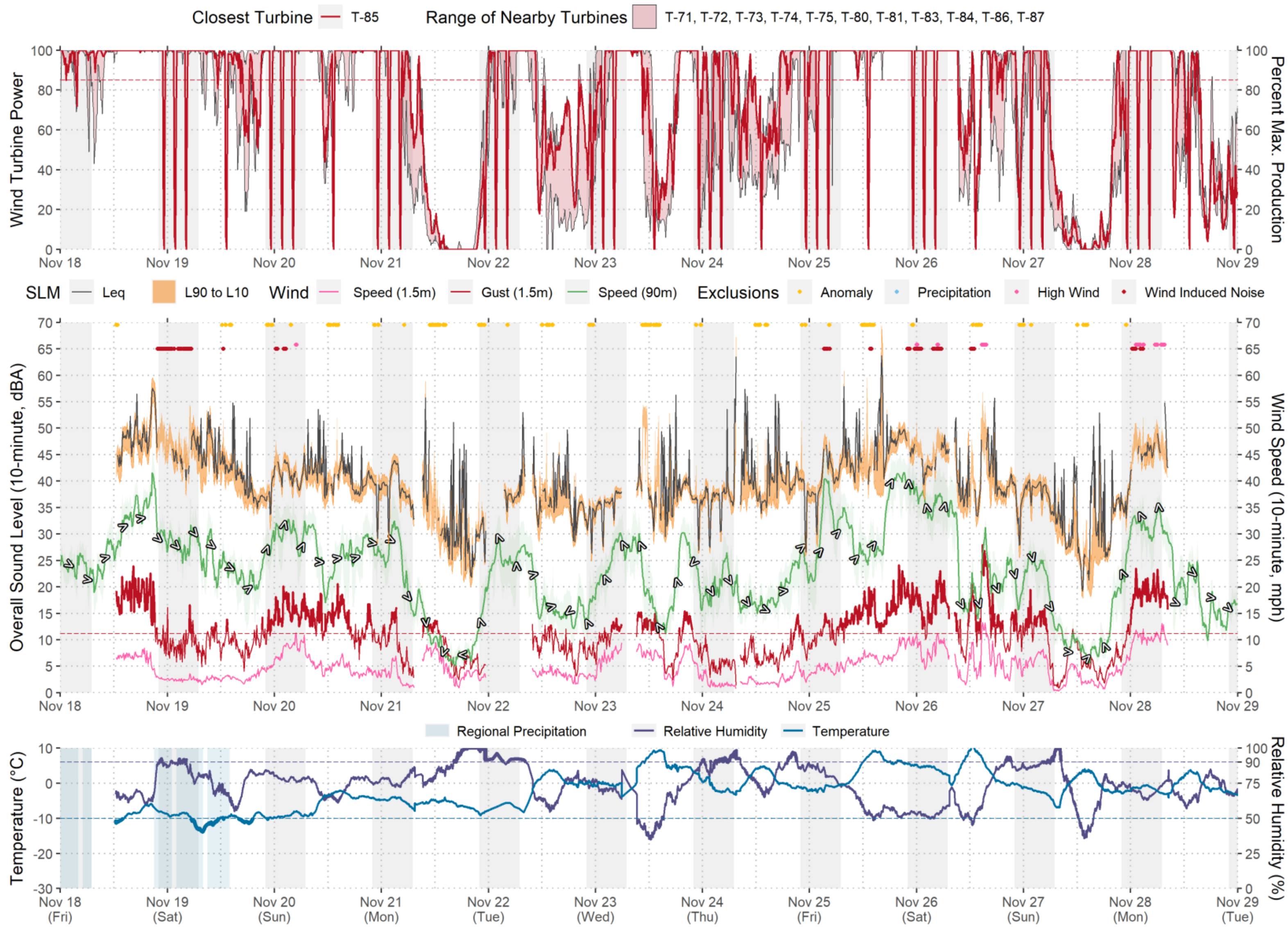


**FIGURE 14: LT2 MONITOR – MONITORING PERIOD 1 – TIME HISTORY PLOT – 2022**

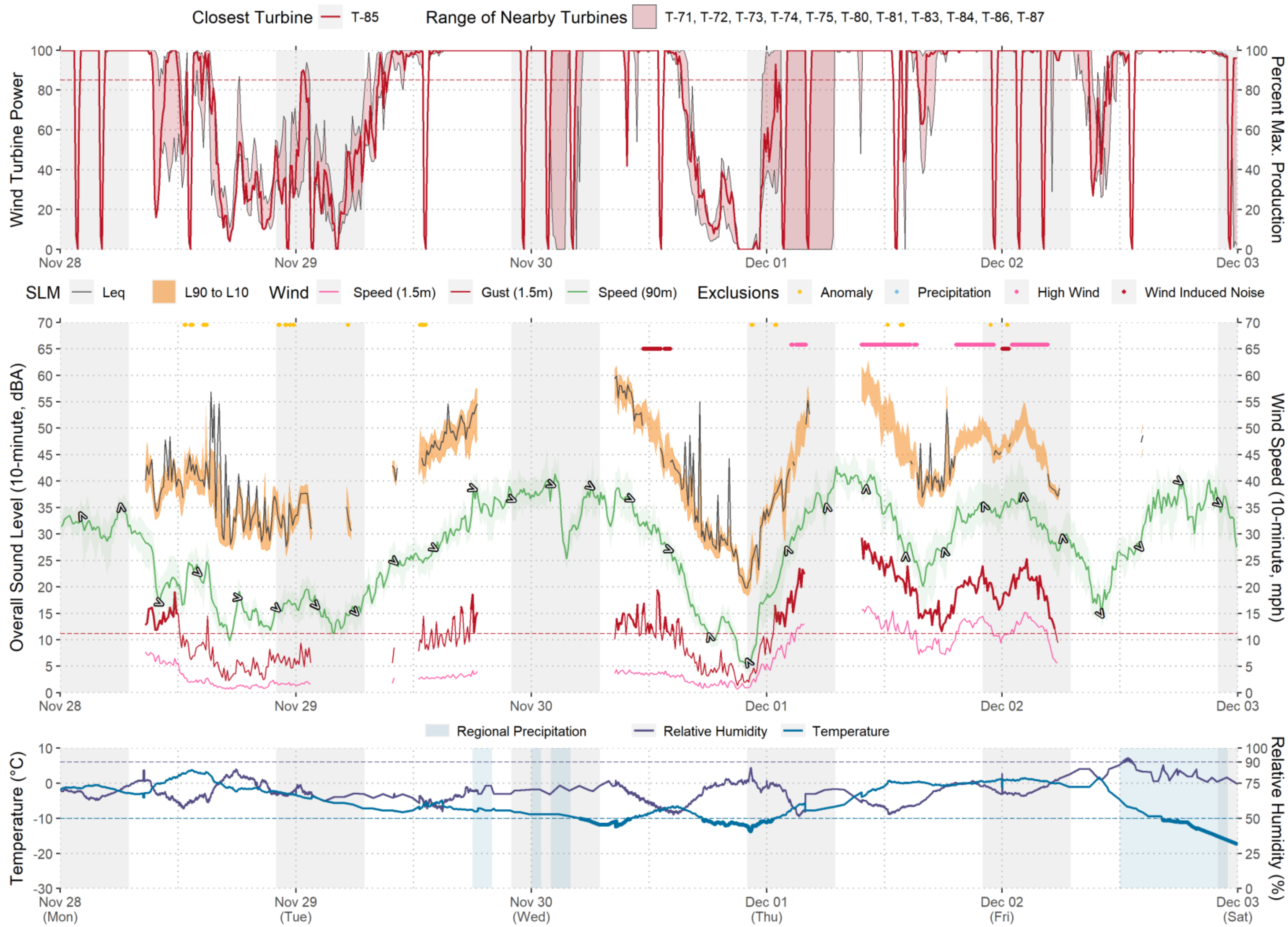


**FIGURE 15: LT2 MONITOR – MONITORING PERIOD 2 – TIME HISTORY PLOT – 2022**

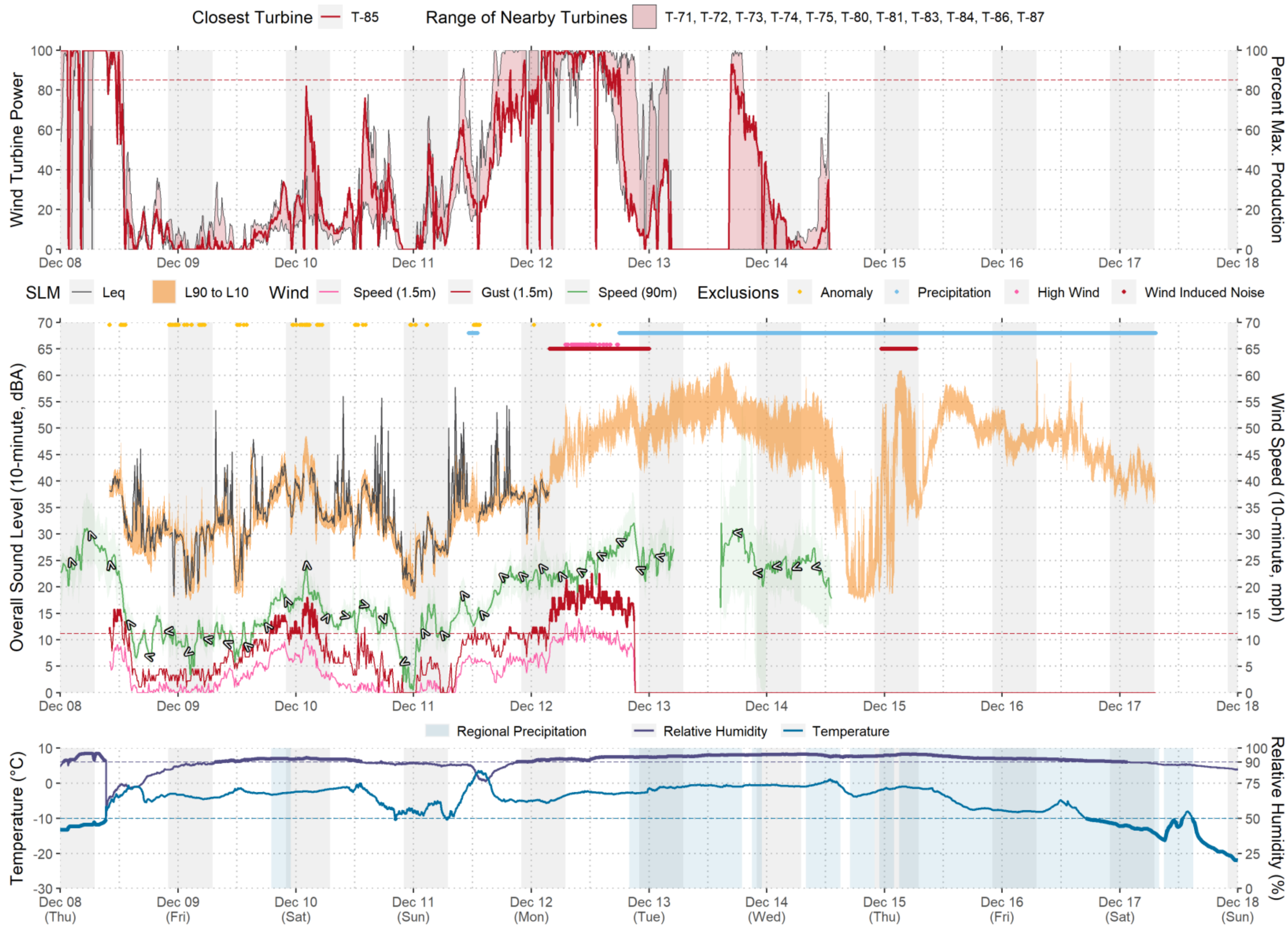


**FIGURE 16: LT2 MONITOR – MONITORING PERIOD 3 – TIME HISTORY PLOT – 2022**

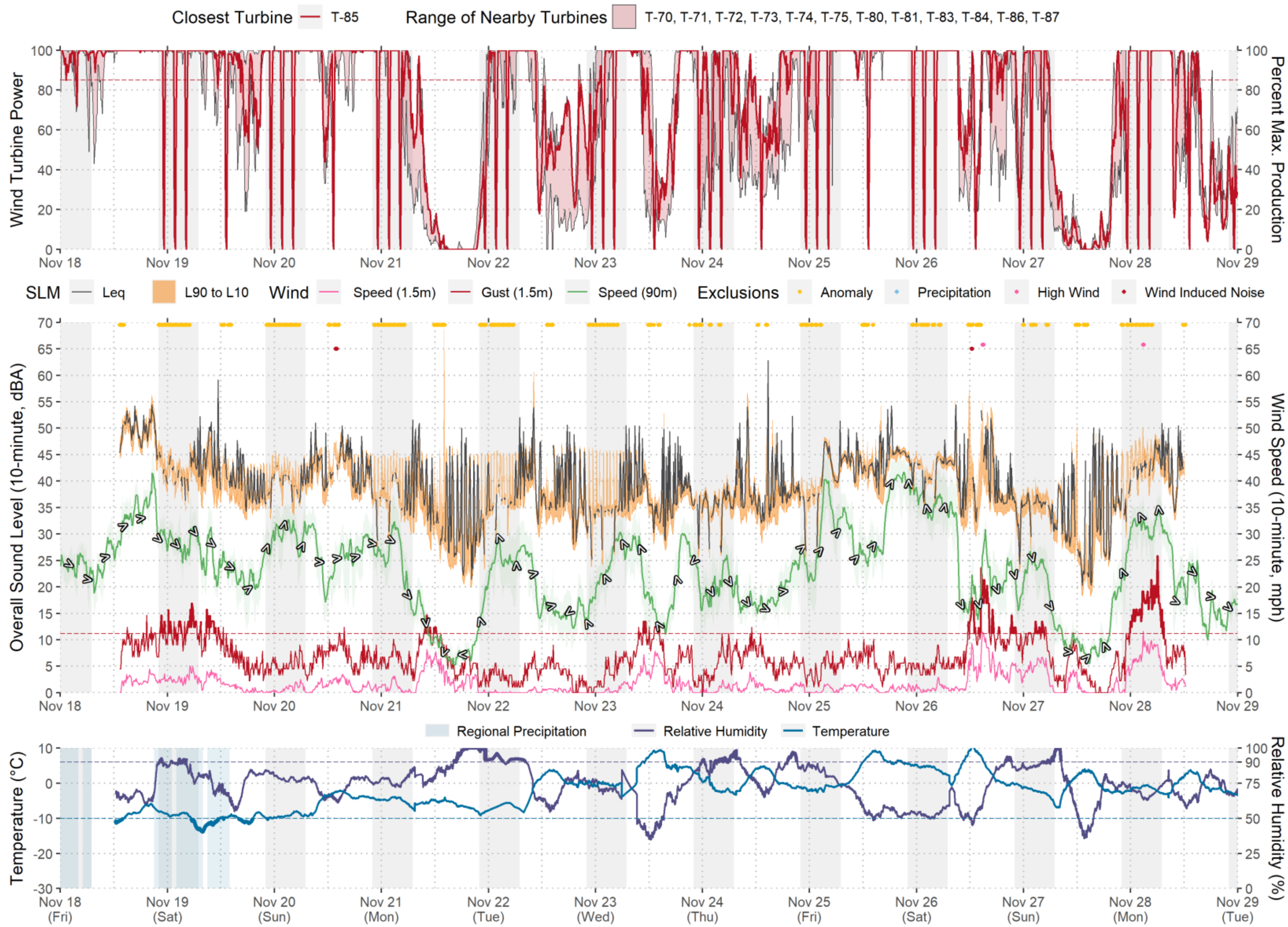


**FIGURE 17: LT3 MONITOR – MONITORING PERIOD 1 – TIME HISTORY PLOT – 2022**

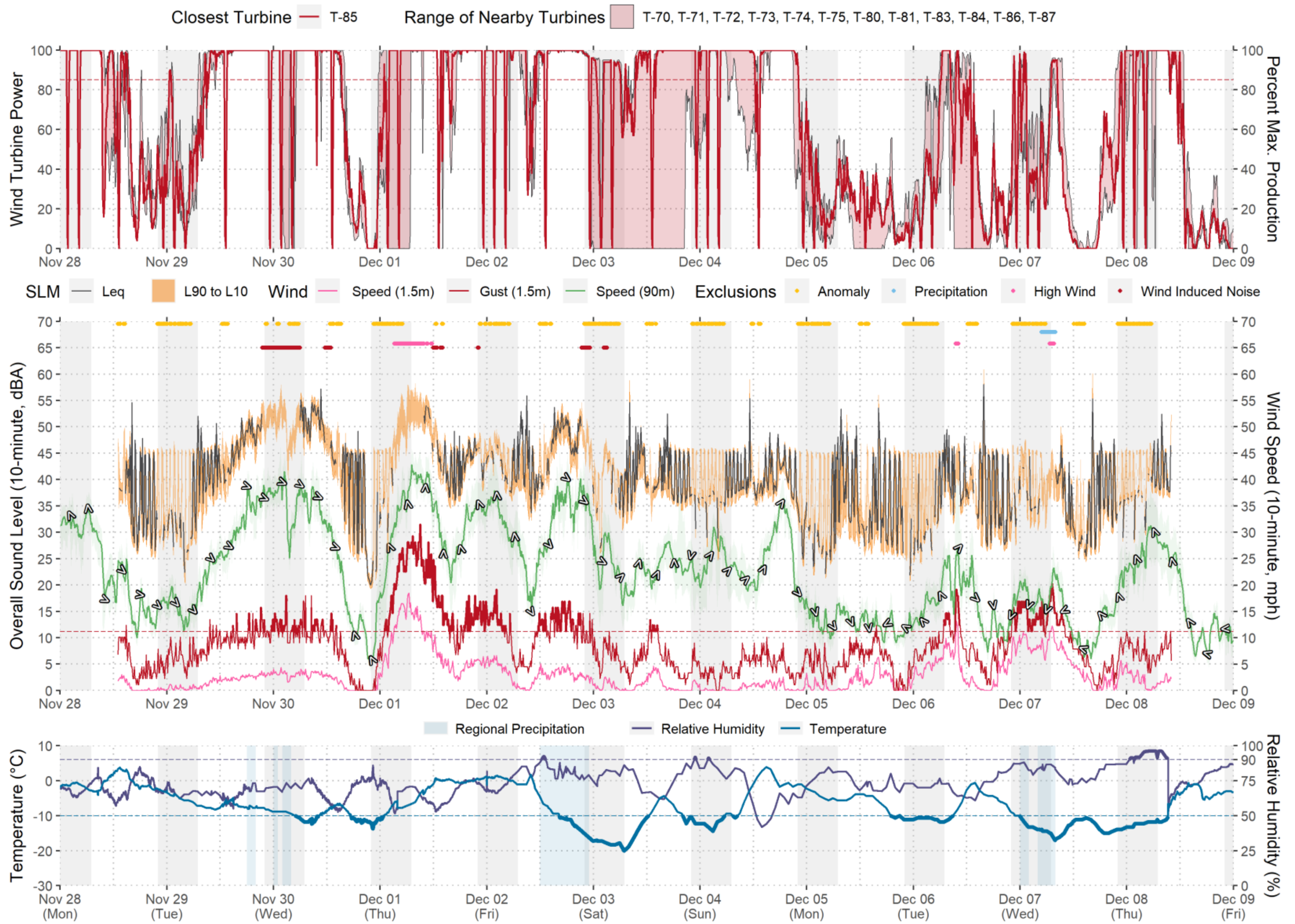


**FIGURE 18: LT3 MONITOR– MONITORING PERIOD 2 – TIME HISTORY PLOT – 2022**

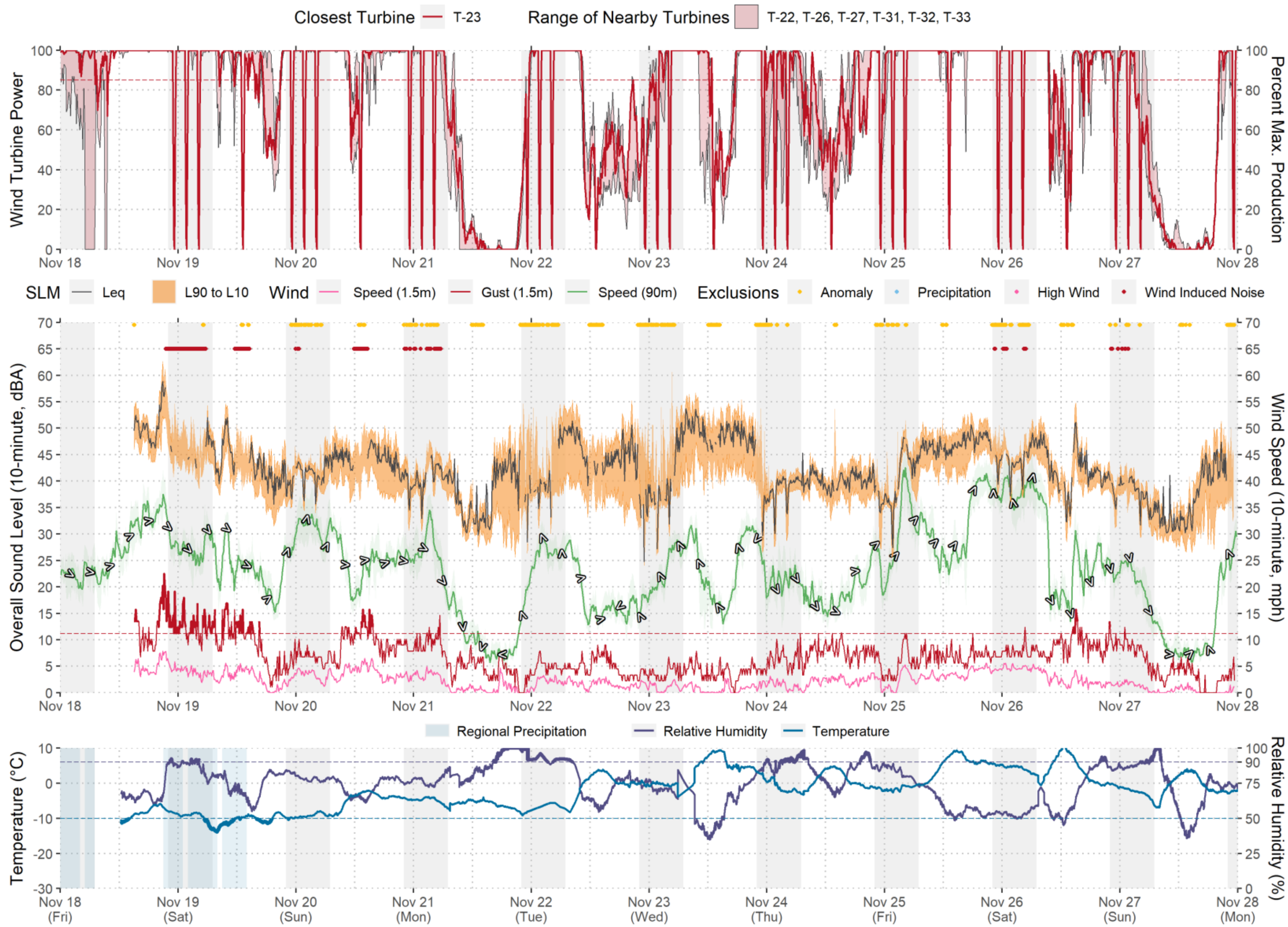


**FIGURE 19: LT6 MONITOR– MONITORING PERIOD 1 – TIME HISTORY PLOT – 2022**

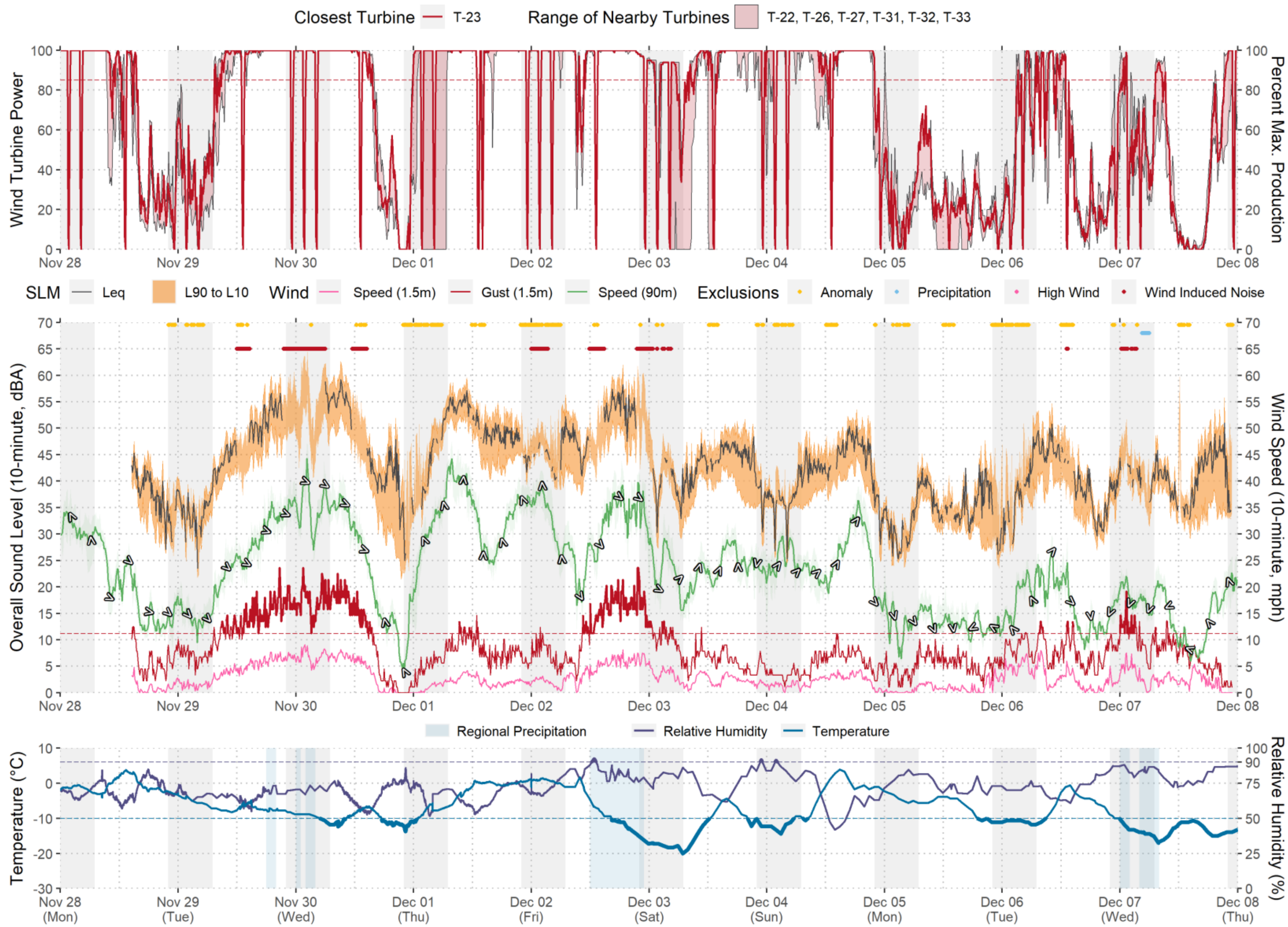


**FIGURE 20: LT6 MONITOR– MONITORING PERIOD 2 – TIME HISTORY PLOT – 2022**

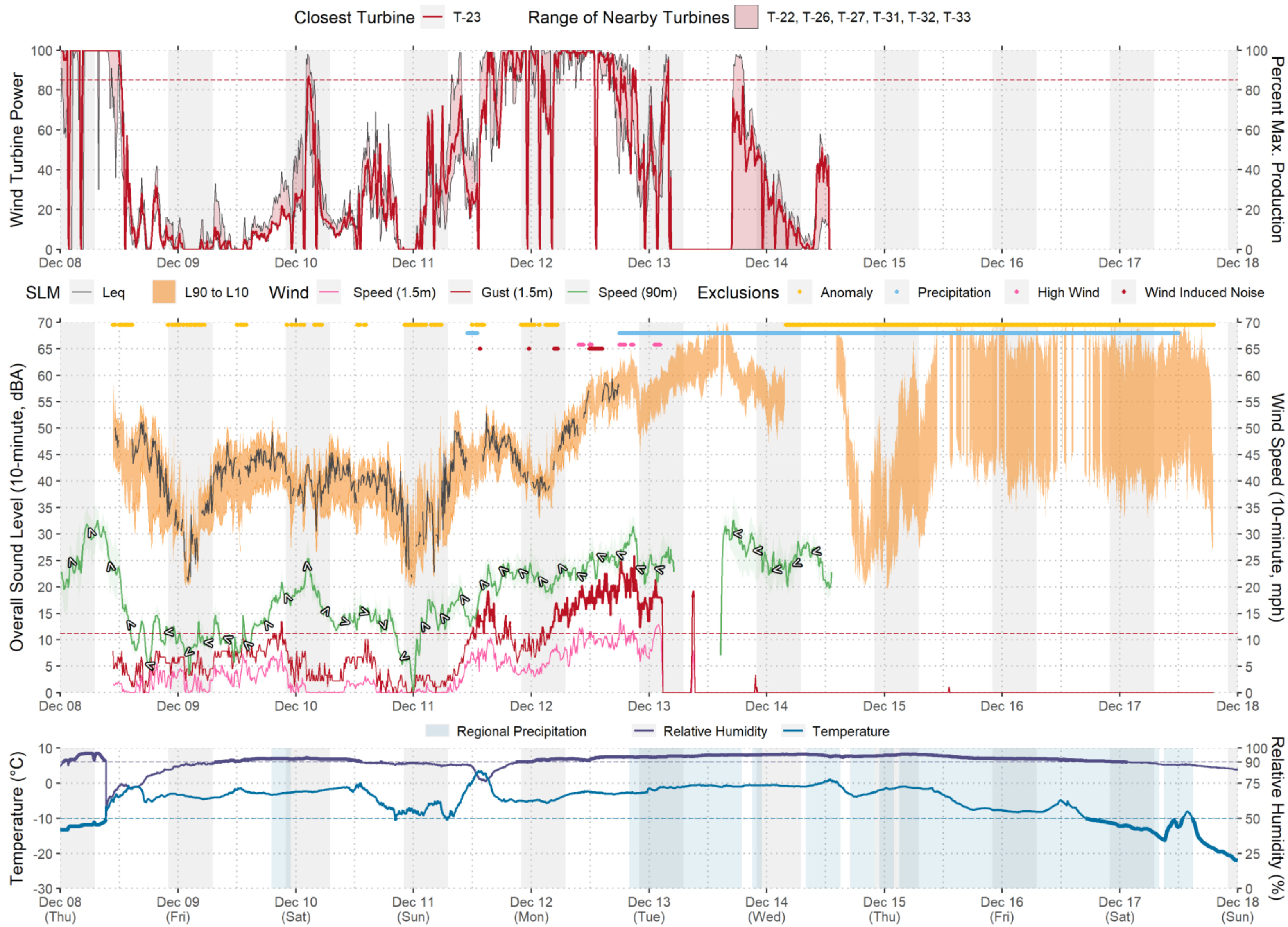


**FIGURE 21: LT6 MONITOR– MONITORING PERIOD 3 – TIME HISTORY PLOT – 2022**

# 5.0 NOISE COMPLIANCE ASSESSMENT

## 5.1 SHUTDOWN OVERVIEW

As noted in the previous sections, wind turbines were shut down periodically to obtain an accurate measure of background sound levels in order to calculate the contribution of the to the measured Project sound levels. One hour of wind turbine operation before and after each shutdown were analyzed, resulting in twelve 10-minute turbine operation periods at each monitor for each shutdown. A diagram of an example overall sound level time history plot in Figure 22 defines the convention given for referring to each evaluation period.

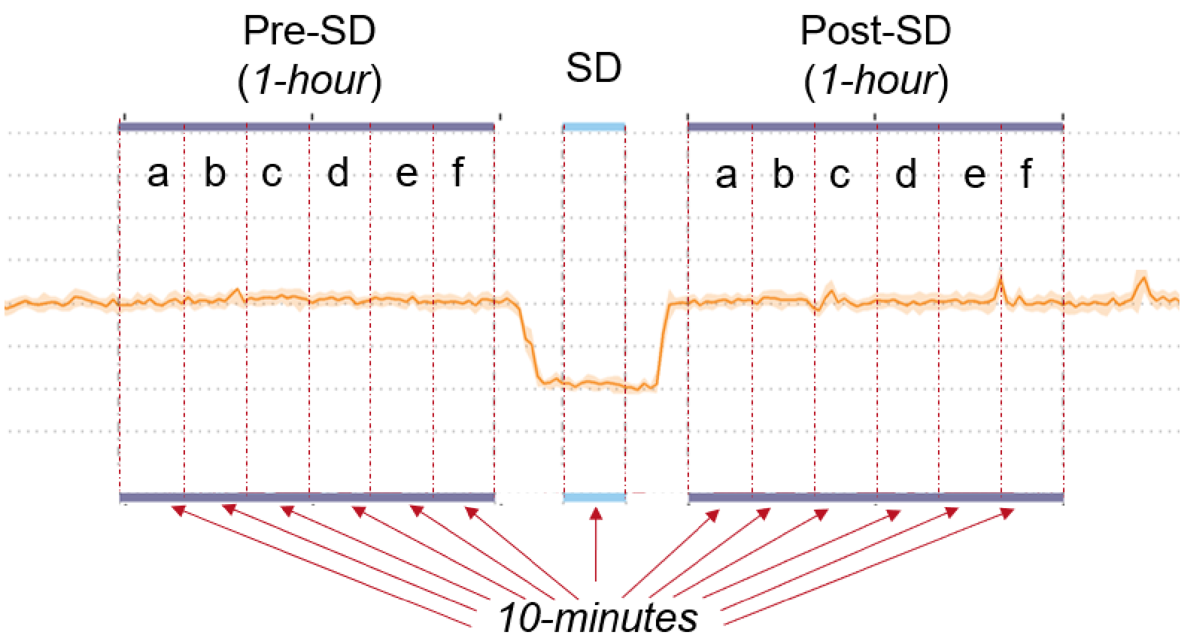


**FIGURE 22: DIAGRAM OF A SOUND LEVEL (Y-AXIS) TIME HISTORY DEMONSTRATING THE CONVENTION FOR IDENTIFYING EVALUATION PERIODS SURROUNDING A TURBINE SHUTDOWN ("SD").**

## 5.2 SHUTDOWN COUNT

One hundred wind turbine shutdowns were performed between November 18 and December 13. Each shutdown provided the opportunity to assess up to twelve 10-minute periods of wind turbine noise, resulting in 1200 potential periods.

As shown in Table 5, about half of these periods had the target conditions specified in the Permit and less than half of those were valid compliance periods, that is, they had sufficient acoustically valid data with the target operating conditions. Finally, each monitor registered between 171 and 208 10-minute valid compliance periods with adequate signal-to-noise ratio (3 dB)[17] between the background and total sound level. A low signal-to-noise ratio means that the received sound of a source (wind turbines in this case) is masked by background sound and an accurate assessment of wind turbine-only sound level cannot be made.

**TABLE 5: COUNTS OF 10-MINUTE PERIODS FOR ASSESSING WIND TURBINE NOISE**

| MONITOR | POTENTIAL PERIODS | PERIODS WITH TARGET OPERATING CONDITIONS | VALID COMPLIANCE PERIOD | |
|---|---|---|---|---|
| | | | ACOUSTICALLY VALID | ADEQUATE SIGNAL TO NOISE RATIO |
| LT2 | 1200 | 656 | 215 | 171 |
| LT3 | | 606 | 239 | 191 |
| LT6 | | 689 | 275 | 208 |

[17] The signal-to-noise ratio refers to the arithmetic difference between the total sound level and the background sound. The minimum signal-to-noise ratio for a valid calculation, on a 1/3 octave band basis, is 3 dB (per ANSI S12.9 Part 3). Although turbine-only levels were calculated on a 1/3 octave band basis, a 3 dB signal-to-noise ratio was also required for overall sound levels; the highest wind turbine-only sound levels were found for periods with an adequate signal-to-noise ratio.

## 5.3 SHUTDOWN RESULTS

This section provides the maximum apparent wind turbine-only levels calculated in addition to the average and expected wind turbine-only sound levels calculated at each monitor.

### Wind Turbine-only Sound Levels

A summary of the expected and observed overall A-weighted values from the Project at each complaint location is computed in Table 6. The mean wind turbine-only sound levels for valid compliance conditions were about 2 dB below the modeled value at each monitor. Including results with a poor signal to noise ratio biased the average turbine-only sound level lower by up to 3 dB. Data exceptions (i.e., relative humidity and temperature extremes) were not present during periods with elevated wind-turbine sound levels.[18] The discrete valid compliance periods with wind turbine sound levels at and above 40 dBA are tabulated in Appendix C. A total of 47, 47, and 76 periods met these criteria at LT2, LT3, and LT6, respectively.

Despite the average sound levels being comparable between this 2022 Noise Complaint Study and the Post-Con Study, the maximum wind-turbine only values obtained were categorically different. The remaining portion of this section details the elevated sound levels observed.

**TABLE 6: MODELED PROJECT-ONLY WIND TURBINE-ONLY SOUND LEVEL (dBA) COMPARED TO THE ARITHMETIC AVERAGE AND MAXIMUM WIND TURBINE-ONLY $L_{eq}$ FROM THE TURBINE SHUTDOWN ANALYSIS AT EACH MONITOR.**

| MONITOR | MODELED | MEAN $L_{eq10min}$ | | MAX $L_{eq10min}$ | |
|---|---|---|---|---|---|
| | PRE-CON | POST-CON | COMPLAINT | POST-CON | COMPLAINT |
| | 2020 | 2021 | 2022 | 2021 | 2022 |
| LT2 | 42.4 | 37.5 | 38.2 | 42.6 | 44.2 |
| LT3 | 41.4 | 35.6 | 37.7 | 40.3 | 45.0 |
| LT6 | 41.7 | 40.2 | 38.9 | 44.3[19] | 44.9 |

[18] Excluding periods where relative humidity and temperature did not meet Class 1 accuracy specifications, the average reported sound levels increased between 0.2 and 0.6 dB.
[19] The maximum turbine-only sound level at LT6 from the Post-Con Study included contaminating sound. From a cursory review of the results from the Post-Con study, the maximum wind turbine contribution at LT6 in from the Post-Con study was likely, more realistically, 41 or 42 dBA.

### *Maximum Wind Turbine-only Sound Levels*

Table 7 lists the maximum wind-turbine only level calculated for each monitor. The measured background $L_{eq10min}$, measured total $L_{eq10min}$, and shutdown reference number associated with the highest calculated turbine-only level for each monitor are provided. Shutdown reference numbers follow the convention established in Figure 22. Detailed time history charts and 1/3 octave band results for the maximum turbine-only sound level for each evaluation period listed in Table 7 are provided in Appendix B.

Table 7 suggests that all complaint monitors can experience wind turbine sound levels at or within 0.8 dB of the 45 dBA limit. The detailed charts in Appendix B reveal that the wind turbine-only sound levels reported for the discrete periods in Table 7 were attributable to the Project. Notably, these periods of elevated sound levels occurred during high wind shear conditions, in which winds aloft were significantly stronger than winds on the ground. For example, a 10-mph ground wind speed compared to 35 mph hub height wind speed would be considered high wind shear. The Project was observed to exhibit elevated sound levels during these periods. The available audio of these periods that was reviewed confirmed strong wind (wind through the trees and across the microphone) and amplitude-modulated wind turbine noise. Amplitude modulation[20] was not explicitly observed in the Post-Con Study. Elevated sound levels were measured under various wind directions; periods downwind from the nearest turbine were uncommon at most sites.

The number of valid compliance periods above the expected sound level (rounded to 42 dBA for all complaint monitors) was 15, 20, and 30 periods at LT2, LT3, LT6, respectively.[21] From the 1200 ten-minute survey period, this represents about 2.5% of the sample.[22] Calculated wind-turbine only sound levels were above the modeled sound levels from the Pre-Construction Study (but remained within the noise limit) in about 5% of the periods with the target wind turbine operating conditions. All elevated wind turbine-only sound level results under valid compliance conditions (> 42 dBA) had acceptable overall signal-to-noise ratios.

**TABLE 7: MAXIMUM WIND TURBINE-ONLY $L_{eq10min}$ (dBA) WITH CORRESPONDING TOTAL AND BACKGROUND SOUND LEVELS AND EVALUATION PERIOD IDENTIFICATION NUMBER.**

| MONITOR | MAXIMUM CALCULATED $L_{eq}$ | MEASURED $L_{eq}$ | | EVALUATION PERIOD ID |
|---|---|---|---|---|
| | Turbine-only | Background | Total | |
| LT2 | 44.2 | 42.6 | 46.7 | SD027_PreSD-f |
| LT3 | 45.0 | 39.7 | 46.1 | SD053_PreSD-d |
| LT6 | 44.9 | 38.1 | 45.7 | SD031_PostSD-a |

20 Amplitude modulation is a repetitive broadband sound (with more low- to mid-frequency content than high-frequency content) produced by wind turbines under conditions of high wind shear, blade imbalance, and/or yaw error, among other factors. See Appendix A for additional information.
21 Exclusions for anomalous and transient sounds were not necessarily removed from periods with total sound level below 45 dBA.
22 It is certainly possible that elevated sound levels from the Project occurred during periods of excessive wind and other interfering background sound but it was otherwise indistinguishable

# 6.0 CONCLUSION

This report describes a sound level monitoring study performed at the Crowned Ridge II Wind Farm (the "Project" or "CRWII") to determine whether the Project complies with the wind turbine only limit of 45 dBA $L_{eq10min}$ at three residences that have registered formal complaints about the Project.

Wind turbines were shut down four times per day (once at midday and three times at night) to obtain an accurate measure of background sound levels. Background sound levels provide context to the total noise on-site, which includes turbine operations and background sounds. A total of 100 shutdowns occurred for the study.

To assess compliance, calculated wind turbine-only sound levels were evaluated when target conditions were observed: all five nearest wind turbines operating and the closest wind turbine operating within 1 dB of maximum sound power emission.

The average wind turbine-only sound level for evaluation periods with the target compliance conditions were typically within 1 dB of the Post-Con Study (40 dBA or less). However, wind turbine-sound levels were found to be higher than in the Post-Con Study. The maximum wind turbine-only sound levels calculated for periods with the target operating conditions were at or less than 1 dB below 45 dBA $L_{eq10min}$ at all monitoring locations.

Sound levels attributable to the Project at or approaching the sound level limit were noted to contain amplitude modulated wind turbine noise. Amplitude modulation can occur under high wind shear conditions, i.e., when winds aloft much stronger than winds on the ground, producing a rhythmically fluctuating sound that increases the equivalent average magnitude of sound emissions. The phenomenon was confirmed by listening to the available audio recordings of some of the highest wind turbine-only sound levels obtained.

Although the presence of amplitude modulation was seen to increase the sound level over typical operation conditions (including those observed in the Post-Con Study), the wind turbine-only contribution to total sound was not found to be above 45 dBA. Thus, we reaffirm that the Project complies with the noise limits set forth in the Permit.

# APPENDIX A. NOISE 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”).[23] 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 23.

### *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.

[23] 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.

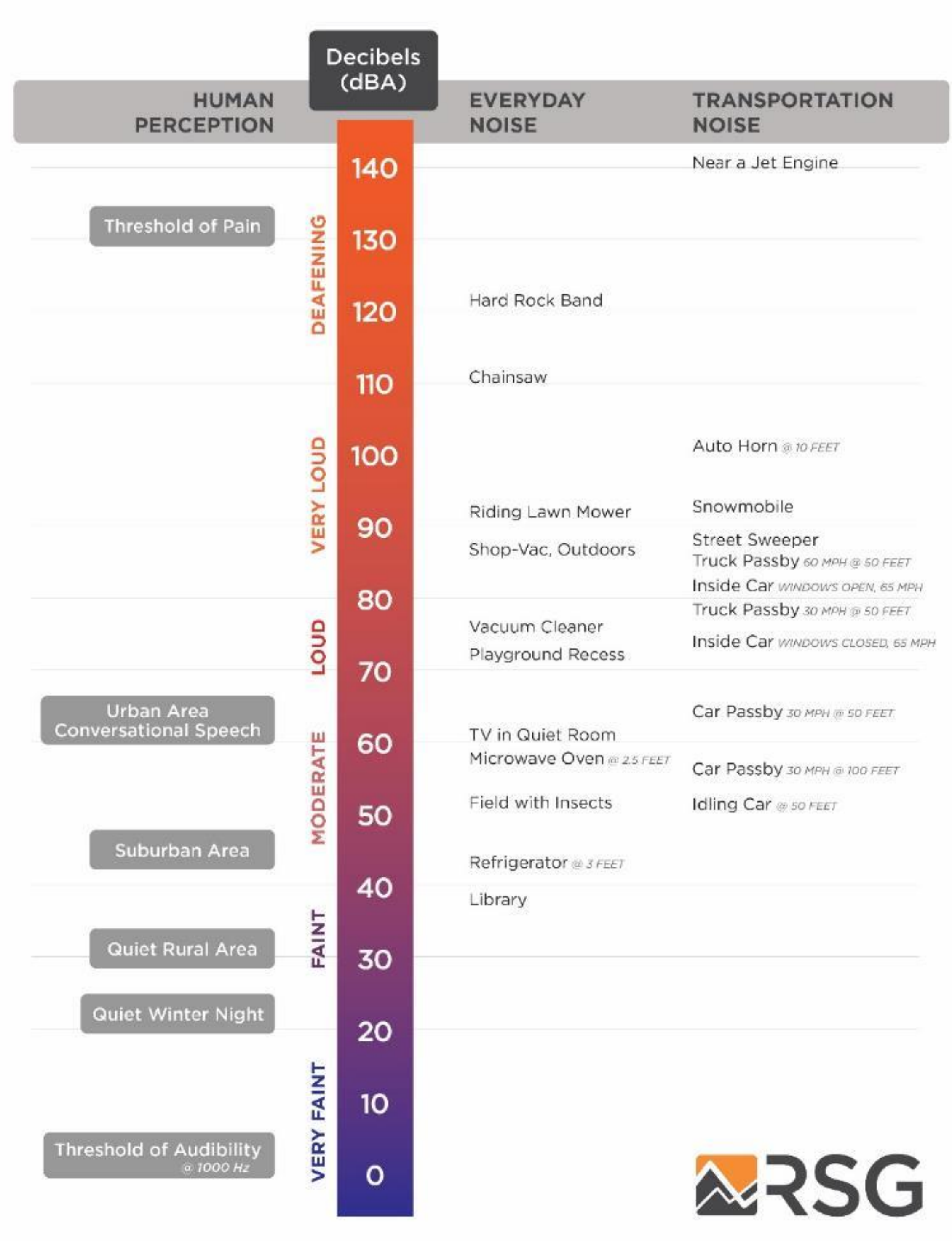


**FIGURE 23: A SCALE OF SOUND PRESSURE LEVELS FOR TYPICAL SOUND SOURCES**

### *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. G-weighting is a standardized weighting used to evaluate infrasound.

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.[24] 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 $L_{eq\ max}$.

### *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 24. 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 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.

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[24] 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.

### *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 24, 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.

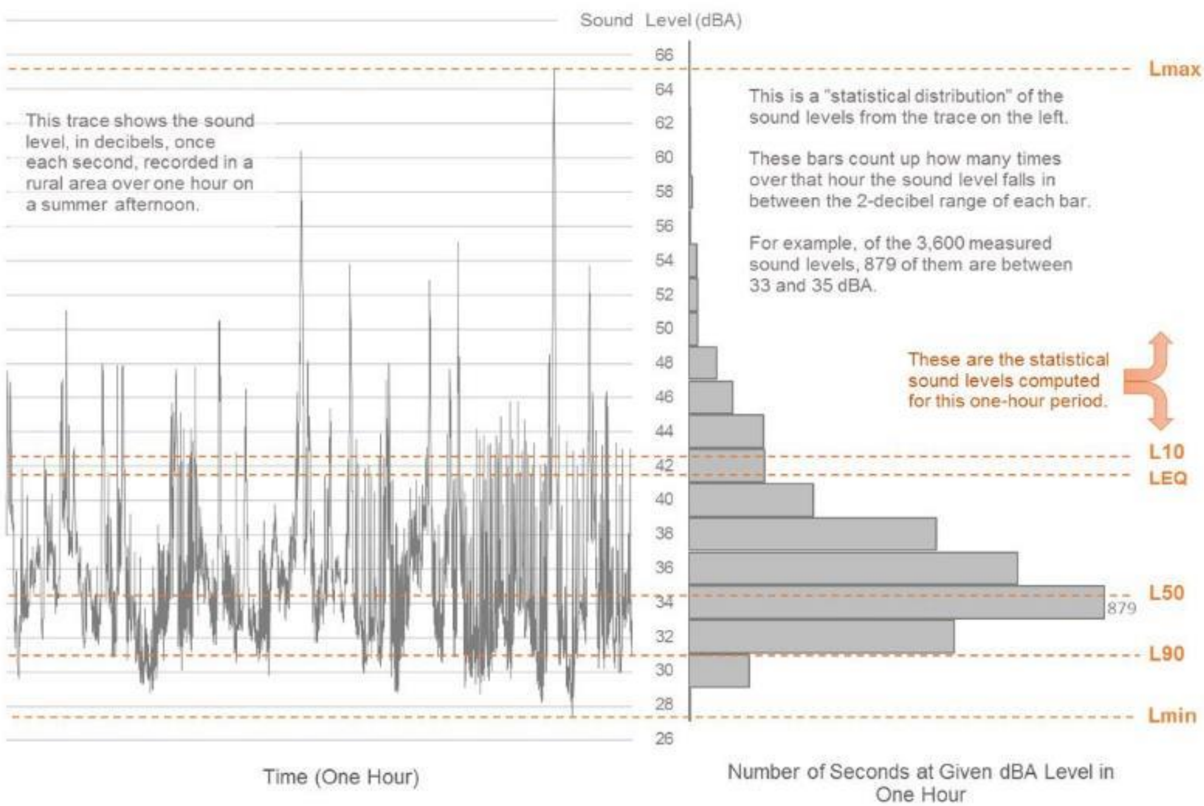


**FIGURE 24: EXAMPLE OF DESCRIPTIVE TERMS OF SOUND MEASUREMENT OVER TIME**

### *Percentile Sound Levels – Ln*

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. (the "median level") is exceeded 50% of the time: half of the time the sound is louder than , and half the time it is quieter than . Note that (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.

## Wind Turbine Noise

### *Sources of Sound Generation by Wind Turbines*

Wind turbines generate two principal types of noise: aerodynamic noise, produced from the flow of air around the blades, and mechanical noise, produced from mechanical and electrical components within the nacelle.

Aerodynamic noise is the primary source of noise associated with wind turbines. These acoustic emissions can be either tonal or broad band. Tonal noise occurs at discrete frequencies, whereas broadband noise is distributed with little peaking across the frequency spectrum.

While unusual, tonal noise can also originate from unstable air flows over holes, slits, or blunt trailing edges on blades. Most modern wind turbines have upwind rotors designed to prevent blade impulsive noise. Therefore, the majority of audible aerodynamic noise from wind turbines is broadband at the middle frequencies, roughly between 200 Hz and 1,000 Hz.

Wind turbines emit aerodynamic broadband noise as the spinning blades interact with atmospheric turbulence and as air flows along their surfaces. This produces a characteristic "whooshing" sound through several mechanisms (Figure 25):

- Inflow turbulence noise occurs when the rotor blades encounter atmospheric turbulence as they pass through the air. Uneven pressure on a rotor blade causes variations in the local angle of attack, which affects the lift and drag forces, causing aerodynamic loading fluctuations. This generates noise that varies across a wide range of frequencies but is most significant at frequencies below 500 Hz.
- Trailing edge noise is produced as boundary-layer turbulence as the air passes into the wake, or trailing edge, of the blade. This noise is distributed across a wide frequency range but is most notable at high frequencies between 700 Hz and 2 kHz.

- Tip vortex noise occurs when tip turbulence interacts with the surface of the blade tip. While this is audible near the turbine, it tends to be a small component of the overall noise further away.
- Stall or separation noise occurs due to the interaction of turbulence with the blade surface.

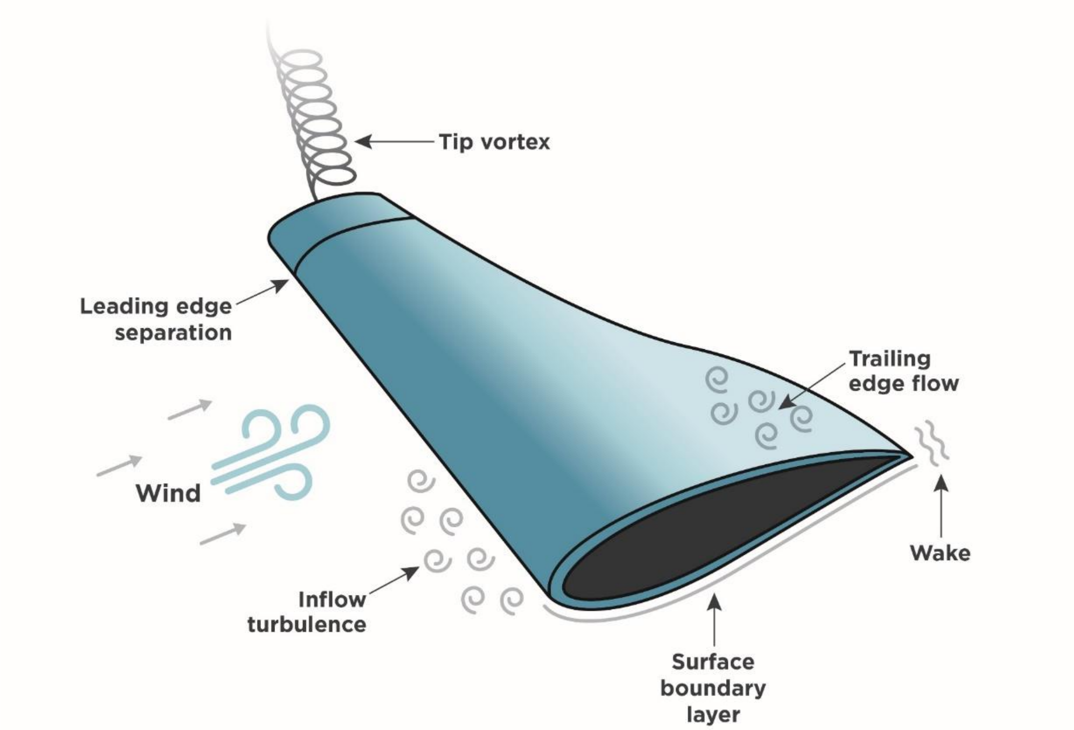


**FIGURE 25: AIRFLOW AROUND A ROTOR BLADE**

Mechanical sound from machinery inside the nacelle tends to be tonal in nature but can also have a broadband component. Potential sources of mechanical noise include the gearbox, generator, yaw drives, cooling fans, and auxiliary equipment. These components are housed within the nacelle, whose surfaces, if untreated, radiate the resulting noise. However modern wind turbines have nacelles that are designed to reduce internal noise, and rarely is the mechanical noise a significant portion of the total noise from a wind turbine.

### *Amplitude Modulation*

Amplitude modulation (AM) is a fluctuation in sound level that occurs at the blade passage frequency. No consistent definition exists for how much of a sound level fluctuation is necessary for blade swish to be considered AM, however sound level fluctuations in A-weighted sound level can range up to 10 dB. Fluctuations in individual 1/3 octave bands are typically more and can exceed 15 dB. Fluctuations in individual 1/3 octave bands can sometimes synchronize and desynchronize over periods, leading to increases and decreases in magnitude of the A-weighted fluctuations. Similarly, in wind farms with multiple turbines, fluctuations can synchronize and desynchronize, leading to variations in AM depth.[25] Most amplitude modulation is in the mid frequencies and most overall A-weighted AM is less than 4.5 dB in depth.[26]

Many confirmed and hypothesized causes of AM exist, including: blade passage in front of the tower, blade tip sound emission directivity, wind shear, inflow turbulence, and turbine blade yaw error. It has recently been noted that although wind shear can contribute to the extent of AM, wind shear does not contribute to the existence of AM in and of itself. Instead, there needs to be detachment of airflow from the blades for wind shear to contribute to AM.[27] While factors like the blade passing in front of the tower are intrinsic to wind turbine design, other factors vary with turbine design, local meteorology, topography, and turbine layout. Mountainous areas, for example, are more likely to have turbulent airflow, less likely to have high wind shear, and less likely to have turbine layouts that allow for blade passage synchronization for multiple turbines. AM extent varies with the relative location of a receiver to the turbine. AM is usually experienced most when the receiver is between 45 and 60 degrees from the downwind or upwind position and is experienced least directly with the receiver directly upwind or downwind of the turbines.

### *Meteorology*

Meteorological conditions can significantly affect sound propagation. The two most important conditions to consider are wind shear and temperature lapse. Wind shear is the difference in wind speeds by elevation and temperature lapse rate is the temperature gradient by elevation. In conditions with high wind shear (large wind speed gradient), sound levels upwind from the source tend to decrease and sound levels downwind tend to increase due to the refraction, or bending, of the sound (Figure 26).

With temperature lapse, when ground surface temperatures are higher than those aloft, sound will tend to refract upwards, leading to lower sound levels near the ground. The opposite is true when ground temperatures are lower than those aloft (an inversion condition).

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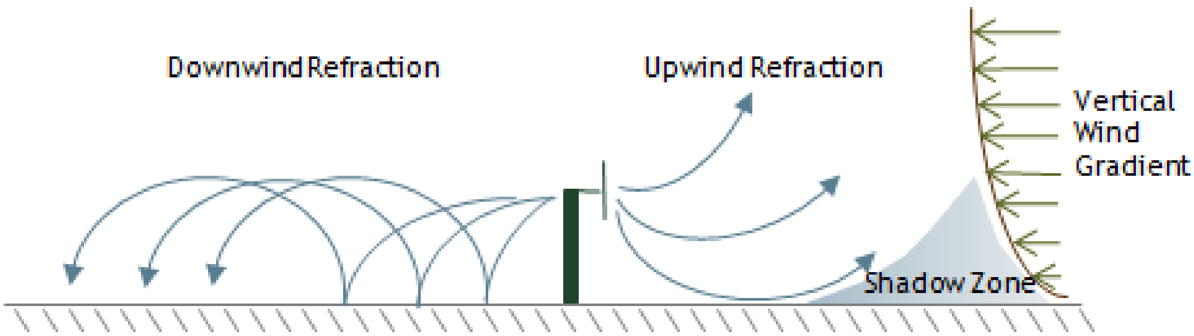
[25] McCunney, Robert, et al. "Wind Turbines and Health: A Critical Review of the Scientific Literature." *Journal of Occupational and Environmental Medicine.* 56(11) November 2014: pp. e108-e130.

[26] RSG, et al., "Massachusetts Study on Wind Turbine Acoustics," Massachusetts Clean Energy Center and Massachusetts Department of Environmental Protection, 2016

[27] "Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect." *RenewableUK.* December 2013.

High winds and high solar radiation can create turbulence which tends to break up and dissipate sound energy. Highly stable atmospheres, which tend to occur on clear nights with low ground-level wind speeds, tend to minimize atmospheric turbulence and are generally more favorable to downwind propagation.

In general terms, sound propagates along the ground best under stable conditions with a strong temperature inversion. This tends to occur during the night and is characterized by low ground-level winds. As a result, worst-case conditions for wind turbines tend to occur downwind under moderate nighttime temperature inversions. Therefore, this is the default condition for modeling wind turbine sound.




Not to scale

**FIGURE 26: SCHEMATIC OF THE REFRACTION OF SOUND DUE TO VERTICAL WIND GRADIENT (WIND SHEAR)**

### *Masking*

As mentioned above, sound levels from wind turbines are a function of wind speed. Background sound is also a function of wind speed, i.e., the stronger the winds, the louder the resulting background sound. This effect is amplified in areas covered by trees and other vegetation.

The sound from a wind turbine can often be masked by wind noise at downwind receivers because the frequency spectrum from wind is similar to the frequency spectrum from a wind turbine. Figure 27 compares the shape of the sound spectrum measured during a 5 m/s wind event to that of the Vestas V120-STE wind turbine. As shown, the shapes of the spectra are similar at lower frequencies. At higher frequencies, the sounds from the masking wind noise are higher than the wind turbine. As a result, the masking of turbine noise occurs at higher wind speeds for some meteorological conditions. Masking will occur most, when ground wind speeds are relatively high, creating wind-caused noise such as wind blowing through the trees and interaction of wind with structures.

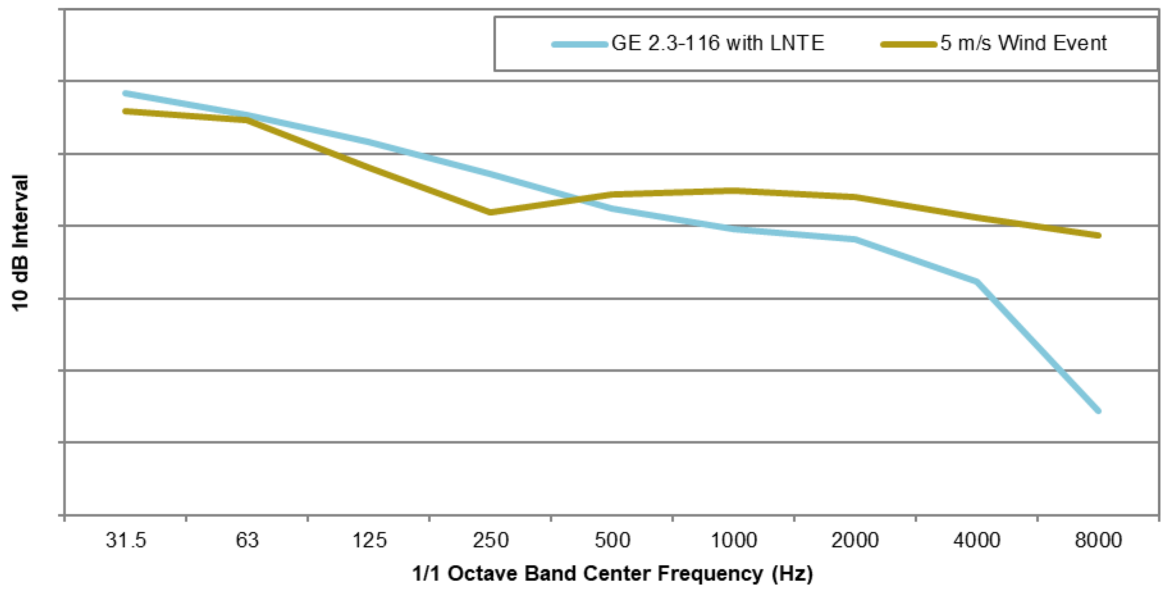



**FIGURE 27: COMPARISON OF NORMALIZED FREQUENCY SPECTRA MEASURED FROM THE WIND AND GE 2.3-116 WITH LNTE[28]**

It is important to note that while winds may be blowing at turbine height, there may be little to no wind at ground level. This is especially true during strong wind gradients (high wind shear), which mostly occur at night. This can also occur on the leeward side of ridges where the ridge blocks the wind.

[28] The purpose of this Figure is to show the shapes to two spectra relative to one another and not the actual sound level of the two sources of sound. The level of each source was normalized independently.

# APPENDIX B. DETAILED SHUTDOWN RESULTS

Data surrounding wind turbine shutdowns are compiled into detailed time history plots and a spectral summary plot for each evaluation period. Charts are provided for the period with maximum wind turbine-only sound level and another selected example for each monitor.

### *Description of Detailed Time History Plots*

The detailed time history plot with three panes.

1) wind turbine power production,
2) equivalent sound levels, wind speed/direction, and associated exclusions, and
3) a 1/3 octave band spectrogram representation of sound levels.

Time flows horizontally through all three panes.

The first pane charts the mean, maximum, and minimum 10-minute wind turbine power production for the closest turbines. The red line depicts the power production of the closest turbine and the green line shows the mean of the closest five wind turbines. The shading represents the range of wind turbine power production for the closest five wind turbines. Wind turbine evaluation categories are indicated in the figures: turbine operation (purple) or turbine shutdown (light blue).

The second pane plots one-minute equivalent continuous A-weighted and C-weighted levels. The plot also contains hub-height wind speed and direction and ground-level gust wind speed (all in meters per second). The ground-level wind speed and gust was measured and plotted on a one-minute basis, the hub-height wind speed measurement and plot intervals were ten-minutes.

The third pane is the 1/3 octave band spectrogram for the period. On the spectrogram plot, the y-axis represents frequency. The color intensity represents the magnitude of the level of sound. Grey shading is out of bounds of the colors bar, which spans from 10 to 70 dB. The spectral data are not weighted (i.e., dBZ). The spectrogram is plotted using one-second 1/3 octave band sound level data.

### *Description of Period Spectral Summary Plots*

The summary plots for the evaluation period indicated contains a plot of the 1/3 octave band sound levels for background, total, and apparent wind turbine-only (left side), as well as the overall A-weighted sound level for each condition (right side). The green points and green bar report the background sound levels when the turbine was not operating. The lower the background sound level relative to the total sound level, the more the wind turbine-only sound contributed to the overall sound level. The total sound level is reported by the orange bars and the turbine-only sound level is presented as black bars.

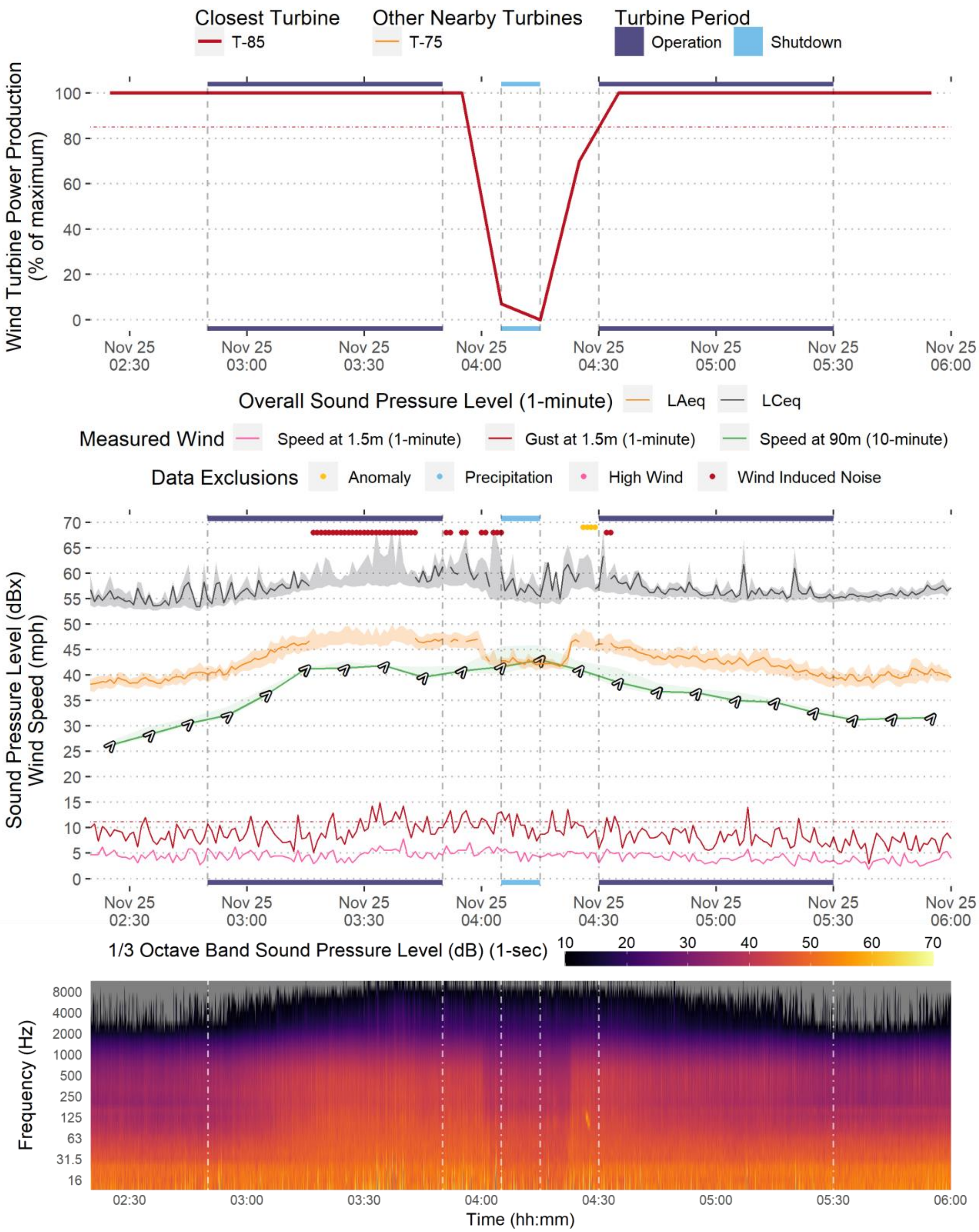



**FIGURE 28: DETAILED TIME HISTORY PLOT FOR LT2 – SHUTDOWN #27**

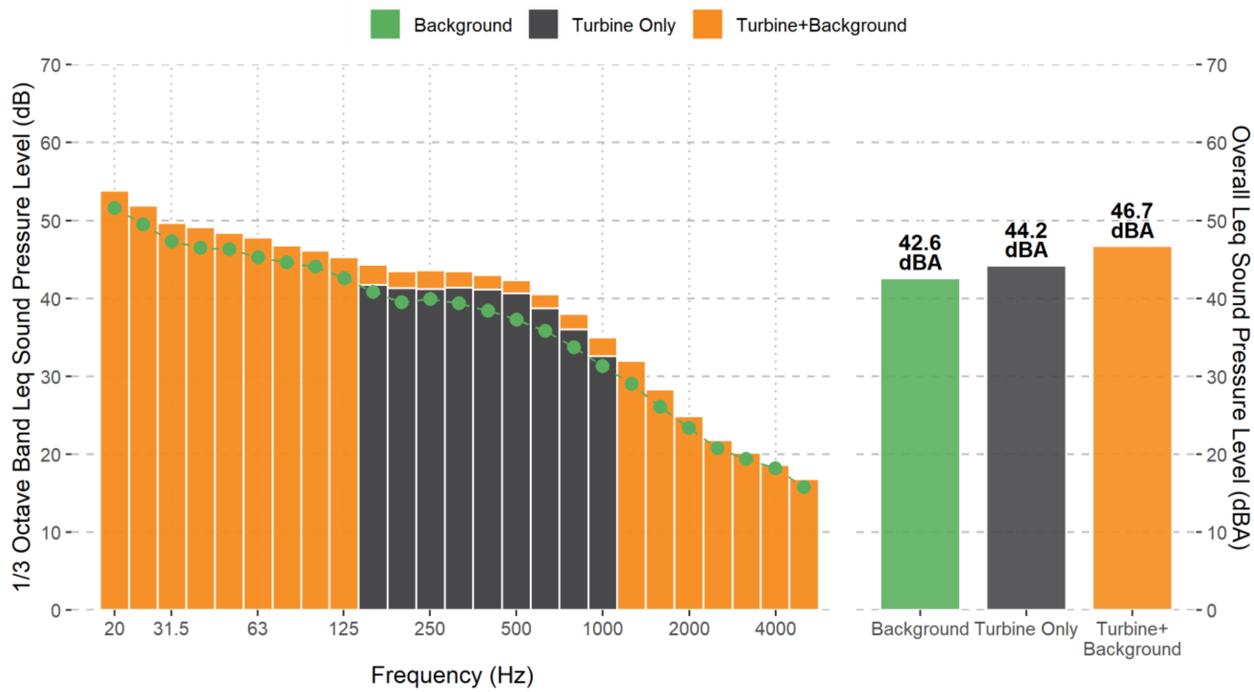



**FIGURE 29: 1/3 OCTAVE BAND RESULTS FOR LT2 – SHUTDOWN #27 – PRESD-F**

*SD027_PreSD-f: 2022-11-25 03:40 to 2022-11-25 03:50*

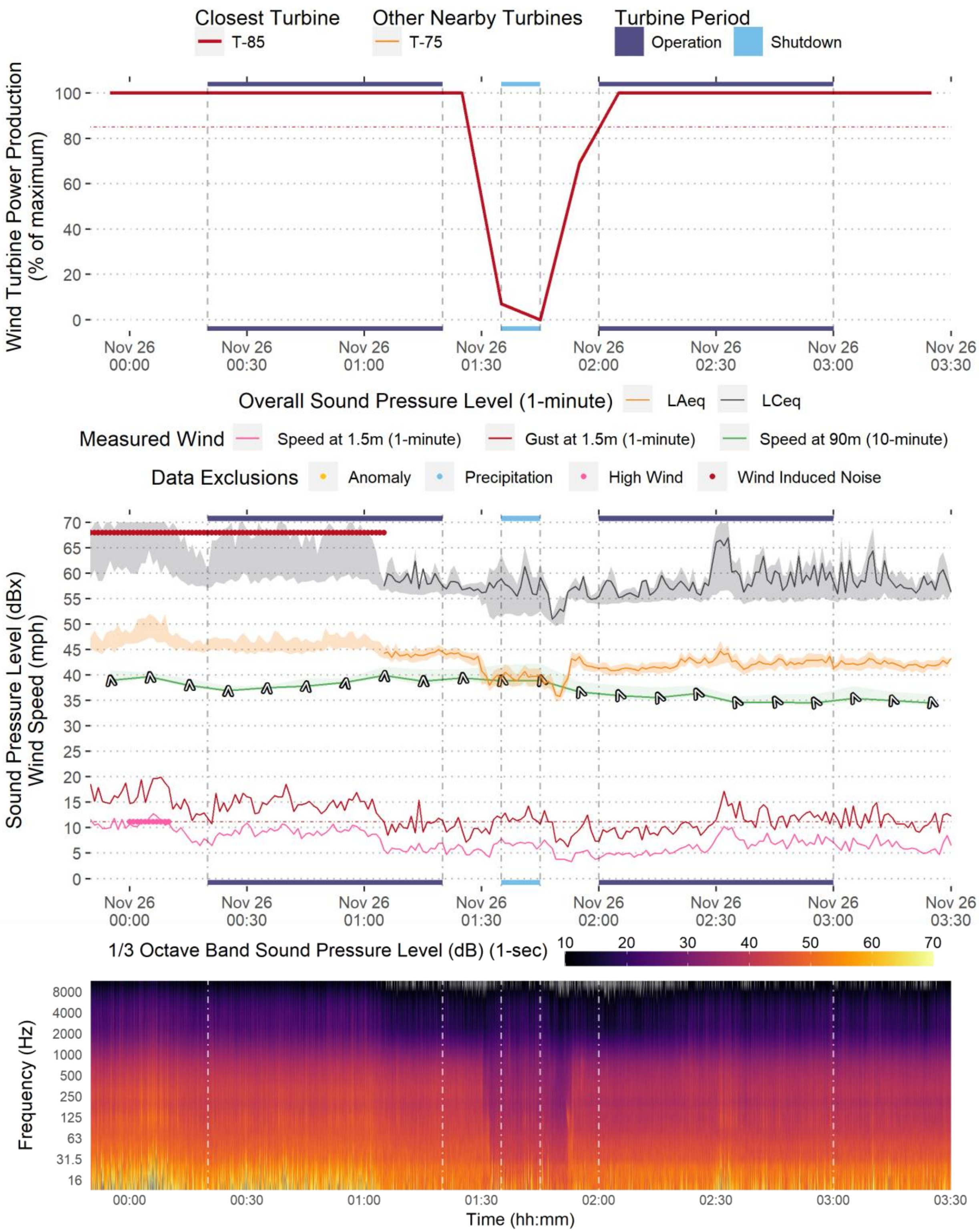



**FIGURE 30: DETAILED TIME HISTORY PLOT FOR LT2 – SHUTDOWN #30**

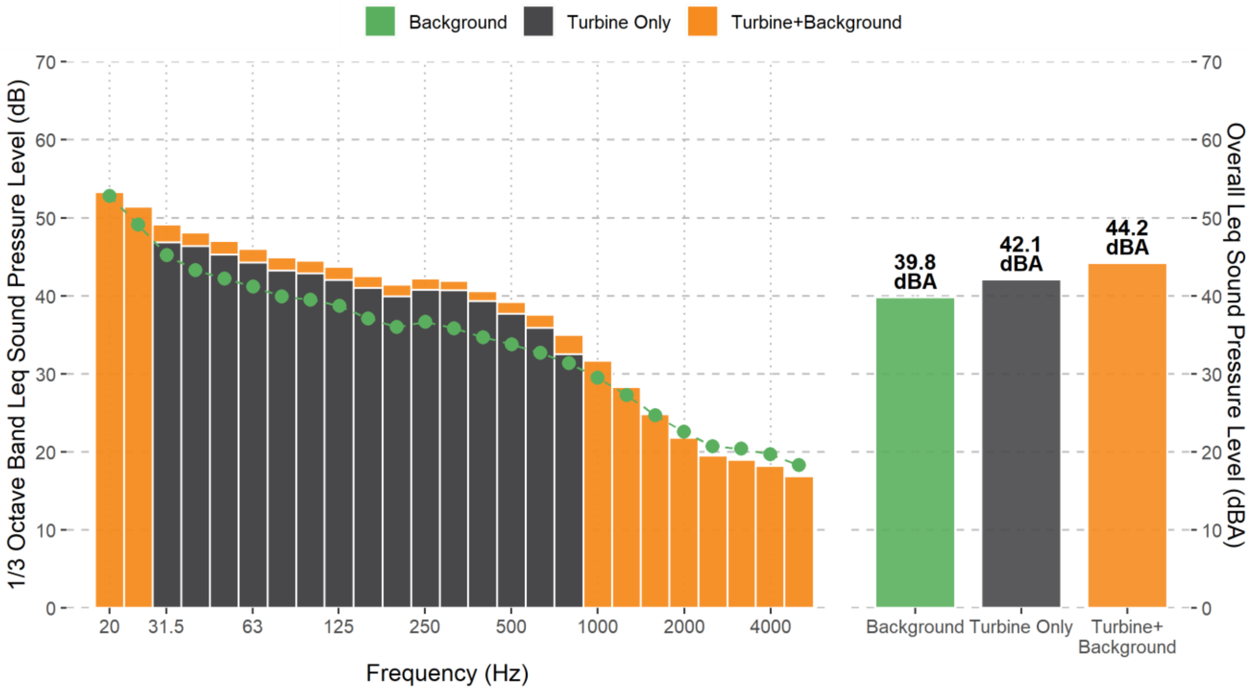



**FIGURE 31: 1/3 OCTAVE BAND RESULTS FOR LT2 – SHUTDOWN #30 – PRESD-E**

*SD030_PreSD-e: 2022-11-26 01:00 to 2022-11-26 01:10*

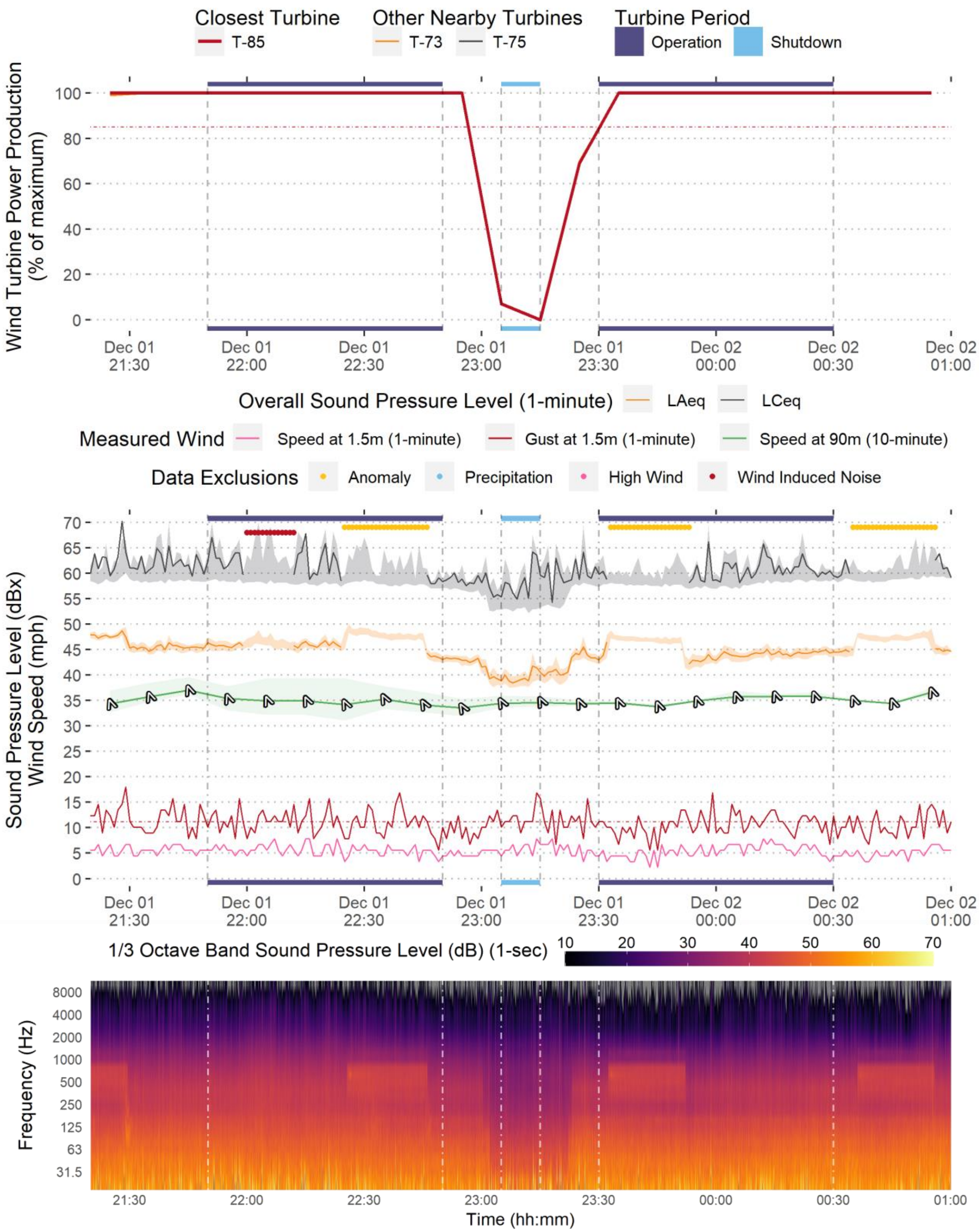



**FIGURE 32: DETAILED TIME HISTORY PLOT FOR LT3 – SHUTDOWN #53**

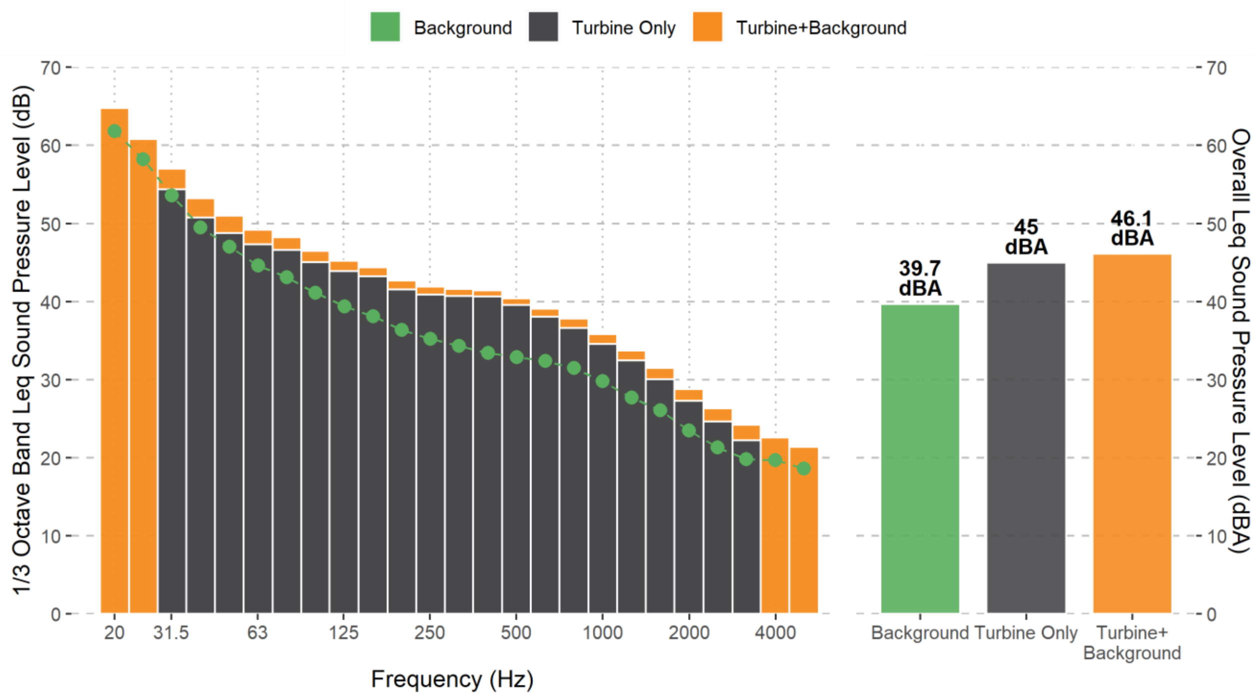



**FIGURE 33: 1/3 OCTAVE BAND RESULTS FOR LT3 – SHUTDOWN #53 – PRESD-D**

*SD053_PreSD-d: 2022-12-01 22:20 to 2022-12-01 22:30*

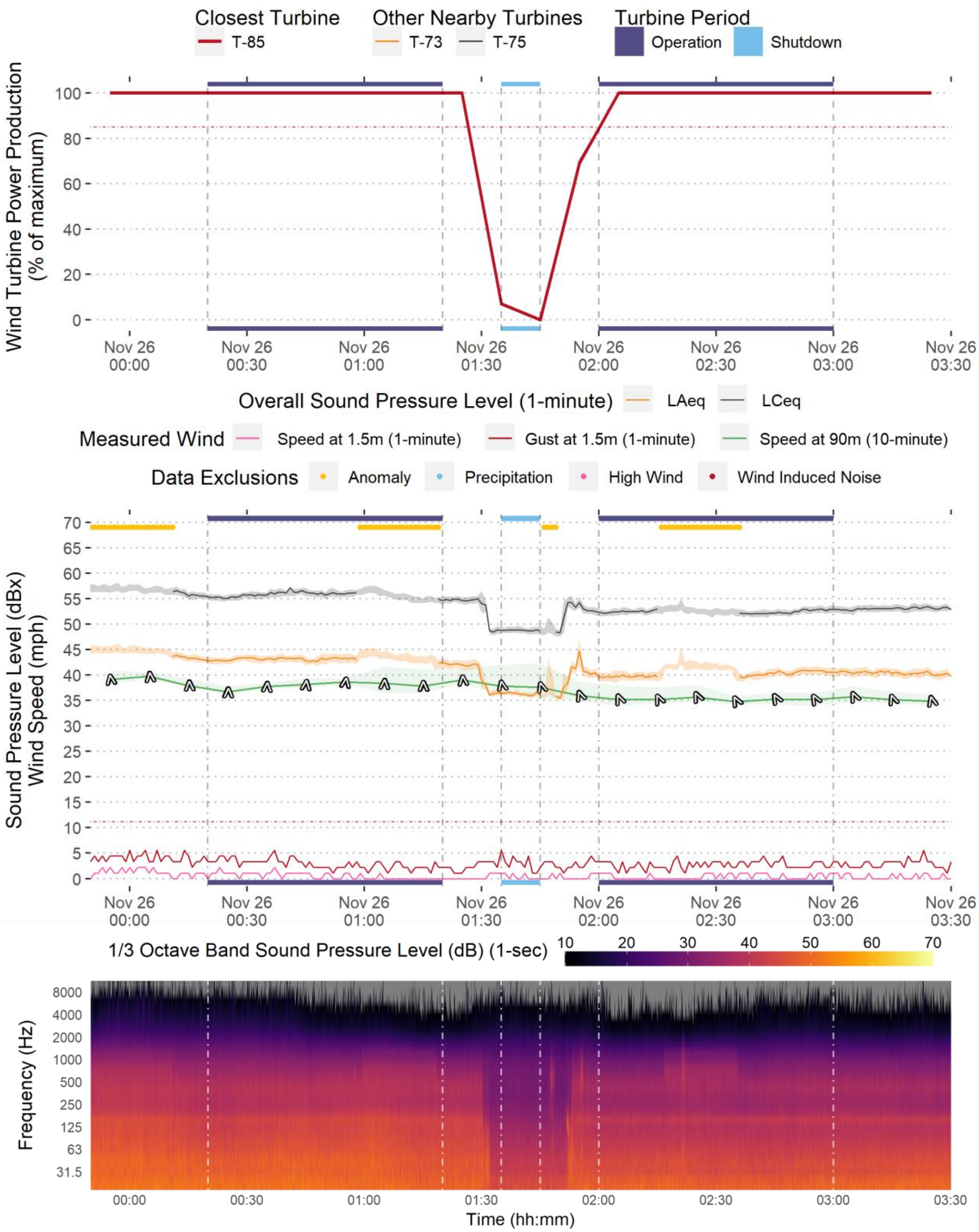



**FIGURE 34: DETAILED TIME HISTORY PLOT FOR LT3 – SHUTDOWN #30**

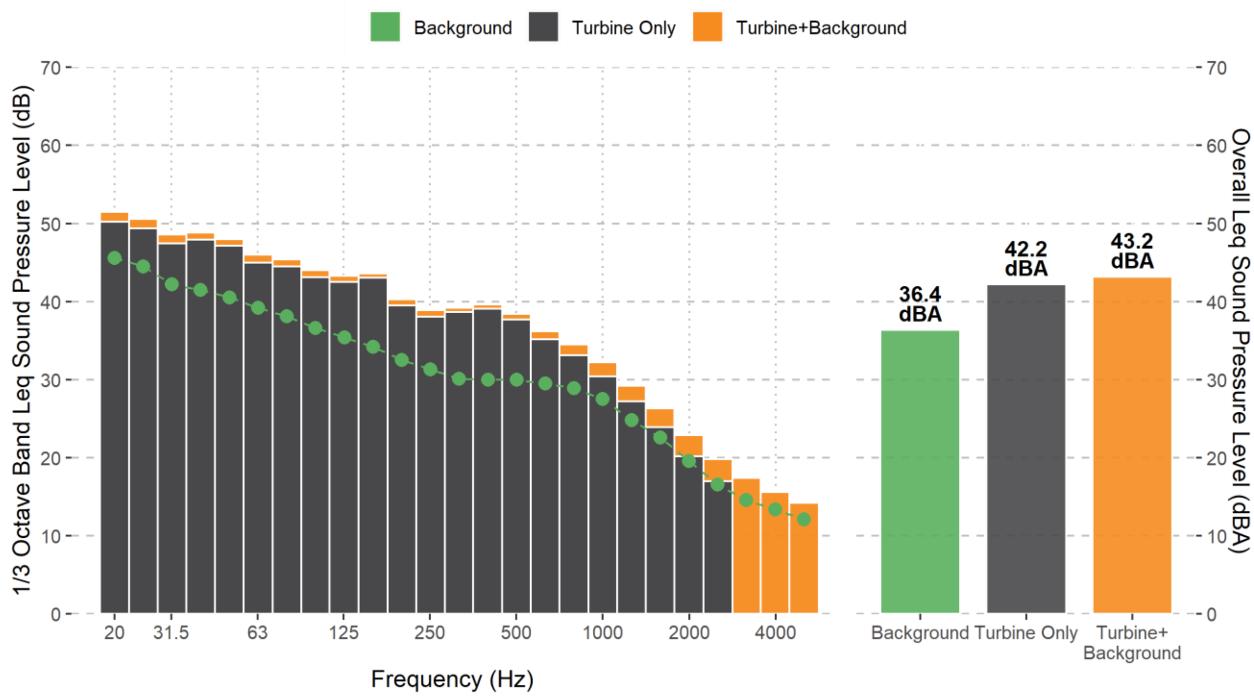



**FIGURE 35: 1/3 OCTAVE BAND RESULTS FOR LT3 – SHUTDOWN #30 – PRESD-B**

*SD030_PreSD-b: 2022-11-26 00:30 to 2022-11-26 00:40*

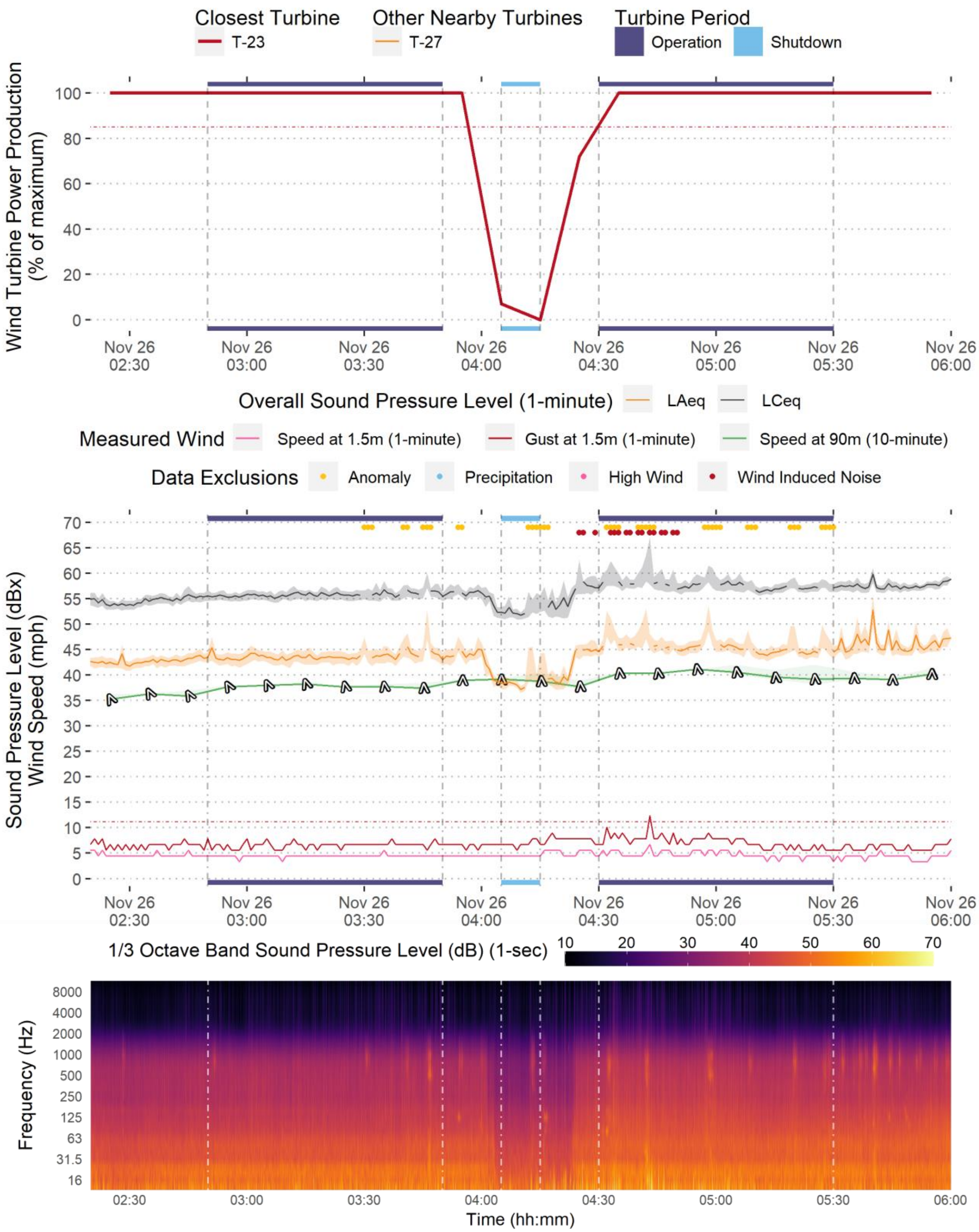



**FIGURE 36: DETAILED TIME HISTORY PLOT FOR LT6 – SHUTDOWN #31**

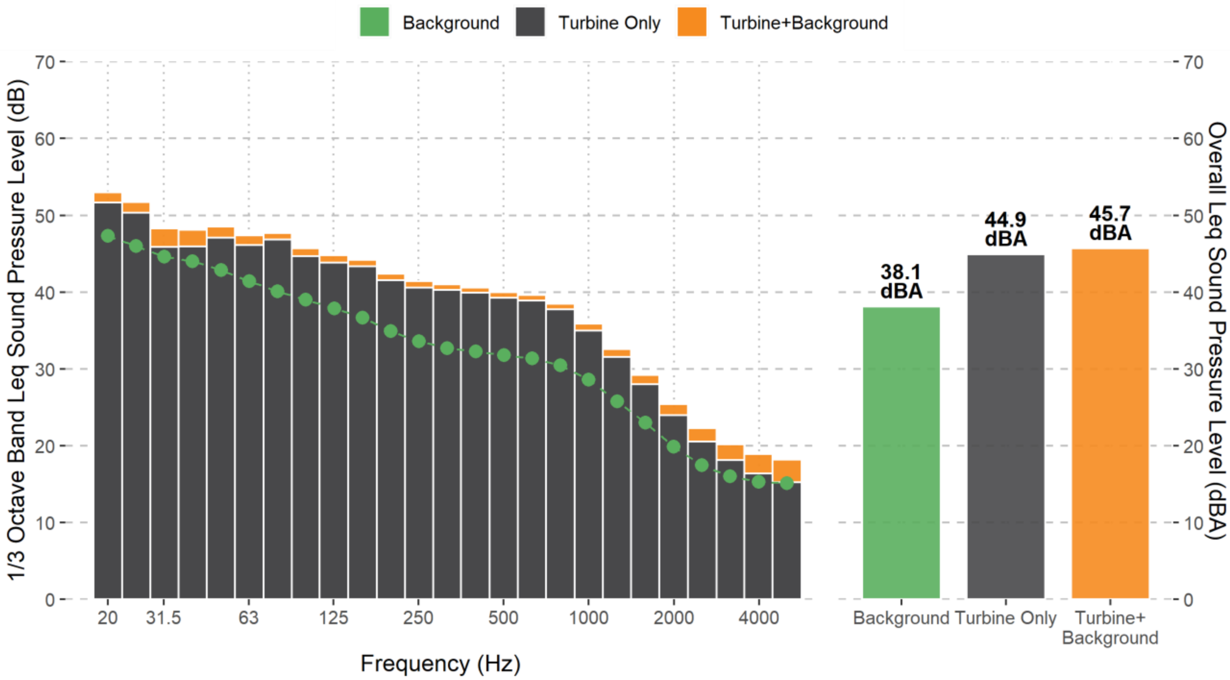



**FIGURE 37: 1/3 OCTAVE BAND RESULTS FOR LT6 – SHUTDOWN #31 – POSTSD-A**

*SD031_PostSD-a: 2022-11-26 04:30 to 2022-11-26 04:40*

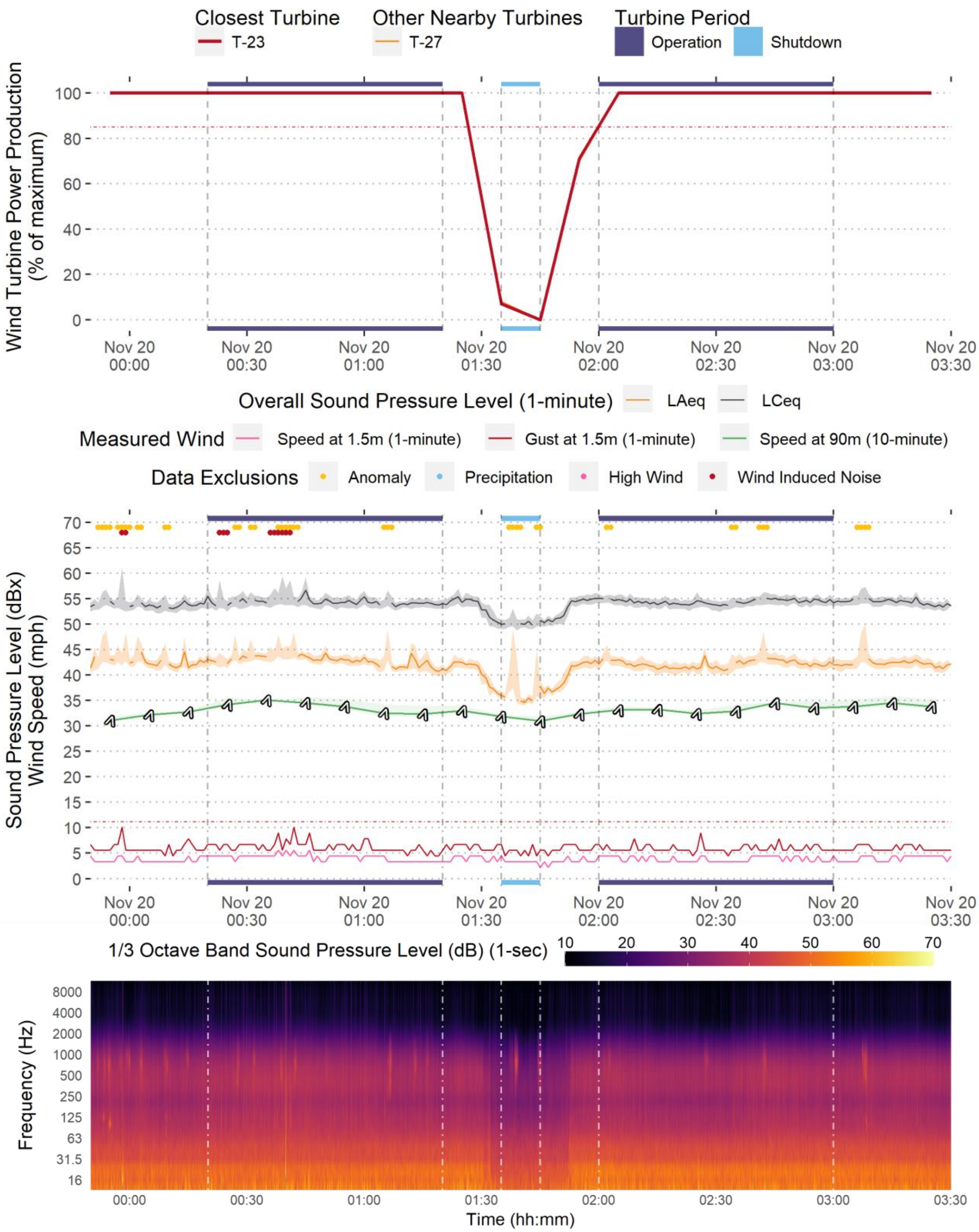



**FIGURE 38: DETAILED TIME HISTORY PLOT FOR LT6 – SHUTDOWN #6**

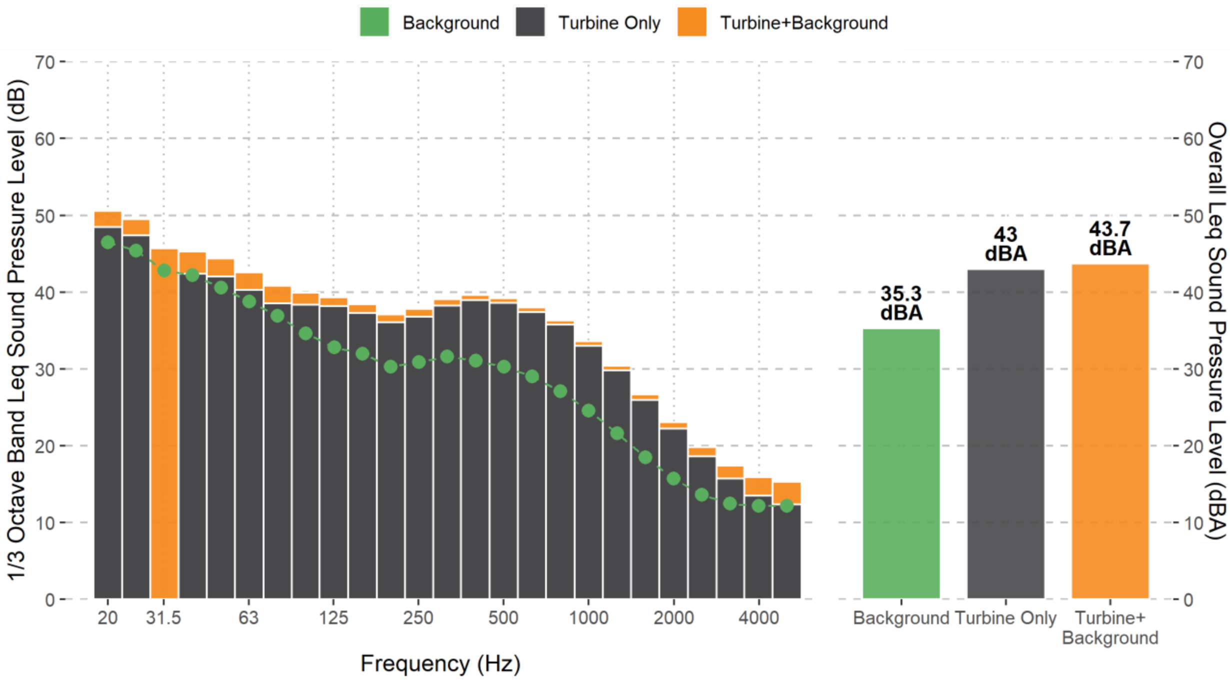



**FIGURE 39: 1/3 OCTAVE BAND RESULTS FOR LT6 – SHUTDOWN #6 – PRESD-B**

*SD006_PreSD-b: 2022-11-20 00:40 to 2022-11-20 00:50*

# APPENDIX C. SHUTDOWN ANALYSIS RESULTS

The following tables show the wind turbine-only sound levels results for valid compliance periods at or above 40 dBA at each monitor. Periods are listed in the order in which they occurred. Wind turbine-only sound levels were calculated on a 1/3 octave band basis, then A-weighted and summed following the procedures of ANSI S12.9 Part 3 Section 6.9. Time history plots of any specific shutdowns are available upon request. Periods with relative humidity or temperature outside of the Class 1 ranges are marked with an asterisk(*).

**TABLE 8: DISCRETE SHUTDOWN RESULTS WITH TURBINE-ONLY SOUND LEVEL AT AND ABOVE 40 dBA AT LT2**

| | | | Sound Pressure Level ($L_{eq}$, dBA) | | | Ground-Level Wind (1.5m) | | Hub Height Wind (92 m) | | Wind Turbine Production During Operation Period (% max) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitor | Shutdown Period ID | Date & Time | Back-ground | Total Sound | Turbine-Only | Mean Speed (m/s) | Gust Speed (m/s) | Mean Speed (m/s) | Mean Direction (deg) | Closest Turbine | Other Nearby Turbines |
| LT2 | 3_PreSD_a | 11/19 02:50 | 40 | 45 | 42* | 2.8 | 0.9 | 12 | 320 | 100 | 100 |
| LT2 | 3_PreSD_c | 11/19 03:10 | 40 | 44 | 40* | 3.1 | 1.1 | 11.4 | 316 | 100 | 100 |
| LT2 | 3_PostSD_f | 11/19 05:20 | 40 | 46 | 44* | 4.3 | 1 | 12.7 | 325 | 100 | 100 |
| LT2 | 4_PreSD_d | 11/19 12:20 | 42 | 46 | 42 | 4.6 | 1.3 | 10.5 | 299 | 99 | 99 |
| LT2 | 5_PostSD_b | 11/19 23:40 | 32 | 41 | 40 | 5.4 | 2.3 | 14.4 | 200 | 100 | 100 |
| LT2 | 5_PostSD_c | 11/19 23:50 | 32 | 41 | 40 | 5.3 | 2.3 | 13.8 | 200 | 100 | 100 |
| LT2 | 5_PostSD_d | 11/20 00:00 | 32 | 42 | 42 | 5.8 | 2.5 | 13.7 | 200 | 100 | 100 |
| LT2 | 5_PostSD_e | 11/20 00:10 | 32 | 43 | 43 | 5.5 | 2.5 | 14.1 | 200 | 100 | 100 |
| LT2 | 6_PreSD_c | 11/20 00:40 | 39 | 44 | 42 | 6.9 | 3.1 | 15.4 | 200 | 100 | 100 |
| LT2 | 6_PreSD_d | 11/20 00:50 | 39 | 43 | 41 | 5.9 | 3 | 15.2 | 200 | 100 | 100 |
| LT2 | 6_PostSD_b | 11/20 02:10 | 39 | 43 | 41 | 7.2 | 3.6 | 14 | 200 | 100 | 100 |
| LT2 | 6_PostSD_c | 11/20 02:20 | 39 | 44 | 42 | 7 | 3.6 | 14 | 200 | 100 | 100 |
| LT2 | 6_PostSD_d | 11/20 02:30 | 39 | 43 | 41 | 7.2 | 3.5 | 13.9 | 200 | 100 | 100 |
| LT2 | 6_PostSD_e | 11/20 02:40 | 39 | 43 | 41 | 7.3 | 3.7 | 14 | 200 | 100 | 100 |
| LT2 | 6_PostSD_f | 11/20 02:50 | 39 | 44 | 42 | 6.8 | 3.7 | 14.3 | 200 | 100 | 100 |

| | | | Sound Pressure Level ($L_{eq}$, dBA) | | | Ground-Level Wind (1.5m) | | Hub Height Wind (92 m) | | Wind Turbine Production During Operation Period (% max) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitor | Shutdown Period ID | Date & Time | Back-ground | Total Sound | Turbine-Only | Mean Speed (m/s) | Gust Speed (m/s) | Mean Speed (m/s) | Mean Direction (deg) | Closest Turbine | Other Nearby Turbines |
| LT2 | 7_PreSD_a | 11/20 02:50 | 38 | 44 | 42 | 6.8 | 4.1 | 14.3 | 200 | 100 | 100 |
| LT2 | 7_PreSD_b | 11/20 03:00 | 38 | 43 | 41 | 6.6 | 4.1 | 14.6 | 200 | 100 | 100 |
| LT2 | 7_PreSD_c | 11/20 03:10 | 38 | 43 | 40 | 7.3 | 4 | 14.5 | 200 | 100 | 100 |
| LT2 | 8_PostSD_c | 11/20 13:50 | 38 | 42 | 40 | 7.3 | 2.5 | 11.9 | 270 | 100 | 100 |
| LT2 | 9_PreSD_a | 11/20 21:50 | 29 | 41 | 40 | 4.9 | 1.4 | 12.2 | 280 | 100 | 100 |
| LT2 | 10_PostSD_a | 11/21 02:00 | 29 | 40 | 40 | 5 | 1.5 | 11.6 | 290 | 100 | 100 |
| LT2 | 10_PostSD_b | 11/21 02:10 | 29 | 41 | 41 | 5 | 1.7 | 12.4 | 290 | 100 | 100 |
| LT2 | 10_PostSD_c | 11/21 02:20 | 29 | 43 | 43 | 5.6 | 2.2 | 13.2 | 290 | 100 | 100 |
| LT2 | 10_PostSD_d | 11/21 02:30 | 29 | 43 | 43 | 5.3 | 2.3 | 13.7 | 290 | 100 | 100 |
| LT2 | 10_PostSD_e | 11/21 02:40 | 29 | 43 | 43 | 5.2 | 2.1 | 13.8 | 290 | 100 | 100 |
| LT2 | 10_PostSD_f | 11/21 02:50 | 29 | 44 | 44 | 5.6 | 2.2 | 14.6 | 290 | 100 | 100 |
| LT2 | 11_PreSD_a | 11/21 02:50 | 38 | 44 | 42 | 5.6 | 2 | 14.6 | 290 | 100 | 100 |
| LT2 | 11_PreSD_b | 11/21 03:00 | 38 | 44 | 42 | 5.1 | 2 | 14.1 | 290 | 100 | 100 |
| LT2 | 11_PreSD_c | 11/21 03:10 | 38 | 43 | 42 | 5.6 | 2.2 | 13.7 | 290 | 100 | 100 |
| LT2 | 11_PreSD_d | 11/21 03:20 | 38 | 43 | 41 | 5.8 | 2 | 13.7 | 290 | 100 | 100 |
| LT2 | 11_PreSD_e | 11/21 03:30 | 38 | 43 | 42 | 4.2 | 1.6 | 14.2 | 290 | 100 | 100 |
| LT2 | 11_PreSD_f | 11/21 03:40 | 38 | 43 | 42 | 3.9 | 1.4 | 14.1 | 290 | 100 | 100 |
| LT2 | 25_PreSD_a | 11/24 21:50 | 26 | 40 | 40 | 4.3 | 1.3 | 12 | 269 | 100 | 100 |
| LT2 | 25_PreSD_b | 11/24 22:00 | 26 | 41 | 40 | 4.1 | 1.4 | 12.1 | 266 | 100 | 100 |
| LT2 | 25_PreSD_d | 11/24 22:20 | 26 | 40 | 40 | 3.5 | 1.1 | 12.4 | 259 | 100 | 100 |
| LT2 | 25_PreSD_e | 11/24 22:30 | 26 | 40 | 40 | 4.2 | 1.4 | 12.1 | 256 | 100 | 100 |
| LT2 | 26_PostSD_f | 11/25 02:50 | 30 | 41 | 41 | 4.8 | 2 | 14.3 | 230 | 100 | 100 |
| LT2 | 27_PreSD_c | 11/25 03:10 | 43 | 46 | 43 | 5.8 | 2 | 18.4 | 226 | 100 | 100 |
| LT2 | 27_PreSD_f | 11/25 03:40 | 43 | 47 | 44 | 6.2 | 2.2 | 17.7 | 221 | 100 | 100 |

| Monitor | Shutdown Period ID | Date & Time | Sound Pressure Level ($L_{eq}$, dBA) | | | Ground-Level Wind (1.5m) | | Hub Height Wind (92 m) | | Wind Turbine Production During Operation Period (% max) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Back-ground | Total Sound | Turbine-Only | Mean Speed (m/s) | Gust Speed (m/s) | Mean Speed (m/s) | Mean Direction (deg) | Closest Turbine | Other Nearby Turbines |
| LT2 | 27_PostSD_a | 11/25 04:30 | 43 | 46 | 41 | 5.7 | 2.1 | 17.2 | 220 | 100 | 100 |
| LT2 | 30_PreSD_e | 11/26 01:00 | 40 | 44 | 42 | 6.7 | 3.1 | 17.9 | 184 | 100 | 100 |
| LT2 | 30_PreSD_f | 11/26 01:10 | 40 | 44 | 42 | 6.7 | 2.9 | 17.4 | 179 | 100 | 100 |
| LT2 | 37_PostSD_d | 11/28 00:00 | 34 | 42 | 41 | 5.3 | 3.2 | 13.3 | 160 | 100 | 100 |
| LT2 | 37_PostSD_e | 11/28 00:10 | 34 | 42 | 41 | 6.1 | 3.4 | 13.6 | 160 | 100 | 100 |
| LT2 | 50_PostSD_c | 12/01 02:20 | 38 | 42 | 40 | 7.2 | 4 | 11.6 | 150 | 100 | 100 |
| LT2 | 50_PostSD_e | 12/01 02:40 | 38 | 44 | 42 | 6.8 | 4.3 | 11.6 | 150 | 100 | 100 |
| LT2 | 50_PostSD_f | 12/01 02:50 | 38 | 43 | 41 | 7.2 | 4.1 | 11.8 | 150 | 100 | 100 |

**TABLE 9: DISCRETE SHUTDOWN RESULTS WITH TURBINE-ONLY SOUND LEVEL AT AND ABOVE 40 dBA AT LT3**

| | | | Sound Pressure Level ($L_{eq}$, dBA) | | | Ground-Level Wind (1.5m) | | Hub Height Wind (92 m) | | Wind Turbine Production During Operation Period (% max) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitor | Shutdown Period ID | Date & Time | Back-ground | Total Sound | Turbine-Only | Mean Speed (m/s) | Gust Speed (m/s) | Mean Speed (m/s) | Mean Direction (deg) | Closest Turbine | Other Nearby Turbines |
| LT3 | 1_PreSD_a | 11/18 21:50 | 41 | 45 | 42 | 4 | 1 | 12.7 | 300 | 100 | 99 |
| LT3 | 1_PreSD_c | 11/18 22:10 | 41 | 46 | 44 | 4.8 | 1.2 | 13.4 | 302 | 100 | 100 |
| LT3 | 1_PreSD_d | 11/18 22:20 | 41 | 45 | 41* | 5 | 1 | 13.8 | 304 | 100 | 100 |
| LT3 | 1_PreSD_e | 11/18 22:30 | 41 | 45 | 42* | 5.3 | 1.1 | 13.8 | 306 | 100 | 100 |
| LT3 | 5_PostSD_d | 11/20 00:00 | 33 | 41 | 41 | 2 | 0 | 13.9 | 200 | 100 | 100 |
| LT3 | 10_PostSD_d | 11/21 02:30 | 30 | 41 | 41 | 2.3 | 0.7 | 13.8 | 290 | 100 | 100 |
| LT3 | 10_PostSD_e | 11/21 02:40 | 30 | 41 | 41 | 3 | 0.8 | 14 | 290 | 100 | 100 |
| LT3 | 13_PostSD_d | 11/22 00:00 | 24 | 44 | 44* | 1 | 0 | 8.8 | 160 | 97 | 64 |
| LT3 | 26_PostSD_f | 11/25 02:50 | 28 | 40 | 40 | 2.3 | 0.1 | 14.8 | 230 | 100 | 100 |
| LT3 | 28_PostSD_a | 11/25 13:30 | 39 | 43 | 40 | 2.8 | 0.4 | 12.7 | 227 | 100 | 100 |
| LT3 | 28_PostSD_b | 11/25 13:40 | 39 | 43 | 41 | 2.8 | 0.3 | 13.1 | 229 | 100 | 100 |
| LT3 | 28_PostSD_c | 11/25 13:50 | 39 | 43 | 40 | 3.3 | 0.4 | 13.3 | 230 | 100 | 100 |
| LT3 | 28_PostSD_d | 11/25 14:00 | 39 | 44 | 42 | 3 | 0.5 | 13.6 | 228 | 100 | 100 |
| LT3 | 29_PreSD_a | 11/25 21:50 | 40 | 45 | 42 | 2.3 | 0.3 | 18.1 | 200 | 100 | 100 |
| LT3 | 29_PreSD_b | 11/25 22:00 | 40 | 44 | 42 | 2.3 | 0.4 | 18.1 | 198 | 100 | 100 |
| LT3 | 29_PreSD_c | 11/25 22:10 | 40 | 45 | 43 | 2.5 | 0.7 | 18.1 | 196 | 100 | 100 |
| LT3 | 29_PreSD_d | 11/25 22:20 | 40 | 44 | 41 | 2.5 | 0.5 | 17.6 | 195 | 100 | 100 |
| LT3 | 29_PostSD_a | 11/25 23:30 | 40 | 43 | 40 | 2.3 | 0.4 | 17.1 | 176 | 100 | 100 |
| LT3 | 29_PostSD_b | 11/25 23:40 | 40 | 44 | 41 | 2.3 | 0.4 | 17.4 | 173 | 100 | 100 |
| LT3 | 29_PostSD_e | 11/26 00:10 | 40 | 43 | 40 | 2.5 | 0.4 | 17 | 177 | 100 | 100 |
| LT3 | 30_PreSD_a | 11/26 00:20 | 36 | 43 | 42 | 2.3 | 0.3 | 16.4 | 181 | 100 | 100 |
| LT3 | 30_PreSD_b | 11/26 00:30 | 36 | 43 | 42 | 2.5 | 0.3 | 16.9 | 184 | 100 | 100 |
| LT3 | 30_PreSD_c | 11/26 00:40 | 36 | 43 | 42 | 2.3 | 0.3 | 17.1 | 187 | 100 | 100 |

| | | | Sound Pressure Level ($L_{eq}$, dBA) | | | Ground-Level Wind (1.5m) | | Hub Height Wind (92 m) | | Wind Turbine Production During Operation Period (% max) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Monitor** | **Shutdown Period ID** | **Date & Time** | **Back-ground** | **Total Sound** | **Turbine-Only** | **Mean Speed (m/s)** | **Gust Speed (m/s)** | **Mean Speed (m/s)** | **Mean Direction (deg)** | **Closest Turbine** | **Other Nearby Turbines** |
| LT3 | 30_PreSD_d | 11/26 00:50 | 36 | 43 | 42 | 2 | 0.2 | 17.3 | 189 | 100 | 100 |
| LT3 | 31_PostSD_a | 11/26 04:30 | 36 | 44 | 43 | 2.3 | 0.3 | 17.5 | 173 | 100 | 100 |
| LT3 | 31_PostSD_b | 11/26 04:40 | 36 | 45 | 44 | 3 | 0.6 | 17.9 | 171 | 100 | 100 |
| LT3 | 31_PostSD_c | 11/26 04:50 | 36 | 45 | 44 | 3 | 0.7 | 17.7 | 170 | 100 | 100 |
| LT3 | 31_PostSD_f | 11/26 05:20 | 36 | 44 | 44 | 2.3 | 0.4 | 17.3 | 175 | 100 | 100 |
| LT3 | 39_PostSD_a | 11/28 04:30 | 41 | 44 | 41 | 7.6 | 3.8 | 13.2 | 160 | 100 | 100 |
| LT3 | 39_PostSD_e | 11/28 05:10 | 41 | 44 | 40 | 8.1 | 3.7 | 14 | 160 | 100 | 100 |
| LT3 | 39_PostSD_f | 11/28 05:20 | 41 | 44 | 41 | 7.3 | 3.7 | 13.5 | 160 | 100 | 100 |
| LT3 | 53_PreSD_a | 12/01 21:50 | 40 | 46 | 45 | 7.3 | 2.6 | 15.8 | 160 | 100 | 100 |
| LT3 | 53_PreSD_c | 12/01 22:10 | 40 | 46 | 45 | 7.3 | 2.6 | 15.6 | 156 | 100 | 100 |
| LT3 | 53_PreSD_d | 12/01 22:20 | 40 | 46 | 45 | 7.3 | 2.6 | 15.3 | 155 | 100 | 100 |
| LT3 | 53_PostSD_d | 12/02 00:00 | 40 | 44 | 41 | 7 | 2.7 | 16 | 160 | 100 | 100 |
| LT3 | 53_PostSD_e | 12/02 00:10 | 40 | 44 | 42 | 6.8 | 2.8 | 16 | 160 | 100 | 100 |
| LT3 | 53_PostSD_f | 12/02 00:20 | 40 | 44 | 42 | 6.5 | 2.5 | 16 | 160 | 100 | 100 |
| LT3 | 54_PostSD_a | 12/02 02:00 | 43 | 46 | 42 | 6.8 | 2.6 | 16.8 | 172 | 100 | 100 |
| LT3 | 54_PostSD_c | 12/02 02:20 | 43 | 47 | 42 | 6.5 | 2.5 | 17.3 | 175 | 100 | 100 |
| LT3 | 59_PreSD_c | 12/03 03:10 | 37 | 43 | 42* | 3.3 | 0.4 | 13.1 | 306 | 94 | 94 |
| LT3 | 59_PreSD_d | 12/03 03:20 | 37 | 43 | 42* | 3 | 0.4 | 13.4 | 305 | 94 | 94 |
| LT3 | 59_PreSD_e | 12/03 03:30 | 37 | 44 | 43* | 4 | 0.7 | 13.1 | 303 | 94 | 94 |
| LT3 | 73_PostSD_c | 12/06 23:50 | 30 | 41 | 40* | 6.5 | 3.6 | 9.2 | 40 | 98 | 72 |
| LT3 | 74_PreSD_c | 12/07 00:40 | 37 | 42 | 41* | 6.8 | 4.5 | 8.4 | 31 | 93 | 59 |
| LT3 | 74_PreSD_d | 12/07 00:50 | 37 | 42 | 40* | 6.5 | 4.4 | 8 | 30 | 99 | 51 |
| LT3 | 79_PostSD_c | 12/08 04:50 | 32 | 41 | 41* | 2.8 | 0.4 | 14 | 160 | 100 | 100 |
| LT3 | 79_PostSD_d | 12/08 05:00 | 32 | 41 | 40* | 3.5 | 0.5 | 13.3 | 160 | 100 | 100 |

**TABLE 10: DISCRETE SHUTDOWN RESULTS WITH TURBINE-ONLY SOUND LEVEL AT AND ABOVE 40 dBA AT LT6**

| | | | Sound Pressure Level ($L_{eq}$, dBA) | | | Ground-Level Wind (1.5m) | | Hub Height Wind (92 m) | | Wind Turbine Production During Operation Period (% max) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitor | Shutdown Period ID | Date & Time | Back-ground | Total Sound | Turbine-Only | Mean Speed (m/s) | Gust Speed (m/s) | Mean Speed (m/s) | Mean Direction (deg) | Closest Turbine | Other Nearby Turbines |
| LT6 | 5_PreSD_a | 11/19 21:50 | 37 | 43 | 41 | 2.3 | 1 | 12.1 | 200 | 100 | 100 |
| LT6 | 5_PostSD_d | 11/20 00:00 | 37 | 43 | 41 | 2.8 | 1.4 | 14.4 | 200 | 100 | 100 |
| LT6 | 5_PostSD_e | 11/20 00:10 | 37 | 42 | 41 | 3.3 | 1.4 | 14.7 | 200 | 100 | 100 |
| LT6 | 5_PostSD_f | 11/20 00:20 | 37 | 43 | 42 | 3 | 1.6 | 15.3 | 200 | 100 | 100 |
| LT6 | 6_PreSD_a | 11/20 00:20 | 35 | 43 | 42 | 3 | 1.8 | 15.3 | 200 | 100 | 100 |
| LT6 | 6_PreSD_b | 11/20 00:30 | 35 | 44 | 43 | 3.5 | 1.8 | 15.7 | 200 | 100 | 100 |
| LT6 | 6_PreSD_c | 11/20 00:40 | 35 | 43 | 43 | 3.8 | 1.8 | 15.4 | 200 | 100 | 100 |
| LT6 | 6_PreSD_d | 11/20 00:50 | 35 | 43 | 42 | 3 | 1.7 | 15.1 | 200 | 100 | 100 |
| LT6 | 6_PreSD_e | 11/20 01:00 | 35 | 42 | 41 | 3.3 | 1.7 | 14.6 | 200 | 100 | 100 |
| LT6 | 6_PreSD_f | 11/20 01:10 | 35 | 42 | 41 | 3 | 1.5 | 14.4 | 200 | 100 | 100 |
| LT6 | 6_PostSD_a | 11/20 02:00 | 35 | 43 | 42 | 3.3 | 1.7 | 14.8 | 200 | 100 | 100 |
| LT6 | 6_PostSD_b | 11/20 02:10 | 35 | 42 | 41 | 3 | 1.6 | 14.8 | 200 | 100 | 100 |
| LT6 | 6_PostSD_c | 11/20 02:20 | 35 | 42 | 41 | 3.5 | 1.6 | 14.5 | 200 | 100 | 100 |
| LT6 | 6_PostSD_d | 11/20 02:30 | 35 | 42 | 41 | 3 | 1.6 | 14.7 | 200 | 100 | 100 |
| LT6 | 6_PostSD_e | 11/20 02:40 | 35 | 43 | 42 | 3.3 | 1.7 | 15.4 | 200 | 100 | 100 |
| LT6 | 6_PostSD_f | 11/20 02:50 | 35 | 42 | 41 | 3 | 1.6 | 15 | 200 | 100 | 100 |
| LT6 | 7_PreSD_a | 11/20 02:50 | 37 | 42 | 41 | 3 | 1.6 | 15 | 200 | 100 | 100 |
| LT6 | 7_PreSD_b | 11/20 03:00 | 37 | 42 | 41 | 3 | 1.6 | 15.1 | 200 | 100 | 100 |
| LT6 | 7_PreSD_c | 11/20 03:10 | 37 | 42 | 41 | 3 | 1.6 | 15.4 | 200 | 100 | 100 |
| LT6 | 7_PreSD_d | 11/20 03:20 | 37 | 42 | 41 | 3 | 1.7 | 15.1 | 200 | 100 | 100 |
| LT6 | 7_PreSD_e | 11/20 03:30 | 37 | 42 | 40 | 3 | 1.6 | 14.5 | 200 | 100 | 100 |
| LT6 | 9_PreSD_a | 11/20 21:50 | 34 | 41 | 41 | 3.8 | 1.2 | 11.7 | 280 | 100 | 100 |
| LT6 | 9_PreSD_c | 11/20 22:10 | 34 | 42 | 41 | 4 | 1.3 | 11.9 | 280 | 100 | 100 |

| | | | Sound Pressure Level ($L_{eq}$, dBA) | | | Ground-Level Wind (1.5m) | | Hub Height Wind (92 m) | | Wind Turbine Production During Operation Period (% max) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitor | Shutdown Period ID | Date & Time | Back-ground | Total Sound | Turbine-Only | Mean Speed (m/s) | Gust Speed (m/s) | Mean Speed (m/s) | Mean Direction (deg) | Closest Turbine | Other Nearby Turbines |
| LT6 | 9_PreSD_d | 11/20 22:20 | 34 | 42 | 42 | 3.8 | 1.3 | 12.6 | 280 | 100 | 100 |
| LT6 | 9_PreSD_e | 11/20 22:30 | 34 | 41 | 40 | 4 | 1.4 | 12.2 | 280 | 100 | 100 |
| LT6 | 9_PreSD_f | 11/20 22:40 | 34 | 42 | 41 | 3.8 | 1.3 | 12.1 | 280 | 100 | 100 |
| LT6 | 10_PreSD_c | 11/21 00:40 | 35 | 42 | 41 | 4.3 | 1.6 | 12.3 | 279 | 100 | 100 |
| LT6 | 10_PostSD_d | 11/21 02:30 | 35 | 42 | 40 | 4 | 1.5 | 14.2 | 290 | 100 | 100 |
| LT6 | 11_PreSD_b | 11/21 03:00 | 39 | 44 | 42 | 4.3 | 1.7 | 15.8 | 290 | 100 | 100 |
| LT6 | 11_PreSD_e | 11/21 03:30 | 39 | 44 | 43 | 4.8 | 1.9 | 15.5 | 290 | 100 | 100 |
| LT6 | 11_PreSD_f | 11/21 03:40 | 39 | 45 | 44 | 4 | 1.8 | 15.6 | 290 | 100 | 100 |
| LT6 | 11_PostSD_a | 11/21 04:30 | 39 | 43 | 41 | 4.8 | 1.7 | 13.8 | 304 | 100 | 100 |
| LT6 | 11_PostSD_b | 11/21 04:40 | 39 | 43 | 41 | 4.5 | 1.7 | 13.4 | 307 | 100 | 100 |
| LT6 | 11_PostSD_c | 11/21 04:50 | 39 | 43 | 41 | 4.5 | 1.8 | 12.8 | 310 | 100 | 100 |
| LT6 | 11_PostSD_d | 11/21 05:00 | 39 | 43 | 40 | 5 | 1.7 | 12.8 | 310 | 100 | 100 |
| LT6 | 11_PostSD_e | 11/21 05:10 | 39 | 43 | 41 | 4.5 | 1.7 | 12.7 | 310 | 100 | 100 |
| LT6 | 15_PreSD_f | 11/22 03:40 | 32 | 42 | 42 | 2.3 | 1.1 | 12.2 | 150 | 100 | 100 |
| LT6 | 19_PostSD_f | 11/23 05:20 | 36 | 44 | 43 | 2.5 | 0.7 | 13.2 | 150 | 100 | 100 |
| LT6 | 22_PostSD_b | 11/24 02:10 | 29 | 40 | 40 | 2.8 | 0.9 | 10.3 | 317 | 97 | 100 |
| LT6 | 23_PreSD_d | 11/24 03:20 | 30 | 41 | 40* | 3.5 | 0.6 | 9 | 330 | 99 | 80 |
| LT6 | 23_PreSD_f | 11/24 03:40 | 30 | 40 | 40* | 3 | 0.5 | 9.9 | 330 | 98 | 93 |
| LT6 | 25_PreSD_a | 11/24 21:50 | 34 | 41 | 40 | 3.3 | 1.5 | 13.4 | 269 | 100 | 100 |
| LT6 | 29_PreSD_a | 11/25 21:50 | 40 | 46 | 44 | 3 | 1.7 | 16.9 | 200 | 100 | 100 |
| LT6 | 29_PreSD_c | 11/25 22:10 | 40 | 45 | 43 | 3 | 1.8 | 17.3 | 196 | 100 | 100 |
| LT6 | 29_PreSD_f | 11/25 22:40 | 40 | 45 | 43 | 3 | 1.9 | 17.4 | 191 | 100 | 100 |
| LT6 | 29_PostSD_a | 11/25 23:30 | 40 | 44 | 41 | 3 | 1.9 | 16.4 | 176 | 100 | 100 |
| LT6 | 29_PostSD_b | 11/25 23:40 | 40 | 44 | 41 | 3 | 1.9 | 16.6 | 173 | 100 | 100 |

| | | | Sound Pressure Level ($L_{eq}$, dBA) | | | Ground-Level Wind (1.5m) | | Hub Height Wind (92 m) | | Wind Turbine Production During Operation Period (% max) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitor | Shutdown Period ID | Date & Time | Back-ground | Total Sound | Turbine-Only | Mean Speed (m/s) | Gust Speed (m/s) | Mean Speed (m/s) | Mean Direction (deg) | Closest Turbine | Other Nearby Turbines |
| LT6 | 29_PostSD_c | 11/25 23:50 | 40 | 44 | 42 | 3 | 1.9 | 17.1 | 171 | 100 | 100 |
| LT6 | 29_PostSD_d | 11/26 00:00 | 40 | 45 | 43 | 3.3 | 1.9 | 17.4 | 174 | 100 | 100 |
| LT6 | 30_PreSD_d | 11/26 00:50 | 38 | 45 | 44 | 3.5 | 2.1 | 18.6 | 189 | 100 | 100 |
| LT6 | 30_PreSD_e | 11/26 01:00 | 38 | 45 | 44 | 3 | 2 | 18.6 | 184 | 100 | 100 |
| LT6 | 30_PreSD_f | 11/26 01:10 | 38 | 45 | 44 | 3.5 | 2 | 18.1 | 179 | 100 | 100 |
| LT6 | 30_PostSD_a | 11/26 02:00 | 38 | 44 | 42 | 3.3 | 2.2 | 16.2 | 158 | 100 | 100 |
| LT6 | 30_PostSD_b | 11/26 02:10 | 38 | 44 | 42 | 3.5 | 2.2 | 16.1 | 156 | 100 | 100 |
| LT6 | 30_PostSD_c | 11/26 02:20 | 38 | 43 | 41 | 3.3 | 2.1 | 15.8 | 155 | 100 | 100 |
| LT6 | 30_PostSD_d | 11/26 02:30 | 38 | 43 | 41 | 3 | 2 | 16.2 | 153 | 100 | 100 |
| LT6 | 30_PostSD_e | 11/26 02:40 | 38 | 43 | 42 | 3.3 | 2 | 16 | 151 | 100 | 100 |
| LT6 | 30_PostSD_f | 11/26 02:50 | 38 | 44 | 42 | 3.3 | 2 | 16.9 | 151 | 100 | 100 |
| LT6 | 31_PreSD_a | 11/26 02:50 | 38 | 44 | 42 | 3.5 | 2 | 16.9 | 151 | 100 | 100 |
| LT6 | 31_PreSD_b | 11/26 03:00 | 38 | 44 | 42 | 3.5 | 2 | 17 | 156 | 100 | 100 |
| LT6 | 31_PreSD_c | 11/26 03:10 | 38 | 44 | 42 | 3.5 | 2 | 17.1 | 161 | 100 | 100 |
| LT6 | 31_PreSD_d | 11/26 03:20 | 38 | 44 | 42 | 3.3 | 2 | 16.8 | 166 | 100 | 100 |
| LT6 | 31_PreSD_e | 11/26 03:30 | 38 | 44 | 42 | 3.5 | 2 | 16.9 | 171 | 100 | 100 |
| LT6 | 31_PreSD_f | 11/26 03:40 | 38 | 44 | 43 | 3.5 | 2 | 16.8 | 176 | 100 | 100 |
| LT6 | 31_PostSD_a | 11/26 04:30 | 38 | 46 | 45 | 4 | 2.1 | 18 | 173 | 100 | 100 |
| LT6 | 31_PostSD_c | 11/26 04:50 | 38 | 45 | 44 | 3.8 | 2.1 | 18.4 | 170 | 100 | 100 |
| LT6 | 31_PostSD_d | 11/26 05:00 | 38 | 46 | 45 | 3.5 | 2.1 | 18.1 | 172 | 100 | 100 |
| LT6 | 31_PostSD_e | 11/26 05:10 | 38 | 44 | 43 | 3.3 | 2 | 17.7 | 174 | 100 | 100 |
| LT6 | 31_PostSD_f | 11/26 05:20 | 38 | 44 | 43 | 3.3 | 2 | 17.5 | 175 | 100 | 100 |
| LT6 | 44_PreSD_a | 11/29 11:50 | 40 | 45 | 42 | 5 | 1.6 | 12.6 | 310 | 100 | 100 |
| LT6 | 44_PreSD_c | 11/29 12:10 | 40 | 44 | 42 | 4.8 | 1.5 | 11.4 | 310 | 99 | 100 |

| | | | Sound Pressure Level ($L_{eq}$, dBA) | | | Ground-Level Wind (1.5m) | | Hub Height Wind (92 m) | | Wind Turbine Production During Operation Period (% max) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Monitor** | **Shutdown Period ID** | **Date & Time** | **Back-ground** | **Total Sound** | **Turbine-Only** | **Mean Speed (m/s)** | **Gust Speed (m/s)** | **Mean Speed (m/s)** | **Mean Direction (deg)** | **Closest Turbine** | **Other Nearby Turbines** |
| LT6 | 55_PreSD_a | 12/02 02:50 | 42 | 46 | 41 | 3.3 | 0.8 | 15.8 | 180 | 100 | 100 |
| LT6 | 55_PreSD_b | 12/02 03:00 | 42 | 46 | 42 | 3.3 | 0.9 | 16 | 180 | 100 | 100 |
| LT6 | 55_PreSD_c | 12/02 03:10 | 42 | 46 | 43 | 3.3 | 0.9 | 16.4 | 180 | 100 | 100 |
| LT6 | 71_PostSD_f | 12/06 05:20 | 35 | 41 | 40* | 4.3 | 2.7 | 9.9 | 148 | 97 | 98 |
| LT6 | 86_PostSD_d | 12/10 02:30 | 36 | 43 | 42* | 2.3 | 0.4 | 11.1 | 167 | 87 | 68 |

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