Wind Colebrook South Monthly

Noise Compliance Measurement Study

Colebrook, Connecticut

February, 2016

Prepared for:

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Executive Summary

A cold weather ("leaf off") noise monitoring study was completed for two 2.85 MW turbines installed at Wind Colebrook South in Colebrook CT during February 2016. In this report, we have reviewed applicable noise standards and criteria and described the measurements made at the location. **Given the data collected as a result of this study, it is our professional opinion that acoustic impacts from the wind turbines in Colebrook of 40-45 dBA are in compliance with and well below the maximum allowable noise levels of 61 dBA during the day and of 51 dBA during nighttime periods at all locations.** Noise levels from the turbines were at or about the level of the wind in the trees background at two locations under windy operating conditions, and well below the background level from highway noise sources at another. The turbine noise levels were about 10 decibels below the levels from frequent plane overflights. Infrasound levels were not measurable with the equipment, but under typical operating conditions levels should be below levels normally detected by the human ear.

Based on this study, we conclude the following:

- L90 Operational levels from the turbines at maximum noise levels were below the appropriate Connecticut standards during both daytime and nighttime periods of 61 dBA and 51 dBA, respectively, at all locations. Peak sound levels at the closest residence including traffic and tree noise were found to be about 4 dBA below the project noise limits.

- The turbine noise levels of about 40-47 dBA were well below levels expected from aircraft flyovers in the area, about 50-55 dBA. Background levels under wind turbine operational conditions from wind and tree noise were between 30 and 50 dBA, but were often comparable to or exceeded turbine noise levels at 2 of 3 monitoring locations under operational conditions. These are nearly the same levels as those expected from the turbine itself at the monitoring locations, indicating that much of the turbine sound was masked by the background under typical operating conditions.

1 Introduction

Wind Colebrook South ("WCS"), located at 17 and 29 Flagg Hill Road in Colebrook, CT is an operational wind farm. This wind farm consists of two 2.85 MW wind turbines with 103 meter diameter blades and 98.3 meter hub heights which feed power into the Connecticut power grid. WCS began commercial operations on November 4, 2015. It is possible that a third wind turbine, located to the southwest of the two operational ones, may go up during 2017. In this case, additional monitoring near this turbine may be needed, which would be done at that time.

Dr. Howard Quin was contracted by BNE Energy to perform a cold weather noise study for the wind turbine installations. The study took place over the months of January-March 2016. Each report summarizes noise measurements made during each of these months; this report summarizes the results for February 2016. Long-term monitoring will also be conducted at two locations over a one year period and the report will be filed in late 2016 when the study is completed. In this report, we review applicable noise standards and criteria, and summarize the measurement noise data at the site. Appendix A provides a description of various noise metrics.

2 Noise Standards and Criteria

Generally speaking, noise standards are usually defined as either absolute levels or amount over ambient background. Ambient is usually defined as the background A-weighted sound level that is exceeded 90 percent of the time (i.e. L90) measured during equipment operating hours, although in some cases is defined using the average level (the Leq). For the case where the turbines run continuously, as they did for many hours during the operational testing, the turbine sound is usually the ambient, depending on locations and other background sources. A wind turbine only operates when there is sufficient wind speed to run it, which is generally 4 meters per second (m/s) (9 mph) measured at a height of 10 meters (m), or about 5 m/sec at hub height. Therefore, it is appropriate to report sound levels when winds are blowing at speeds of 5 m/s or higher at hub height for purposes of comparison to the turbine noise emissions, if possible. Typically turbines would create peak sound levels near full production levels between 10 and 12 m/sec.

The noise monitoring program was conducted to demonstrate that the operation of the wind turbines at Colebrook South will meet the Connecticut Department of Energy and Environmental Protection's (DEEP) noise control regulations (Title 22a, §§ 22a-69-1 to 22a69-7), which are contained in the Regulations of Connecticut State Agencies. These regulations are:

Table 1

Noise Zone Standards, L90 (dBA)

Table 1

Noise Zone Standards, L90 (dBA)

Emitter Zone	Class A Daytime	Class A Nighttime	Class B	Class C
Class A (Residential)	55	45	55	62
Class B (Commercial)	55	45	62	62
Class C (Industrial)	61	51	66	70

Source: Control of Noise (Title 22a, Section 22a-69-1 to 22a-69-7.4), Regulations of Connecticut

The Emitter Zone for Colebrook South is Class C (Industrial) which shall not emit noise exceeding the levels stated in Table 1 at the adjacent noise zones. The relevant sound limits from the table are 61 dBA daytime and 51 dBA nighttime. Based on earlier sound results it is anticipated that noise concerns in the community may be an issue at some locations. In measuring compliance with Noise Zone Standards, the following short-term noise level excursions over the noise level standards established by these Regulations shall be allowed, and measurements within these ranges of established standards shall constitute compliance.

Allowable levels (dBA) above standards	Time period of such levels (minutes/hour)
3	15
6	7 ½
8	5

3 Measurement Program

A total of four sites were chosen for weekly sound measurements near the two turbines on Flagg Hill Road. Two of these sites were to have weekly monitors for one week intervals during the monthly monitoring program, while one other was to have seasonal monitors for one week each quarter as well as during the monthly program, while a final location was to have seasonal monitoring only. The seasonal monitoring was performed concurrently with the February monthly program; the results are in a separate report. The monitoring locations were identified in the Colebrook South Post Construction Noise Monitoring Program approved by the Connecticut Siting Council on November 22, 2011. Figure 1 shows the turbines and monitoring locations. The two turbines are clearly visible on the map below inside the property line. The monitoring locations were as follows;

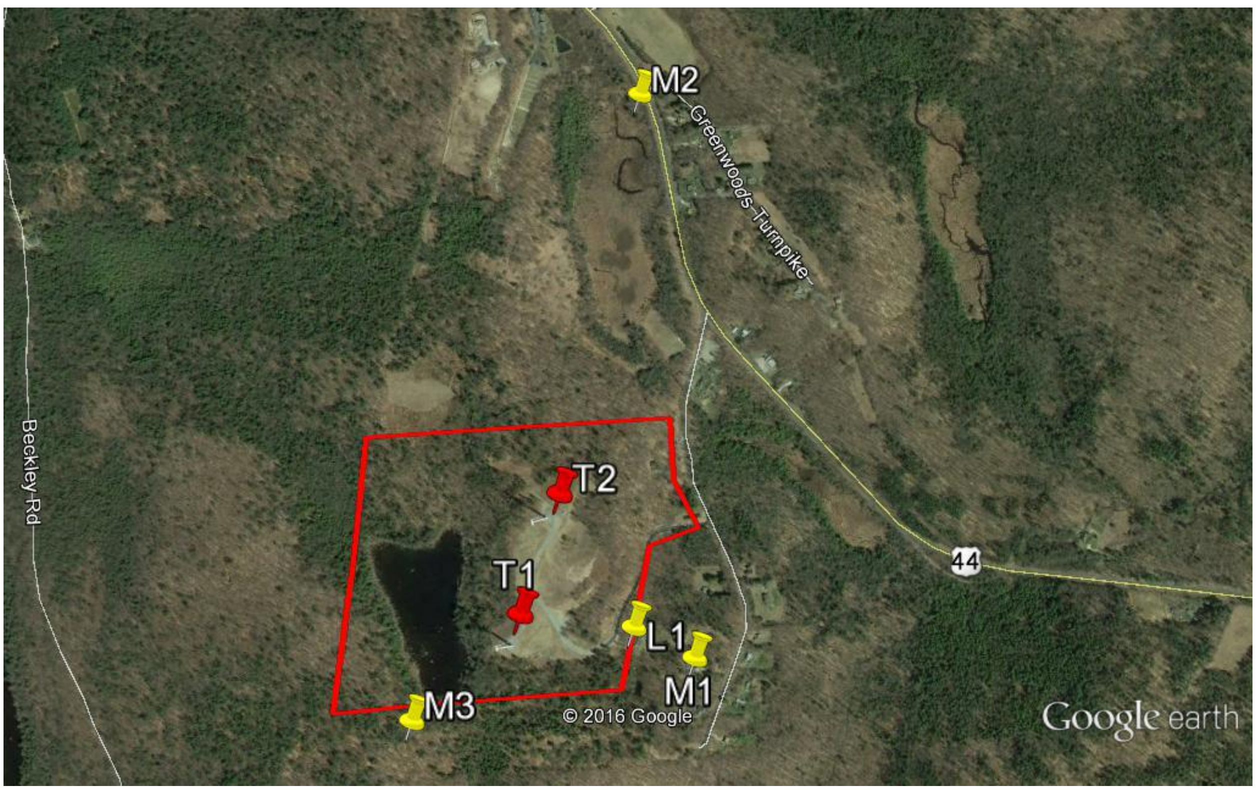


Figure 1.

Monitoring Sites and Property Line

Near Wind Colebrook South

M1 – Located near the Residence on 45 Flagg Hill Road. Identified as Receptor Location 5 (R5) in the Noise Report dated October 2010. The latitude and longitude coordinates are 41° 57.709'N Latitude, 73° 8.488'W Longitude. This location was also used for seasonal monitoring.

M2 – Located on the west side of the road near the Residences on Greenwoods Turnpike. Identified as Receptor Location 2 (R2) in the Noise Report. The latitude and longitude coordinates are 41° 58.363'N Latitude, 73° 8.569'W Longitude.

M3 – Located near the property line of the Residence on Beckley Road. Identified as Receptor Location 7 (R7) in the Noise Report. The latitude and longitude coordinates are 41° 57.641'N Latitude, 73° 8.910'W Longitude.

L1 – Located near the closest Residence to the turbines on 29 Flagg Hill Road, which has a Wind Farm Neighbor Agreement with Wind Colebrook South, and is the closest residence to Turbine 1. This is the seasonal monitoring location where measurements will be conducted for one week during each season. It was also monitored during this program, and described in a separate report. Note that actual monitoring locations M1 and M2 were closer to the turbines than the closest nearby residents or property lines. Consequently, turbine sound levels measured at these locations are conservative; actual turbine sound levels at nearby relevant receptors would be lower.

At each location, long term data was collected in one hour intervals, in accordance with Connecticut DEEP requirements, with the meter on “slow” setting. As specified by DEEP requirements, the L90 metric will be used to verify compliance with DEEP regulations. Since the DEEP regulations also contain standards for shorter time intervals, the L10, L15, and L25 metrics will be examined to approximate the L90s for shorter time periods. Note that this is a conservative estimate; typically one hour L10s would have higher levels than six minute L90s in ten high wind periods over the same hour. The hourly Leq (average) level was also to be collected.

Noise measurements were conducted with Larson Davis 831 octave band sound level meters/noise analyzers for intervals of one hour, in order to comply with the Connecticut monitoring requirements. Field calibrations with acoustic calibrators were conducted for all of the measurements. All instrumentation components, including microphones, preamplifiers and field calibrators have current laboratory certified calibrations traceable to the National Institute of Standards and Technology. Microphones were fitted with special 7 inch windscreens for use in windy areas, which are usually used for wind turbine sound monitoring.

Attended short term monitoring was not made during this monitoring period. This was because the turbines were not both operational during both of the short term monitoring visits, and it was determined that both turbines should be running in order to verify on-site compliance. Additional on-site monitoring was done in March with both turbines operational in order to further verify compliance.

The February measurement program was conducted by Howard Quin from February 17, 2016 to February 23, 2016. The sound levels measured are typical of those expected during dry winter conditions with light snow cover on the ground. Insect noise was absent during the winter. Meters were deployed for about a week at each location; the program was reduced by less than a day due to inclement weather. Quality data for several days of both turbine operations were obtained.

Weather varied moderately during the measurement period, which was timed to occur after a period of extreme cold (10-15 below zero) which could have led to meter failure. Weather data were obtained from station KCTNORFO2, Great Mountain Forest, about 4 miles west near Tobey Pond; wind data was obtained on site from the turbine SCADA system. High temperatures ranged from about 24 degrees to 51 degrees Fahrenheit, while lows ranged from about 9 degrees to about 33 degrees. Leaves were off trees, and snow cover was consistently patchy throughout the monitoring period. This is therefore typical of winter conditions in the study area. Wind conditions were peak operational wind conditions occurred on a few days during the study, most noticeably on February 18-20. Both turbines were running during all operational periods.

Figure 2. Sound Monitoring Site Photos

Monitoring Location M1 Behind 45 Flagg Hill Road

Monitoring Location M2 Across From Greenwoods Turnpike

Monitoring Location M3 Near SW Property Line

4 Measurement Results

Figures 3, 4, and 5 represent graphs of the L90, L10 and Leq at sites M1, M2, and M3 for each one hour period. Wind speed is shown in blue, while sound level is in red. The established project limits are in green. The conservative nighttime is 51 dBA, while the 15 minute limit of 54 dBA which is 3 dBA above the Connecticut hourly limit is shown on the L10 graph. The graph shows that, typical L90s varied from approximately 32 to 45 dBA at Location M1, from 29 to 48 dBA at M2 which was dominated by traffic noise, and from 26 to 47 at M3, with high wind noise producing the peaks at both locations. Note that noise recorded includes all sound on site, not just the turbine noise, including noise from wind, trees, cars, trucks and planes. ***The data shows that the turbines were in compliance with the most stringent (nighttime) levels of 51 dBA at all times during the study period even when including background noise caused by the wind, trees, cars, trucks and planes.***

In order to examine compliance with various metrics employed by DEEP, we have correlated the wind speed with SCADA data obtained from the wind turbine hub. For this analysis, we have used data from turbine T1, which is closest to the residences; similar data was obtained from turbine T2. The SCADA data is obtained in 10 minute windows, which makes for ready comparison with various metrics. We have plotted the L10 metric against the highest hourly 10 minute wind speed increment, the Leq metric against the average wind speed for each hour, and the L90 metric against the lowest hourly 10 minute wind speed, which is the exact interval used for Connecticut compliance evaluation. It should be noted that there is not an exact correlation here; the L10 and L90 are the highest and lowest 10% levels over an entire hour, whereas the 10 minute wind speed averages are only the highest and lowest separate 10 minute intervals. Nonetheless, they are closely correlated with the actual wind occurring during the highest and lowest 10 percent times at locations where wind noise and turbine noise predominate. Note that the L10 is also relevant, as it is above two other compliance metric levels, the 15 and 7 ½ minute levels; if the L10 is in compliance, those levels will be in compliance too.

During the monitoring period, wind speeds varied from about 5 to 12 m/sec, and at least one turbine was operating during most of the monitoring period. An examination of the data indicates that there is a strong correlation between the hub wind speed and the sound levels at two of the locations, the meter near the residence on 45 Flagg Hill Road (M1), and the meter near the pond to the southwest of the turbines (M3). However, it should be noted that this is by no means a one-to-one correspondence. This is due to the fact that the wind direction varies somewhat, and residents are most affected by sound from the upwind direction. This means that the peak sound levels from the turbine at 45 Flagg Hill Road are usually from winds from the west or southwest, while peak sound levels from the turbine at the pond area to the southwest are from winds to the east and northeast.

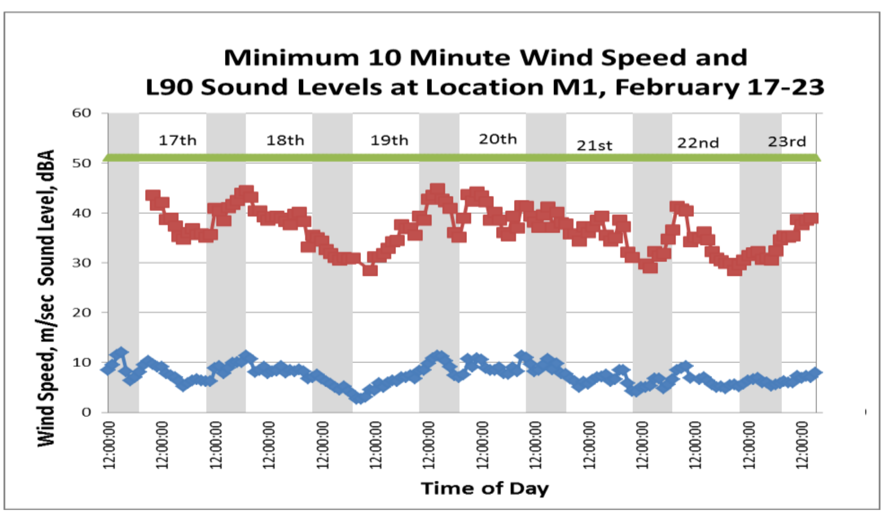
Wind directionality had differing, but important effects, at each measurement location. This is due to differing orientations with regard to both sound and wind propagation, and differing background conditions. At location M1, sound was due to both wind turbine noise and background in the trees, with both being about equal in intensity depending on local gustiness. Sound levels were actually slightly higher when wind was from the south, as seen on the 20^{th}, as this allowed the wind to blow straight along the side of the hill without being blocked, as it would be when the wind was from the west. This caused the background levels from wind in the trees to be somewhat higher, compensating for the fact that sound from the turbine moved from downwind to sidewind. This directional effect was also seen at location M3. When the wind was from the west, sound levels were dominated almost entirely by the turbine, as the hill blocked most of the tree wind noise, while when they were from the south the background levels in the trees were greater.

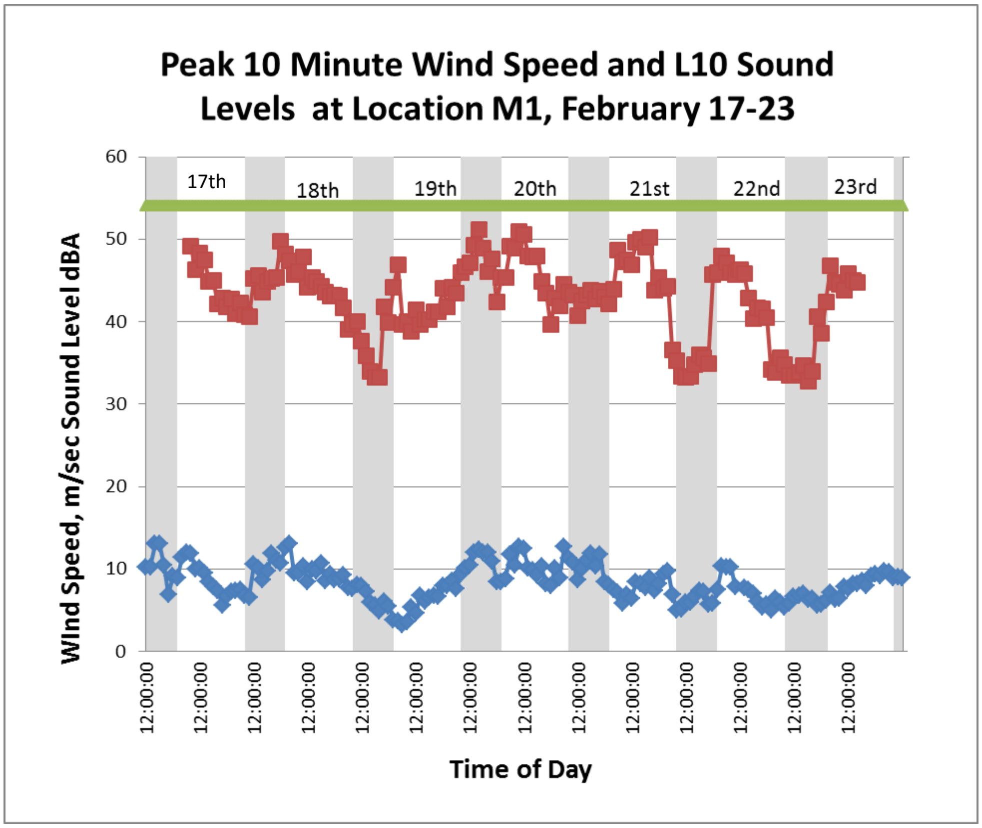
An examination of the levels at locations M1 and M3 also indicates slightly lower levels in the later portion of the measurement campaign, beyond the effect of lower wind speeds. This was due to the fact that turbine T2 (the one further from the residents) was not operational during a few hours on the afternoon of the 19th and again from 5 P.M. on the 20th until the end of the measurement period. Consequently, the data in this time period does not reflect full operational wind farm sound levels; they are about 2-3 decibels lower than they would be under the condition with both turbines operational. Compliance evaluation, then, should be based on levels from the 17th to the 20th, with both turbines running. ***An examination of the wind during that time indicates that there were several hours in which both turbines were operating at peak sound producing levels. The turbines were in compliance during all of these hours.*** Additional monitoring time was also added in March to allow for more data to be collected with both turbines running.

At location M2, sound was actually mostly dominated by traffic noise. Some bad data due to late night cold weather was removed on the night of the 21st and 22nd. This was true through most of the day under normal turbine operating conditions, as the turbine noise levels were not particularly high in this area. This means that there was little correlation of the L90 and L10 levels with the turbine operations on site. ***The data at location M2 shows that in this area, sound is dominated by the road, car, truck or tree noise; the turbines contribute relatively little to the overall sound environment in this area.***

Overall, all locations should experience similar levels from air flight flyovers, as this area is under the western flight path of Bradley International Airport. As there was no variation in flyover conditions from January, the flyover levels were also between about 50 and 55 dBA.

Figure 3.




Peak 10 Minute Wind Speed and L10 Sound Levels at Location M1, February 17-23
WInd Speed, m/sec Sound Level dBA
Time of Day
17th
18th
19th
20th
21st
22nd
23rd
0
10
20
30
40
50
60
12:00:00

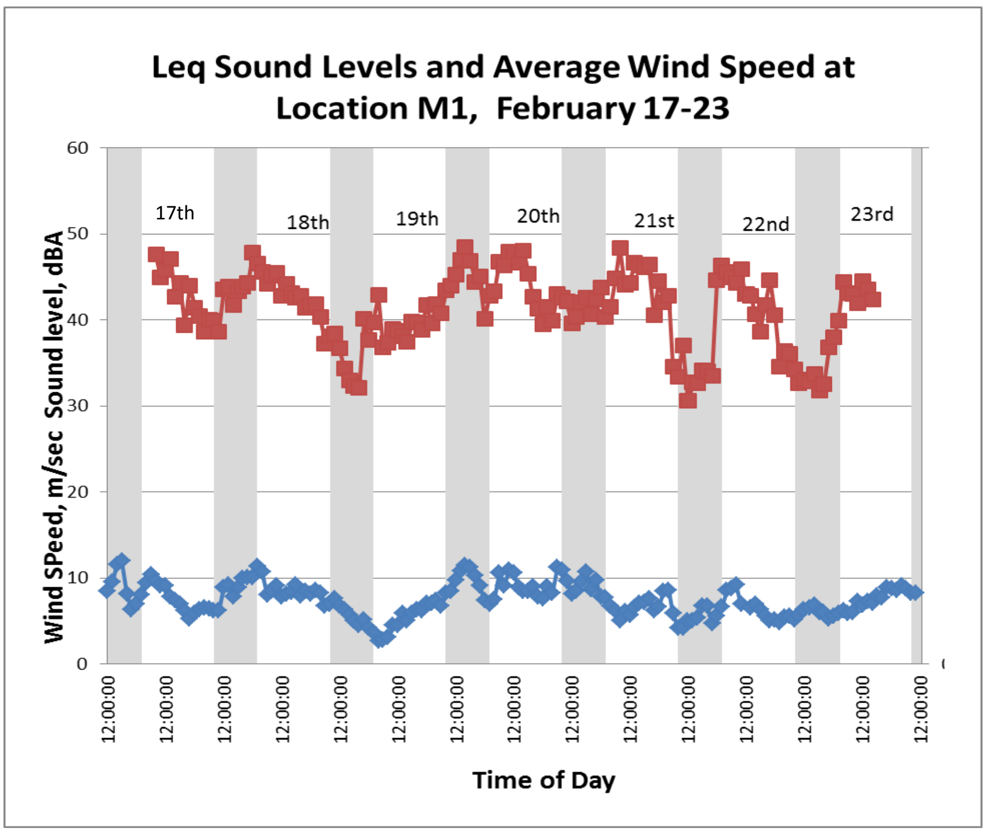
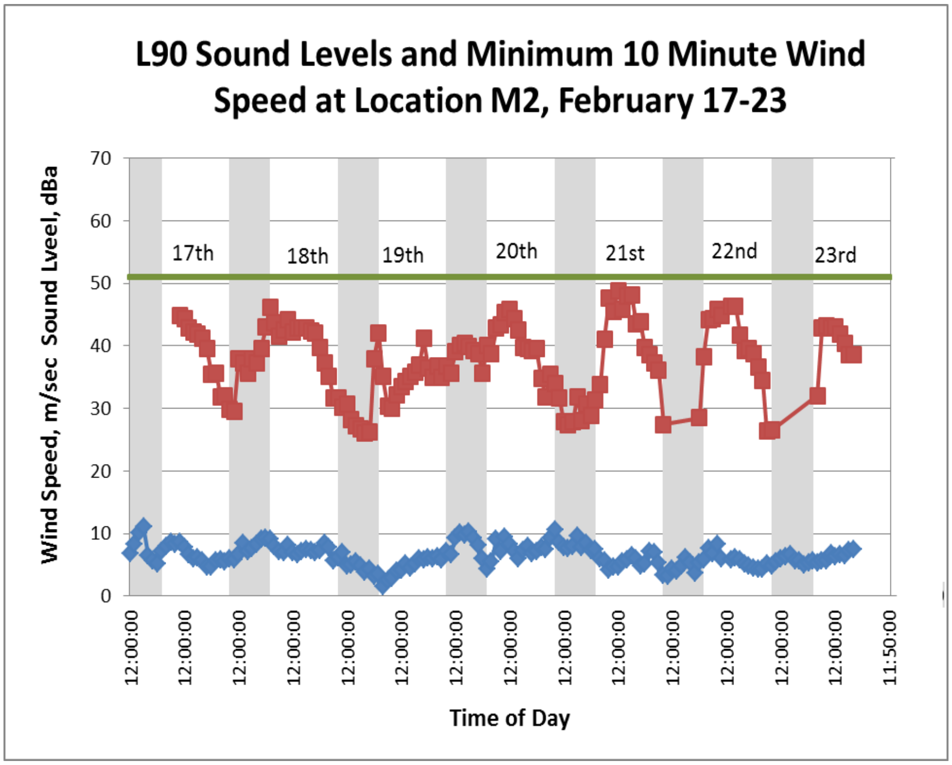
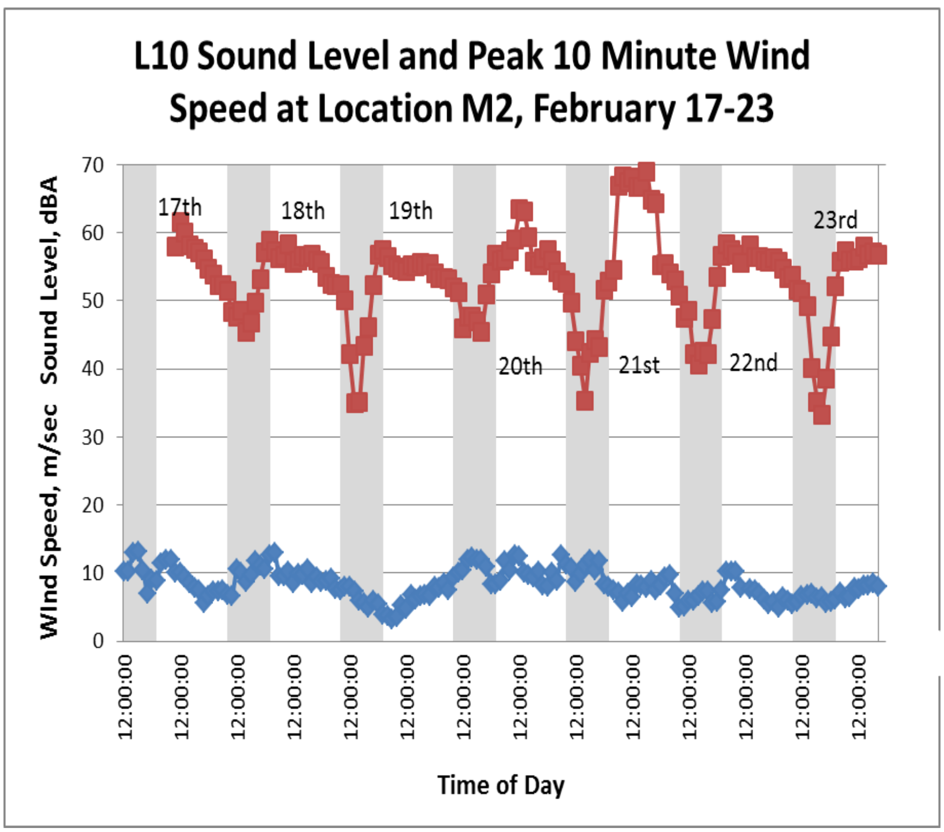

Leq Sound Levels and Average Wind Speed at Location M1, February 17-23
Wind SPeed, m/sec Sound level, dBA
Time of Day
17th
18th
19th
20th
21st
22nd
23rd
0
10
20
30
40
50
60
12:00:00

Figure 4.


L90 Sound Levels and Minimum 10 Minute Wind Speed at Location M2, February 17-23
Wind Speed, m/sec Sound Lveel, dBa
70
60
50
40
30
20
10
0
17th
18th
19th
20th
21st
22nd
23rd
12:00:00
11:50:00
Time of Day


L10 Sound Level and Peak 10 Minute Wind Speed at Location M2, February 17-23
WInd Speed, m/sec Sound Level, dBA
70
60
50
40
30
20
10
0
17th
18th
19th
20th
21st
22nd
23rd
12:00:00
Time of Day

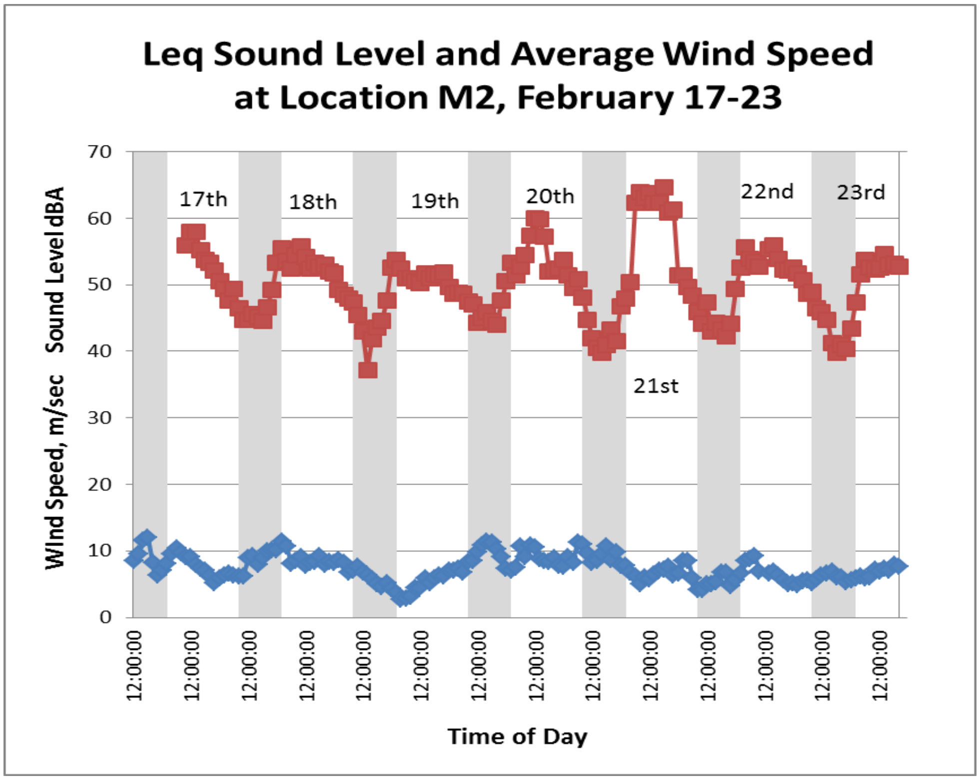
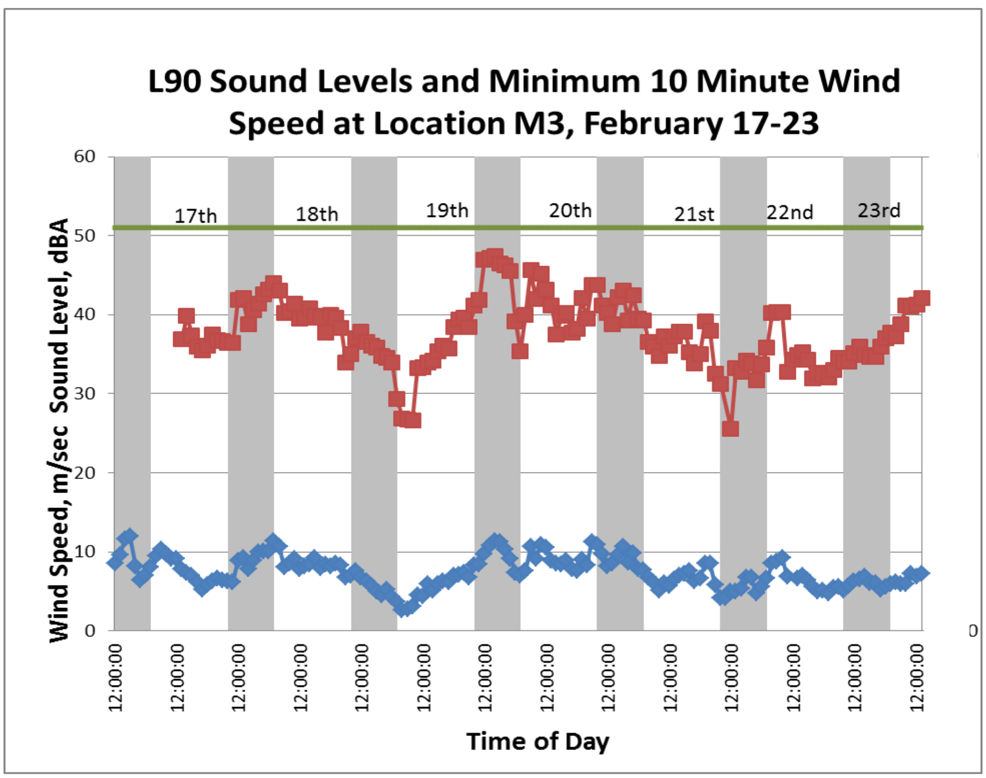
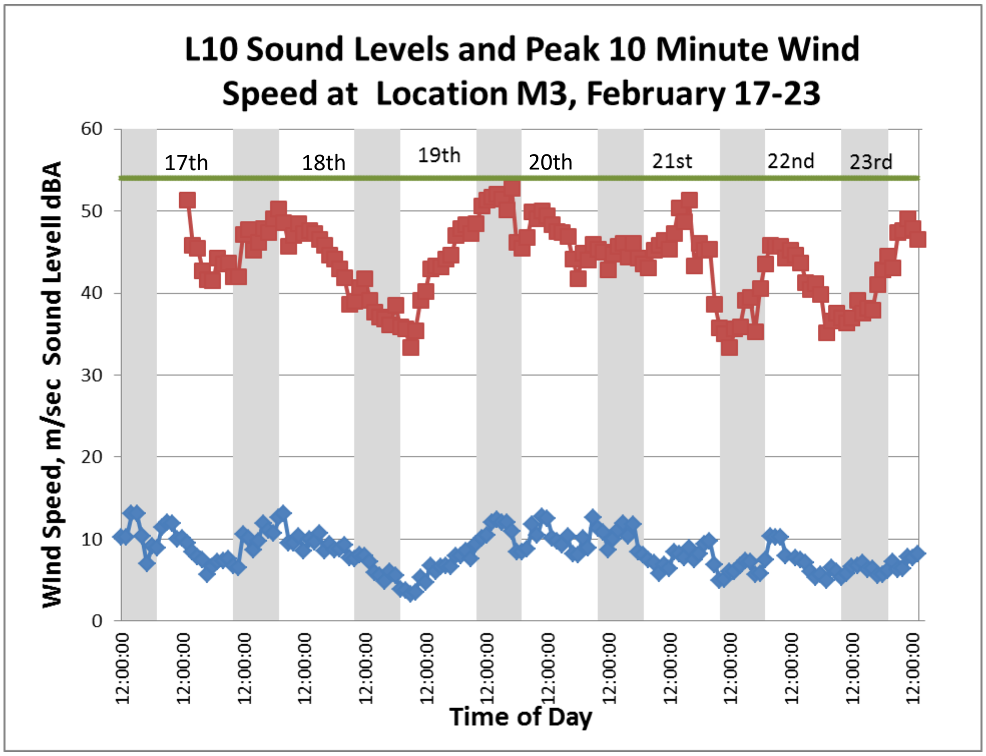

Leq Sound Level and Average Wind Speed at Location M2, February 17-23
Wind Speed, m/sec Sound Level dBA
70
60
50
40
30
20
10
0
17th
18th
19th
20th
21st
22nd
23rd
12:00:00
Time of Day

Figure 5.


L90 Sound Levels and Minimum 10 Minute Wind Speed at Location M3, February 17-23
Wind Speed, m/sec Sound Level, dBA
60
50
40
30
20
10
0
17th
18th
19th
20th
21st
22nd
23rd
12:00:00
Time of Day


L10 Sound Levels and Peak 10 Minute Wind Speed at Location M3, February 17-23
WInd Speed, m/sec Sound Levell dBA
Time of Day
17th
18th
19th
20th
21st
22nd
23rd
0
10
20
30
40
50
60
12:00:00

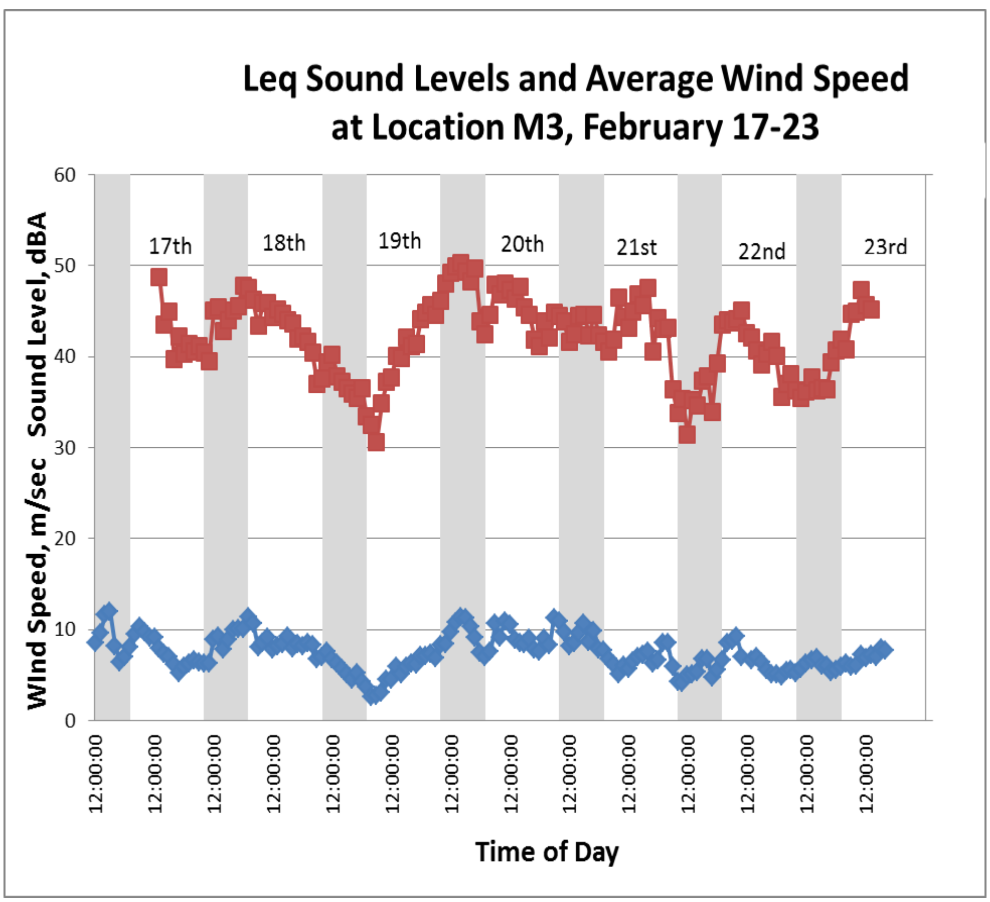
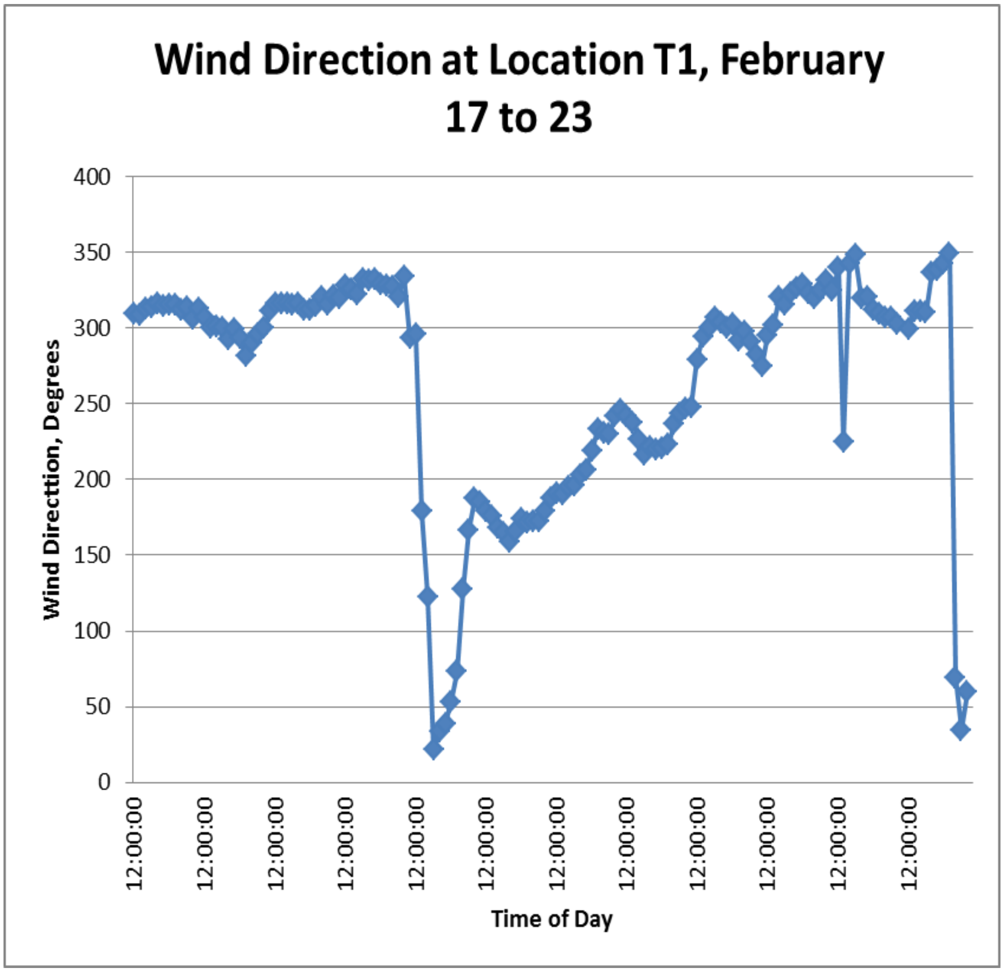

Leq Sound Levels and Average Wind Speed at Location M3, February 17-23
WInd Speed, m/sec Sound Level, dBA
Time of Day
17th
18th
19th
20th
21st
22nd
23rd
0
10
20
30
40
50
60
12:00:00

Figure 6.


Wind Direction at Location T1, February 17 to 23
Wind Directtion, Degrees
400
350
300
250
200
150
100
50
0
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
Time of Day

Appendix A Description of Noise Metrics

This Appendix describes the noise metrics used in this report.

1. A-weighted Sound Level, dBA

Loudness is a subjective quantity that enables a listener to order the magnitude of different sounds on a scale from soft to loud. Although the perceived loudness of a sound is based somewhat on its frequency and duration, chiefly it depends upon the sound pressure level. Sound pressure level is a measure of the sound pressure at a point relative to a standard reference value; sound pressure level is always expressed in decibels (dB), a logarithmic quantity.

Another important characteristic of sound is its frequency, or “pitch.” This is the rate of repetition of sound pressure oscillations as they reach our ears. Frequency is expressed in units known as Hertz (abbreviated “Hz” and equivalent to one cycle per second). Sounds heard in the environment usually consist of a range of frequencies. The distribution of sound energy as a function of frequency is termed the “frequency spectrum.”

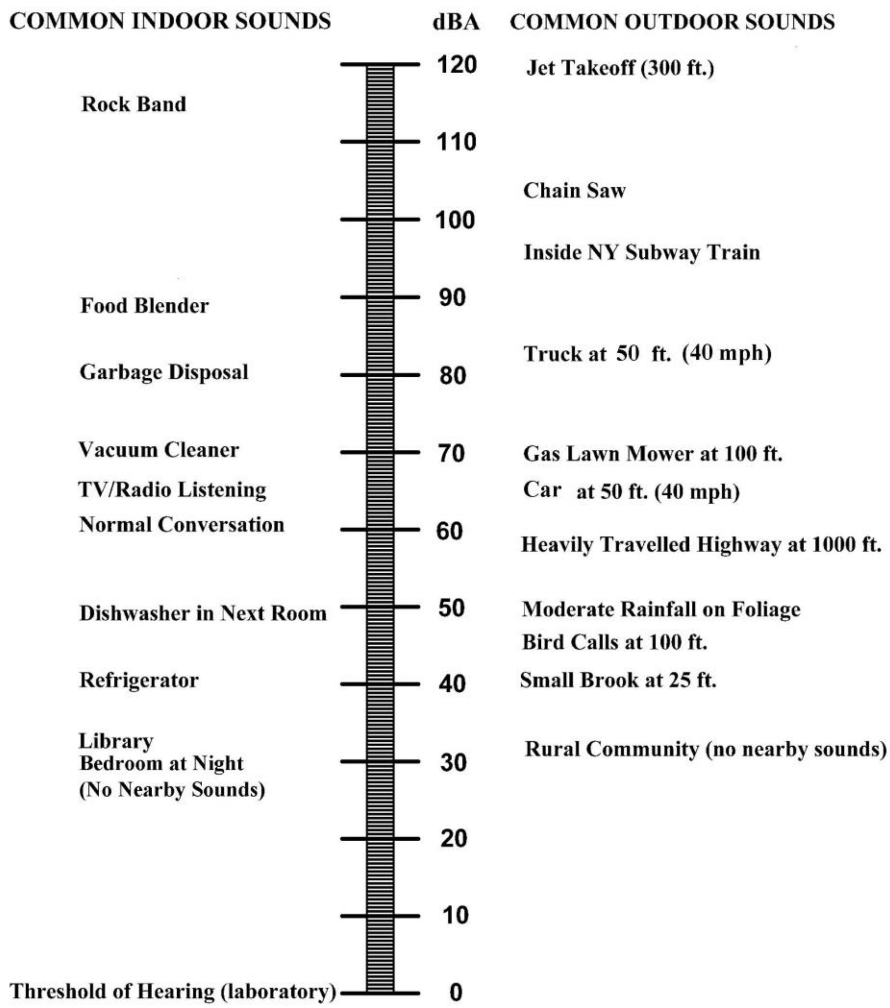
The human ear does not respond equally to identical noise levels at different frequencies. Although the normal frequency range of hearing for most people extends from a low of about 20 Hz to a high of 10,000 Hz to 20,000 Hz, people are most sensitive to sounds in the voice range, between about 500 Hz to 2,000 Hz. Therefore, to correlate the amplitude of a sound with its level as perceived by people, the sound energy spectrum is adjusted, or “weighted.”

The weighting system most commonly used to correlate with people's response to noise is “A-weighting” (or the “A-filter”) and the resultant noise level is called the “A-weighted noise level” (dBA). A-weighting significantly de-emphasizes those parts of the frequency spectrum from a noise source that occurs both at lower frequencies (those below about 500 Hz) and at very high frequencies (above 10,000 Hz) where we do not hear as well. The filter has very little effect, or is nearly “flat,” in the middle range of frequencies between 500 and 10,000 Hz. A-weighted sound levels have been found to correlate better than other weighting networks, including C weighting, with human perception of “noisiness” from turbines, which is why C weighting is not usually used for wind turbine compliance analysis One of the primary reasons for this is that the A-weighting network emphasizes the frequency range where human speech occurs, and noise in this range interferes with speech communication. The figure below shows common indoor and outdoor A-weighted sound levels and the environments or sources that produce them.

2. Equivalent Sound Level, Leq

The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the total exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest -- for example, an hour, an 8-hour school day, nighttime, or a full 24-hour day. However, because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric. Such durations are often identified through a subscript, for example L_{eq1h}, or $L_{eq(24)}$.

L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as (is "equivalent" to) the actual time-varying sound level with its normal peaks and valleys. It is important to recognize, however, that the two signals (the constant one and the time-varying one) would sound very different from each other. Also, the "average" sound level suggested by L_{eq} is not an arithmetic value, but a logarithmic, or "energy-averaged" sound level. Thus, the loudest events may dominate the noise environment described by the metric, depending on the relative loudness of the events.



3. Statistical Sound Level Descriptors

Statistical descriptors of the time-varying sound level are often used instead of, or in addition to L_{eq} to provide more information about how the sound level varied during the time period of interest. The descriptor includes a subscript that indicates the percentage of time the sound level is exceeded during the period. The L_{50} is an example, which represents the sound level exceeded 50 percent of the time, and equals the median sound level. Another commonly used descriptor is the L_{10}, which represents the sound level exceeded 10 percent of the measurement period and describes the sound level during the louder portions of the period. The L_{90} is often used to describe the quieter background sound levels that occurred, since it represents the level exceeded 90 percent of the period.