Wind Colebrook South

Noise Compliance Measurement Study

Colebrook, Connecticut

December, 2016

Prepared for:

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17 Flagg Hill Road
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Contents

Figures

Tables

Executive Summary

A long term noise monitoring study was completed for two 2.85 MW wind turbines installed at Wind Colebrook South in the Town of Colebrook, Connecticut during the year of 2016. In this report, we have reviewed applicable noise standards and criteria and described the measurements made at the locations. **Given the data collected in this study, it is our professional opinion that acoustic impacts from the wind turbines located in Colebrook of 40-49 dBA are in compliance with and well below the maximum allowable noise levels of 61 dBA during the daytime and 51 dBA during nighttime periods at both the long term locations and at the nearest residential receptors from the wind turbines.**

Measurements were made in each of four quarterly seasons, winter, spring, summer, and fall, for a period of one week each under turbine operational conditions at two locations near the turbines next to the two closest residences to the turbines with the exception of the residence at 17 Flagg Hill Road that is owned by the project. Measurements were made with Larson Davis Type I sound meters set to record both A-weighted and octave band levels. The weekly measurements were supplemented with on-site short term monitoring to verify noise conditions. In this report, we have reviewed applicable noise standards and criteria and described the measurements made at the locations.

Based on this study, we conclude the following:

- **L90 Operational levels from the wind turbines at maximum noise levels of 40-49 dBA were below the appropriate Connecticut standards during both daytime and nighttime periods at locations L1 and M1 for all seasons**.
- The data shows that the wind turbines were in compliance with the most stringent nighttime level of 51 dBA at location M1, and the nearest residence to location M1 at 45 Flagg Hill Road under all conditions, even with all other background noise (wind in trees, insects, birds) included. The data also shows that the wind turbines were in compliance with the most stringent nighttime level of 51 dBA at location L1, and the closest residence to the turbines on 29A Flagg Hill Road, which has a wind farm neighbor agreement with Wind Colebrook South, under all conditions after removal of background noise. Background levels under wind turbine operational conditions from wind, tree, bird and insect noise were between 30 and 55 dBA; they varied considerably due to changes in leaf, wind, ground cover and weather conditions during the year. The background levels are nearly the same levels as those expected from the turbine itself at location M1 under higher wind conditions during fall winter and spring; insect noise dominated during the summer, and was clearly louder than the turbines under low wind conditions. At location L1, sound was from both the turbines and wind in the trees, except during the summer, when insect noise dominated under low wind conditions.

1 Introduction

Wind Colebrook South (WCS), located at 17 and 29 Flagg Hill Road in Colebrook, Connecticut is an operational wind farm. This wind farm consists of two GE 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 west of the two operational turbines, may go up during 2018. 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 noise study for the wind turbine installations. Dr. Quin is a respected member of the Institute of Noise Control Engineering. The study took place over the entire year of 2016. Each report summarizes quarterly seasonal noise measurements made during one week in each quarter of the year. This report summarizes conditions under all seasons. The winter measurements occurred between February 16 and 23, the spring measurements occurred between May 9 and 18, the summer measurements occurred between August 14 and 24, and the fall measurements were made between November 12 and 19. 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 the various noise metrics used in this report.

2 Noise Standards and Criteria

Generally speaking, noise standards are usually defined as either absolute levels or amount over ambient background. Ambient is defined as the background A-weighted sound level that is exceeded 90 percent of the time (i.e. L90) measured during equipment operating hours. For the case where the turbines run continuously, as they did for many hours during the operational testing, the turbine sound is the ambient. 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.

The noise monitoring program was conducted to demonstrate that the operation of the wind turbines at Colebrook South comply with 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)				
	Class A Daytime	Class A Nighttime	Class B	Class C
Emitter Zone				
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. 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)	Time period of above standards such levels (minutes/hour)
3	15
6	7 ½
8	5

3 Measurement Program Overview

A total of two sites were chosen for seasonal measurements for a period of one week each quarter near the two turbines on Flagg Hill Road; other sites were monitored during the winter cold weather campaign. This site was to have seasonal monitors for one week each quarter. These monitoring locations were chosen after a site visit on December 22, 2015 by BNE and Dr. Howard Quin. Figure 1 shows the turbines and monitoring locations. The quarterly seasonal measurements were monitored at Location L1 and Location M1; the short term monitoring locations M2 and M3 are listed to show the cold weather compliance monitoring stations, but data was not collected at either location for this report. The two turbines are shown as T1 and T2. The monitoring locations were as follows:

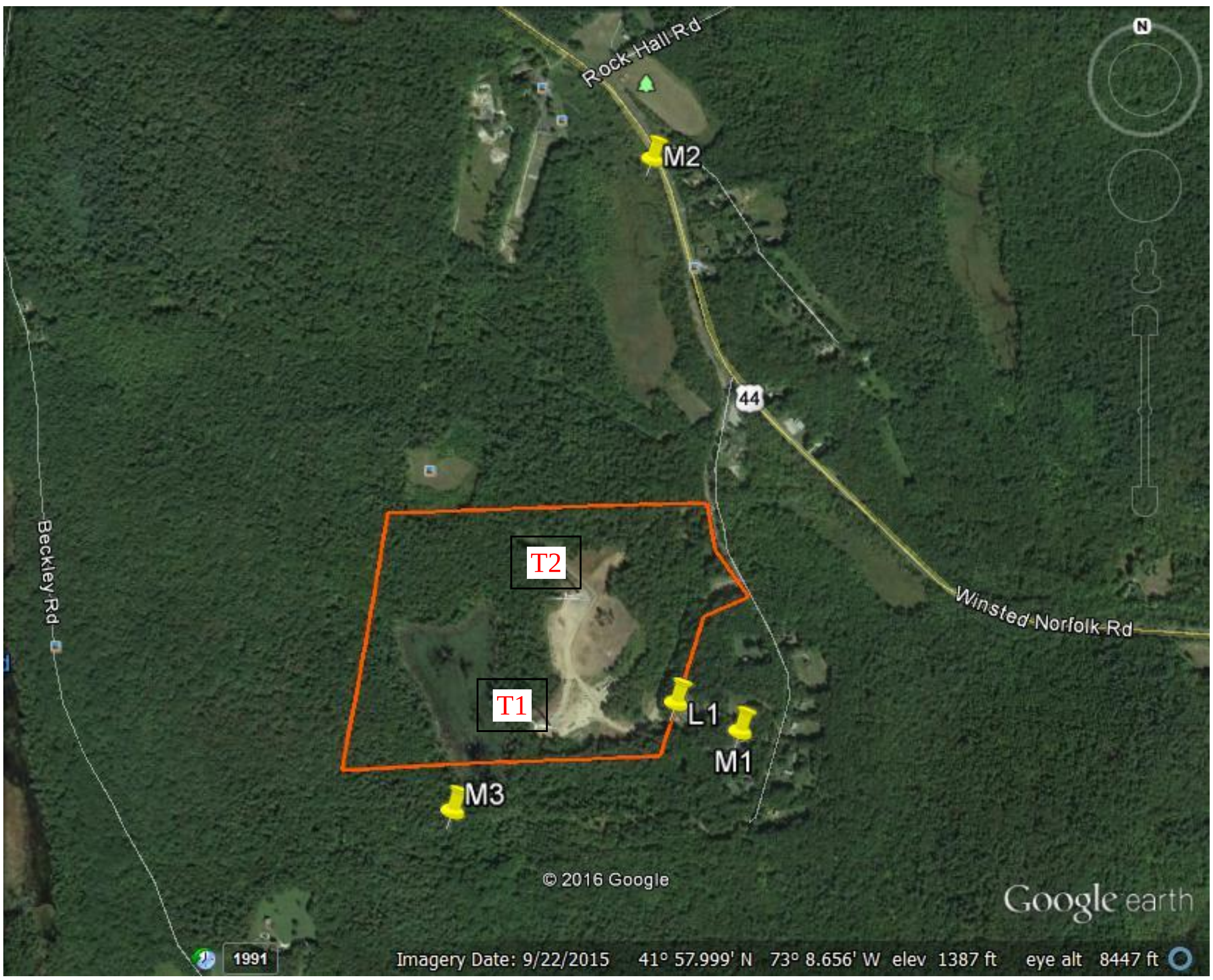


Figure 1.

Monitoring Sites Near Wind Colebrook South

L1 – Located near the closest residence to the turbines on 29A 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 were conducted for one week during each season. The latitude and longitude coordinates are 41° 57.740'N Latitude, 73° 8.577'W Longitude.

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.

M2 – Located on the west side of the road (closer to the turbines) near the residences on Greenwoods Turnpike. The monitoring location for M2 corresponds to receptor location R2 in the Noise Report, but it is approximately 180 feet closer to the turbines than R2. The latitude and longitude coordinates are 41° 58.363'N Latitude, 73° 8.569'W Longitude. Measurements at the M2 location that were done during the winter cold weather campaign are a more conservative indication of the noise levels at R2, which is further away from the turbines. Therefore, compliance verified at the M2 location proves compliance at R2 as it is approximately 180 feet further away from the turbines than the M2 location.

M3 – Located between the turbines and the property line of the Residence on Beckley Road. The monitoring location for M3 corresponds to receptor location R7 in the Noise Report, but it is approximately 1,265 feet closer to the wind turbines. The latitude and longitude coordinates are 41° 57.641'N Latitude, 73° 8.910'W Longitude. Measurements at the M3 location that were done during the winter cold weather campaign are a more conservative indication of the noise levels at R7, which is much further away from the turbines. Therefore, compliance verified at the M3 location proves compliance at R7 as it is approximately 1,265 feet further away from the turbines than the M3 location.

Long term data was collected at L1 and M1 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 examine compliance with DEEP regulations. Since the DEEP regulations also contain standards for shorter time intervals, the L10, L15, and L25 metrics were collected 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 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.

Each study occurred during different monitoring conditions. Each monitoring period recorded different background sound, although sound from the turbines was similar through all four monitoring periods. The February study occurred under conditions of light snow cover, and leaves off the trees. The May study occurred under conditions where leaves had just come on the trees and insect noise was moderate. The August study occurred with full leaves on the trees and insect noise. The November study occurred under conditions where almost all leaves were off the trees, and insect noise did not exist.

The differing sets of monitoring conditions led to differing levels of background sound from trees, insects and animals. However, some background sound levels were similar for all four monitoring programs. These included sound from jet aircraft flyovers, which were typically about 10 dBA higher than the turbine, and sound from gun shots at the nearby shooting range, which also exceeded the turbine noise by about 10 dBA (on “slow” setting).

The monitoring time period for each study varied slightly due to differing weather and equipment operational issues. The February, May and November studies were both a week long; the August study extended over 11 days due to equipment issues with thunderstorms. Each study contained periods where the wind turbines were operational under a variety of wind speeds including peak wind speeds; consequently, a wide range of possible turbine sound levels were recorded for each season. Given the full range of conditions monitored throughout the program, it is very unlikely that any kind of wind turbine noise conditions which would have been noticeable to the residents were not recorded during the monitoring period. We therefore believe that the monitoring program was sufficient to adequately verify wind turbine sound levels throughout the yearly monitoring time period.

4 Seasonal Monitoring Program

The first measurement program was conducted by Dr. Howard Quin from February 17, 2016 to February 23 2016. The sound levels measured are typical of those expected during dry winter conditions. Insect noise was absent during the winter. Meters were deployed for a week at the monitoring locations.

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 was 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. Peak operational wind conditions occurred on a few days during the study period, most noticeably on February 18th and February 20th.

Figure 2.

February Sound Monitoring Site Photos

Monitoring Location L1 On Flagg Hill Road Near Turbine

Monitoring Location M1 Behind 45 Flagg Hill Road

The second measurement program was conducted by Dr. Howard Quin from May 9, 2016 to May 18, 2016. The sound levels measured are typical of those expected during spring conditions. Leaves had just come on the trees, and there was insect noise during the evening.

This is therefore typical of mid-spring conditions in the study area. Meters were deployed for more than a week at these locations.

Figure 3.

May Sound Monitoring Photos

Monitoring Location L1 On Flagg Hill Road Near Turbine

Monitoring Location M1 Behind 45 Flagg Hill Road

Weather varied moderately during the May measurement period. Weather data was 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 50 degrees to 77 degrees Fahrenheit, while lows ranged from about 34 degrees to about 53 degrees. The turbines had operational wind on most days in the study period. Peak operational wind conditions occurred on a few days during the study period, most noticeably on May 15 and May 16.

The third measurement program was conducted by Dr. Howard Quin from August 14, 2016 to August 24, 2016. The sound levels measured are typical of those expected during summer conditions. Leaves were on the trees, there was insect noise both during the day and during the evening. This is therefore typical of mid-late summer conditions in the study area. Meters were deployed for a week at the monitoring locations.

Weather varied moderately during the measurement period. Weather data was 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 80 degrees to 96 degrees Fahrenheit, while lows ranged from about 61 degrees to about 70 degrees. The turbines had operational wind on about half the days in the study. Peak operational wind conditions occurred on a few days during the study period, most noticeably on August 14, 17 and August 21.

Figure 4.

August Sound Monitoring Photos

Monitoring Location L1 On Flagg Hill Road Near Turbine

Monitoring Location M1 Behind 45 Flagg Hill Road

The final measurement program was conducted by Dr. Howard Quin from November 13, 2016 to November 20, 2016. The sound levels measured are typical of those expected during autumn conditions. Leaves were off the trees, there was no insect noise both during the day and during the evening. This is therefore typical of mid-late autumn conditions in the study area. Meters were deployed for a week at the same locations.

Weather varied moderately during the measurement period. Weather data was 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 49 degrees to 63 degrees Fahrenheit, while lows ranged from about 30 degrees to about 45 degrees. The turbines had operational wind on about half the days in the study. Peak operational wind conditions occurred on a few days during the study period, most noticeably on November 15, 16 and November 17.

Figure 5.

November Sound Monitoring Site Photos

Monitoring Location L1 On Flagg Hill Road Near Turbine

Monitoring Location M1 Behind 45 Flagg Hill Road

5 Monitoring Results

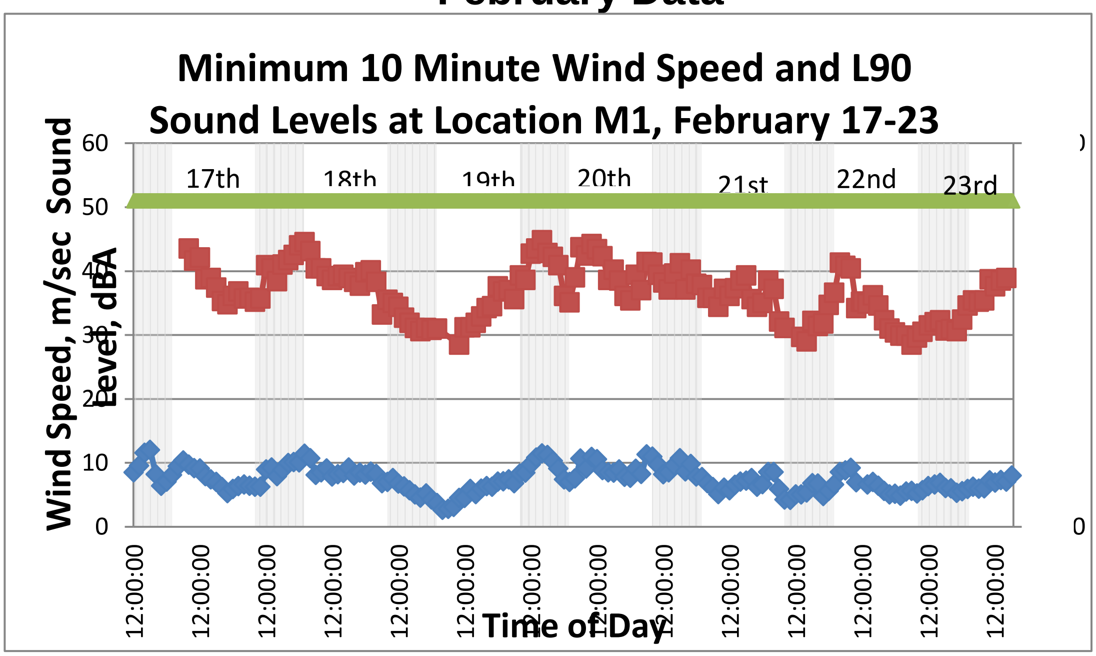
Figures 6 represents graphs of the February L90, L10 and Leq at sites M1 and L1 for each one hour period. The graph shows that, typical L90s varied from approximately 28 to 45 dBA at Location M1, and 22 to 48 at L1. The levels show that the sound was controlled primarily by the wind speed; higher sound levels were almost directly correlated with high wind speeds. The highest noise occurred during high wind events at all locations, as expected, with L90 sound levels in the 45–50 decibel range at location L1 including background noise during very windy conditions and 42-45 at location M1. Higher Leq levels at location M1 are due to higher local activity; the wind turbines are usually the L90 under operational conditions.

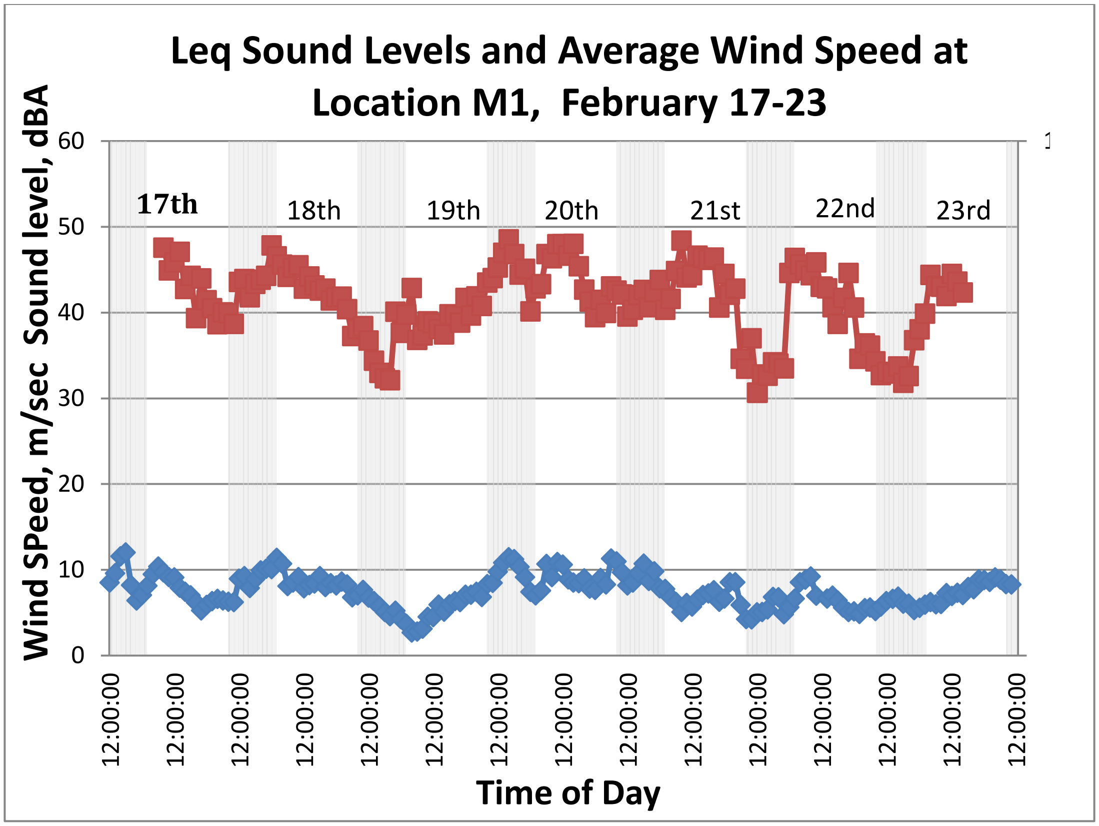
Higher Leq levels at location M1 are due to higher local wind noise in the trees; the wind turbine is usually the L90 under operational conditions. Sound levels were actually slightly higher when wind was from the south, as seen on the 20th, as this allowed the wind to blow straight along the side of the hill without being blocked, as it would be when the wind was from the west. At location L1, almost all sound was from the turbines; the open location downslope from western winds with leaves off the trees was not affected significantly by tree noise during the measurement period, except under high wind conditions.

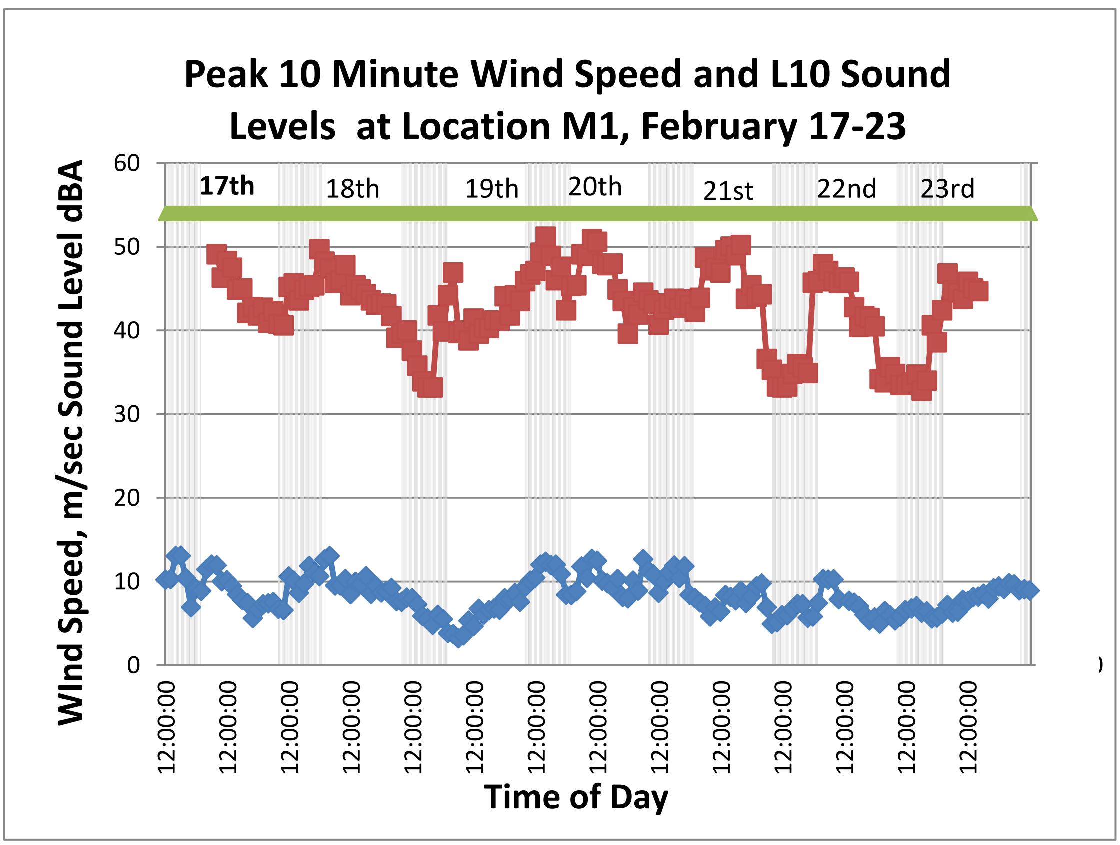
An examination of the levels at both locations M1 and L1 also indicates slightly lower levels in the later portion of the measurement campaign, beyond the effect of lower wind speeds. This was due to the fact that Turbine 2 (the one further from the residents) was not operational during a few hours on 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.

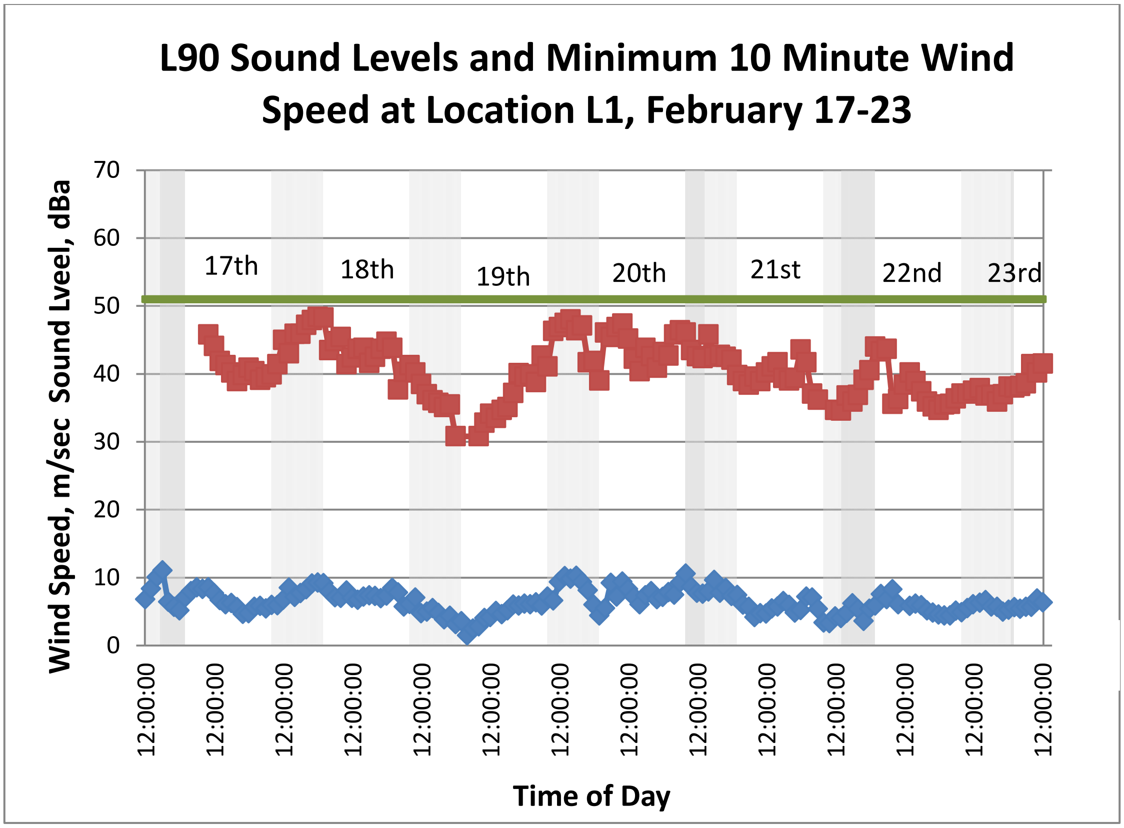
Figure 6.

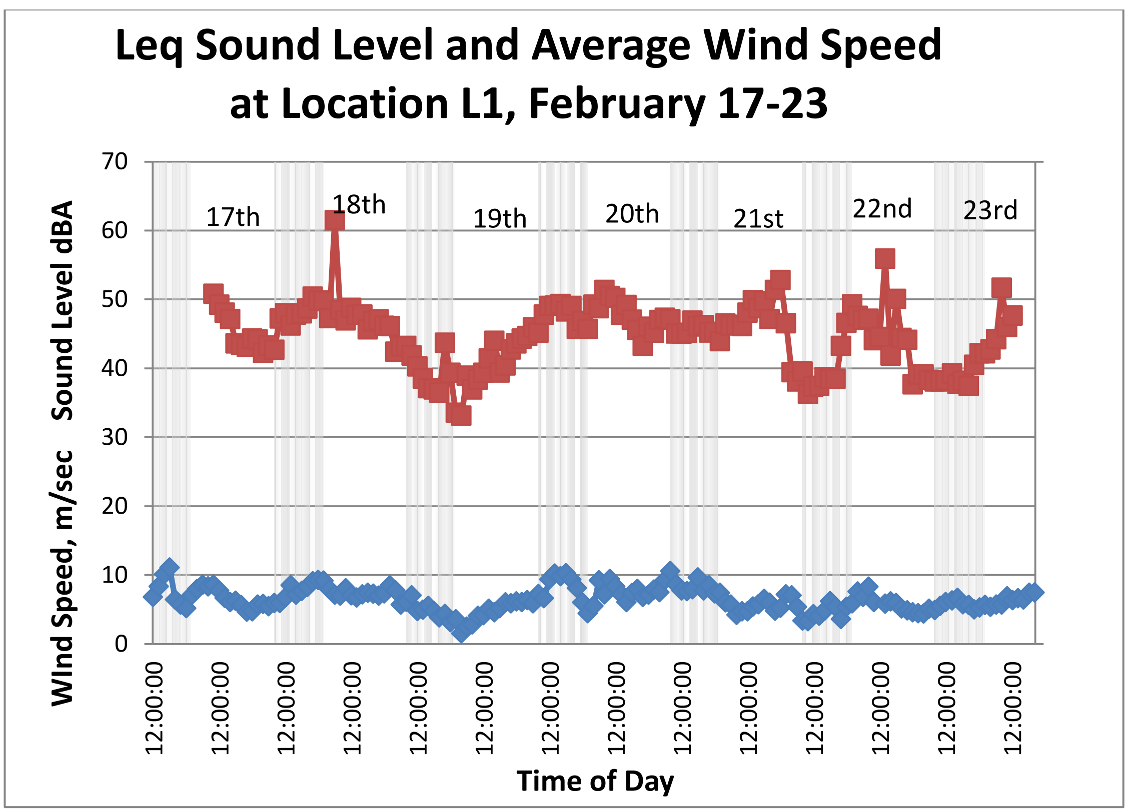
February Data

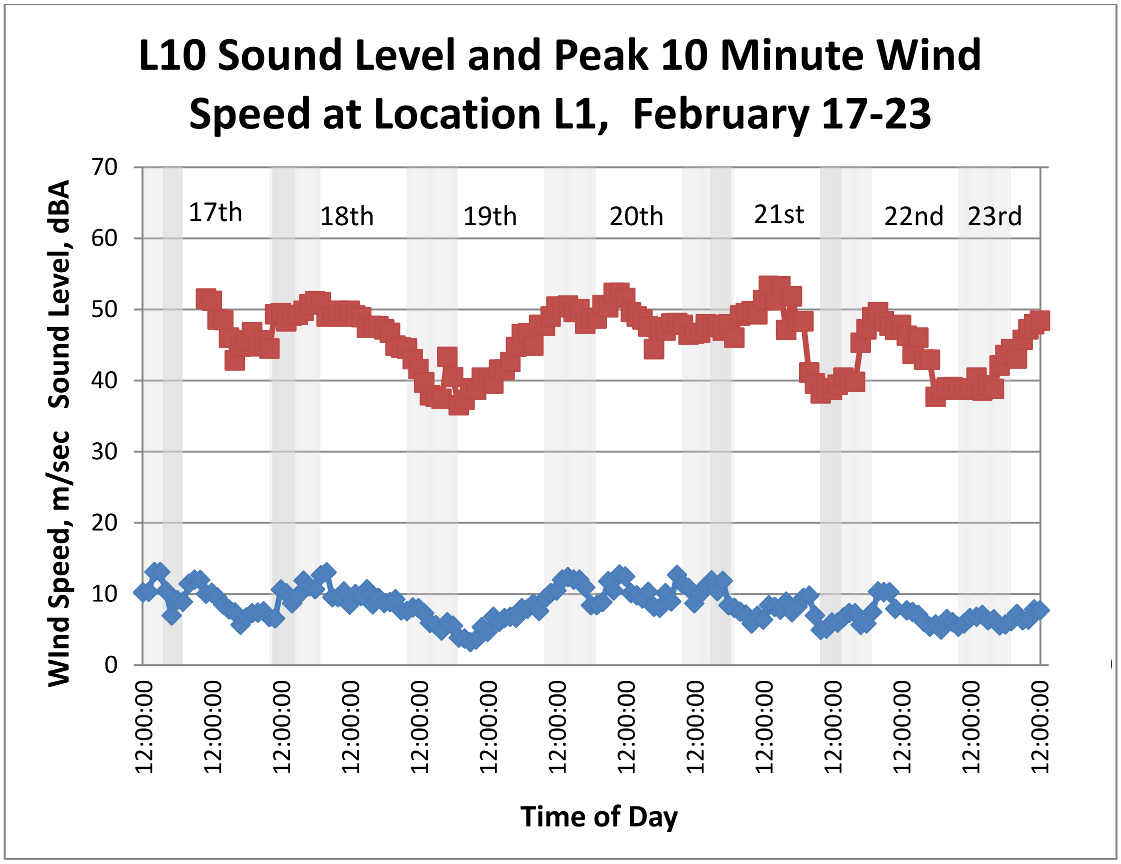



Leq Sound Levels and Average Wind Speed at Location M1, February 17-23
Wind SPeed, m/sec Sound level, dBA
60
50
40
30
20
10
0
17th
18th
19th
20th
21st
22nd
23rd
12:00:00
Time of Day


Peak 10 Minute Wind Speed and L10 Sound Levels at Location M1, 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


L90 Sound Levels and Minimum 10 Minute Wind Speed at Location L1, 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
Time of Day


Leq Sound Level and Average Wind Speed at Location L1, 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



Note that no short term data was collected during the February monitoring period, as conditions were not appropriate for this during the time of the site visits. On site observations during the visits showed sound levels consistent with those measured during the remainder of the monitoring program. Short term data for January and March is in the monthly cold weather monitoring reports.

Figure 7 represents graphs of the May L90, L10 and Leq at sites M1 and L1 for each one hour period. The graph shows that, typical L90s varied from approximately 27 to 53 dBA at Location L1, and 28 to 48 at M1 including background noise. The highest wind turbine sound levels were recorded on May 15 and 16 when the wind was around 8-11 m/sec. At location L1, although higher sound levels were sometimes correlated with high wind speeds, L90 levels above 51 dBA were correlated with construction activity occurring on the road below the turbines. The levels show that the sound was controlled primarily by the wind speed at location M1; higher sound levels were usually correlated with high wind speed, although there were higher low wind noise levels due to bird and some insect background. Higher Leq levels at location M1 are due to higher local activity; the wind turbine is usually the L90 under operational conditions.

The wind direction was primarily from the west to northwest during the monitoring period. This means that the residents and monitors were usually downwind of the turbines during that time, which gives typical worst case conditions. On May 13, the wind was primarily from the south. This resulted in slightly higher background levels at location M1, as the wind was not blocked by the hill as it blew through the nearby trees. At location L1, the sound did not show any increase in this direction, as the meter is further from trees, so any resulting background increase would not have been readily detected.

Short term monitoring was done at two times, during meter set up on the morning of May 9 and the evening before the monitoring was concluded on May 17. During the first short term (daytime) period, the wind was blowing fairly strongly, around 8 m/sec at hub height, and the turbines were producing at fairly close to full power. The L90s observed at both M1 and L1 are from the turbines; at M1, the turbine Leqs were actually close to 44 or 45 dBA during much of the observation time. Note that construction activity at L1 due to a power shovel caused a higher Leq than would have occurred otherwise. At M1 there was some wind in the trees, bird noise, construction noise in the background of about 40 dBA, and variation of the turbine noise, which raised the Leq by about 2-3 dBA.

During the second short term period, on the evening of May 17, the turbines were operating at lower power due to a lower wind speed, about 5 to 6 m/sec. This gave a lower L90 at M1 of about 37 dBA with the turbine operating, with occasional levels of up to 40 to 42. The additional sound was due to bird noise, which was actually louder than the turbine under much of the monitoring period. At location L1, sound was from the turbine, which gave an L90 of 43 dBA; there was some cricket background (there was no noise in the trees), as well as some variation in the turbine sound, which gave a higher overall Leq.

TABLE 2.

MAY SHORT TERM MONITORING RESULTS

Location	Date	Time	Leq	L90	L50	L25	L10
L1	May 9	12:20 P.M.	50.5	44.7	47.2	49.2	51.7
M1	May 9	11:45 A.M.	45.5	41.4	44.0	45.3	46.6
L1	May 17	9:02 P.M.	44.9	43.0	44.5	45.4	46.3
M1	May 17	8:25 P.M.	44.0	36.8	42.9	44.5	46.1

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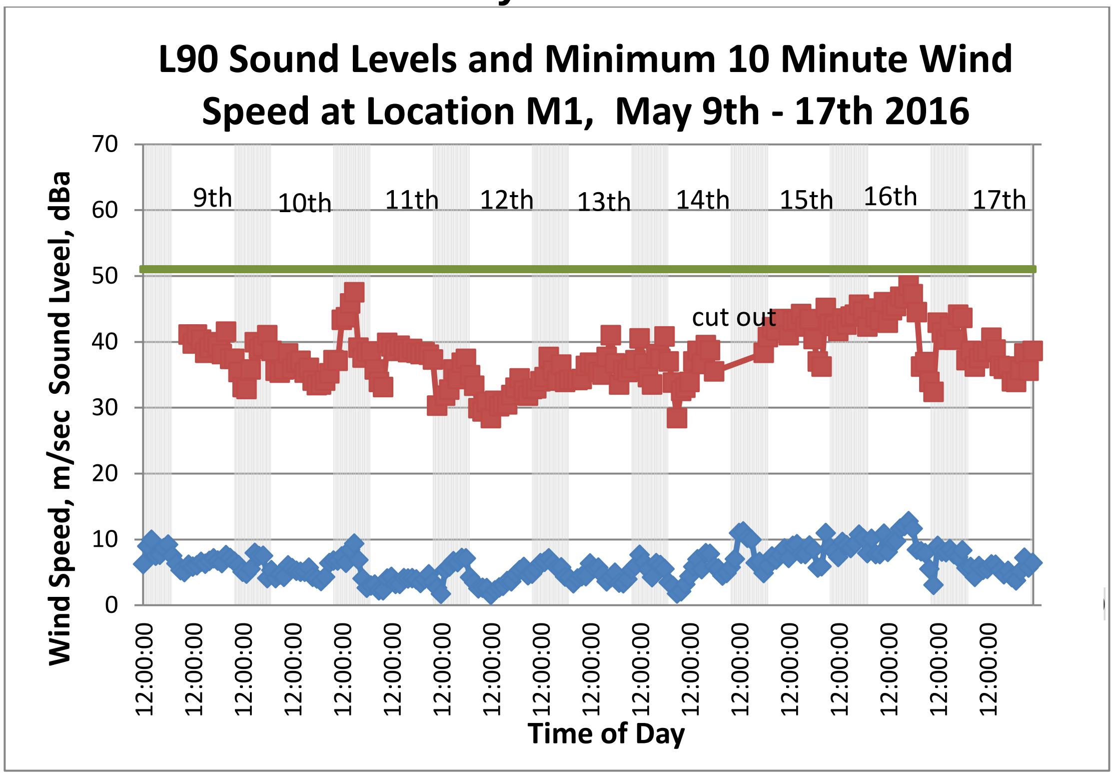
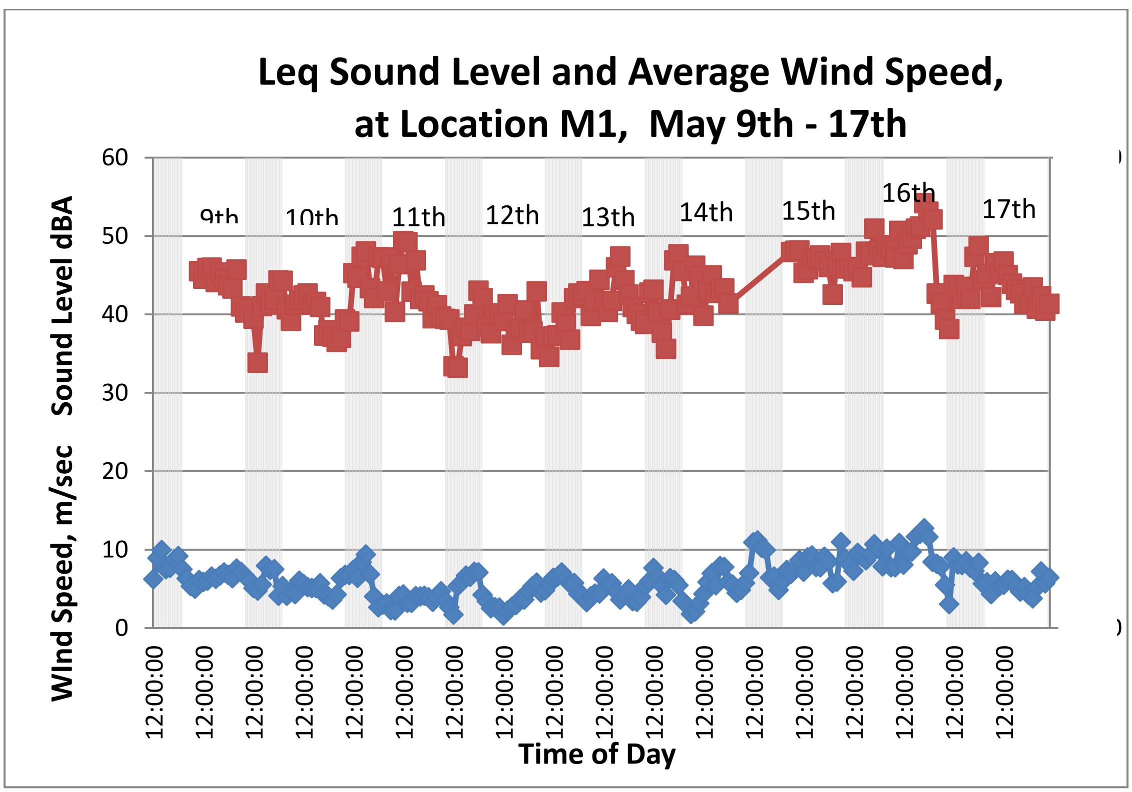
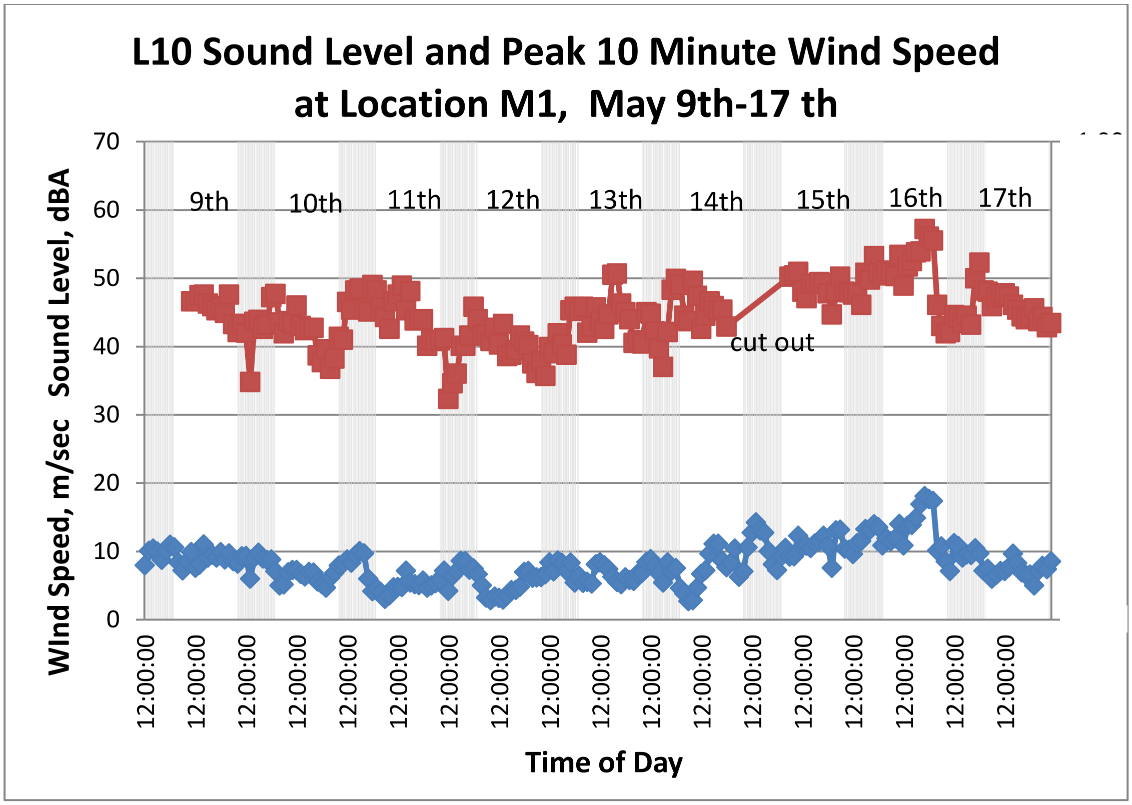
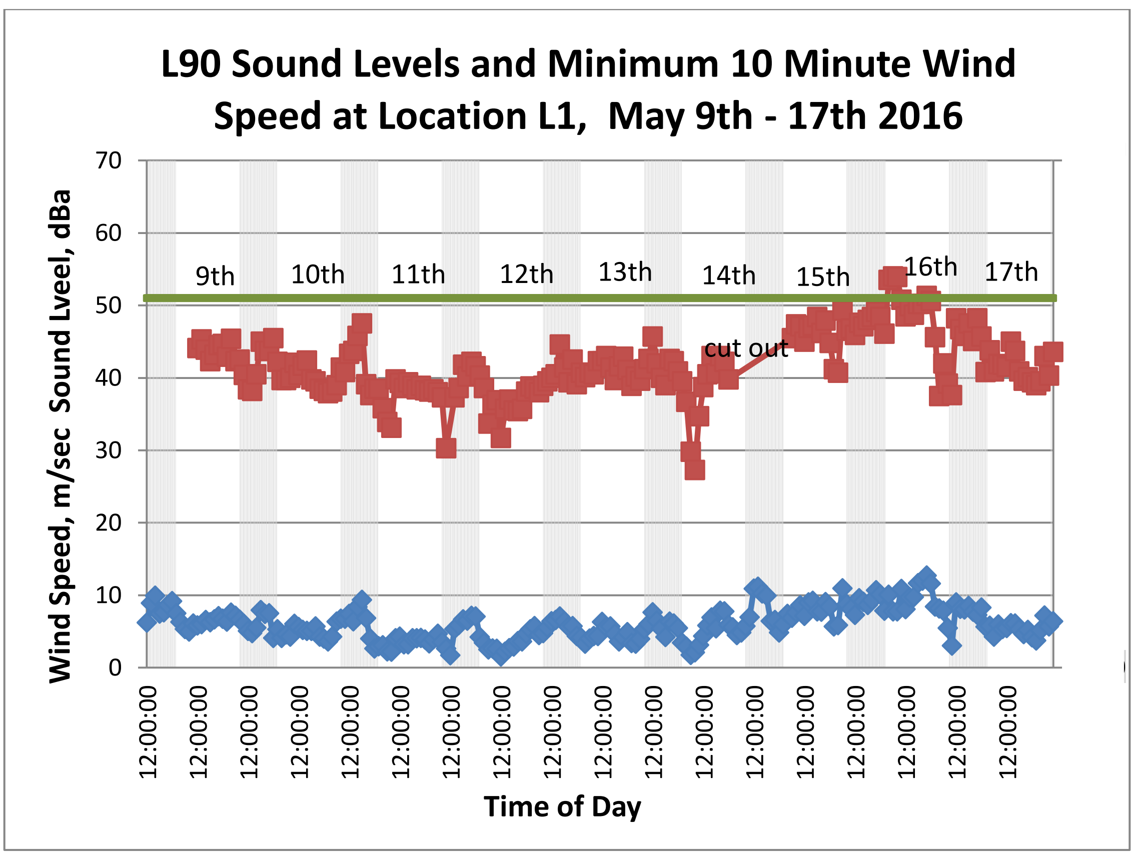
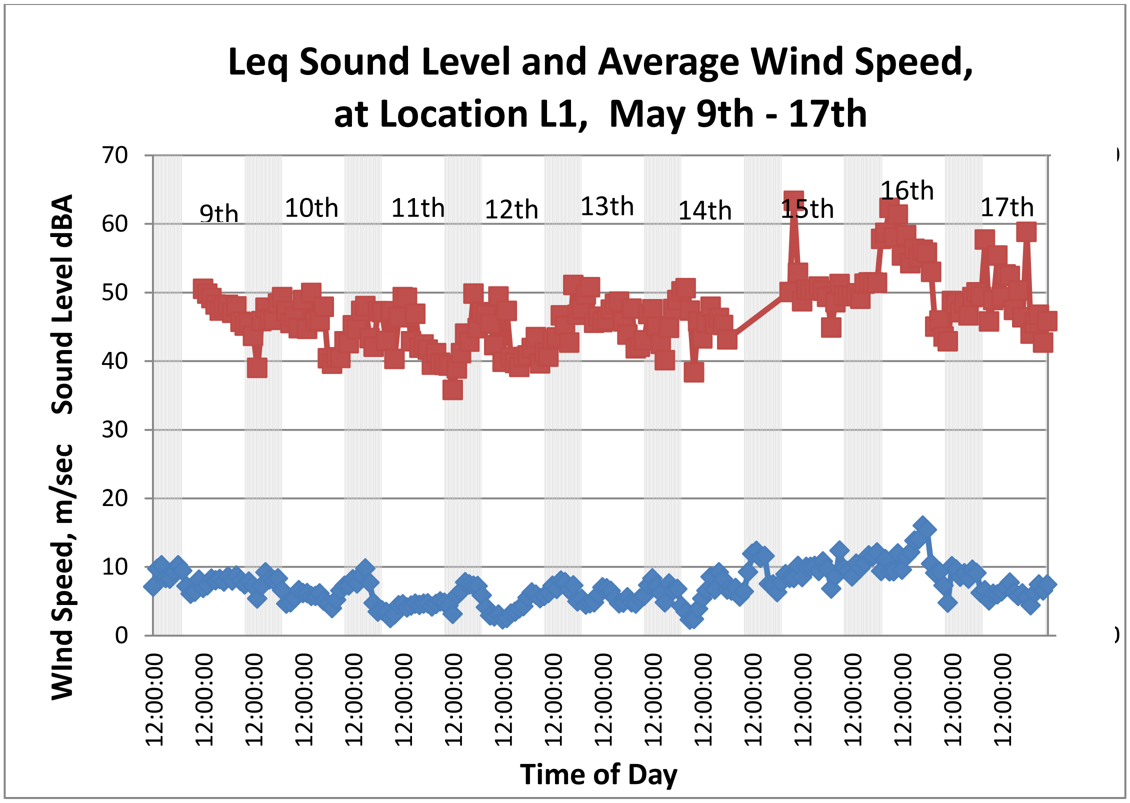
Figure 7.
May Data

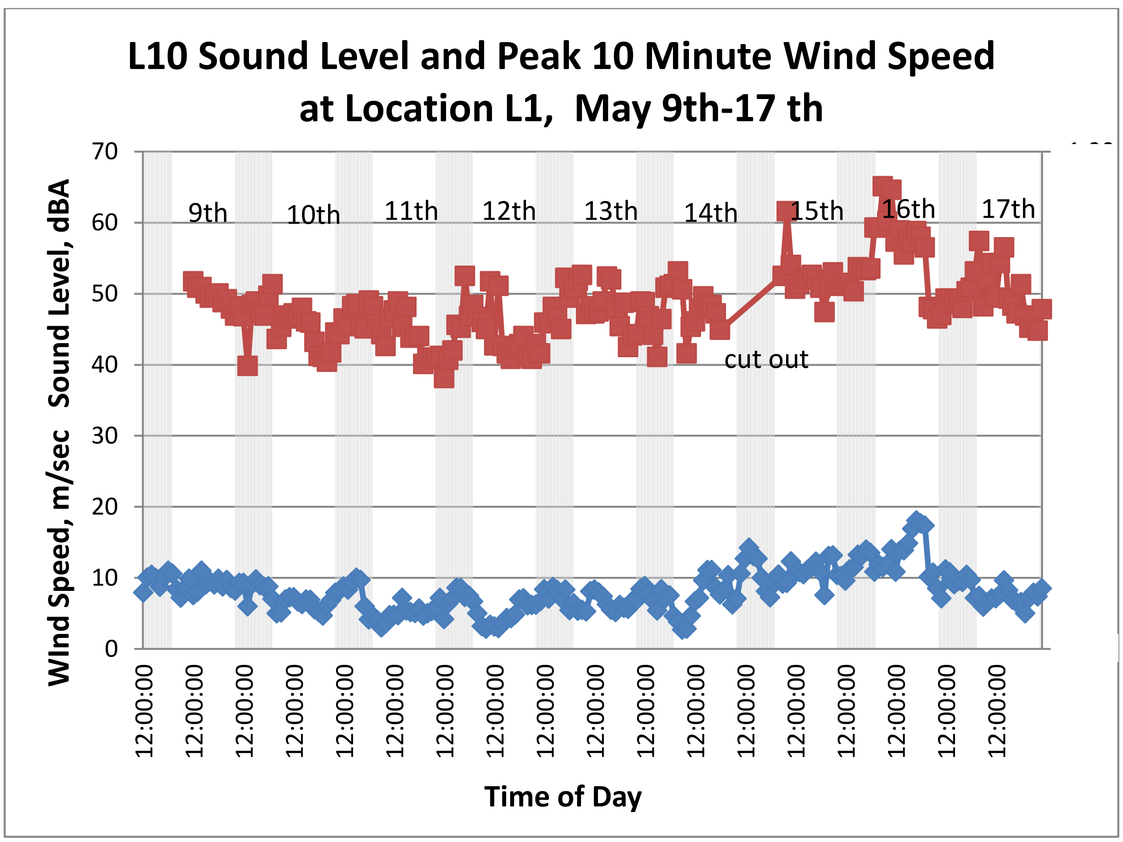





L10 Sound Level and Peak 10 Minute Wind Speed at Location M1, May 9th-17 th
WInd Speed, m/sec Sound Level, dBA
70
60
50
40
30
20
10
0
9th
10th
11th
12th
13th
14th
15th
16th
17th
cut out
12:00:00
Time of Day


L90 Sound Levels and Minimum 10 Minute Wind Speed at Location L1, May 9th - 17th 2016
Wind Speed, m/sec Sound Lveel, dBa
70
60
50
40
30
20
10
0
9th
10th
11th
12th
13th
14th
15th
16th
17th
cut out
12:00:00
Time of Day


Leq Sound Level and Average Wind Speed,
at Location L1, May 9th - 17th
WInd Speed, m/sec Sound Level dBA
Time of Day
9th
10th
11th
12th
13th
14th
15th
16th
17th
0
10
20
30
40
50
60
70
12:00:00


L10 Sound Level and Peak 10 Minute Wind Speed
at Location L1, May 9th-17 th
WInd Speed, m/sec Sound Level, dBA
Time of Day
9th
10th
11th
12th
13th
14th
15th
16th
17th
cut out
0
10
20
30
40
50
60
70
12:00:00

Figures 8 represents graphs of the August L90, L10 and Leq at sites M1 and L1 for each one hour period. Winds were lower at this time of year, rarely exceeding 10 m/sec. The highest winds occurred on the 15^{th}, 21^{st} and the 22^{nd}. The graph shows that, typical L90s, including background noise, varied from approximately 38 to 55 dBA at Location L1, and 40 to 53 at M1. Both turbines were running under all operational wind speeds during the monitoring program except for short (less than 20 minute) duration breaks about once each day. The lines with bags on shows data lost to covering the microphones with plastic bags to prevent damage during thunderstorms and high winds (note that the two were often correlated).

At location L1, highest L90 sound levels were usually correlated with the nighttime hours. (A few hours at location L1 were also affected by on-site human activity.) In addition, an examination of the data indicates that the data showed a significant daily variation *regardless of the wind speed*; the levels went up and down from night to day. This indicates that insect noise at night was the primary source of high sound levels at this location, not the turbines.

In order to examine the background to see how much noise the insects contributed, data was examined from two different late night time calm periods, with no wind or turbine noise. Data was examined from the morning of August 19 at location M1, and the morning of August 23 at location L1, between the hours of 3 and 7 A.M at each location. At location M1, the average level was 45.3 and at location L1 it was 41.2. This indicates that insect noise comprised half or more of the noise at location M1, and a third or more at location L1 during calm conditions. This is a conservative estimate; the overall data shows that insect noise levels are actually slightly higher during earlier nighttime hours. This is consistent with on-site observations which indicated that insect noise was comparable with wind turbine noise at both locations.

The sound levels during the daytime hours of the 22^{nd} at location L1 when the turbines were operational at almost peak levels at higher wind speeds show the highest non-insect noise sound (insects would have been quiet due to high winds.). This indicated that the combined sound of the turbines and wind was about 49 dBA at this location under these conditions. This is consistent with on-site observations which indicated that the noise from the turbines and the wind in the trees was of similar level. This would give a reasonable estimate of about 47-48 dBA for the wind turbines only under peak power conditions, consistent with data obtained in earlier observational programs.

The L90 levels show that the sound was controlled primarily by both the wind speed and insect activity at location M1; higher sound levels were almost directly correlated with either high wind speed or nighttime insect activity, as discussed above. During the daytime of the 16^{th} and 17^{th} under higher wind conditions, the sound levels from the turbines and wind noise in the trees were about 46-47 dBA (insect noise would have been low due to daytime wind). Since the turbines and wind noise in the trees were comparable, this would give a level of about 45 dBA from the turbines alone at this location, comparable to the levels recorded in earlier monitoring campaigns.

The wind direction did not vary significantly during the monitoring period; it was usually from the northwest during operational periods (the periods showing easterly wind direction were actually from low wind times when the nacelle orientation was not correlated with the wind direction). This means that the residents and monitors were usually downwind of the turbines during that time, which gives typical worst case conditions.

Short term monitoring was done at two times, during meter set up on the afternoon of August 14 and during the evening of August 16 right before a thunderstorm. During the first short term (daytime) period, the wind was blowing moderately, around 5-6 m/sec at hub height, and the turbines were producing at about half power. The L90s observed at both M1 and L1 are from the turbines, wind in trees and insect noise. It is hard to determine the exact contribution of each source at each location, as all contributed. At L1, the turbines and insect noise were of similar level, while at M1, additional noise was heard from wind in the trees.

During the second short term period, on the evening of August 16, the turbines were operating near full power. This gave an L90 at M1 of about 45 dBA with the turbines operating, with occasional levels of up to 51. The additional sound was due to insect noise, which was actually louder than the turbines under much of the monitoring period. At location L1, sound was from the turbines and insects, which gave an L90 of about 49 dBA; there was high cricket background (there was some noise in the trees), as well as some variation in the wind background due to sound from an impending thunderstorm.

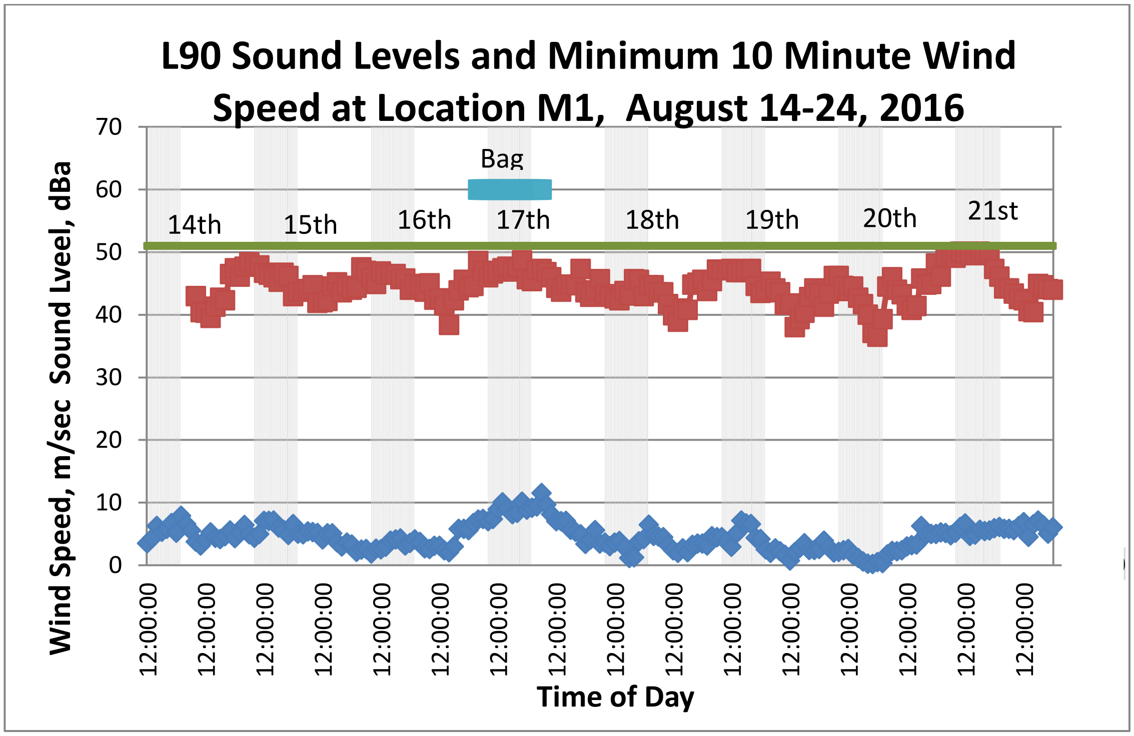
TABLE 3.

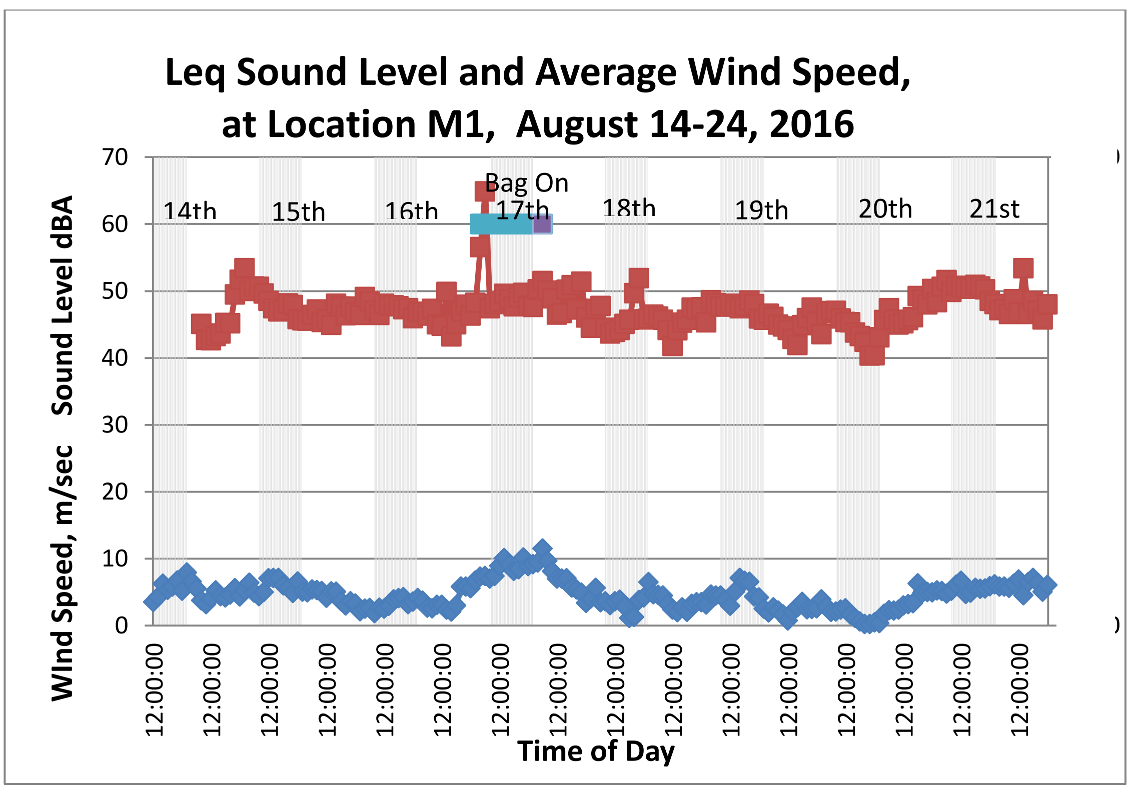
AUGUST SHORT TERM MONITORING RESULTS

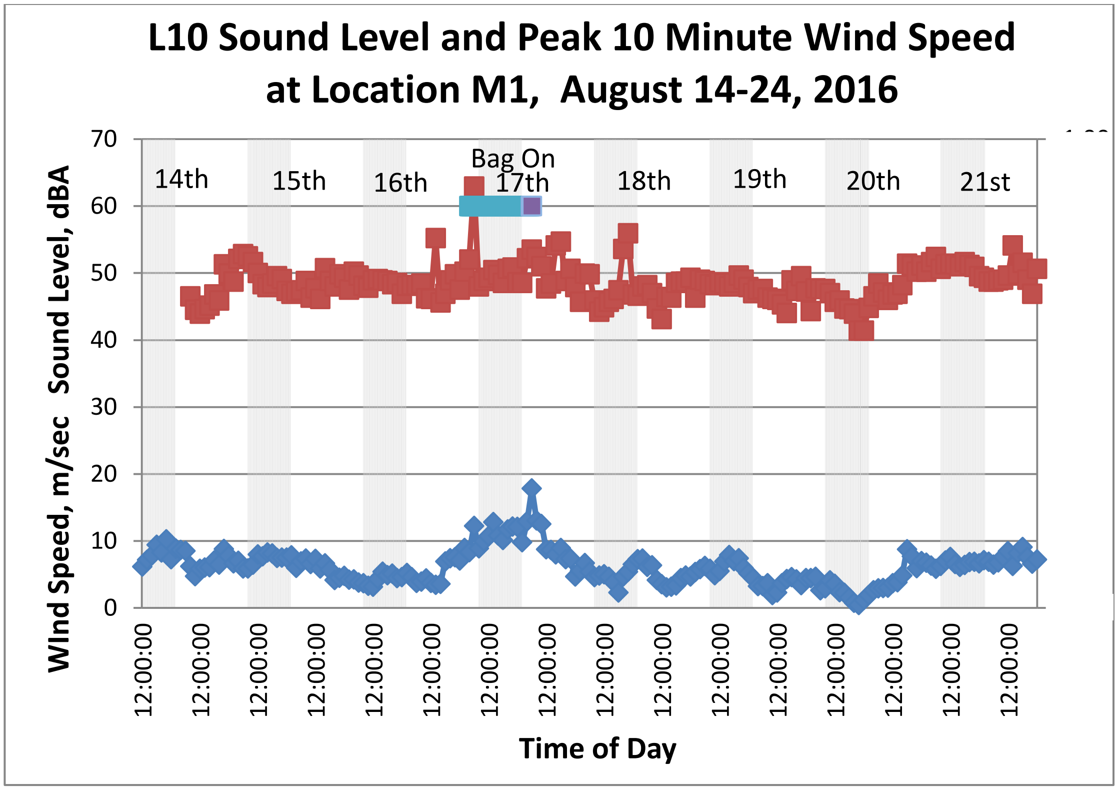
Location	Date	Time	Leq	L90	L50	L25	L10
L1	August 14	15:00	53.4	46.8	50.4	52.6	53.9
M1	August 14	16:09	49.0	45.4	47.9	50.0	50.9
L1	August 16	20:59	50.1	49.2	50.0	50.6	51.1
M1	August 16	20:18	49.8	45.4	47.9	50.0	50.8

Figure 8.

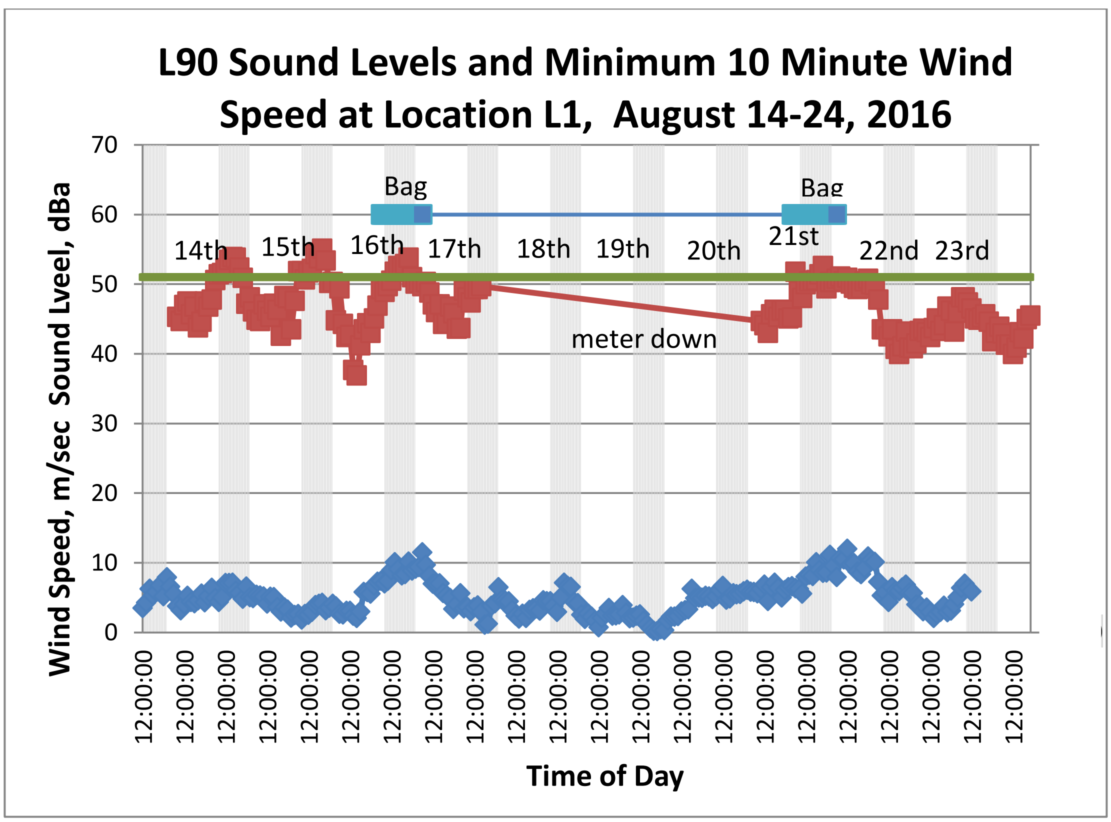
August Data



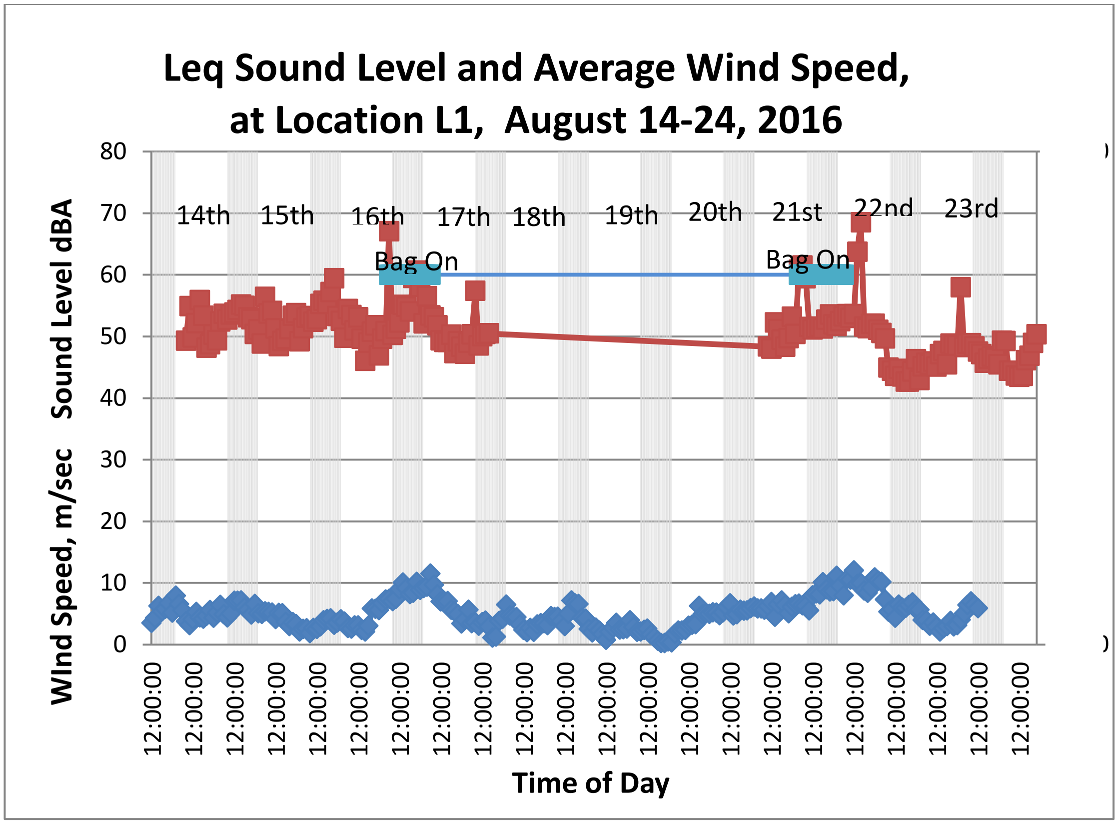




L10 Sound Level and Peak 10 Minute Wind Speed at Location M1, August 14-24, 2016
Wind Speed, m/sec Sound Level, dBA
Time of Day
Bag On
14th
15th
16th
17th
18th
19th
20th
21st



L90 Sound Levels and Minimum 10 Minute Wind Speed at Location L1, August 14-24, 2016
Wind Speed, m/sec Sound Lveel, dBa
Time of Day
Bag
Bag
meter down
14th
15th
16th
17th
18th
19th
20th
21st
22nd
23rd


Leq Sound Level and Average Wind Speed, at Location L1, August 14-24, 2016
WInd Speed, m/sec Sound Level dBA
Time of Day
14th
15th
16th
17th
18th
19th
20th
21st
22nd
23rd
Bag On
Bag On
80
70
60
50
40
30
20
10
0
12:00:00

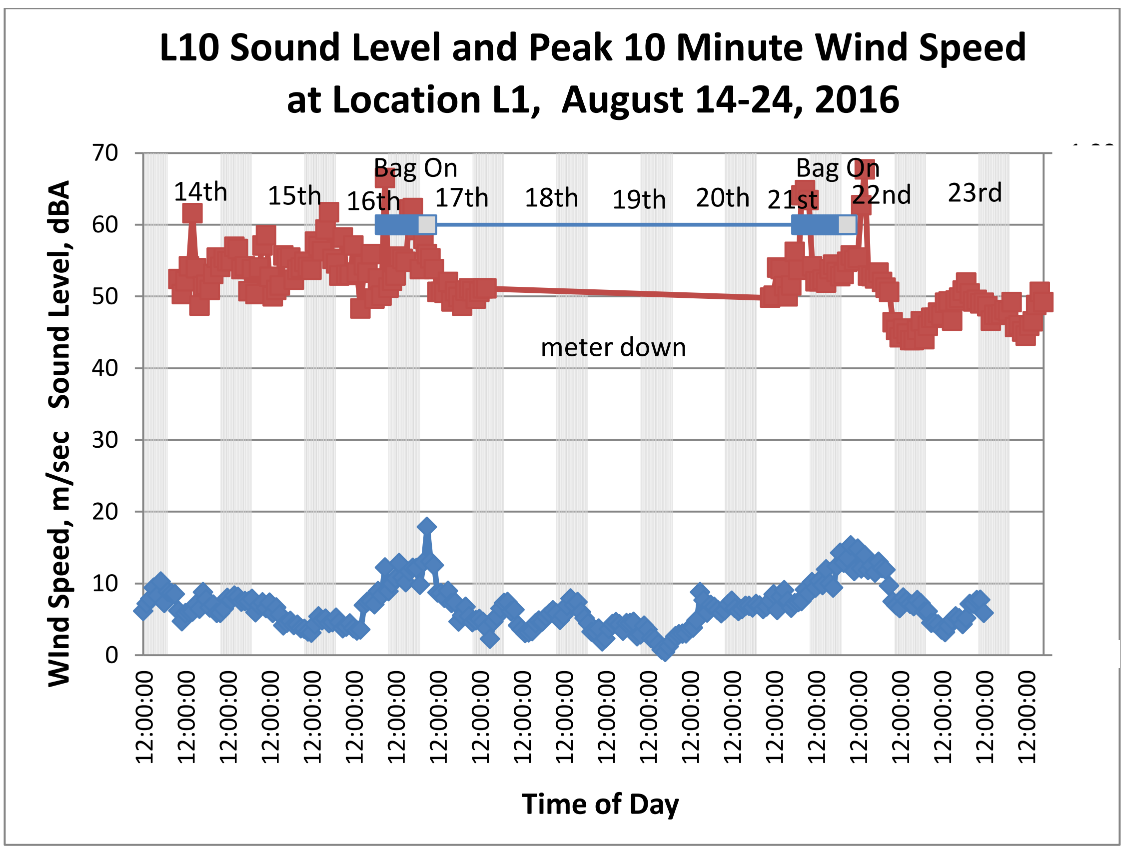

L10 Sound Level and Peak 10 Minute Wind Speed at Location L1, August 14-24, 2016
WInd Speed, m/sec Sound Level, dBA
Time of Day
14th
15th
16th
17th
18th
19th
20th
21st
22nd
23rd
Bag On
Bag On
meter down
70
60
50
40
30
20
10
0
12:00:00

Figure 9 represents graphs of the L90, L10 and Leq at sites L1 and M1 for each one hour period during November. The graph shows that, typical L90s varied from approximately 28 to 53 dBA at Location L1, and 28 to 54 at M1, which includes background noise from wind, trees, leaves, and insects. Both turbines were running under all operational wind speeds during the monitoring program. The highest wind speeds and sound levels occurred on the 13th and 17th. At locations L1 and M1, higher L90 sound levels were usually correlated with higher wind speeds. The lowest levels (below 40 dBA) occurred on quiet nights when the turbines were not operational. Under operational conditions, the turbine noise levels at L1 ranged from 41 to 49 dBA, with typical levels of 46 to 47 dBA, similar to those seen at the other times of the year. The highest operational level at L1 was 51 including background noise at a wind speed of 15 m/sec.

The L90 levels show that the sound was controlled primarily by the wind speed at location M1; higher sound levels were almost directly correlated with high wind speed, while low levels (below 40 dBA) occurred when the turbines were not running. Typical turbine noise levels ranged from 43 to 46 dBA as seen during other monitoring periods; the highest level (48 dBA) occurred when the wind speed was about 15 m/sec. The wind direction was usually from the west or northwest during the monitoring period. This means that the residents and monitors were usually downwind of the turbines during that time, which gives typical worst case conditions.

Short term monitoring was done at two times. During the first short term (daytime) period on November 16, the wind was blowing moderately, around 6 m/sec at hub height, and the turbines were producing at about half power. The L90s observed at both M1 and L1 are from the turbines. At M1 the turbine levels varied from 36 to 40 dBA, while at L1 the levels varied from 43 to 46 dBA. Wind in the trees typically added from 1 to 3 decibels at each location.

During the second short term period, on the evening of November 19, the turbines were operating at about half power. This gave an L90 at M1 of about 37-39 dBA with the turbine operating, with occasional levels due to gusts of up to 41 dBA. At Location L1, the turbine levels were around 41-42 dBA; with wind gusts the overall levels were around 44 to 45 dBA. There was no other significant sound at either location besides the turbines and the wind in the trees.

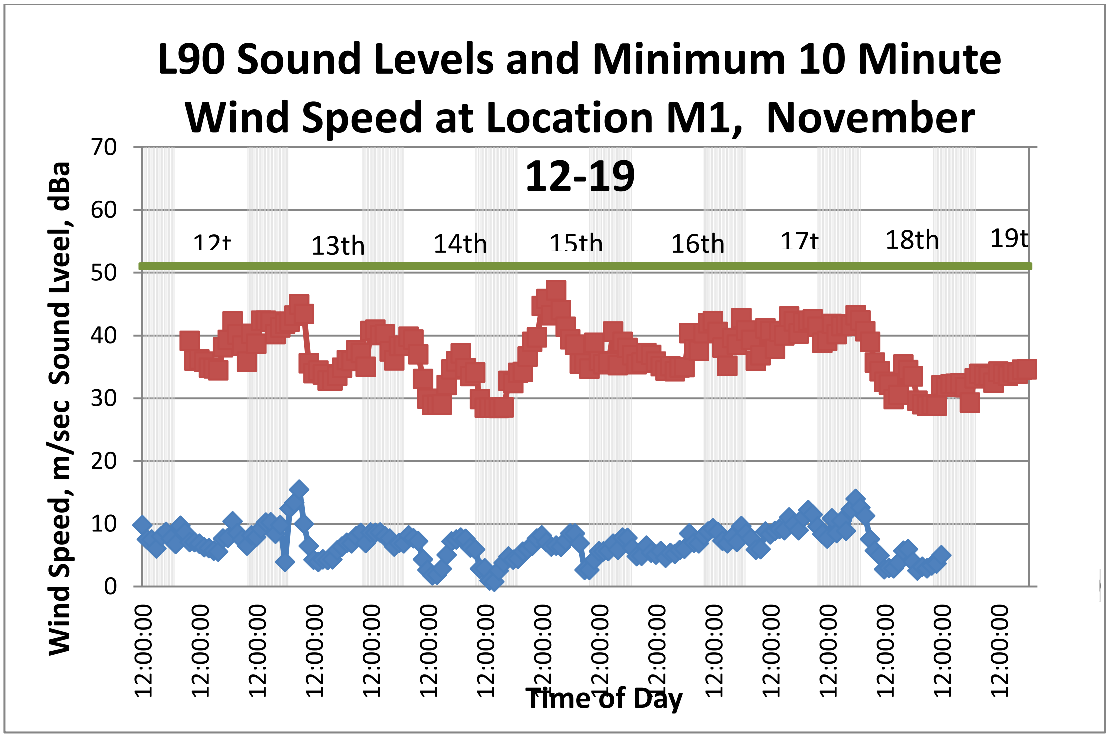
TABLE 4.

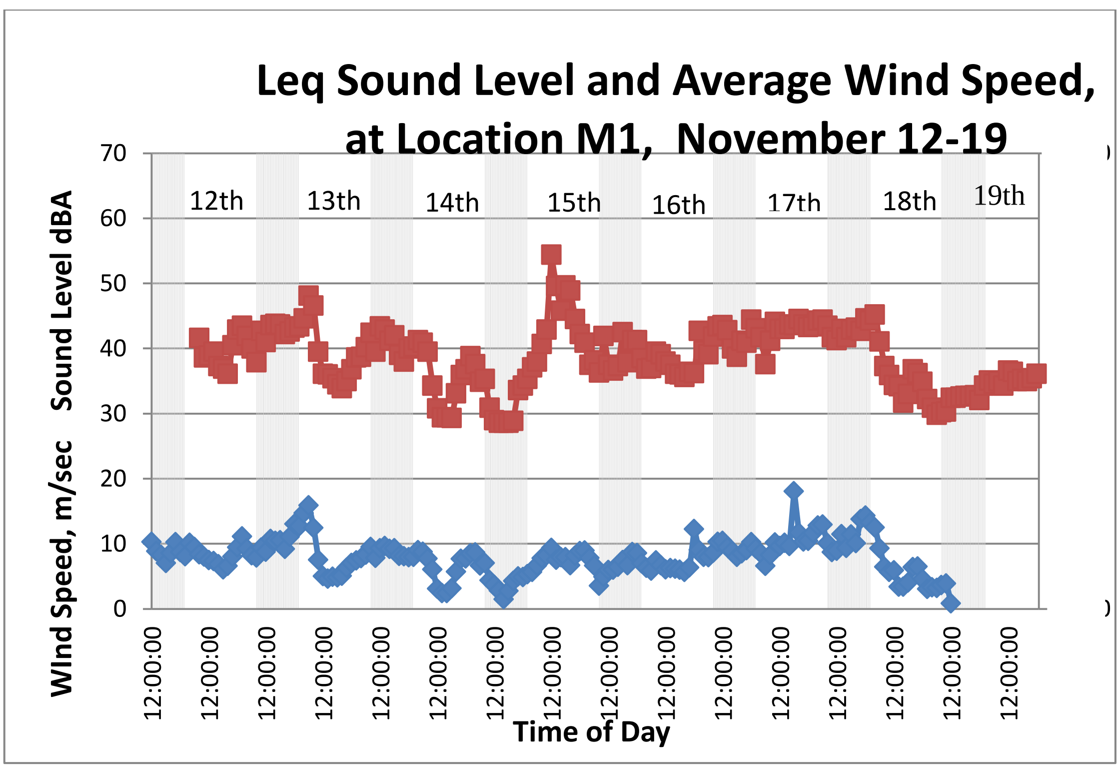
NOVEMBER SHORT TERM MONITORING RESULTS

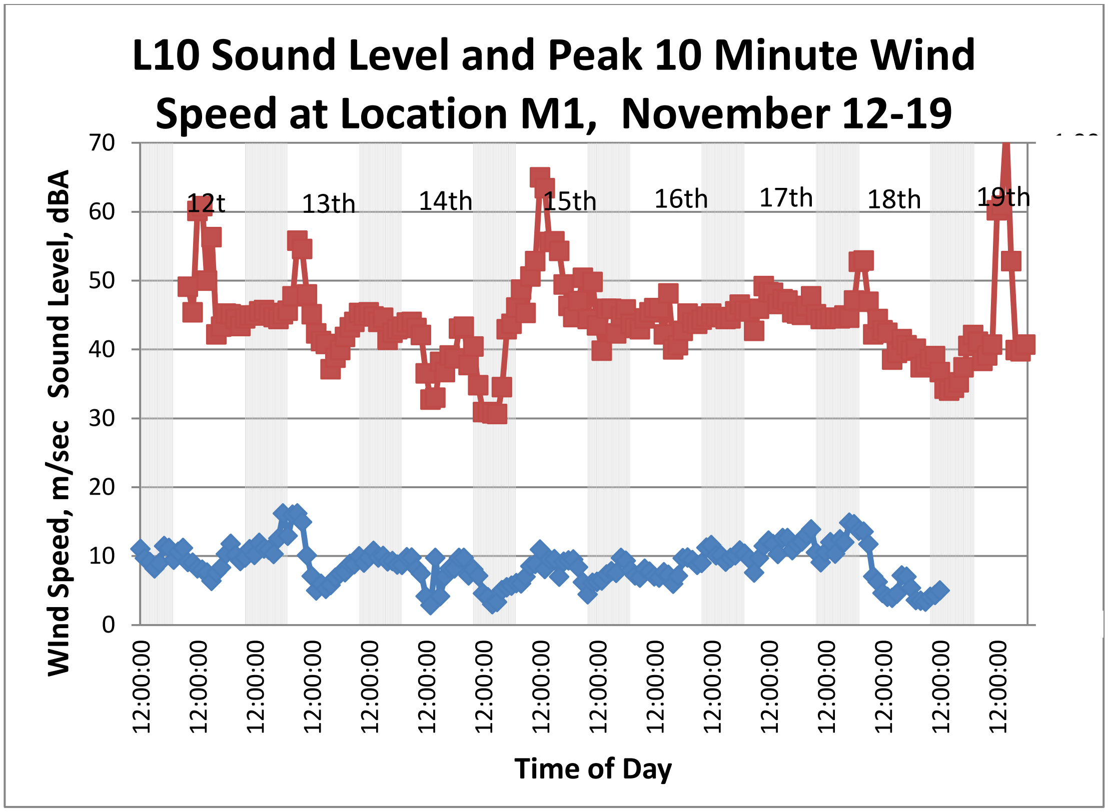
Location	Date	Time	Leq	L90	L50	L25	L10
L1	November 16	14:08	45.7	42.7	44.8	46.3	48.0
M1	November 16	15:03	40.8	37.2	39.3	41.0	42.4
L1	November 19	18:36	42.9	40.0	42.5	43.3	44.4
M1	November 19	19:23	38.3	35.1	37.2	39.1	41.3

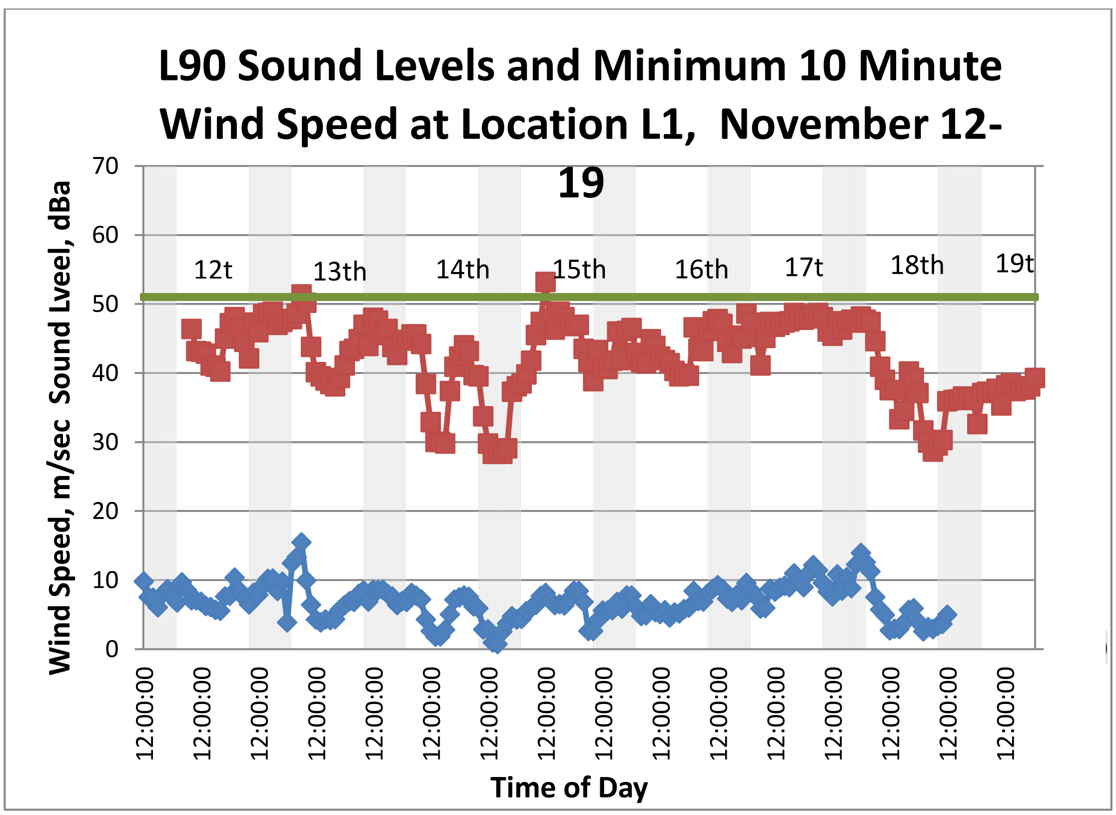
Figure 9.

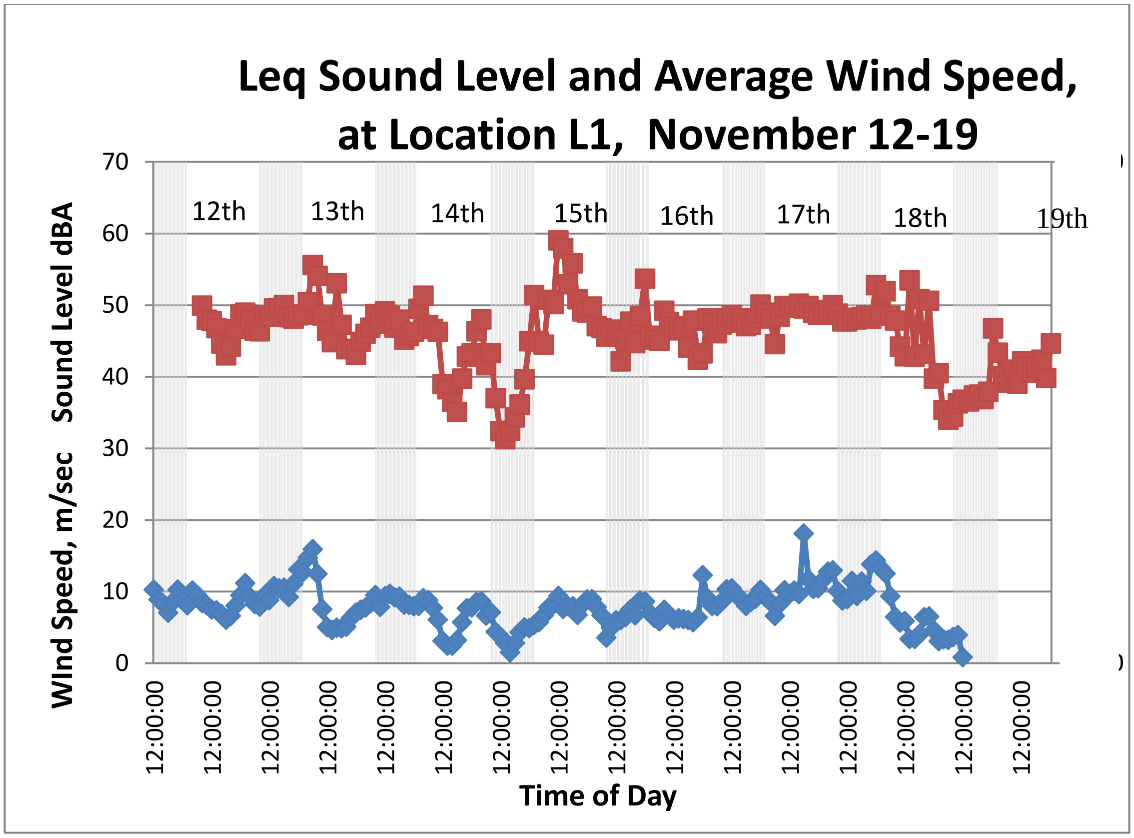
November Data

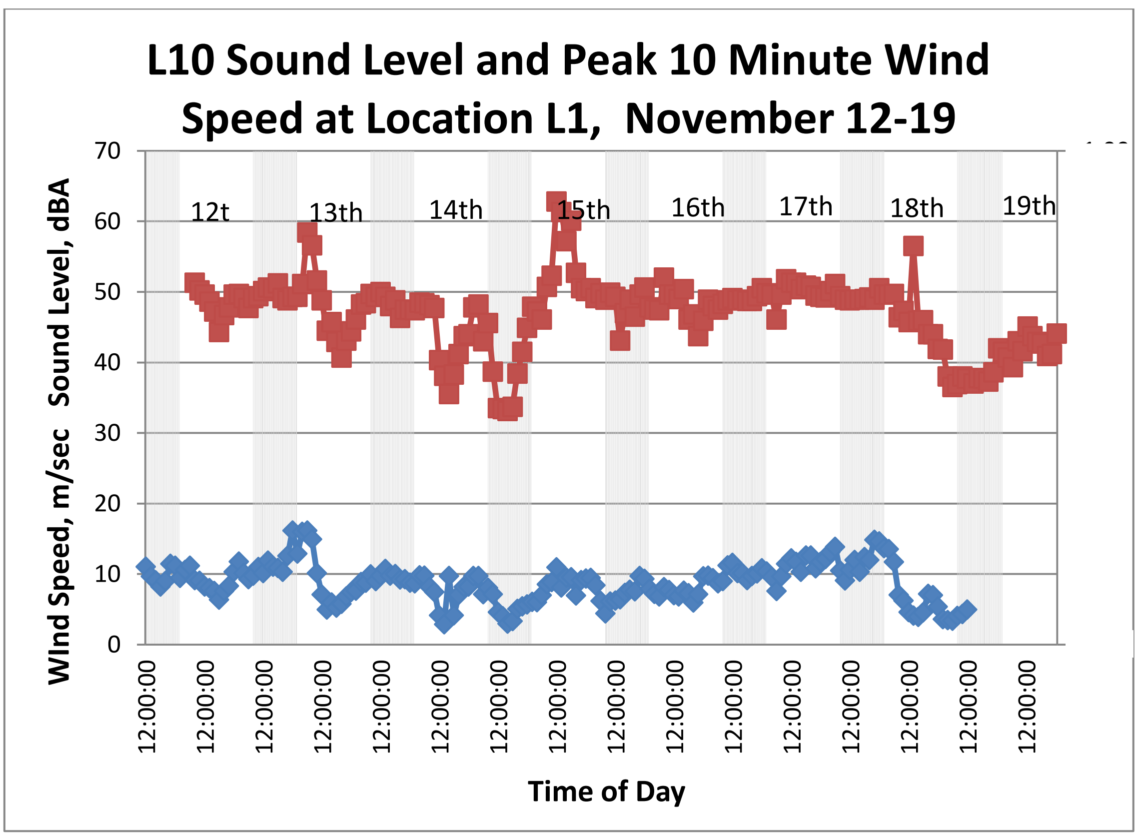





L10 Sound Level and Peak 10 Minute Wind Speed at Location M1, November 12-19
WInd Speed, m/sec Sound Level, dBA
70
60
50
40
30
20
10
0
12t
13th
14th
15th
16th
17th
18th
19th
12:00:00
Time of Day


L90 Sound Levels and Minimum 10 Minute Wind Speed at Location L1, November 12-19
Wind Speed, m/sec Sound Lveel, dBa
70
60
50
40
30
20
10
0
12t
13th
14th
15th
16th
17t
18th
19t
12:00:00
Time of Day


Leq Sound Level and Average Wind Speed, at Location L1, November 12-19
Wind Speed, m/sec Sound Level dBA
Time of Day
12th
13th
14th
15th
16th
17th
18th
19th
70
60
50
40
30
20
10
0
12:00:00


L10 Sound Level and Peak 10 Minute Wind Speed at Location L1, November 12-19
Wind Speed, m/sec Sound Level, dBA
Time of Day
12t
13th
14th
15th
16th
17th
18th
19th
70
60
50
40
30
20
10
0
12:00:00

6 Comparison of Quarterly Data

The seasonal data for all quarters are plotted below for stations M1 and L1 in Figure 10. *In summary, the data shows that the wind turbines were in compliance with the most stringent nighttime level of 51 dBA at location M1, and the nearest residence to location M1 at 45 Flagg Hill Road under all conditions, even with all other background noise (wind in trees, insects, birds) included.* The data also shows that the wind turbines were in compliance with the most stringent nighttime level of 51 dBA at location L1, and the closest residence to the turbines on 29A Flagg Hill Road, which has a wind farm neighbor agreement with Wind Colebrook South, under all conditions after removal of background noise. The data also shows a number of important seasonal variations. In particular, the cold weather data and the warm weather data show distinct differences. These differences are expected, as warm weather sound sources from plant and animal sources such as insects, birds, and leaf rustling contribute significantly to the sound levels, and do not in cold weather.

The cold weather data, shown in blue and green, for time periods February and November, show distinctly lower overall sound levels for the lower wind speed intervals than the warm weather data for May and August, shown in red and purple. An examination of the two sets of cold weather recordings shows additional differences. The November data shows a clear linear trend with wind speed from 4 to 10 m/sec above which the sound increases very little; the sound increases by about 12-15 dBA at both locations over this wind speed range. This is directly correlated with the turbine noise curve for this wind speed range. An examination of the wind directions at this time shows that most wind came from the northwest, which means that both locations would have been nearly downwind from the turbines, with considerable terrain shielding to block low level noise from wind in the trees, meaning that most of the recorded sound came from the turbines.

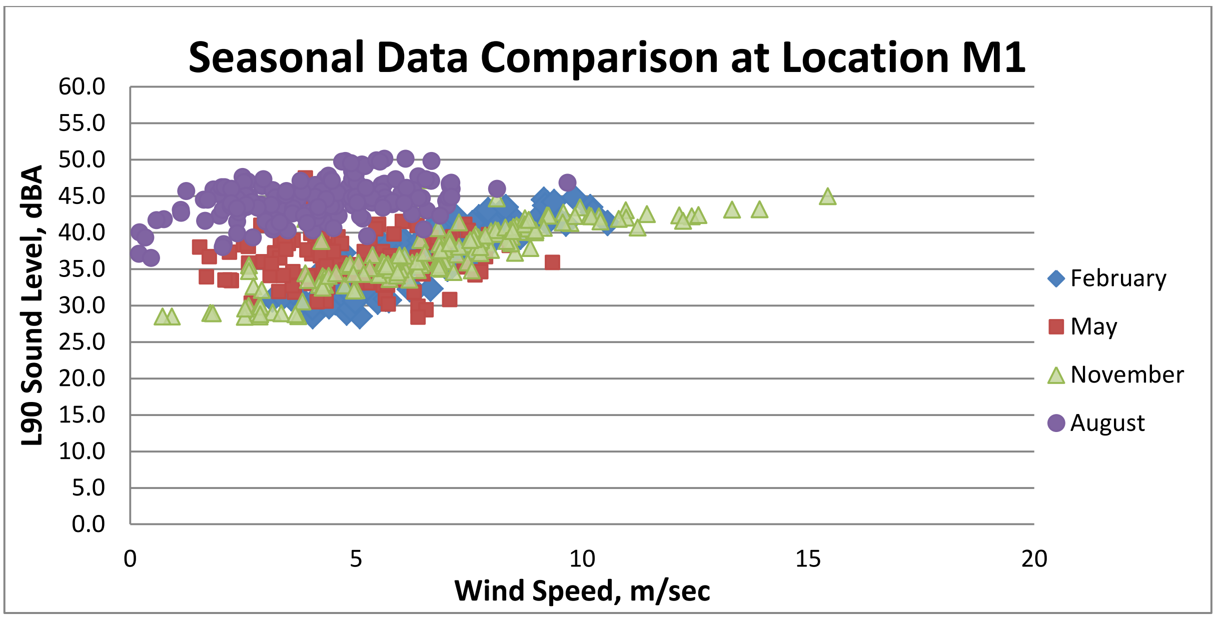
The February data shows a similar trend, but with more scatter. This is due to the fact that both the wind direction and the ground cover showed more variation during this time period. The wind was mostly from the west, but also came from other directions during this time period, during which time it would have created higher background in the trees as it blew uphill or across the hill. In addition, the ground cover during February showed some variation due to snow fall and snow melting, leading to variations in turbine sound levels from differing ground cover effects.

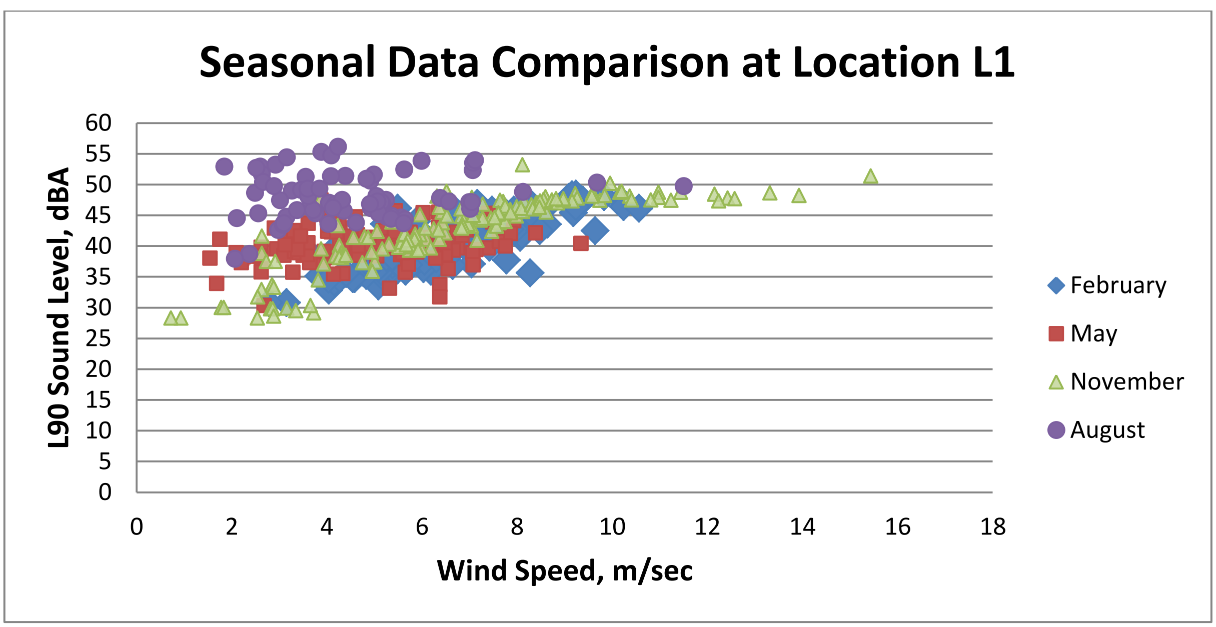
The warm weather data shows significantly higher background levels at lower wind speeds. The May data shows several decibels higher sound levels under these conditions; overall, the background predominates at low wind speeds, and the background and turbine noise levels are of similar overall levels at most higher wind speeds. This is consistent with higher background from some leaves on the trees and bird noise during this time period.

The low wind August data, which are nearly 15 decibels above the cold weather background, show that, in fact, the sound levels from the background are actually considerably higher than the levels from the turbines, showing a peak of 50-55 decibels under very low wind activity. This is consistent with insect noise being the primary background at low wind speeds; at higher wind speeds the insects would have avoided flying and stayed under cover, and sound would have come instead from the turbines and leaf rustling, which gave levels similar to the cold weather data at these wind speeds.

In conclusion, we recorded data from a wide range of typical operating conditions and directions including peak operating conditions during each quarter of the noise monitoring campaign. The data collected as a result of this study demonstrates that the acoustic impacts from the wind turbines at Wind Colebrook South of 40-49 dBA are in compliance with and well below the maximum allowable noise levels of 61 dBA during the day and 51 dBA during nighttime periods at both long term monitoring locations and at the nearest residential receptors from the wind turbines.

Figure 10.





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

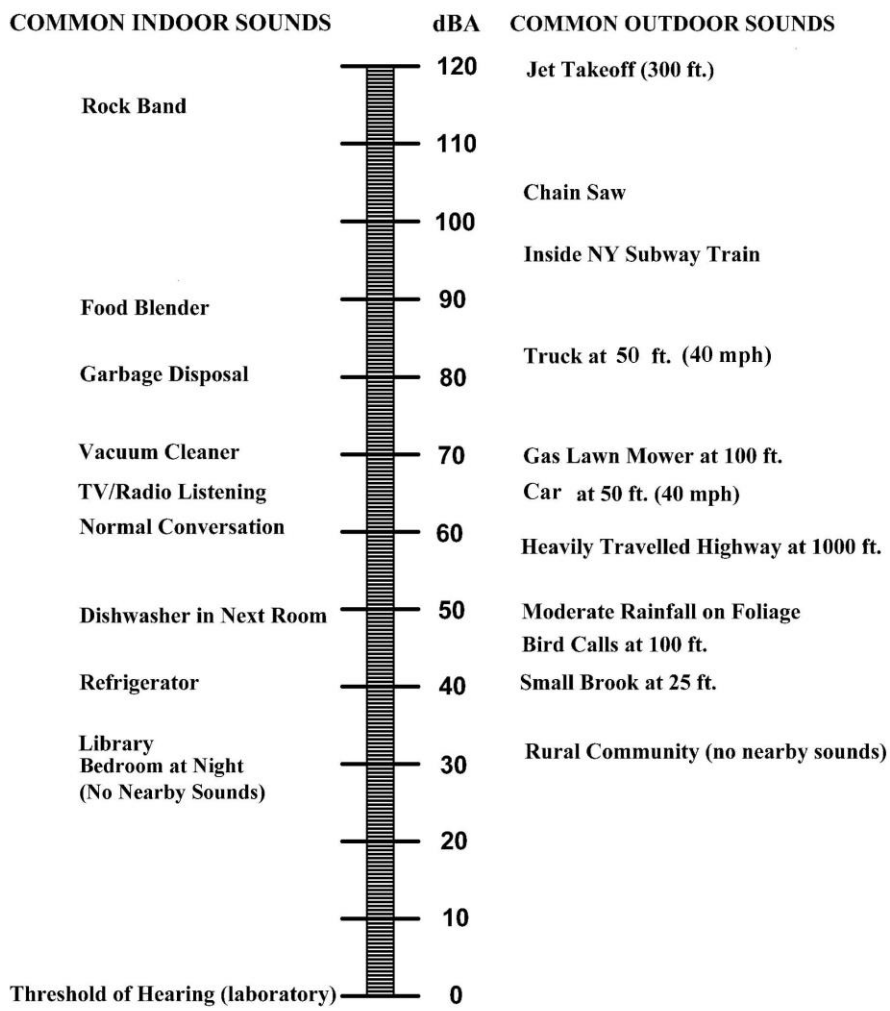
to 2,000 Hz. Therefore, to correlate the amplitude of a sound with its level as perceived by people, the sound energy spectrum is adjusted, or "weighted."

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 with human perception of "noisiness." 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.