Report of Sound Measurements
Second Round

June 12, 2014

Tests Conducted by Jacob Zeuske of the Wisconsin Structures and Materials Testing Laboratory

Report Prepared by Jacob Zeuske

For the Wisconsin Department of Natural Resources

Site Location: Mud Lake Wildlife Area – Columbia County

Date: May 29, 2014

Objective

The Wisconsin Structures and Materials Testing Laboratory was contacted May 21, 2014 by Michael Watt of the Wisconsin Department of Natural Resources for the purpose of conducting follow-up sound measurements in the area surrounding a proposed public shooting range. Previous measurements were made on May 6, 2014 during a period of high winds of approximately 20 mph, sustained (gusts nearly 30 mph). The range location is to be at the Mud Lake Wildlife Area near Poynette in Columbia County. This second round of measurements, reported here, was conducted on May 29, 2014. The goal of the measurements was to establish a baseline sound level in the surrounding area due to a typical hunting rifle of .308 caliber being fired at the shooting range location, under calm wind conditions.

Background

Sound is the ear's interpretation of pressure waves occurring within a frequency range of roughly 20 Hz to 20 kHz. Pressure is generally measured in Pascals (Pa), with 20 μPa corresponding to the lower threshold of human hearing. The decibel scale is used to better describe the sound pressure level (SPL) with the more familiar dB unit. At 20 μPa the SPL is equivalent to 0 dB. The dB unit system is a logarithmic scale which allows for better graphical representation of the wide range of pressure level sensitivity of the human ear. The dB scale also gives a better relation of the SPL to our ear's physical perception of sound.

To better mimic the human ear's sensitivity to sound at various frequencies and intensity levels, weighting functions are applied to measured sound data. The A-weighting function is the most widely used of these, and has been applied for the measurements reported here. Sound pressure level is converted from Pa to dB with the following equation:

$$\mathrm{dB} = 20\log_{10}\left(\frac{Pressure}{20\ \mu\mathrm{Pa}}\right).$$

Some common sounds and their respective decibel levels are listed in Table 1.

0 dB	Threshold of Hearing
60 dB	Normal Conversation
90 dB	Lawnmower
110 dB	Car Horn
120 dB	Airplane Take-Off
140 dB	Threshold of Pain

Table 1. Decibel levels of common sounds.

Description of Equipment and Methods

Sound measurements were made with a PCB 130D20 ¼" free-field microphone fitted with a 60-mm diameter windscreen. The microphone was calibrated April 18, 2014. Data acquisition was performed with a Brüel & Kjær Lan XI Type 3160-A-042 and a laptop computer.

Seven measurement locations along with one location for the shot source were chosen by Michael Watt. Mr. Watt was responsible for firing shots from a .308 caliber rifle at the shot source location. Jacob Zeuske travelled to each measurement location and coordinated with Mr. Watt to begin the shot sequence, consisting of a series of three shots fired seconds apart from one another. At each location, two sets of measurements were made. The first measurement was a 30-second acquisition, during which Mr. Watt fired a three shot sequence. The microphone was supported on a tripod and directed toward the shot source location. The second 30-second acquisition at each location was made with no shots fired in order to establish ambient conditions at each location. Winds were moderate with variable direction, but predominantly from the southeast.

Measurement Locations and Conditions

Table 2 lists the seven measurement locations, described using the Universal Transverse Mercator (UTM) coordinate system. The UTM system describes position with a set of Cartesian coordinates given in meters. Approximate distance between each measurement location and the shot location was calculated using Pythagorean's Theorem and converted into feet. At each location, the microphone was directed toward the source of the shot. Figure 1 is an aerial photo of the survey area. Each of the measurement locations are identified with a dot and corresponding location number. The shot source and location 1 share a marker. All locations were consistent, both in numbering and location, with the measurements conducted on May 6, 2014, except that location 1 was moved further away (southward) to 150 ft, and a seventh measurement location was added. Shots were fired from a .308 caliber rifle at the source location. For a safe backstop, the shots were fired toward the east at a slight hillside approximately 30 feet away, as shown in Figure 2. This is the same shot caliber, location, direction, and backstop as used on May 6th.

Weather conditions were more favorable than May 6th, with winds gusting to approximately 12 mph from the east/southeast. Measurement location 1 and the shot source were again located in a well sheltered area, with no cover or geography disturbing the line of sight between the shot and microphone (see Figure 2). At the second measurement location, Figure 3, winds were breezy coming out of the east. Measurement location 3 (Figure 4) experienced winds from the east, again breezy but not near the level of

May 6th. At each of the locations foliage was abundant. Figure 5 shows the fourth measurement location, where winds were mild from the east. As seen in in Figure 6, measurement location 5 has significantly more vegetation when compared to the May 6th conditions (Figure 23, Appendix). At location 5, winds began to pick up out of the east, and rustling of leaves and grasses were audible. At measurement location 6 winds were mild and swirling, coming predominantly from the north and east (see Figure 7). Measurement location 7 (Figure 8) was added to create a location approximately equidistant to the north from the shot source, with respect to location 4. Location 7 is separated from the shot source by varied terrain, including woods and a large marsh, as seen in Figure 1. Here winds were breezy from the east, and a chipmunk was frequently calling at ~30 yards behind the microphone.

Location	UTM Coordinates (16T)	Distance to Source (approx.)
Source	4807401 N 312745 E	-
1	4807356 N 312745 E	150 ft
2	4807696 N 313410 E	2,300 ft
3	4807284 N 312119 E	2,100 ft
4	4805934 N 312624 E	4,800 ft
5	4807531 N 313011 E	900 ft
6	4807385 N 312450 E	1000 ft
7	4809138 N 312624 E	5700 ft

Table 2. Sound source and seven measurement location UTM coordinates with approximate line of sight distance between the source and each measurement location.

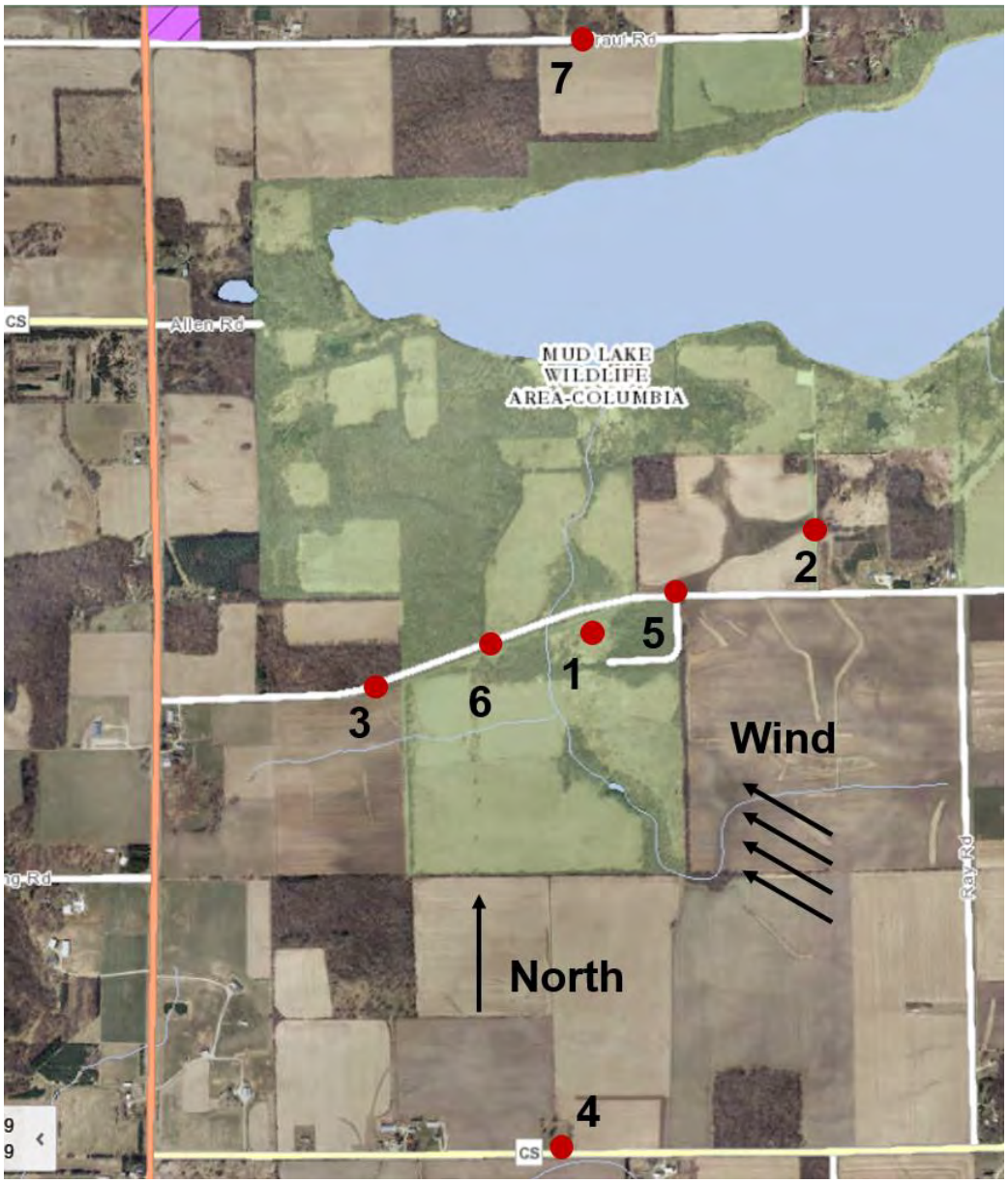

Figure 1. Aerial imagery of the measurement locations. Marker 1 represents the location of the source as well as the first measurement site. Approximate wind direction is shown as coming predominantly from the southeast.

Figure 2. Photograph of a shot scenario with slight hillside 30 feet to the east. Image is facing east. Data for location 1 was collected with the microphone at 150 feet from the shot source, as shown here.

Figure 3. Second measurement location. The microphone is pointed toward the source (marked by arrow), which is ~2,300 feet away beyond the trees. Image is facing southwest.

Figure 4. Third measurement location. The source is ~2,100 feet away beyond the trees, marked by the arrow. Image is facing east.

Figure 5. Fourth measurement location. The source is ~4,800 feet away over the hill, marked by the arrow. Image is facing north.

Figure 6. Fifth measurement location. The source is ~900 feet away through the trees, marked by the arrow. Image is facing west.

Figure 7. Sixth measurement location. The source is ~1000 feet away at the edge of the trees, marked by the arrow. Image is facing east.

Figure 8. Seventh measurement location. The source is ~5700 feet away beyond the far trees, marked by the arrow. Image is facing south.

Results Summary

Data from a three-shot sequence and ambient conditions at each location are plotted in Figures 9 through 22. Each shot occurrence in the data plot is noted on the figures with letters A, B, or C marking the first, second, and third shot peak signals, respectively. In general, the ambient conditions at each measurement location were much quieter than on May 6th. For this round of measurements there was additional background noise due to increased foliage rustling, along with birds and chipmunks calling.

Measurement location 1 was moved 75 feet further to the east from where it was on May 6th, to be at 150 feet from the shot source. Figure 9 shows the ambient conditions, which were quite calm. The data from the three-shot sequence is shown in Figure 10. The peak sound level was around 127 dB, just a few decibels lower than what was measured on May 6th. Location 1 is a sheltered area, so it is expected that there would be minimal sound level change with wind speed reduction.

Figure 11 shows the ambient conditions at location 2. Shot sequence sound pressure levels at the second measurement location, as seen in Figure 12, were at about 65 dB, very similar to May 6th (62-70 dB). In each of these two figures, signal traces due to bird calls are seen and are nearly the same magnitude as the shot sound level. Approximately equidistant from the shot source, but to the west, sound levels at

location 3 are shown in Figures 13 and 14. Ambient conditions at location 3 were quite calm. Figure 14 shows sound levels of 85 - 93 dB, very similar to the previously measured 85-92 dB on May 6th.

Results of the measurements at location 4 are shown in Figures 15 and 16. The three-shot sequence resulted in sound pressure levels of 55-65 dB, compared to the 60-70 dB range recorded on May 6th. Measurement location 7 was added to have an approximately equidistant location to the north of the shot with respect to location 4. Figures 21 and 22 show the measurement results from location 7. During these measurements, a chipmunk was calling twice a second as seen in Figure 22. The signal from the three shots resulted in peak sound pressure levels of 66-73 dB

Measurement location 5 results, displayed in Figures 17 and 18, show an average peak SPL of 80 dB during the shot sequence. On May 6th the three shot group also averaged 80 dB. Measurement location 6 ambient and shot sequence results are shown in Figures 19 and 20, respectively. The three-shot sequence resulted in an average peak signal of 85 decibels at location 6. Again, this compares similarly with measurements from May 6th, when the SPL was around 85-90 dB.

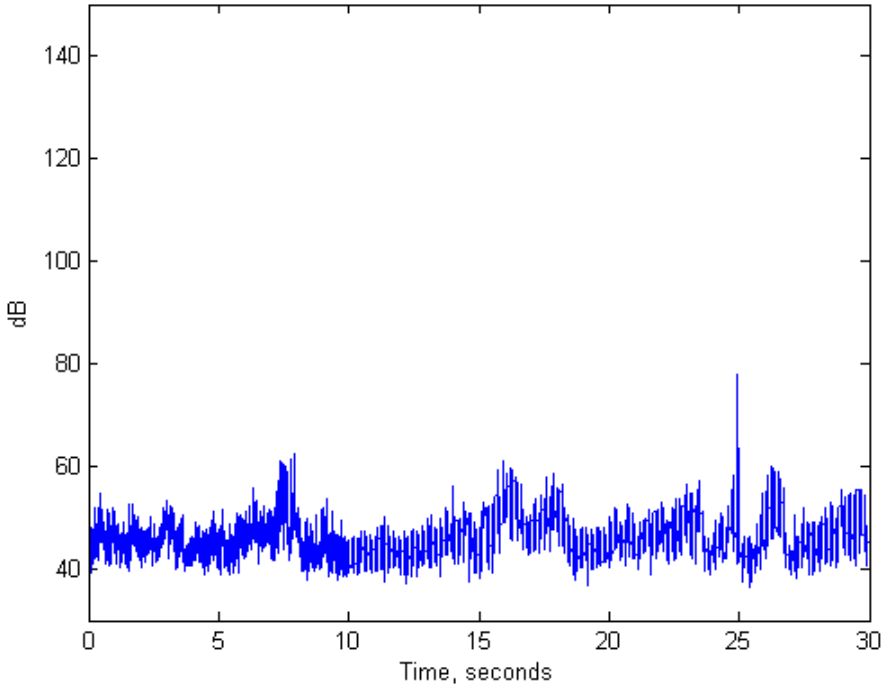

Figure 9. Measurement of ambient conditions at location 1.

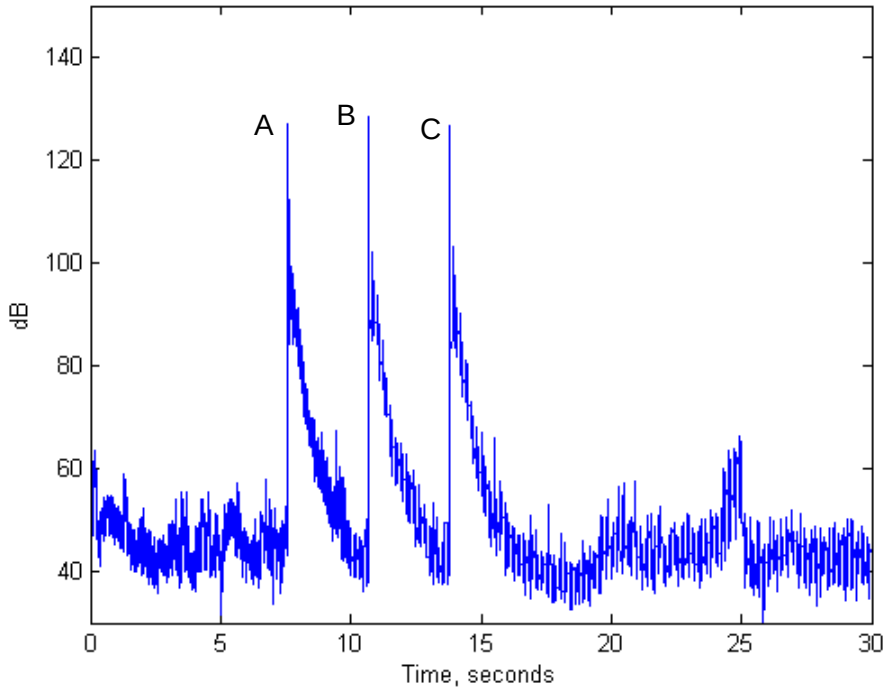

Figure 10. Location 1 three shot group (shot peaks at A, B, C).

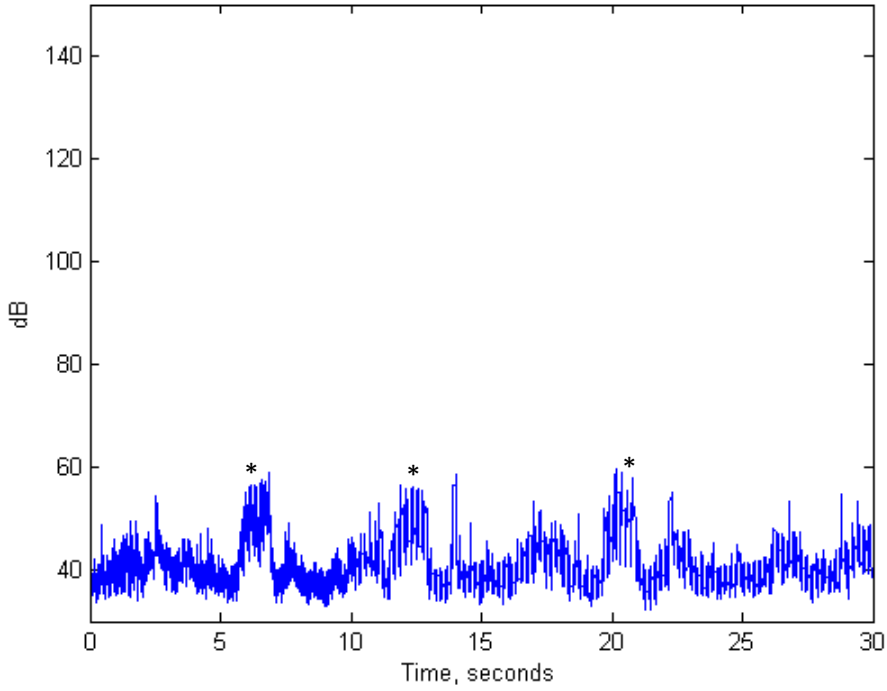

Figure 11. Measurement of ambient conditions at location 2. Bird calls (*) were common at this location.

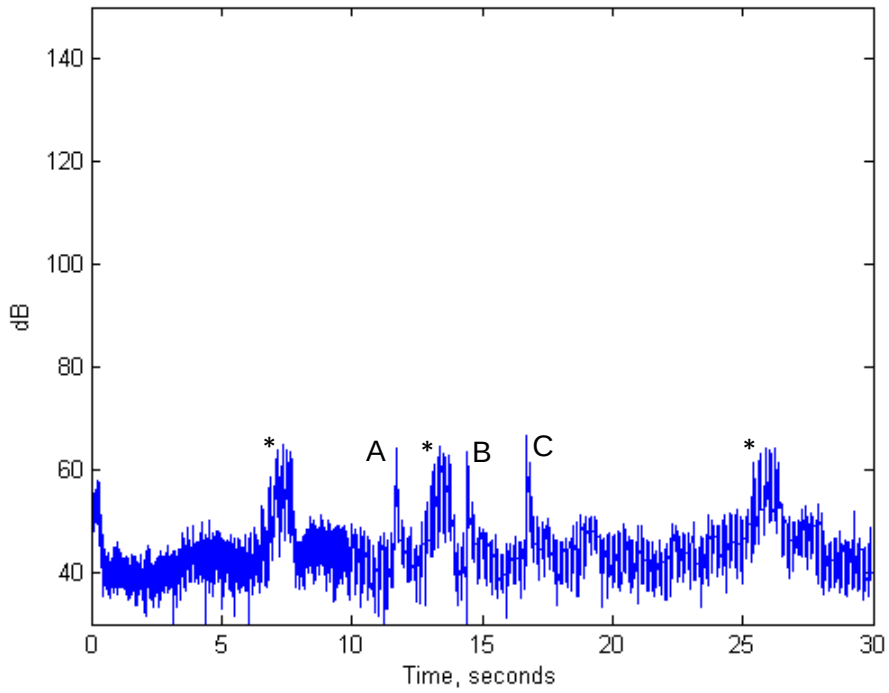

Figure 12. Location 2 three shot group (shot peaks at A, B, C). Bird calls are marked (*)

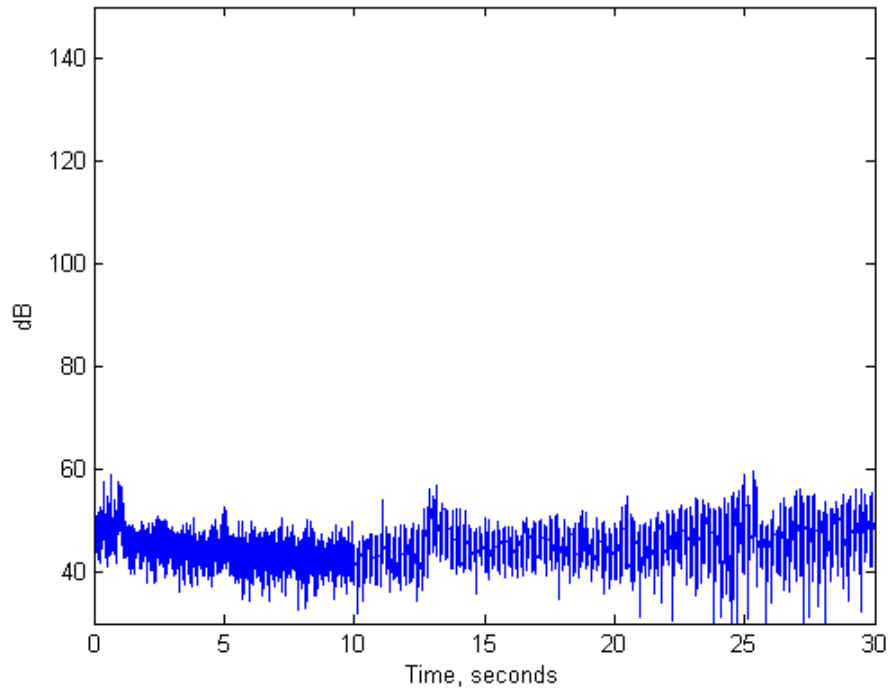

Figure 13. Measurement of ambient conditions at location 3.

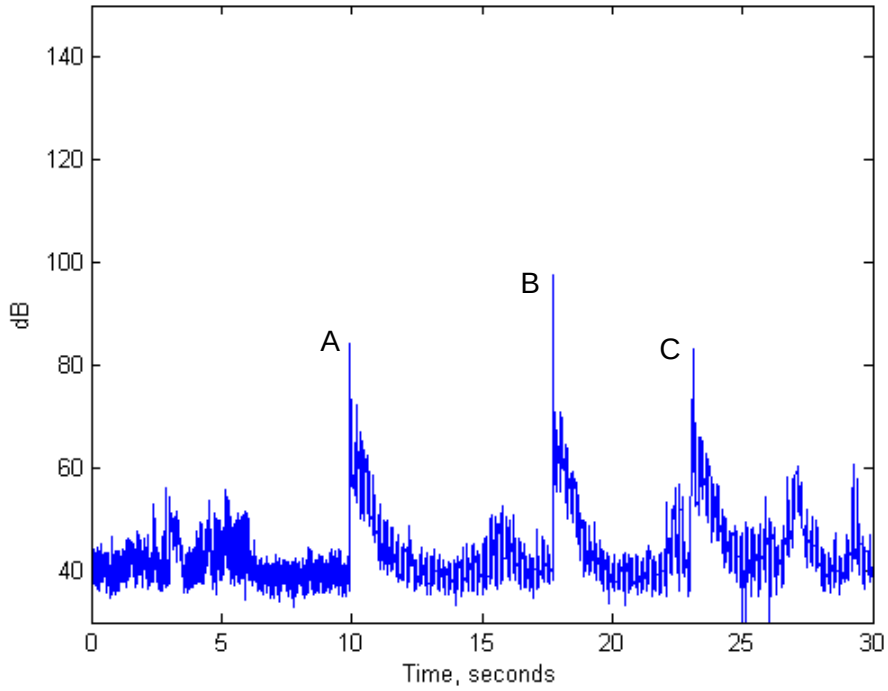

Figure 14. Location 3 three shot group (shot peaks at A, B, C).

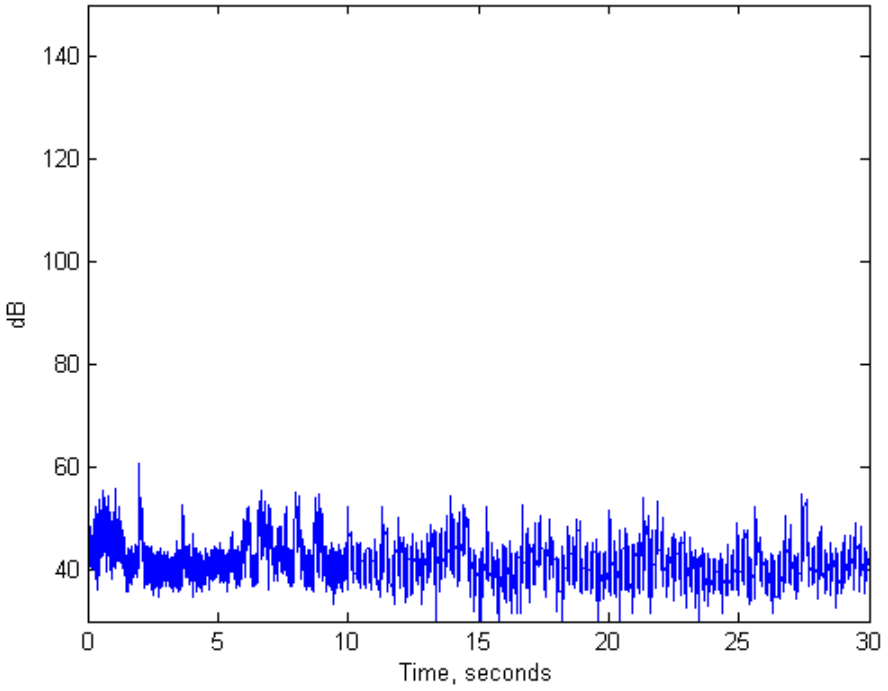

Figure 15. Measurement of ambient conditions at location 4.

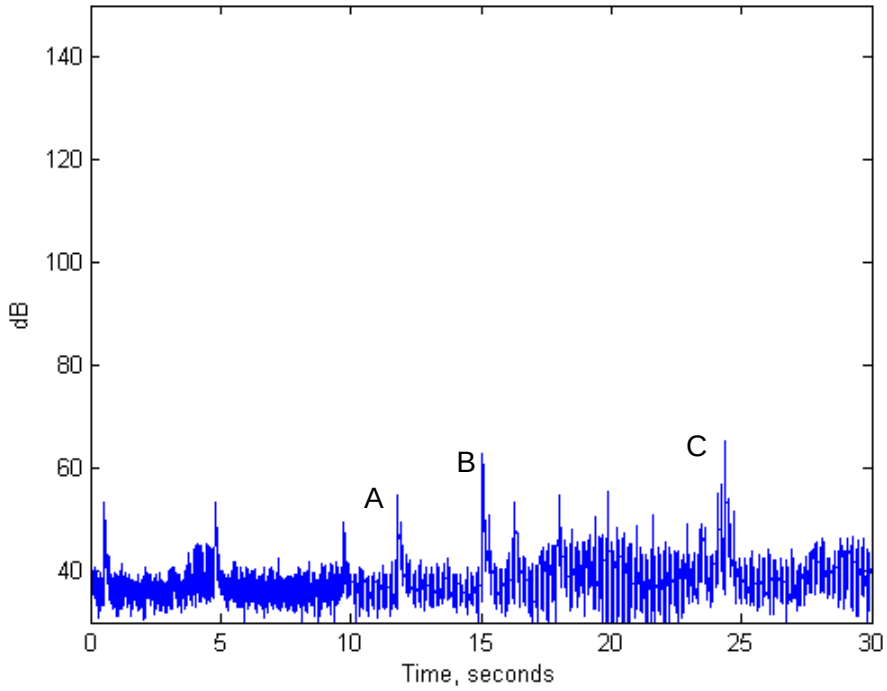

Figure 16. Location 4 three shot group (shot peaks at A, B, C).

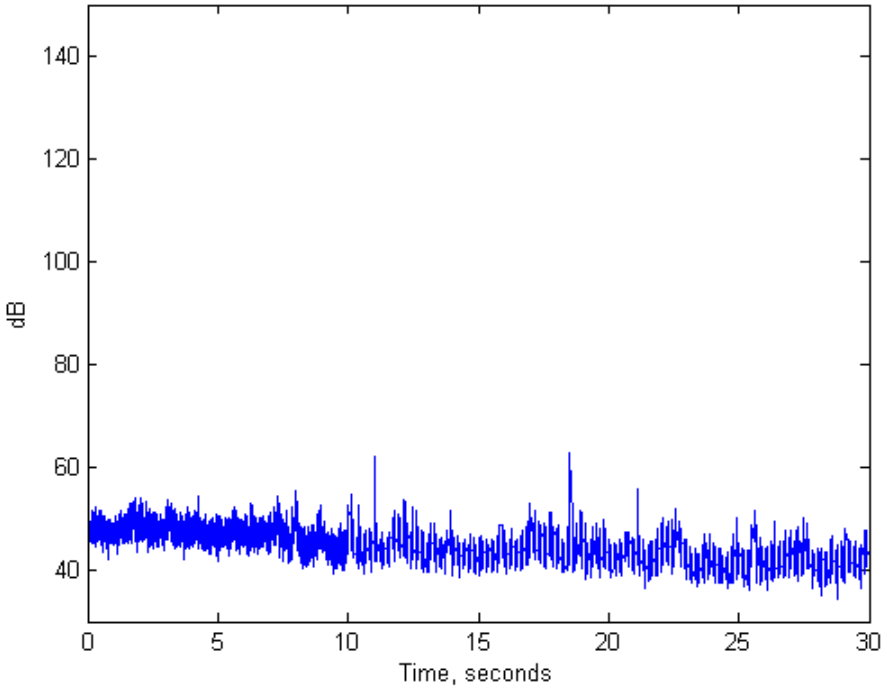

Figure 17. Measurement of ambient conditions at location 5.

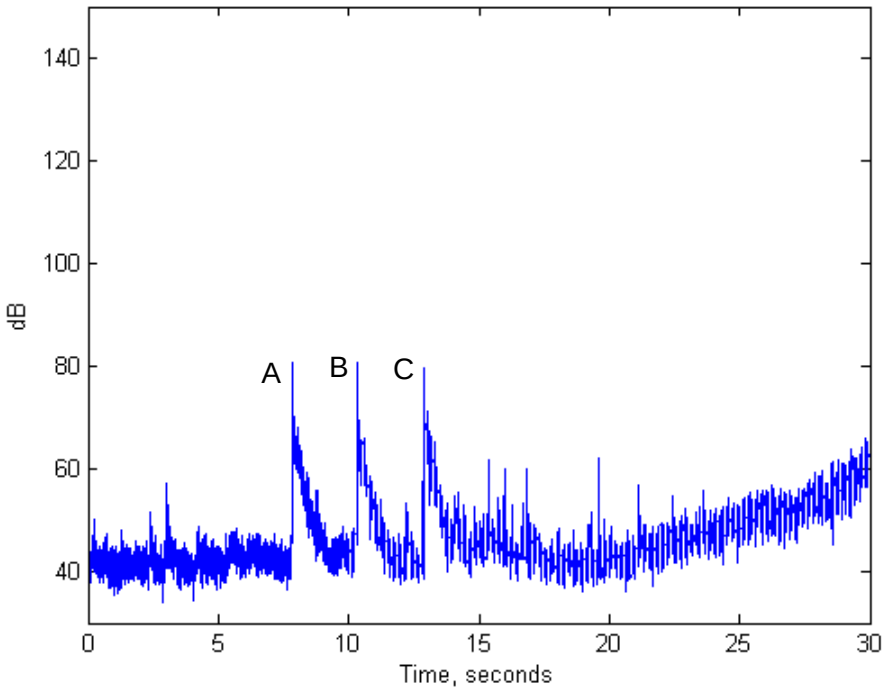

Figure 18. Location 5 three shot group (shot peaks at A, B, C). After 20 seconds the baseline noise level is increasing due to a car approaching from down the road.

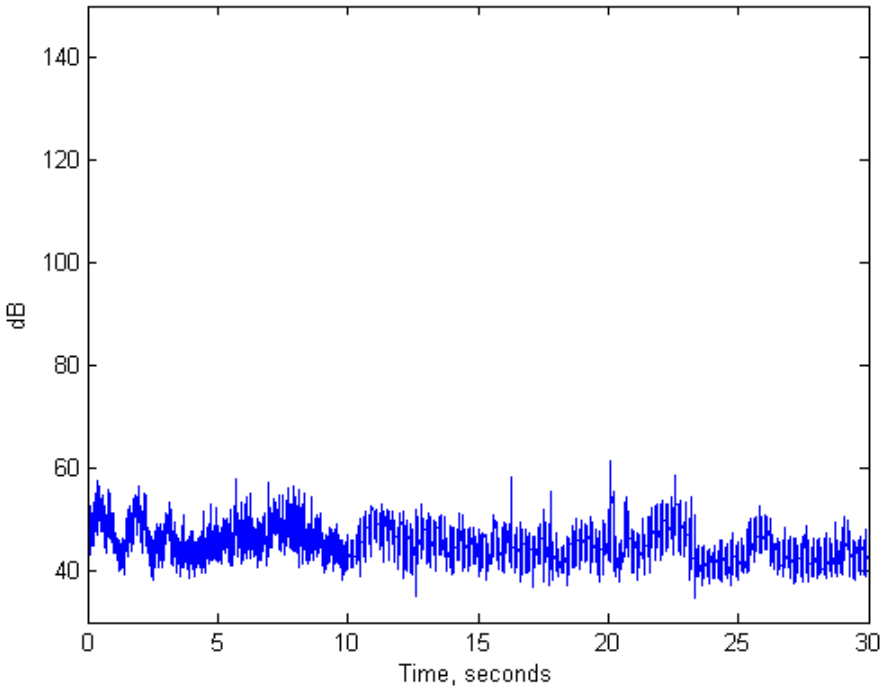

Figure 19. Measurement of ambient conditions at location 6.

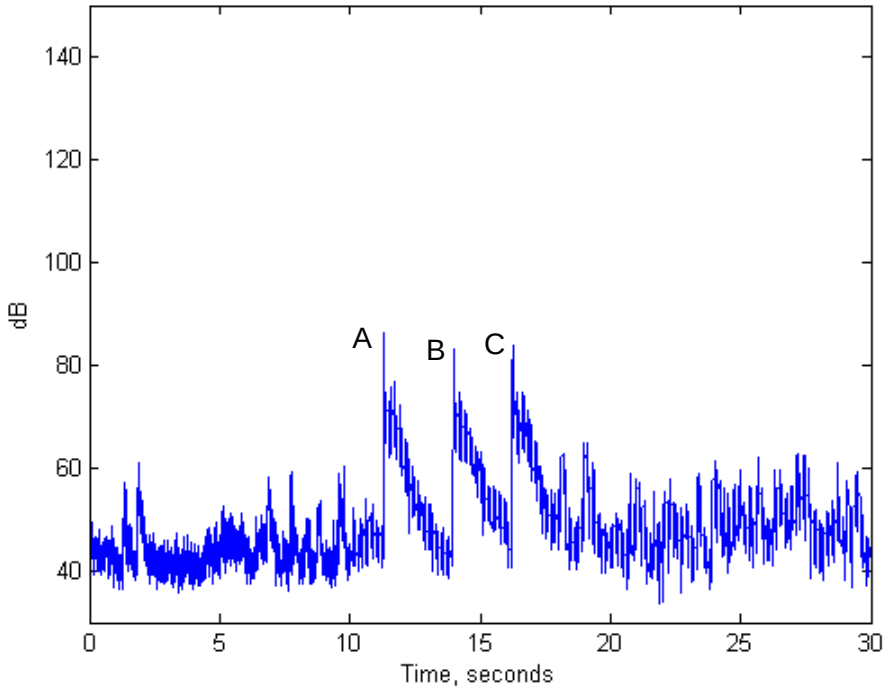

Figure 20. Location 6 three shot group (shot peaks at A, B, C).

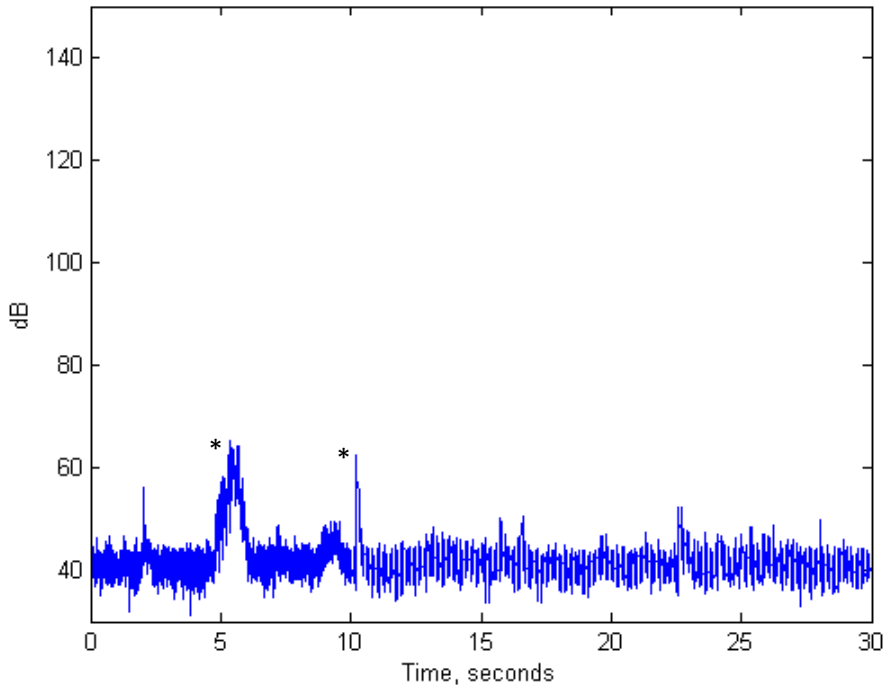

Figure 21. Measurement of ambient conditions at location 7. Bird and chipmunk calls are marked (*).

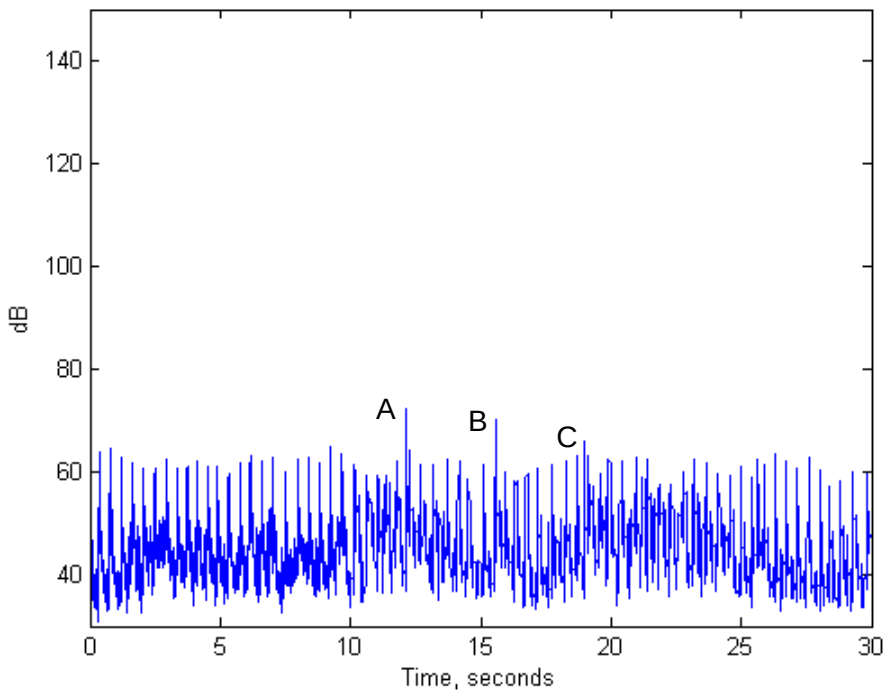

Figure 22. Location 7 three shot group (shot peaks at A, B, C). Each of the other peaks, occurring roughly 2 times each second over the entire 30 seconds, are from a chipmunk calling 35 yards behind the microphone.

Appendix

Figure 23. May 6th, 2014 photo showing the lack of vegetation at measurement location 5.

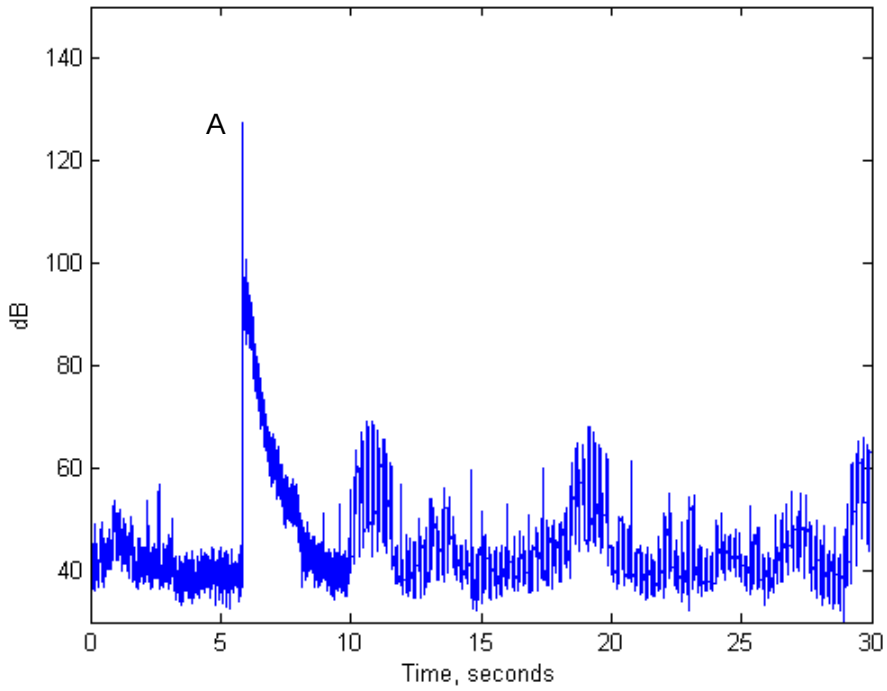

Figure 24. Location 1 single shot peak at A.

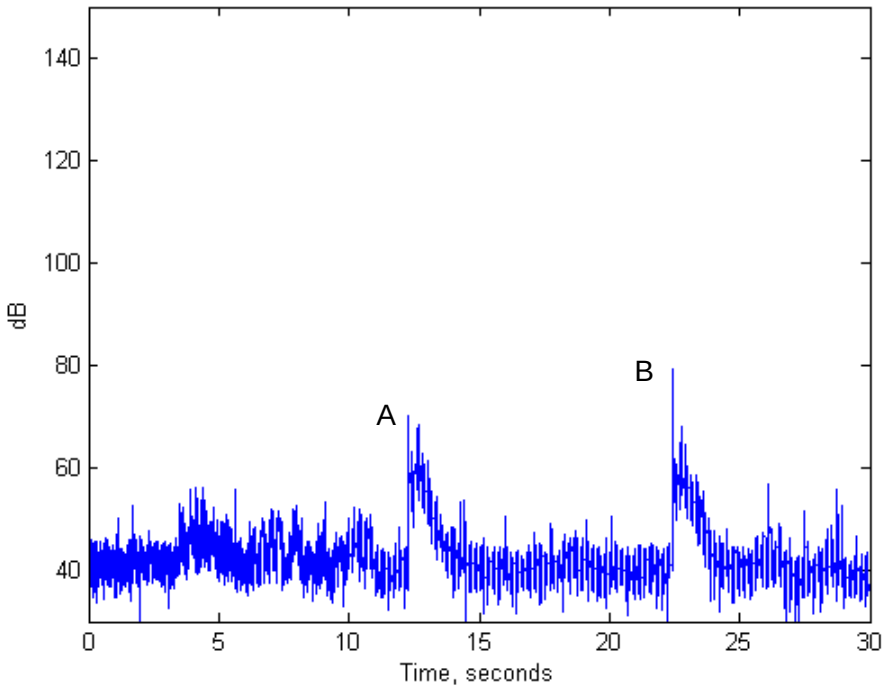

Figure 25. Location 3 two shot group (shot peaks at A, B).

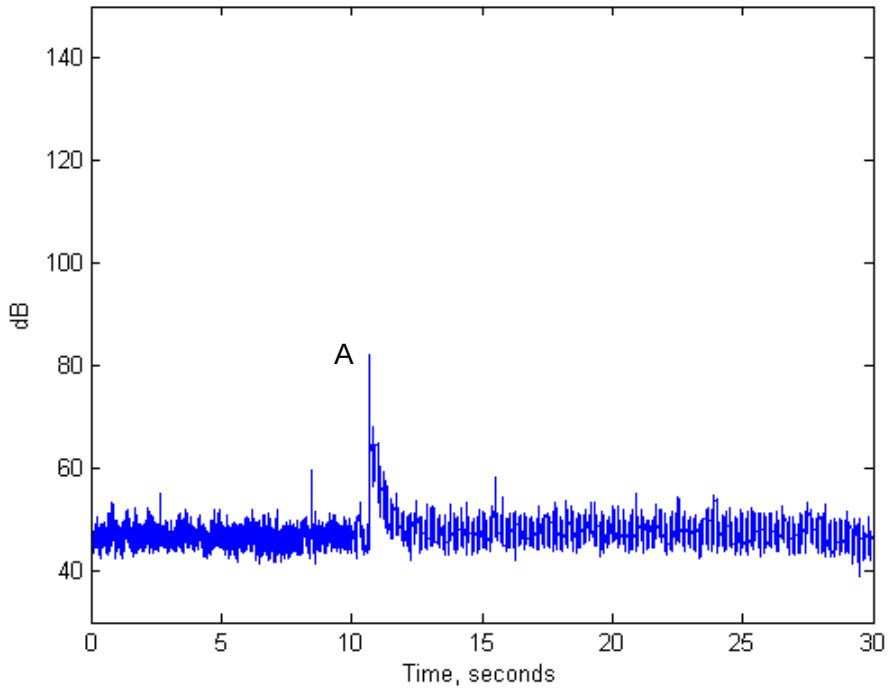

Figure 26. Location 5 single shot peak at A.

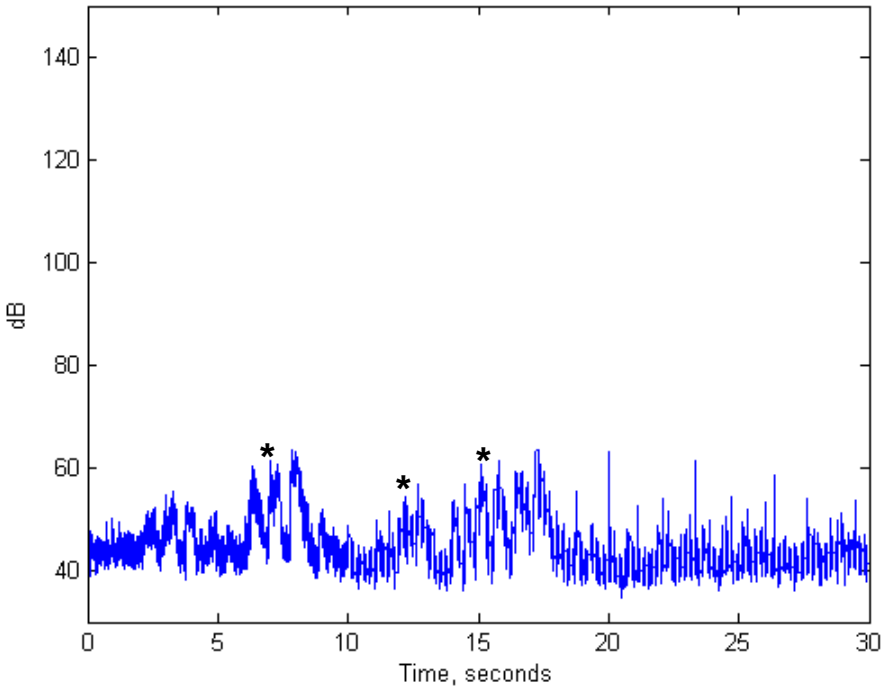

Figure 27. Measurement of ambient conditions at location 5. Crows were calling in the woods, denoted by *.

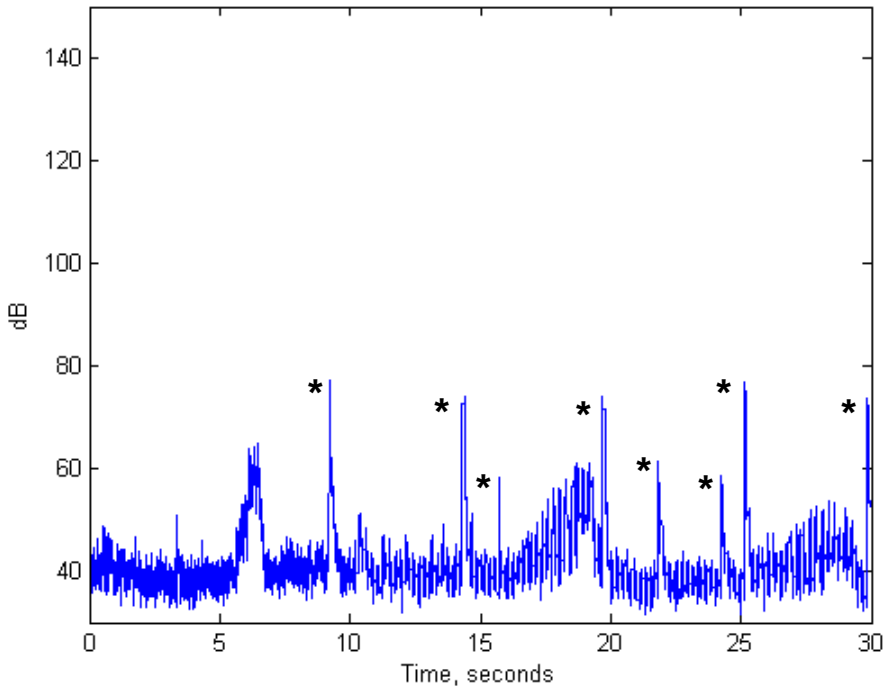

Figure 28. Measurement of ambient conditions at location 7, with a chipmunk calling (*) from within 30 yards directly behind the microphone.