Noise Level Compliance Analysis

for the

California Ridge Wind Energy Project

Vermillion County, Illinois

March 7, 2014

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1. Introduction

The California Ridge Wind Energy Center is a 214 mega-watt wind turbine facility located in both Champaign and Vermillion Counties, Illinois. The facility was constructed, and is owned and operated by California Ridge Wind Energy, LLC (CRWE). The wind farm began commercial operations in 2012. In response to complaints from two residents this study was commissioned to measure acoustic emissions of the turbines near these residences and to determine if the emissions are in compliance with Illinois Pollution Control Board (IPCB) regulation Title 35, Subtitle H., Noise. The study was conducted by Hankard Environmental Inc. of Verona, Wisconsin, and Schomer and Associates of Champaign, Illinois.

This report describes and documents the execution of this study and its results, and is organized as follows:

- Chapter 2 provides information regarding the wind turbine project, including the location of the residences that are the source of the subject complaints
- Chapter 3 describes the IPCB regulation as it applies to this project, and the resulting noise level limits
- Chapter 4 describes enforcement and noise measurement issues relevant to this compliance assessment
- Chapter 5 presents the noise measurement test plan designed for and implemented on this project
- Chapter 6 describes the data analysis methodology employed, which is primarily concerned with removing the background levels from the total measured levels to yield just the wind turbine noise levels
- The measurement and analysis results are provided in Chapter 7
- The issue of measurement and analysis uncertainty is discussed in Chapter 8
- The conclusions reached based on these results are provided in Chapter 9
- Detailed data and other information are provided in appendices, as noted in the text

2. Project Description and Location

The California Ridge Wind Energy Center is located in Champaign and Vermillion Counties, Illinois. The general location of the facility is shown in Figure 2-1. The two subject residences are located near State Highway 49 in Vermillion County, as shown in Figure 2-2. Also shown in Figure 2-2 are the locations of the four closest turbines (T75, T57, T56, and T76). The distances between the turbines and the residences and measurement locations are listed in Table 5-1. The turbine model employed on this project is the General Electric Model 1.6-100, which is a 1.6 mega-watt, 100 meter hub-height turbine. Additional turbine information is provided in Appendix A.

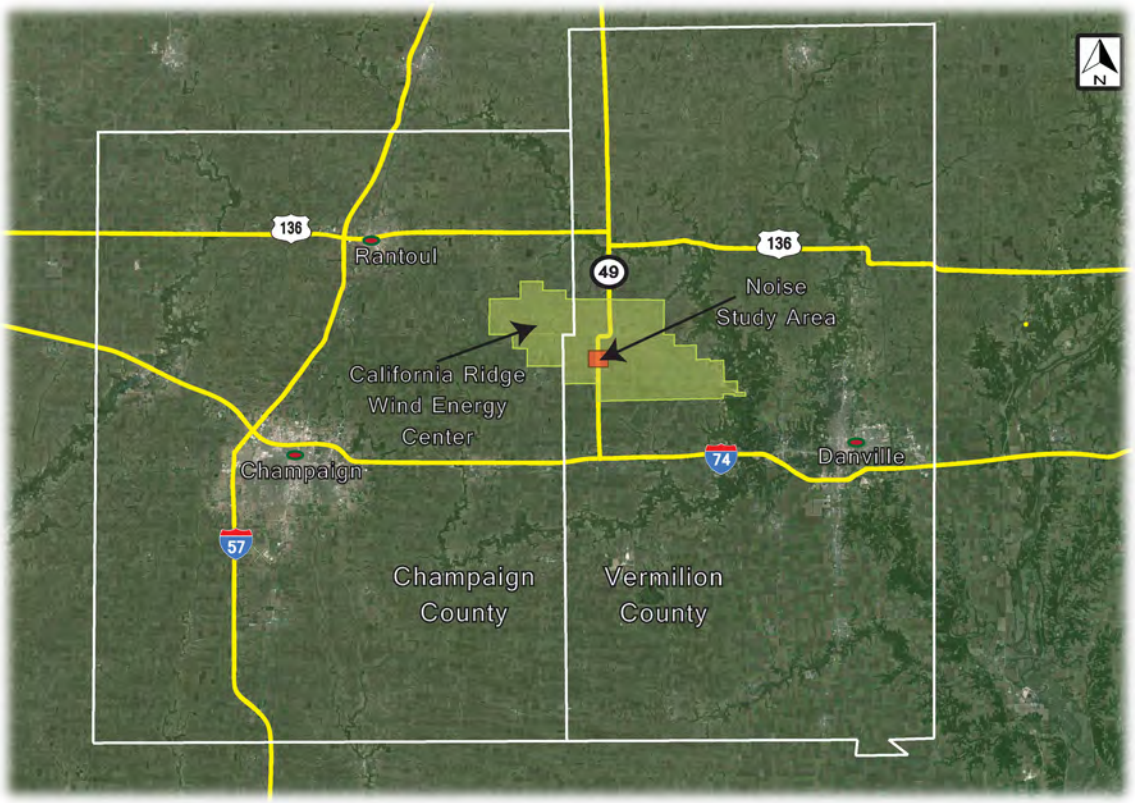

Figure 2-1: General Location of the Project and Noise Study Area

Figure 2-2: Location of the Subject Residences, Nearest Wind Turbines, and Noise Measurements

3. Applicable Noise Regulations and Limits

Illinois is one of a minority of states that has statewide noise rules. These rules are promulgated by Illinois Title 35: Environmental Protection, Subtitle H: Noise, Chapter I: Pollution Control Board. Specifically applicable to this project is Part 900, General Provisions; Part 901, Sound Emission Standards and Limitations for Property Line-Noise-Sources; and Part 910, Measurement Procedures for the Enforcement of 35 IL Adm. Code 900 and 901.

Part 901 is concerned with the noise generated on an "emitting parcel" of land that travels through the air and crosses the property line onto a "receiving parcel" of land. The noise level limits applicable under the Illinois rules change with land use occurring on the emitting and receiving lands. The rules specify three forms of emitting land use and two forms of receiving land use. Specifically, the emitting land uses specified are nominally residential (Type A), commercial (Type B), and industrial (Type C). The two land uses that are protected by the rules are residential (Type A) and commercial (Type B). In this matter, the complaints are from people in their homes so the receiving land use is Type A, residential, and the emitting land use which is power generation is Type C, industrial.

The noise limits under the Illinois rules also differ with time of day. Limits are lower during the nighttime, which is defined as 22:00 to 07:00 (and therefore daytime is defined as 07:00 to 22:00). This definition for daytime and nighttime is consistent with that which is used in many national and international noise standards. As wind farm noise emissions are approximately equal during daytime and nighttime for any given operating scenario, and because the project will operate 24 hours per day, the more stringent nighttime limits are the controlling limits.

Furthermore, the Illinois limits are expressed in terms of nine different "octave bands levels". This is in contrast to most other noise rules where the limit is a single number (usually the "A-weighted level"). The A-weighted level is simpler to explain and for the public to understand, but it presents some resolution and measurement issues that make it ill-suited for wind turbine projects. The A-weighted level represents the sum of all acoustic energy across the entire audible spectrum, which in general ranges from 20 to 20,000 Hertz (Hz). For the purposes of measurement and analysis, this large spectrum of frequencies has been divided into nine standard sub-ranges, or bands, by the American National Standards Institute (ANSI S1.11). The bands have center frequencies of 31.5, 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz. Note that each frequency is a doubling of the one before it, i.e. an octave.

The Illinois rules provide specific limits in each of these nine octave bands separately. Based on land use and time of day as discussed above, the limits applicable on this project are listed in Table 3-1, below. The Illinois rules state that no person shall cause or allow the emission of sound from any property-line-noise-source that exceeds any allowable octave band sound pressure level when measured at any point within a receiving land, provided, however, that no measurement of sound pressure levels shall be made less than 25 feet from such property-line-noise-source. As the levels are rounded to the nearest whole decibel, this means that the actual limits are the stated limits in decibels plus 0.49 dB.

Finally, the Illinois limits apply to what is termed a "one-hour equivalent level", or one-hour L_{eq}. That is, the Illinois rules are not simply the levels one would read when viewing the display of a sound level meter. Rather, they are an average of the summed "energies" for each of the 3,600 seconds in an hour. One effect of energy averaging is that it greatly emphasizes the louder seconds in the hour.

Table 3-1: Allowable Octave Band Sound Pressure Levels (dB) of Sound Emitted to Any Receiving Class A Land from Any Class C Land

Octave Band Center Frequency (Hz)	*Nighttime Noise Level Limit (dB)*
31.5	69
63	67
125	62
250	54
500	47
1,000	41
2,000	36
4,000	32
8,000	32

Source: Amended at 30 Ill. Reg.5533, effective March 10, 2006

4. Enforcement and Noise Measurement Issues

Part 910 of the IPCB rules specifies measurement procedures for the enforcement of the numerical limits. Most of Part 910 deals with determination of the background sound level, which for the purposes of this matter is the total of the sound emitted by all non-turbine sound sources audible within the project study area. The following is a list of background sound sources audible and measurable at the project site:

1. Roadway traffic and trains
2. Harvest equipment, including both near and distant mobile and stationary equipment
3. Birds and Insects
4. Occasional rain
5. Ground winds (noise generated as wind blows through vegetation, through the wind screen, and across the microphone)

However, when a microphone and analyzer are placed in the environment as was the case on this project, the levels measured during turbine operations are necessarily a sum of that produced by the turbines and that produced by all background sources. This is particularly the case considering that the measured level is an average over the course of an entire hour.

One potential method of separating the turbine and background sources would be to turn all of the nearby turbines off for approximately 30 minutes (for example) and then turn them all back on, all while continuously measuring sound levels. This will result in a measurement of all sources combined, and that of just the background. Then, by definition, the noise emitted by the turbines is the total sound level at the selected measurement point minus the background sound measured at that same point. But the logic here depends on the ability to apply this subtraction correctly which in turn requires the ability to remove all short term transient sounds fully and completely and that the remaining total sound and background sound both be statistically stationary. As discussed later, the traffic noise, which is the primary contributor to the background, is very often too heavy to be considered to be short-term transients, but not frequent enough to be statistically stationary over time frames relevant to the project. In addition, conducting noise measurements before and after turbine shut off really calls for observers to be present, and this all must be timed with turbines being at or near maximum operations and low ground winds. This is very challenging logistically. As we show, we would have spent many, many hours in the field waiting for these conditions to come together.

The fact that turbine noise is correlated with wind speed, and, in general, ambient noise increases with increasing wind speed creates additional measurement challenges. Note that the measurement procedures in Part 910 were written by one of the authors (Paul Schomer) in the 1980's for the IPCB, and subsequently used for the first edition of ANSI S 12.9 Part 3. Wind farms and the correlation between the source in question and the background were not considered when this procedure was developed. Since that time, S 12.9 Part 3 has been revised two or three times with the latest revision promulgated just last year (2013). As with the other versions of the standard, the issue of wind turbine noise being correlated with wind induced noise is not dealt with in the most recent version. Instead, as described in Section 6, below, the method selected to

separate turbine and non-turbine noise levels varied by background source. The effect of birds and insects was minimized by the fact that only November data were analyzed, and they were not present to any significant degree at that time. Similarly, noise from harvesting was avoided by not using October data, and through an analysis of measured frequency spectra. Most significantly, the noise from traffic and trains was minimized by eliminating the times they were present based on a review of the level versus time graph of each hour studied.

This leaves the contribution of noise by the wind. It is well understood that the level of noise generated by wind turbines is positively correlated with wind speed. As wind speeds aloft increase, so does the rotational speed of the turbine and subsequently the level of noise generated. At a certain point, however, the turbines reach a maximum rotational speed and noise levels do not continue to increase with increasing wind speeds. It is also well understood that the level of sound generated by ground winds is positively correlated with wind speed. Ground winds generate sound by rustling vegetation, and in the form of "pseudo-noise" where the microphone interprets turbulence in the air as acoustical signals. There is intrinsic turbulence in the air from thermal mixing and from objects large and small over and through which the air travels, and there is wake turbulence generated by the microphone itself being in the airstream.

There is almost always some ground wind noise present during moderate to maximum turbine operations. But there are select times when the closest turbines are operating near or at maximum rotational speed and the level of ground wind noise is relatively low. These are important times in terms of these measurements. This condition, strong winds aloft but light to no winds on the ground, is the only condition during which wind farm noise can be accurately and reliably measured. This condition occurs primarily at night.

The purpose of the subject measurements is to demonstrate, to a reasonable degree of scientific certainty, whether or not noise levels from the wind turbines are in compliance with the applicable IPCB numerical limits. Part of the procedure is the deletion of short-term transient sounds and the latest version of S12.9 Part suggests that more than 12 events per hour be considered part of the long-term background. Also, the latest version corrects a 3 dB error that was in an EPA report that was the basis for the "table look up" for establishing the background sound level for purposes of estimating the *source alone* sound level. Even more importantly, the latest version of S12.9 Part 3 prohibits the use of the "table look up" procedure in any matter that concerns demonstrating a violation of or compliance with any noise rule, law, or ordinance, etc. Because there is great uncertainty to this "table look up" method, the standard suggests $\pm$ 10 dB as the 95% prediction interval when using this method.

5. Noise Measurement Test Plan

The following noise level measurement plan was developed and executed for this project based on the combined efforts and experiences of the authors.

5.1 Initial Site Review and Selection of Measurement Locations

An initial review and tour of the site was conducted by both authors jointly in early August 2013. Scaled maps of the area were reviewed, including the distances from each of the subject residences to their nearest turbines. The complainants would not allow measurements to be conducted on their property. Thus, measurement locations were selected based on available land, with the goal being to place the microphones at distances to the nearest turbines as similar as possible to those which exist between the residences and the turbines. Measurements were taken at two "Primary" locations, Primary 1 and Primary 2, which are considered acoustically representative of the residences themselves. Table 5-1 lists the distances between the nearest turbines, the subject residences, and the Primary measurement locations. It is the data from these two locations that are used to draw the conclusions reached by this study. Measurements were also taken at one "Control" location near Turbine 57, as shown in Figure 2. While not a "compliance" location, data from this location were useful in the analysis of turbine spectral information because it is closer to the nearest turbine than either of the Prime locations. A sound level meter was initially placed near Turbine 75 as well, but this meter malfunctioned for the first few weeks of the study. As it was not critical to the study, and similar information was already being collected near Turbine 57, measurements were discontinued at Turbine 75 and the focus placed on the more important Prime locations. Pictures of each measurement location are included in Appendix B.

Table 5-1: Distances between Subject Residences, Measurement Locations, and Nearest Turbines

Location	*Distance to Nearest Turbine (feet)*	*Distance to 2nd Nearest Turbine (feet)*
Primary 1	1,400	2,575
Primary 2	1,500	2,450
Miles Residence	1,750	2,350
Hartke Residence	1,700	2,250

Source: Google Earth measurements by authors (approximate)

Finally, measurements were taken at two "Surrogate" locations near Turbine 84. These locations were selected based on having distances to the nearest turbines similar to that of the subject residences. Also, these locations are orientated north-south of the nearest turbines, versus the northeast-southwest relationship that exists between the Primary locations and their nearest turbines. The north-south alignment was selected because in August when the study began the

historic monthly wind data showed the potential for south winds. As wind turbine noise is generally loudest when measured due downwind, it was prudent to have meters stationed in these directions. We ended up using November data for the study, which has a good deal of northeast-southwest wind in it. Regardless, initial review of the Surrogate meter data showed turbine noise levels were at least a few dB below those of the primary meters. Thus, these data were not further reviewed or included in the analysis.

5.2 Measurement Equipment and Parameters

As shown in the pictures in Appendix B, the microphones were mounted on steel poles. The microphones were all positioned 5 feet above the ground. Seven-inch diameter, 80ppi density windscreens were used. Hydrophobically treated windscreens were used on the Primary microphones (Aco Pacific Model WS7-80T), while a standard windscreen was used on the Control microphone (Aco Pacific Model WS7). Lines of sight to the nearest two turbines were completely free. Lines of sight to the next closest two turbines was partially blocked by trees, which in November were void of leaves. The ground wind speed anemometer was mounted atop a pole and situated approximately eight feet above the ground (at the Prime 2 location).

Bruel and Kjaer Model 2250/2270 sound level meters were used at all three measurement locations. A model B&K 4189 microphone was used at Primary 2 and Turbine 57 Control. A B&K model 4952 microphone was used at Prime 1. A description of the sound level meters and microphones employed is included in Appendix C. Also included in Appendix C are the calibration certificates for each meter. Field calibrations were also conducted approximately every two weeks. The results of those are listed in Table 5-2.

Table 5-2: Results of Noise Meter Field Calibrations

Date (2013)	*Prime 1*	*Prime 2*	*Control 57*
August 8	94.0	94.0	94.0
August 26, 27	94.0	94.1	93.7
September 8, 9	94.0	94.0	93.6
September 23, 24	93.8	94.0	93.6
October 8, 9	93.9	94.0	93.9
October 22, 23	93.7	94.0	94.2
November 6, 7, 8	93.8	94.2	94.0
November 20	93.8	93.9	94.0

Source: Hankard Environmental

Audio was recorded at the Prime 2 location using an Aco Pacific MK-224 microphone, a Studio Six Digital Pre-amp and analog to digital converter, and the AudioTools software package. This meter was field calibrated before, during, and after the study and the drift was less than 0.3 dB. Ground wind speed and direction were measured using a Davis Vantage Vue. The anemometer was calibrated after the measurements. The calibration showed that the anemometer was measuring 0.4 m/s low at 1.7 m/s, 0.3 m/s slow at 3.4 m/s, and 0.1 m/s low at 5 m/s. Thus, wind speeds were actually a few 10^{ths} of a m/s higher than those reported. Operational data were

provided by CRWE. Five-minute average values of turbine rpm, hub-height wind speed, and turbine power were provided for the eight turbines closest to the measurement locations, as well as overall site power. These data were time-synchronized to the noise data to an accuracy of approximately one-minute.

5.4 Instrument Parameter Settings

All three sound level meters had their measurement parameters set identically, including:

1. 10 second interval duration - all three meters were time synchronized to within approximately 10 seconds of one another
2. Parameters saved each interval include the overall A-weighted level, C-weighted level, and one-third octave band spectrum (6.5 to 20,000 Hz)
3. Metrics saved each interval: L_{eq}, L_{10}, L_{50}, L_{90}

The audio recorder was set to five minute intervals and time-synchronized with the sound level meters to an accuracy of approximately one minute. The weather station was set to 5-minute intervals (because of memory restrictions) and time synchronized with the sound level meters to an accuracy of approximately one minute.

5.4 Duration of Study and Resulting Database

Measurements began on the afternoon of August 9th, 2013, and ceased on the morning of November 20th, 2013. Measurements were conducted continuously during that time, except for:

1. Between November 6 and 8 the noise meter at Prime 2 was placed on a ground board at Prime 1 for the purpose of determining the difference between IEC 61400-11 ground-board measurements and a typical 1.5 meter tripod measurement. The results of this analysis were general in nature, and not reported herein.
2. Ground meteorological data were lost due to a power failure between September 10 and 24, 2013. This does not impact the November analysis.
3. Operational data were unavailable in November between the 9th at 2300 to the 10th at 0700, and also for one hour on the 17th.

5.5 Applicable Measurement Standards

1. ANSI S1.4-1983 (R2006) American National Standard Specification for Sound Level Meters
2. ANSI S1.13-2005 (R2010) American National Standard Measurement of Sound Pressure Level in Air
3. ANSI S12.9-Part 3--2013 American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound - Part 3: Short-Term Measurements With an Observer Present
4. ANSI S12.18-1994 (R2009), Outdoor Measurement of Sound Pressure Level

6. Data Analysis Methodology

As described in Chapter 3, noise levels from the California Ridge wind turbines are not permitted to exceed the IPCB limits listed in Table 3-1 (above). Noise level limits are prescribed for each of nine standard octave bands. It is very uncommon for the noise from a single source to be near the limits in all or even most of the nine octave bands. Much more commonly, noise levels from a source are near the limit in only one or two octave bands, and well below the limit in the other seven or eight octave bands. On this project it was determined that the 500 and 1,000 Hz octave bands required the most analysis to separate the turbine and non-turbine noise. Noise levels in the other seven bands are below the IPCB numerical limits during maximum turbine operations.

In the octave bands below 500 Hz, even though turbine sound emissions increase, the allowable levels increase more. The same is true of the octave bands higher in frequency than 1,000 Hz. Turbine emissions decrease above 1,000 Hz, but the limits decrease more. Furthermore, there is a great deal of interference generated by the noise of wind rustling vegetation, traffic, and insects and birds above 1,000 Hz. Removing these sounds from the measured data is discussed in detail below. Such separation is difficult but possible in the 500 and 1,000 Hz bands, but in the higher bands it becomes much more difficult, if not impossible. Note that the ANSI/ASA standard on measuring the background in quiet settings that is set for final review and has no negative positions (ANSI/ASA S12.100 2014) calls for the complete elimination of the 2,000, 4,000, and 8,000 Hertz bands from A-weighted levels when insect, bird, or leaf-rustle noise is present. Note that an analysis of all of the octave bands was conducted regardless. The results are discussed in Section 7.

Therefore, the primary goal of this analysis was to determine whether or not the turbine-only noise emissions exceed 47 dB in the 500 Hz octave band or 41 dB in the 1,000 Hz octave band. Since the rules state that these levels shall not be exceeded, and since the levels are rounded to the nearest whole decibel, only levels at or above 47.5 dB in the 500 Hz octave band or at or above 41.5 dB in the 1,000 Hz octave band are a violation of the IPCB rules.

The first step in the data analysis process was to determine which month or months of data to include in the analysis. There were very limited maximum or near maximum turbine operations in August or September due to light winds, and the facility was under a U.S. Fish and Wildlife Service endangered species curtailment order where most of the turbines did not operate under low wind conditions. For these reasons these months were not included in the analysis.

In October there were significant near maximum turbine operations, but also a great deal of background noise produced by harvest equipment, such as combines, haul trucks, blowers, dryers, and conveyors. Noise from this equipment often has a distinct maximum in the 500 Hz one third octave band. Thus, when present, harvest noise contributes significantly to the 500 Hz octave band level, and as previously noted, this is one of the octave bands of primary concern on this project. We know that harvesting started in October, but we do not know exactly when or where it occurred in the vicinity of the sound level meters. We were not confident with a reasonable degree of scientific certainty in the success of our initial attempts to separate harvest noise from turbine noise. On some audio recordings the sound of a nearby combine, for example,

is very noticeable, and can also be seen in noise level versus time graphs. It is the distant harvest noise that, while evident in the measured spectra, was not readily discernible in the audio files.

As these 500 Hz harvest noise levels approach the IPCB limit of 47 dB, they become a measurement problem. By its nature, these harvest noises are part of the long-term background, they are clearly not transients. As such, the IPCB procedure, ANSI/ASA S12.9 Part 3, and good engineering practice all say that when the harvest noise reaches or exceeds 44 dB, measurement of the turbine noise in that octave band is impossible and that no violation can be found. If the raw measured data are used uncorrected, then great caution must be used in interpreting the results. For example, if the turbines alone produced exactly 47 dB in the 500 Hz octave band then a harvest noise level of 39 dB would result in an apparent 500 Hz octave band level of 48 dB. The problem only gets worse as the harvest noise gets louder. When the harvest noise contribution is more than 44 dB, then any turbine-only noise levels in excess of about 44 dB will be in apparent excess of a 47 dB limit.

We identified special characteristics of the frequency spectrum of noise from harvest activity, and used that to eliminate from the analysis one night in November when these special characteristics were strongly present, and at times dominant. An extensive review of the one third octave band spectra of the noise levels measured during August through November was conducted, and this review only showed the presence of tonal components in October and November. Sometimes the tone was in the 400 Hz one third octave band, sometimes the 500 Hz band, and sometimes multiple bands. The times when combines came close to the sound level meters were determined by listening to audio files, and the spectra for those times clearly show the tonal component. However, harvest noise was not always clearly discernible in the audio files at some times when the tonal component was evident in the spectra. Such is the case on the night of November 3rd into the 4th, 2013, when the 500 Hz octave band levels at Prime 1 exceed the limit by 0.3 dB, and levels at Prime 2 are close to but below the limit.

Figure 6-1 shows the average spectra for the hours of 22:00 on November 3rd through 05:00 on November 4th in comparison to select hours from August, September, October, and November for Prime 1. The spectra shown are all for the hours indicated, after the data for these hours were run through the traffic noise eliminator process, which is described in Section 6, below.

- The hour shown for August is during the one time that month when turbine operations were even close to maximum. The spectrum displays its maximum at 315 Hz, as expected for the turbine sounds, and there is no tone at or near 500 Hz.

- The hour shown for September is during one of the very few times that month when turbine operations were even close to their maximum. The spectrum displays its maximum at 315 Hz, as expected for the turbine sounds, and there is no tone at or near 500 Hz.

- The hour shown for October was selected because the turbines were operating near their maximum capacity, the harvest tone is clearly observed in the spectrum, and the clear sound of a nearby combine (in addition to turbine noise) can be heard when listening to

the audio file. The spectrum for this October hour clearly shows a maximum in the 500 Hz one third octave band that is not present in the August or September spectra.

- Two times are shown for November. The first is the 23:00 hour on the 1st. This hour was selected because it is one of the hours thought to be most representative of maximum turbine operations since it can be characterized by low ground-level wind speed and minimal interference from non-turbine noise sources. The spectrum is similar to the spectra measured in August and September.

- The second November time shown is during the suspected harvest-influenced period on the 14th. The shape of the spectrum is similar to that measured during known harvesting in October, with a clear maximum in the 500 Hz one third octave band.

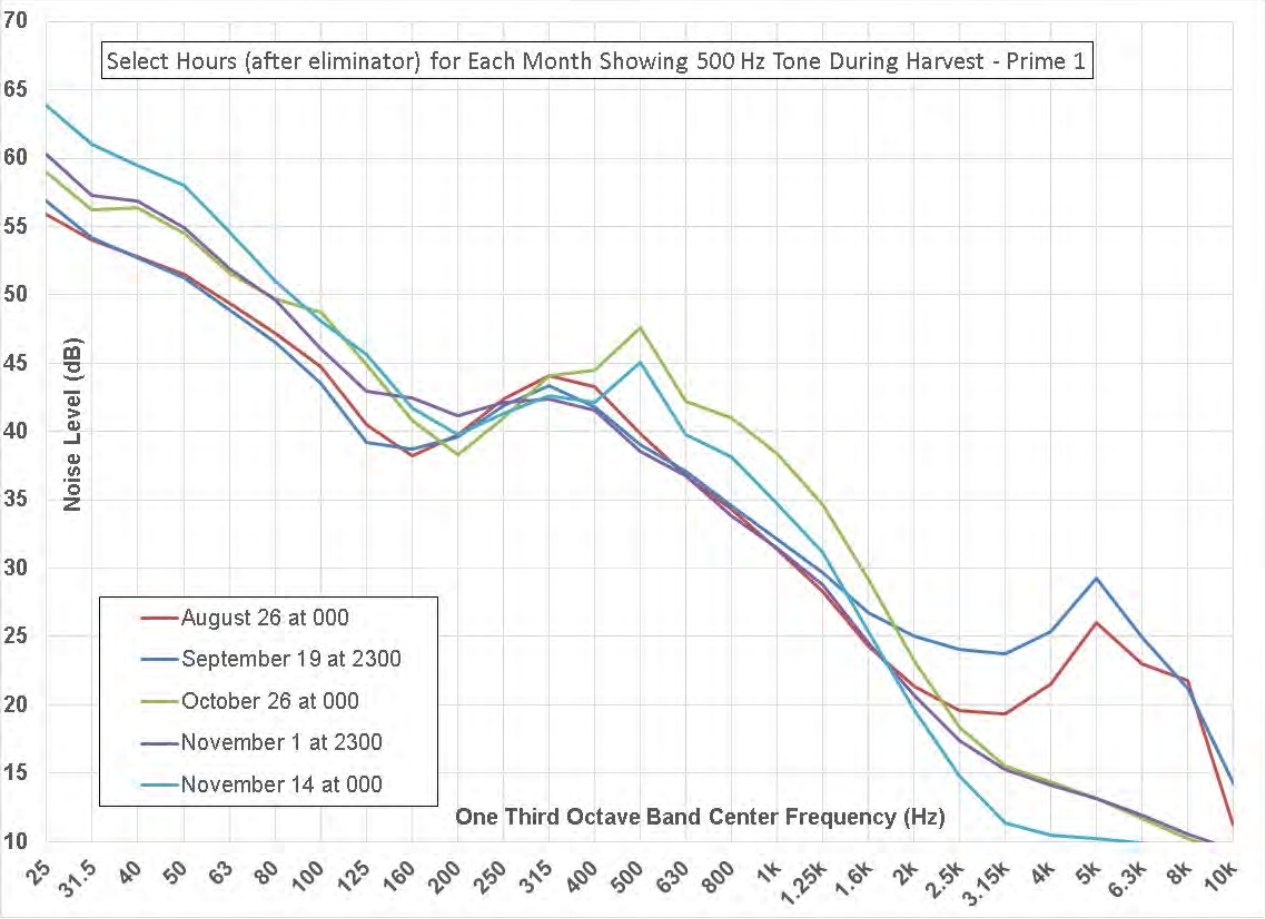

Figure 6-1: Spectra of Select Hours During Each Month of the Measurements at Prime 1

Figure 6-2 shows the results of a monthly analysis based on averaging all of the one-hour spectra for each month when turbines were operating near maximum conditions, and winds were less than 5 m/s as measured at Prime 2, and as approximated at Prime 1 based on the 25 Hz one third octave band noise level being less than 70 dB[1]. These one hour spectra were not run through the traffic eliminator process described in Section 6, below. The results are similar to the hourly analysis discussed above, in that:

- The August and September spectra show no evidence of the 500 Hz one third octave tone
- The October spectrum shows the strongest evidence of a 500 Hz tone
- The overall November average also shows evidence of the tone, but when the two days when it was most prominent are removed from the average the resulting spectrum is more similar in shape to that of the August and September averages.

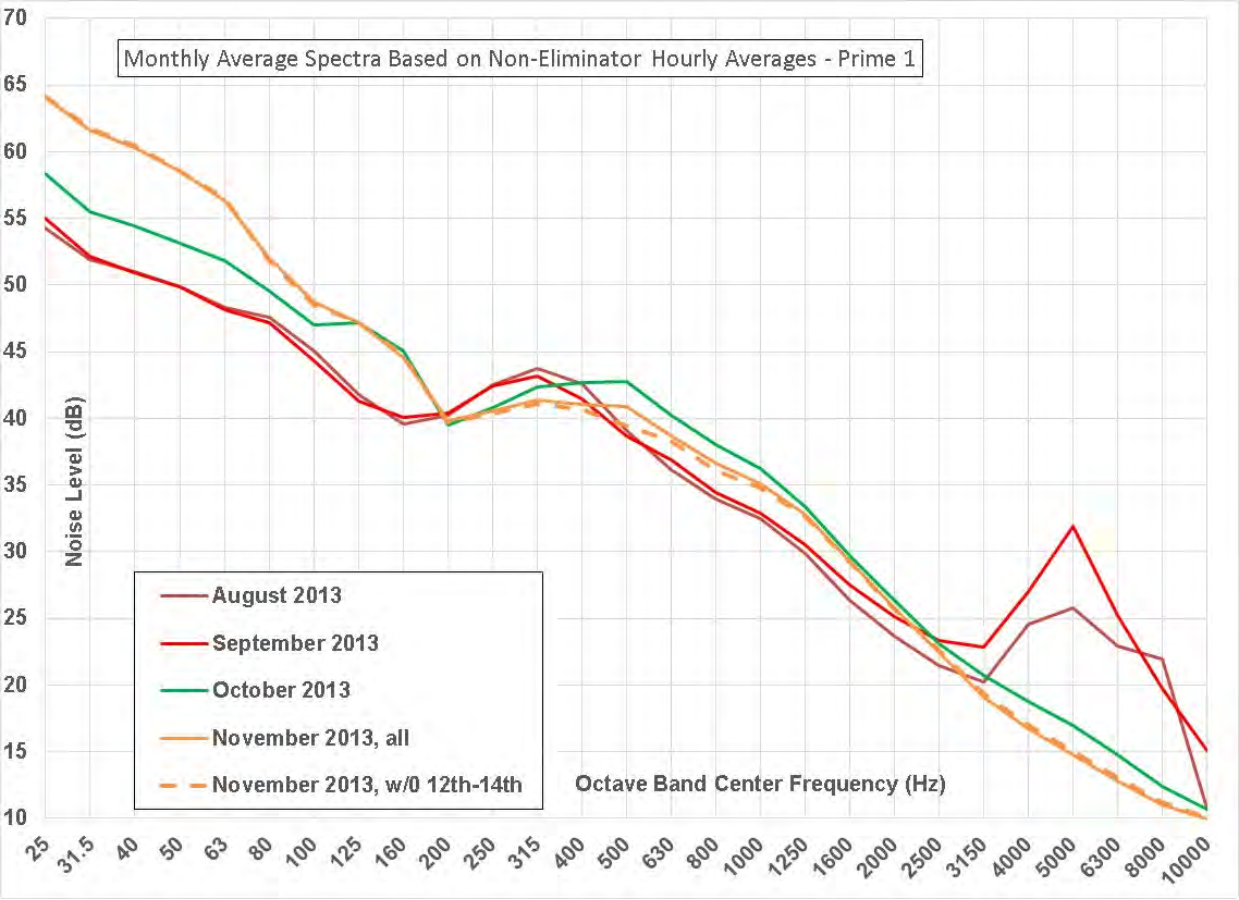

Figure 6-2: Spectra of Monthly Averages During Maximum Turbine Operations at Prime 1

1 Because of shielding by nearby buildings, ground wind speeds measured at Prime 2 do not always sufficiently approximate ground wind speeds at Prime 1. Thus, at Prime 1 we used an alternative method to gauge wind noise interference (greater than 5 m/s), as described in Section 6, below to threshold high wind situations.

Therefore, for all of the reasons just described, the data in October were not used, as harvest noise cannot be accurately separated.

Turbine operations at near maximum power during November were far greater than during any other month of the study. These conditions occurred more than twice as often during November as they did during October, and more than 14 times as often as they did during August or September. Furthermore, with the exception of one night, interference from harvest related noise was minimal. Thus, November is the best month to analyze, and the only month that can provide for a worst-case analysis. Therefore, the final data analysis included only data measured from November 1st at 0:00 through November 20th at 6:00 (last day of measurements).

The next step in the analysis procedure was to determine which hours of the day to analyze. Daytime hours were not analyzed because (a) background noise such as traffic is much louder thus making it more difficult to separate from turbine noise, (b) turbine noise does not propagate as readily during the daytime, again making it more difficult to separate from background noise, and (c) the daytime limits are 5 dB higher than the nighttime limits. Thus, nighttime is the controlling condition, and, initially at least, we analyzed all nighttime data in November as defined by the IPCB, i.e., 22:00 to 07:00.

The next step in the analysis was to separate traffic and train noise from turbine noise as accurately as possible, without rejecting true turbine noise. Our guiding principle here was to err on the side of leaving in some traffic and train noise versus possibly removing valid turbine noise. Specifically, we developed a spreadsheet containing four noise level versus time charts (500 Hz octave band, 1,000 Hz octave band, the overall A-weighted level, and the overall AI-weighted level[2]). We reviewed each of the charts and selected a 500 Hz threshold and 1,000 Hz threshold for each hour above which the sound level was considered to be that from trains or traffic, and below which was the "ambient" or baseline level for that hour.

In general, the 1,000 Hz octave band and the two A-weighted charts look very much alike with the 500 Hz octave band chart frequently being a bit less similar. From our listening to audio recordings, we found that trains excite the 500 Hz octave band more than the 1,000 Hz band, cars and small trucks excite the 1,000 Hz octave band more than the 500 Hz band, and loud trucks excite both bands. Since both the 500 and 1,000 Hz octave band charts identify times when vehicle noise is present and affecting the levels, we have used the union of these two sets of points to delete vehicle noise from the measurements. In order to better visualize this process, on the charts all of the deleted points are marked in red. This procedure is in consonance with pressing a pause button on a sound level meter or deleting whole short-term transient sounds from a time history record. But again we are conservative in that we do not delete the "tails" to these transient events which could contain turbine noise, but also likely contain some vehicle noise. All of the 500 Hz and 1,000 Hz traffic analysis charts used in the analysis are shown in Appendix D.

2 AI-weighting is defined in a new ANSI/ASA standard for measuring ambient sound levels in very quiet residential areas or in quiet wilderness areas. It is basically the standard A-weighting with all the acoustic energies above the 1000 Hz octave band removed.

Figure 6-3 shows, as an example, the noise level charts for the 3:00 hour at Prime 2 on November 4, 2013. There are about 5 significant vehicles during this hour and it appears that three of the five are probably trains or large trucks. In the 1,000 Hz diagram, there are five distinct peaks, but in the 500Hz diagram only 3 show up. This occurs because the vehicle noise comes from the interaction of tire tread with the road. Small vehicles have smaller tread spacing creating only higher frequency noise. Large trucks, especially with lug tire tread patterns, will create lower frequencies and overtones. Note especially the small vehicle 20 minutes into the hour creates relatively high levels in the 1,000 Hz diagram but is totally invisible in the 500 Hz diagram. With trains the low frequencies are primarily the large diesel engines and typically trains take a longer time to pass by than do motor vehicles (also due to their distance from the meter). Since the pass-bys in these diagrams that appear in the 500 Hz diagram are all about 100 seconds long, they could be a train or a truck.

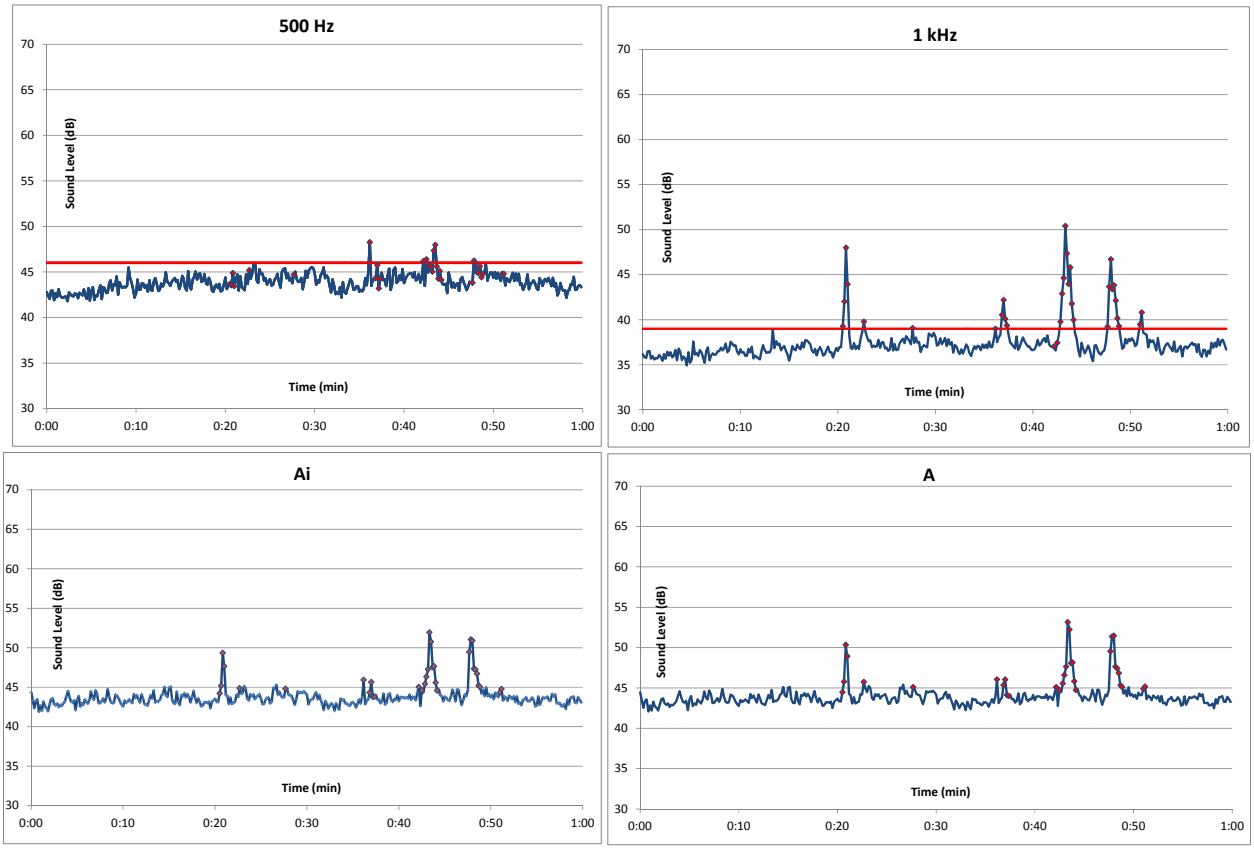

Figure 6-3: Example Level versus Time Charts for November 4, 2013 at 03:00

Figure 6-4 shows the 1,000 Hz diagrams for the nine hours of the night from 22:00 through 06:00 on November 3 and 4, 2013. One can clearly see the diurnal traffic pattern in the nighttime hours. This particular example also shows some examples of the weekly pattern. The 3rd of November was a Sunday night, so unlike other days of the week there was less traffic in the 22:00 and 23:00 hours than other days of the week. But Monday morning begins in a normal busy fashion. In particular, the 22:00 and 23:00 hours Figure 6-2 each show only a handful of vehicles. The hours

of 0:00 through 04:00 show less than a handful per hour, but beginning at about 05:20 traffic picks up very noticeably, and picks up even more at 05:40. By 06:00 there is a large number of vehicles. Technically, the new ANSI standard for these types of measurements suggests that transient, loud, background noise events, which the vehicle pass-bys are, be limited to about 12 per hour. Above 12 events per hour, the data should be included as part of the long-term background.

Approximately 10 hours analyzed had more than 20 pass-bys, particularly the hours of 22:00 and 5:00. However, for the sake of not culling any possible turbine related noise, these hours were left in the analysis if at all reasonable. Three exceptions are:

1. The 5:00 hour on November 1 had about 22 pass-bys overall, with a majority occurring in the 2nd ½ of the hour. Thus the 5:00 to 5:30 time period was combined with the 4:30 to 5:00 time period to make a full hour of data with acceptable levels of traffic. It is the 4:30 to 5:30 hour that was included in the analysis, but all of the data are included in the appendix.

2. Similarly, the 5:00 hour on November 14 had about 26 pass-bys overall, with a majority occurring in the 2nd ½ of the hour. Again, the 5:00 to 5:30 time period was combined with the 4:30 to 5:00 time period to make a full hour of data with acceptable levels of traffic. It is the 4:30 to 5:30 hour that was included in the analysis.

3. Finally, the 22:00 hour on November 9 had about 22 pass-bys overall, with a majority occurring in the 1st ½ of the hour. Thus, the 22:30 to 23:00 time period was combined with the 23:00 to 23:30 time period to make a full hour of data with acceptable levels of traffic. It is the 22:30 to 23:30 hour that was included in the analysis.

Overall we feel that we have been very conservative in our approach to correction for the train and traffic background noise. We permit short term transients to occur at about double the ANSI-recommended rate (more than 20 per hour versus 12 per hour). Further, when actually correcting for the ambient we have applied only one of the two correction methods to any given hour rather than applying both methods. Even so, we find that nearly every 06:00 hour except on two Sundays has too many vehicles (more than 24; more than double the recommended rate) and, averaged over the hour, the noise from just motor vehicles is louder, frequently much louder than is the total noise emitted from all sources during the wee hours of the night.

The Illinois procedure notes that if subtraction of short term transient leaves less than 15 minutes of data, then the test shall be redone with much or all of the short-term sound (noise) considered part of the long-term sound. The new ANSI standard suggests that if there are more than 12 short-term transients in an hour, they should be considered to be part of the long-term background. The basic requirement in the IPCB procedure and in every version of S12.9-Part 3 is that the background and the long-term sound level of the source of interest both be statistically stationary over the time frame of the measurements. Unfortunately, this is not the case with a motor vehicle source and a few months as a time frame. There is significant variation from day to day, week to week and month to month.

Consider the 06:00 hour 1,000 Hz data shown in Table 6-1. The table lists the noise levels measured during the 06:00 hour at Prime 2 during which time the winds were light (less than about 2 m/s) and the turbines were turning very slowly or not at all (nearest turbines rpm less than 4). We have analyzed these data a number of ways to demonstrate the variability of the traffic noise. Table 6-2 lists the average 1,000 Hz noise levels measured under various conditions. One can conclude from this analysis that:

- There is no difference between *no power being generated* and *a little power being generated*
- On the average day, the 06:00 traffic noise alone is just 1 dB below the IPCB limit
- The Monday through Saturday mean level is at the IPCB limit so 06:00 traffic noise for half of these days exceeds the IPCB limit
- The one-hour L_{Aeq} range from 25 to 54 dB, a huge, clearly non-stationary, range
- The standard deviation at 5.5 dB is quite large and, again, non-stationary for the purposes of this study
- The Sunday levels are significantly lower than the Monday through Saturday levels
- For Monday through Saturday, the one-hour L_{Aeq} range from 33 to 54 dB, a very large, clearly non-stationary, range
- The standard deviation at 4.6 dB is quite large and, again, non-stationary for our purposes
- Sundays are significantly quieter but again, the range of the one-hour L_{Aeq} data is large (25 to 42 dB), and the standard deviation at 5.4 dB is quite large
- Thus, we conclude that traffic noise is not stationary for the purposes of this study.

Figure 6-4: Example of Diurnal Traffic Pattern During the Night of November 3rd – 4th, 2013

Table 6-1: 06:00 Hour Noise Levels on Low Turbine Days

Date and Time	Overall (dBA)	500 Hz (dB)	1,000 Hz (dB)	Ground Wind Sp (m/s)	Turbine 57 (rpm)	Turbine 75 (rpm)	Turbine 56 (rpm)	Turbine 76 (rpm)	Site Power (kw)
8/11/2013 6:00	38	35	33	0.0	2	1	0	1	-612
8/12/2013 6:00	44	38	41	0.0	0	0	4	0	-399
8/14/2013 6:00	43	40	41	0.8	2	2	10	2	13258
8/15/2013 6:00	46	41	44	0.0	0	0	0	0	-684
8/16/2013 6:00	43	42	39	0.9	2	0	0	2	-604
8/18/2013 6:00	36	32	31	1.3	2	2	10	2	6381
8/19/2013 6:00	46	42	44	0.0	0	0	0	0	-716
8/20/2013 6:00	45	40	43	0.0	0	0	0	0	-499
8/21/2013 6:00	45	41	43	0.0	2	2	10	2	11002
8/22/2013 6:00	43	37	40	0.2	1	2	10	2	22072
8/23/2013 6:00	43	38	38	0.9	2	2	10	2	8059
8/25/2013 6:00	39	34	35	0.0	2	2	10	2	20703
8/29/2013 6:00	45	33	33	2.0	2	1	10	0	-716
8/30/2013 6:00	47	40	40	0.1	2	2	9	2	6639
8/31/2013 6:00	42	36	34	0.0	2	2	10	2	11370
9/1/2013 6:00	45	28	25	0.2	0	1	7	1	907
9/3/2013 6:00	45	40	43	0.0	0	0	4	0	-721
9/4/2013 6:00	48	42	46	0.0	1	2	9	2	1668
9/5/2013 6:00	46	40	43	0.0	2	2	10	2	16810
9/6/2013 6:00	43	38	38	0.4	2	2	10	2	22009
9/8/2013 6:00	45	33	32	0.1	0	0	0	0	-802
9/12/2013 6:00	47	38	37	<2	2	2	10	2	9313
9/13/2013 6:00	42	39	39	<2	2	0	10	0	3897
9/18/2013 6:00	42	38	39	<2	2	2	10	2	23720
9/19/2013 6:00	48	37	39	<2	2	2	10	2	19658
9/22/2013 6:00	39	36	36	<2	2	2	10	2	12430
9/23/2013 6:00	43	42	40	<2	2	2	0	2	20734
9/25/2013 6:00	42	40	38	2.0	2	2	2	2	1734
9/26/2013 6:00	42	38	39	1.1	2	2	10	2	14108
9/27/2013 6:00	53	48	52	0.1	2	2	2	2	5832
9/28/2013 6:00	51	47	50	0.1	3	3	1	1	-103
9/30/2013 6:00	43	38	41	0.3	0	0	0	0	-776
10/1/2013 6:00	44	36	41	1.3	2	2	2	2	4456
10/2/2013 6:00	42	35	38	1.2	2	2	0	2	2495
10/3/2013 6:00	44	37	41	2.1	2	2	2	2	24161
10/6/2013 6:00	38	37	32	0.3	0	0	0	0	-716
10/7/2013 6:00	45	40	42	0.6	2	3	2	2	21197
10/8/2013 6:00	56	50	54	0.0	2	2	10	2	16010
10/27/2013 6:00	45	41	42	0.1	0	0	0	0	-756
10/28/2013 6:00	47	44	46	0.0	0	0	0	0	-674
11/3/2013 6:00	43	42	39	0.1	0	0	0	9	1176

= Sunday

Table 6-2: 06:00 Hour Noise Levels on Low Turbine Days

	Wind Speed (m/s)	All data	No Power Being Generated	Very Little Power Being Generated	Monday through Saturday	Sunday
Mean	0.5	39.8	39.7	39.8	41.1	34.1
Deviation	0.6	5.5	5.6	5.5	4.7	5.4
Maximum	2.1	54	50	54	54	42
Minimum	0.0	25	32	25	33	25

Thus, the analysis methodology can be summarized as follows:

1. A table of measured 500 Hz and 1,000 Hz octave band levels for the hours of 22:00 to 05:00 was first assembled for November 1 through 20th, 2013.

2. The table was shortened to include only those hours where the nearest turbine to the microphone was spinning at an rpm of 14 or greater, and the site power was 75% of capacity.

3. Each hour in this table was reviewed individually for both the Prime 1 and 2 meters. Thresholds for each hour were set individually, and the 500 and 1,000 Hertz octave band levels were calculated for the energy below the thresholds.

4. The resulting 500 Hz and 1,000 Hz octave band noise levels were compared to the IPCB limits.

7. Noise Measurement and Analysis Results

7.1 Prime 2 Results

The results of the measurements and analyses conducted for the Prime 2 location are discussed first. This is because wind speed was measured here, but not at Prime 1, and the wind speed versus noise level curves developed from the analysis of the Prime 2 data were applied to the Prime 1 data, as discussed in Section 7.3. Furthermore, audio was recorded at Prime 2 only, and this aided in the identification of noisy events. Thus, what was learned analyzing Prime 2 data was applied to the analysis of Prime 1 data.

Table 7-1 lists all of the hourly-average noise levels measured at Prime 2 when the nearest turbine (No. 75) was turning at a rate of 14 rpm or greater, and the site power was approximately 75% of full power or greater. The first two columns list the day and hour in November 2013 that the levels were measured. The next two columns list the "raw" 500 Hz and 1,000 Hz octave band measured noise levels (dB). These levels include contributions from both turbine and non-turbine sources. The next two columns list the 500 Hz and 1,000 Hz octave band noise levels (dB) after traffic and train noise was minimized without affecting turbine noise levels. The next two columns list the threshold levels used in the traffic and train analysis. The remaining columns list the ground wind speed and direction measured at Prime 2 (m/s, degrees magnetic north), the hourly average rotational speed of the nearest four turbines (rpm), and the hourly average site power output (mega-watts).

The data in Table 7-1 were sorted by ground wind speed, and the resulting plots of the 500 Hz and 1,000 Hz octave band noise levels versus ground wind speed are shown in Figure 7-1. Both plots show a clear trend of increasing noise levels with increasing ground wind speed. Both plots also show some variation in the data, particularly at lower wind speeds, and this may be the result of residual traffic noise (that was not excluded in our analysis, as we were relatively conservative), distant trains and farm sources, variation in wind effects, and variation in atmospheric conditions. Note that all of the data in Figure 7-1 were measured when the nearest turbines were spinning at 14 rpm or greater. The maximum rotational speed observed during the measurements for these GE turbines was 15.6 rpm, so, all of these data represent maximum or near-maximum operating conditions.

The data fall into the following two categories:

1. Noise levels on the night of November 13 into 14, 2013 have a relatively distinct "tone" in the 500 Hz one-third octave band, which in turn affects primarily the 500 Hz octave band level. The average one-third octave band frequency spectra for these hours is shown in Figure 7-2, along with the average spectra for three different wind speed categories. As described in Section 6, above, this "tone" is not thought to be turbine related for a number of reasons, but likely the result of distant farm related activity, such as harvesting, a fan/blower, or a conveyor. First, the tone does not appear during the limited times in August or September when the turbines were operating near full capacity, but does occur often in October when harvest equipment was known to be frequently in use throughout

the project study area. Regardless, none of the 500 Hz or 1,000 Hz levels for these hours exceed the IPCB limits at Prime 2.

2. All of the other measured noise levels are the result mainly of the turbines and wind, with some residual traffic noise. Referring again to Figure 7-2, which shows the average one-third octave band spectra of the levels measured when the wind speed was between 0 and 2.9 m/s, 3.0 and 4.9 m/s, and over 5 m/s. The turbine spectral shape is evident in the data taken during low ground wind conditions (0 to 2.9 m/s). Above 3 m/s there is some evidence of wind noise, but the spectral shape is still similar to that of turbine noise. Above 5 m/s the wind noise dominates across the entire spectrum. Thus, only the levels measured with winds below 5 m/s can be compared to the IPCB limits. This is in accordance with ANSI standards and U.S. EPA guidelines. From Table 7-1 and Figure 7-1 it can be seen that none of the turbine-only 500 Hz or 1,000 Hz octave band noise levels exceed the IPCB limits when the measured ground wind speed is less than 5 m/s.

Table 7-1: Prime 2 Measured and Analyzed Noise Levels

Month	Day	Hour	Noise Levels with All Sources		Noise Levels without Vehicles		Thresholds		Ground Wind Speed	Ground Wind Direction	Turbine 57 (rpm)	Turbine 75 (rpm)	Turbine 56 (rpm)	Turbine 76 (rpm)	Site Power (megawatt)
			500 Hz	*1,000 Hz*	*500 Hz*	*1,000 Hz*	*500 Hz*	*1,000 Hz*	*(m/s)*	*(N=0, deg)*					
11	20	3	42	36	41.1	33.2	44	36	0.4	131	13	14	13	13	179,638
11	10	4	46	41	45.8	39.6	47	41	0.5	229	n/a	n/a	n/a	n/a	n/a
11	10	2	45	40	44.4	38.6	46	40	0.8	225	n/a	n/a	n/a	n/a	n/a
11	10	3	46	41	45.4	39.4	47	41	0.9	225	n/a	n/a	n/a	n/a	n/a
11	9	22	47	44	46.3	41.4	48	43	0.9	225	15	15	15	15	201,991
11	3	23	42	37	42.1	35.9	45	38	1.2	143	14	15	15	15	202,314
11	9	23	46	42	45.2	40.3	47	42	1.2	225	15	15	15	15	202,518
11	3	22	42	37	41.7	34.9	44	37	1.3	150	14	15	14	14	197,872
11	10	5	46	42	45.2	39.0	47	41	1.3	225	n/a	n/a	n/a	n/a	n/a
11	10	0	46	49	45.1	39.8	46	41	1.4	225	n/a	n/a	n/a	n/a	n/a
11	4	0	42	36	41.8	35.0	44	38	1.5	135	13	14	14	15	198,159
11	4	1	42	37	42.1	36.3	44	39	1.6	139	15	15	15	15	202,844
11	10	1	45	40	44.5	39.2	46	41	1.6	225	n/a	n/a	n/a	n/a	n/a
11	11	4	46	41	46.0	38.5	48	41	1.8	135	14	14	13	13	198,563
11	4	2	42	37	42.0	36.2	45	38	1.9	150	15	15	15	15	202,953
11	4	3	44	38	43.8	37.0	46	39	2.0	135	14	15	15	15	203,010
11	15	2	44	38	43.0	35.5	45	38	2.1	120	13	14	13	14	187,073
11	15	5	44	42	43.7	37.2	45	39	2.1	113	14	14	14	14	188,901
11	15	1	43	38	42.2	34.9	44	37	2.2	150	12	14	12	13	190,428
11	15	0	44	37	43.0	36.3	45	38	2.3	128	13	14	13	14	199,555
11	14	23	44	40	43.9	38.5	46	40	2.5	128	15	15	14	15	202,404
11	15	4	44	40	43.2	36.7	45	40	2.7	113	13	14	14	14	183,395
11	5	2	46	39	45.2	37.5	48	42	2.7	143	13	14	13	13	180,329
11	1	2	46	41	44.7	39.7	46	41	2.8	240	14	15	14	15	194,031
11	11	3	46	41	45.4	37.7	48	41	2.9	128	14	14	13	12	194,332
11	4	23	47	42	46.3	40.3	48	42	2.9	120	14	15	15	15	199,455
11	4	22	47	42	46.5	41.2	48	42	3.0	113	15	15	15	15	203,045
11	4	4	44	40	43.7	38.1	47	40	3.0	158	15	15	15	15	203,020
11	4	5	44	40	43.7	38.0	46	39	3.1	146	14	15	15	15	202,002
11	14	2	47	42	46.4	40.9	49	43	3.1	173	15	15	15	15	202,869
11	1	3	45	40	45.0	39.7	47	43	3.3	225	15	15	15	15	201,486
11	14	22	45	42	43.9	39.1	46	40	3.4	143	15	15	15	15	202,911
11	16	0	45	41	44.4	40.2	46	42	3.4	158	15	15	15	15	202,984
11	1	1	47	43	45.4	41.0	48	42	3.4	229	15	15	15	15	196,684
11	12	4	45	40	44.2	38.4	47	42	3.5	113	14	14	14	13	179,387
11	1	4	45	41	44.7	39.1	47	41	3.5	225	15	14	15	15	203,039
11	13	22	48	42	47.0	41.3	49	43	3.6	113	15	15	15	15	202,889
11	14	5	47	43	46.2	40.6	48	42	3.7	120	15	15	0	15	202,899
11	15	22	44	42	43.5	38.8	45	40	3.8	158	15	15	15	15	203,000
11	14	3	46	44	45.5	39.9	48	42	3.8	113	14	15	1	14	202,879
11	16	2	44	41	44.2	39.8	46	41	3.8	143	15	15	15	15	203,038
11	12	3	45	40	44.8	39.1	47	43	3.9	113	14	15	15	14	198,832
11	15	23	44	42	44.3	40.6	46	42	3.9	158	15	15	15	15	203,000
11	12	2	46	42	45.3	41.1	48	44	4.0	113	15	15	15	15	202,811
11	14	4	47	43	46.4	40.7	49	43	4.0	113	15	15	0	15	202,891
11	16	3	44	40	43.9	38.6	46	40	4.0	158	15	15	14	15	201,482
11	13	23	48	43	46.7	40.8	49	42	4.1	128	15	15	15	15	202,873
11	1	5	45	42	44.9	39.9	47	42	4.2	225	15	15	15	15	203,006
11	16	1	44	40	44.2	39.8	46	41	4.2	154	15	15	15	15	203,001
11	12	5	45	40	43.5	37.0	46	39	4.3	113	14	14	14	13	173,635
11	14	0	47	42	46.7	40.9	49	43	4.4	203	15	15	15	15	202,859
11	16	23	47	44	46.4	41.2	48	43	4.4	128	15	15	15	15	200,209
11	14	1	47	42	46.7	41.1	49	43	4.4	203	15	15	15	15	202,887
11	16	4	45	41	44.7	39.9	46	42	4.6	158	15	15	15	15	202,885
11	17	2	45	41	44.9	40.1	47	43	4.8	120	15	15	14	15	190,986
11	16	5	45	42	45.0	40.4	47	41	5.0	158	15	15	15	15	203,108
11	12	1	46	44	46.0	43.4	48	46	5.2	113	15	15	15	15	202,804
11	6	0	47	45	46.6	44.1	49	47	5.6	128	15	15	15	15	203,088
11	6	2	47	47	47.2	45.6	49	48	5.7	120	15	15	15	15	203,141
11	6	1	48	46	47.5	45.6	49	48	5.8	120	15	15	15	15	203,138
11	6	3	48	46	47.4	45.4	49	48	6.0	113	15	15	15	15	203,163
11	12	0	47	46	46.6	45.9	48	48	6.1	113	15	15	15	15	202,816
11	6	4	48	47	48.2	46.1	51	49	6.7	113	15	15	15	15	203,167
11	6	5	49	48	48.8	47.2	51	50	6.7	113	15	15	15	15	203,148
11	9	3	49	46	48.6	45.7	51	48	7.0	143	15	15	15	15	202,922
11	11	23	48	48	47.6	46.8	49	48	7.0	113	15	15	15	15	202,803
11	11	22	50	50	49.6	48.3	51	50	7.5	113	15	15	15	15	202,814

= Hours Influenced by 500 Hz Tone

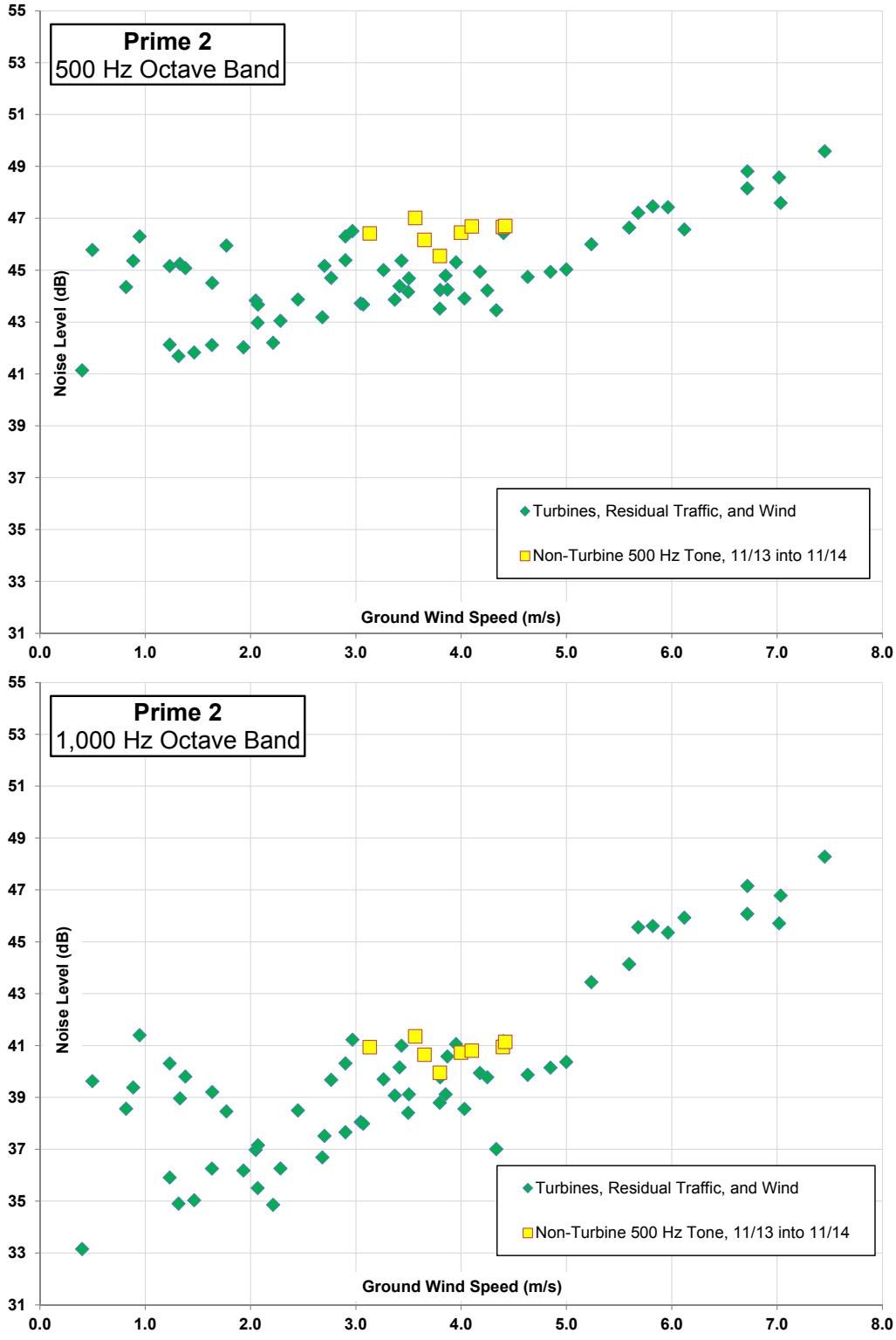

Figure 7-1: Noise Levels versus Ground Wind Speed – Prime 2

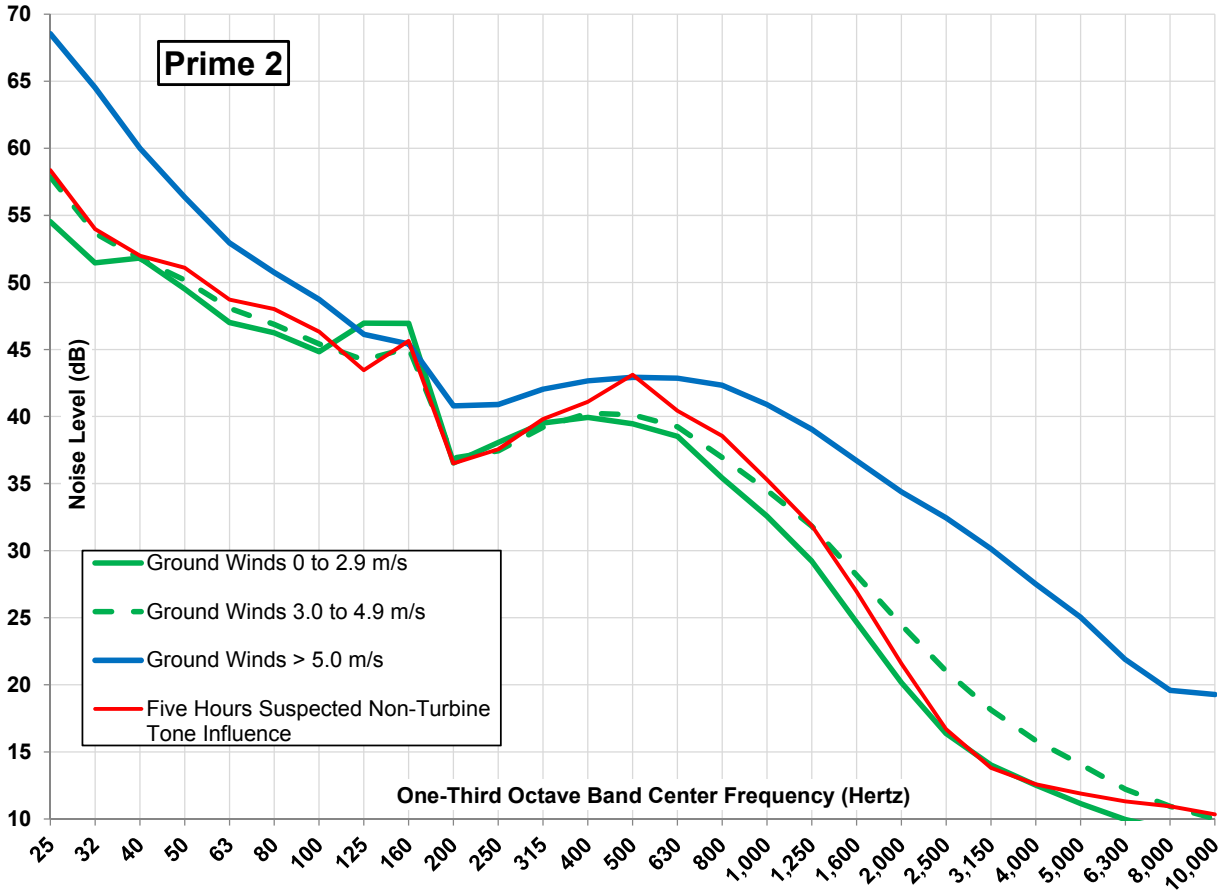

Figure 7-2: One-Third Octave Band Spectra of Turbine, Farm Related Tonal, and Wind Noise – Prime 2

7.2 Prime 2 Maximum Turbine Analysis Results

A second, alternative analysis was conducted on the measured noise levels at Prime 2 with the goal of determining the maximum turbine-only noise levels and spectral shape. That is, turbines operating at or near full capacity, and minimal interference from traffic and wind. Instead of looking at each hour, filters were applied to the entire list of "raw" 10-second measured noise levels for November 1 to 20, 2013. The filters act in a manner similar to that of the thresholds used in the primary analysis described in Section 7.1. The filters applied to the data were developed after careful review of all four months of measured data. The data were filtered to retain only the measured levels when turbine operations were maximum, ground winds were minimum, and interference from non-turbine sources was minimum. Thus, only 10-second samples meeting the following criteria were retained:

1. Turbine 75 rpm >= 14 and site power > 75%
2. 22:00 to 05:00 (nighttime only, less 06:00 hour)
3. Ground wind speed <= 3.0 m/s
4. 500 Hertz octave band noise level >= 42 and < 50 dB
    a. Levels less than 42 are not of concern because they are well below the 47 dB criterion
    b. Based on an extensive review of the data and listening to audio files, levels above 50 dB are non-turbine
5. 1,000 Hertz octave band noise level <= 43 dB
    a. The 1,000 Hz octave band is the most difficult band to analyze, and the most likely to contain non-turbine noise. This is because the turbines produce less energy in this band compared to 500 Hz, and because traffic and wind have relatively strong contributions. In general, this study has found turbine noise to be less than 39 dB in the 1,000 Hz band, thus the 43 dB limit used here is conservative, and greatly helps to minimize non-turbine noise.
6. 500 Hz octave band level minus 1,000 Hz level >= 1 dB
    a. Analyses of data on this and other turbine projects show that turbine noise levels roll off relatively steeply above 500 Hz on an octave band basis. When the spectrum does not roll of above 500 Hz, measured levels are not turbine-only and likely contain significant contributions from wind or traffic.

The energy average of all 10-second data meeting the above criteria was calculated, and the resulting spectrum is shown in Figure 7-3 in comparison to the primary analysis results. The results are remarkably similar, despite being arrived at in a completely different manner. The 500 Hz octave band level of the resulting spectrum is 45 dB, and the 1,000 Hz band level is 39 dB.

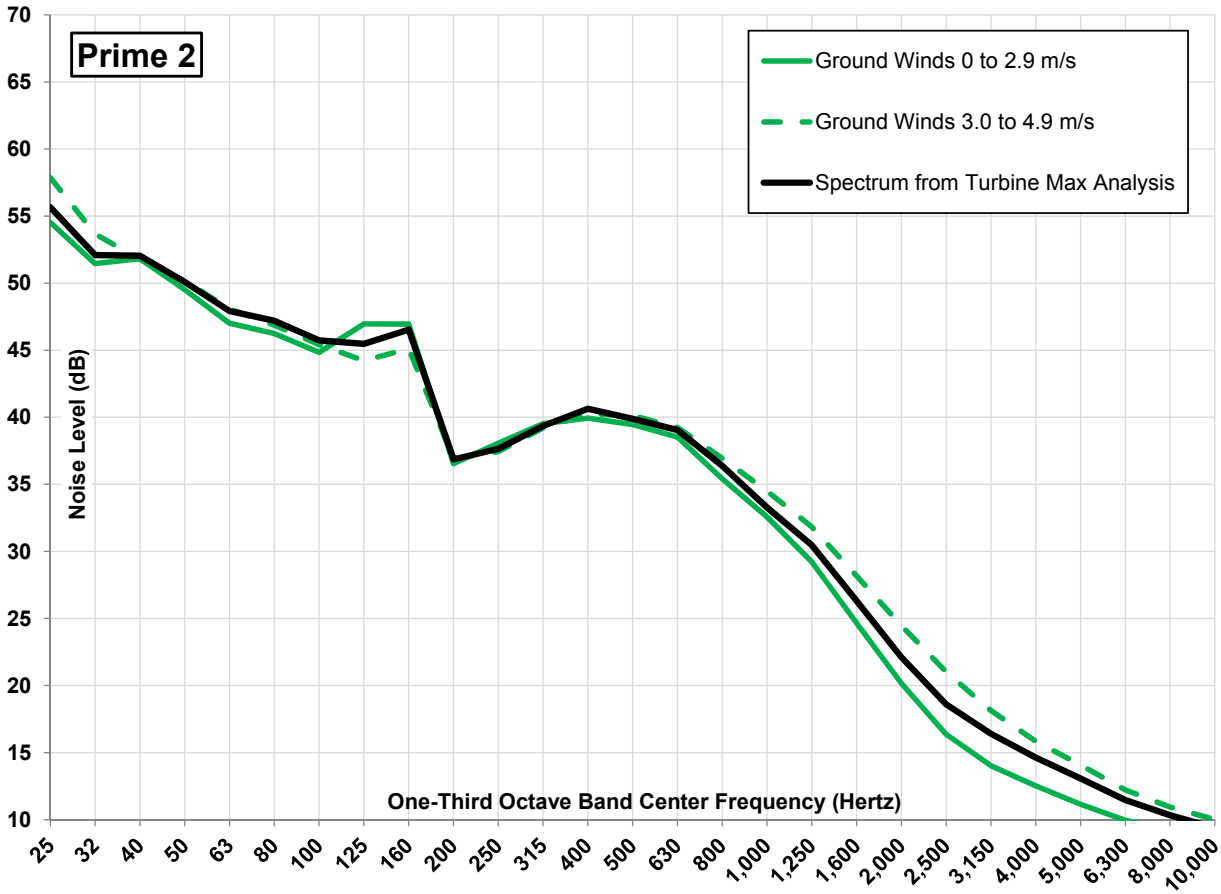

Figure 7-3: Maximum Turbine-Only One Third Octave Band Spectra – Prime 2

7.3 Prime 1 Results

Table 7-2 lists all of the hourly-average noise levels measured at Prime 1 when the nearest turbine (No. 57) was turning at a rate of 14 rpm or greater, and the site power was 75% or greater. The Prime 1 data were analyzed as follows:

1. As discussed above for the Prime 2 data, the measurement of turbine-only noise levels is not possible when the ground winds are 5 m/s or greater. ASA/ANSI S12.9 Part 3 limits noise measurements to wind speeds that are less than 5 m/s, and the IPCB limits measurements to wind speeds that are less than 12 mph (5 m/s is equal to 11 mph). Unfortunately, we did not have an anemometer at Prime 1, and we suspect that there are wind speed differences between the Prime 2 location, which is somewhat sheltered by mature trees and houses and terrain, and the fully-exposed Prime 1 location.

   However, there is a reliable way to determine when wind noise was dominant at Prime 1. It is well known that wind pseudo-noise is a low frequency phenomenon that increases with wind speed. In Figure 7-4 we have plotted the 25 Hz one third octave band level measured at Prime 2 versus the ground wind speed measured at Prime 2, and we find that it correlates very well with actual ground wind speed. We found for Prime 2 that the 25 Hz level is approximately 65 dB when the wind speed is 5 m/s.

   Because we had no anemometer at Prime 1, we sorted the Prime 1 data on the basis of its 25 Hz one-third octave band. The resulting regression plots for the 500 Hz and 1,000 Hz octave bands are shown in Figure 7-5. None of the resulting levels measured when the 25 Hz level is less than 65 dB (i.e. wind speed less than 5 m/s) exceed the IPCB limits, with the exception of the night when harvest noise is suspected as discussed below. In fact, we find that the 25 Hz level can reach 70 dB before wind noise completely dominates the measured level at Prime 1 (vs 65 dB at Prime 2). Even so, none of the resulting turbine-only noise levels measured when the 25 Hz level is less than 70 dB exceed the IPCB limits either.

2. As with Prime 2, noise levels at Prime 1 on the night of November 13 into 14, 2013 have a distinct "tone" in the 500 Hz one-third octave band, which in turn affects primarily the 500 Hz one-third octave band level. The average one-third octave band frequency spectra for these hours is shown in Figure 7-6, along with the average spectra for various wind conditions. Again, this "tone" is not thought to be turbine related as discussed above. Three of the hours have a 500 Hz level 0.1 dB above the limit, and none of the 1,000 Hz levels for these hours exceed the limits at Prime 1.

Table 7-2: Prime 1 Measured and Analyzed Noise Levels

Month	Day	Hour	Noise Levels with All Sources		Noise Levels without Vehicles		Thresholds		Turbine 57	Turbine 75	Turbine 56	Turbine 76	Site Power
			500 Hz	*1,000 Hz*	*500 Hz*	*1,000 Hz*	*500 Hz*	*1,000 Hz*	*(rpm)*	*(rpm)*	*(rpm)*	*(rpm)*	(megawatt)
11	3	22	43	38	42.1	34.3	45	38	14	15	14	14	197,872
11	11	3	46	40	44.5	36.1	47	40	14	14	13	12	194,332
11	11	4	46	39	44.7	36.0	47	39	14	14	13	13	198,563
11	15	5	44	39	42.6	34.3	45	36	14	14	14	14	188,901
11	4	5	46	42	45.4	38.1	47	40	14	15	15	15	202,002
11	3	23	43	38	42.9	35.5	45	38	14	15	15	15	202,314
11	15	22	45	42	42.7	37.8	44	39	15	15	15	15	203,000
11	16	3	45	40	43.2	37.3	45	39	15	15	14	15	201,482
11	14	3	48	42	46.3	38.9	49	42	14	15	1	14	202,879
11	4	3	46	40	45.3	37.2	47	40	14	15	15	15	203,010
11	4	23	46	39	44.2	36.6	46	39	14	15	15	15	199,455
11	4	2	44	39	43.7	36.5	46	39	15	15	15	15	202,953
11	4	22	45	40	44.7	38.4	46	40	15	15	15	15	203,045
11	14	23	43	38	42.8	36.2	45	38	15	15	14	15	202,404
11	4	1	44	38	43.5	36.9	46	40	15	15	15	15	202,844
11	14	22	45	40	43.0	37.2	45	39	15	15	15	15	202,911
11	13	22	48	42	47.2	40.9	50	44	15	15	15	15	202,889
11	4	4	47	42	45.5	38.4	47	40	15	15	15	15	203,020
11	10	5	43	38	42.6	35.9	45	38	n/a	n/a	n/a	n/a	n/a
11	9	22	45	42	44.6	39.5	46	41	15	15	15	15	201,991
11	14	4	48	42	46.2	39.5	49	42	15	15	0	15	202,891
11	14	0	48	42	47.6	40.3	50	42	15	15	15	15	202,859
11	16	2	44	40	43.4	38.4	45	40	15	15	15	15	203,038
11	14	2	48	41	47.6	40.0	50	42	15	15	15	15	202,869
11	16	1	43	39	43.2	38.1	45	40	15	15	15	15	203,001
11	13	23	48	42	47.0	40.3	49	43	15	15	15	15	202,873
11	14	5	47	42	45.8	39.1	48	41	15	15	0	15	202,899
11	10	4	44	38	43.4	36.9	46	39	n/a	n/a	n/a	n/a	n/a
11	16	4	44	40	43.4	37.9	45	40	15	15	15	15	202,885
11	16	0	44	40	43.2	38.2	45	40	15	15	15	15	202,984
11	1	3	46	41	45.1	39.8	48	43	15	15	15	15	201,486
11	17	2	43	38	42.5	36.8	45	39	15	15	14	15	190,986
11	14	1	48	41	47.6	40.1	50	42	15	15	15	15	202,887
11	10	3	43	38	42.9	36.7	45	39	n/a	n/a	n/a	n/a	n/a
11	16	23	45	41	44.2	38.7	47	41	15	15	15	15	200,209
11	10	1	43	37	42.9	36.5	45	39	n/a	n/a	n/a	n/a	n/a
11	10	0	44	44	43.3	37.1	46	39	n/a	n/a	n/a	n/a	n/a
11	1	4	46	41	45.3	40.1	47	43	15	14	15	15	203,039
11	9	23	44	39	43.6	38.0	46	40	15	15	15	15	202,518
11	15	23	43	40	43.1	38.7	45	40	15	15	15	15	203,000
11	10	2	44	37	42.8	35.9	45	38	n/a	n/a	n/a	n/a	n/a
11	16	5	44	41	43.7	38.7	45	40	15	15	15	15	203,108
11	1	2	46	40	45.1	39.3	47	42	14	15	14	15	194,031
11	6	0	45	43	44.8	41.3	47	43	15	15	15	15	203,088
11	5	23	45	42	44.5	41.3	47	44	14	12	14	15	168,044
11	7	2	45	38	44.6	37.6	47	41	14	15	15	15	202,360
11	1	5	48	44	46.8	43.5	50	46	15	15	15	15	203,006
11	6	23	45	39	44.7	38.7	47	41	15	15	15	15	202,927
11	6	1	46	45	46.1	44.0	48	47	15	15	15	15	203,138
11	6	2	46	45	45.7	43.6	48	47	15	15	15	15	203,141
11	6	3	47	44	46.0	43.7	48	47	15	15	15	15	203,163
11	12	5	46	41	45.7	39.2	48	42	14	14	14	13	173,635
11	6	22	45	41	44.4	38.8	47	42	15	15	15	15	202,939
11	1	1	48	44	47.3	42.9	50	46	15	15	15	15	196,684
11	12	4	46	40	45.8	39.5	48	44	14	14	14	13	179,387
11	12	3	47	41	46.6	40.2	49	43	14	15	15	14	198,832
11	6	4	47	45	46.6	44.0	49	47	15	15	15	15	203,167
11	9	3	49	44	47.4	42.8	49	45	15	15	15	15	202,922
11	7	1	46	40	45.4	39.6	48	43	14	15	15	15	200,210
11	6	5	48	46	47.4	45.6	50	48	15	15	15	15	203,148
11	11	22	49	46	48.8	46.3	51	49	15	15	15	15	202,814
11	12	2	47	43	47.0	43.1	49	46	15	15	15	15	202,811
11	12	1	48	46	47.6	44.8	50	47	15	15	15	15	202,804
11	11	23	49	46	48.4	46.1	50	48	15	15	15	15	202,803
11	12	0	48	46	48.3	46.0	50	49	15	15	15	15	202,816

= Hours Influenced by 500 Hz Tone

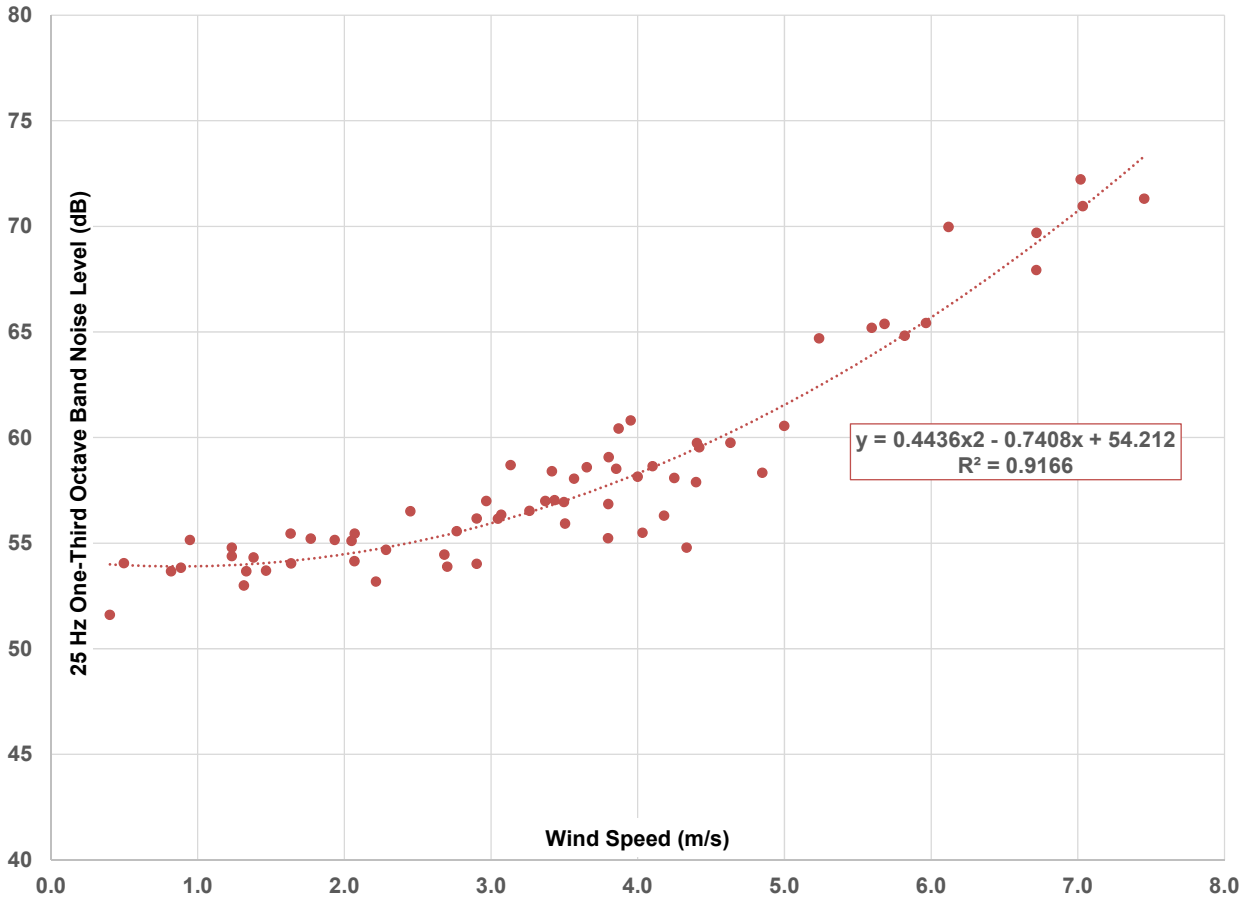

Figure 7-4: Ground Wind Speed versus 25 Hz One-third Octave Band Noise Level – Prime 2

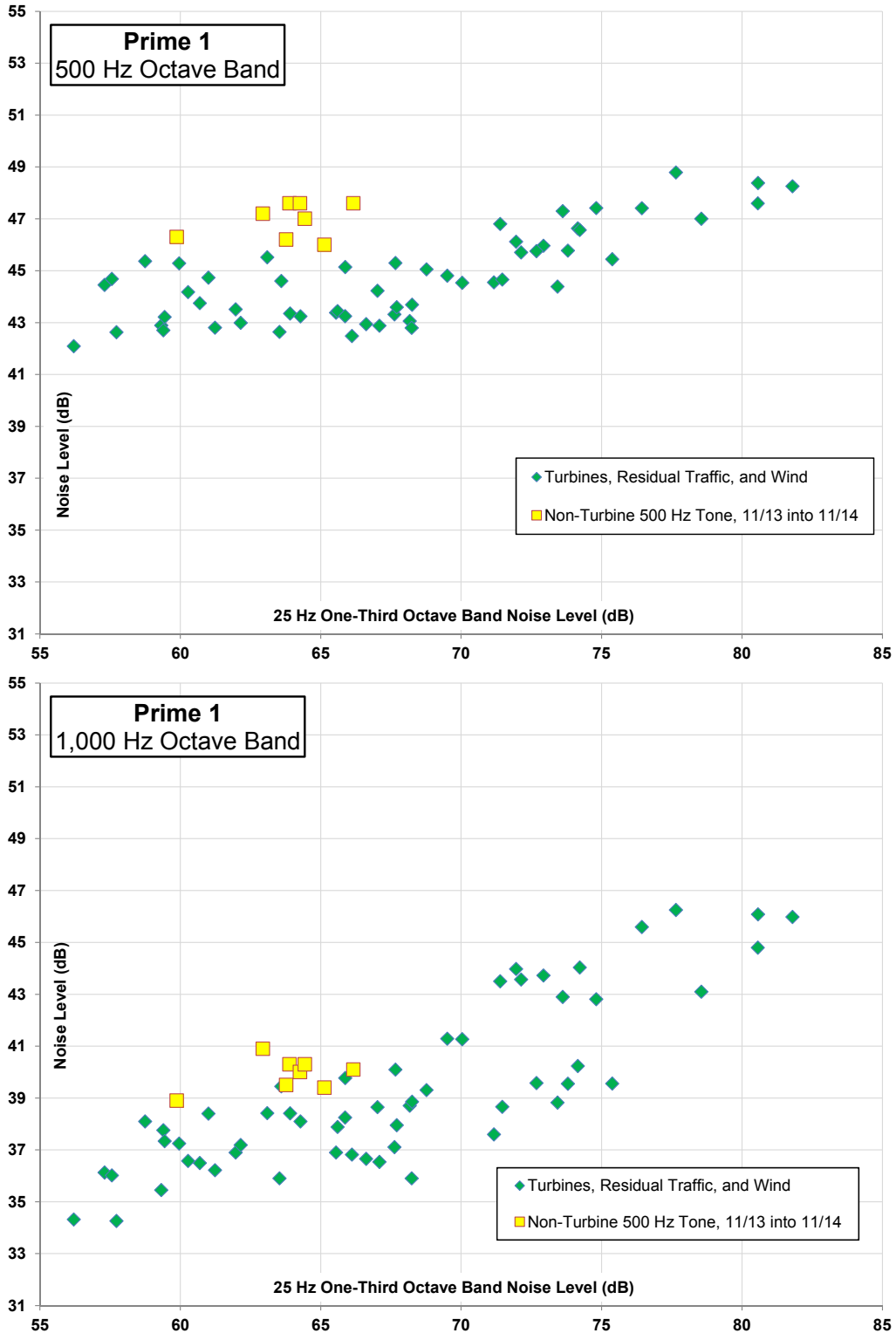

Figure 7-5: Noise Level versus 25 Hz One-Third Octave Band Level (wind speed surrogate) – Prime 1

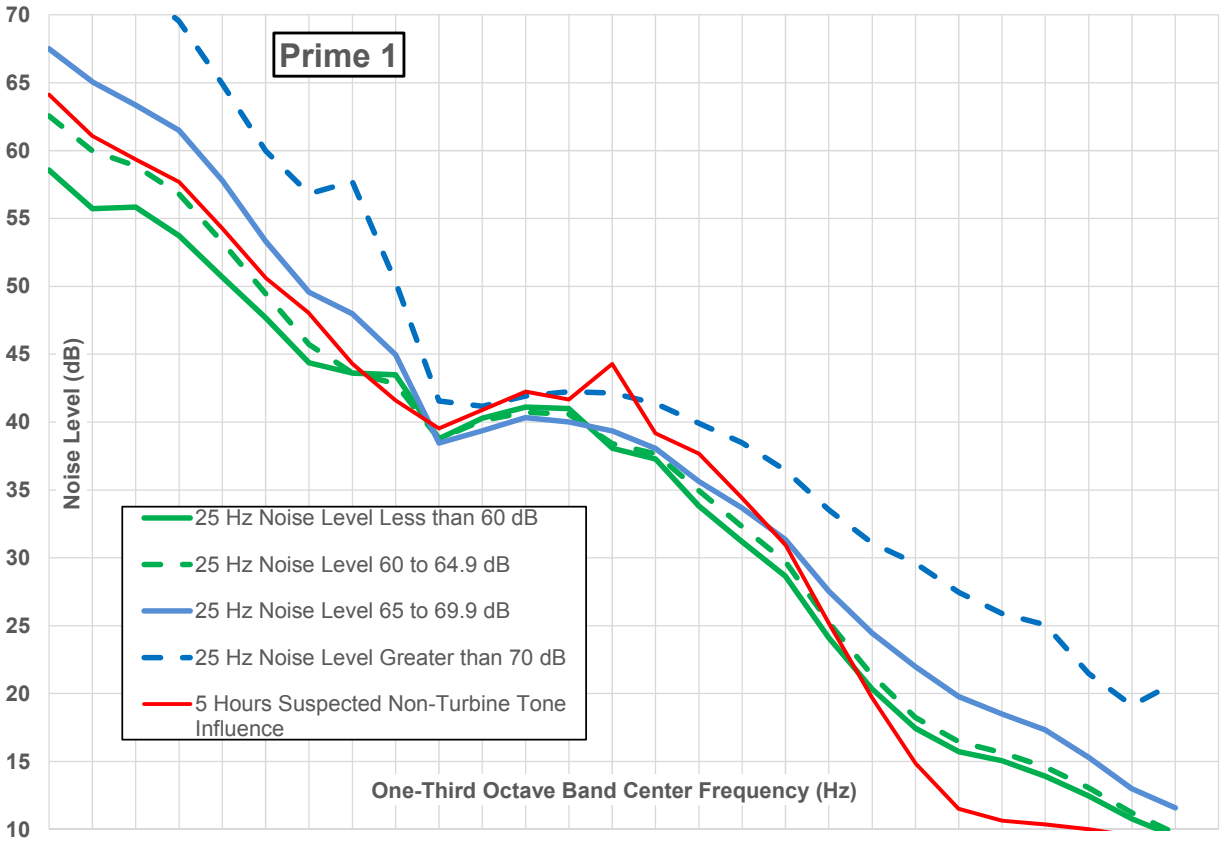

Figure 7-6: One-Third Octave Band Spectra of Turbine, Harvest, and Wind Noise – Prime 1

7.4 Prime 1 Maximum Turbine Analysis Results

As described above for Prime 2, an alternative analysis was conducted on the measured noise levels at Prime 1 with the goal of determining the maximum turbine-only noise levels and spectral shape. The only differences in the analysis for Prime 1 versus that described for Prime 2 is that (a) Turbine 57 was used to determine rpm, as it is the closest turbine to Prime 1, and (b) a 25 Hz one-third octave band level of 70 dB was used as a cut-off for high wind. The energy average of all remaining 10-second spectrum was calculated, and is shown in comparison of the hourly analysis results in Figure 7-7. The results are remarkably similar, despite being arrived at in a completely different manner. The 500 Hz octave band level of the resulting spectrum is 45 dB, and the 1,000 Hz band level is 39 dB.

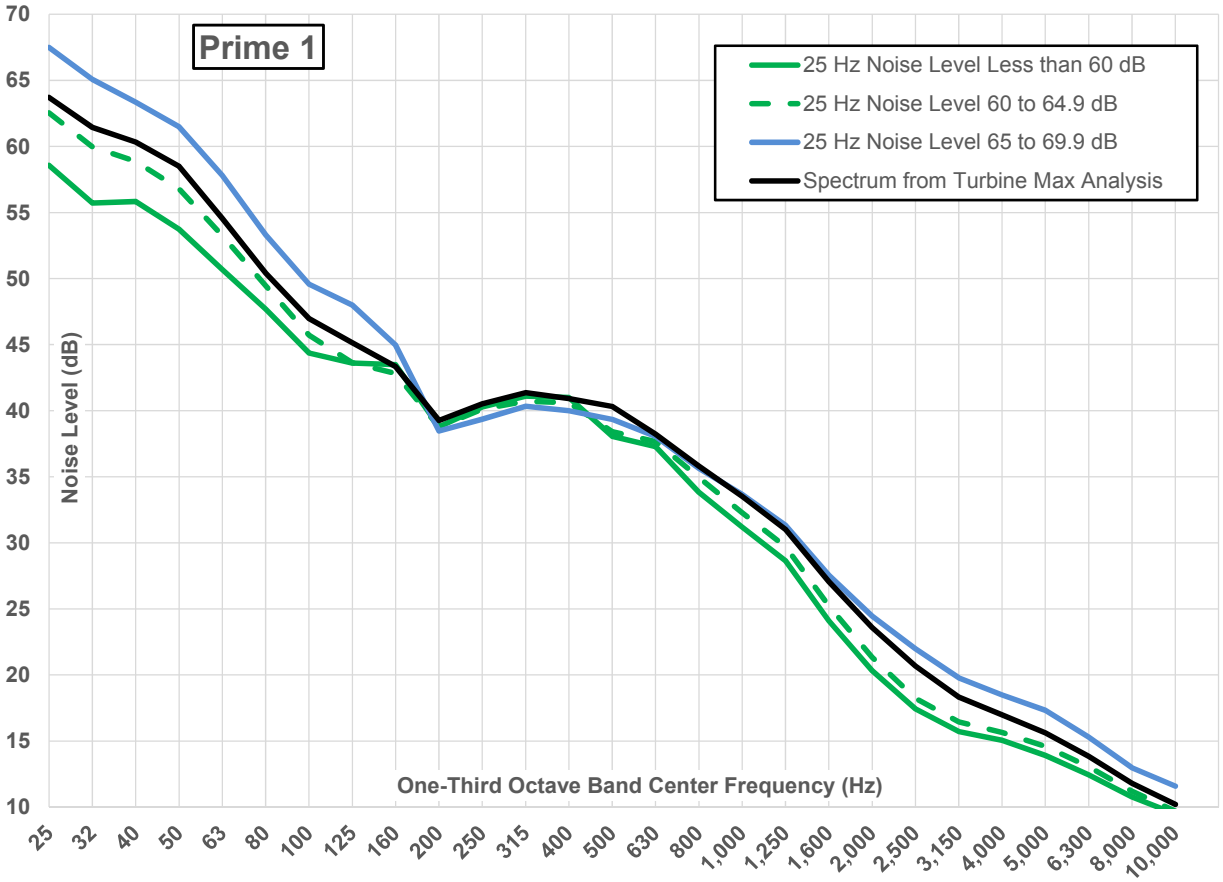

Figure 7-7: Turbine Maximum One-Third Octave Band Spectra – Prime 1

7.5 Analysis of Octave Band Levels

Tables 7-3 and 7-4 show all of the octave band levels measured at Prime 1 and Prime 2, respectively, after having been analyzed for traffic noise. The line in Table 7-3 represents where the 70 dB wind cut-off lies. Above the line winds are considered to be less than 5 m/s. The line in Table 7-4 represents 5 m/s as measured at Prime 2. With the exception of the 31 Hz band, none of the levels measured with the winds less than 5 m/s exceed their respective limits. As for the 31 Hz octave band exceedance, this is expected given our cut-off of 70 dB in the 25 Hz one third octave band. These exceedances at 31 Hz are clearly the result of wind, not turbines.

7.6 Comparison to Complaint Times

During the measurement survey the two subject residents emailed complaints to CRWE about turbine noise. Table 7-5 lists the date and hour of each complaint, and the corresponding turbine operations and noise levels. Overall, the complaints match up very well with near maximum turbine operations, particularly from late-September through November. In mid-September the residents correctly observed that noise was coming from single turbines, primarily Turbines 56 and 76. The complaints in August and early September took place during relatively low turbine operations, but that is because there were no periods of high turbine operations at all during this timeframe.

A review of complaints dating from May 2013 until early August 2013 was also conducted. This timeframe is prior to the noise study. Table 7-6 lists the date and hour of each complaint and the corresponding turbine operations. Again, overall the complaints match up very well with maximum or near maximum turbine operations. Approximately 75% of the time the complaints occurred during maximum or near maximum operations, and operations were at least moderate the other 25% of the time.

Table 7-3: Octave Band Sound Levels Measured at Prime 1

Octave Band Sound Levels								
31.5 (dB)	63 (dB)	125 (dB)	250 (dB)	500 (dB)	1000 (dB)	2000 (dB)	4000 (dB)	8000 (dB)
59	53	49	43	42	34	24	18	15
60	56	48	46	44	36	25	15	14
60	55	48	46	45	36	24	15	14
61	56	48	45	43	34	22	13	14
63	57	50	44	45	38	29	25	19
63	57	49	44	43	35	25	20	16
62	56	47	45	43	38	28	16	14
62	56	49	45	43	37	27	17	14
62	56	47	45	46	39	25	14	14
64	58	50	44	45	37	27	23	18
63	57	49	47	44	37	27	19	16
64	57	49	43	44	36	27	22	18
64	58	48	46	45	38	28	20	16
64	58	47	45	43	36	24	14	14
65	59	48	44	44	37	27	23	18
65	59	48	45	43	37	25	15	14
66	59	52	46	47	41	27	15	14
66	59	49	44	46	38	29	26	20
66	60	52	42	43	36	24	16	15
67	60	50	44	45	39	27	17	15
66	59	48	45	46	40	26	15	14
67	60	51	46	48	40	27	15	14
67	59	48	45	43	38	29	18	14
67	60	50	46	48	40	27	16	14
67	60	48	45	43	38	28	17	14
67	60	50	46	47	40	27	16	14
68	61	51	46	46	39	27	16	14
69	62	51	42	43	37	25	18	15
68	61	49	45	43	38	29	18	15
69	61	50	45	43	38	29	18	15
69	63	52	44	45	40	31	24	18
69	63	50	44	42	37	28	18	14
69	62	51	46	48	40	27	17	15
70	63	53	42	43	37	25	18	15
70	64	52	45	44	39	30	21	16
70	63	53	41	43	37	26	20	16
71	64	53	43	43	37	26	19	16
71	65	54	45	45	40	32	25	19
71	64	53	42	44	38	28	20	16
71	63	51	44	43	39	29	19	16
71	64	54	41	43	36	25	20	16
71	63	51	46	44	39	30	20	16
72	67	57	45	45	39	31	24	19
72	64	52	45	45	41	35	30	24
72	64	53	46	45	41	35	31	25
75	67	55	42	45	38	27	22	18
74	68	57	46	47	43	37	30	24
75	69	55	42	45	39	28	21	17
74	66	55	47	46	44	37	32	26
75	68	55	46	46	44	37	32	26
76	68	56	46	46	44	37	32	26
76	69	57	44	46	39	27	20	18
77	71	59	42	44	39	30	23	19
77	70	62	47	47	43	36	30	24
77	70	58	44	46	40	28	22	19
78	70	58	45	47	40	28	22	19
77	70	57	47	47	44	38	32	25
77	68	57	49	47	43	37	32	25
79	73	59	43	45	40	31	26	22
79	71	59	48	47	46	40	34	27
80	69	63	48	49	46	40	35	28
82	74	63	46	47	43	34	29	26
84	75	65	47	48	45	37	33	28
83	74	65	48	48	46	40	35	29
85	76	67	48	48	46	40	35	30

Table 7-4: Octave Band Sound Levels Measured at Prime 2

Octave Band Sound Levels								
31.5	63	125	250	500	1000	2000	4000	8000
(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)
54	51	53	41	41	33	21	12	13
57	51	50	45	46	40	27	15	13
56	51	50	44	44	39	26	17	13
56	51	50	45	45	39	26	15	13
57	52	47	45	47	43	33	18	14
58	52	50	40	42	36	26	19	15
57	52	47	44	45	40	29	18	13
55	50	51	39	42	35	24	17	14
57	51	53	45	45	39	26	14	13
57	51	48	44	45	40	28	17	13
57	52	52	41	42	35	25	18	14
58	52	49	40	42	36	27	21	16
56	51	51	44	45	39	27	17	13
58	53	51	45	46	38	26	15	13
58	52	49	40	42	36	27	21	16
59	53	52	41	44	37	27	22	16
58	53	53	43	43	36	23	13	13
59	54	52	42	44	37	26	14	13
57	52	52	42	42	35	22	14	14
58	54	52	43	43	36	24	13	13
60	55	50	43	44	39	27	17	15
58	54	52	42	43	37	25	14	13
57	53	54	44	45	38	26	18	14
58	53	50	43	45	40	30	22	16
57	53	51	44	45	38	26	15	13
59	55	51	44	46	40	29	18	15
60	55	50	44	47	41	30	21	16
59	54	50	41	44	38	30	25	19
59	53	51	41	44	38	29	24	18
61	54	50	43	46	41	29	18	16
59	54	50	43	45	40	30	22	15
60	55	50	43	44	39	28	18	16
60	53	49	41	44	40	32	19	15
60	54	51	43	45	41	32	25	18
59	51	49	45	44	38	26	16	14
59	54	50	42	45	39	29	22	16
60	55	51	44	47	41	29	18	16
60	54	50	43	46	41	28	17	15
58	53	49	40	44	39	30	17	14
59	53	49	42	46	40	27	15	14
61	52	49	41	44	40	31	20	16
60	53	49	45	45	39	27	17	14
62	53	49	41	44	41	32	21	16
62	53	48	45	45	41	30	20	15
60	53	49	42	46	41	28	17	15
58	53	51	41	44	39	29	18	14
61	55	50	43	47	41	28	18	16
59	55	50	43	45	40	31	24	17
60	52	49	41	44	40	31	19	15
57	51	49	44	43	37	24	14	13
60	55	51	43	47	41	28	17	15
62	54	51	45	46	41	32	22	15
61	55	51	43	47	41	29	19	17
61	52	49	42	45	40	31	21	16
60	52	49	42	45	40	31	19	14
62	52	49	42	45	40	32	21	17
66	55	48	45	46	43	35	25	17
67	57	51	44	47	44	38	32	26
67	57	51	45	47	46	39	33	27
67	57	52	45	47	46	39	33	27
67	58	52	45	47	45	39	33	27
72	59	51	46	47	46	40	32	22
70	60	53	47	48	46	41	34	25
72	61	54	47	49	47	42	36	27
74	61	53	48	49	46	38	32	27
73	60	51	47	48	47	41	33	23
73	61	52	48	50	48	42	34	26

Table 7-5: Analysis of Complaint Times During Noise Study

Date and Hour of Complaint	Turbine 57 Speed (rpm)	Turbine 75 Speed (rpm)	Site Power (% full)	P2 500 Hz Noise Level (dB)	P2 1k Hz Noise Level (dB)	Notes
8/24/2013 6:55	13	12	68	36	33	Relatively low turbine operations
8/26/2013 4:00	14	0	76	38	29	Relatively low turbine operations
8/27/2013 7:00	8	13	50	41	36	Relatively low turbine operations
8/28/2013 3:00	0	15	77	43	33	Moderate turbine operations
9/2/2013 6:50	11	12	48	37	30	Relatively low turbine operations
9/7/2013 4:00	0	0	40	31	23	Turbine 56 only was on, as noted by resident
9/19/2013 0:00	0	0	48	37	28	Turbine 56 only was on, as noted by resident
9/19/2013 23:00	15	15	99	46	41	Near maximum turbine operations
9/22/2013 23:00	0	0	37	36	30	Turbine 76 only was on, as noted by resident
9/24/2013 1:00	14	15	69	38	31	Moderate turbine operations
9/28/2013 23:00	14	14	75	44	38	Near maximum turbine operations
10/26/2013 20:00	13	13	81	40	33	Moderate turbine operations
10/30/2013 21:00	15	15	99	47	43	Ground wind 8 m/s
10/31/2013 21:00	13	12	71	42	36	Moderate turbine operations
11/1/2013 21:00	13	13	70	43	37	Moderate turbine operations
11/4/2013 5:00	14	15	99	44	38	Near maximum turbine operations
11/4/2013 21:00	15	15	99	46.5	41.2	Near maximum turbine operations
11/4/2013 22:00	15	15	99	46.5	41.2	Near maximum turbine operations
11/7/2013 17:00	15	15	99	---	---	No noise data at Prime 2
11/8/2013 0:00	13	14	86	---	---	No noise data at Prime 2
11/9/2013 3:00	15	15	99	49	45	Ground wind 7 m/s
11/9/2013 22:00	15	15	99	46.9	41.8	Hour noted in Section 7.1
11/15/2013 4:00	13	14	89	43	37	Near maximum turbine operations

Table 7-6: Comparison of Complaint Times Prior to Noise Study

Date and Hour of Complaint	Turbine 57 Speed (rpm)	Turbine 75 Speed (rpm)	Site Power (% full)	Notes
5/9/2013 21:00	15	15	87	Near maximum turbine operations
5/11/2013 23:00	15	15	98	Near maximum turbine operations
5/12/2013 2:00	14	15	94	Near maximum turbine operations
5/19/2013 23:00	15	15	99	Near maximum turbine operations
5/20/2013 22:00	15	15	95	Near maximum turbine operations
5/23/2013 2:00	10	13	53	Moderate turbine operations
5/26/2013 23:00	15	15	99	Near maximum turbine operations
5/27/2013 3:00	13	13	70	Moderate turbine operations
5/27/2013 4:00	14	14	96	Near maximum turbine operations
5/27/2013 5:00	14	13	85	Near maximum turbine operations
5/27/2013 6:00	15	15	96	Near maximum turbine operations
6/16/2013 4:00	12	13	80	Moderate turbine operations
6/19/2013 1:00	12	11	49	Moderate turbine operations
6/19/2013 23:00	12	11	63	Moderate turbine operations
6/21/2013 1:00	14	14	84	Near maximum turbine operations
6/24/2013 23:00	14	14	84	Near maximum turbine operations
6/25/2013 0:00	14	14	81	Near maximum turbine operations
6/25/2013 22:00	12	12	77	Moderate turbine operations
6/25/2013 23:00	14	13	89	Near maximum turbine operations
6/26/2013 5:00	14	14	90	Near maximum turbine operations
7/1/2013 23:00	13	12	85	Near maximum turbine operations
8/2/2013 7:00	11	13	85	Near maximum turbine operations

8. Measurement and Analysis Uncertainty

Uncertainty is present in any measurement and analysis procedure. Every measurement has an expected tolerance and uncertainty. The uncertainty arises from a variety of sources. First, the source itself may vary with time, even if it is restricted to its maximum noise configuration. For example, we can expect a wind turbine to vary with wind direction even though it is producing full power. Also the propagation of sound from a source to a receiver depends on, among other factors, meteorological conditions and ground cover. We formulated an estimate of the measurement variability by computing the standard deviation to the measured levels at Prime 2 for wind speeds less than or equal to 3 m/s from the data in Table 7-1. This turns out to be 28 data points. The same was done with the measured levels at Prime 1 by taking the 28 data points that have the lowest level in the 25 Hz one third octave band. These data, their mean and standard deviation are given in Table 8-1.

Table 8-1: Calculation of Uncertainty of Measured Noise Levels

Prime 1			Prime 2		
Levels without traffic & trains		**Level in 25 Hz 1/3 octave band**	**Levels without traffic & trains**		**Wind Speed**
500	**1000**	dB	**500**	**1000**	**(m/s)**
42.1	34.3	56.2	41.1	33.2	0.4
44.5	36.1	57.3	45.8	39.6	0.5
44.7	36.0	57.6	44.4	38.6	0.8
42.6	34.3	57.7	45.4	39.4	0.9
45.4	38.1	58.7	46.3	41.4	0.9
42.9	35.5	59.3	42.1	35.9	1.2
42.7	37.8	59.4	45.2	40.3	1.2
43.2	37.3	59.4	41.7	34.9	1.3
45.3	37.2	60.0	45.2	39.0	1.3
44.2	36.6	60.3	45.1	39.8	1.4
43.7	36.5	60.7	41.8	35.0	1.5
44.7	38.4	61.0	42.1	36.3	1.6
42.8	36.2	61.2	44.5	39.2	1.6
43.5	36.9	62.0	46.0	38.5	1.8
43.0	37.2	62.9	42.0	36.2	1.9
45.5	38.4	63.1	43.8	37.0	2.0
42.6	35.9	63.5	43.0	35.5	2.1
44.6	39.5	63.6	43.7	37.4	2.1
43.4	38.4	63.9	42.2	34.9	2.2
43.2	38.1	64.3	43.0	36.3	2.3
43.4	36.9	65.5	43.9	38.5	2.5
43.4	37.9	65.6	43.2	36.7	2.7
43.2	38.2	65.9	45.2	37.5	2.7
45.1	39.8	65.9	44.7	39.7	2.8
42.5	36.8	66.1	45.4	37.7	2.9
42.9	36.7	66.6	46.3	40.3	2.9
44.2	38.7	67.0	46.5	41.2	3.0
42.9	36.5	67.1	43.7	38.1	3.0
43.7	37.1	**Mean**	44.0	37.8	
1.0	1.3	**Standard Deviation**	1.6	2.1	

Site and measurement factors can also lead to uncertainty. These include specific site factors such as a reflecting surface, microphone height, specific microphone placement, and other parameters affected by the person doing the measurements. Site variability is not well researched but is at least 1 dB. A third category of uncertainty is that related to the sound level meter. The standard deviation to the meter measurement is given in various sources as about 0.5 to almost 1 dB.

Table 8-2 lists the average of the Prime 1 and Prime 2 standard deviations separately for 500 and 1,000 Hz octave bands. This table also includes 1 dB for the measurement site standard deviation and 0.5 dB for the measurement meter uncertainty. Since these three factors are independent, the joint standard deviation is given as the square root of the sum of the squares of the individual standard deviations. These are also included in Table 8-2. Finally, in accordance with ISO Acoustical Standards practice, the expanded uncertainty of 95 percent confidence is given by 2 times the joint standard deviation (2 sigma). So the expanded uncertainty is 3.5 dB at 500 Hz and 4.2 dB at 1,000 Hz, or about 4 dB overall.

An expanded uncertainty of 4 dB means that if investigators A and B both go out separately on two separate days, each with their own different instruments, we are 95 percent confident that their two one-hour measurements, if they attempt to hold everything constant, will be within 4 dB of one another and that each will be within 4 dB of the true value. For the measurements herein, the sites are fixed and the basic meters are fixed so the only variation from day to day is the calibration change which typically is one tenth to a few tenths of a dB. That is, for example, with a 4 dB expanded uncertainty one can be 95% certain that a measured level of 47 dB, for example, is between 43 and 51 dB.

Table 8-2: Calculation of Uncertainty of Measured Noise Levels

Octave Band (Hz)	Average Prime 1 and Prime 2 Sigma	Equipment Position Height Technique Sigma	Measuring Instrument Sigma	Joint Sigma	95% prediction interval 2*sigma
500	1.3	1	0.5	1.7	3.5
1000	1.8	1	0.5	2.1	4.2

NOTES:

1. Sigmas all in dB
2. Joint sigma = square root of the sum of the squares of the 3 indivdual sigmas

9. Conclusions

1. Noise levels were analyzed in November 2013, during which time turbine operations were greater than any other month of the study.

2. The analysis considered only nighttime hours, less the 06:00 hour due to the inability to adequately separate traffic noise at this hour because of the numerous vehicles on Highway 49. Turbine noise levels during the daytime are lower due to less stable atmospheric conditions, and the limits during the daytime are 5 dB higher than at night.

3. The analysis also only considered the hours when turbine operations were at or near full capacity, defined herein as a turbine speed of 14 rpm or greater and a site power of greater than 75% of full capacity. At other times turbine noise levels will be lower, and the relative interference from background sources higher making an analysis of turbine-only noise levels all the more difficult.

4. Finally, the analysis considered noise levels measured when the local ground wind speed is above 5 m/s to be dominated by the sound of wind blowing over the microphone and/or through vegetation, and not representative of turbine-only noise levels, nor can the two sources be separated at these wind speeds. This is consistent with ANSI noise measurement standards and U.S. EPA guidelines.

5. At location Prime 2, which is located similar distances to the nearest turbines as are the subject residences, no turbine-only noise levels exceed the IPCB limits. For one hour, noise levels in the 1,000 Hz octave band were 0.1 dB below the limit, but this was during an hour when there was significant traffic present and this one hour likely exceeded the capability of our conservative traffic noise elimination procedure.

6. At location Prime 1, which is located about 100 feet closer to the nearest turbines than are the subject residences, no turbine-only noise levels exceed the IPCB limits. There was one night when noise levels in the 500 Hz octave band exceeded the limit by 0.2 dB for three hours, but this is thought to contain a significant contribution from harvest noise.

7. In summary, no turbine-only noise levels exceed the IPCB limits, and the average of the turbine-only noise levels measured when turbine operations were at or near maximum ($\geq$14 rpm, >75 % power) are 45 dB in the 500 Hz octave band and 39 dB in the 1,000 Hz octave band. These levels are 2 dB below the limits of 47 dB and 41 dB, respectively.

Appendix A - Wind Turbine Information

GE Energy

– Original Instructions –

Technical Documentation
Wind Turbine Generator Systems
1.6-100 - 50 Hz and 60 Hz

Product Acoustic Specifications

Normal Operation according to IEC
Incl. Octave Band Spectra

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1 Introduction

This document summarizes the acoustic emission characteristics of 1.6-100 wind turbine for normal operation, including calculated apparent sound power levels $L_{WA,k}$, as well as uncertainty levels associated with the apparent sound power levels, tonal audibility, and calculated third octave band apparent sound power level.

All provided sound power levels are A-weighted.

GE continuously verifies specifications with measurements, including those performed by independent institutes. If a wind turbine noise performance test is carried out, it needs to be done in accordance with the regulations of the international standard IEC 61400-11, ed. 2.1: 2006 and Machine Noise Performance Test document.

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2 Normal Operation Calculated Apparent Sound Power Level

The apparent sound power levels $L_{WA,k}$ are initially calculated as a function of the hub height wind speed v_{HH}. The corresponding wind speeds v_{10m} at 10 m height above ground level have been evaluated assuming a logarithmic wind profile. In this case a surface roughness of z_{0ref} = 0.05 m has been used, which is representative of average terrain conditions.

$$v_{10m} = v_{HH} \frac{\ln\left(10m / z_{0ref}\right)}{\ln\left(hub\ height / z_{0ref}\right)} \quad *$$

The calculated apparent sound power levels $L_{WA,k}$ and the associated octave-band spectra are given in Table 1 and Table 2 for two different hub heights. The values are provided as mean levels as a function of v_{10m} for Normal Operation (NO) over cut-in to cut-out wind speed range. The uncertainties for octave sound power levels are generally higher than for total sound power levels. Guidance is given in IEC 61400-11, Annex D.

Wind speed at 10 m height (m/s)	Wind speed at hub height (m/s)	1.6-100 80 m hub height L_{WA} (dBA)	63 Hz Octave band level (dBA)	125 Hz Octave band level (dBA)	250 Hz Octave band level (dBA)	500 Hz Octave band level (dBA)	1000 Hz Octave band level (dBA)	2000 Hz Octave band level (dBA)	4000 Hz Octave band level (dBA)	8000 Hz Octave band level (dBA)	16000 Hz Octave band level (dBA)
5	7.0	97.8	81.4	86.5	90.6	92.4	91.2	89.9	82.9	62.5	17.9
5.5	7.7	100.2	83.5	88.8	93.1	95.1	93.4	92.0	85.6	65.7	20.5
6	8.4	102.4	85.5	90.8	95.3	97.7	95.5	93.9	87.8	68.8	23.2
6.5	9.1	103.7	87.4	92.3	95.6	98.5	98.1	95.5	88.0	68.3	24.3
7	9.7	105.0	89.0	93.7	95.7	99.0	100.5	97.0	88.2	68.5	25.3
8	11.1	105.0	89.2	93.9	95.5	98.5	100.8	97.0	87.6	68.6	24.6
9	12.5	105.0	89.2	94.0	95.6	98.6	100.8	96.8	86.9	67.4	25.5
10 – cutout	14 - cutout	105.0	89.1	93.8	95.6	98.8	101.0	96.2	86.1	67.2	27.3

Table 1: Normal Operation Calculated Apparent Sound Power Level, 1.6-100 with 80 m hub height as a function of 10 m wind speed (z_{0ref} = 0.05 m), the octave band spectra are for information only

* Simplified from IEC 61400-11, ed. 2.1: 2006 equation 7

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Wind speed at 10 m height (m/s)	Wind speed at hub height (m/s)	1.6-100 96 m hub height L_{WA} (dBA)	63 Hz Octave band level (dBA)	125 Hz Octave band level (dBA)	250 Hz Octave band level (dBA)	500 Hz Octave band level (dBA)	1000 Hz Octave band level (dBA)	2000 Hz Octave band level (dBA)	4000 Hz Octave band level (dBA)	8000 Hz Octave band level (dBA)	16000 Hz Octave band level (dBA)
5	7.2	98.4	81.9	87.1	91.2	93.0	91.7	90.5	83.6	63.4	18.5
5.5	7.9	100.8	84.1	89.3	93.7	95.8	94.0	92.5	86.1	66.5	21.3
6	8.6	102.9	86.0	91.3	95.7	98.2	96.2	94.4	88.2	69.2	23.7
6.5	9.3	104.2	88.0	92.8	95.5	98.7	99.1	96.0	87.9	67.8	24.6
7	10.0	105.0	89.1	93.8	95.6	98.7	100.6	97.1	88.2	69.2	25.4
8	11.5	105.0	89.2	94.0	95.6	98.5	100.8	97.0	87.3	67.8	24.5
9	12.9	105.0	89.2	94.0	95.6	98.6	100.9	96.7	86.7	67.2	25.8
10 - cutout	14 - cutout	105.0	89.1	93.8	95.6	98.8	101.0	96.2	86.1	67.2	27.3

Table 2: Normal Operation Calculated Apparent Sound Power Level, 1.6-100 with 96 m hub height as a function of 10 m wind speed (z_{0ref} = 0.05 m), the octave band spectra are for information only

At 10 m wind speeds lower than 5 m/s the sound power levels decreases, and may get so low that the wind turbine noise becomes indistinguishable from the background noise. For a conservative calculation the data at 5 m/s may be used.

For 10 m wind speeds above 10 m/s, the wind turbine has reached rated power and the blade pitch regulation acts in a way that tends to decrease the noise levels. For a conservative calculation the data at 10 m/s may be used.

The highest normal operation calculated apparent sound power level for the 1.6-100 is $L_{WA,k}$ = 105.0 dB.

3 Uncertainty Levels

The apparent sound power levels given above are calculated mean levels. If a wind turbine noise performance test is carried out, it needs to be done in accordance with the regulations of the international standard IEC 61400-11, ed. 2.1: 2006. Uncertainty levels associated with measurements are described in IEC/TS 61400-14.

Per IEC/TS 61400-14, L_{WAd} is the maximum apparent sound power level for 95 % confidence level resulting from n measurements performed according to IEC 61400-11 standard: $L_{Wad} = L_{WA} + K$, where L_{WA} is the mean apparent sound power level from IEC 61400-11 testing reports and $K = 1.645\ \sigma_T$.

The testing standard deviation values σ_T, σ_R and σ_P for measured apparent sound power level are described by IEC/TS 61400-14, where σ_T is the total standard deviation, σ_P is the standard deviation for product variation and σ_R is the standard deviation for test reproducibility.

Assuming $\sigma_R < 0.8$ dB and $\sigma_P < 0.8$ dB as typical values leads to a calculated $K < 2$ dB for 95 % confidence level.

4 Tonal Audibility

At the reference measuring point R_0 the 1.6-100 turbine has a value for tonality of $\mathbf{\Delta L_{a,k} \leq 2\ dB}$.

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5 IEC 61400-11 and IEC/TS 61400-14 Terminology

- $L_{WA,K}$ is wind turbine apparent sound power level (referenced to 10^{-12}W) measured with A-weighting as function of reference wind speed v_{10m}. Derived from multiple measurement reports per IEC 61400-11, it is considered as a mean value
- σ_P is the product variation i.e. the 1.6-100 unit-to-unit product variation; typically < 0.8 dB
- σ_R is the overall measurement testing reproducibility as defined per IEC 61400-11; typically < 0.8 dB with adequate measurement conditions and sufficient amount of data samples
- σ_T is the total standard deviation combining both σ_P and σ_R
- $K = 1.645\ \sigma_T$ is defined per IEC/TS 61400-14 for 95 % confidence level
- R_0 is the ground measuring distance from the wind turbine tower axis per IEC 61400-11, which shall equal the hub height plus half the rotor diameter
- $\Delta L_{a,k}$ is the tonal audibility according to IEC 61400-11, described as potentially audible narrow band sound

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Reference:

- IEC 61400-1. Wind turbines – part 1: Design requirements. ed. 2. 1999
- IEC 61400-11, wind turbine generator systems part 11: Acoustic noise measurement techniques, ed. 2.1, 2006-11
- IEC/TS 61400-14, Wind turbines – part 14: Declaration of apparent sound power level and tonality values, ed. 1, 2005-03
- MNPT – Machine Noise Performance Test, Technical documentation, GE 2011

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Appendix I - Calculated Third Octave Band Apparent Sound Power Level $L_{WA,k}$

1.6-100 - Normal Operation 3rd Octave Band Spectra									
Standard WS at 10 m [m/s]		**5**	**5.5**	**6**	**6.5**	**7**	**8**	**9**	**10-Cutout**
Hub Height WS at 80 m [m/s]		**7.0**	**7.7**	**8.4**	**9.1**	**9.7**	**11.1**	**12.5**	**14-Cutout**
Frequency [Hz]	25	61.8	63.9	65.7	67.5	69.0	69.3	69.4	69.3
	32	66.2	68.3	70.1	71.9	73.5	73.8	73.8	73.7
	40	70.2	72.3	74.2	75.9	77.5	77.8	77.9	77.7
	50	73.4	75.5	77.4	79.2	80.7	81.0	81.1	80.9
	63	76.3	78.4	80.4	82.2	83.8	84.0	84.1	83.9
	80	78.6	80.8	82.8	84.7	86.4	86.5	86.6	86.4
	100	80.5	82.7	84.7	86.6	88.2	88.4	88.4	88.2
	125	81.7	83.9	85.9	87.6	89.0	89.2	89.3	89.1
	160	82.8	85.1	87.2	88.4	89.5	89.8	89.8	89.7
	200	84.3	86.6	88.8	89.5	90.2	90.3	90.4	90.3
	250	85.7	88.2	90.4	90.7	90.8	90.7	90.8	90.7
	315	87.0	89.6	92.0	91.9	91.6	91.2	91.3	91.3
	400	87.5	90.1	92.7	92.8	92.6	92.1	92.1	92.3
	500	87.8	90.5	93.2	93.9	94.1	93.6	93.6	93.9
	630	87.4	90.2	92.8	94.4	95.4	95.1	95.1	95.4
	800	86.5	89.0	91.5	93.9	95.8	95.8	95.9	96.1
	1000	86.1	88.2	90.4	93.2	95.8	96.1	96.2	96.4
	1250	86.6	88.6	90.3	92.9	95.4	96.1	96.1	96.1
	1600	86.0	88.0	89.7	91.8	93.7	94.2	94.2	93.6
	2000	85.3	87.4	89.3	90.7	92.1	92.0	91.6	90.9
	2500	83.9	86.2	88.2	89.2	90.0	89.2	88.6	88.0
	3150	81.4	83.8	86.0	86.4	86.8	85.9	85.3	84.5
	4000	76.7	79.6	82.0	81.8	81.7	81.6	80.5	79.9
	5000	71.0	74.1	76.5	76.0	76.1	76.2	74.7	74.5
	6300	62.3	65.5	68.5	68.0	68.2	68.3	67.1	66.9
	8000	50.0	52.9	55.9	56.1	56.7	56.9	55.9	55.5
	10000	35.5	38.1	41.0	41.7	42.7	42.5	42.4	42.6
	12500	17.9	20.5	23.1	24.3	25.3	24.6	25.4	27.3
	16000	-7.1	-4.3	-1.8	-0.7	0.0	-0.2	2.0	4.9
	20000	-35.1	-31.5	-28.4	-27.9	-27.8	-26.6	-23.8	-20.4
Total apparent sound power level $L_{WA.k}$ [dB]		**97.8**	**100.2**	**102.4**	**103.7**	**105.00**	**105.00**	**105.00**	**105.00**

Table 3: Calculated Apparent Third Octave Band Sound Power Level (A-weighted) 1.6-100 with 80 m hub height as Function of Wind Speed v_{10m}

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1.6-100 - Normal Operation 3rd Octave Band Spectra									
Standard WS at 10 m [m/s]		**5**	**5.5**	**6**	**6.5**	**7**	**8**	**9**	**10-Cutout**
Hub Height WS at 96 m [m/s]		**7.2**	**7.9**	**8.6**	**9.3**	**10.0**	**11.5**	**12.9**	**14-Cutout**
Frequency [Hz]	25	62.4	64.4	66.2	68.1	69.1	69.4	69.4	69.3
	32	66.7	68.8	70.7	72.5	73.5	73.8	73.8	73.7
	40	70.7	72.8	74.7	76.5	77.6	77.8	77.9	77.7
	50	73.9	76.1	78.0	79.8	80.8	81.0	81.1	80.9
	63	76.8	79.0	80.9	82.8	83.8	84.0	84.1	83.9
	80	79.2	81.4	83.4	85.4	86.4	86.6	86.6	86.4
	100	81.0	83.2	85.2	87.2	88.3	88.4	88.4	88.2
	125	82.3	84.5	86.5	88.1	89.1	89.3	89.2	89.1
	160	83.4	85.7	87.7	88.8	89.6	89.8	89.8	89.7
	200	84.9	87.2	89.2	89.7	90.2	90.3	90.4	90.3
	250	86.4	88.8	90.8	90.6	90.7	90.7	90.8	90.7
	315	87.7	90.2	92.3	91.7	91.4	91.2	91.3	91.3
	400	88.2	90.8	93.1	92.7	92.3	92.1	92.1	92.3
	500	88.5	91.3	93.7	94.0	93.9	93.6	93.6	93.9
	630	88.1	90.9	93.4	94.8	95.2	95.1	95.2	95.4
	800	87.1	89.7	92.2	94.7	95.8	95.8	95.9	96.1
	1000	86.6	88.8	91.1	94.3	96.0	96.1	96.2	96.4
	1250	87.1	89.1	90.9	93.9	95.7	96.1	96.2	96.1
	1600	86.5	88.5	90.3	92.5	93.9	94.2	94.1	93.6
	2000	85.8	87.9	89.7	91.2	92.2	91.9	91.5	90.9
	2500	84.5	86.7	88.6	89.5	89.9	89.2	88.5	88.0
	3150	82.0	84.4	86.4	86.5	86.7	85.7	85.2	84.5
	4000	77.4	80.2	82.3	81.5	81.8	81.3	80.4	79.9
	5000	71.8	74.7	76.8	75.6	76.5	75.5	74.7	74.5
	6300	63.1	66.2	68.9	67.5	68.9	67.5	66.9	66.9
	8000	50.8	53.7	56.4	55.9	57.2	56.5	55.7	55.5
	10000	36.2	38.9	41.5	41.8	43.0	42.2	42.3	42.6
	12500	18.5	21.3	23.7	24.6	25.4	24.5	25.8	27.3
	16000	-6.4	-3.6	-1.3	-0.4	-0.1	0.0	2.5	4.9
	20000	-34.2	-30.7	-27.8	-27.9	-27.9	-26.1	-23.2	-20.4
Total apparent sound power level $L_{WA.k}$ [dB]		**98.4**	**100.8**	**102.9**	**104.2**	**105.00**	**105.00**	**105.00**	**105.00**

Table 4: Calculated Apparent Third Octave Band Sound Power Level (A-weighted), 1.6-100 with 96 m hub height as Function of Wind Speed v_{10m}

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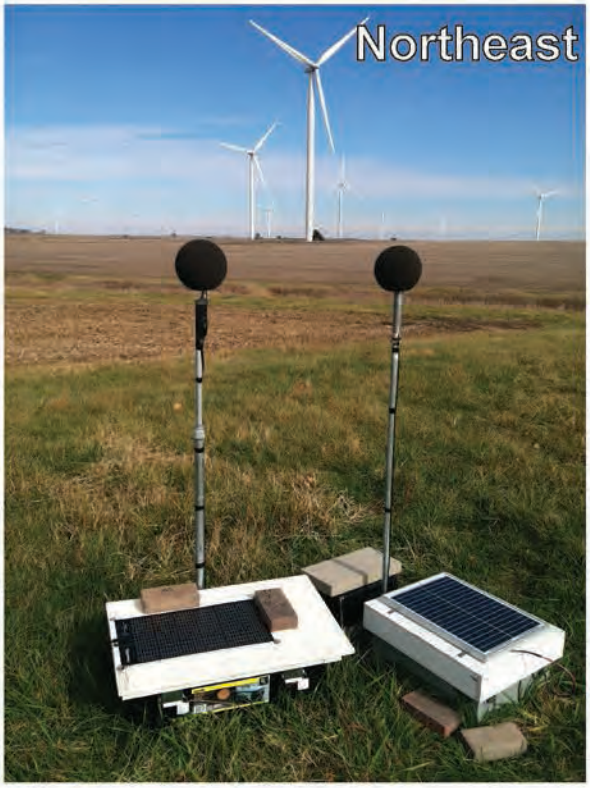
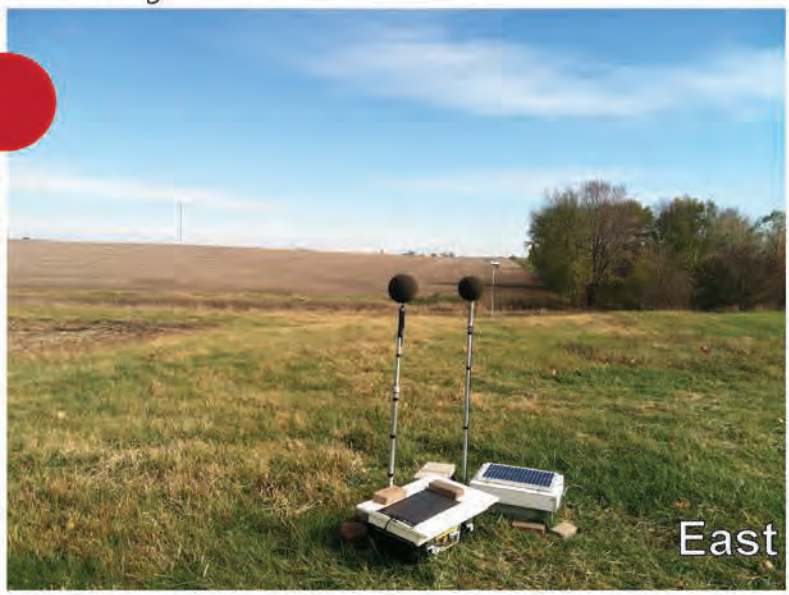
Appendix B - Pictures of Measurement Locations

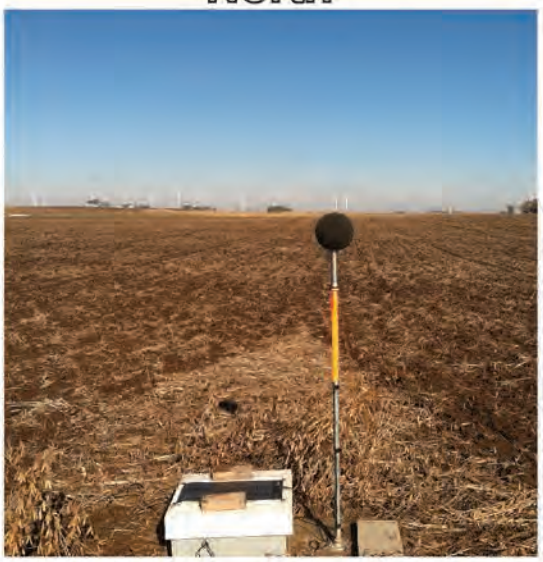
Primary 1



Primary 2



North



West

Control

Northeast

Southwest

Appendix C - Sound Measurement Equipment and Calibrations

Brüel & Kjær
creating sustainable value

Sound Level Meter - Type 2250

An advanced, single-channel, hand-held analyzer and sound level meter that has everything needed to perform high-precision, Class 1 measurement tasks in environmental, occupational and industrial application areas. Type 2250 is a versatile, modular measurement platform with many optional application modules such as frequency analysis, FFT, advanced logging (profiling), sound recording and building acoustics.

Uses

- General-purpose Class 1 sound measurements to the latest international standards
- Occupational noise assessment
- Environmental noise assessment and logging
- Product development and quality control
- FFT analysis of sound and vibration
- Sound power determination
- Single-channel building acoustics measurements

Features

- Single-channel input (microphone, accelerometer or direct signal)
- 4.2 Hz - 22.4 kHz broadband linear frequency range with supplied microphone Type 4189
- 16.6 - 140 dB A-weighted dynamic range with supplied microphone Type 4189
- Inputs: AC or CCLD, External Trigger
- Outputs: Generator and Headphone
- Communication via USB, LAN, or GPRS/3G modems
- USB 2.0 host for connection to printer, GPS, weather station, modem
- Plug-in rechargeable Li-ion battery (> 8h operation)

Forget about input ranging

24-bit recording captures the tiniest whisper and the loudest bang in the same recording without clipping, compression or range adjustment. This feature also makes recording suitable for re-analysis during post-processing to extract additional information and run more complex analysis.

Flexible application modules

The Type 2250 software concept allows you to configure the instrument to precisely match your requirements, using your preferred combination of application modules. Additional modules can be purchased as required – and simply installed with a new licence. In this way, your investment is securely protected as your measurement platform can expand along with your needs. All application modules are constantly maintained to ensure our sound level meters always comply with the very latest international standards.

PC software

Included with every Type 2250 is a dedicated PC software package that handles data transfer, archiving of data, export of data, setup, remote display, and software maintenance (for example, license installation and updates).

Touch-sensitive screen and key pad

The large colour screen presents a wealth of information clearly, and is highly customisable - making interaction easy and intuitive. Buttons give single-click access to the most important and frequent commands like start/pause, save, voice comment and event marking.

Select the night-time colour scheme and you can easily read the display without disturbing your night vision, while the keys are gently backlit.

Expandable memory

Two SD memory slots that support Secure Digital High Capacity (SDHC) cards allow you to

always increase your storage space.

Confident measurement quality

Immediate, detailed feedback about measurement quality comes from features such as a 'smiley face' quality indicator and a 'traffic light' system - informing you of measurement status even from a distance.

Always in touch

Both a USB interface and an Ethernet port allow Type 2250 to directly connect to a Local Area Network (LAN) - so you can control your sound level meter over large distances.

Speaks your language

The user-interface of all Type 2250 software packages is available in over 20 different languages.

Annotate on the go

Press the commentary button and record voice comments on a separate microphone with a dedicated channel either before, during or after a measurement. The comments file is then attached to the measurement project as documentation.

Smart transducer database

Many transducers can be connected to the instrument, and once one has been used it is remembered by the transducer database. Simply selecting it from the menu automatically attaches all the relevant data to the measurement, including the transducer's last calibration. Polarisation voltage is also set automatically.

Automatic windscreen correction

Type 2250 automatically detects when you mount and removing the windscreen, and applies the corresponding correction filter. The specific windscreen information is saved permanently with the measurement setup and data.

Calibration Certificate Number 1568.01

The Brüel & Kjær Calibration Laboratory
2815 Colonnades Court
Norcross, GA 30071-1588
Telephone: 770/209-6907
Fax: 770/447-4033
Web site address: http://www.bkhome.com

CERTIFICATE OF CALIBRATION

Certificate No: 1-319112991-802

CALIBRATION OF:

Sound Level Meter:	Brüel & Kjær	2270	Serial No: 3001084
Microphone:	Brüel & Kjær	4189	Serial No: 2799404
Preamplifier:	Brüel & Kjær	ZC-0032	Serial No: 16913
Software version:	BZ7222 Version 4.0.2	Instruction manual:	BE1713-23

CLIENT:

Bruel & Kjaer N.A. Demo
2815-A Colonnades Court
Norcross, GA 30071

CALIBRATION CONDITIONS:

Preconditioning: 4 hours at 23 ± 3 °C

Environment conditions See actual values in Environmental Condition sections

SPECIFICATIONS:

This document certifies that the instrument as listed under "Model/Serial Number" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95%. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurement. The calibration of the listed instrumentation, was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and ISO 10012-1. For "as received" and/or "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation This Certificate and attached data pages shall not be reproduced, except in full, without the written approval of the Brüel and Kjær Calibration Laboratory-Norcross, GA. Results relate only to the items tested. This instrument has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

Brüel and Kjær Model 3630 Sound Level Meter Calibration System Software 7763 Version 4.5 - DB: 4.50 Test Collection 2270-4189.

RESULTS:

As Received Condition	As Received Data	Final Data
_X_ Received in good condition	_X_ Within acceptance criteria	_X_ Within acceptance criteria
___ Damaged - See attached report	___ Outside acceptance criteria	___ Limited test - See attached details
	___ Inoperative	
	___ Data not taken	

Date of Calibration: 08 Nov. 2012

Certificate issued: 12 Nov. 2012

Debra Wilson

Calibration Technician

John Artalile

Quality Representative

Calibration Certificate Number 1568.01

The Brüel & Kjær Calibration Laboratory
2815 Colonnades Court
Norcross, GA 30071-1588
Telephone: 770/209-6907
Fax: 770/447-4033
Web site address: http://www.bkhome.com

CERTIFICATE OF CALIBRATION

Certificate No: 1-360212201-902

CALIBRATION OF:

Sound Level Meter:	Brüel & Kjær	2270	Serial No: 3001109
Microphone:	Brüel & Kjær	4189	Serial No: 2804488
Preamplifier:	Brüel & Kjær	ZC-0032	Serial No: 17074
Software version:	BZ7222 Version 4.1.1	Instruction manual:	BE1713-23

CLIENT:

Bruel & Kjaer N.A. Demo
2815-A Colonnades Court
Norcross, GA 30071

CALIBRATION CONDITIONS:

Preconditioning:	4 hours at 23 ± 3 °C
Environment conditions	See actual values in Environmental Condition sections

SPECIFICATIONS:

This document certifies that the instrument as listed under "Model/Serial Number" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95%. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurement. The calibration of the listed instrumentation, was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and ISO 10012-1. For "as received" and/or "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation This Certificate and attached data pages shall not be reproduced, except in full, without the written approval of the Brüel and Kjær Calibration Laboratory-Norcross, GA. Results relate only to the items tested. This instrument has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

Brüel and Kjær Model 3630 Sound Level Meter Calibration System Software 7763 Version 4.7 - DB: 4.70 Test Collection 2270-4189.

RESULTS:

As Received Condition	As Received Data	Final Data
_X_ Received in good condition	_X_ Within acceptance criteria	_X_ Within acceptance criteria
___ Damaged - See attached report	___ Outside acceptance criteria	___ Limited test - See attached details
	___ Inoperative	
	___ Data not taken	

Date of Calibration: 15 May. 2013

Certificate issued: 16 May. 2013

Ken Human

Calibration Technician

John Aitalile

Quality Representative

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

MICROPHONE

Manufactured by:	**BRUEL & KJAER**
Model No:	**4952**
Serial No:	**2653064**
Calibration Recall No:	**23269**

Submitted By:

Customer:	**MIKE HANKARD**
Company:	**MICHAEL THERIAULT ACOUSTICS INC**
Address:	**100 PARK AVENUE**
	VERONA WI 53593

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Procedure No. 4952 BRUE

Upon receipt for Calibration, the instrument was found to be:

Within (X) see attached Report of Calibration.

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements, ISO 10012-1 MIL-STD-45662A, ANSI/NCSL Z540-1, IEC Guide 25, ISO 9001:2008 and ISO 17025.

Note: With this Certificate, Report of Calibration is included.

Calibration Date: 29-Jul-13

Certificate No: 23269 - 7

Approved by:

FC

Felix Christopher (QA Mgr.)

ISO/IEC 17025:2005

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration
1575 State Route 96, Victor, NY 14564, U.S.A.

ACCREDITED

Calibration Lab. Cert. # 1533.01

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

MICROPHONE

Manufactured by:	BRUEL & KJAER
Model No:	4952
Serial No:	2653065
Calibration Recall No:	23269

Submitted By:

Customer:	MIKE HANKARD
Company:	MICHAEL THERIAULT ACOUSTICS INC
Address:	100 PARK AVENUE
	VERONA WI 53593

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Procedure No. 4952 BRUE

Upon receipt for Calibration, the instrument was found to be:

Within (X) see attached Report of Calibration.

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements, ISO 10012-1 MIL-STD-45662A, ANSI/NCSL Z540-1, IEC Guide 25, ISO 9001:2008 and ISO 17025.

Note: With this Certificate, Report of Calibration is included.

Calibration Date: 29-Jul-13

Certificate No: 23269 - 8

Approved by:

FC

Felix Christopher (QA Mgr.)
ISO/IEC 17025:2005

ACCREDITED

Calibration Lab. Cert. # 1533.01

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration
1575 State Route 96, Victor, NY 14564, U.S.A.

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

HAND HELD ANALYZER

Manufactured by:	**BRUEL & KJAER**
Model No:	**2250**
Serial No:	**2676018**
Calibration Recall No:	**23269**

Submitted By:

Customer:	**MIKE HANKARD**
Company:	**MICHAEL THERIAULT ACOUSTICS INC**
Address:	**100 PARK AVENUE**
	VERONA WI 53593

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Procedure No. 2250 BRUE

Upon receipt for Calibration, the instrument was found to be:

Within (X) see attached Report of Calibration.

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements, ISO 10012-1 MIL-STD-45662A, ANSI/NCSL Z540-1, IEC Guide 25, ISO 9001:2008 and ISO 17025.

Note: With this Certificate, Report of Calibration is included.

Calibration Date: 26-Jul-13

Certificate No: 23269 - 2

Approved by:

FC

Felix Christopher (QA Mgr.)
ISO/IEC 17025:2005

ACCREDITED
Calibration Lab. Cert. # 1533.01

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration
1575 State Route 96, Victor, NY 14564, U.S.A.

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

HAND-HELD ANALYZER

Manufactured by:	BRUEL & KJAER
Model No:	2250
Serial No:	2676058
Calibration Recall No:	23269

Submitted By:

Customer:	MIKE HANKARD
Company:	MICHAEL THERIAULT ACOUSTICS INC
Address:	100 PARK AVENUE
	VERONA WI 53593

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Procedure No. 2250 BRUE

Upon receipt for Calibration, the instrument was found to be:

Within (X) see attached Report of Calibration.

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements, ISO 10012-1 MIL-STD-45662A, ANSI/NCSL Z540-1, IEC Guide 25, ISO 9001:2008 and ISO 17025.

Note: With this Certificate, Report of Calibration is included.

Calibration Date: 26-Jul-13

Certificate No: 23269 - 1

Approved by:

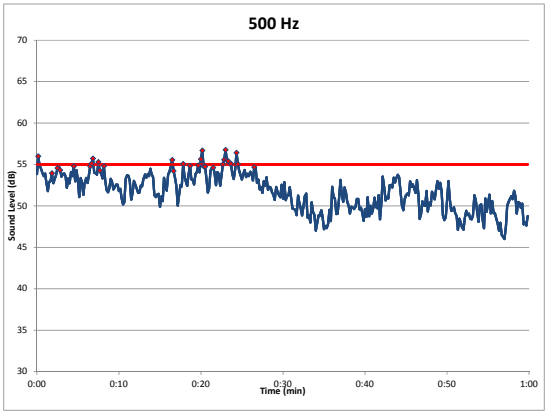
Fc

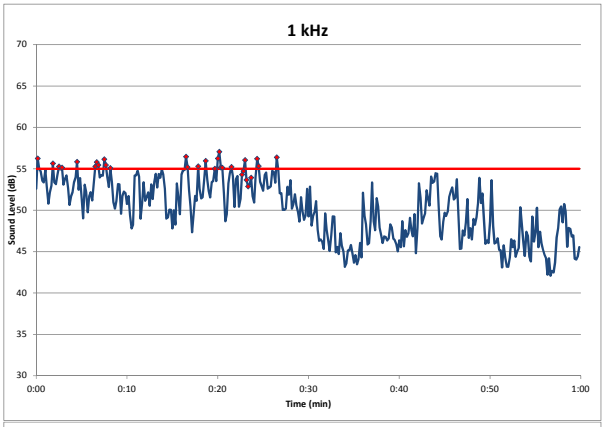
Felix Christopher (QA Mgr.)
ISO/IEC 17025:2005

ACCREDITED
Calibration Lab. Cert. # 1533.01

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration
1575 State Route 96, Victor, NY 14564, U.S.A.

Appendix D - Traffic and Train Noise Threshold Plots





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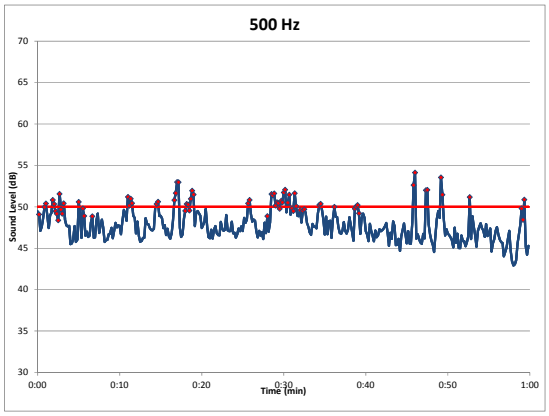

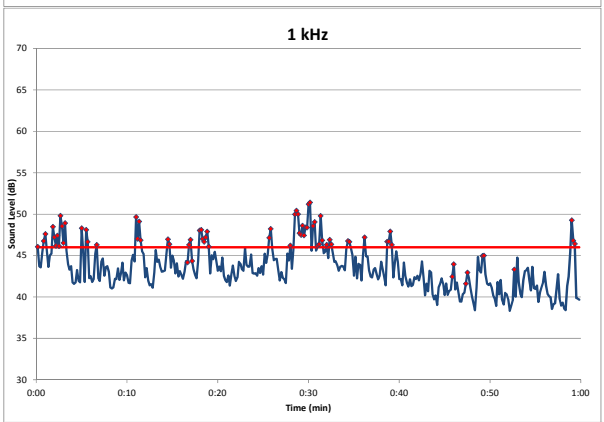

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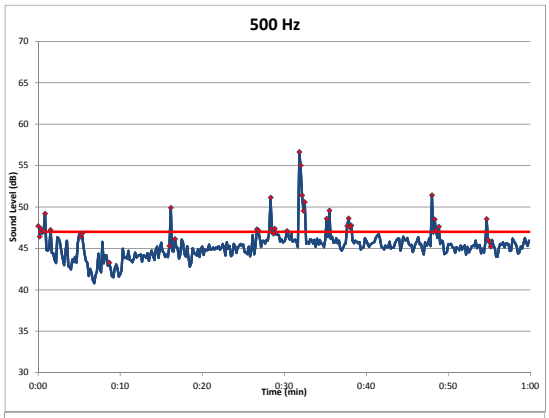

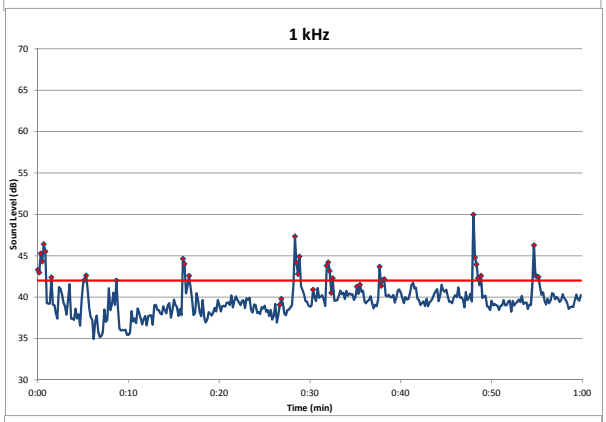

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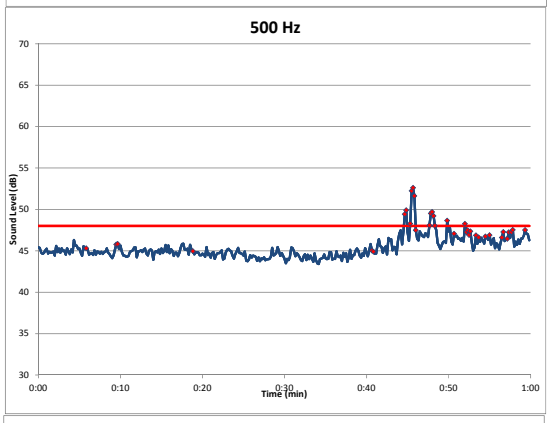

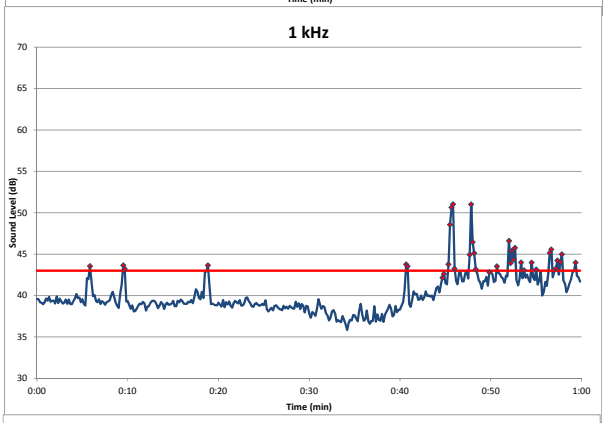

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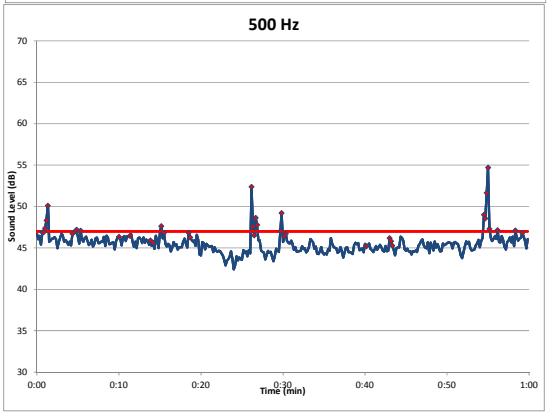

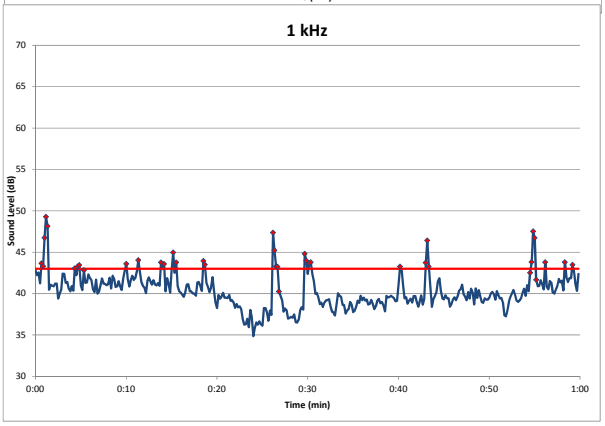

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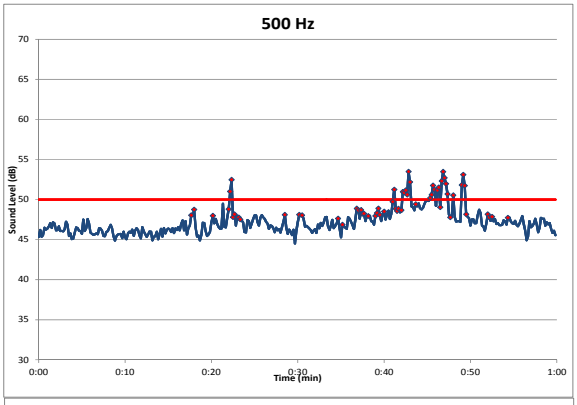

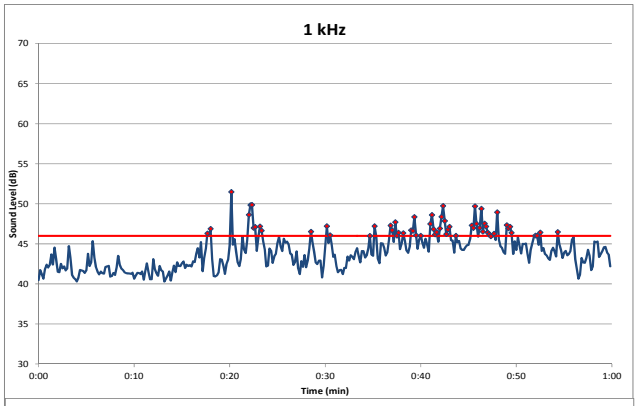

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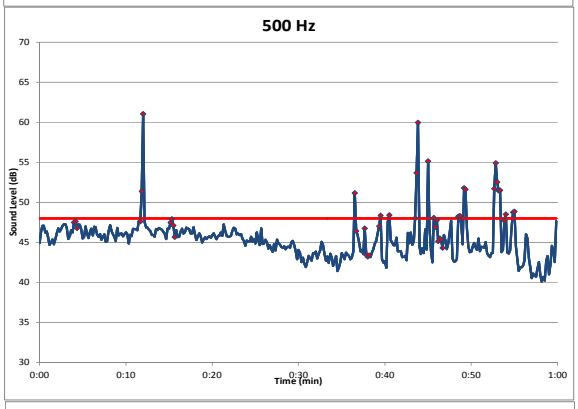

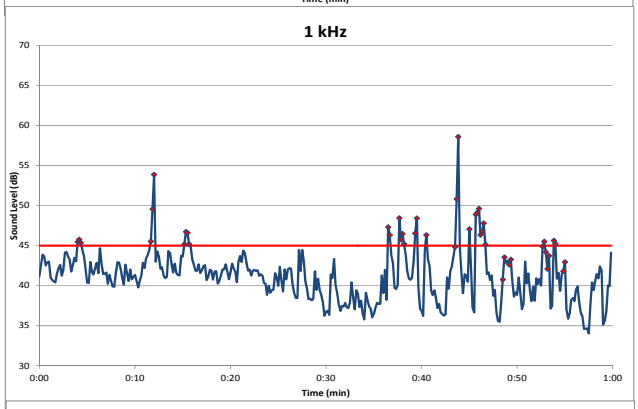

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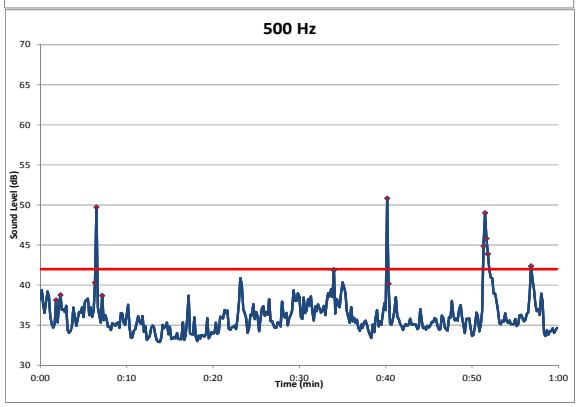

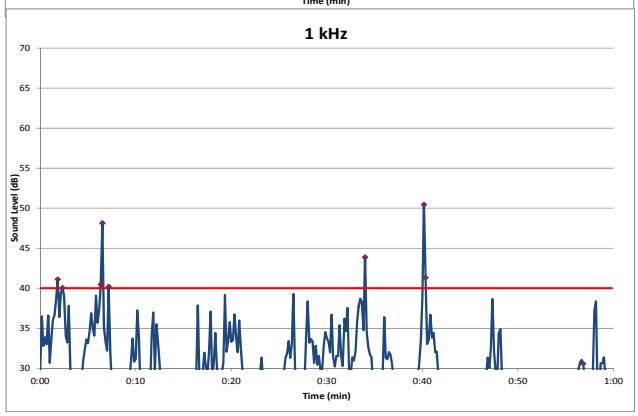

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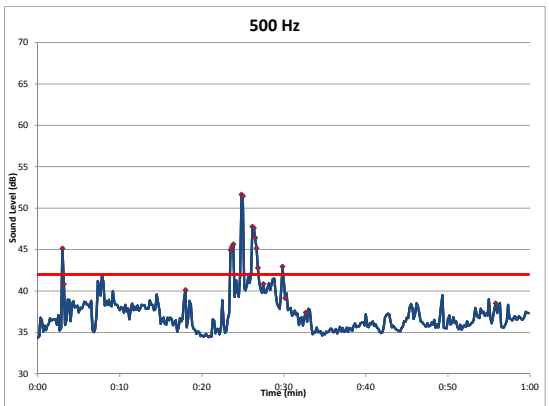

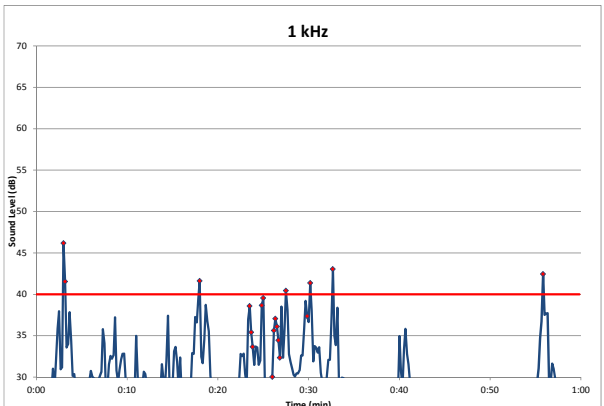

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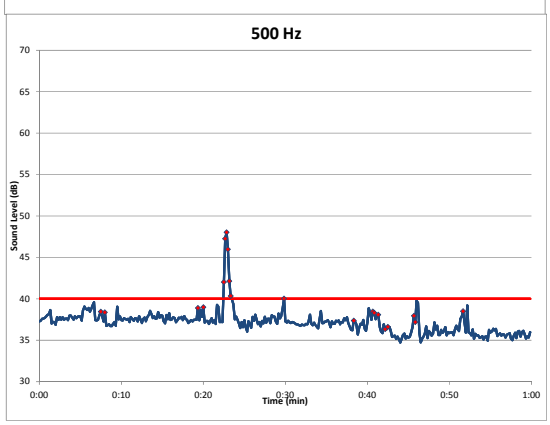

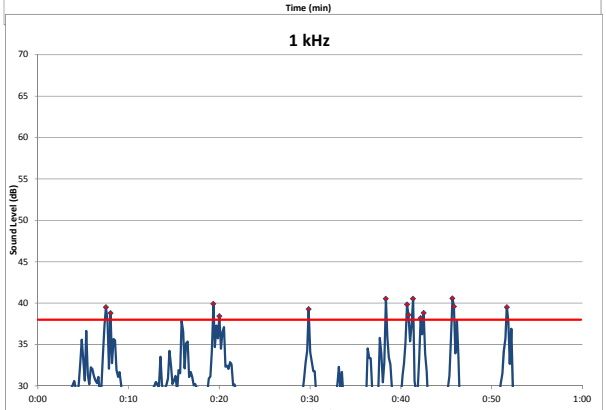

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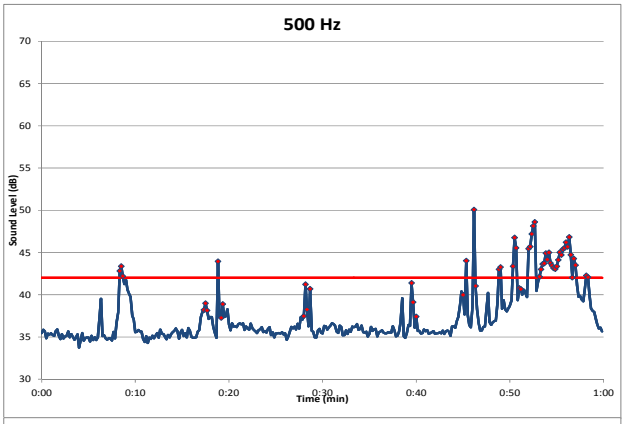

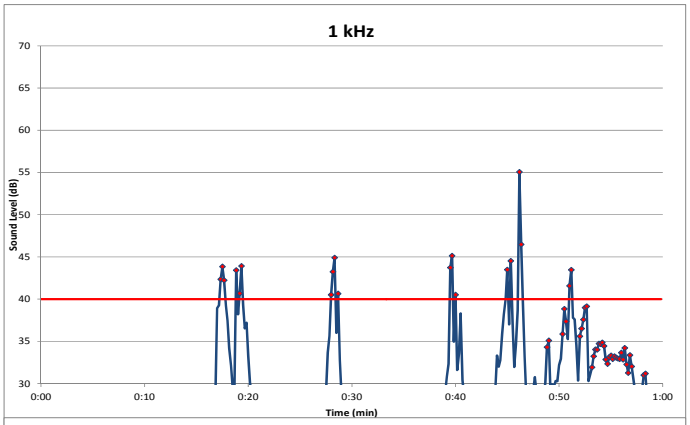

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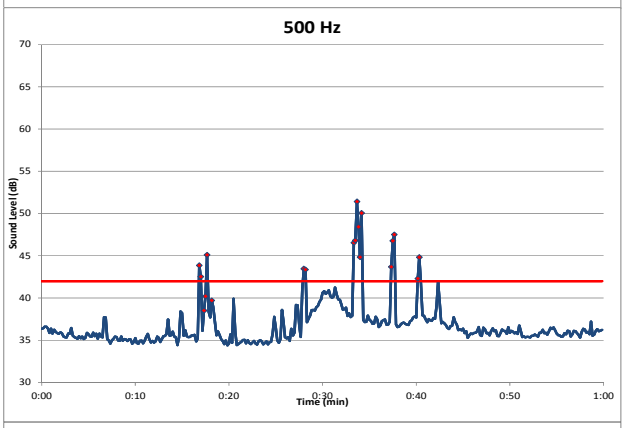

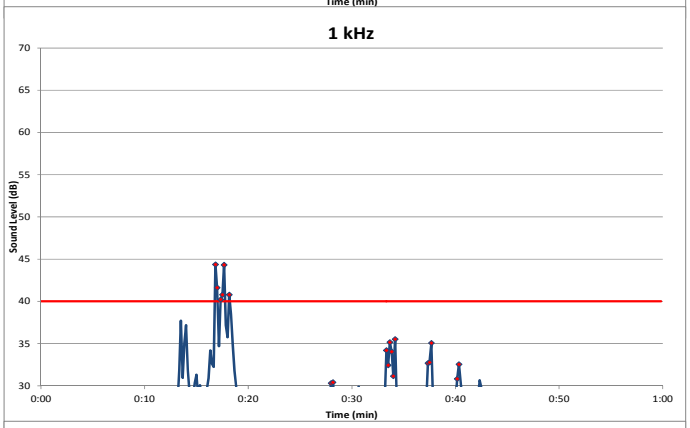

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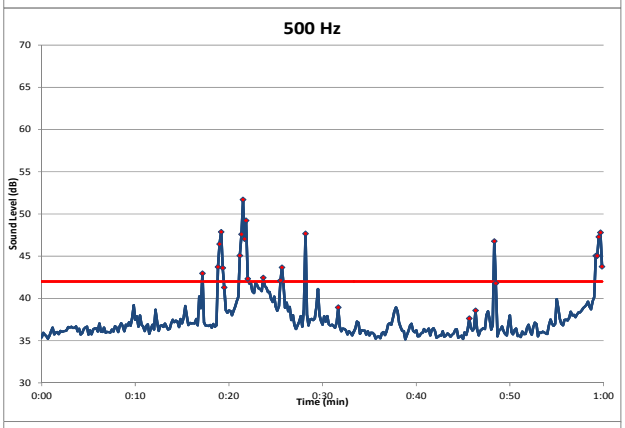

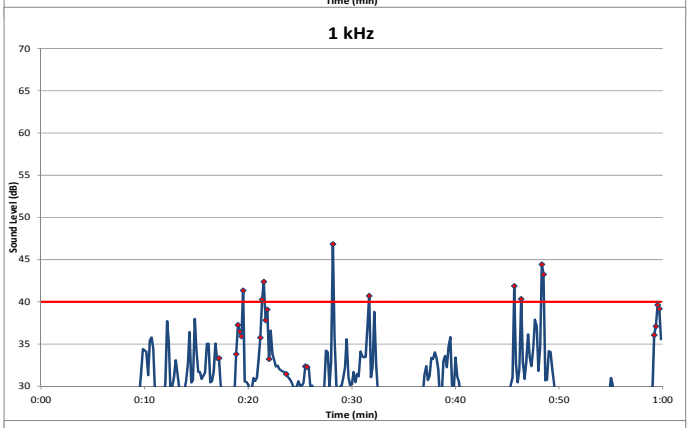

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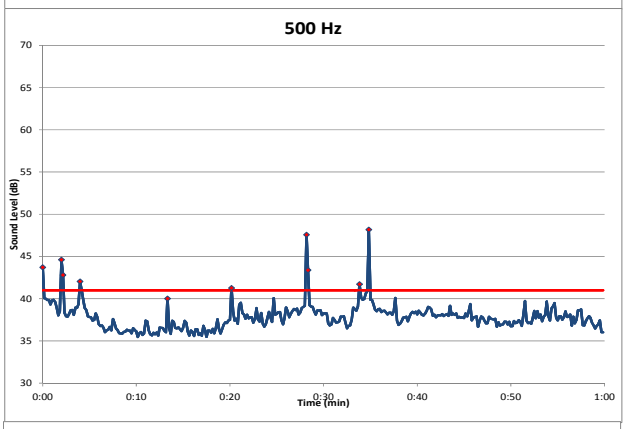

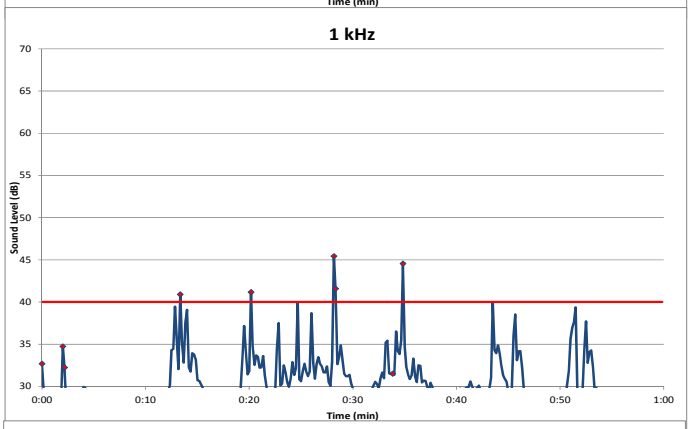

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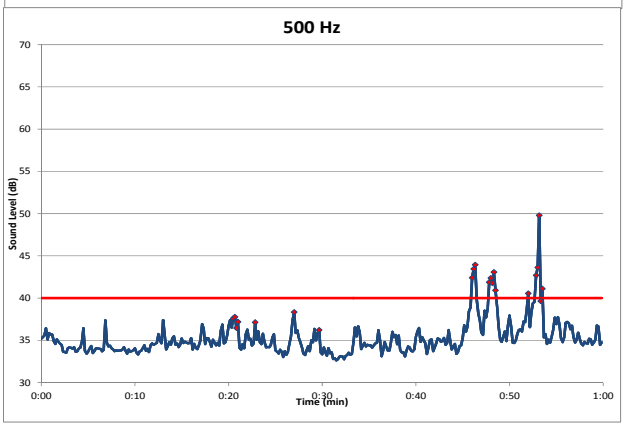

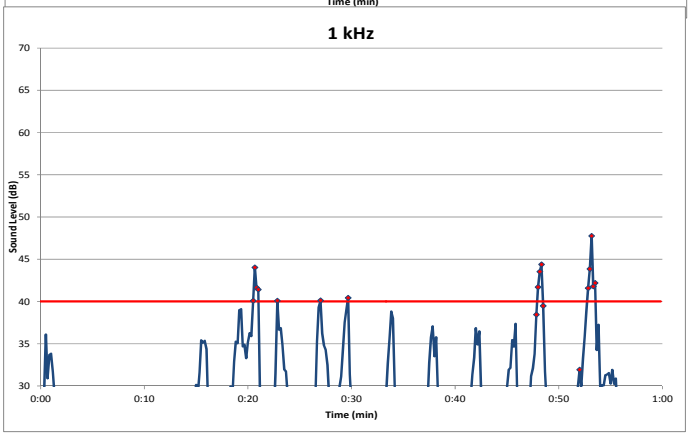

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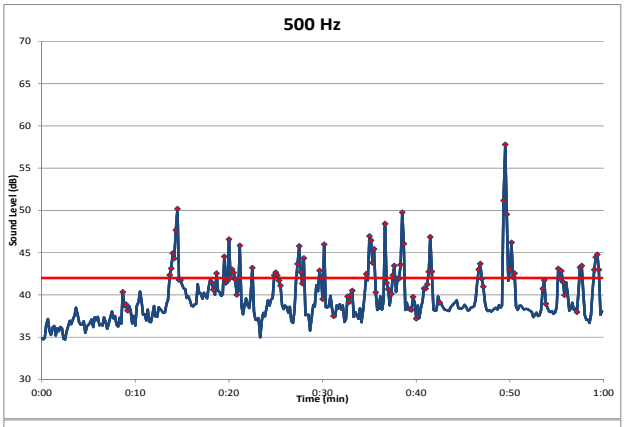

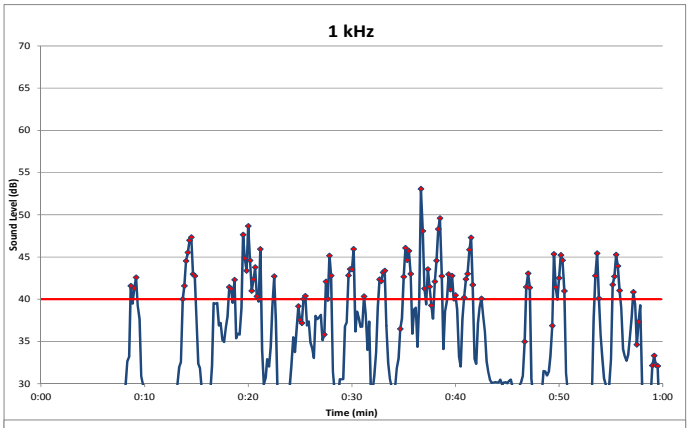

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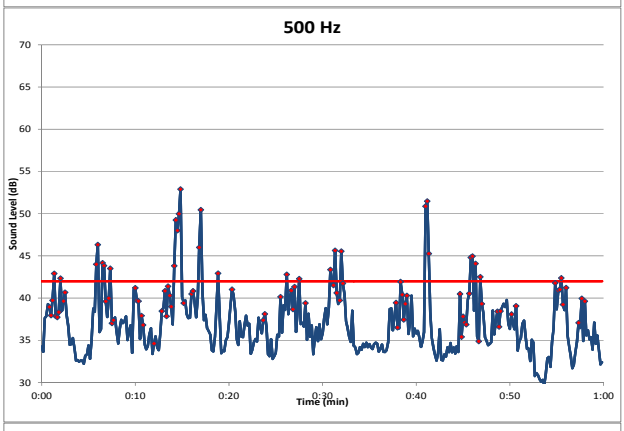

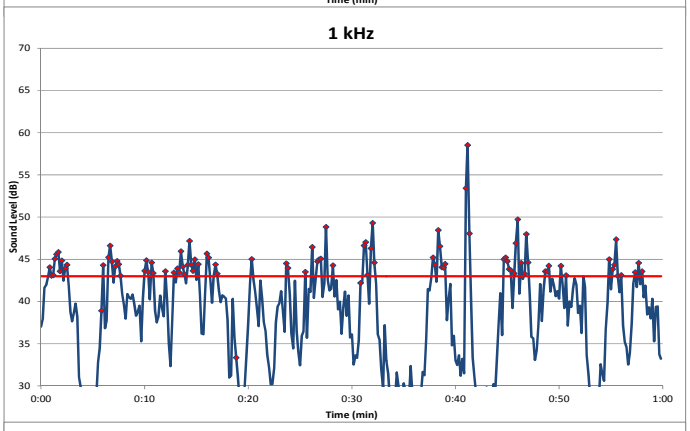

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NOV 2

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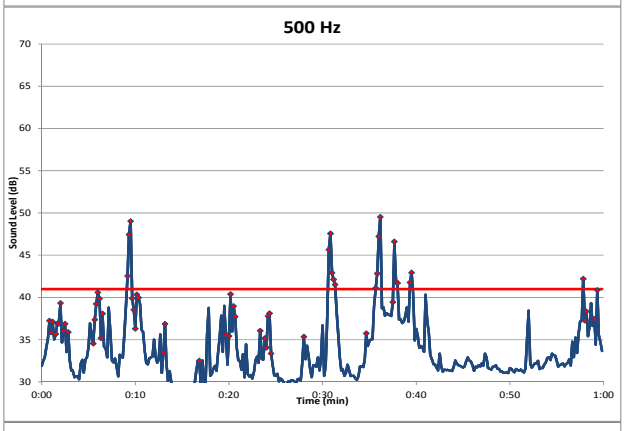

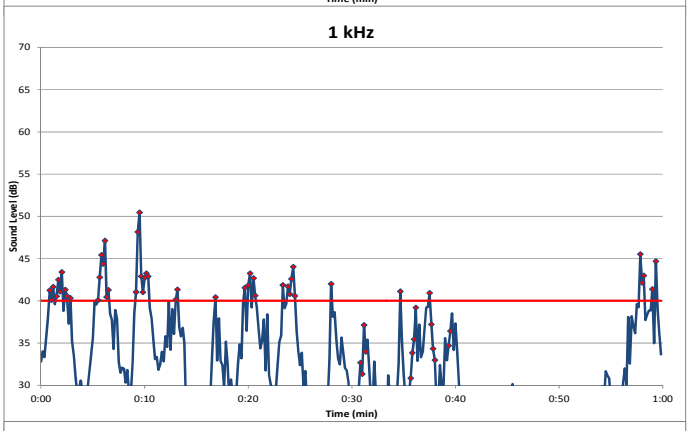

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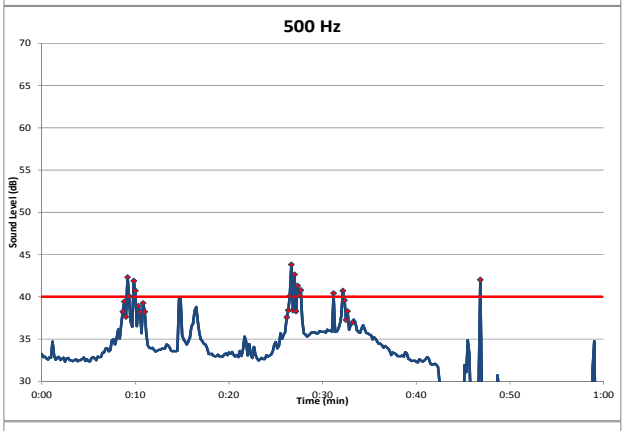

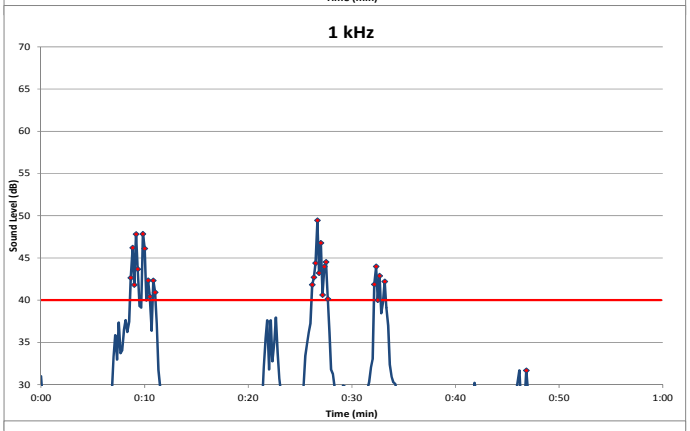

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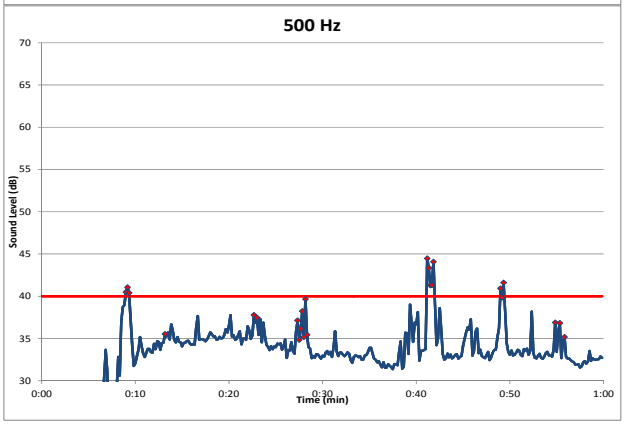

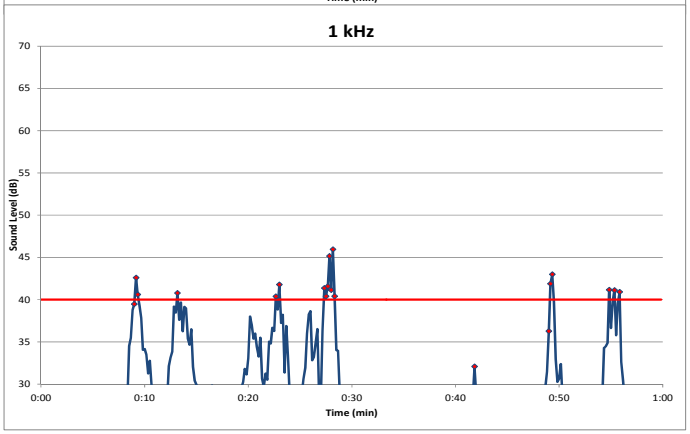

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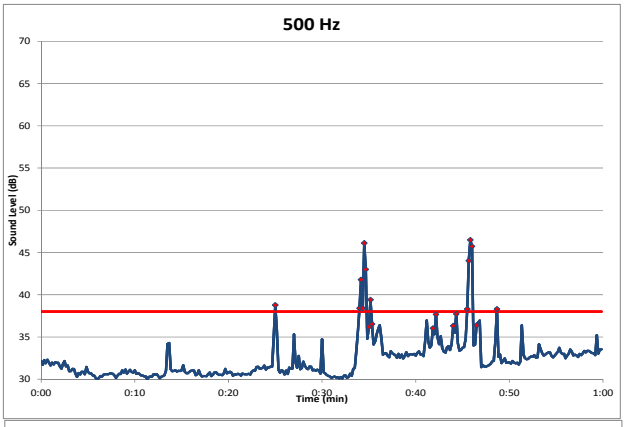
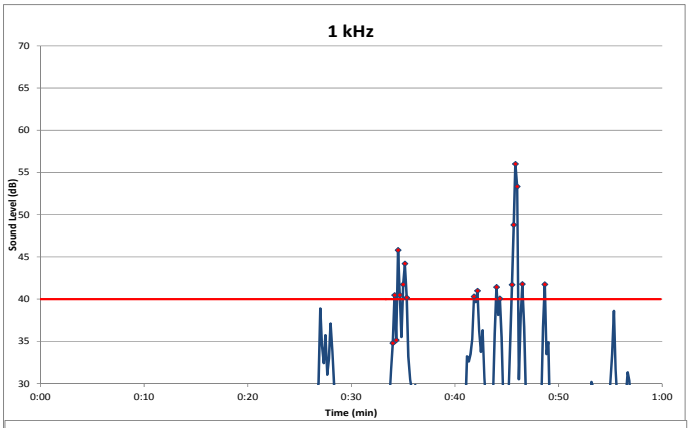
NOV 3

1:00





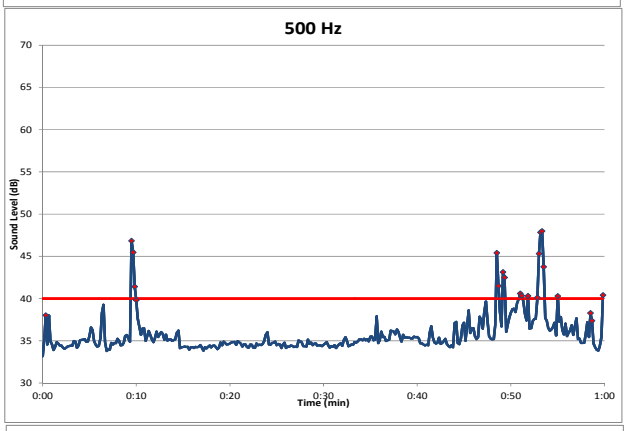
2013

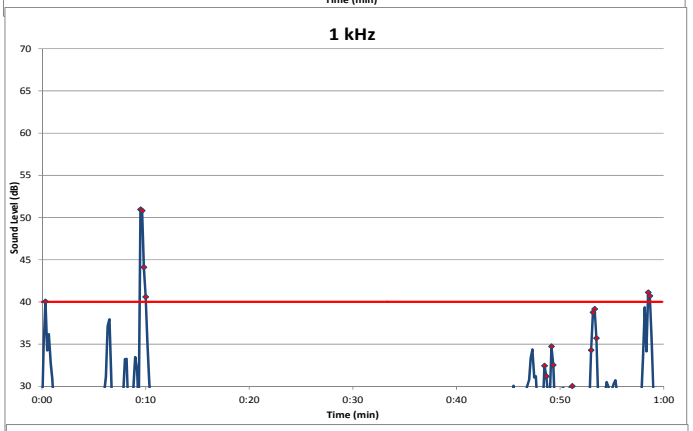
NOV 3

1:00

daylight savings

Prime 1





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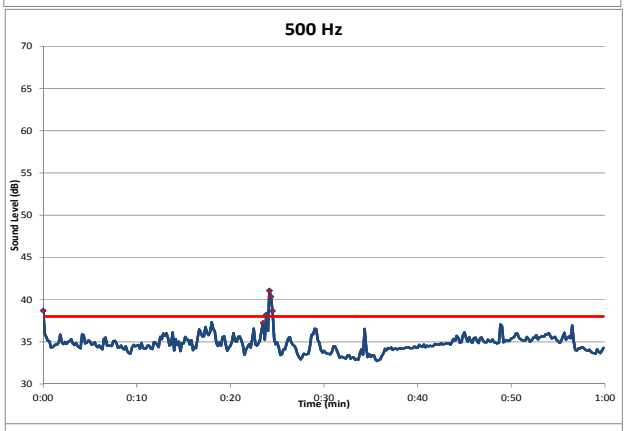
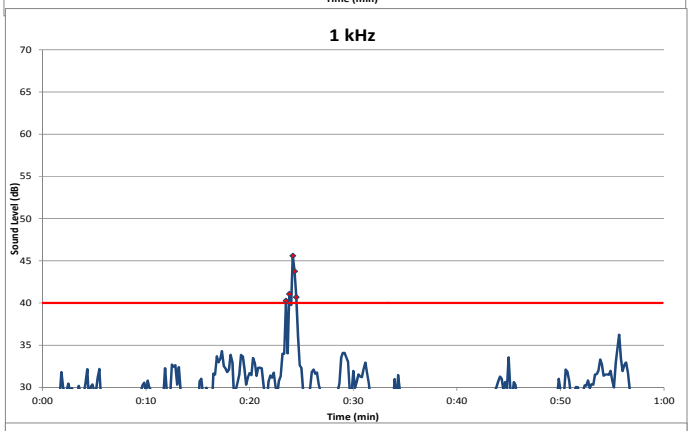
NOV 3

2:00





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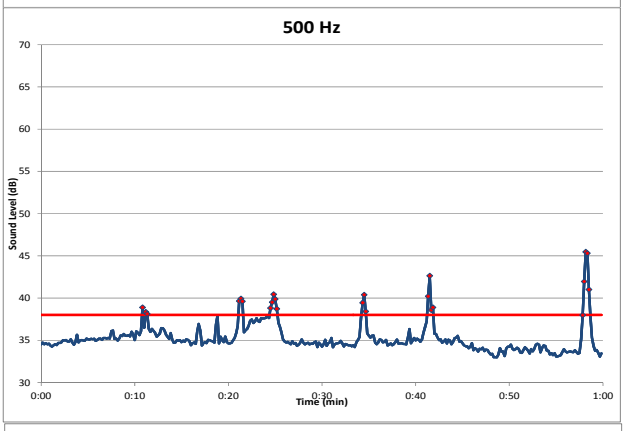
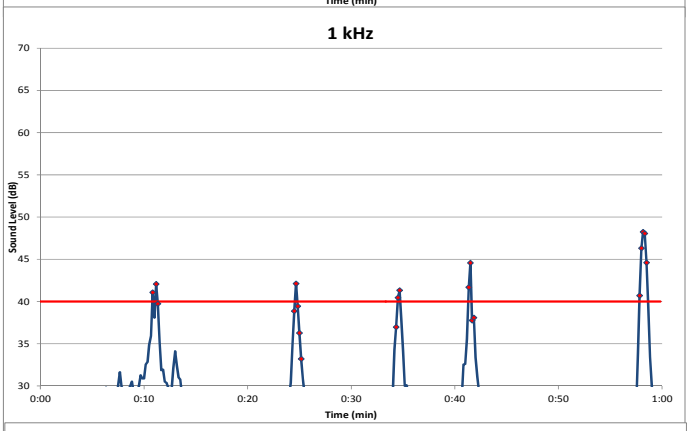
NOV 3

3:00





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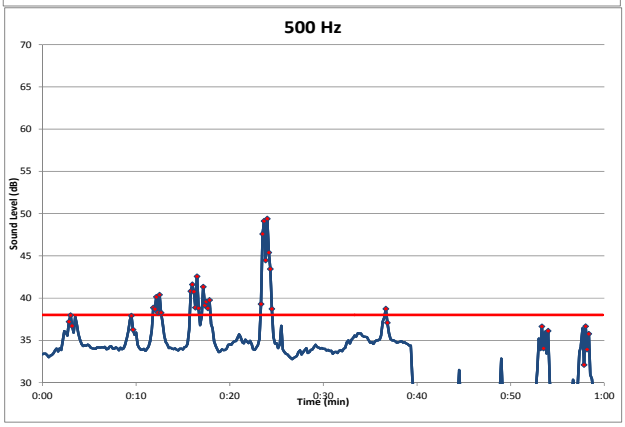
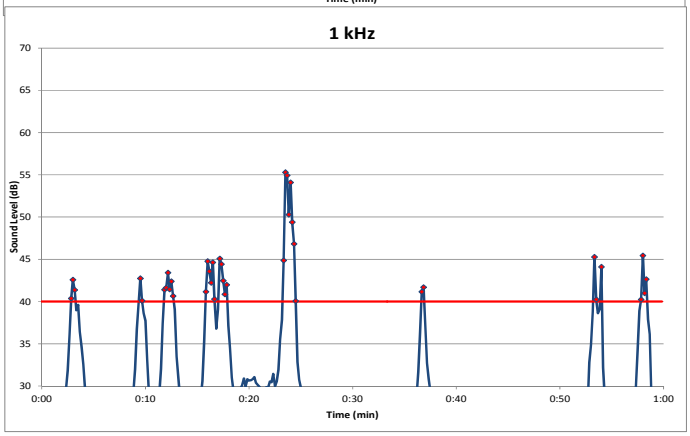
NOV 3

4:00





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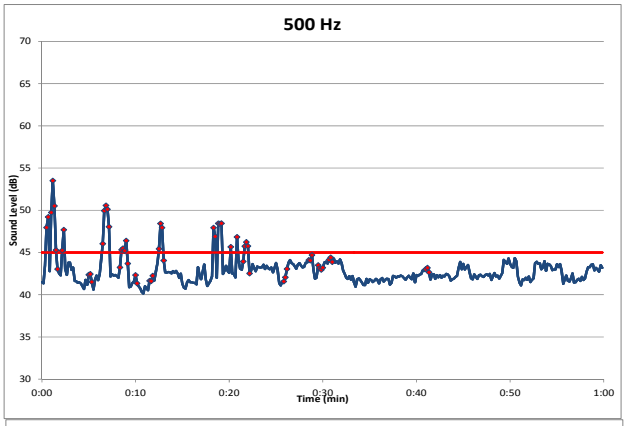
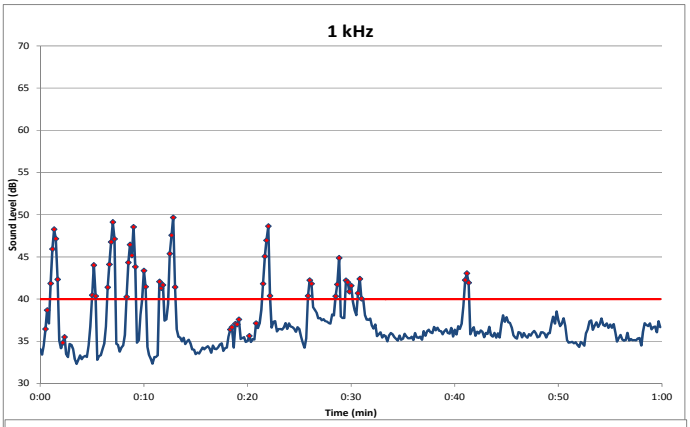
5:00





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NOV 3

6:00

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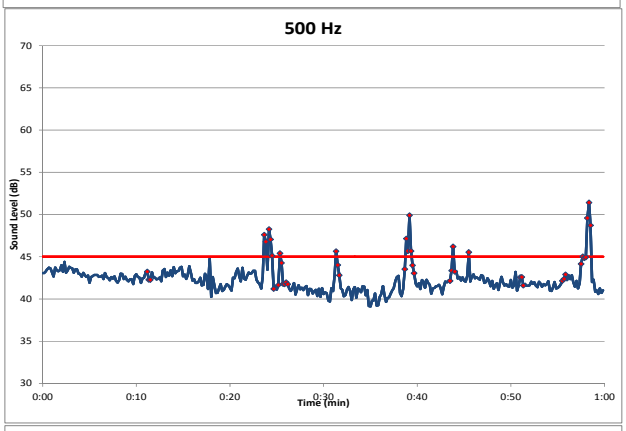

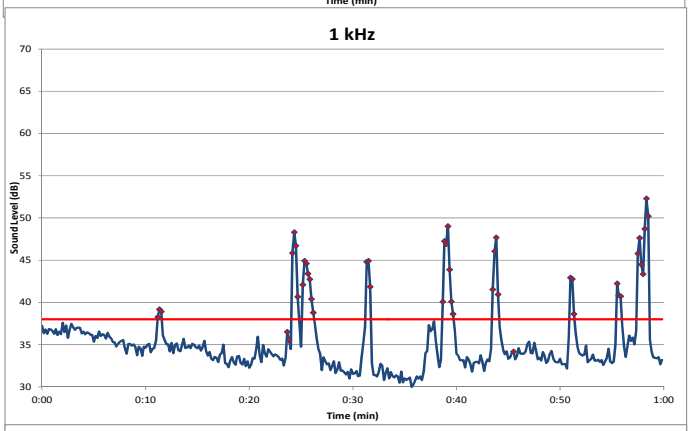

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NOV 3

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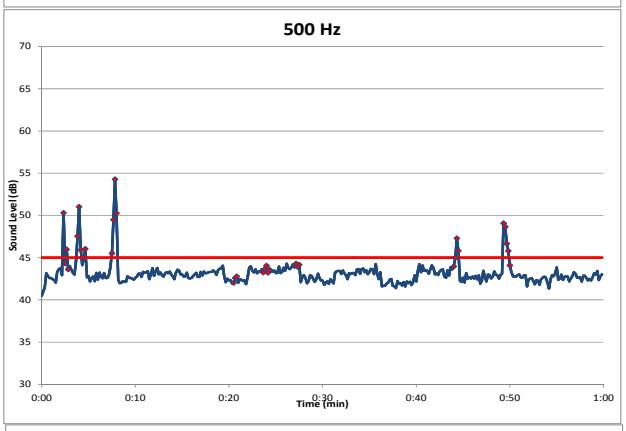

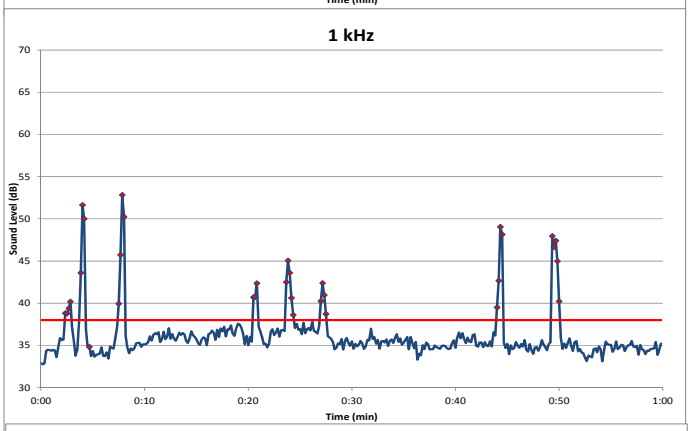

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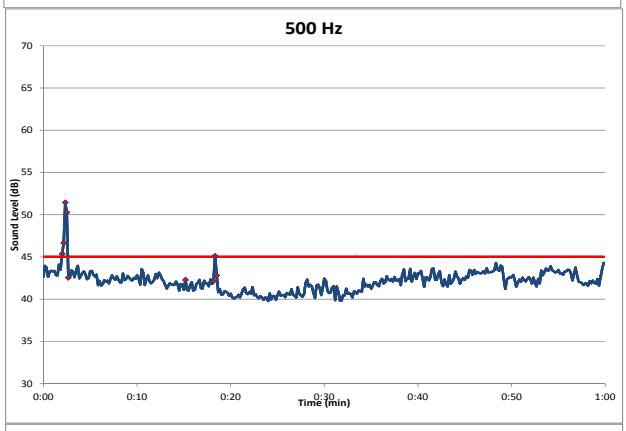

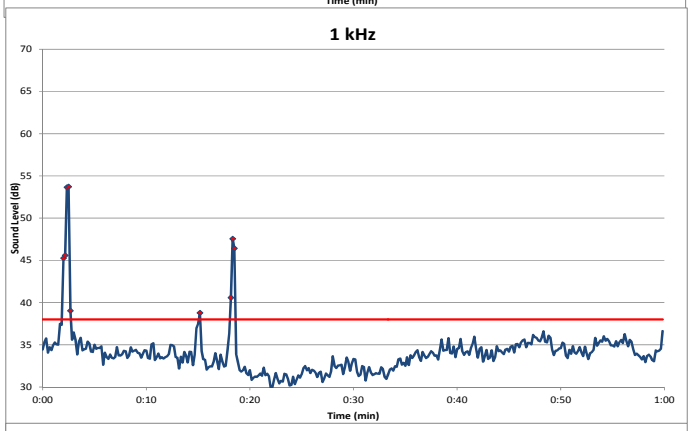

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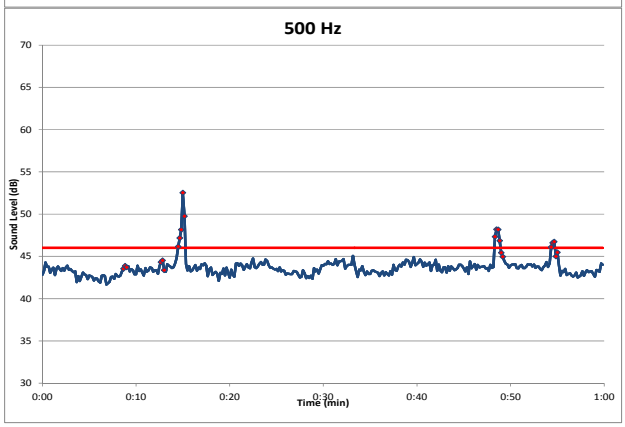
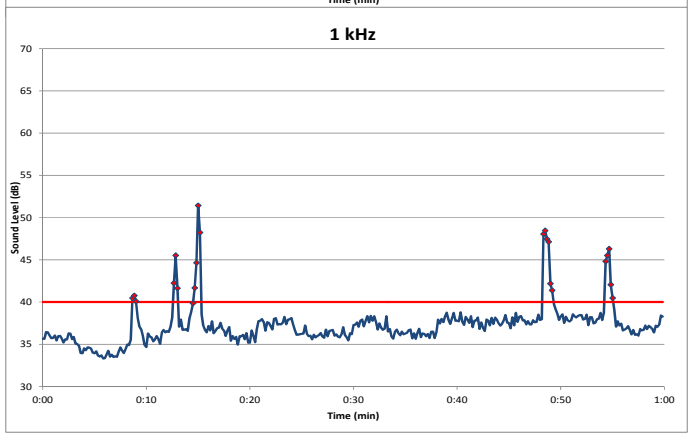
NOV 4

0:00





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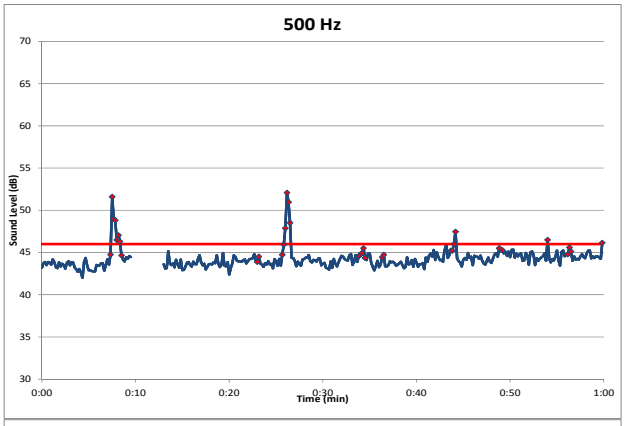

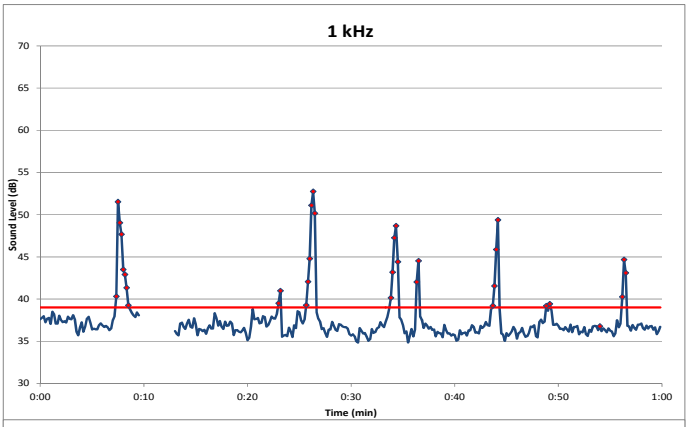

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NOV 4

2:00

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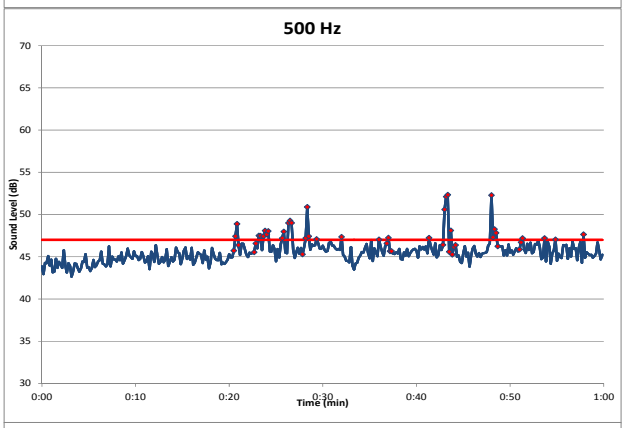

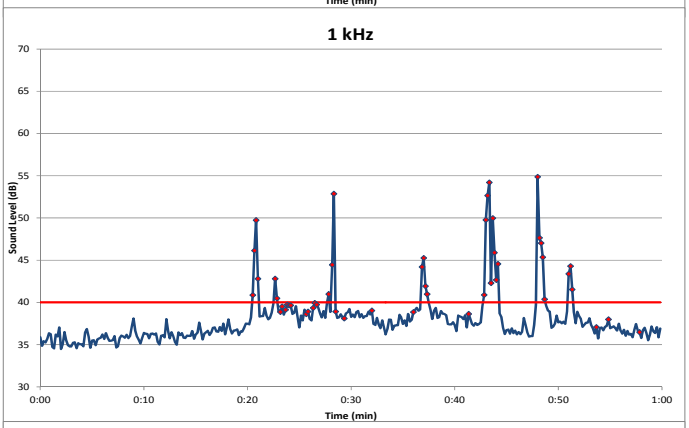

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NOV 4

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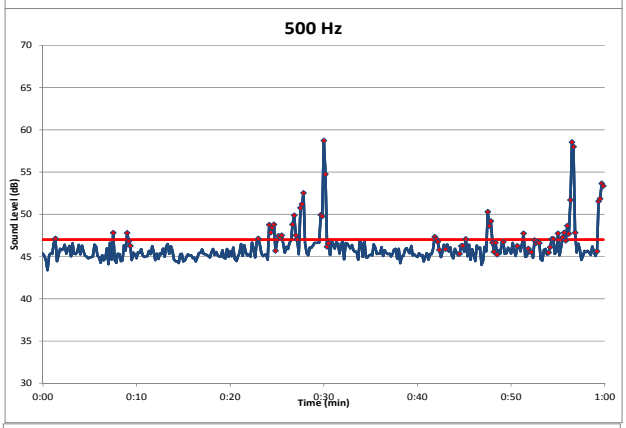

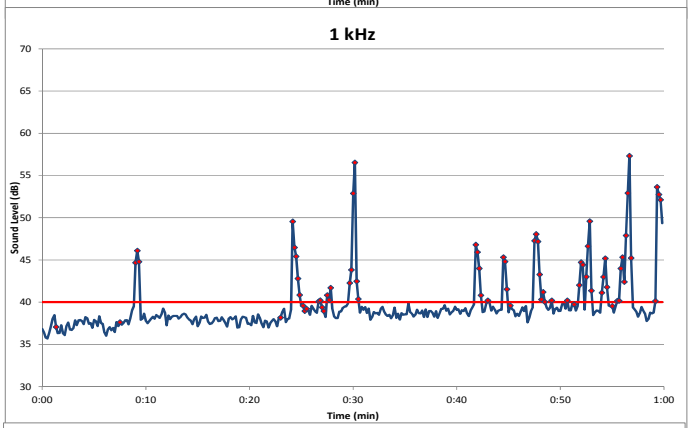

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NOV 4

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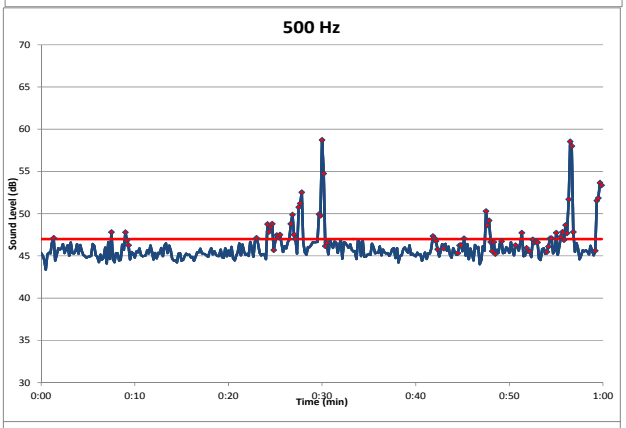

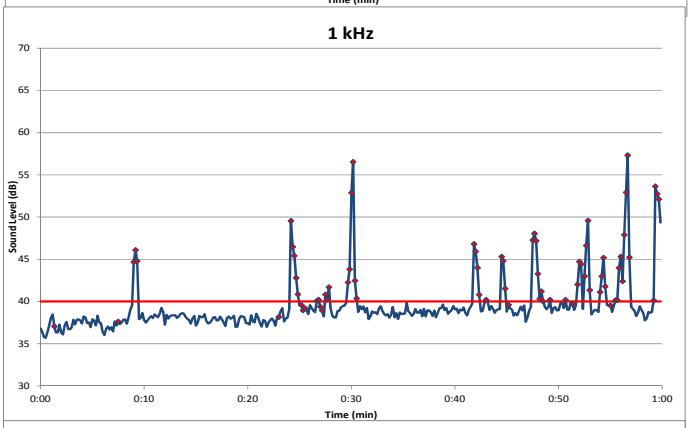

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NOV 4

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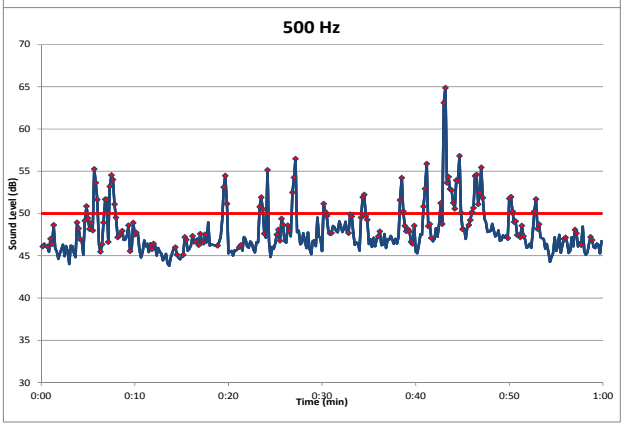

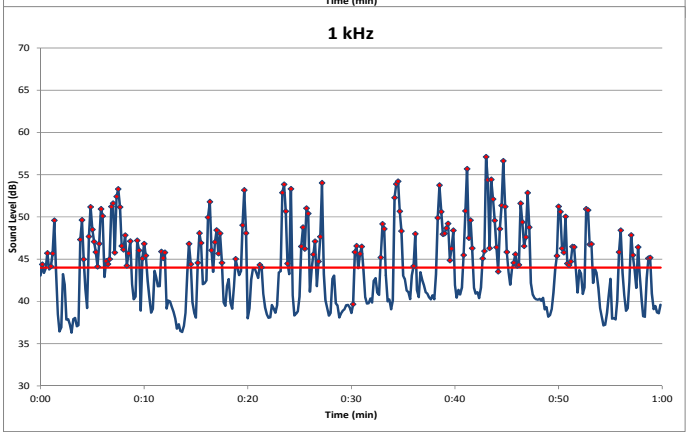

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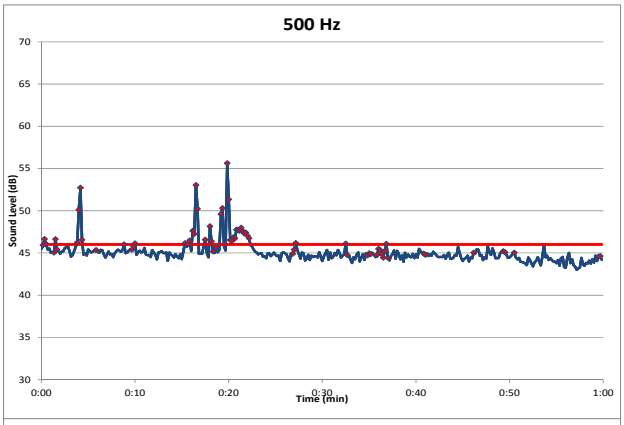

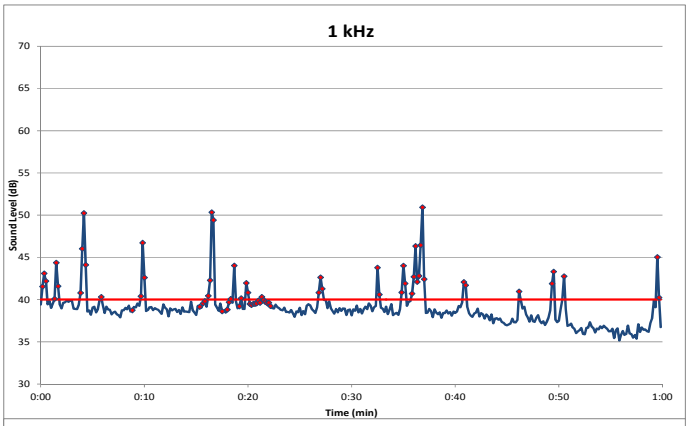

2013

NOV 4

22:00

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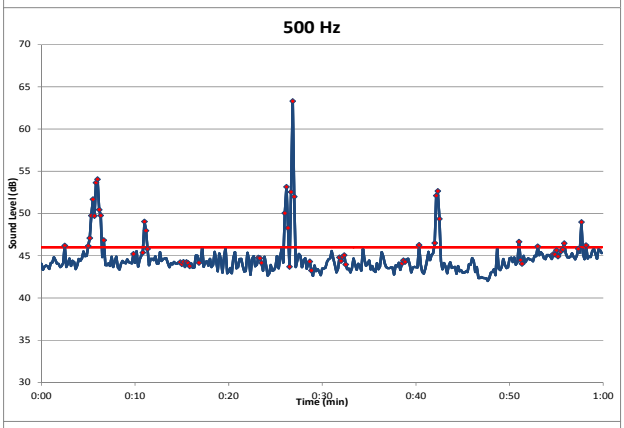

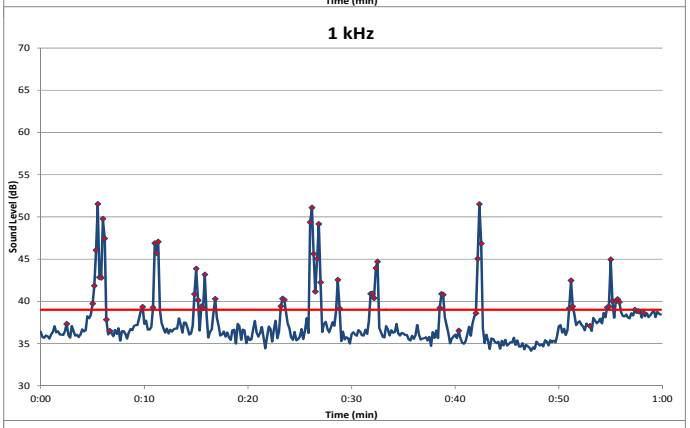

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NOV 4

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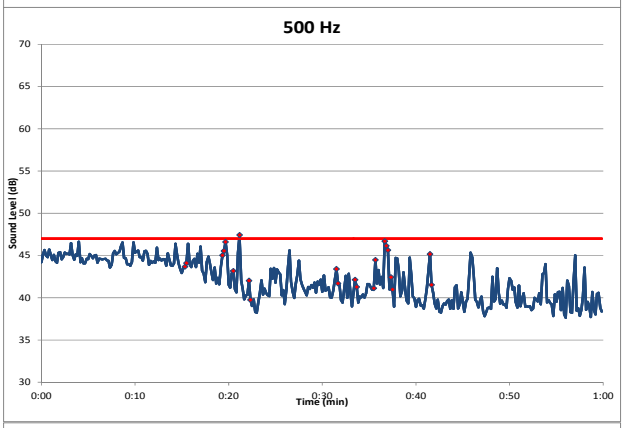

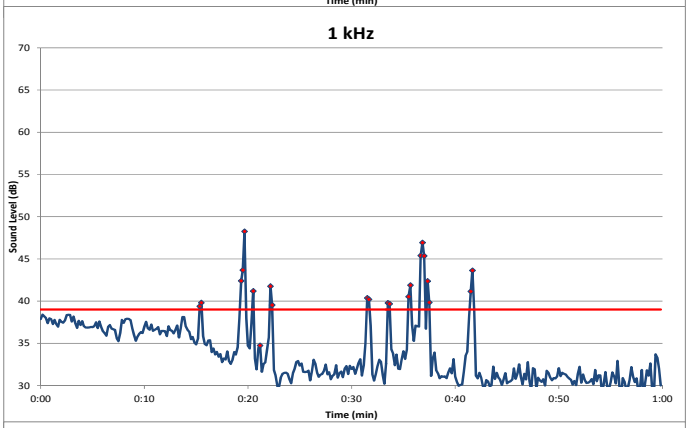

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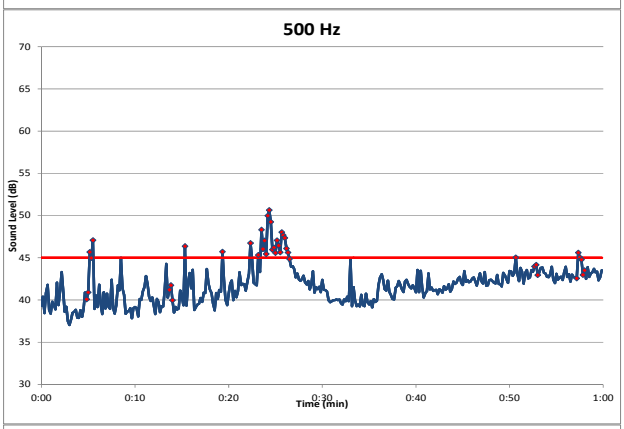

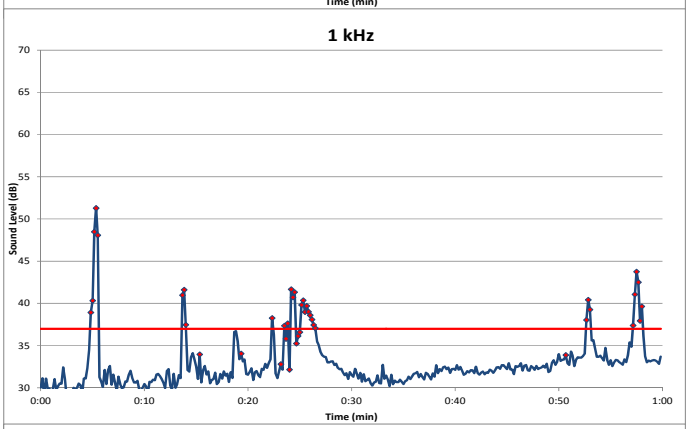

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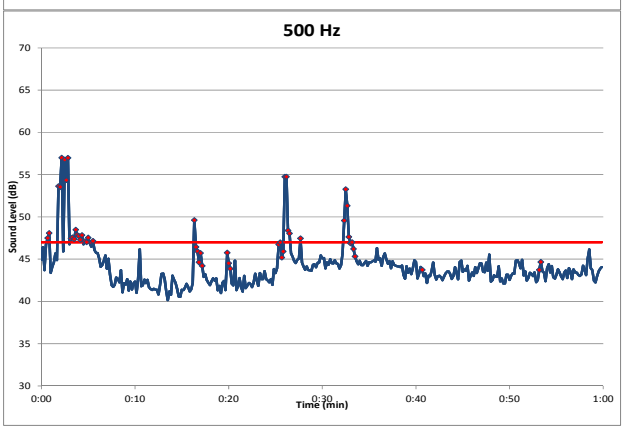

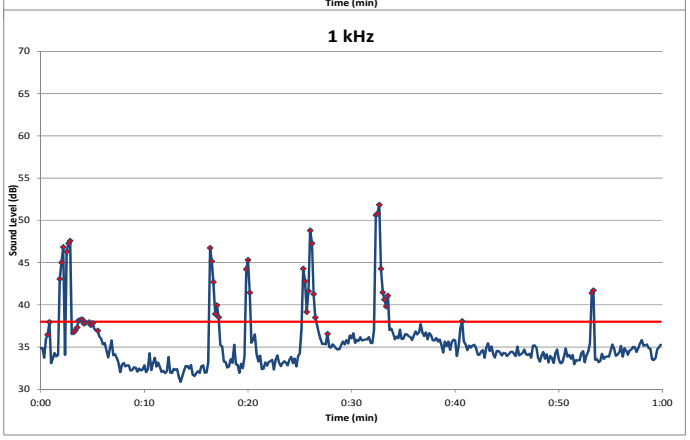

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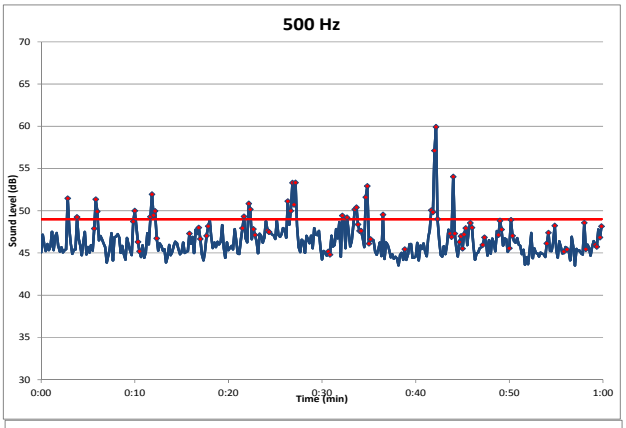

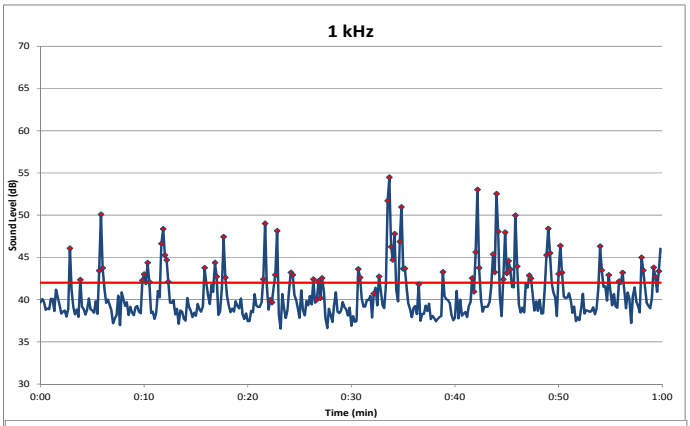

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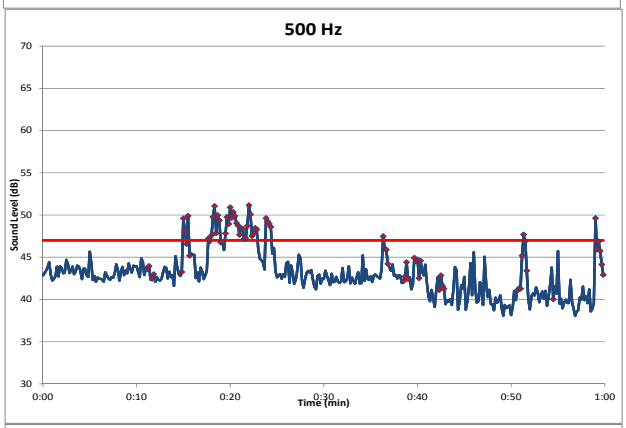

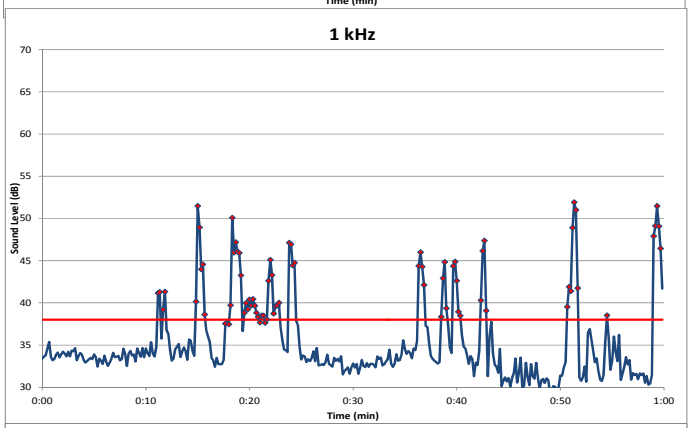

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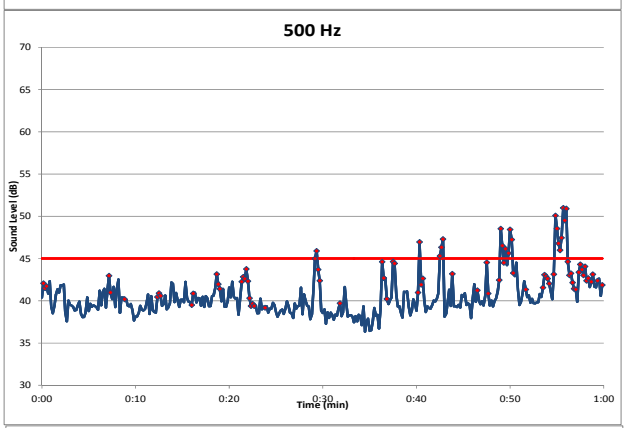

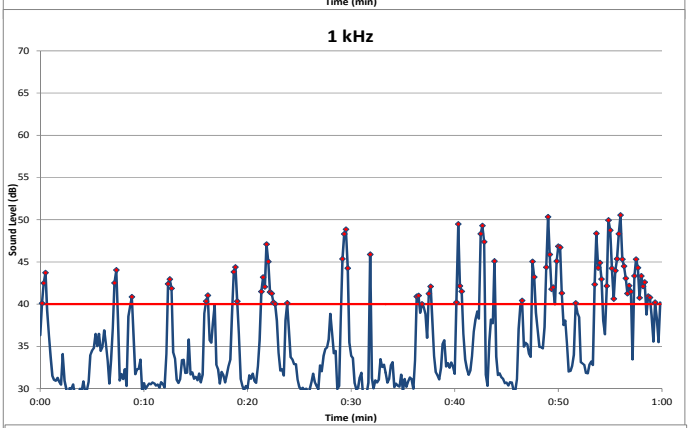

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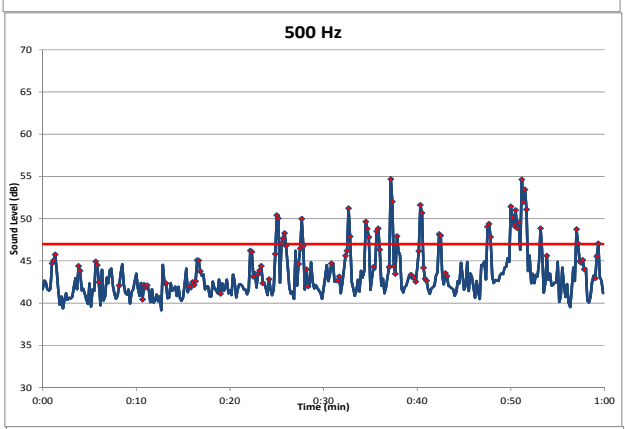

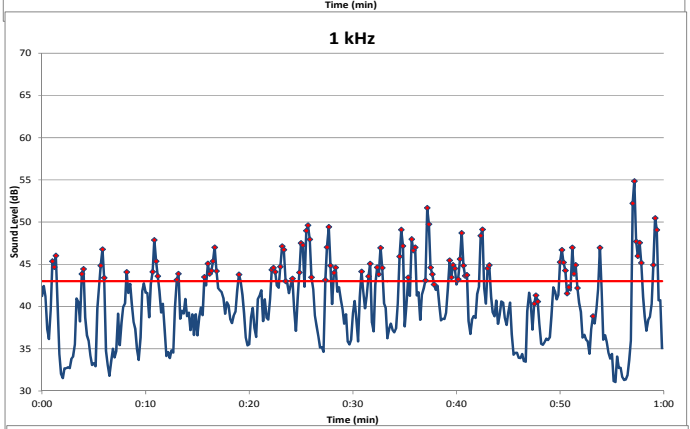

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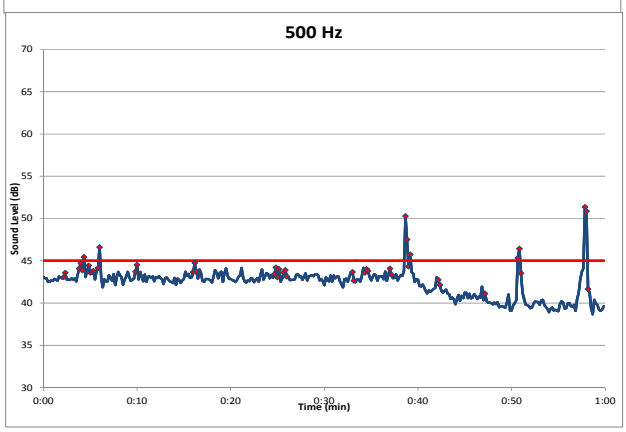

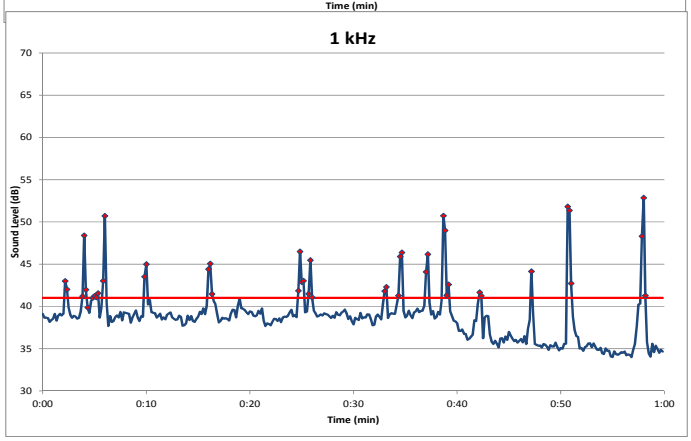

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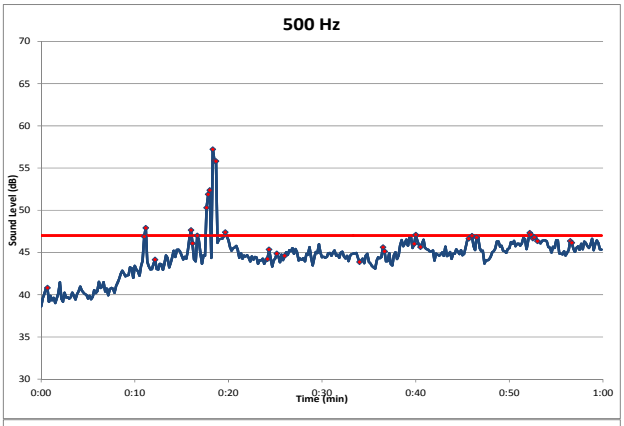

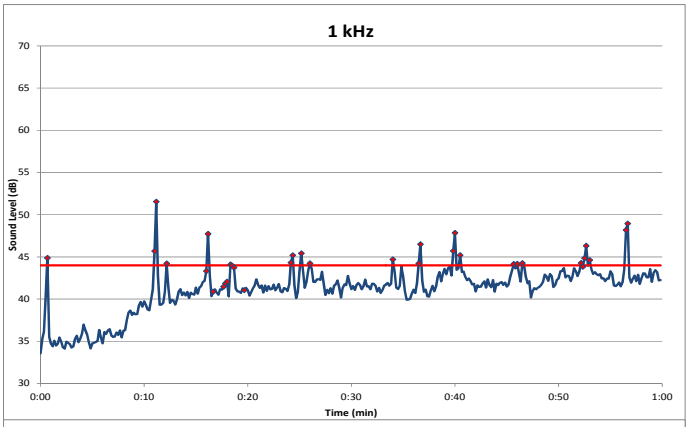

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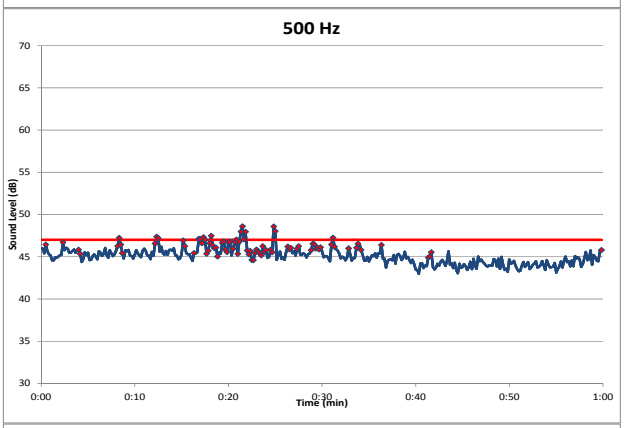

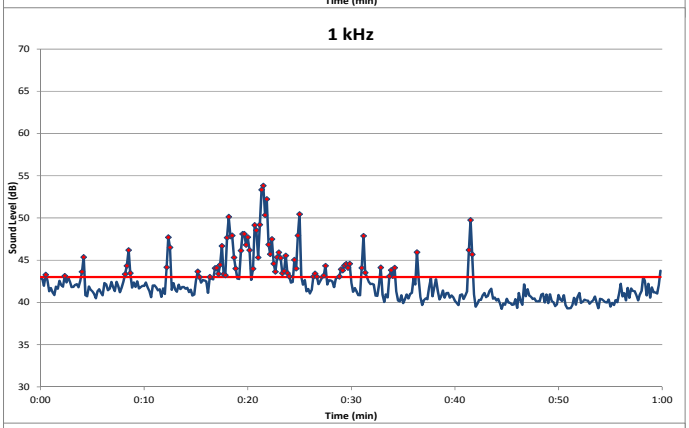

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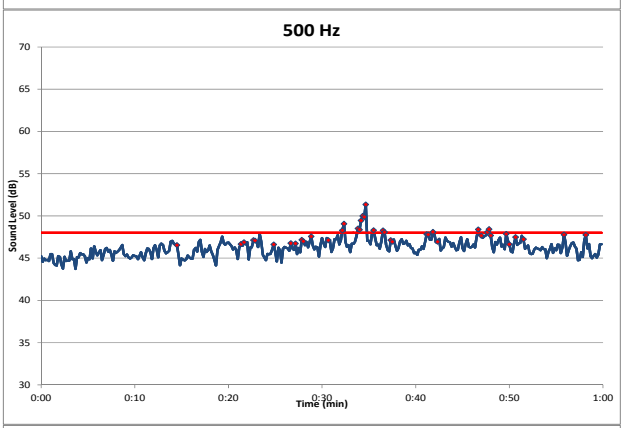

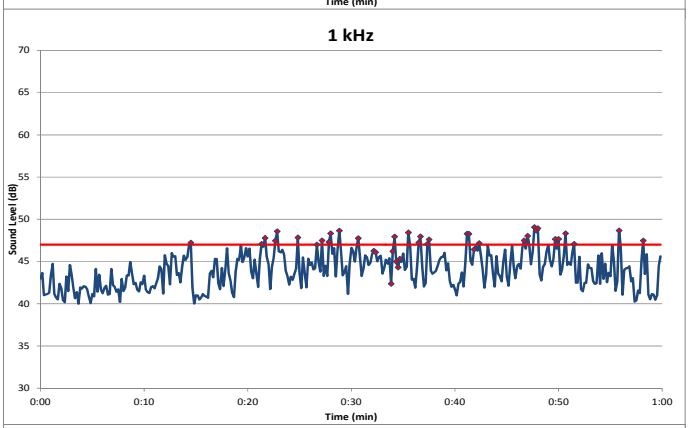

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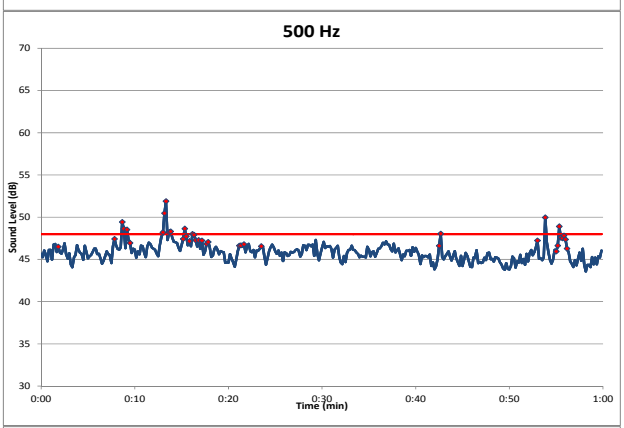

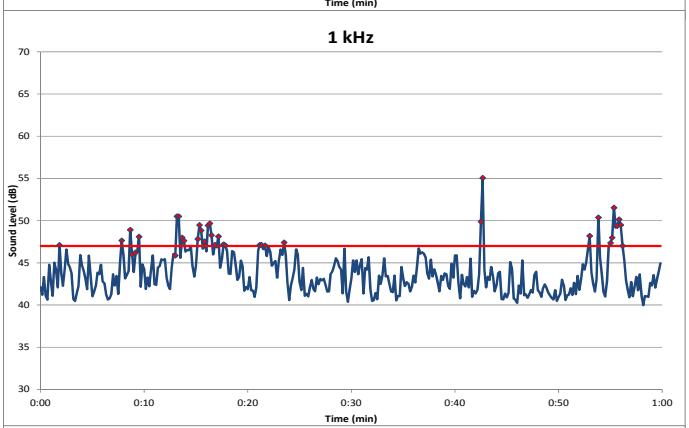

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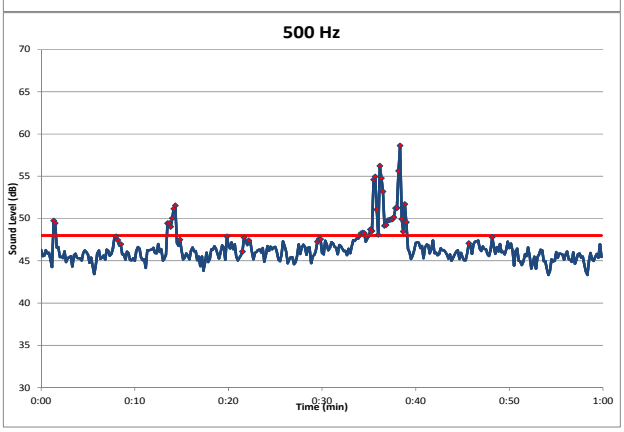

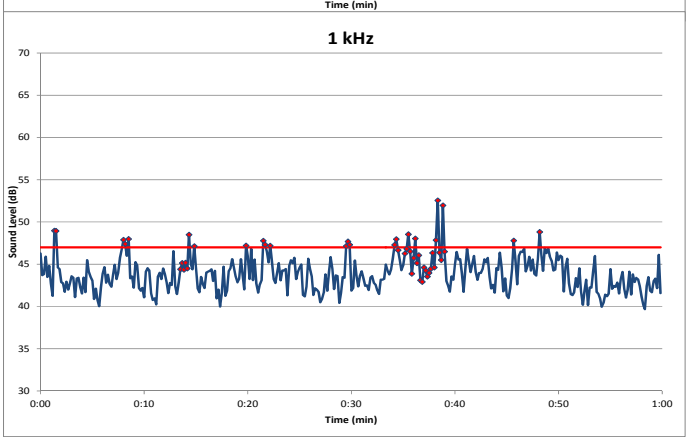

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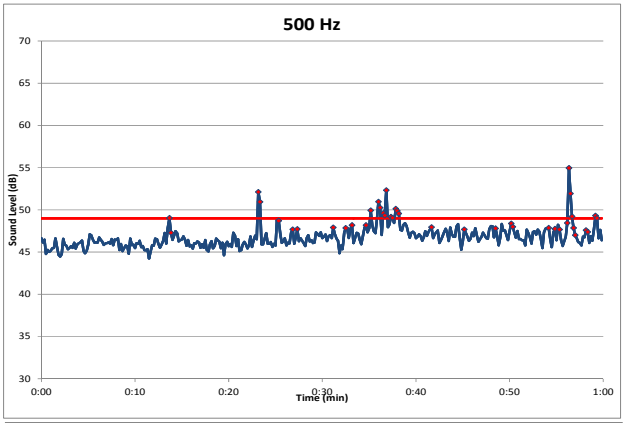

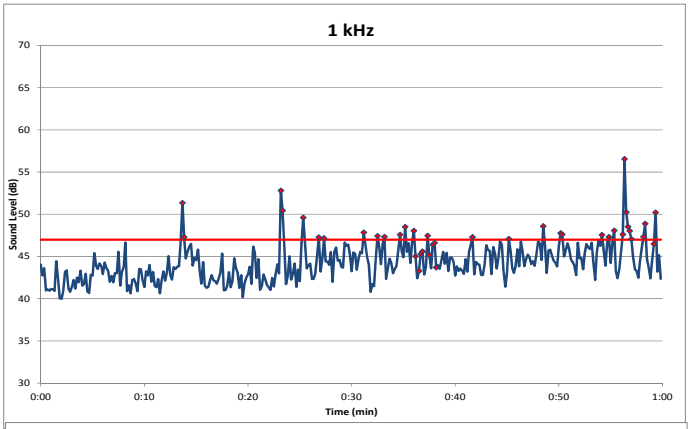

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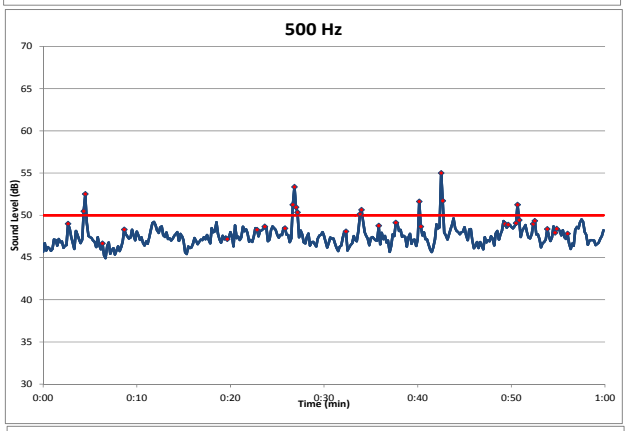

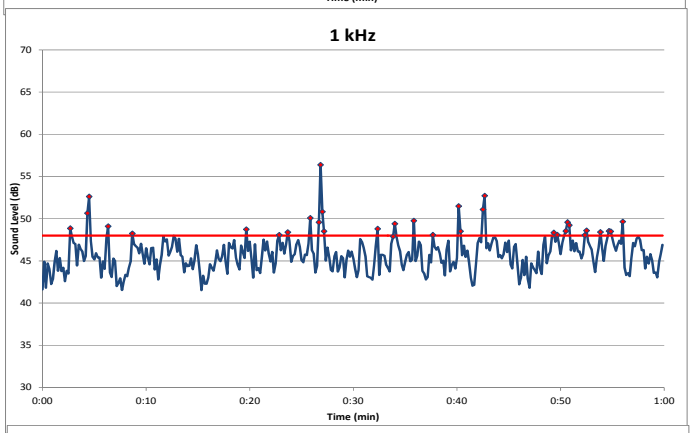

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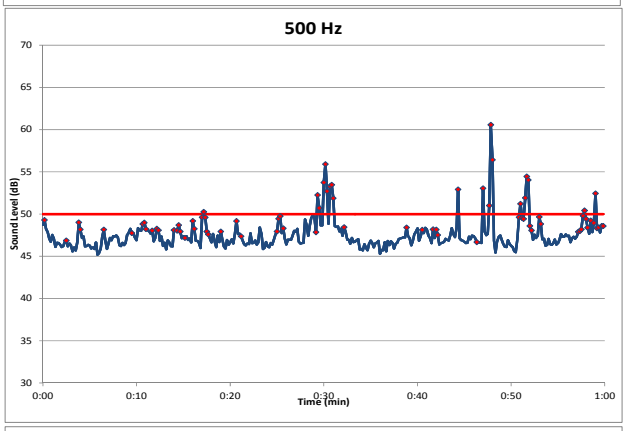

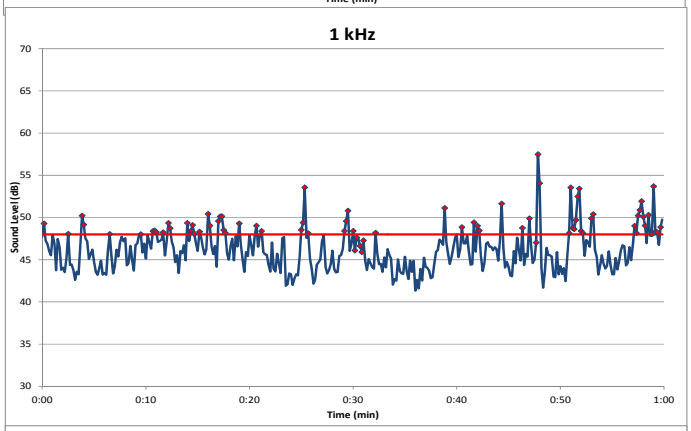

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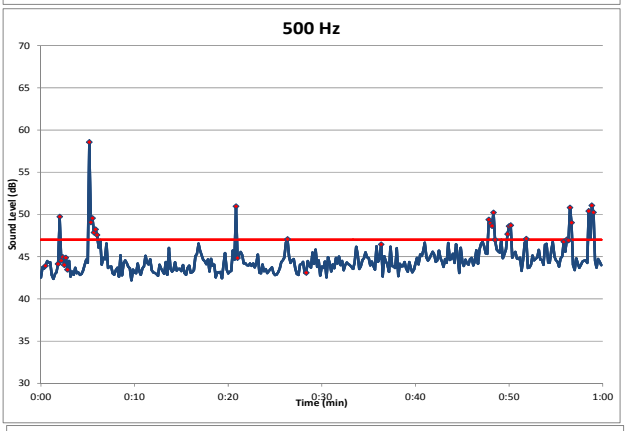

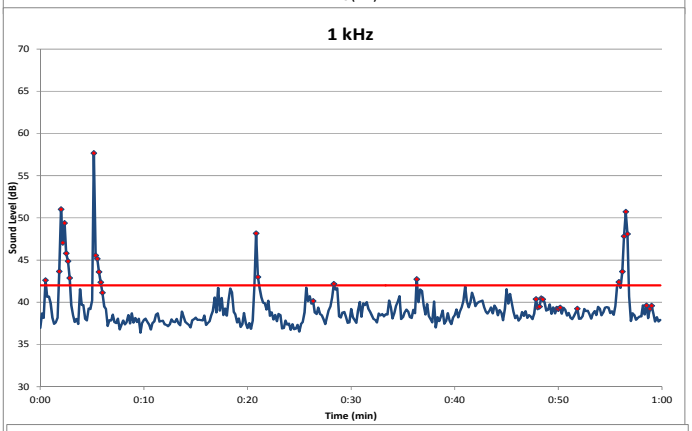

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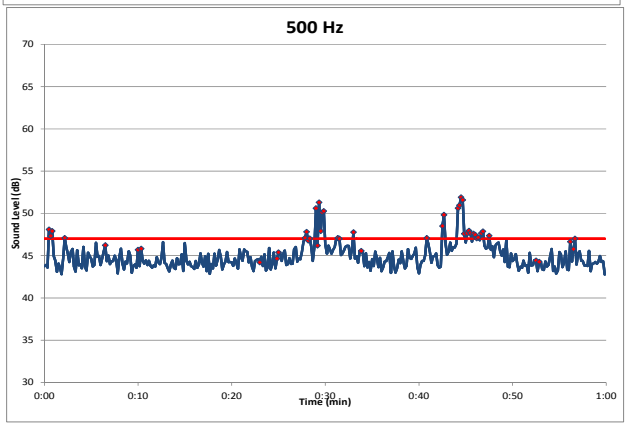

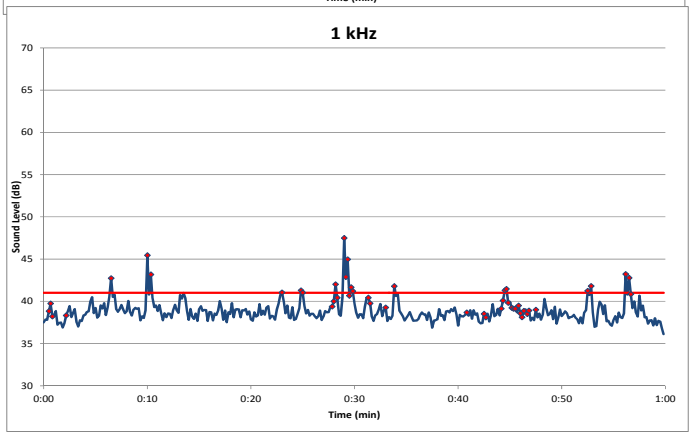

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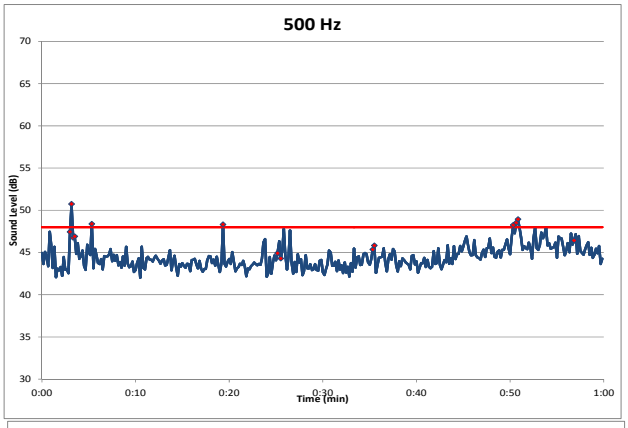

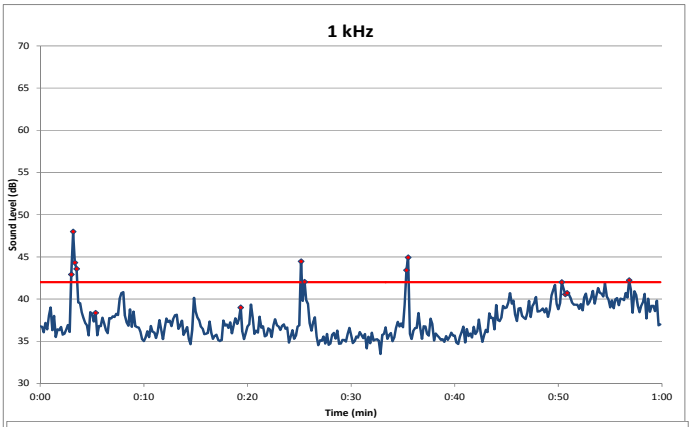

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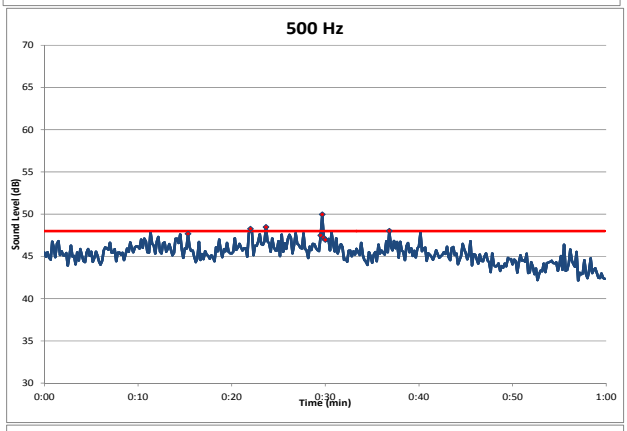

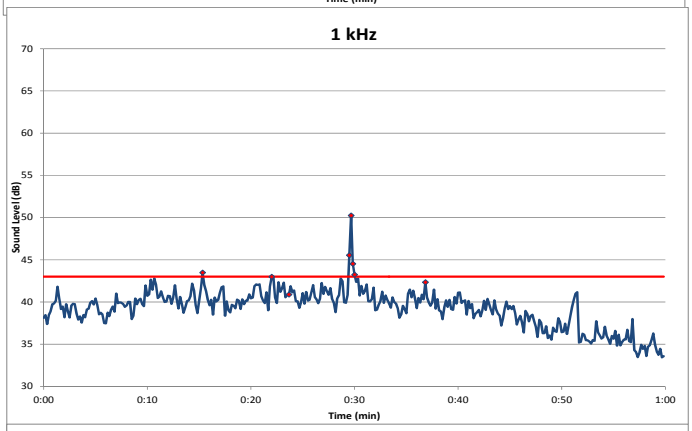

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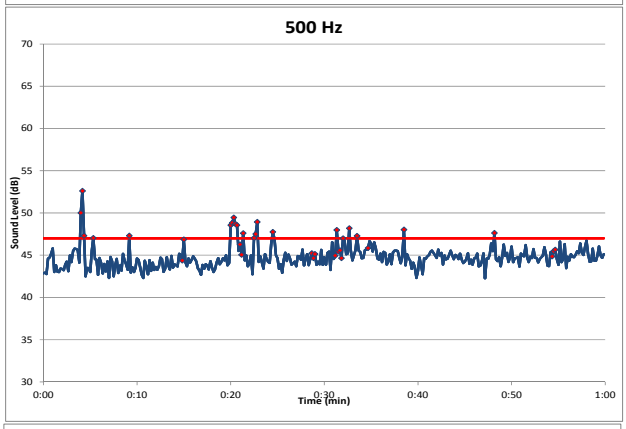

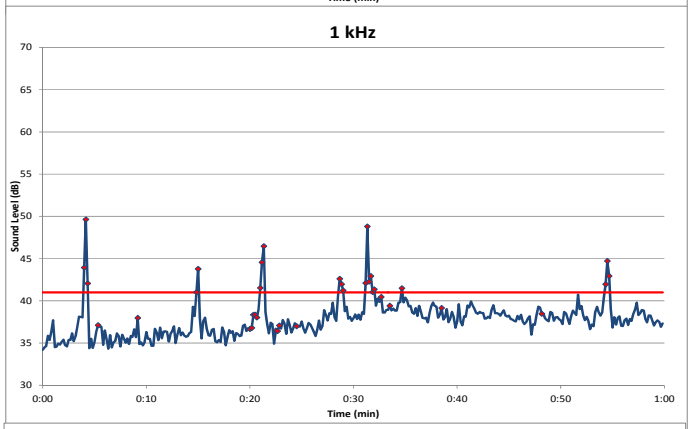

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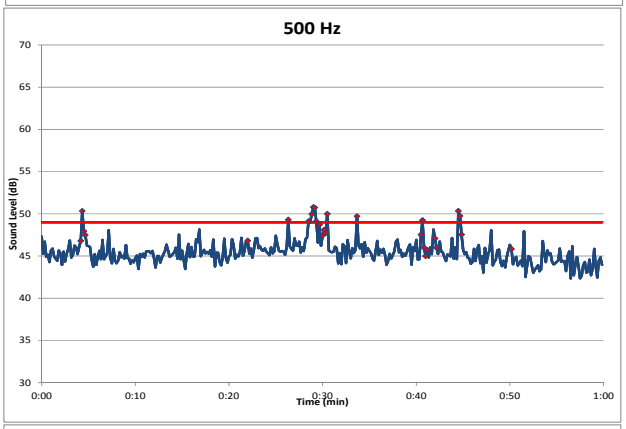

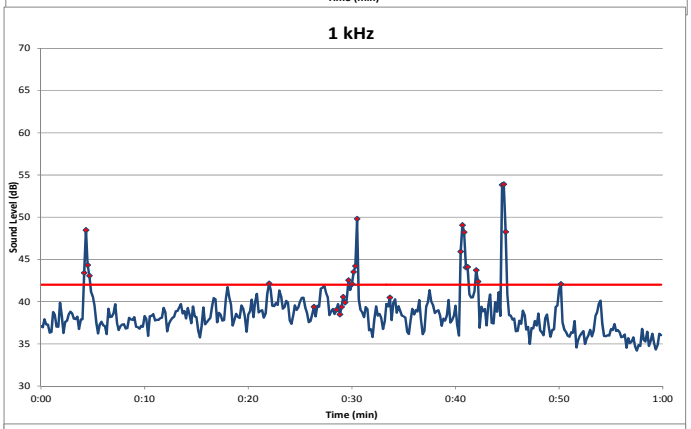

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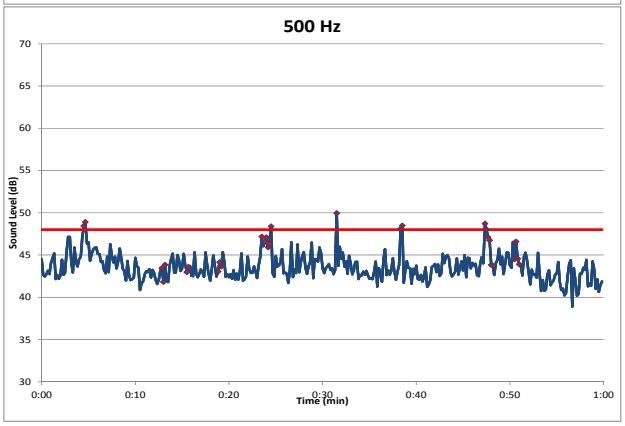

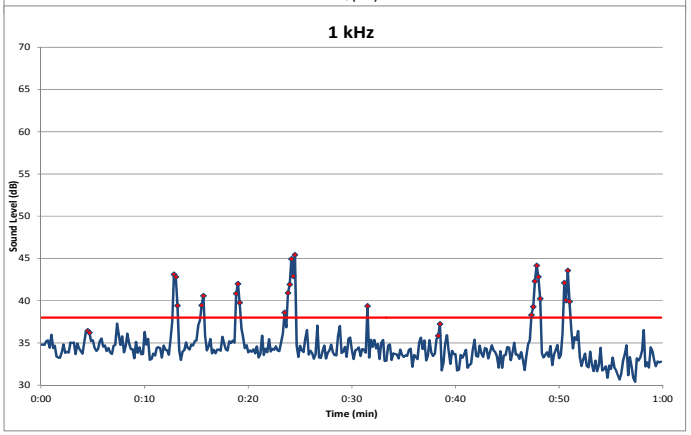

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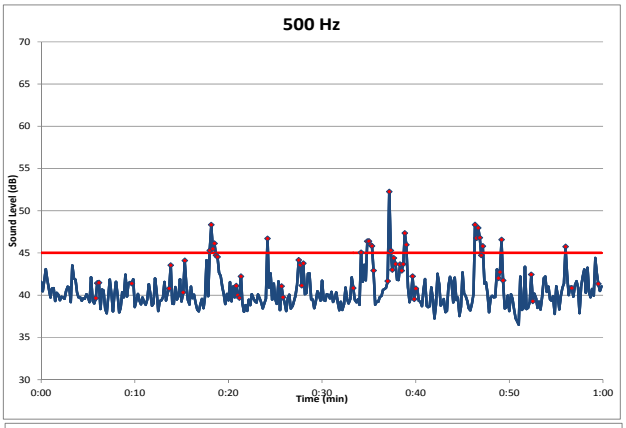

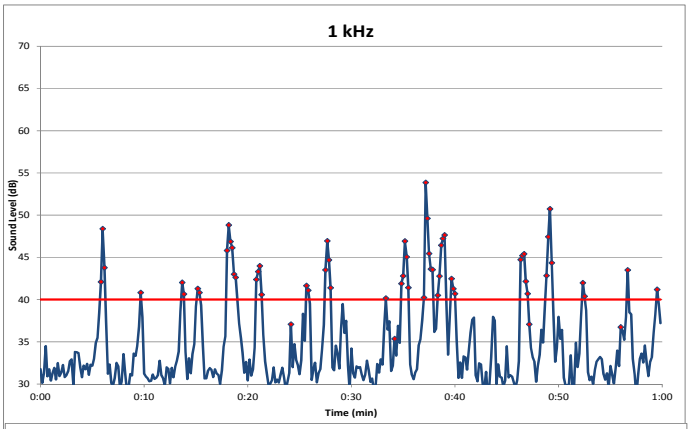

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NOV 7

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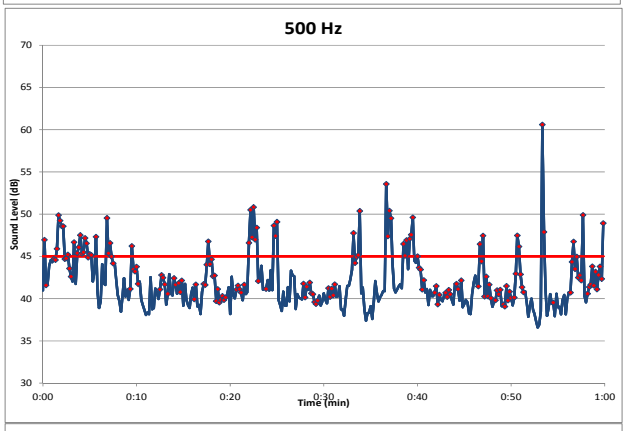

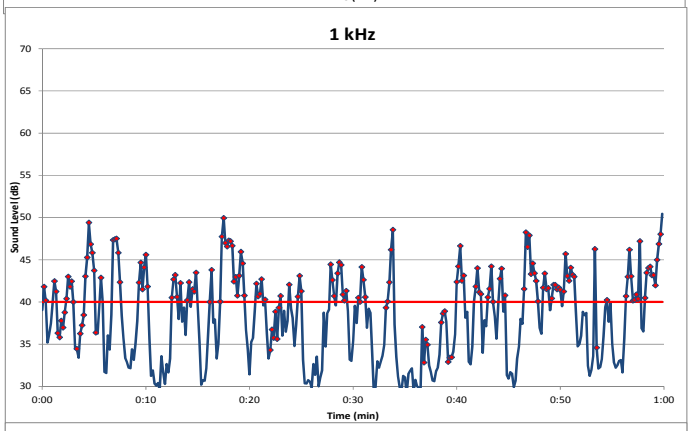

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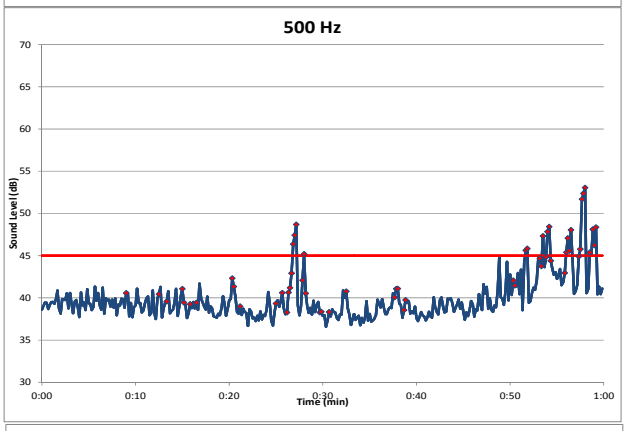

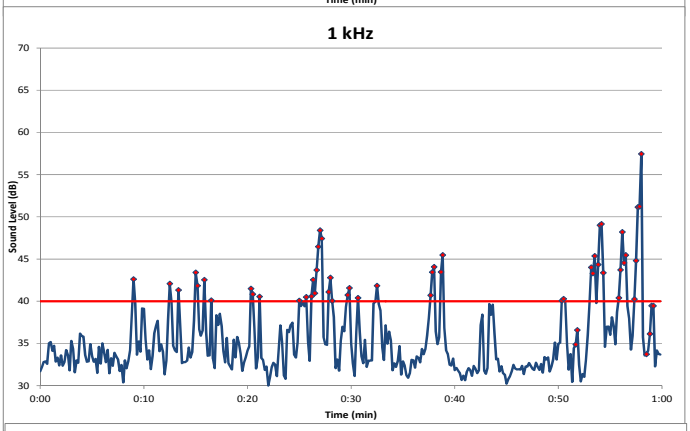

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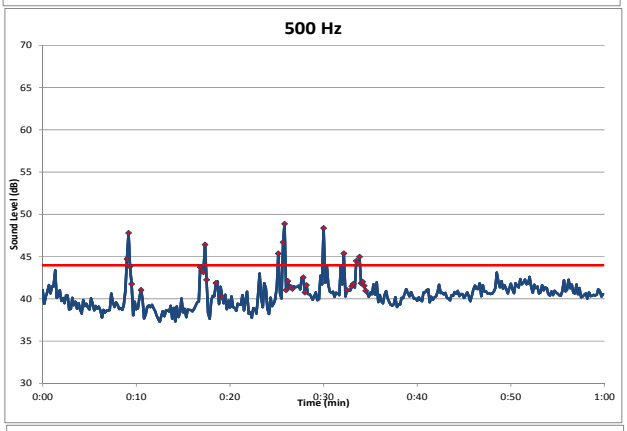

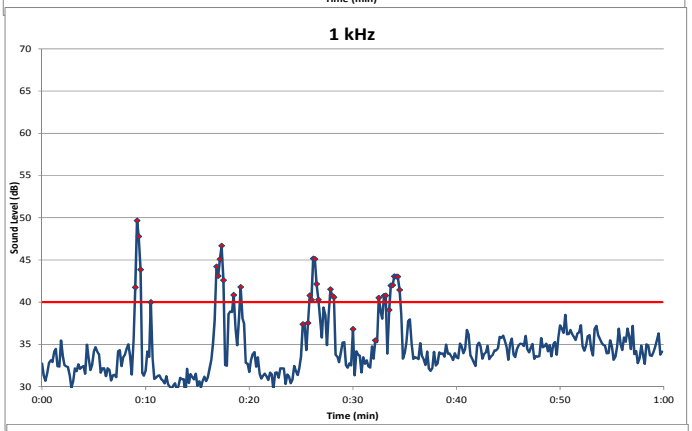

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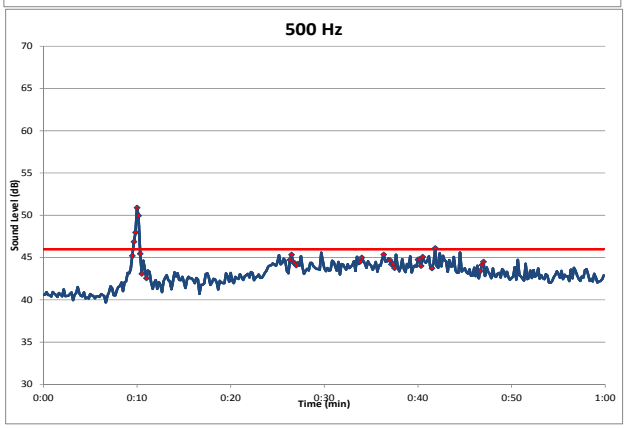

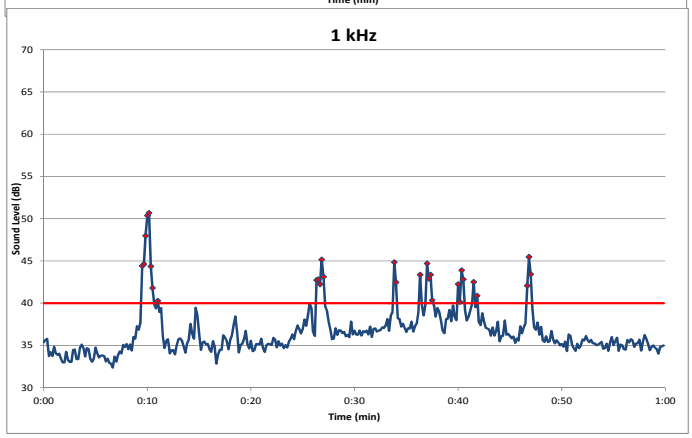

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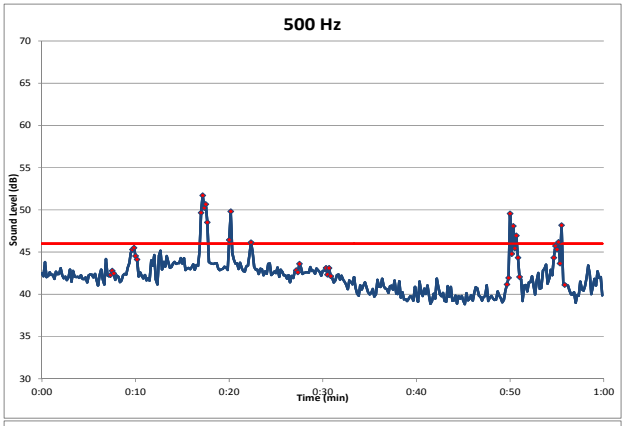

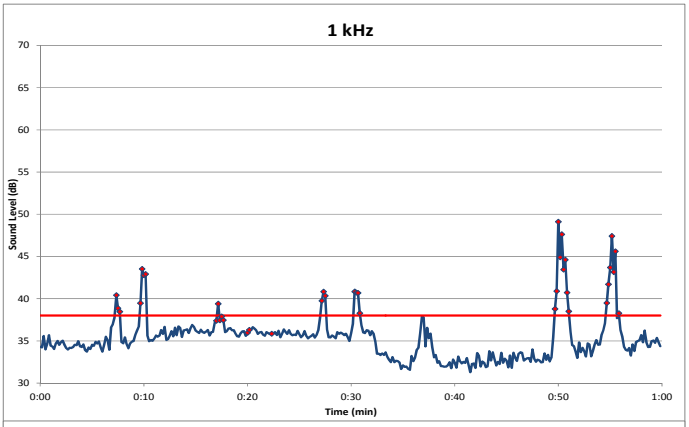

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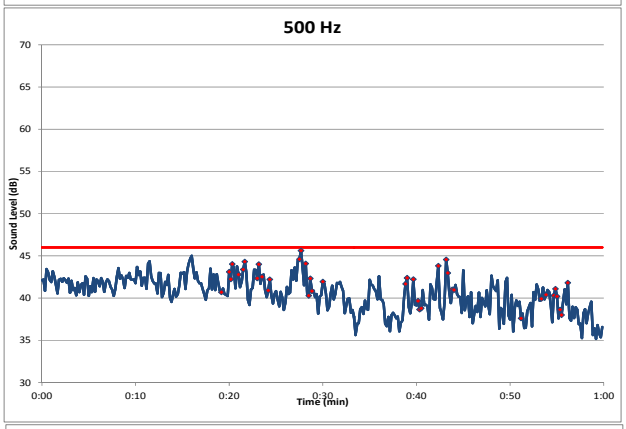

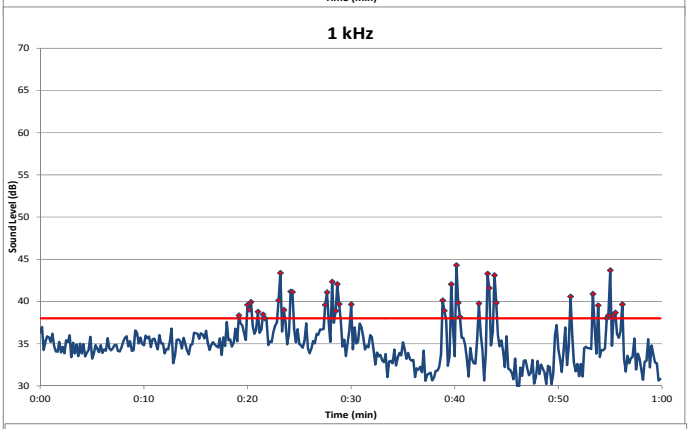

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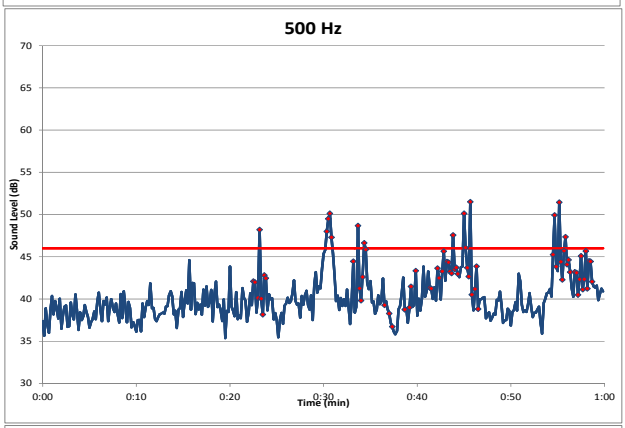

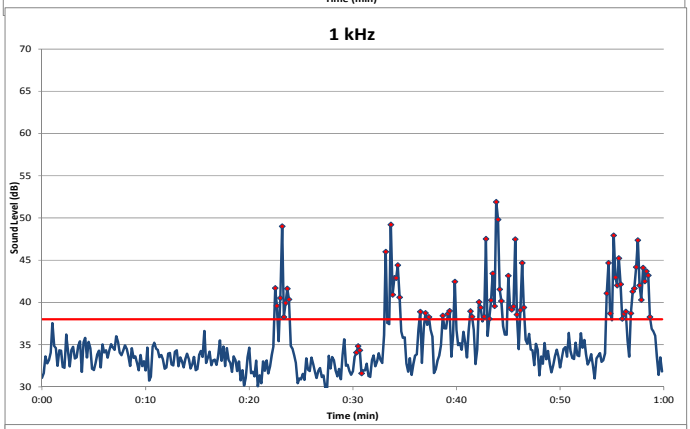

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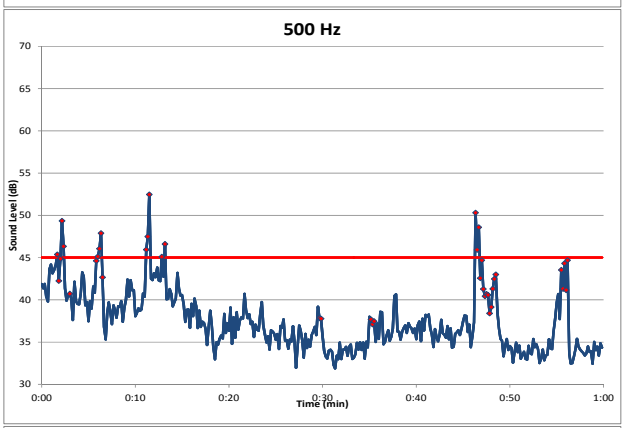

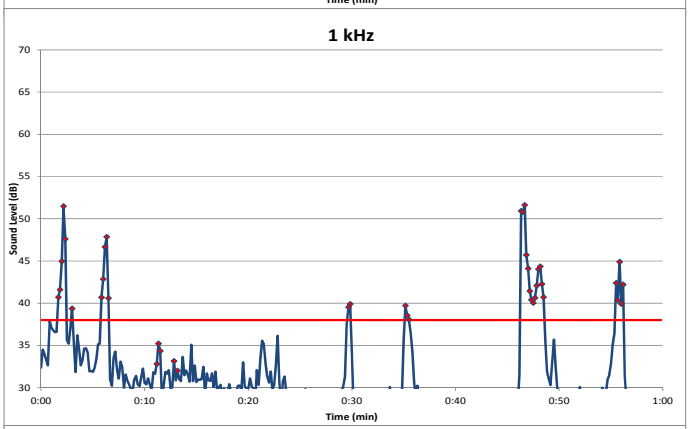

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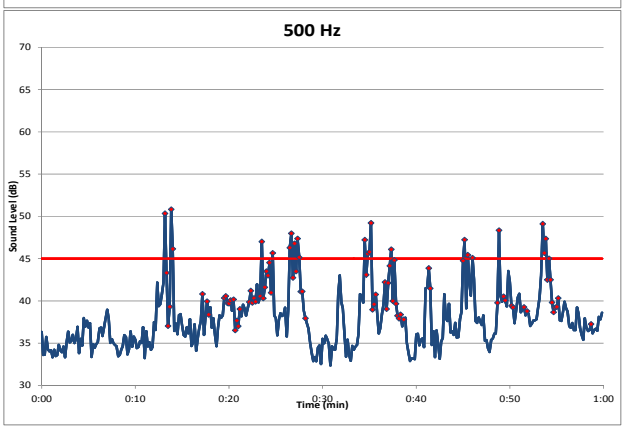

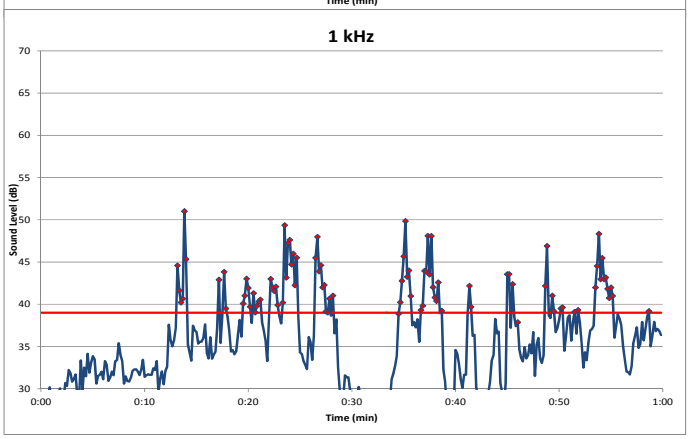

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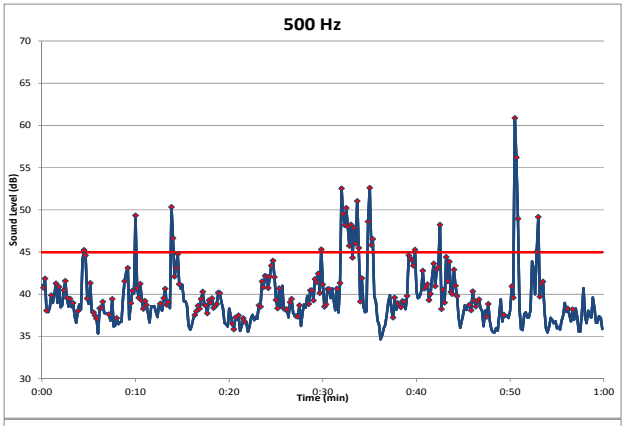

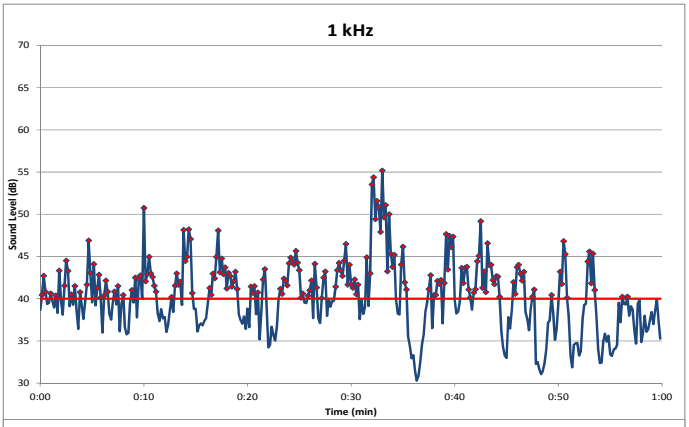

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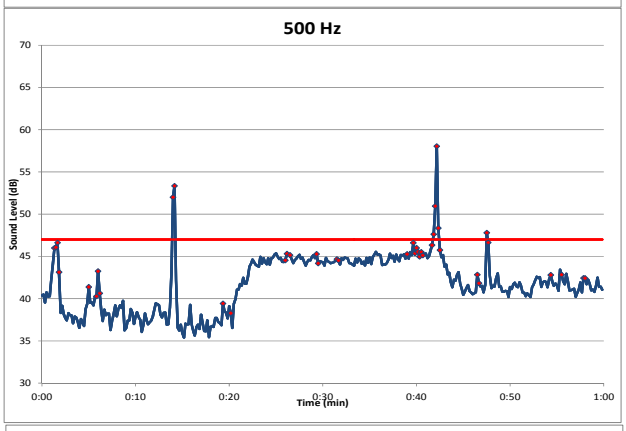

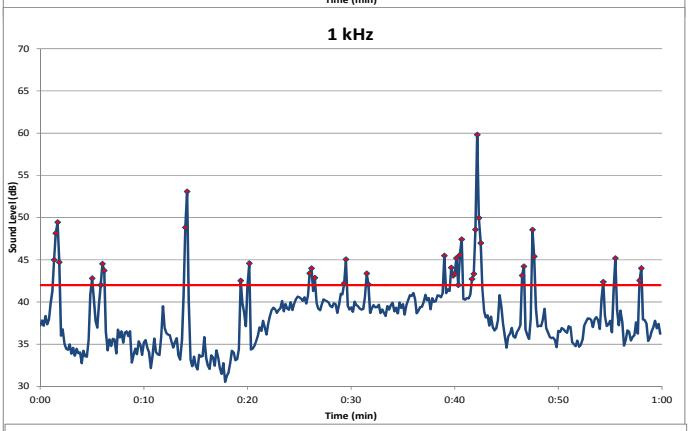

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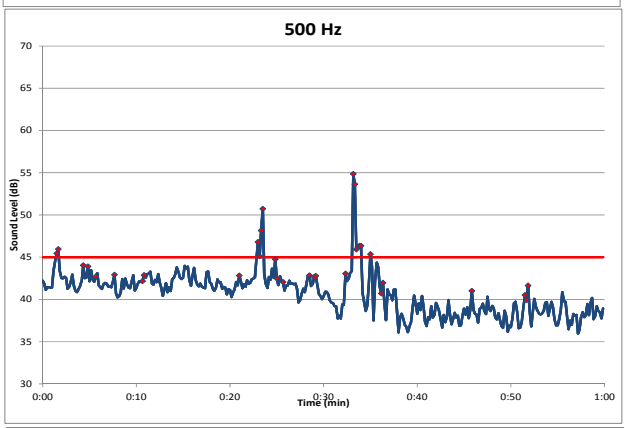

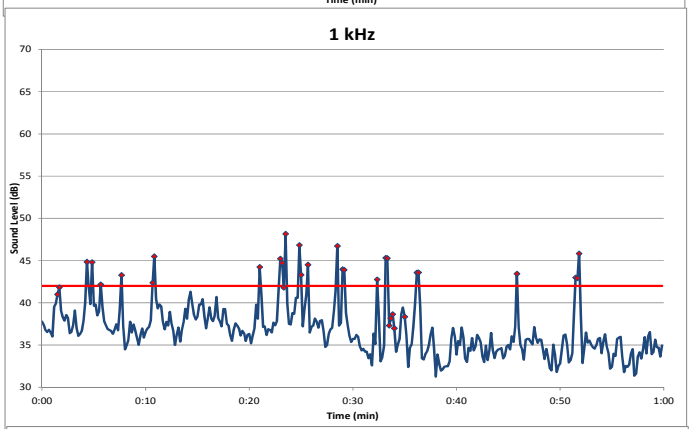

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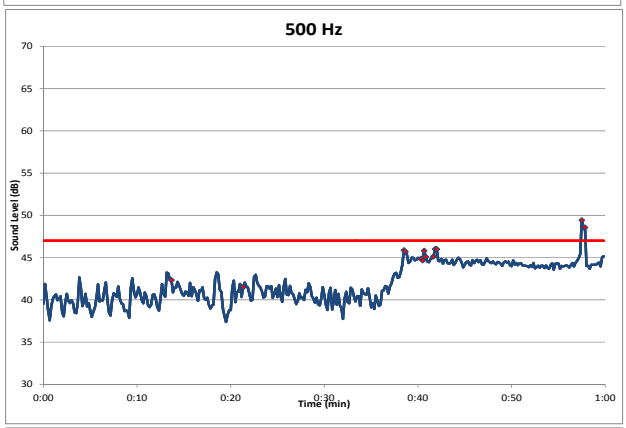

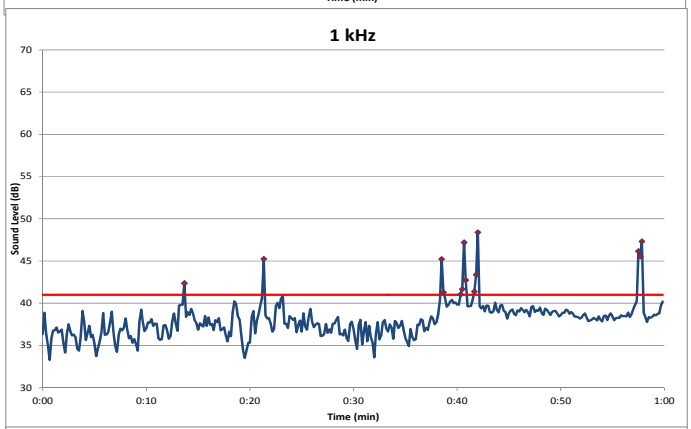

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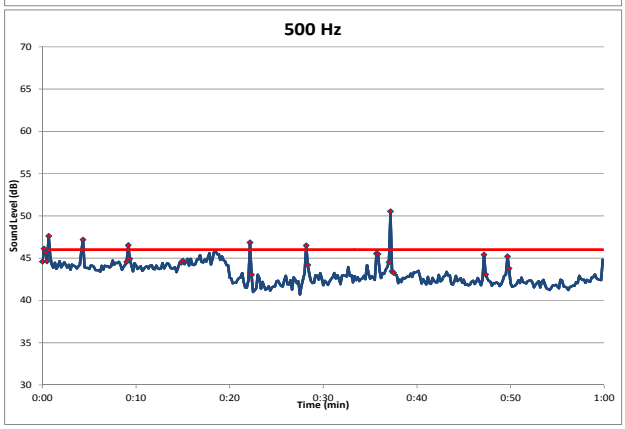

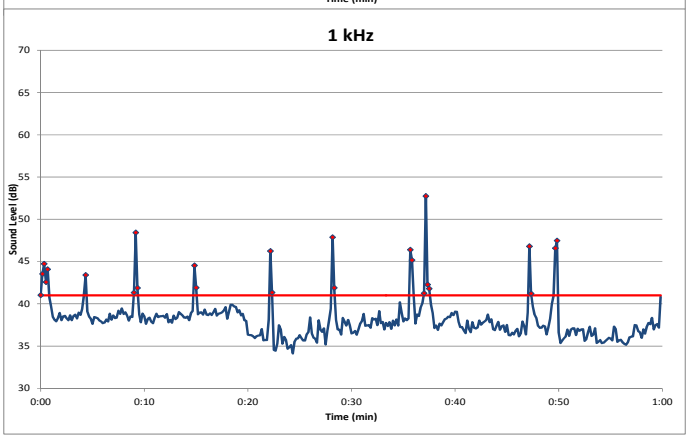

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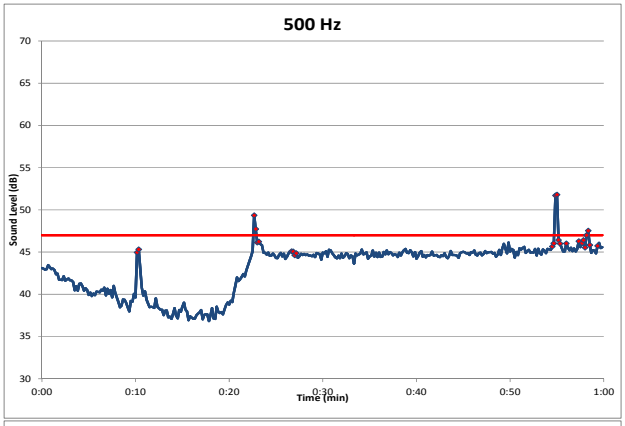

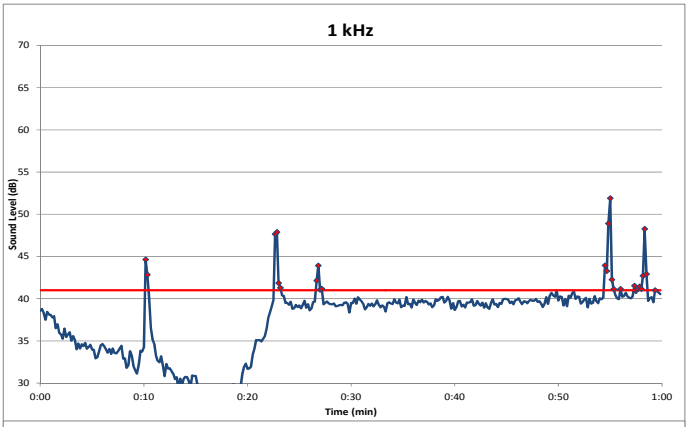

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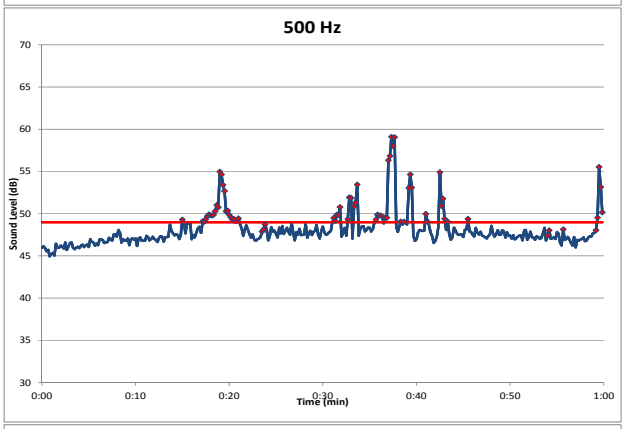

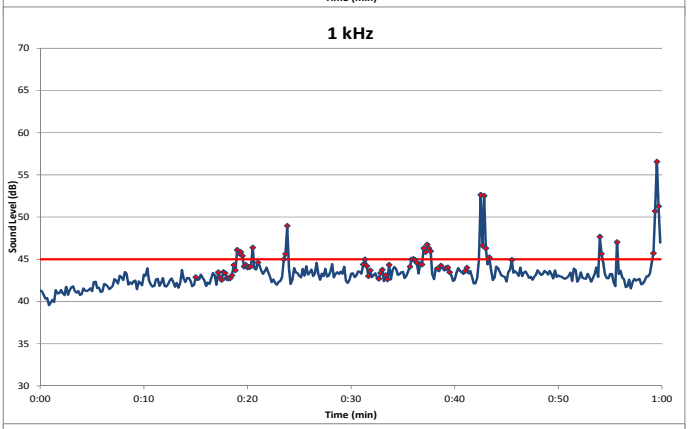

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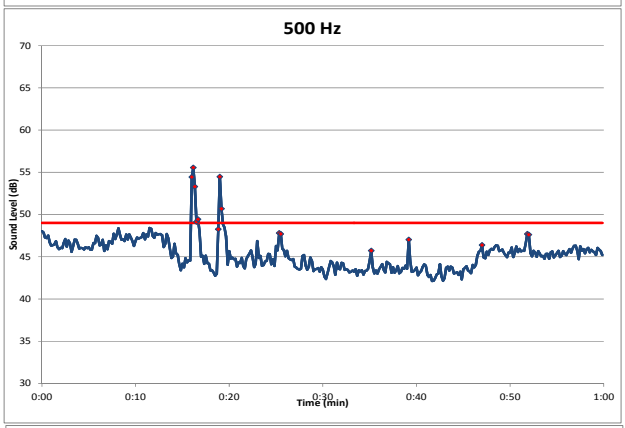

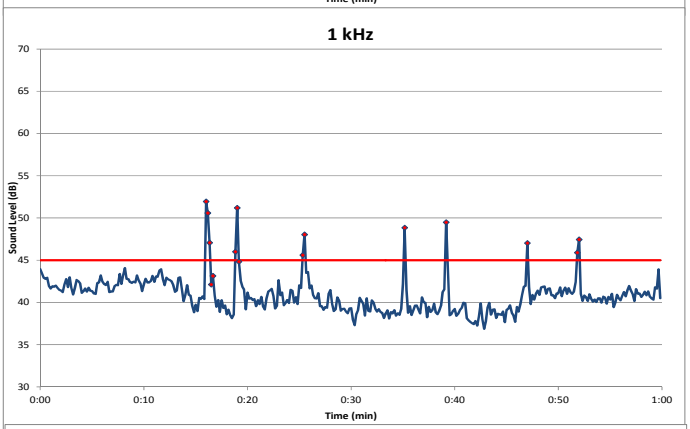

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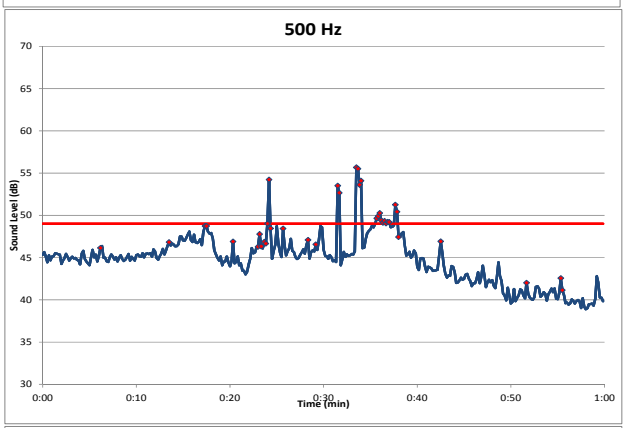

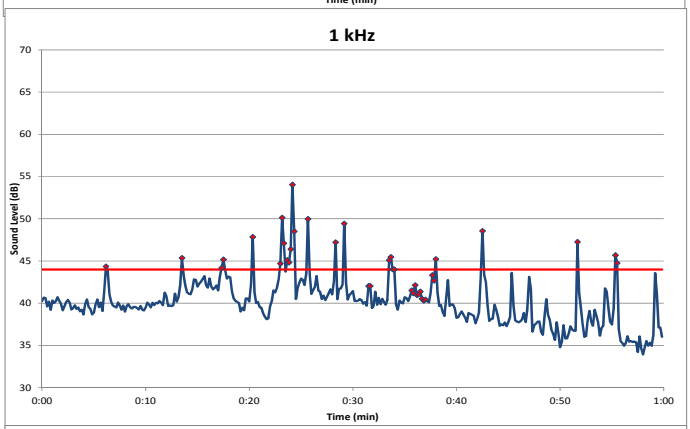

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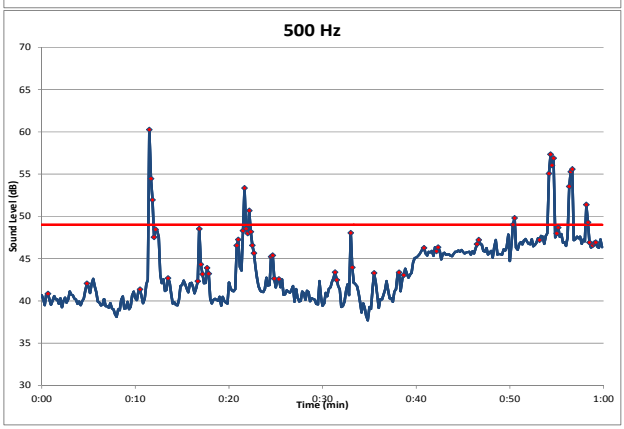

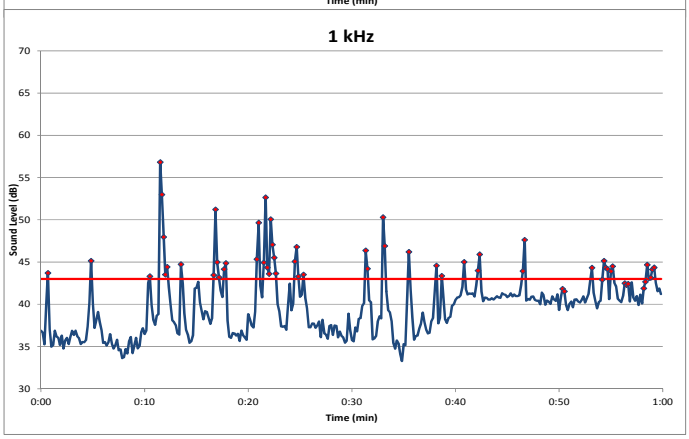

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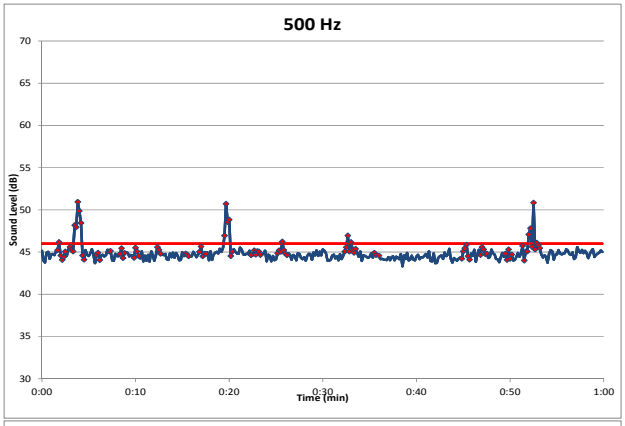

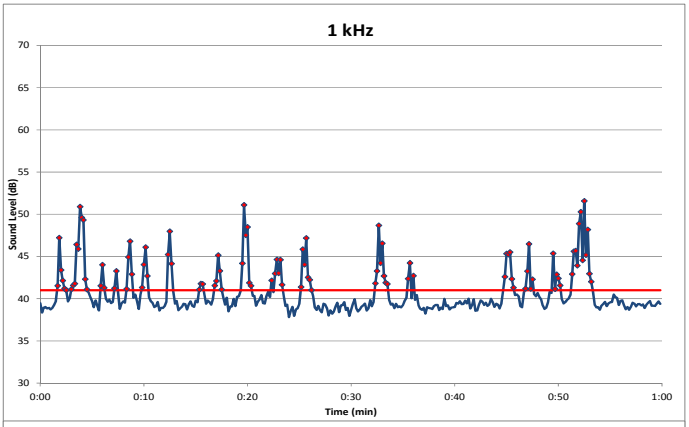

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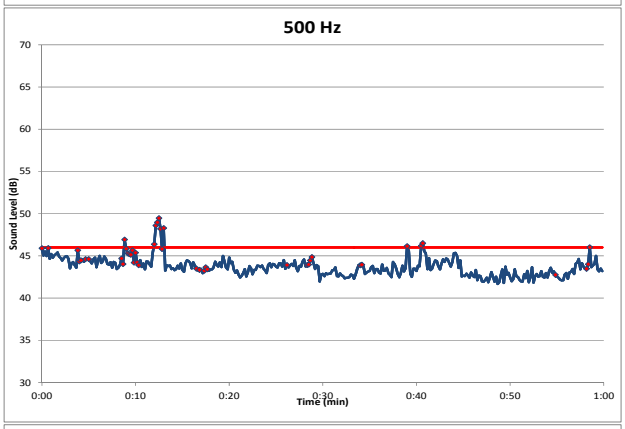

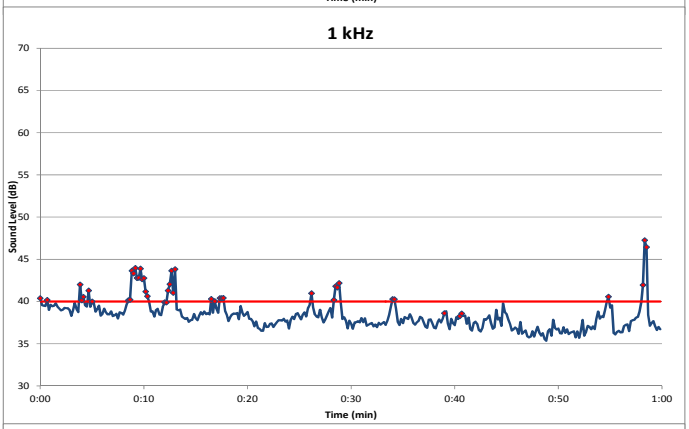

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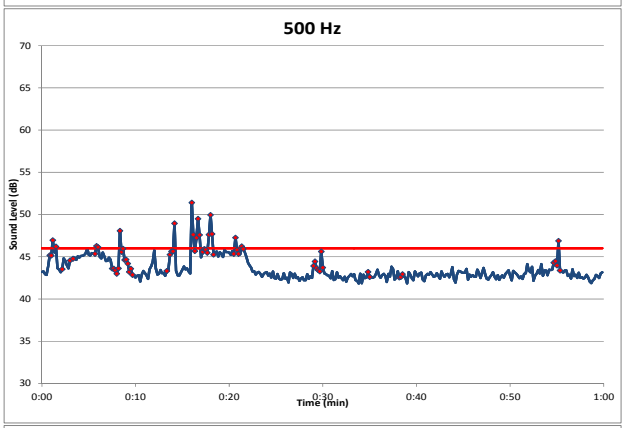

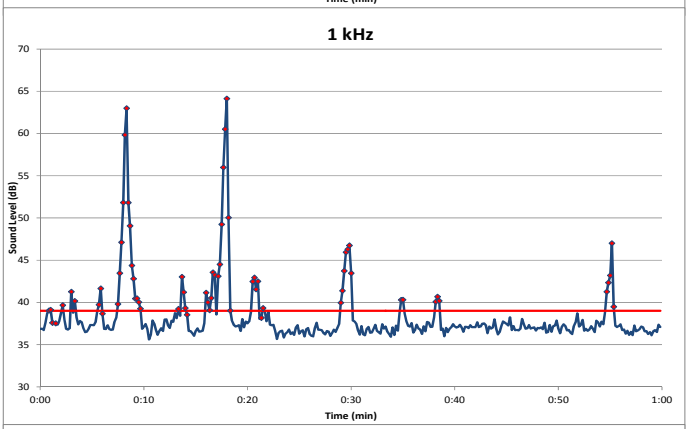

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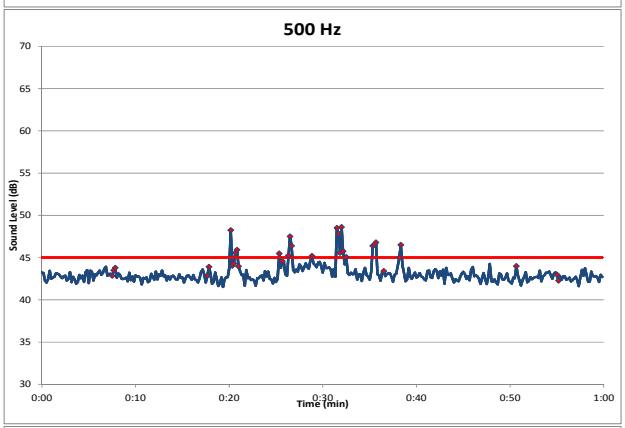

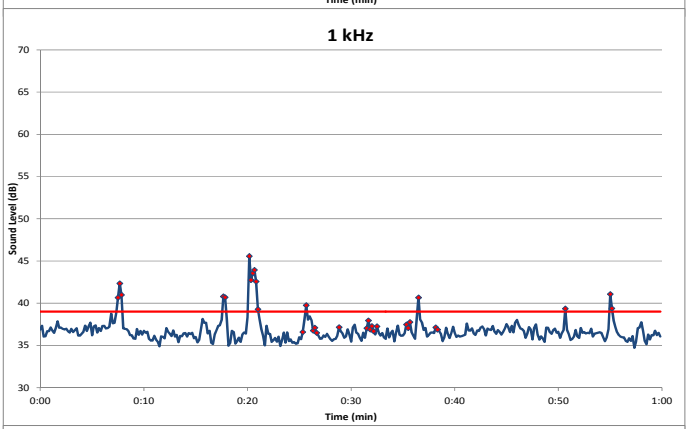

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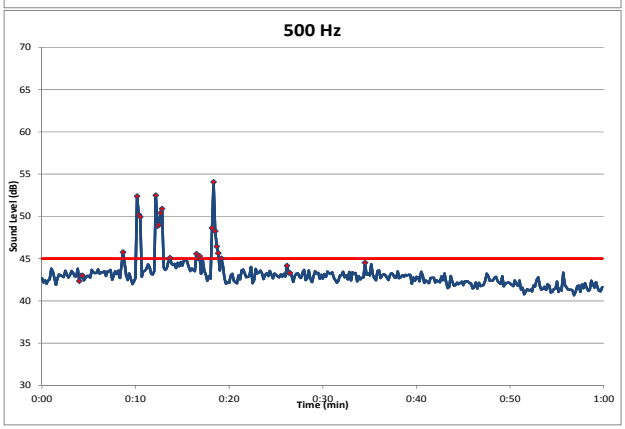

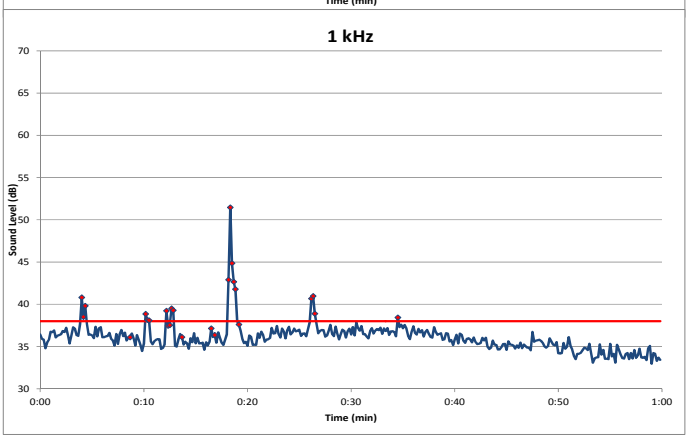

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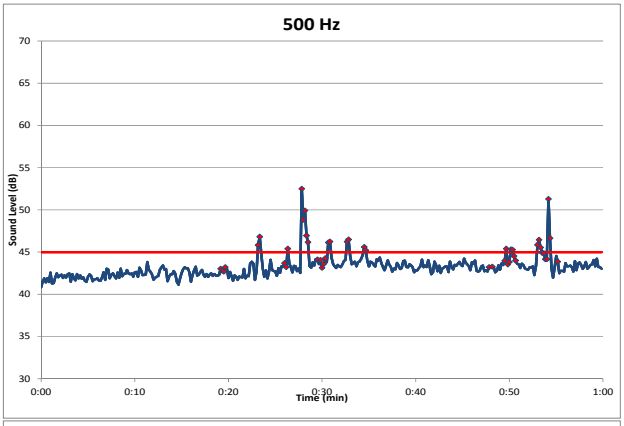

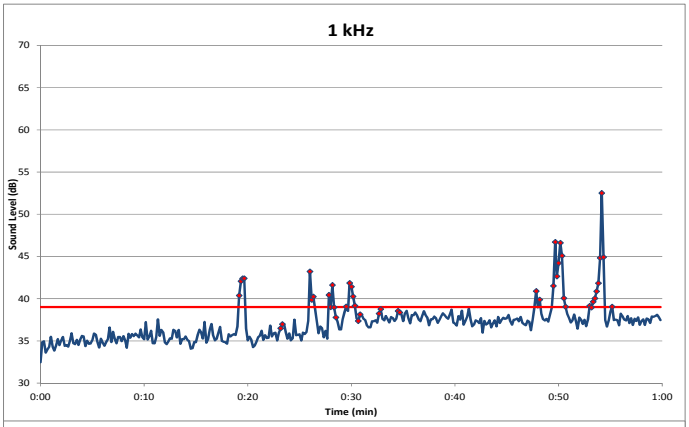

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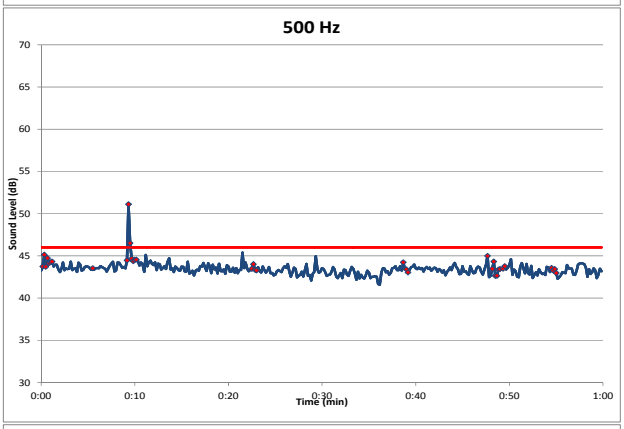

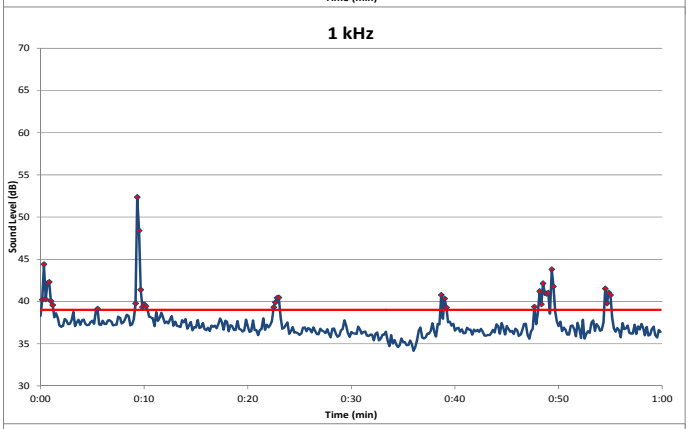

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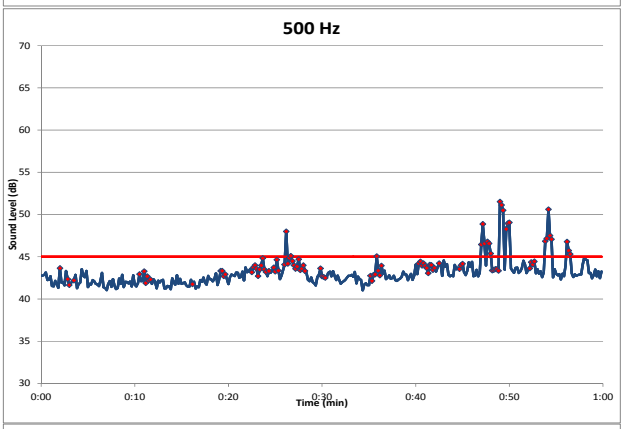

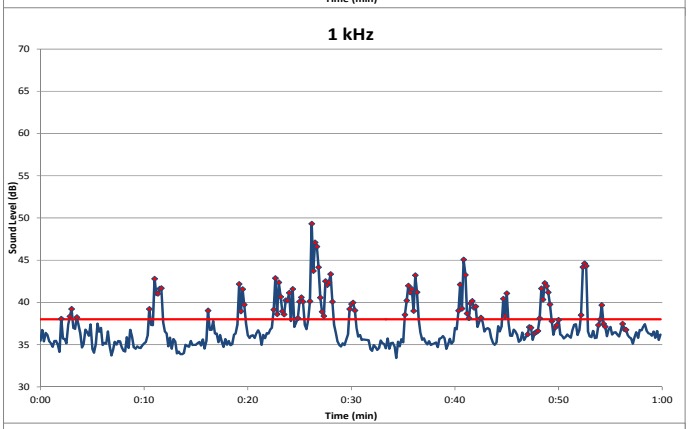

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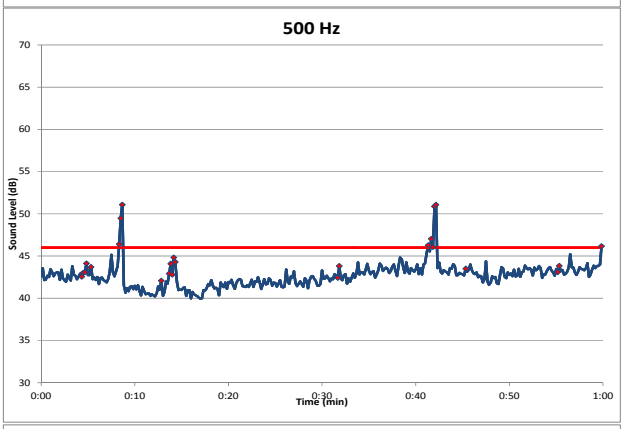

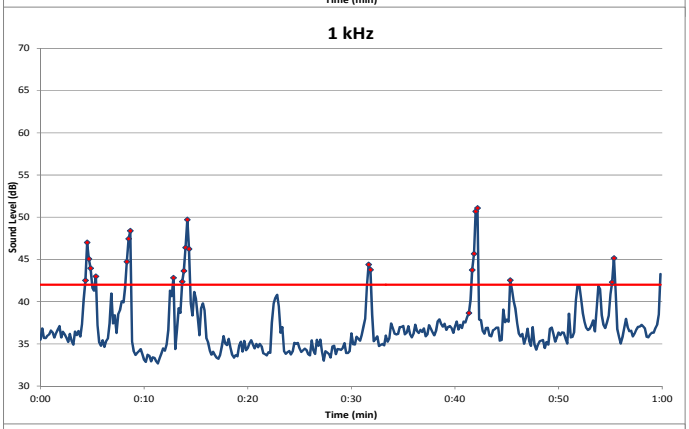

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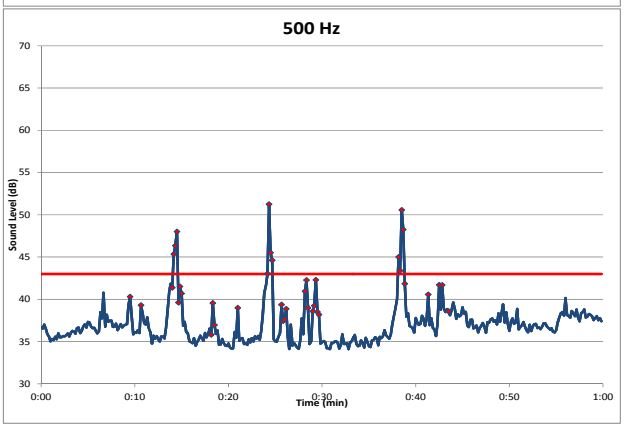

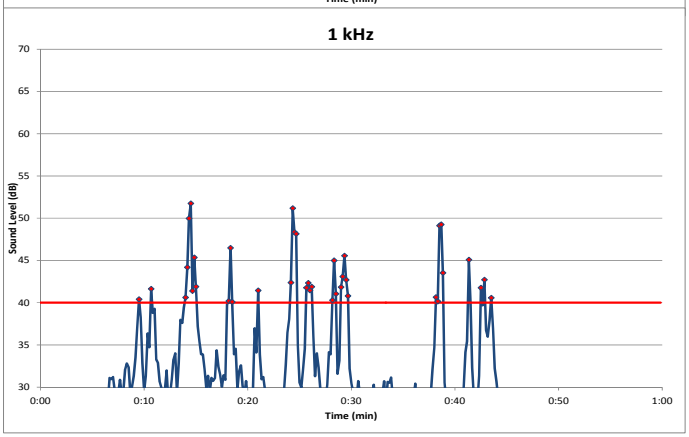

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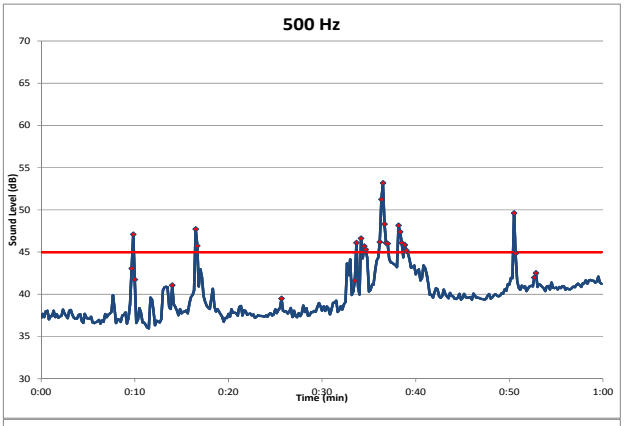

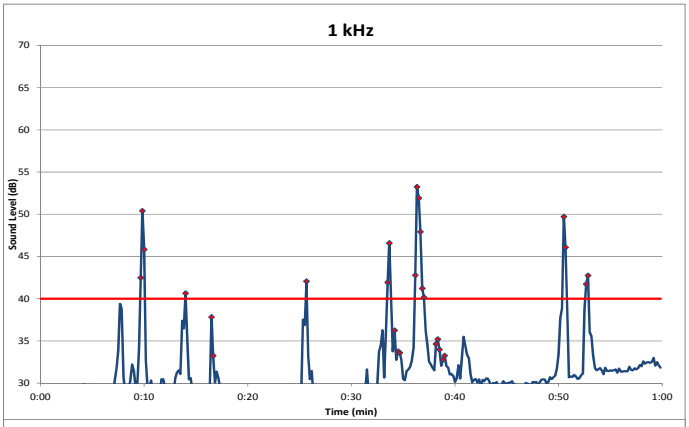

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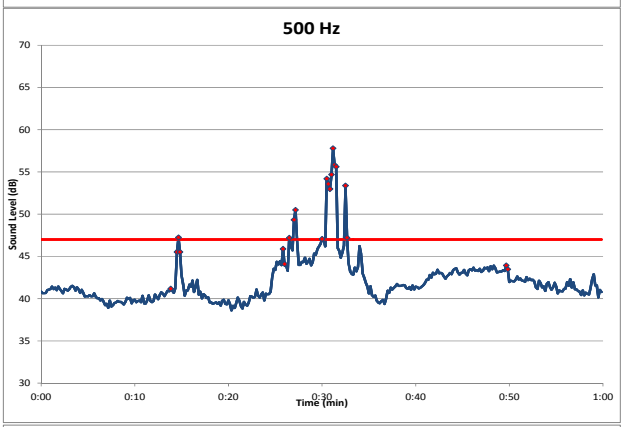

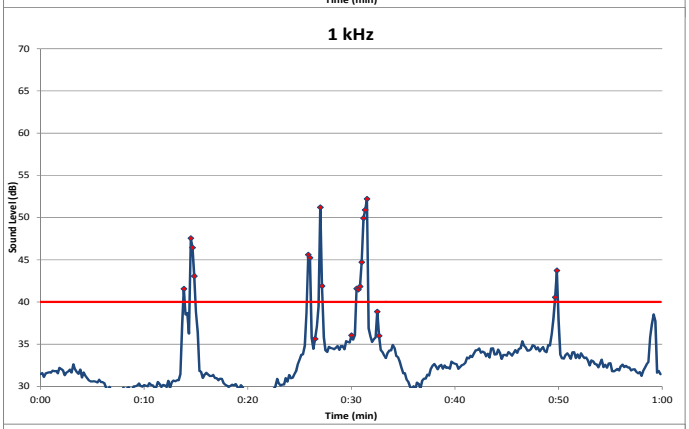

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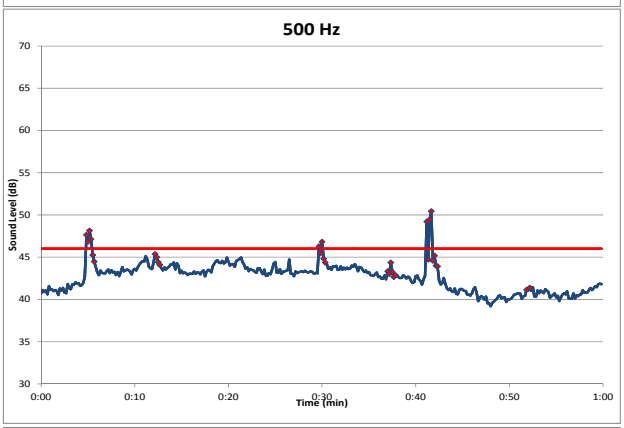

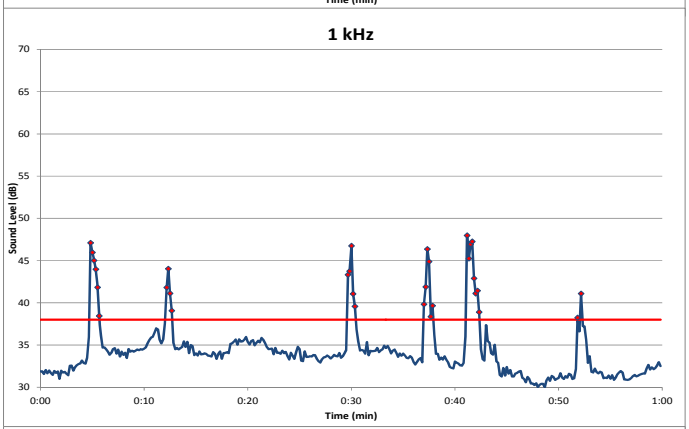

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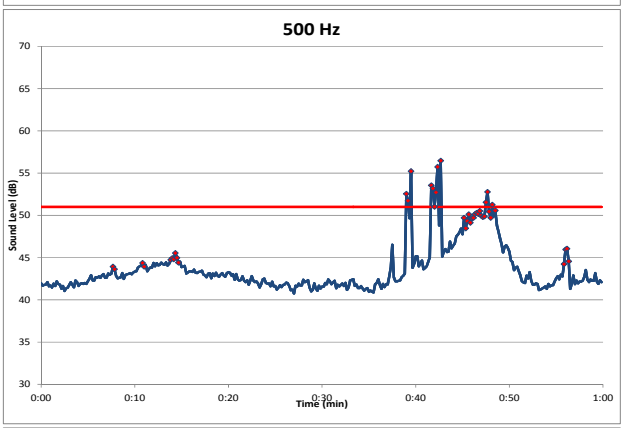

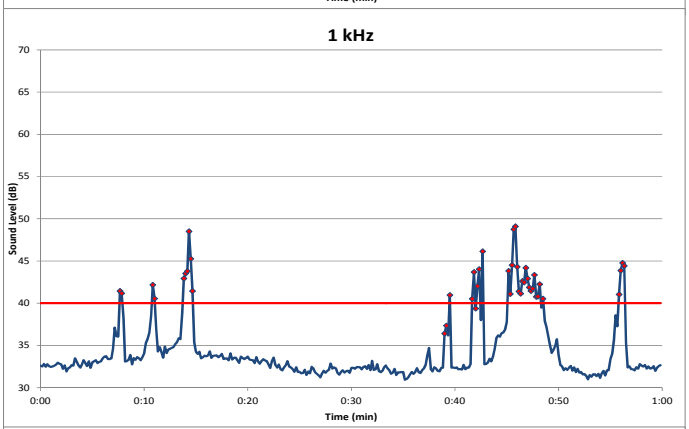

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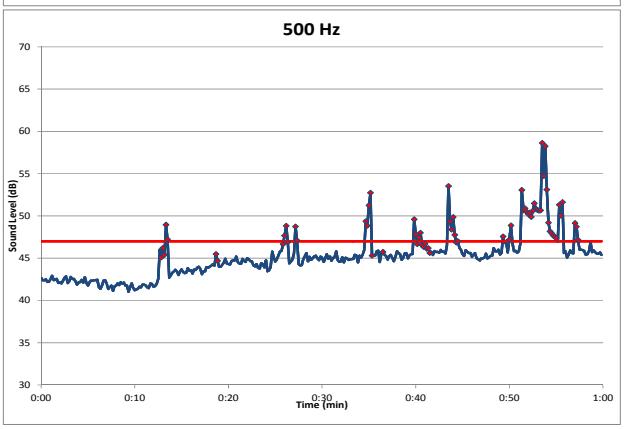

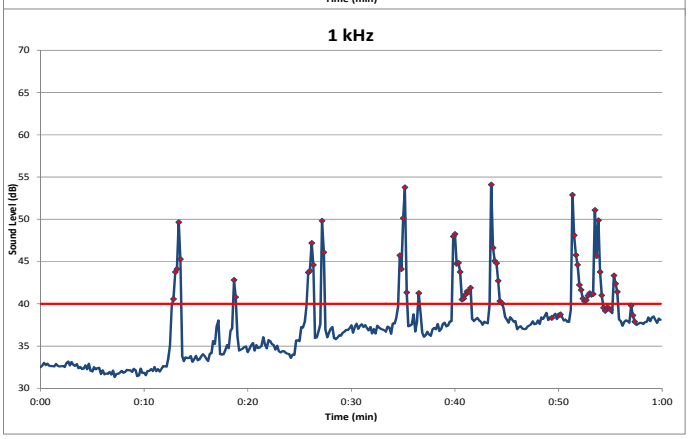

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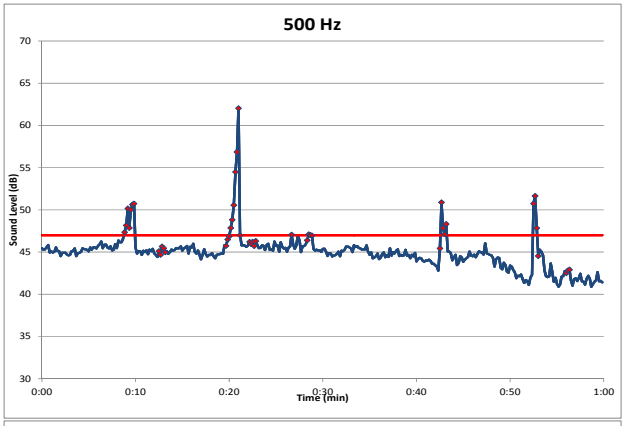

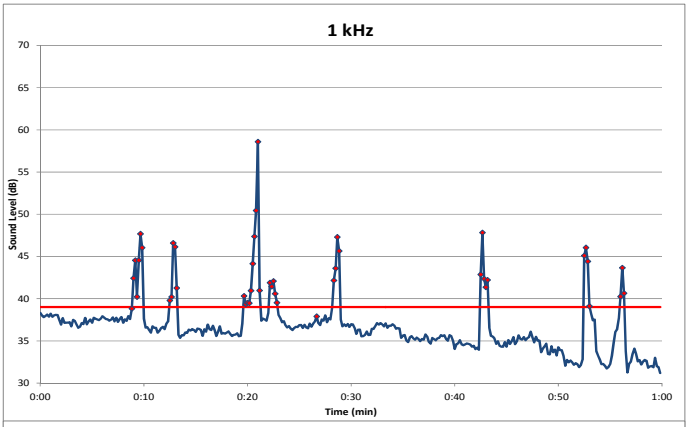

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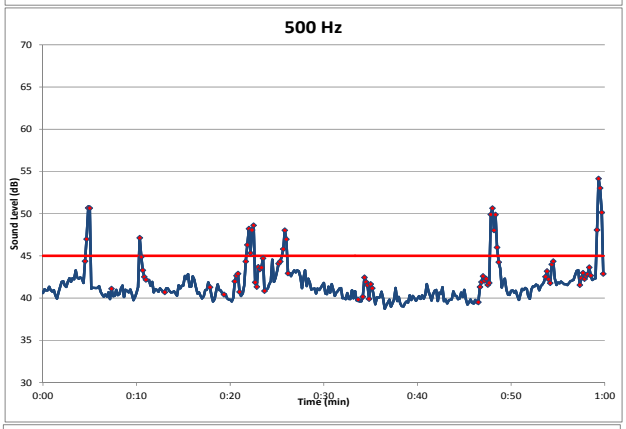

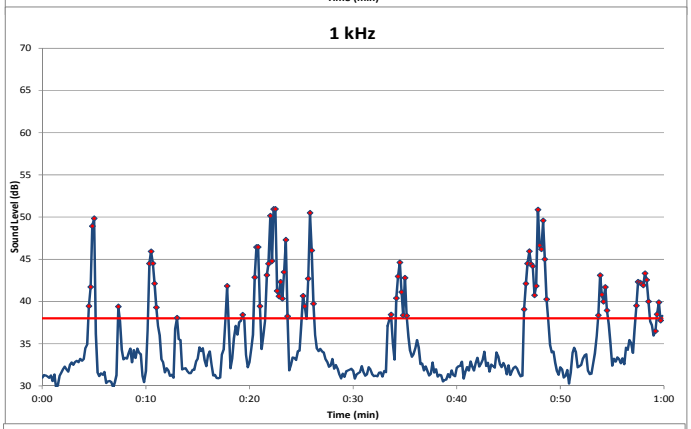

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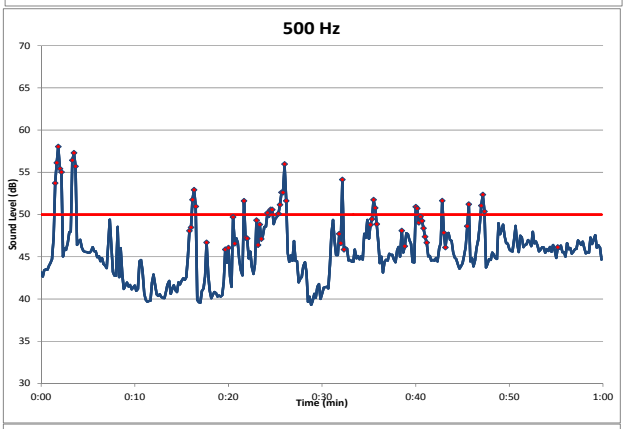

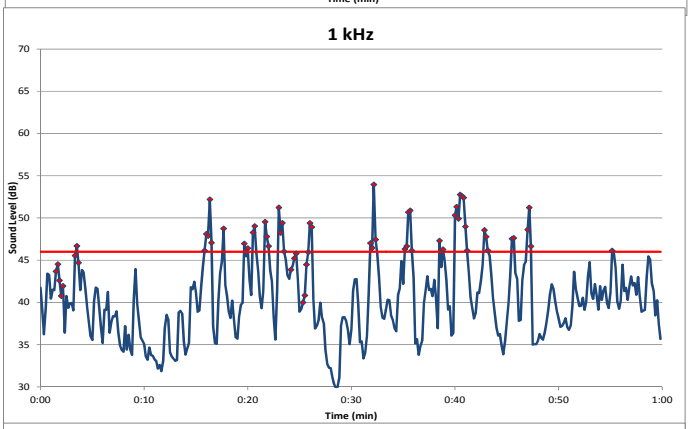

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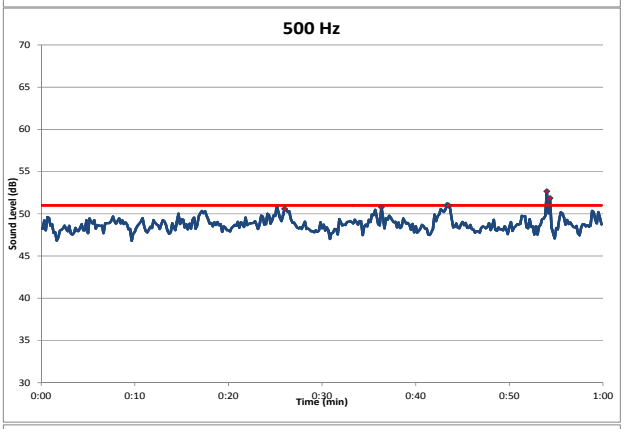

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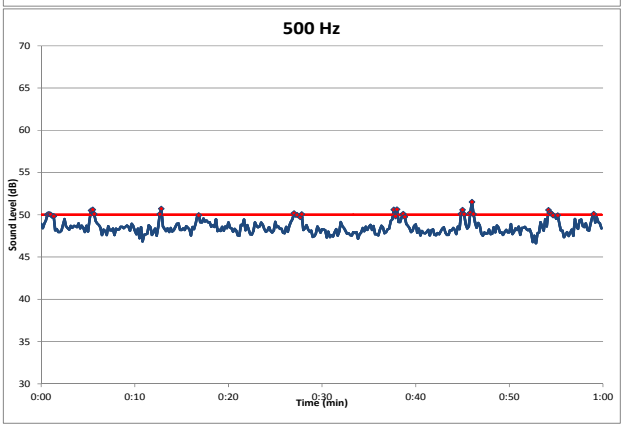

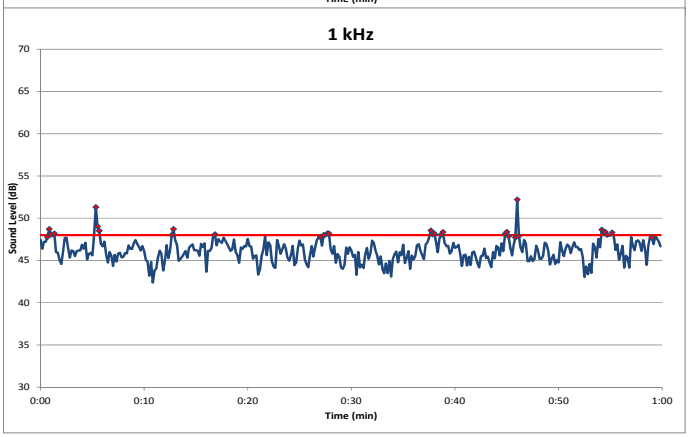

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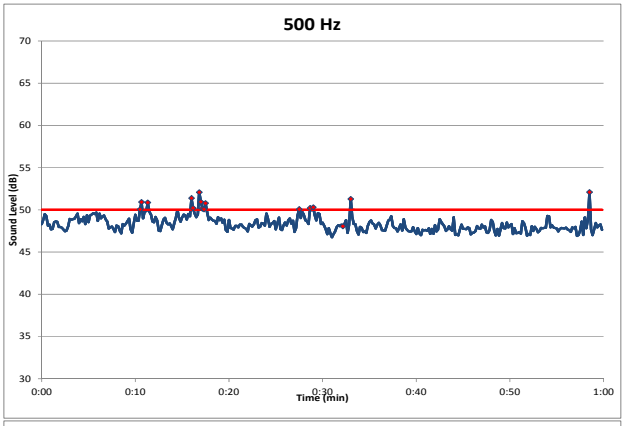

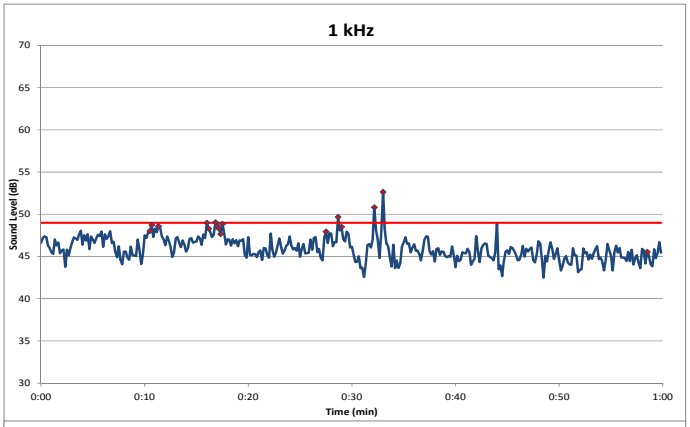

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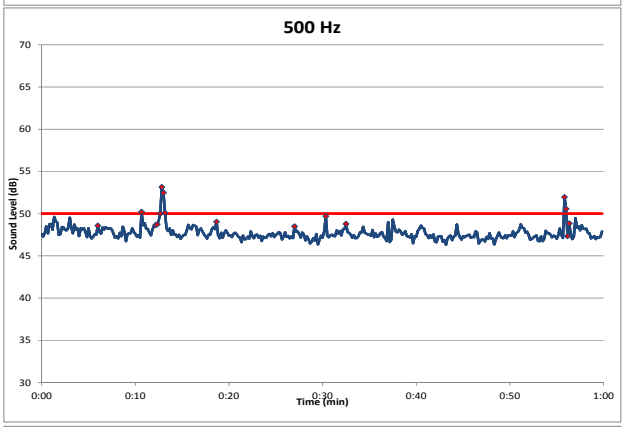

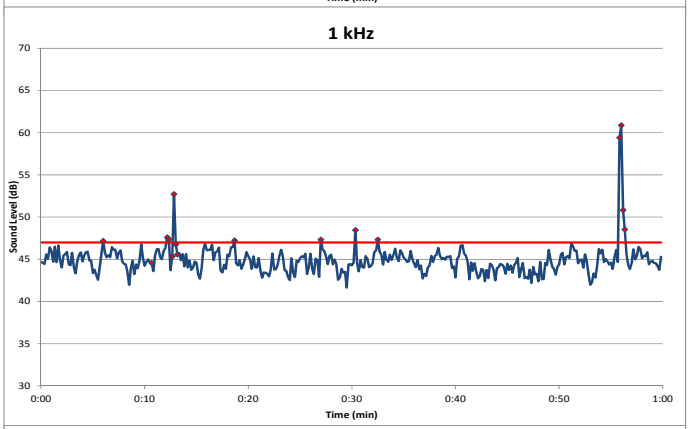

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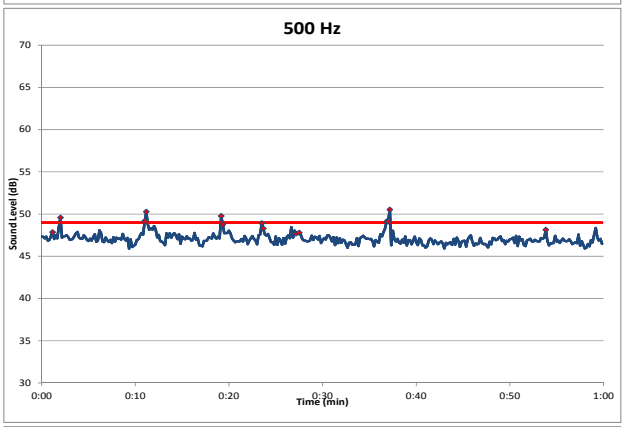

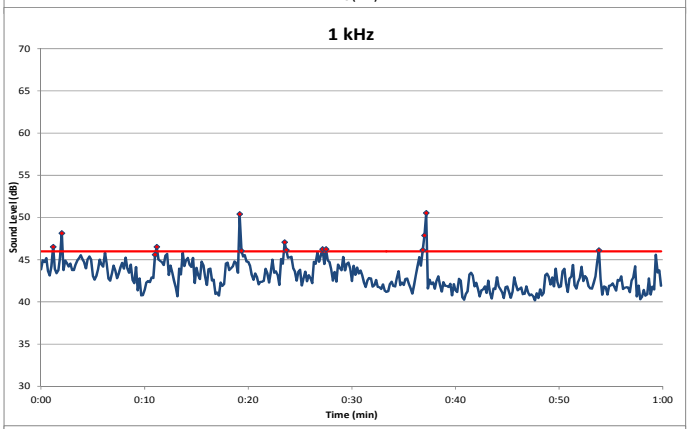

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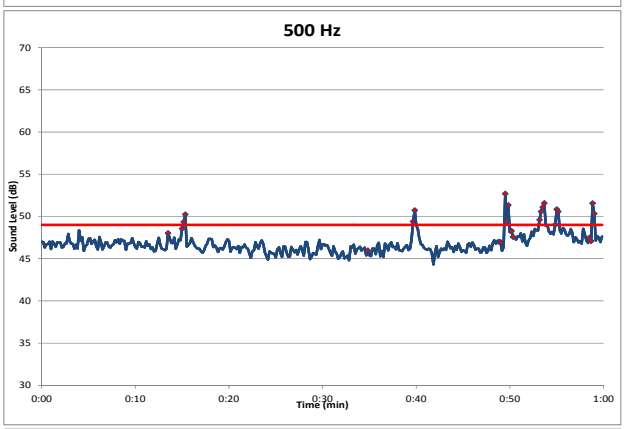

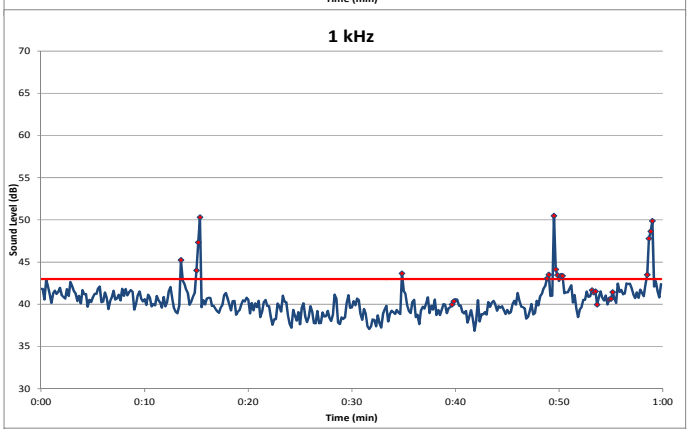

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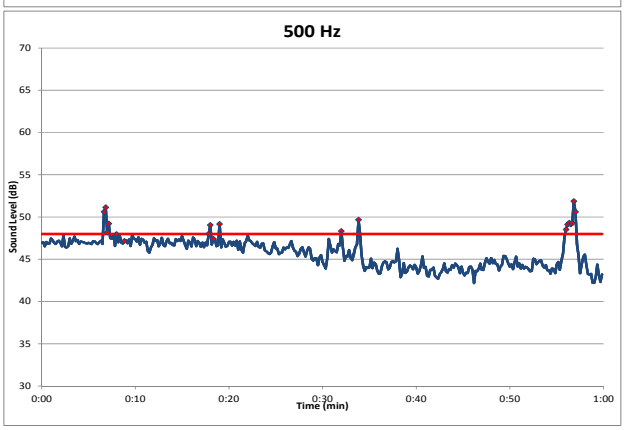

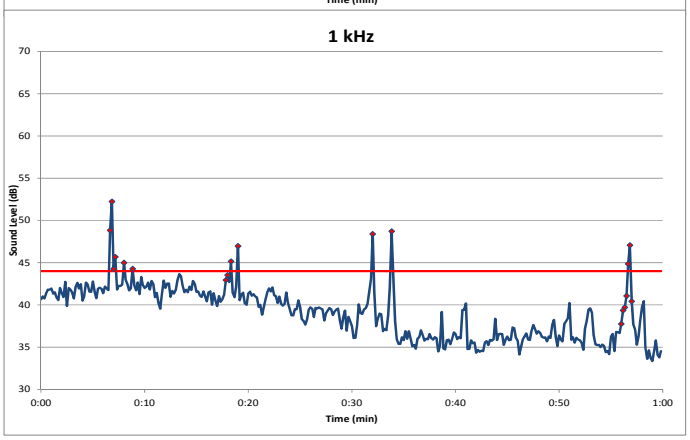

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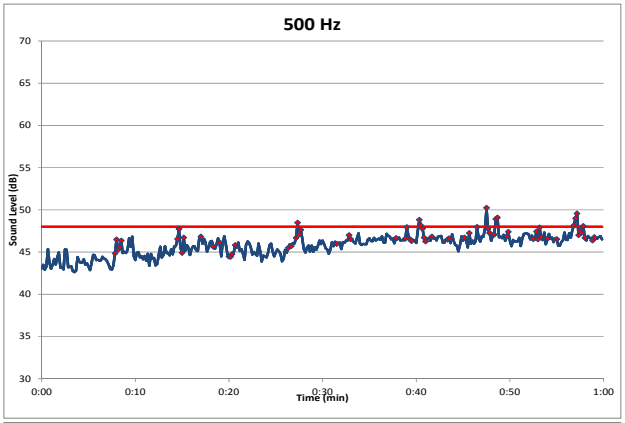

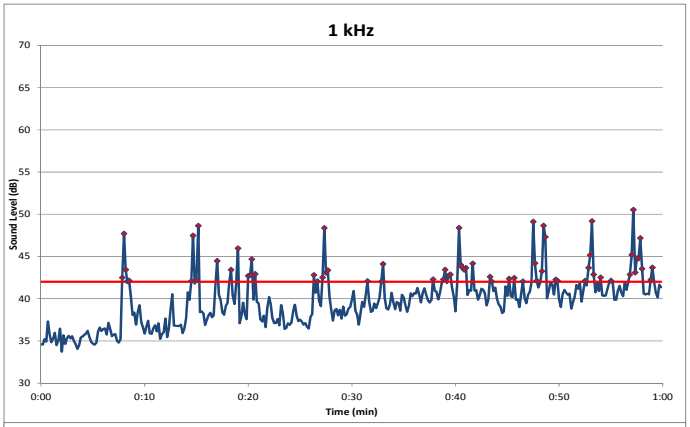

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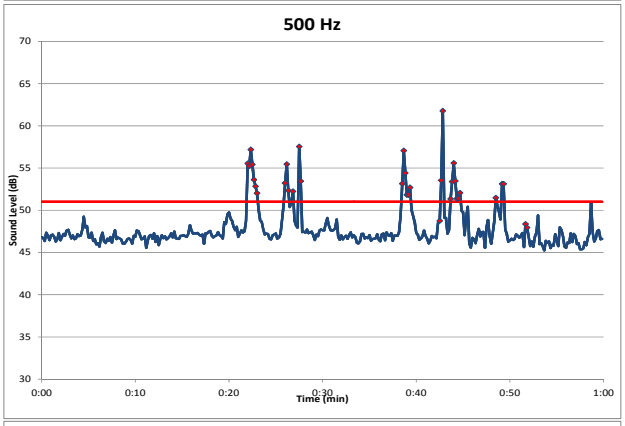

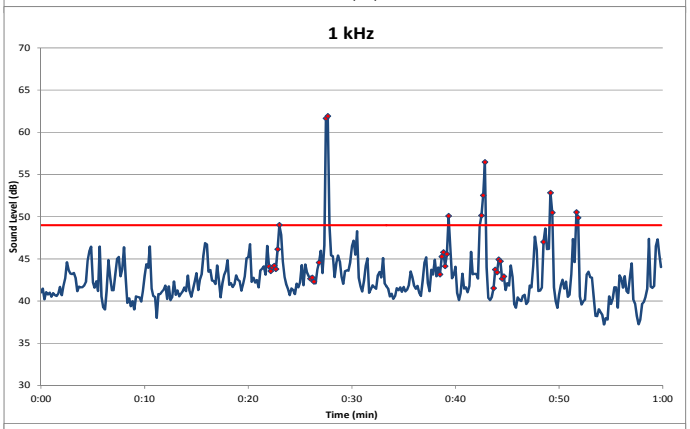

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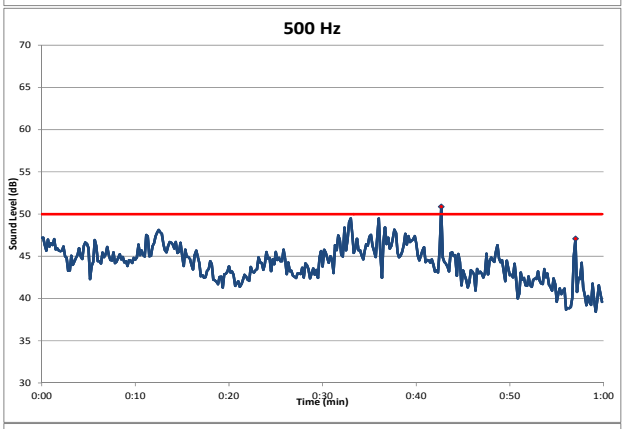

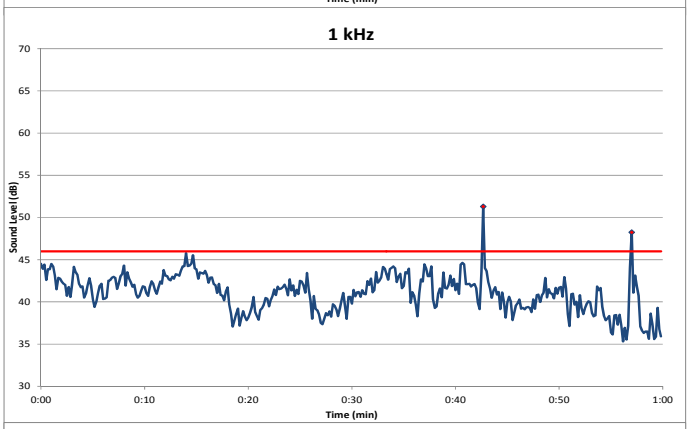

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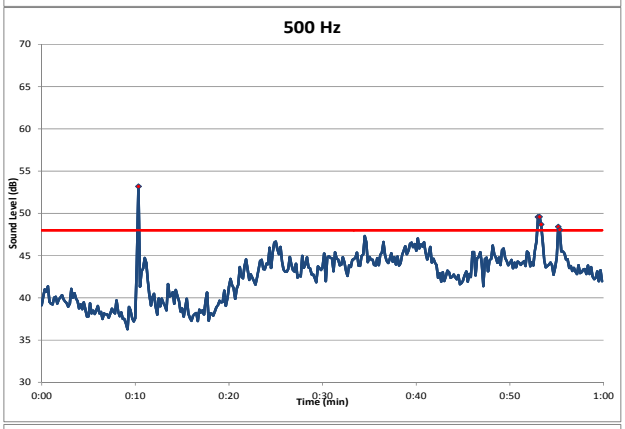

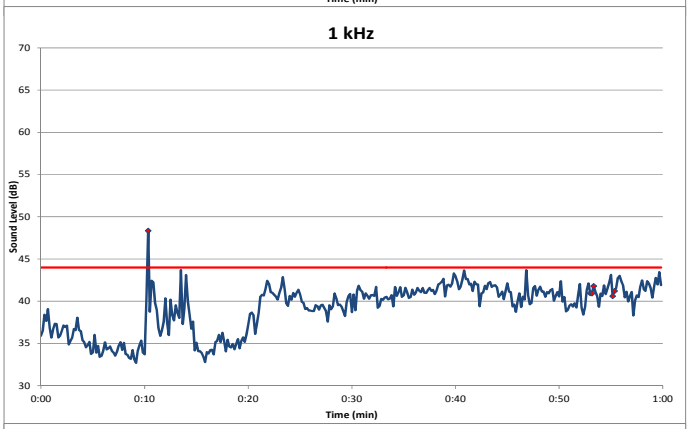

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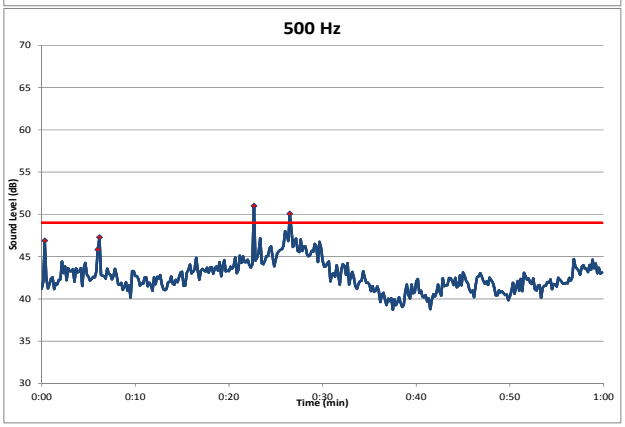

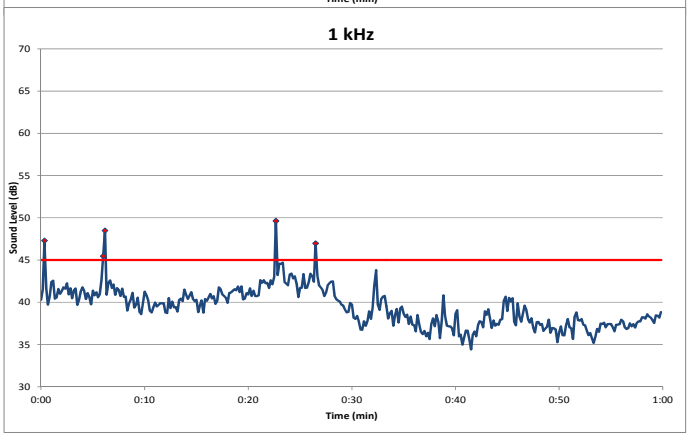

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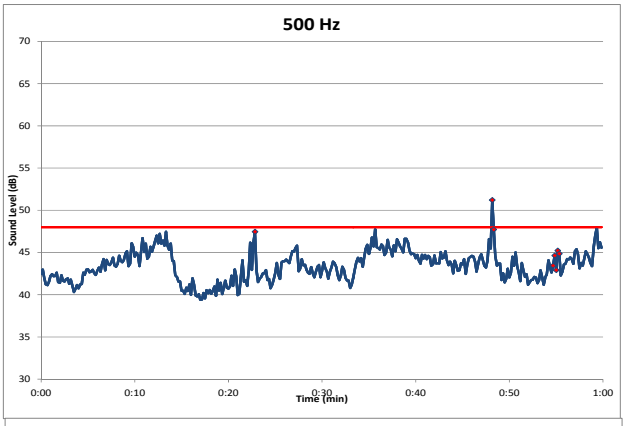

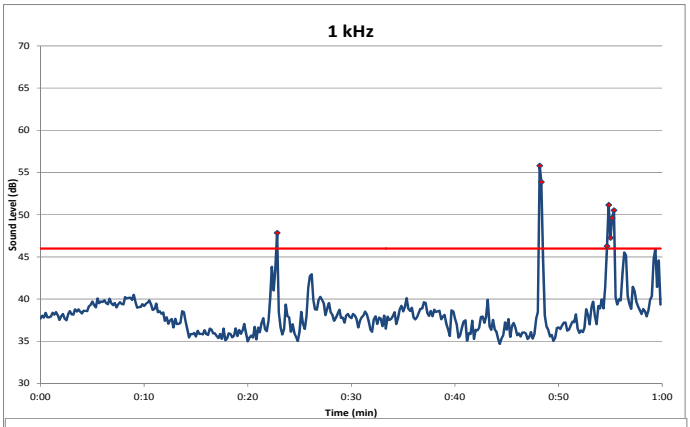

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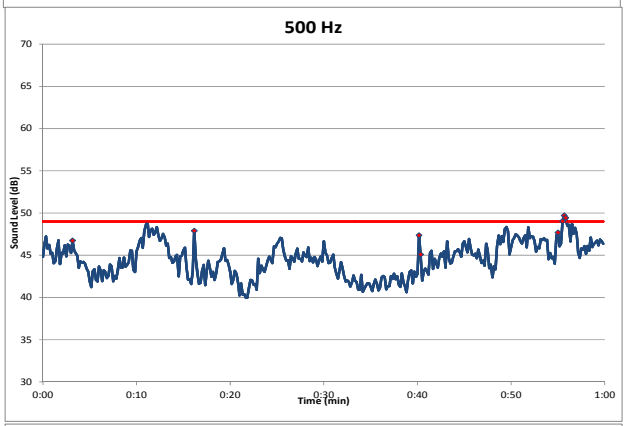

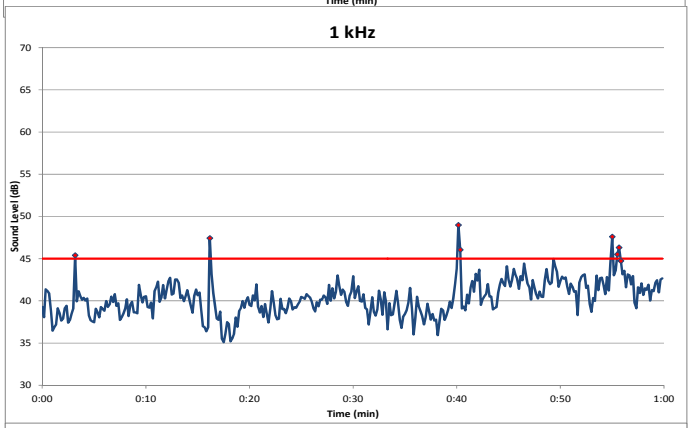

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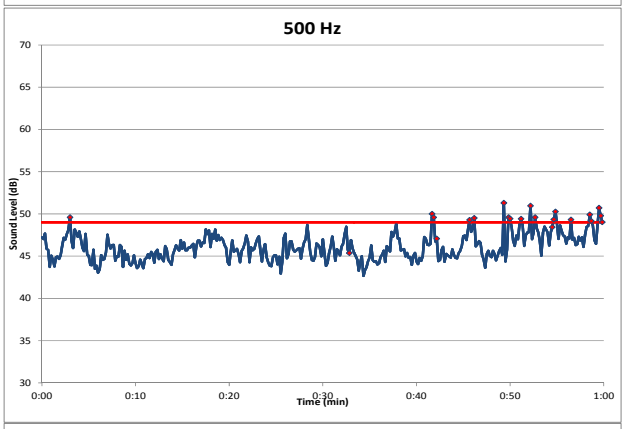

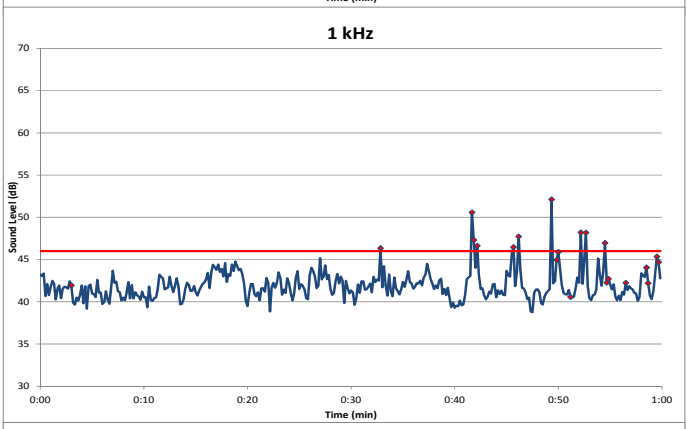

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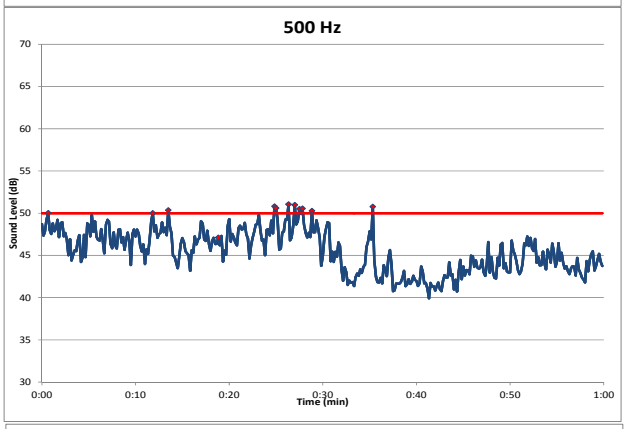

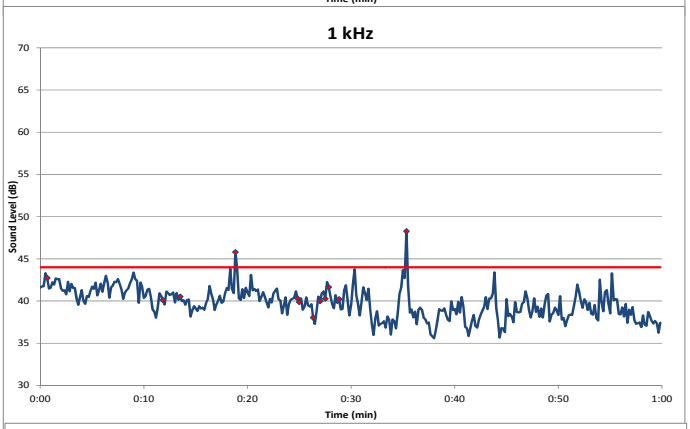

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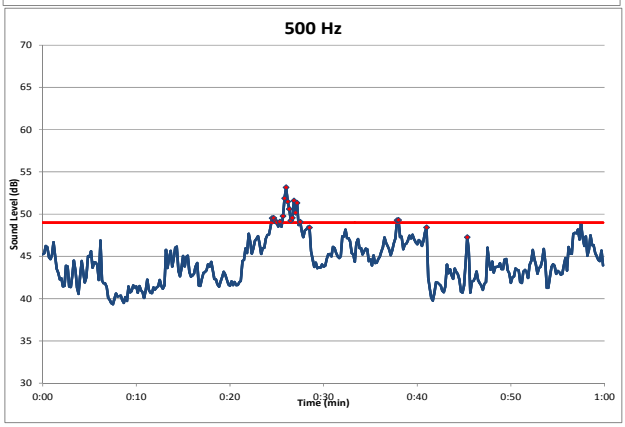

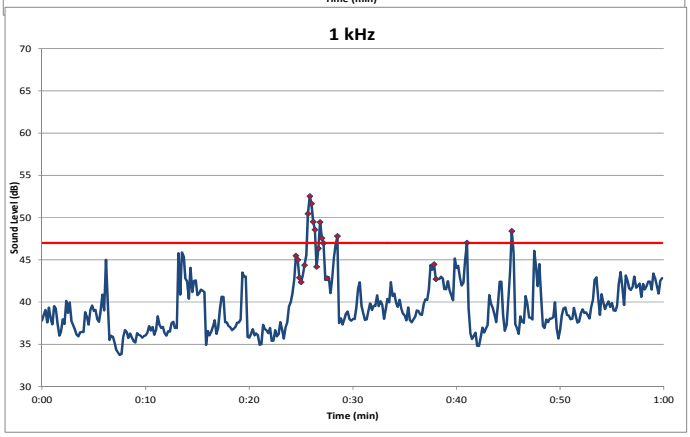

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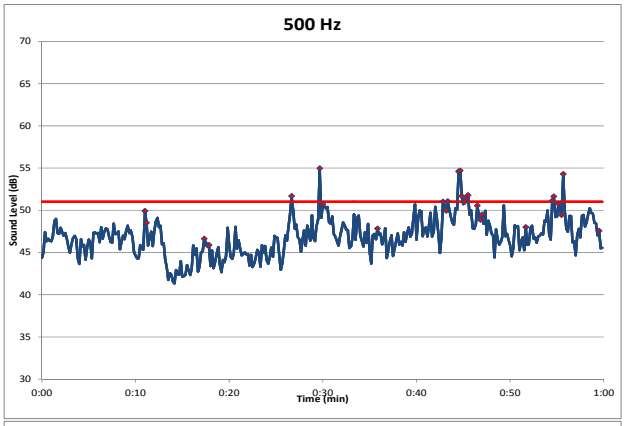

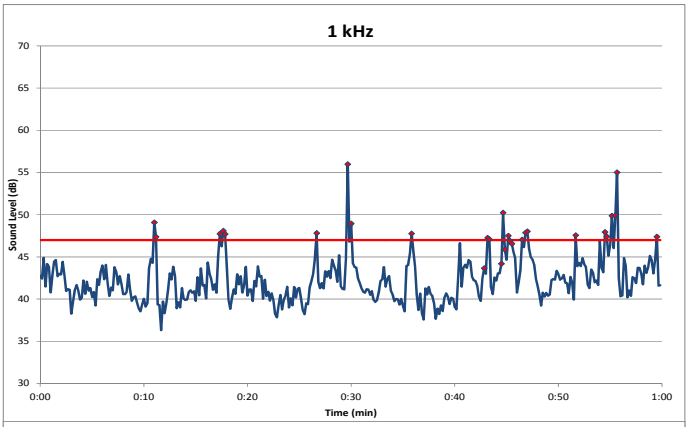

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NOV 13

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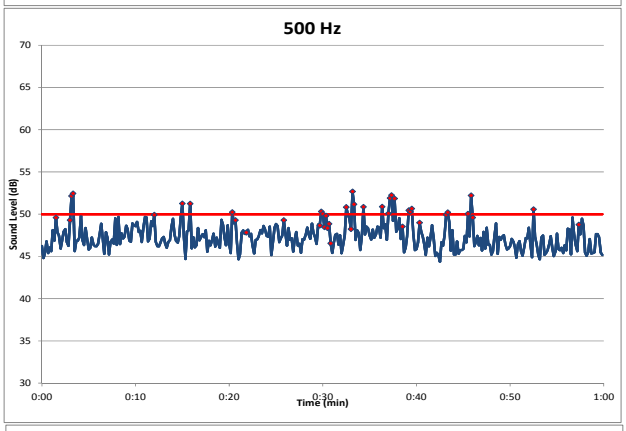

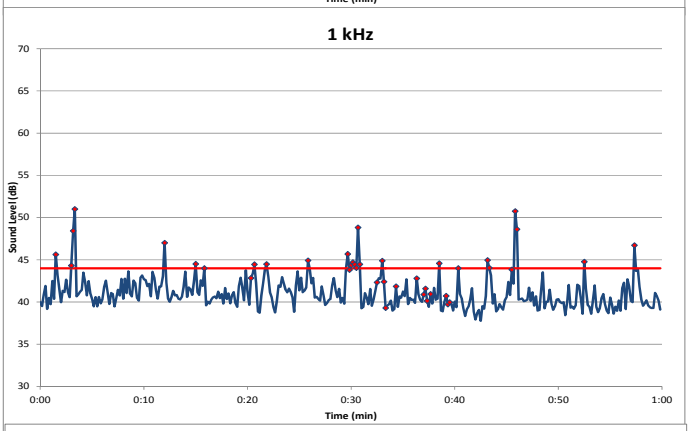

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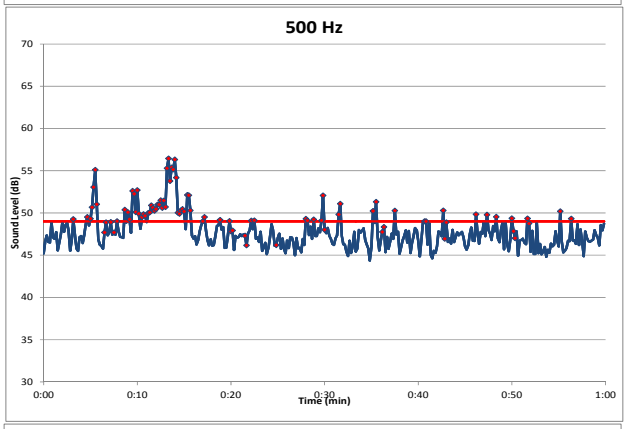

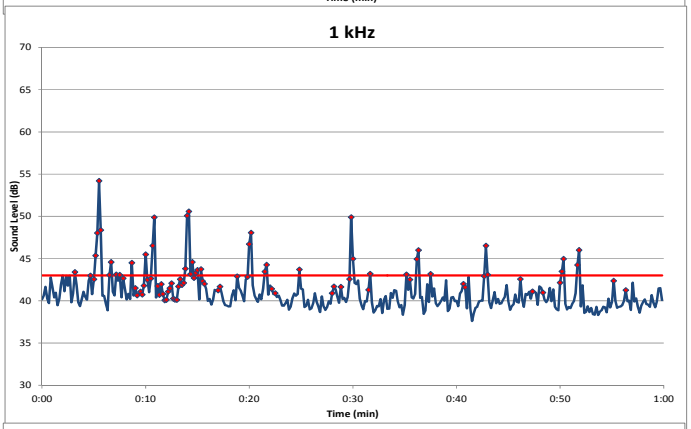

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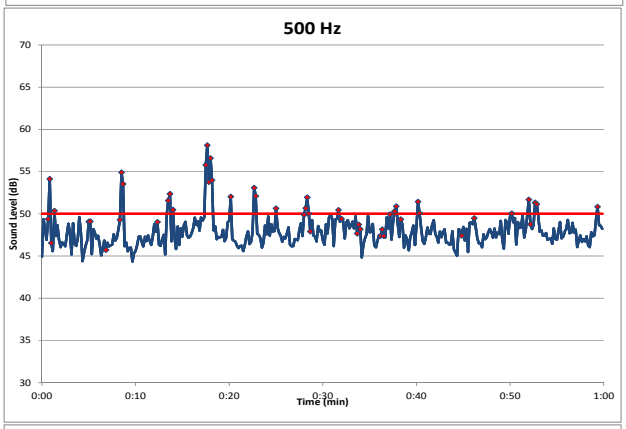

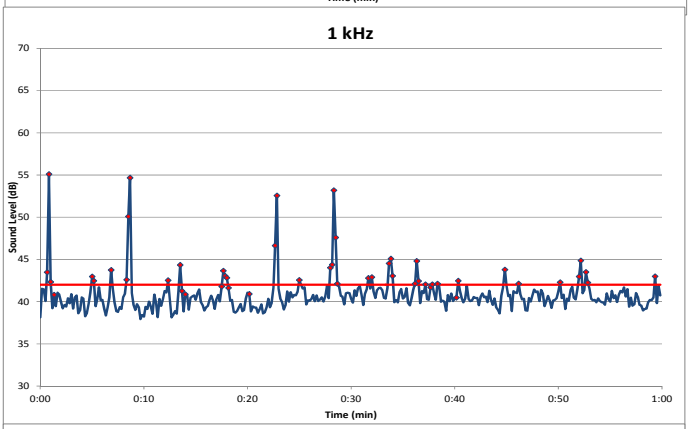

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NOV 14

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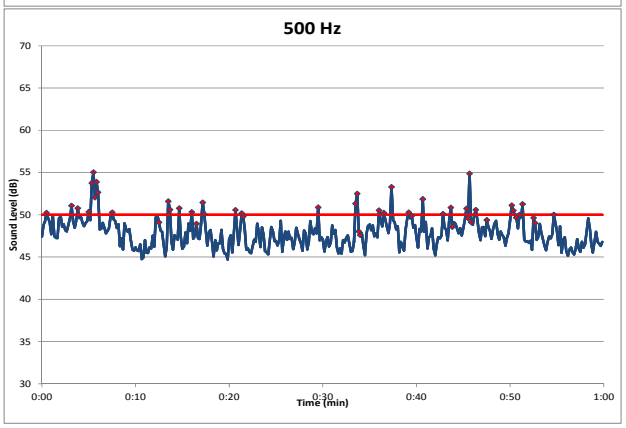

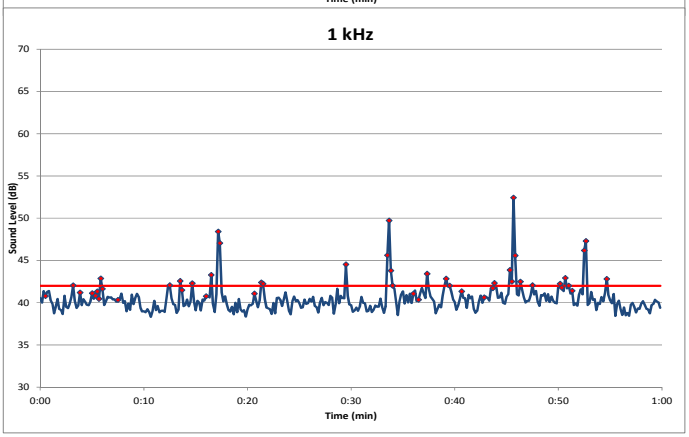

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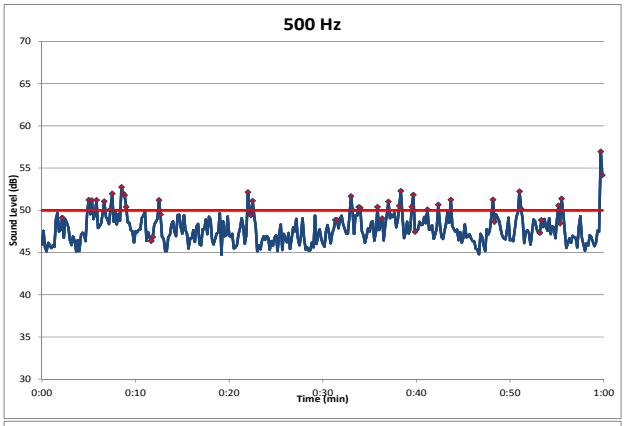

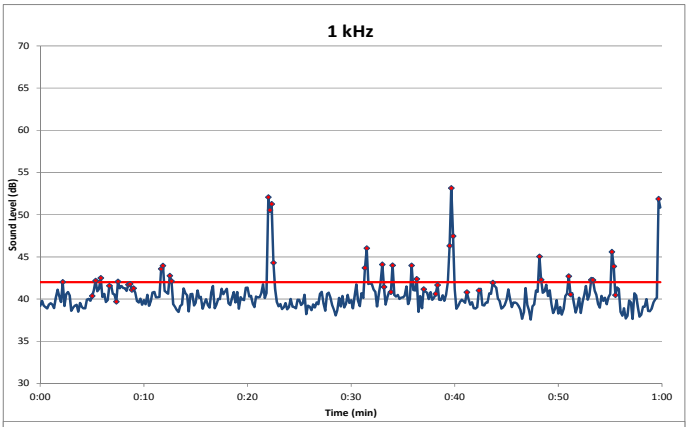

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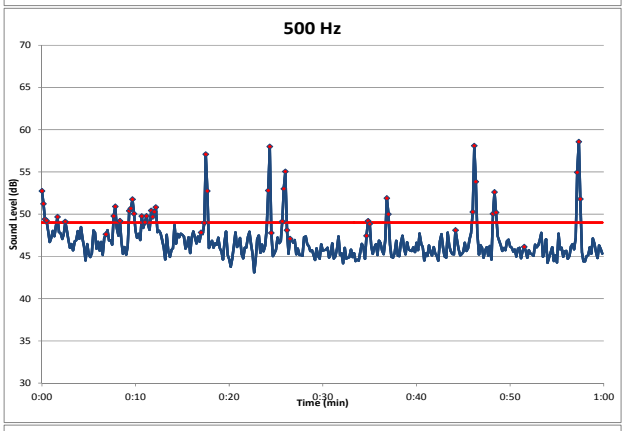

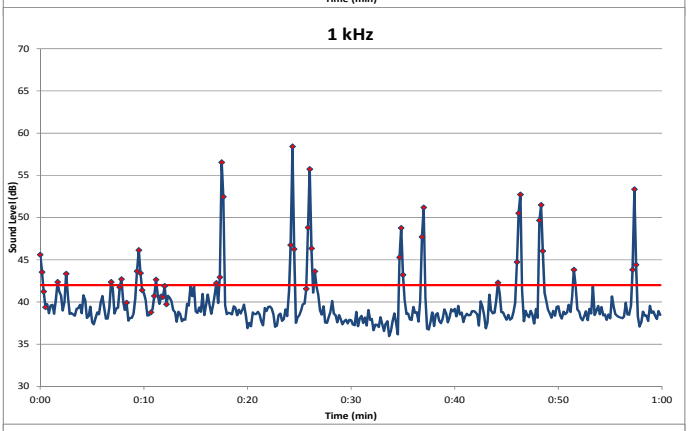

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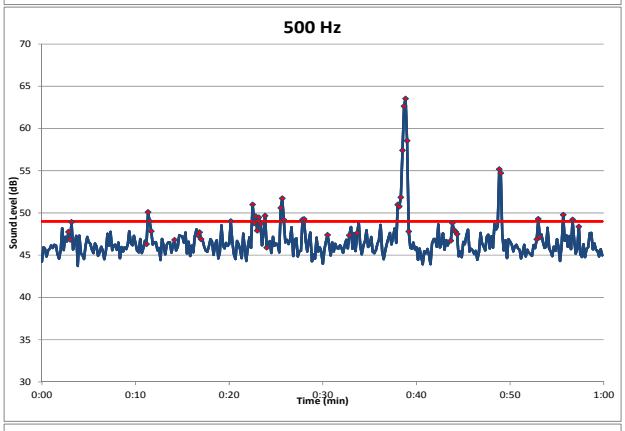

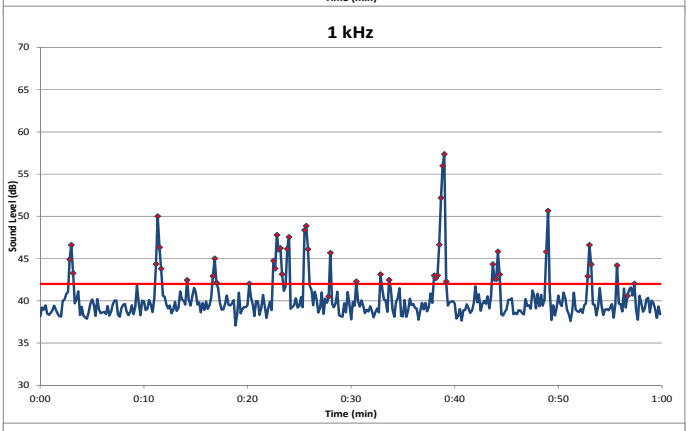

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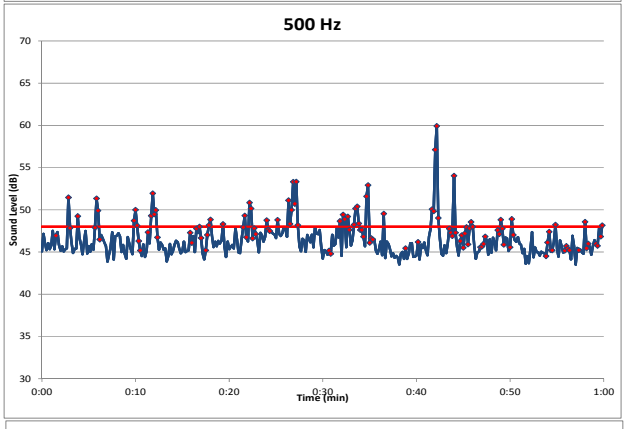

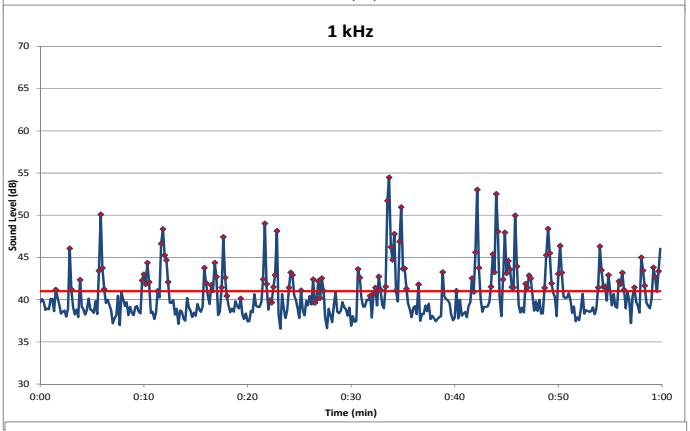

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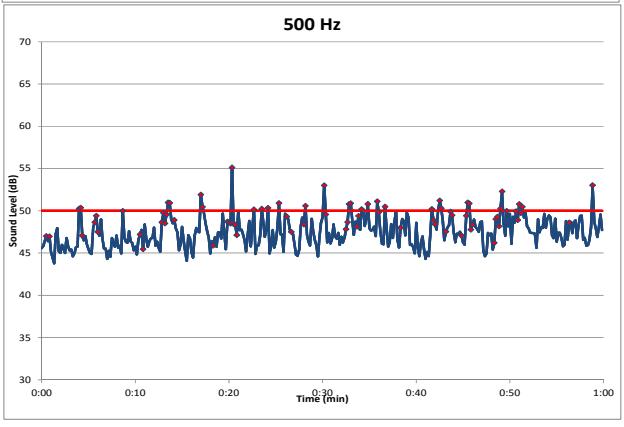

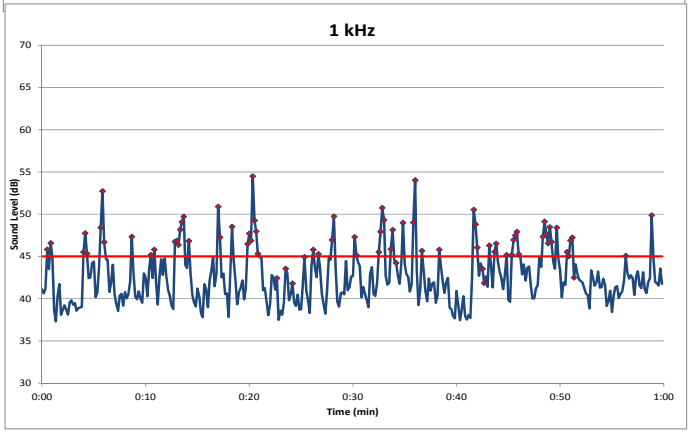

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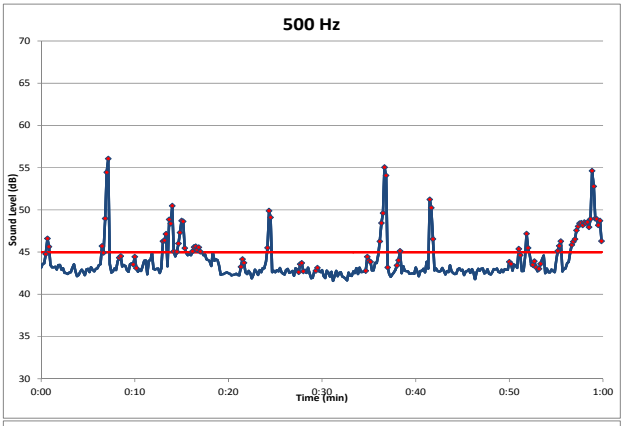

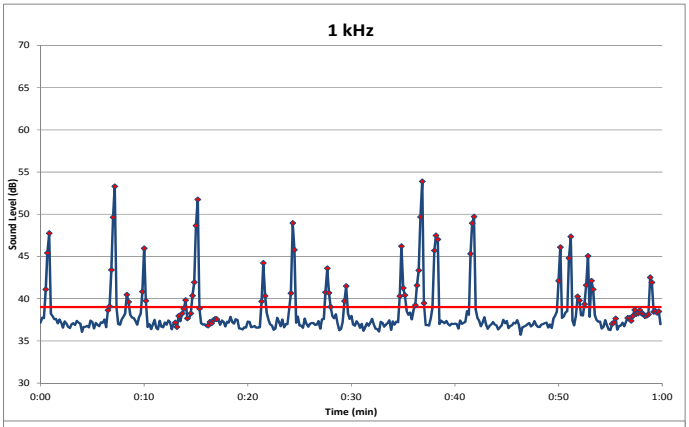

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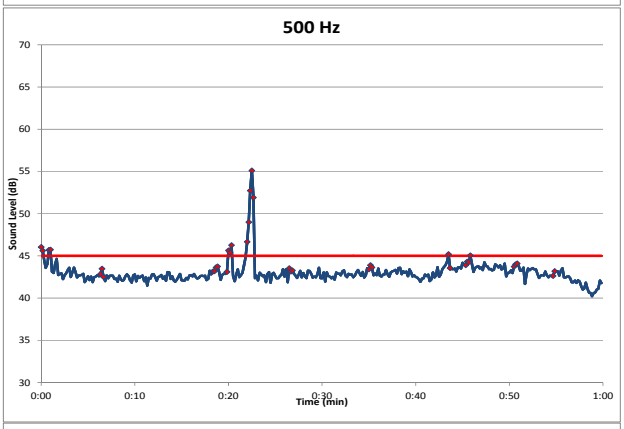

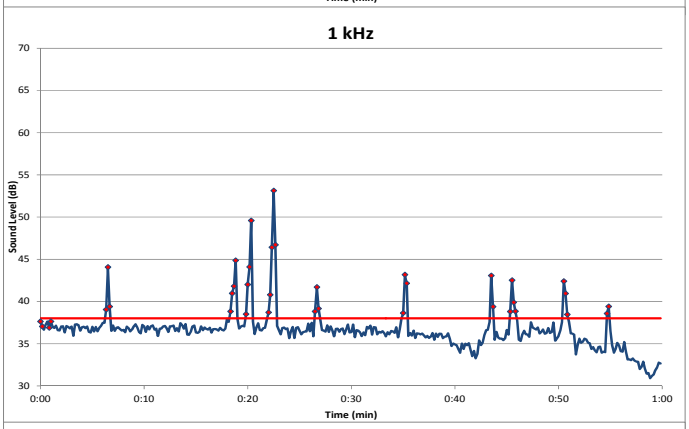

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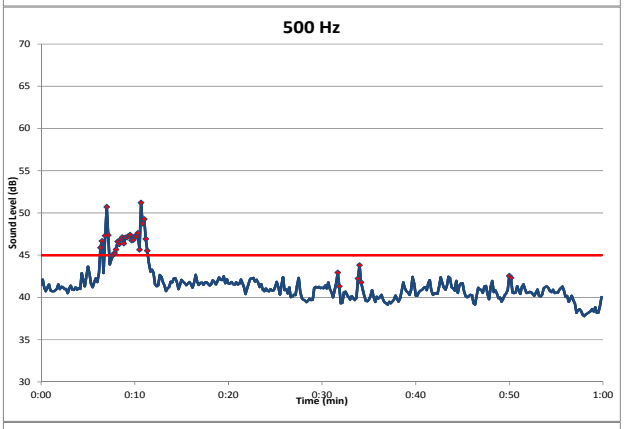

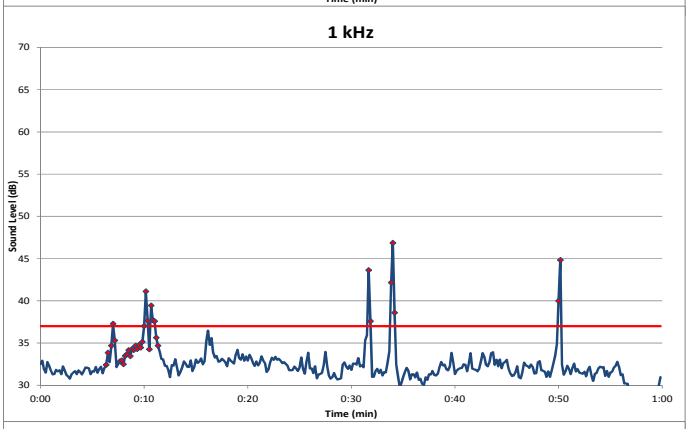

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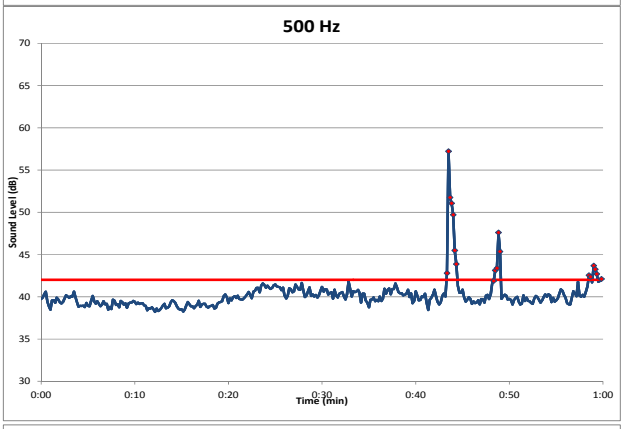

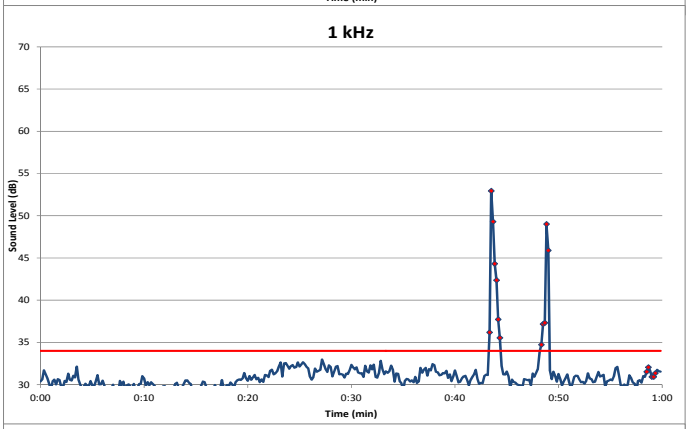

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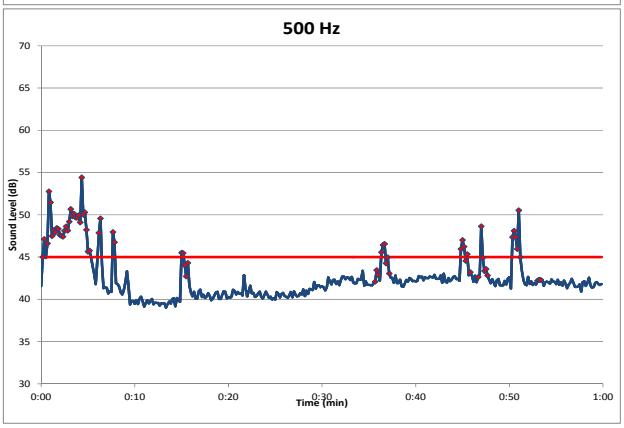

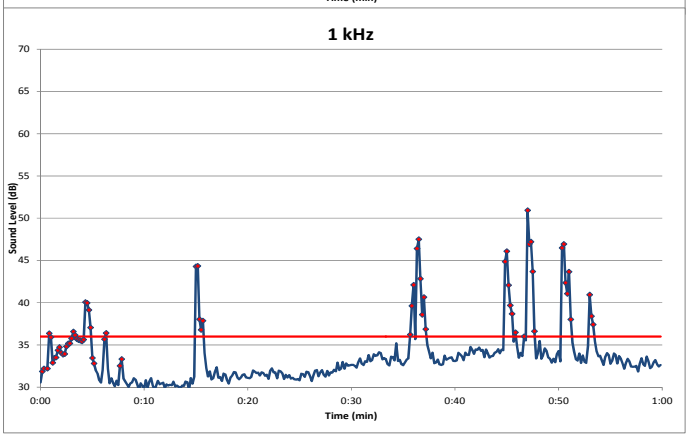

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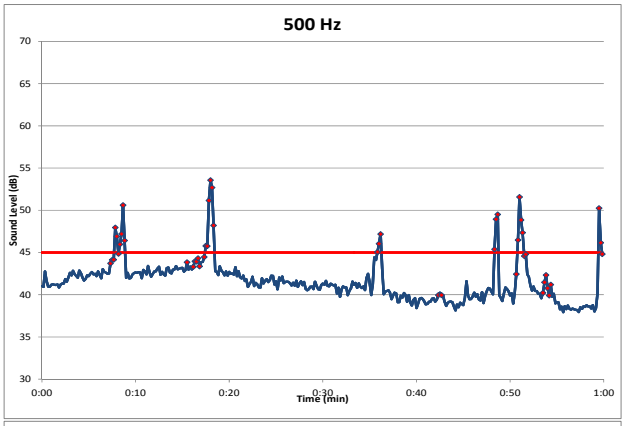

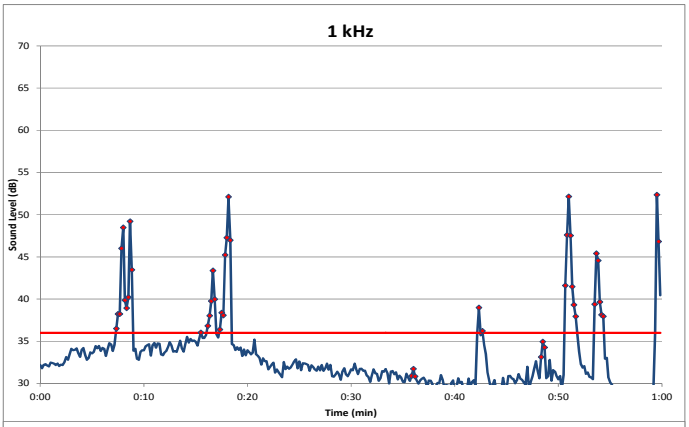

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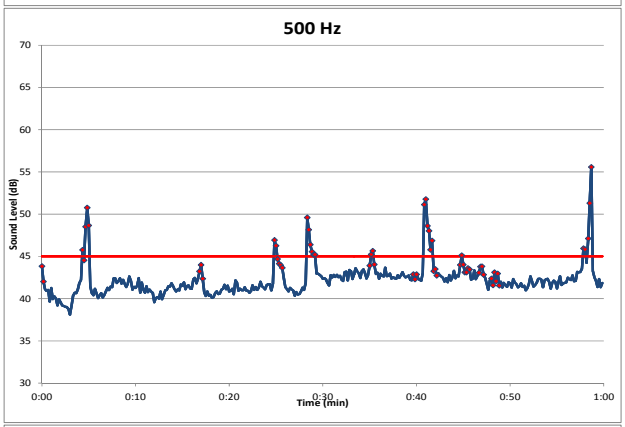

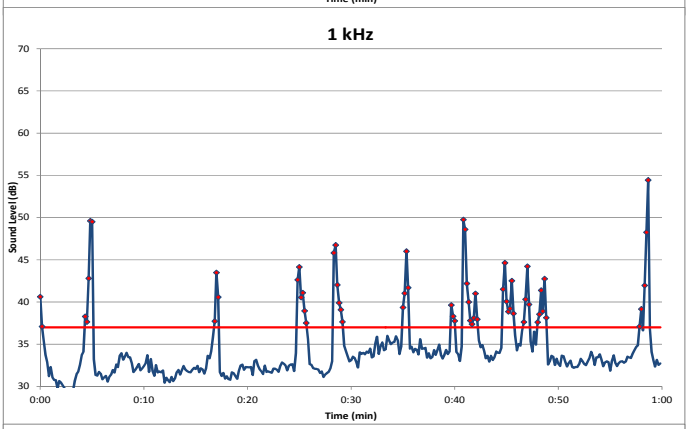

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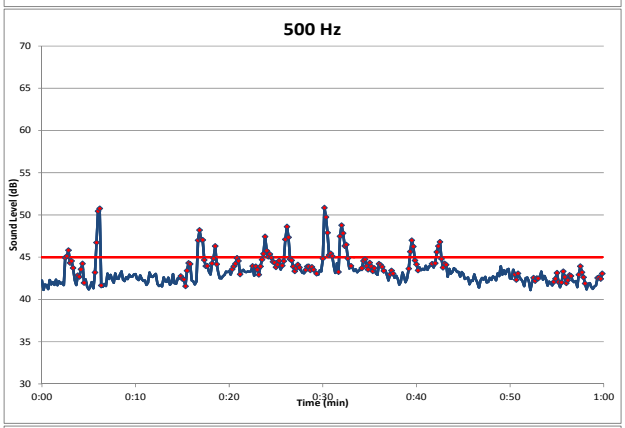

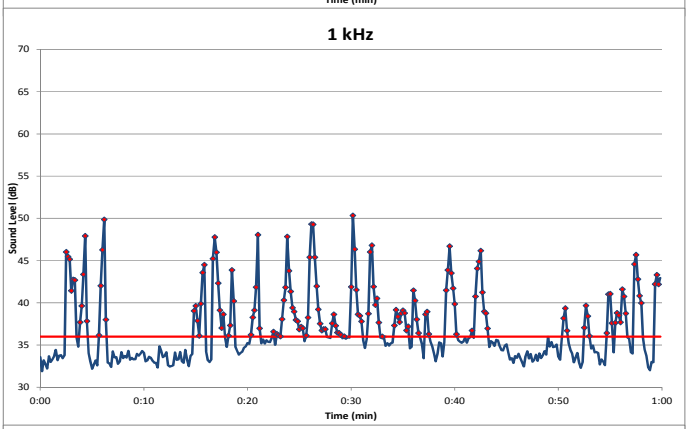

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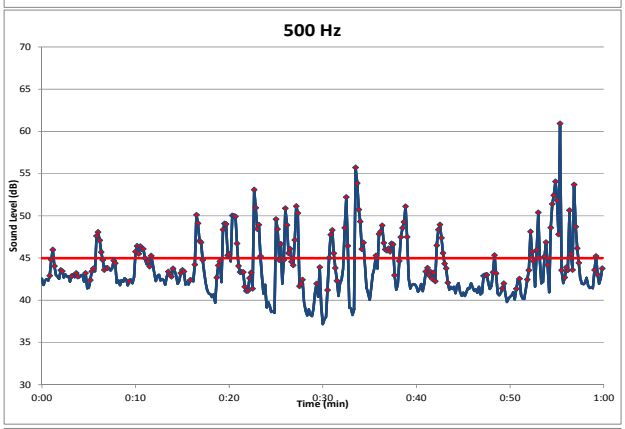

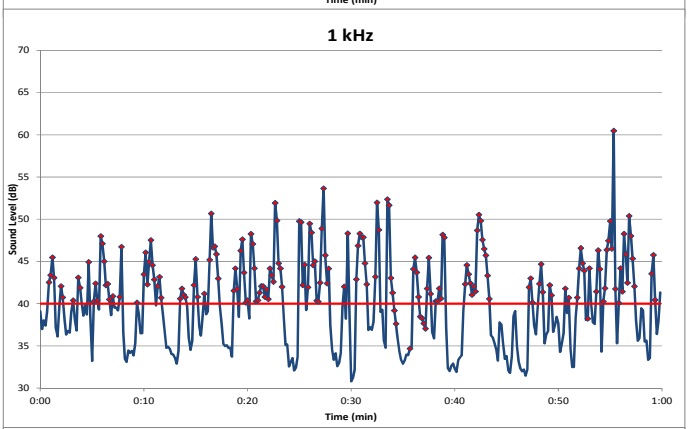

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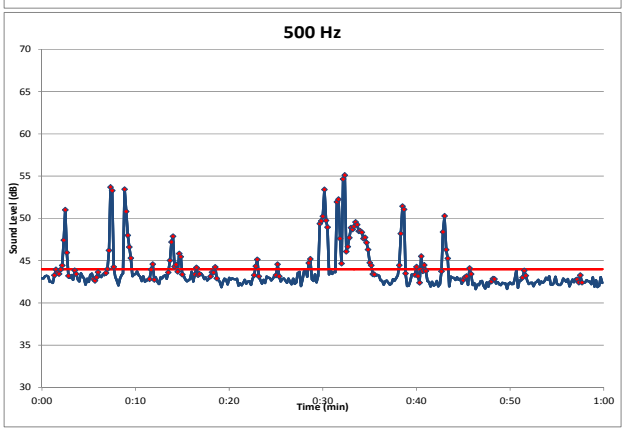

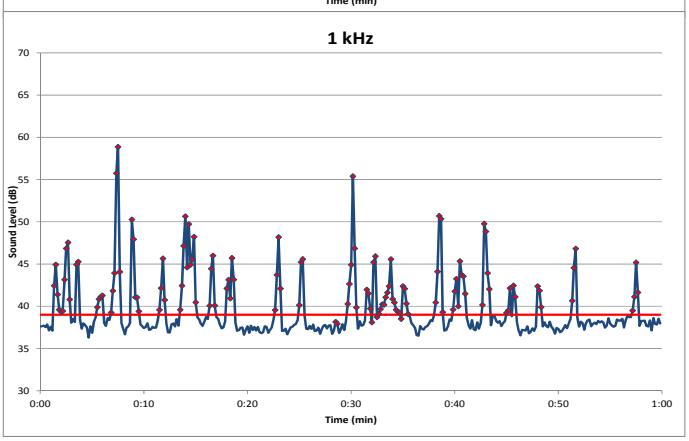

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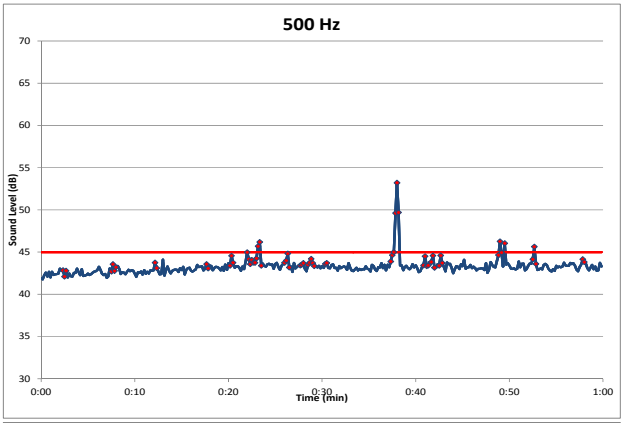

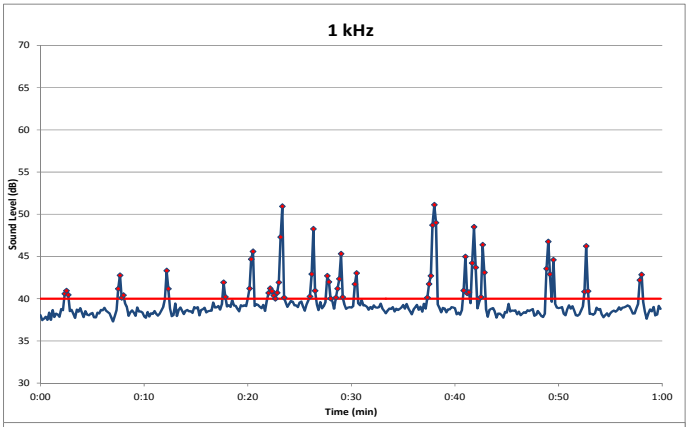

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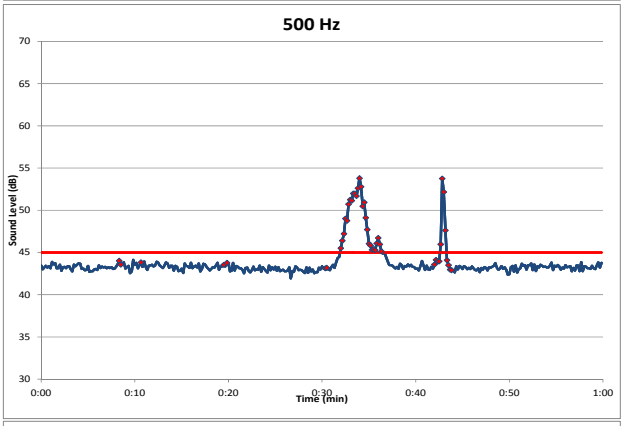

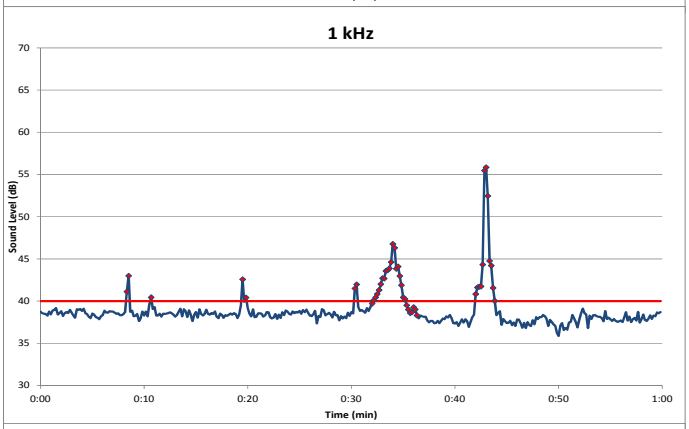

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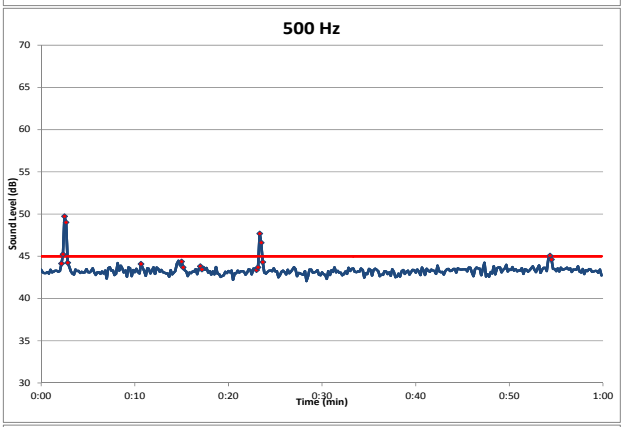

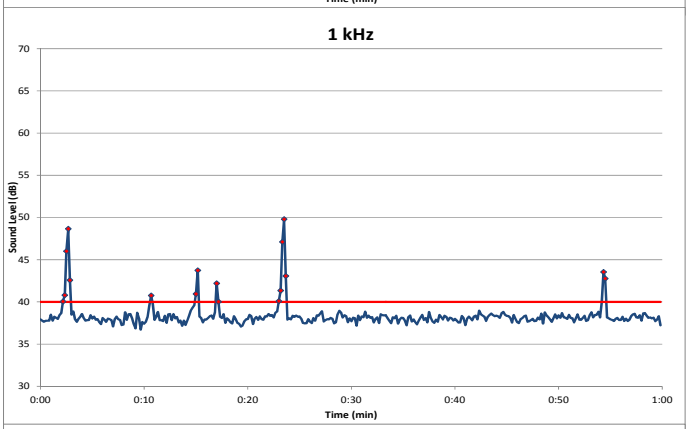

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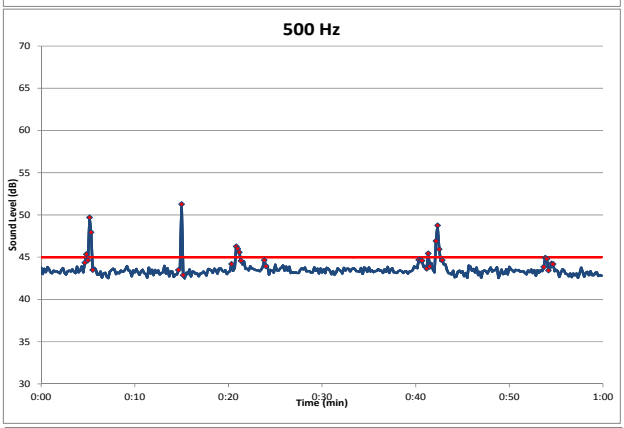

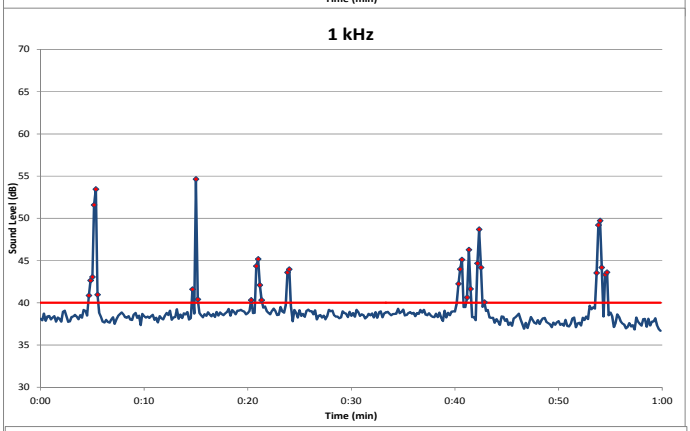

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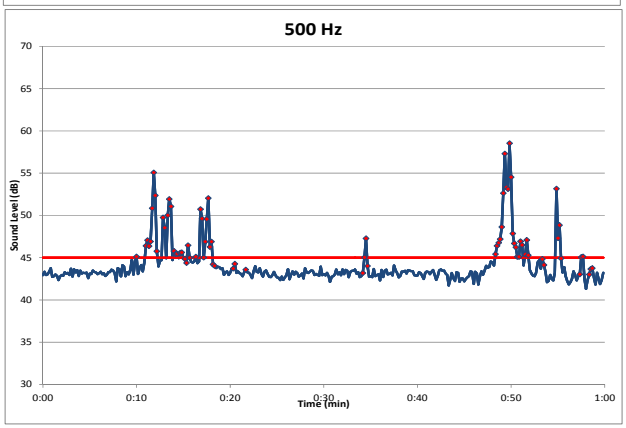

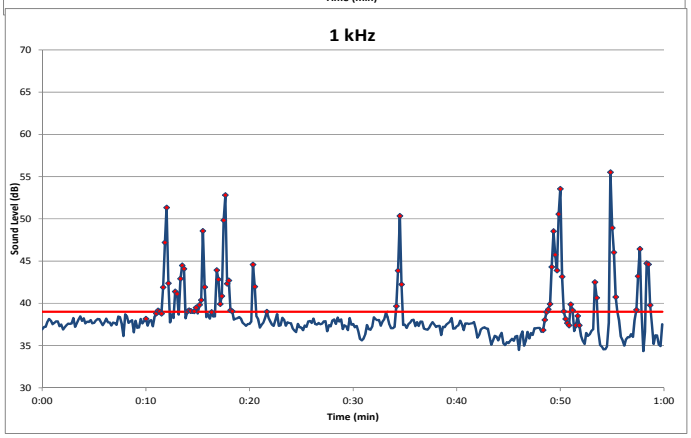

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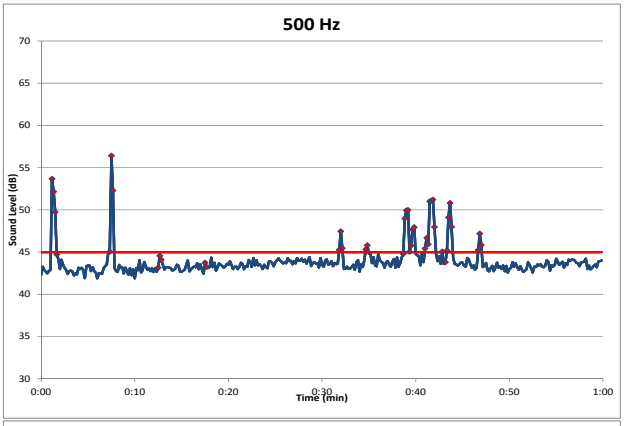

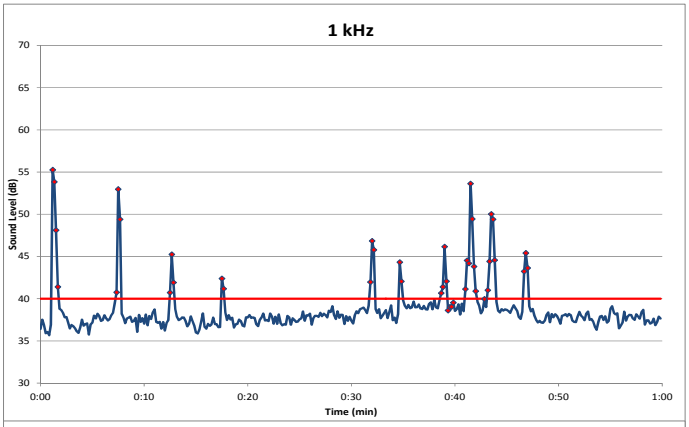

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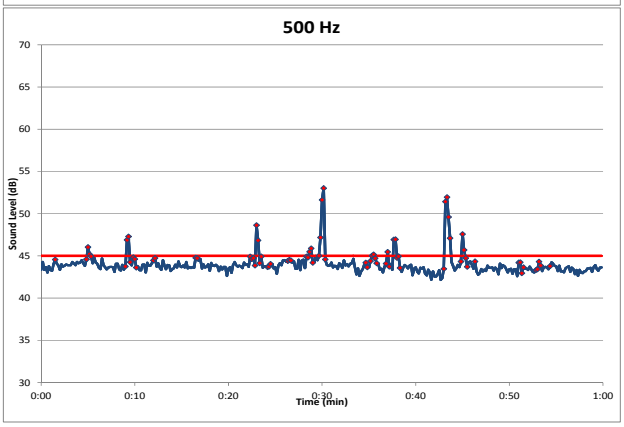

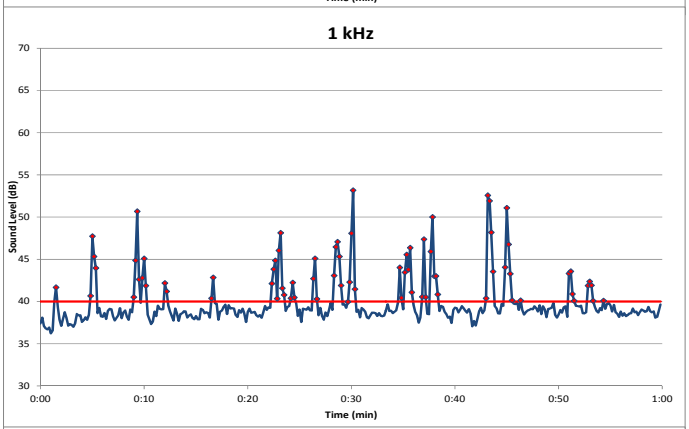

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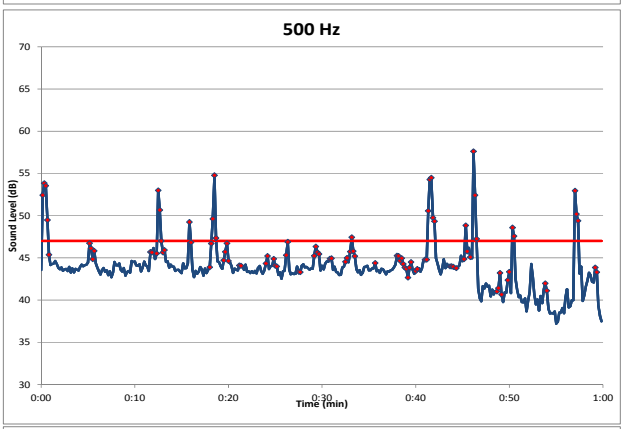

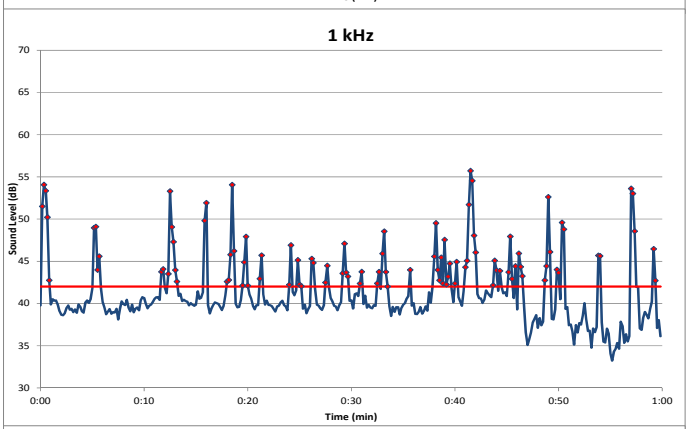

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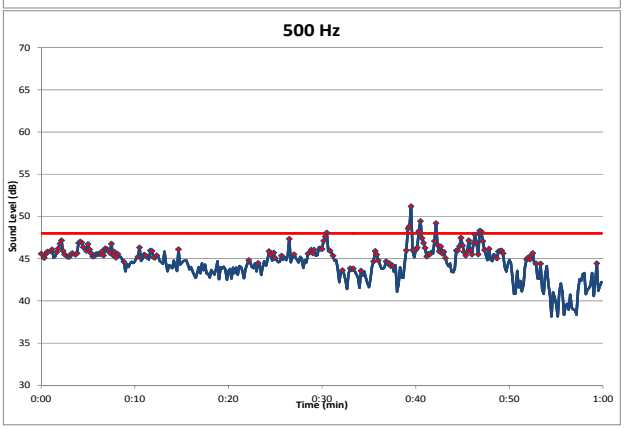

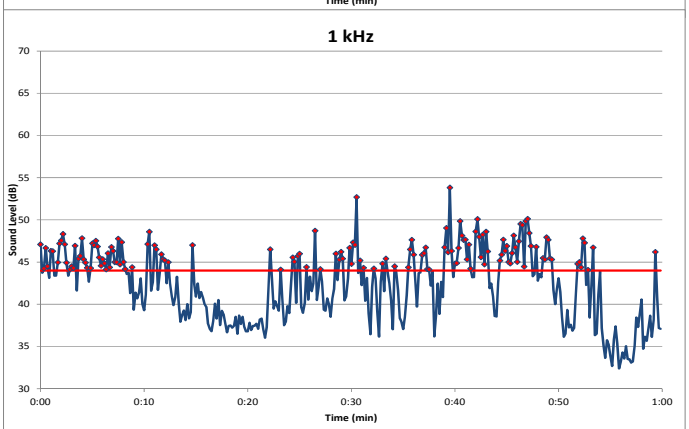

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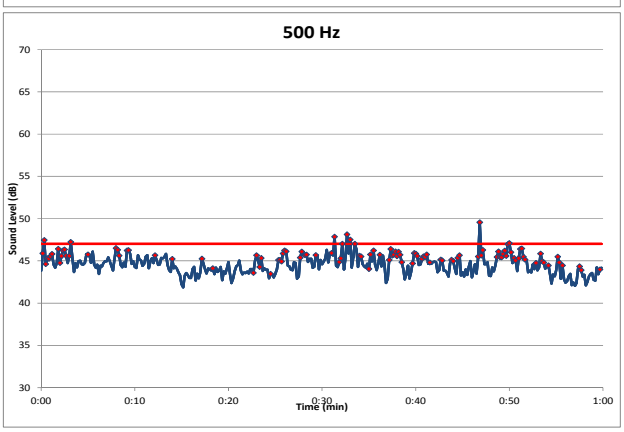

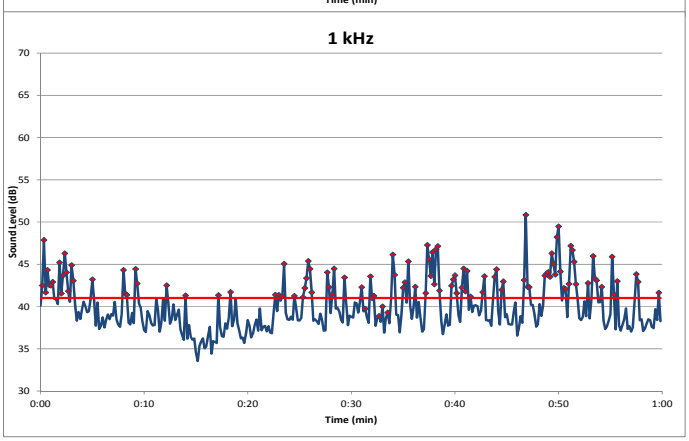

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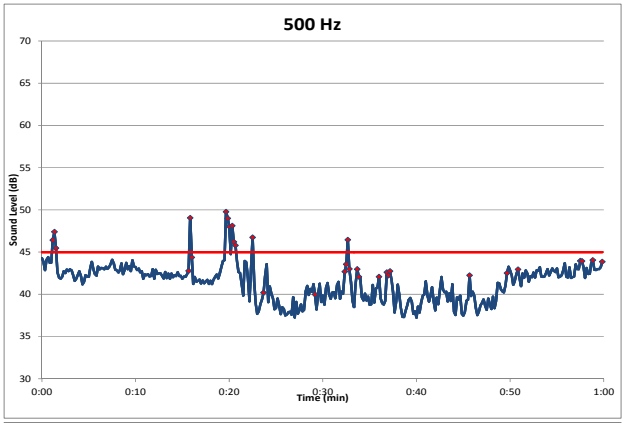

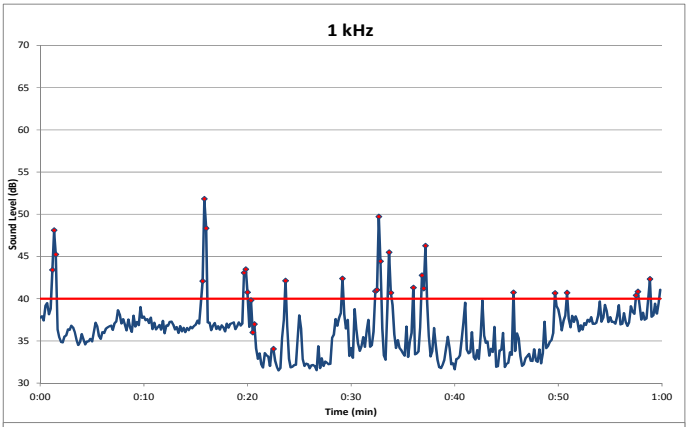

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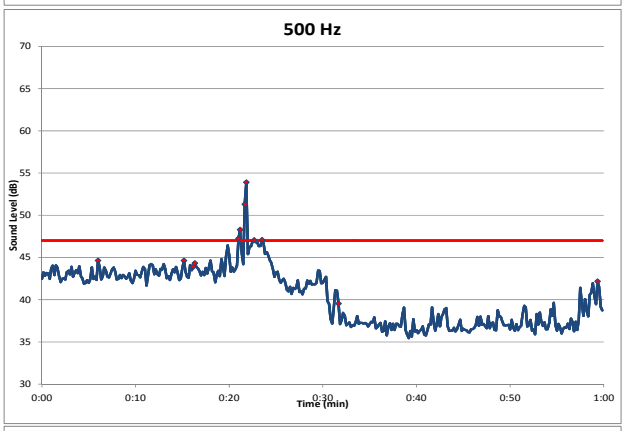

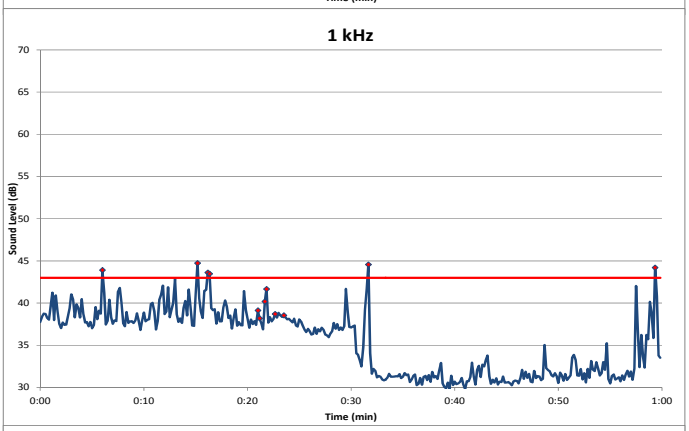

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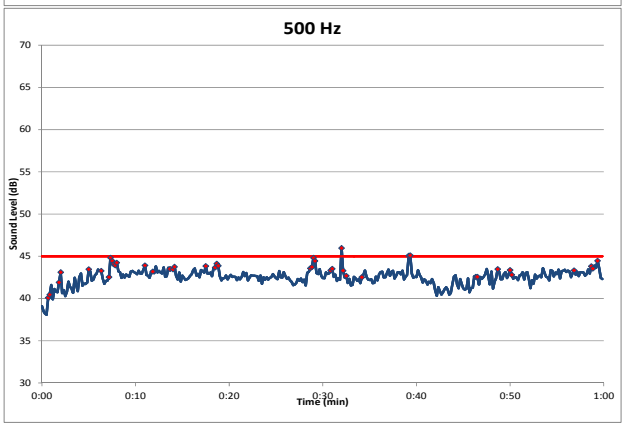
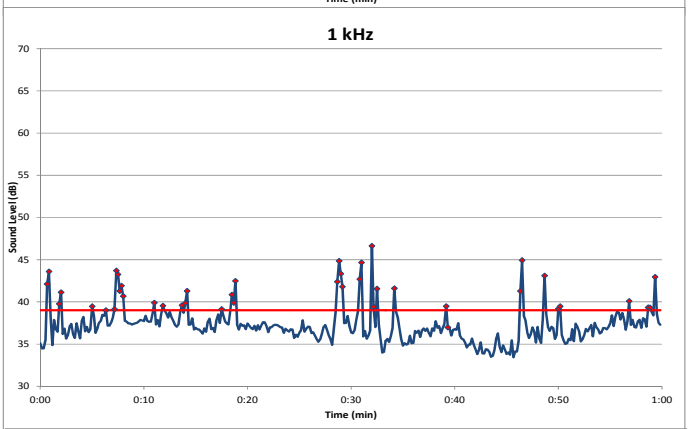
NOV 17

1:00





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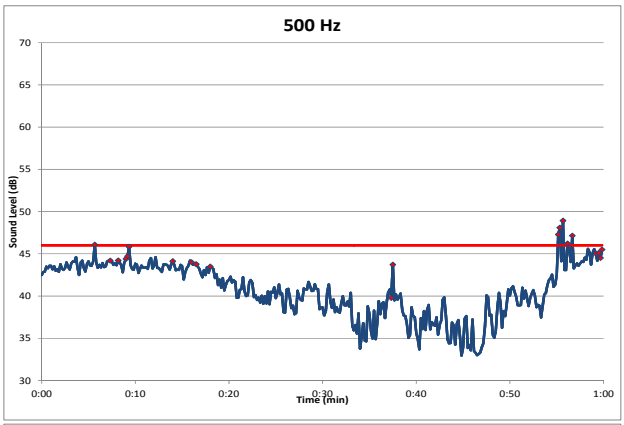

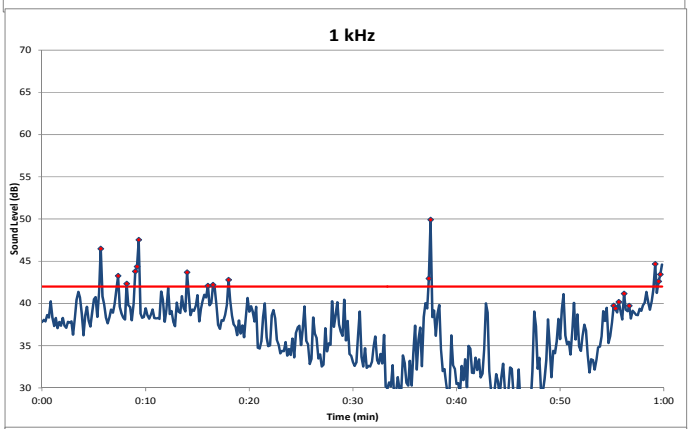

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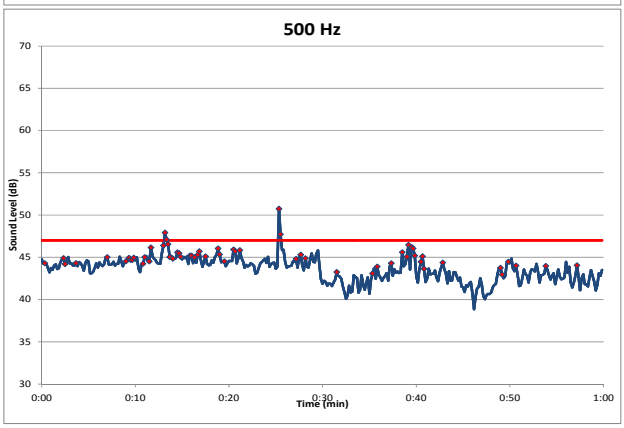

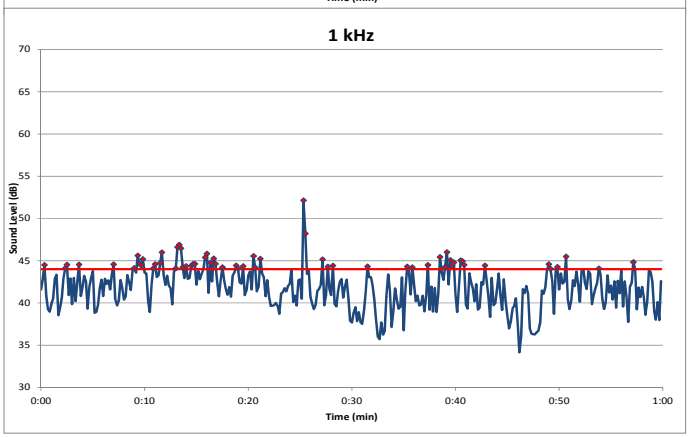

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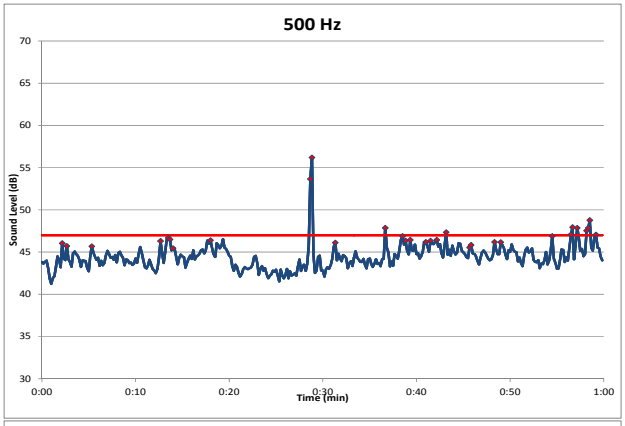

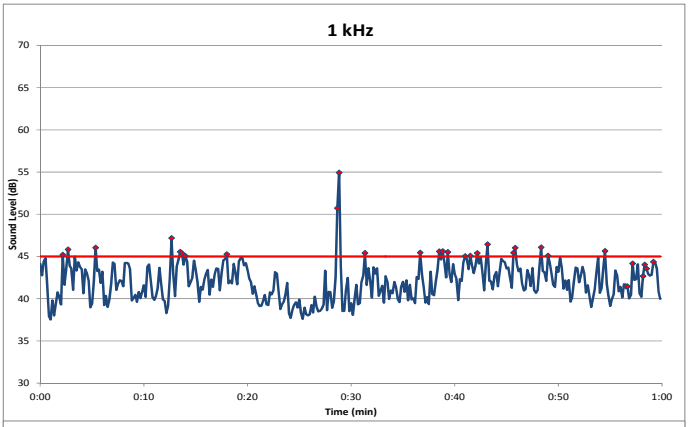

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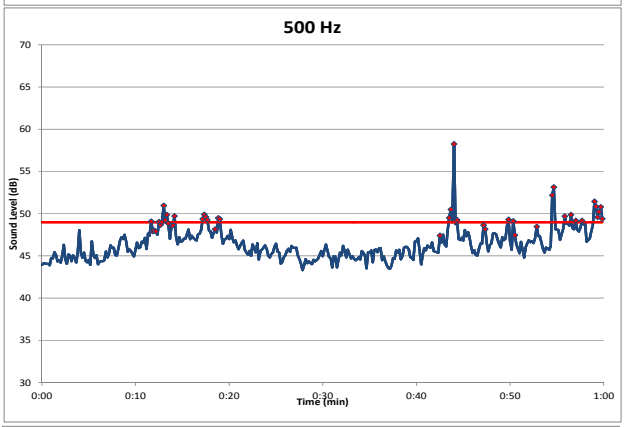

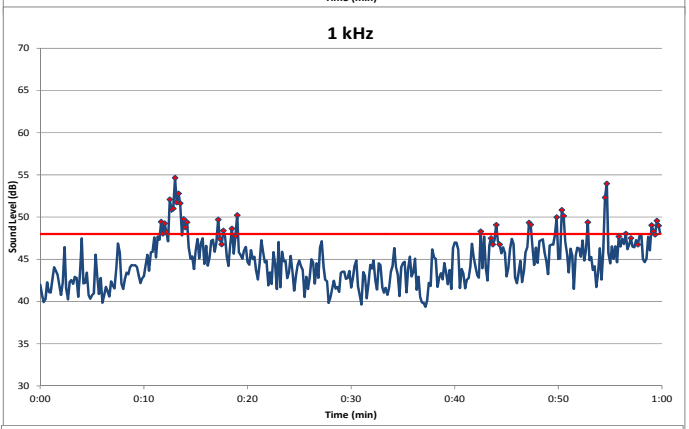

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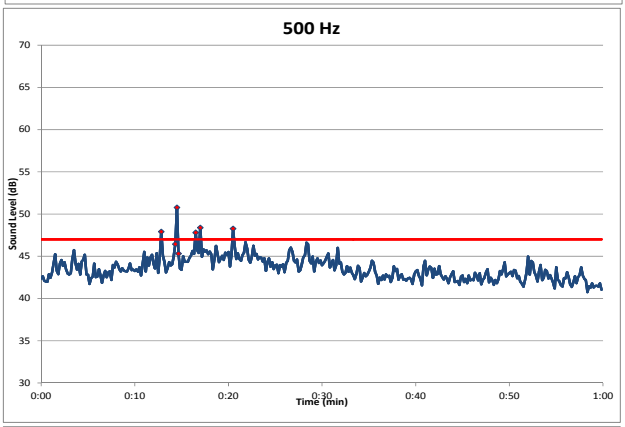

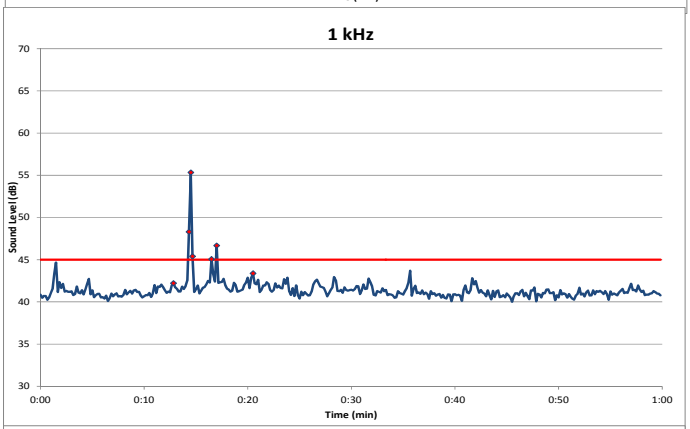

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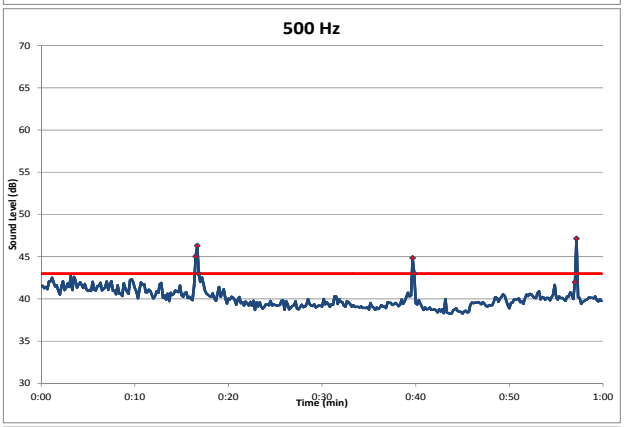

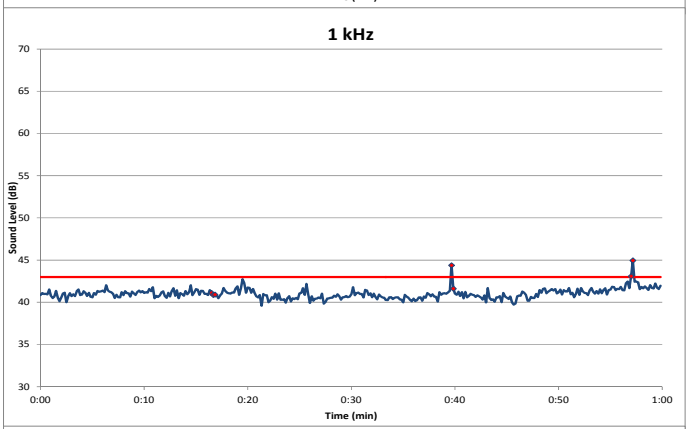

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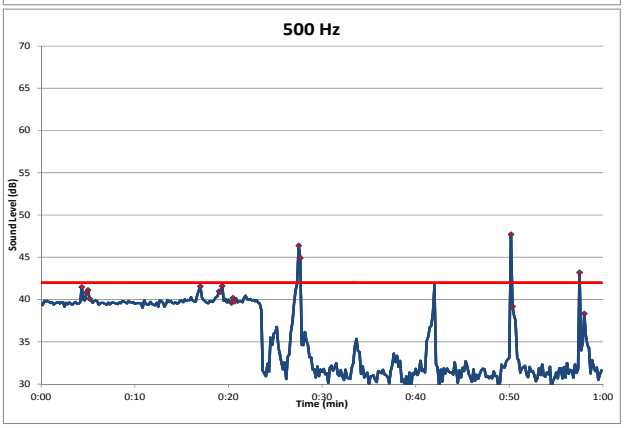

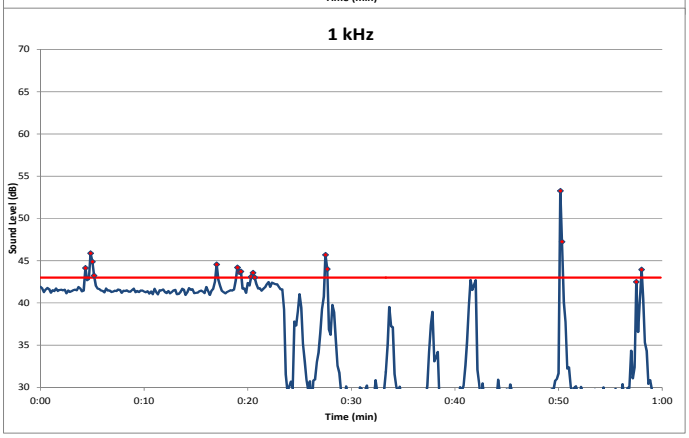

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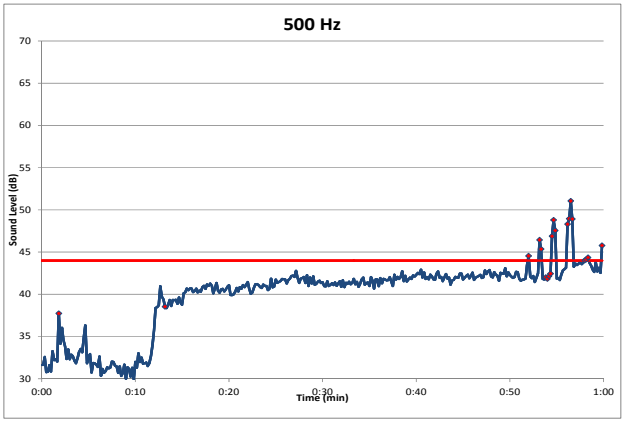

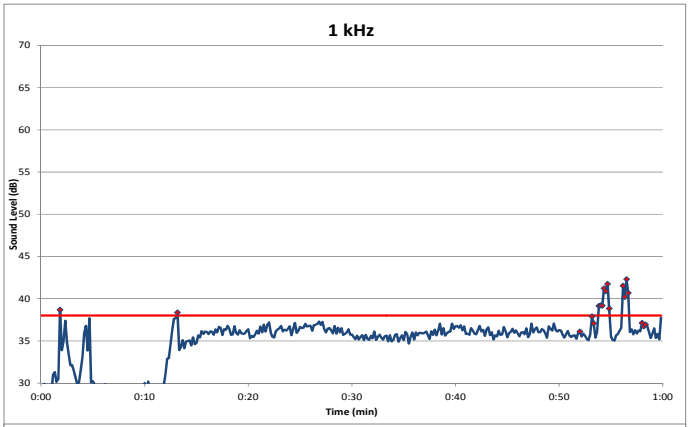

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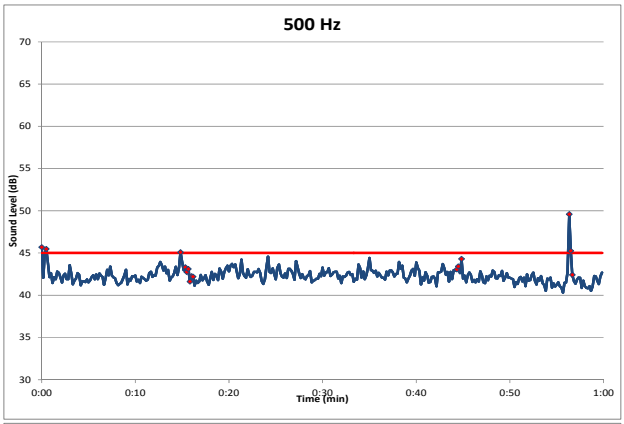

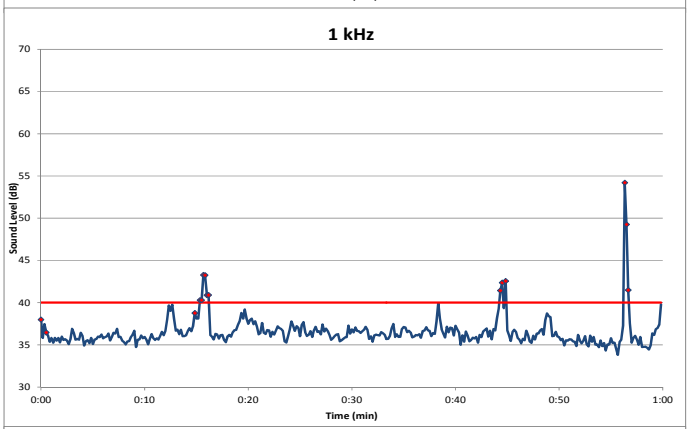

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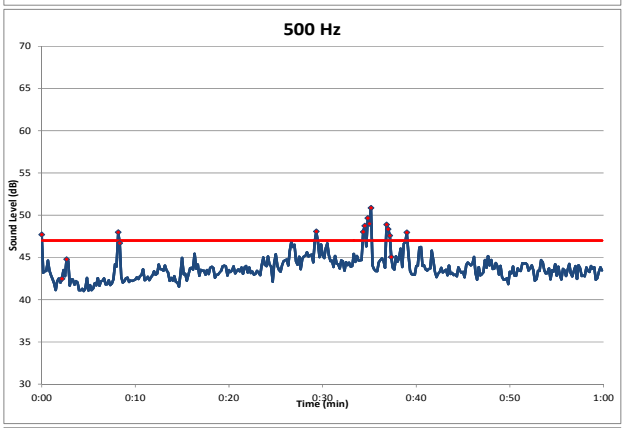

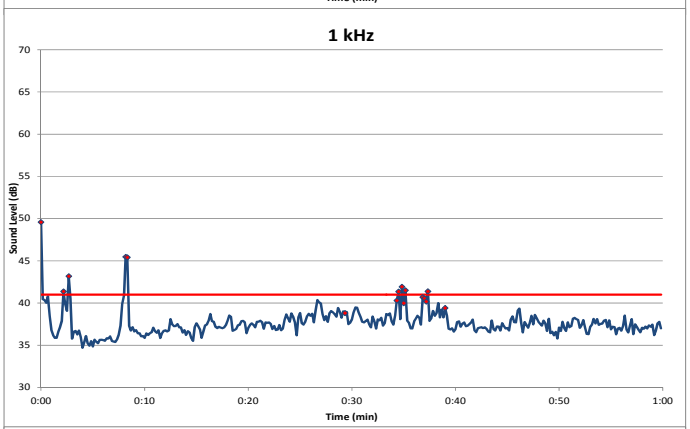

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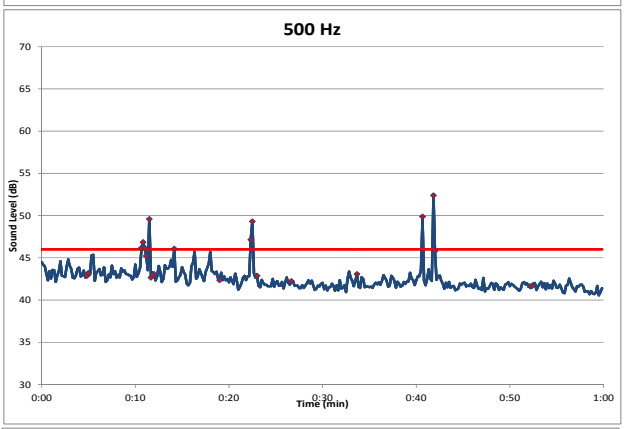

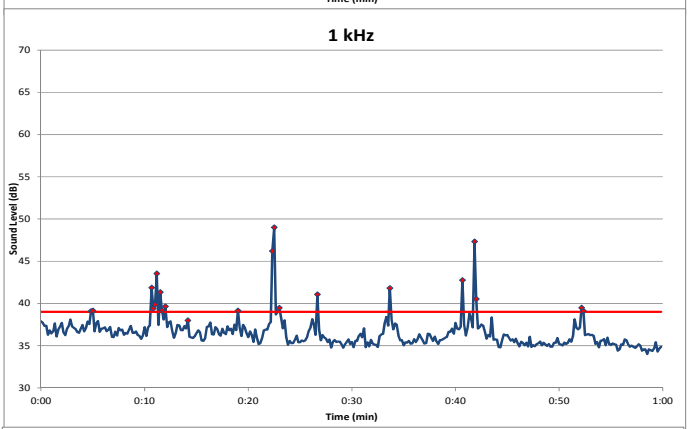

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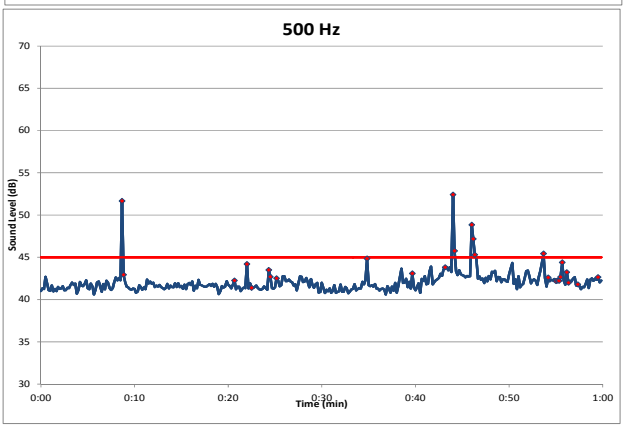

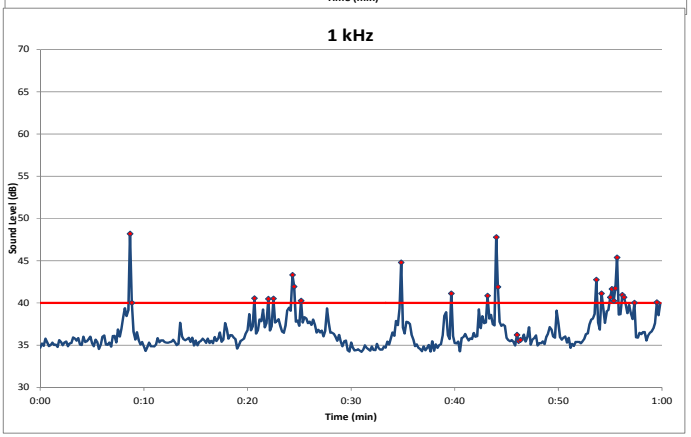

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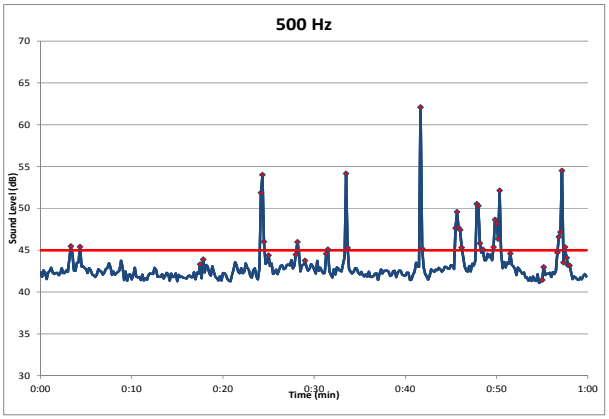

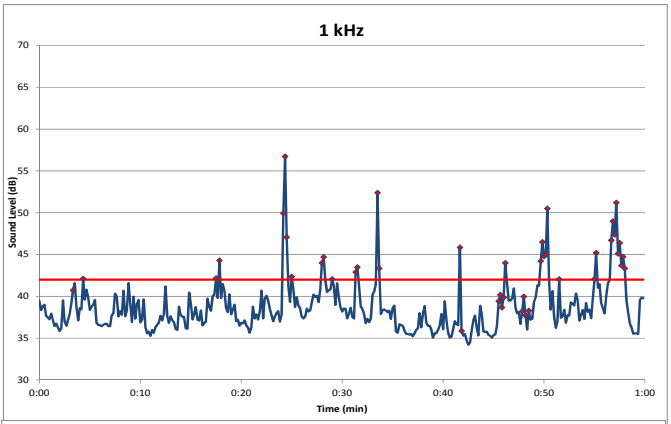

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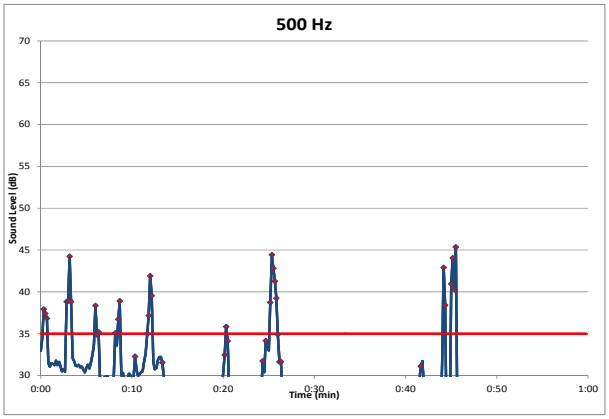

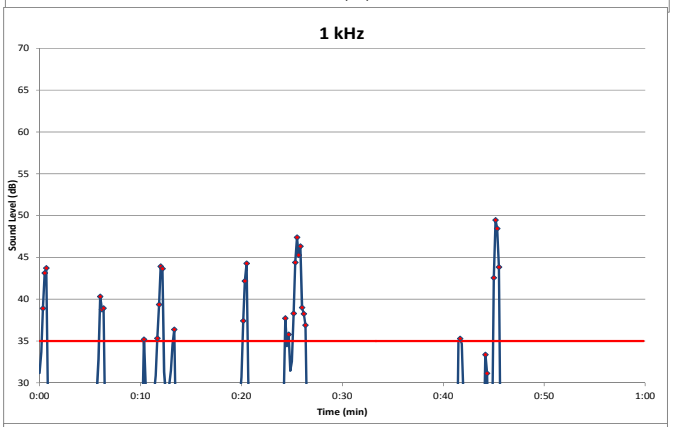

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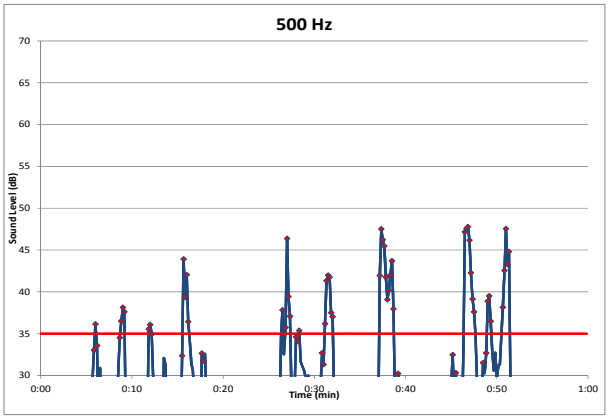

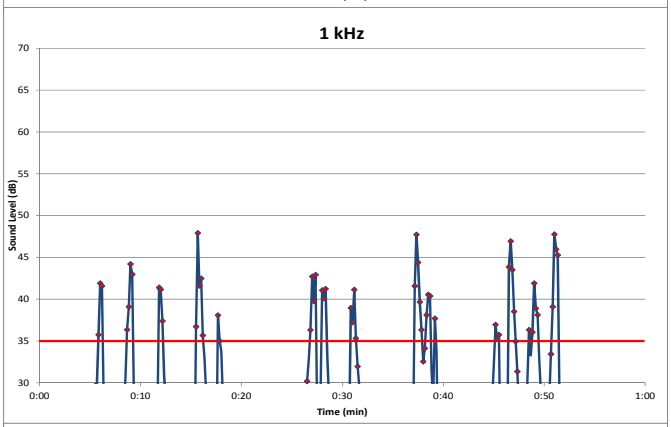

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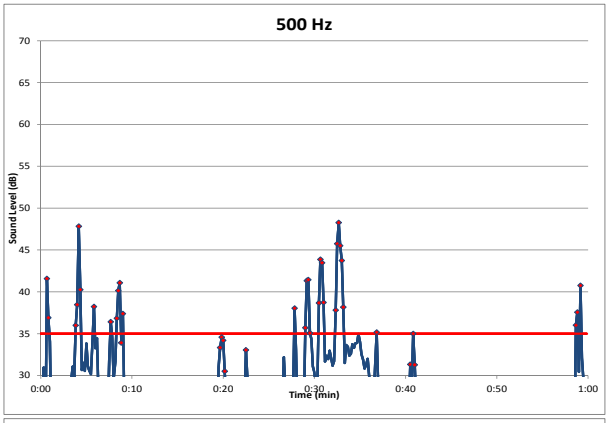

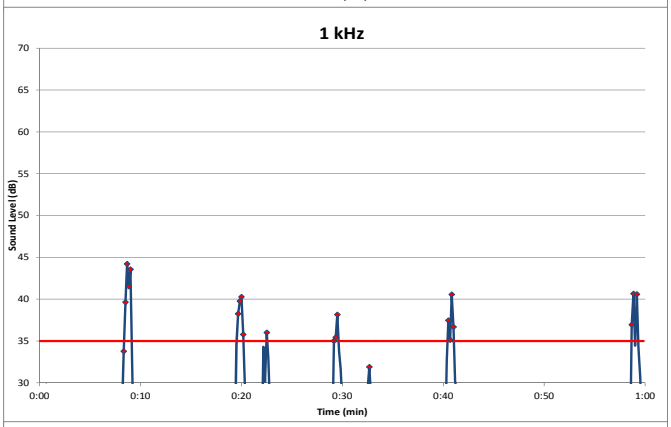

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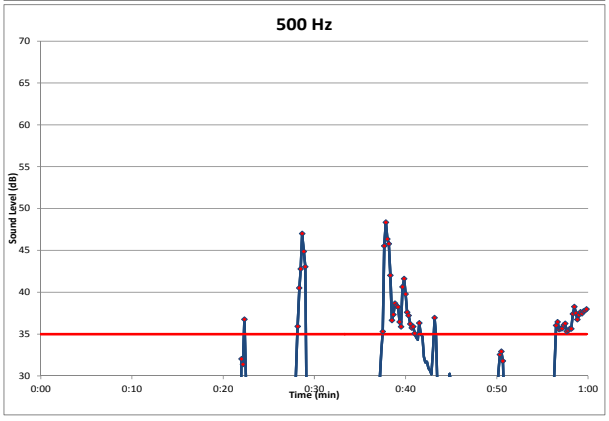

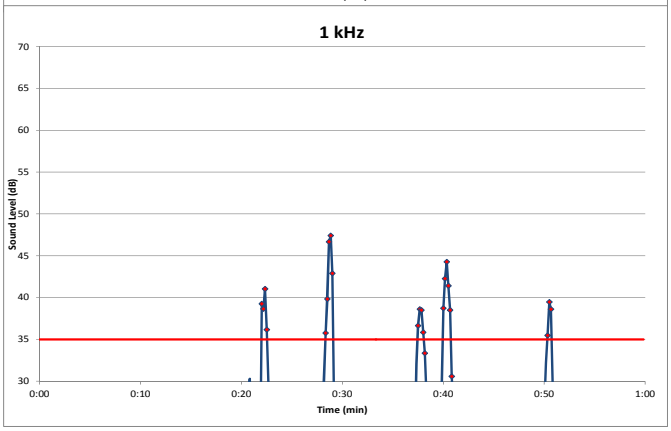

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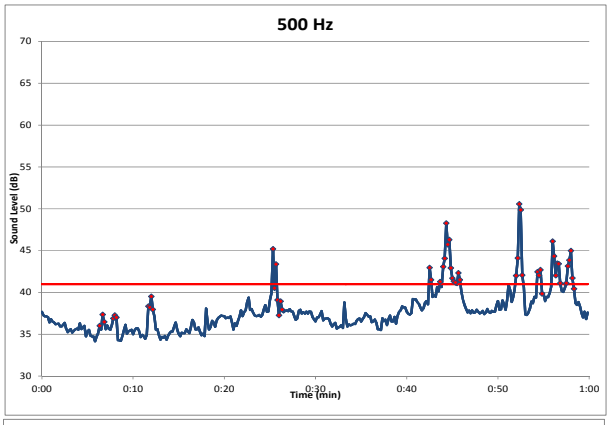

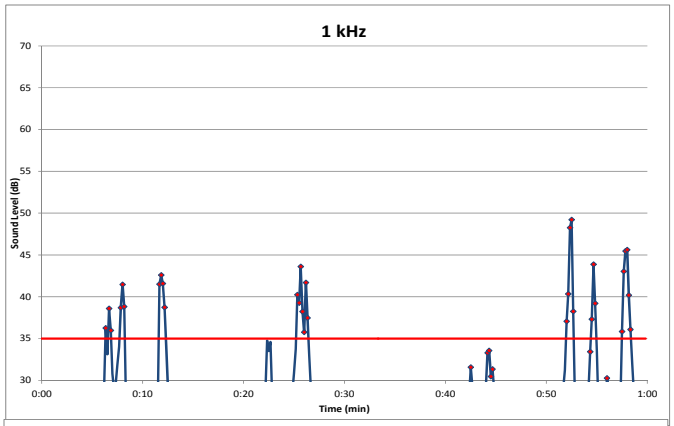

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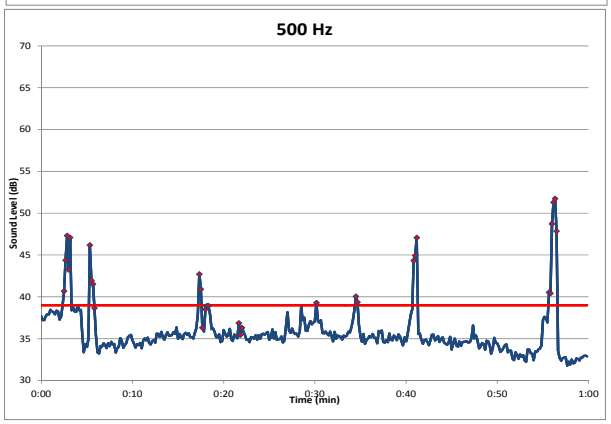

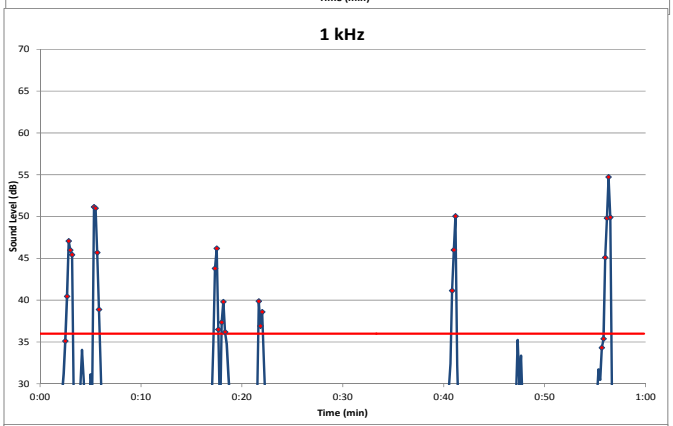

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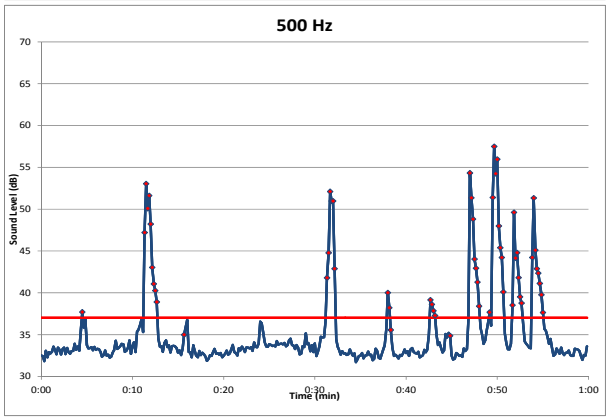

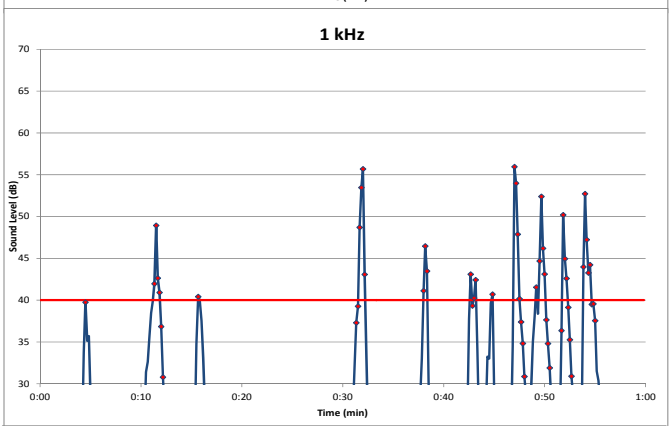

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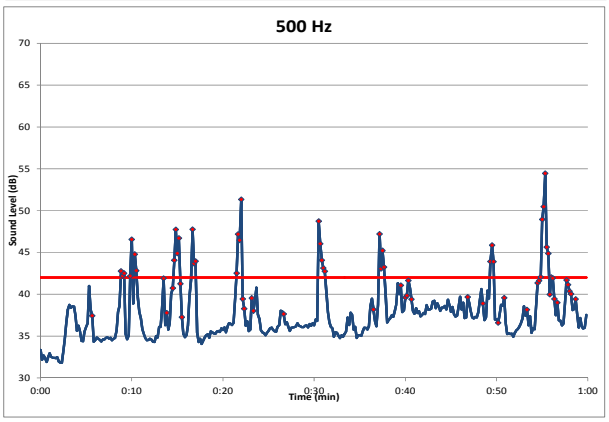

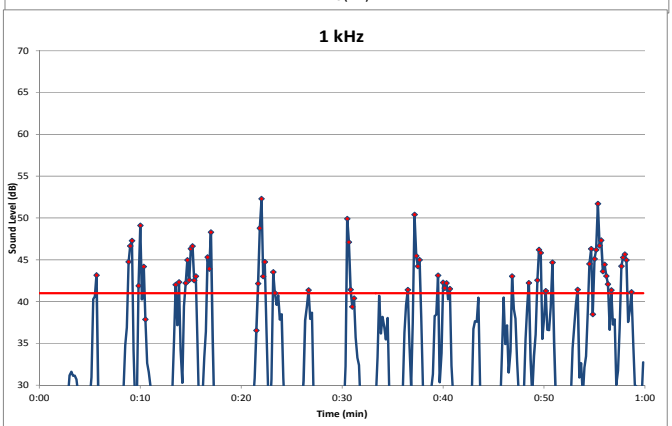

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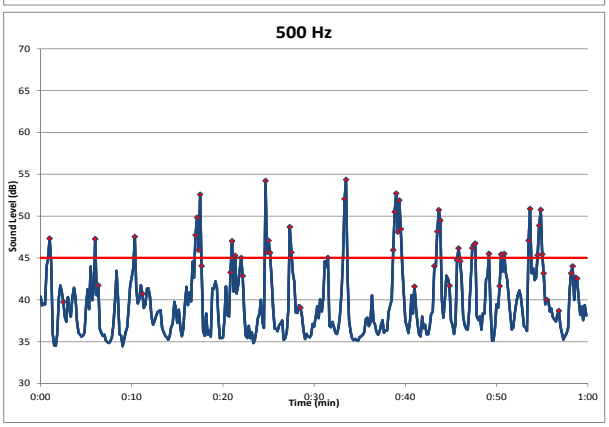

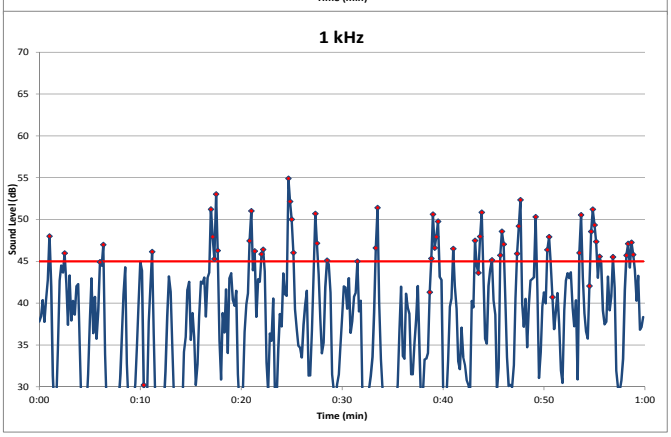

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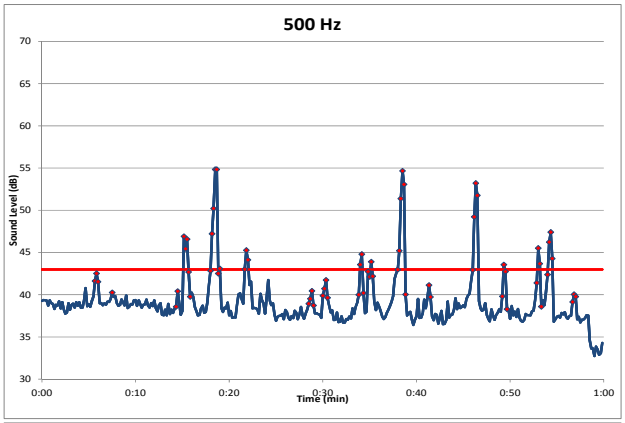

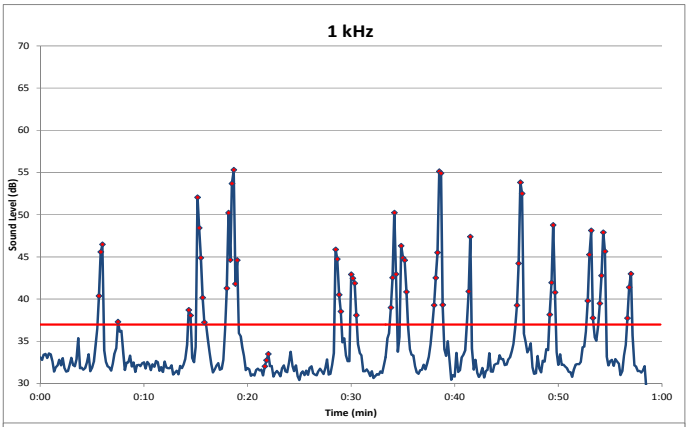

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NOV 19

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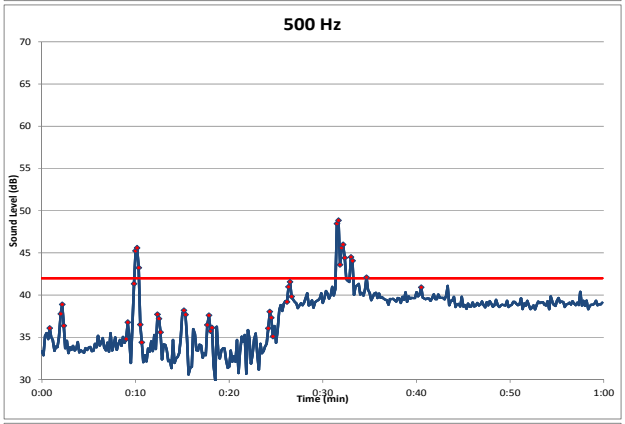

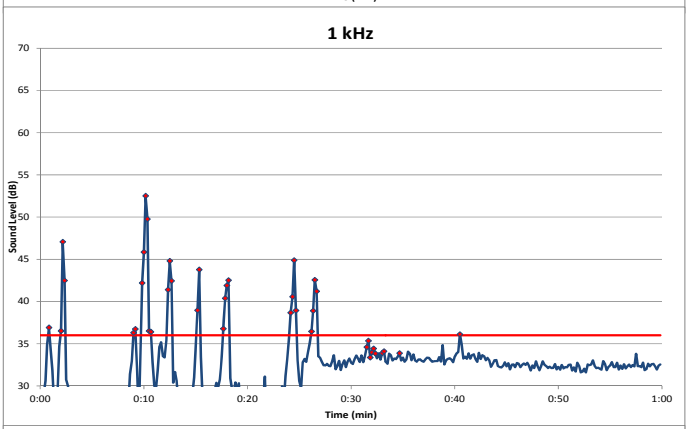

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NOV 19

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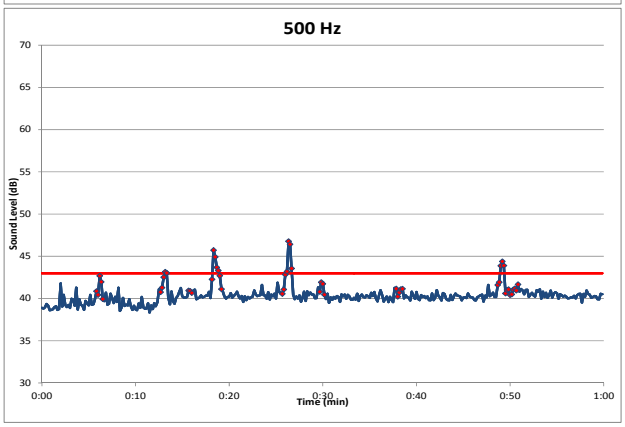

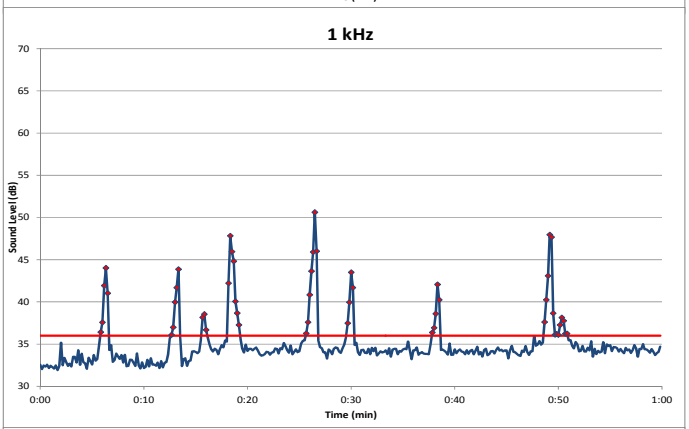

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NOV 20

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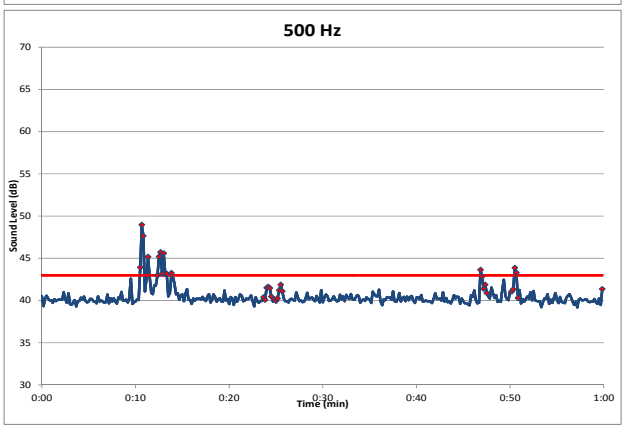

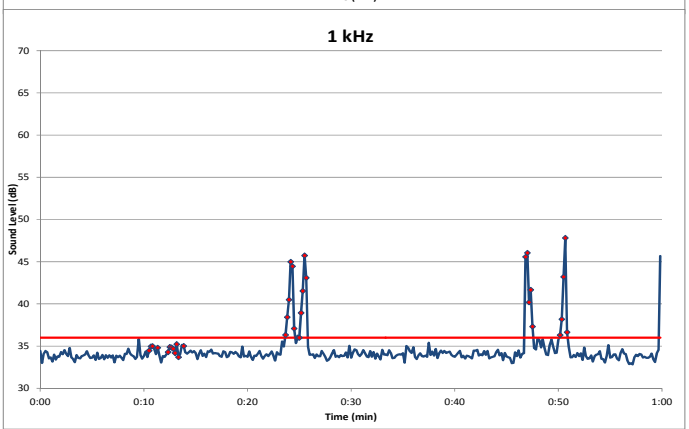

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NOV 20

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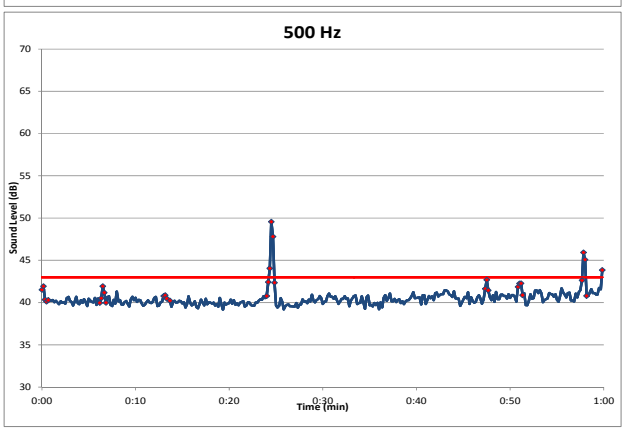

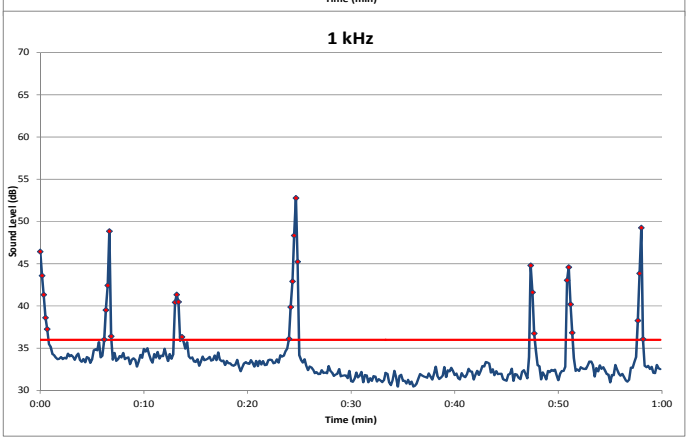

2013

NOV 20

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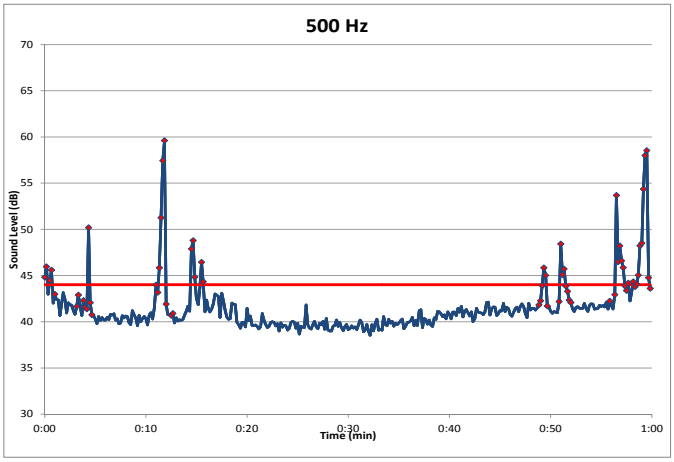

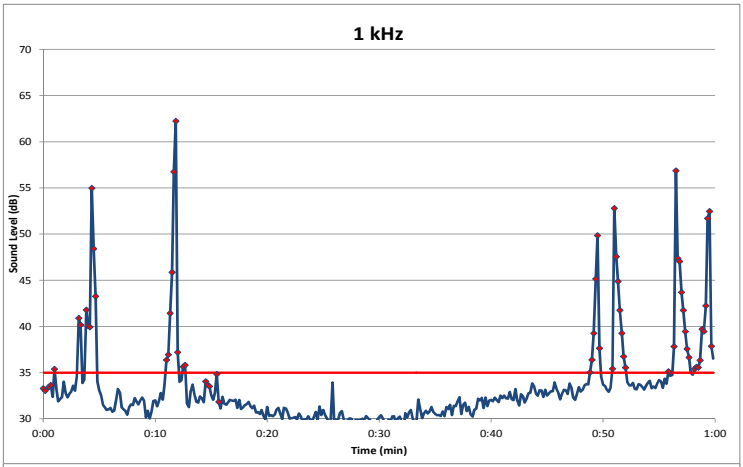

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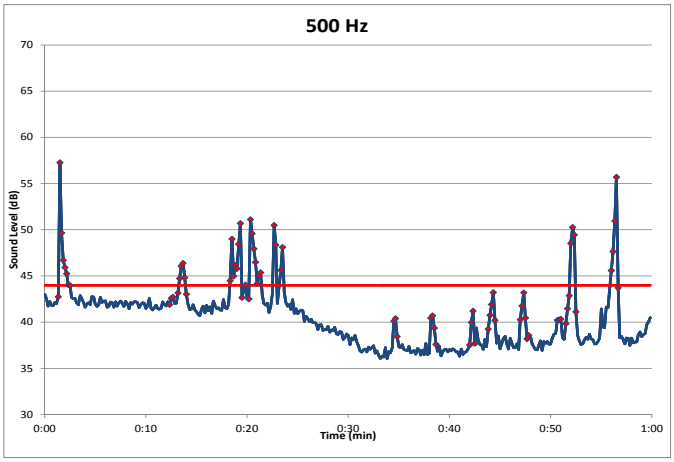

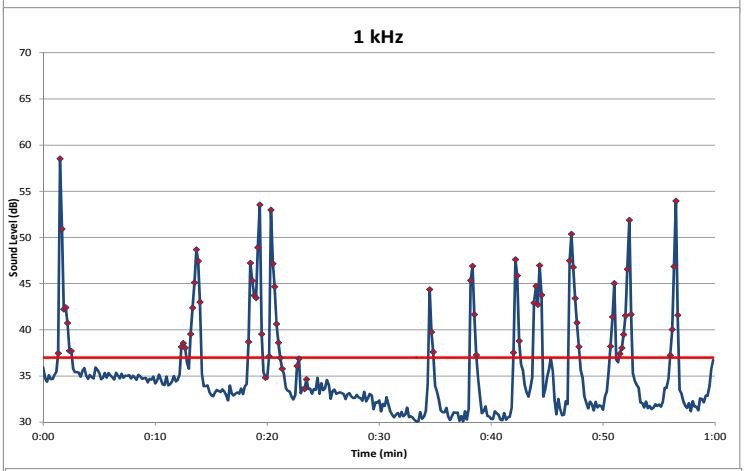

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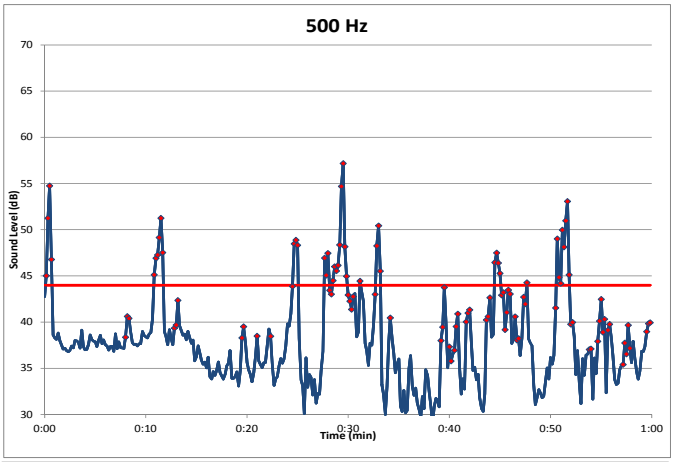

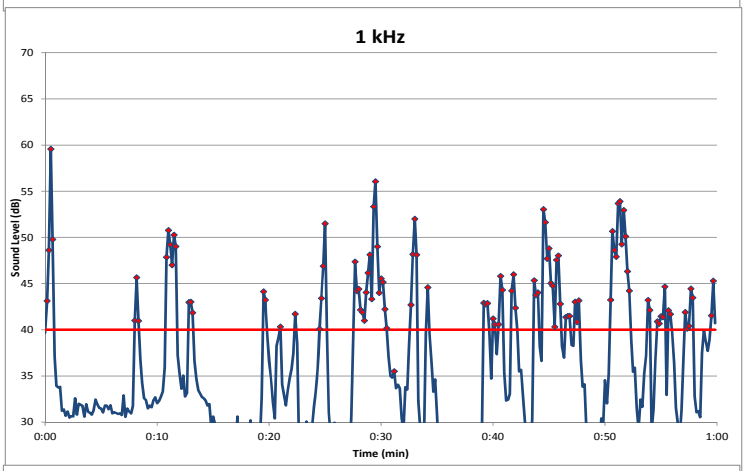

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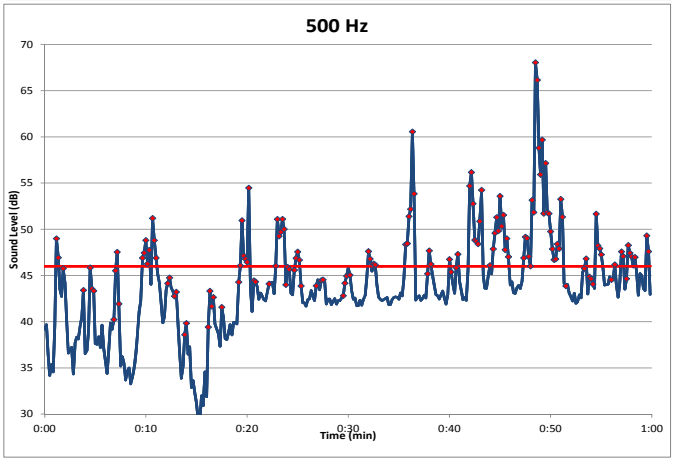

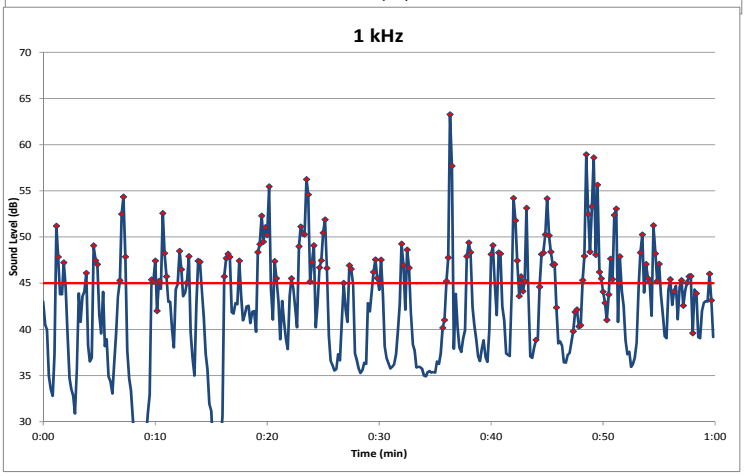

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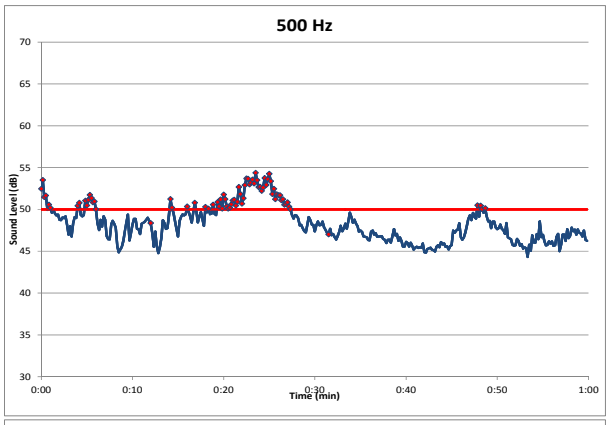

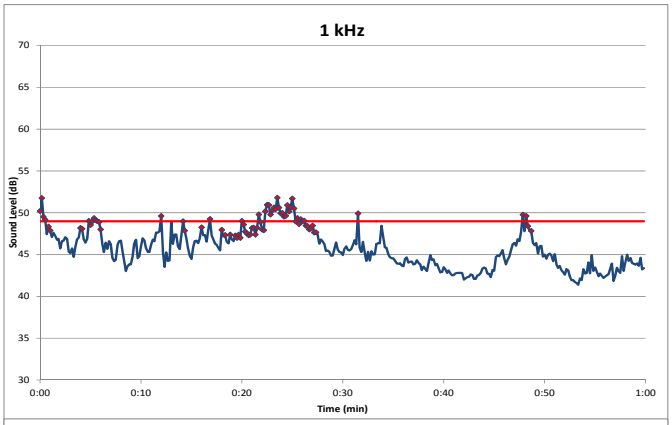

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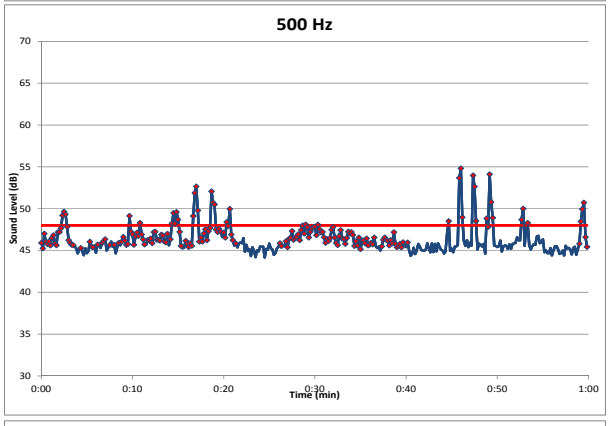

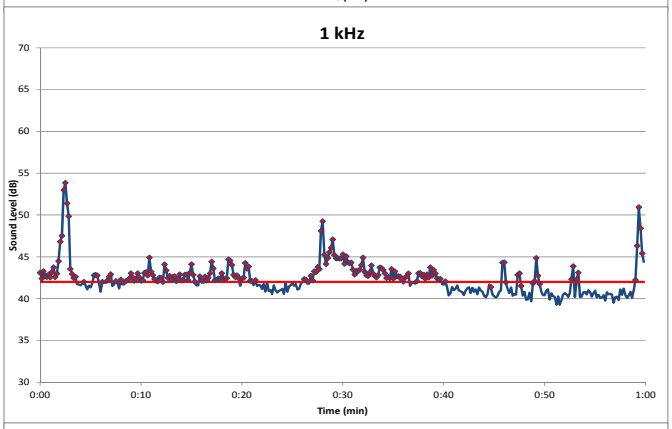

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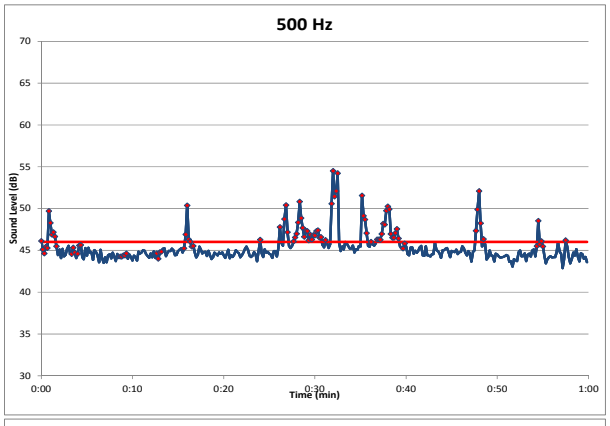

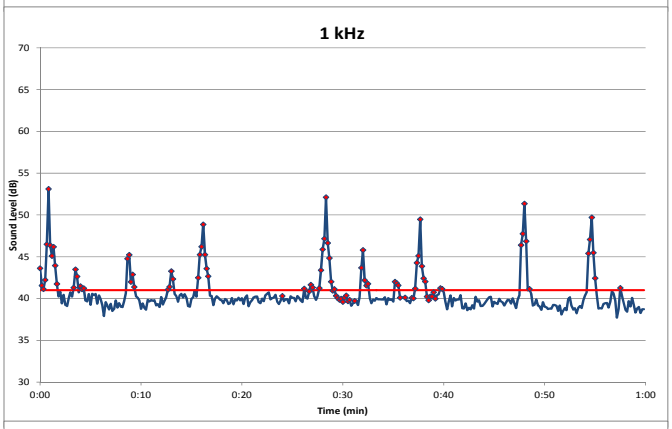

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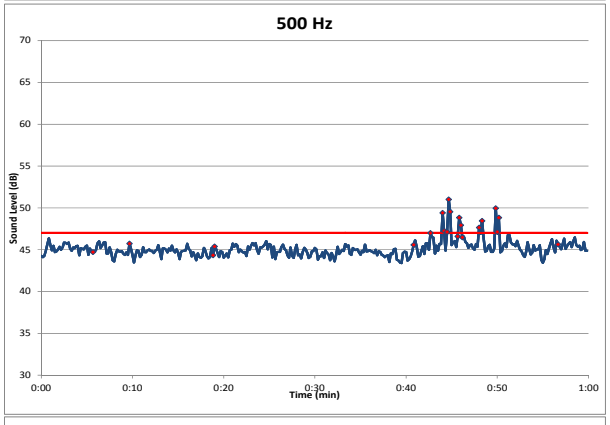

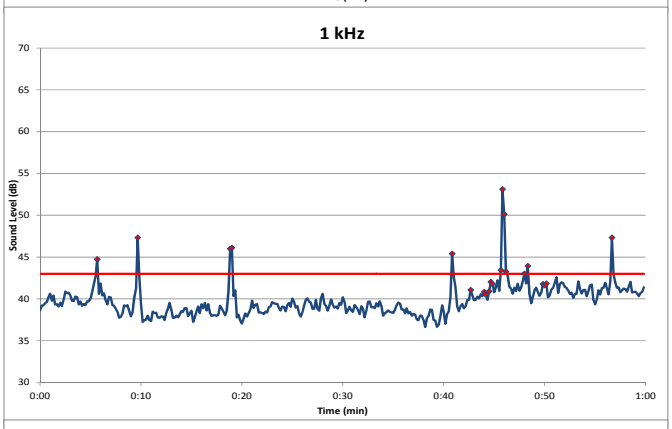

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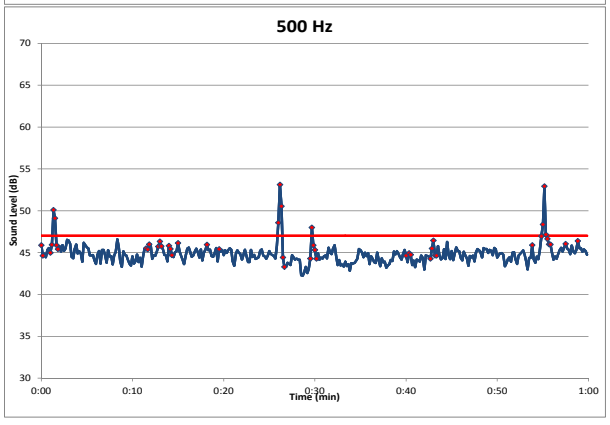

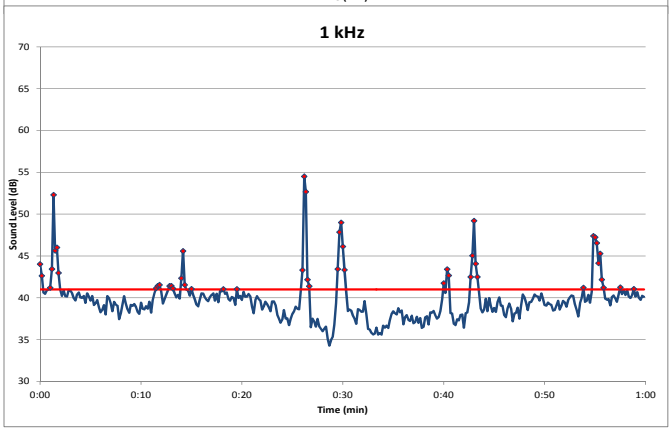

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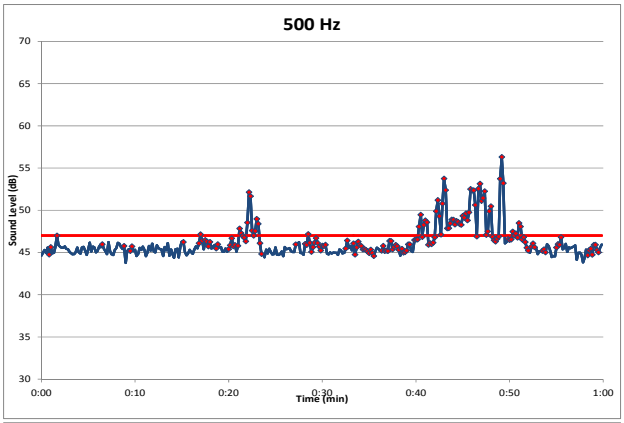

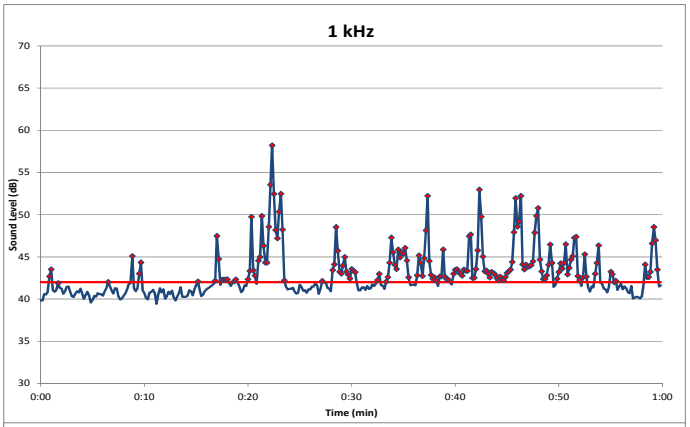

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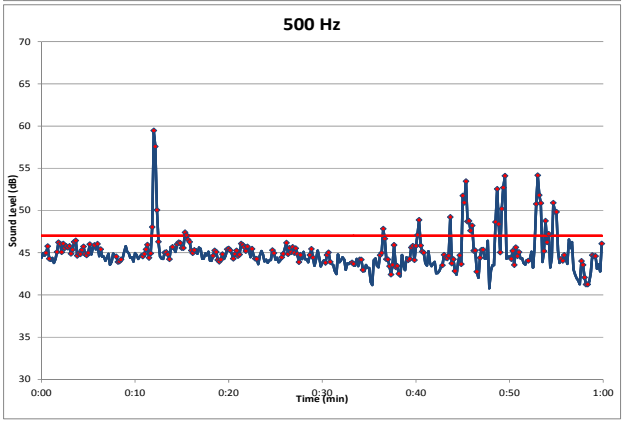

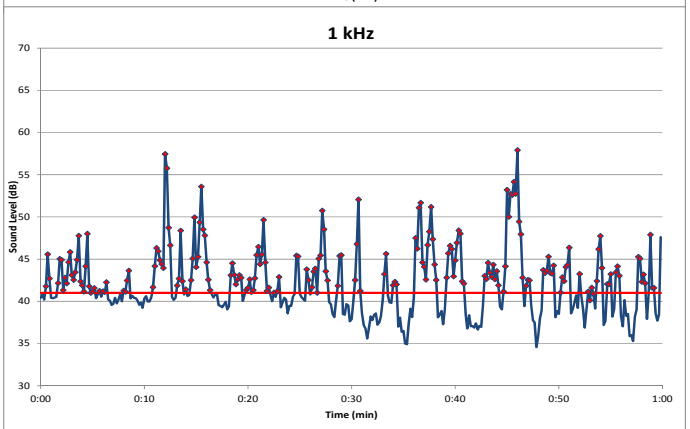

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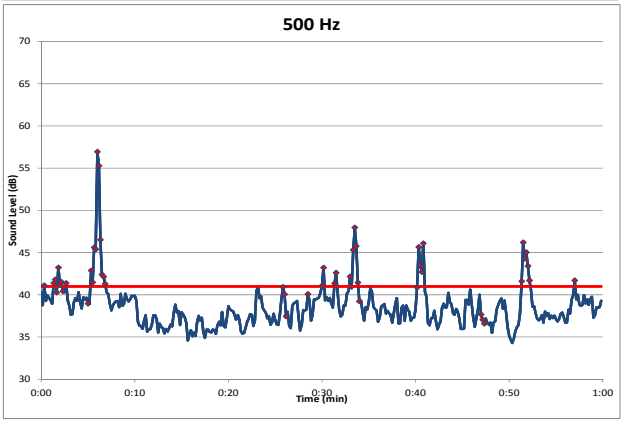

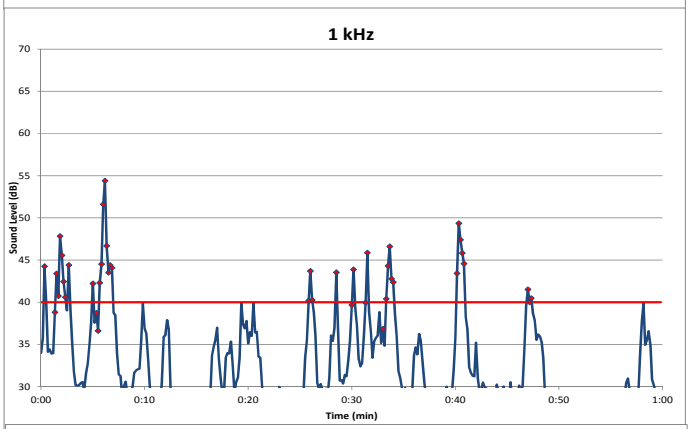

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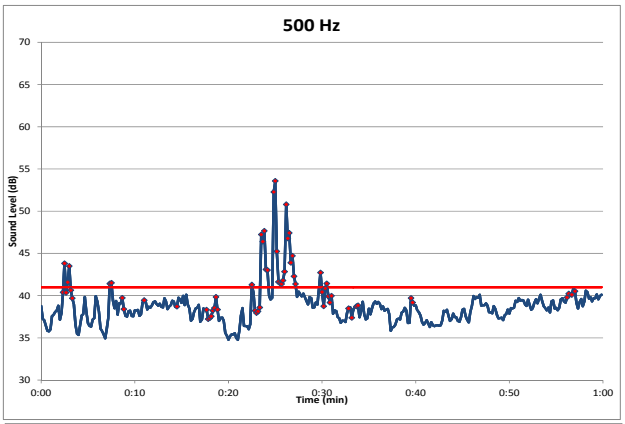

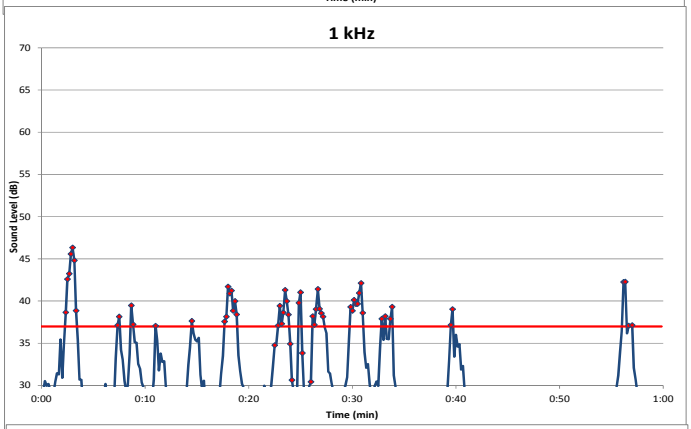

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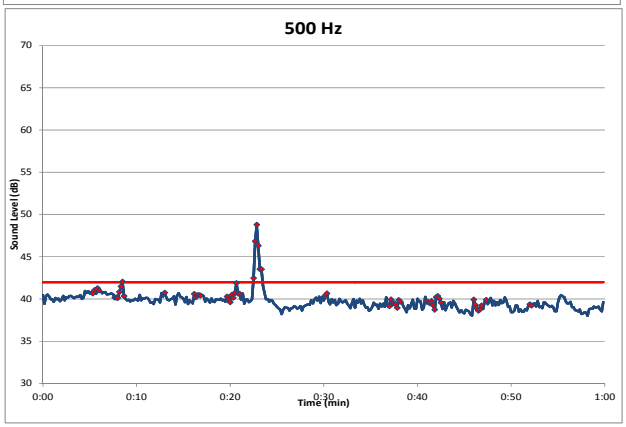

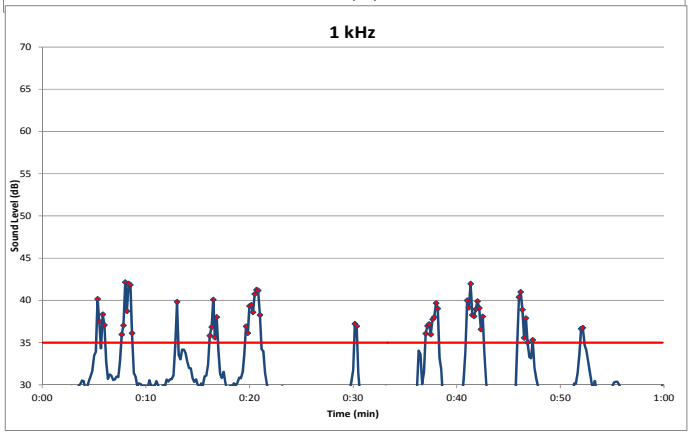

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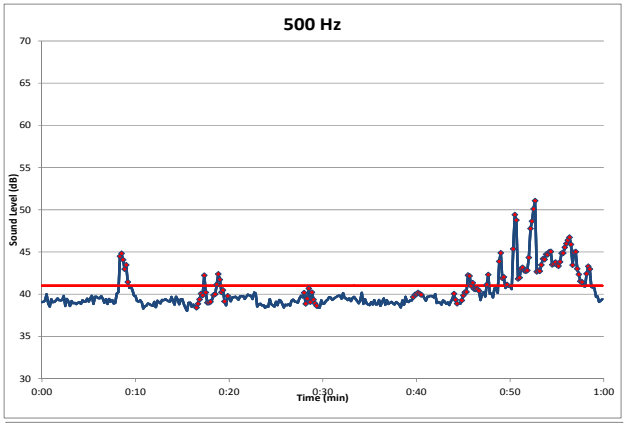

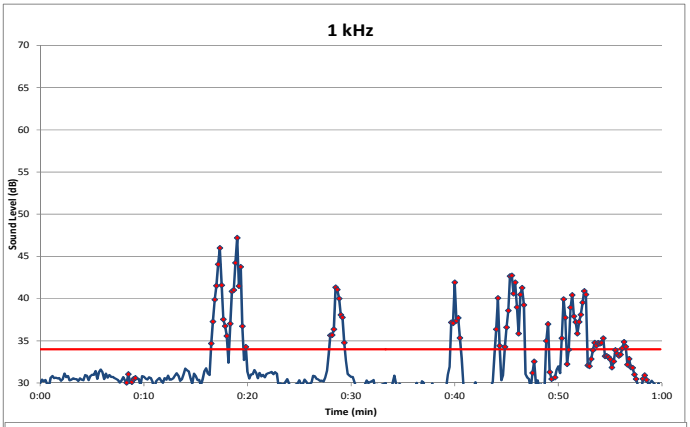

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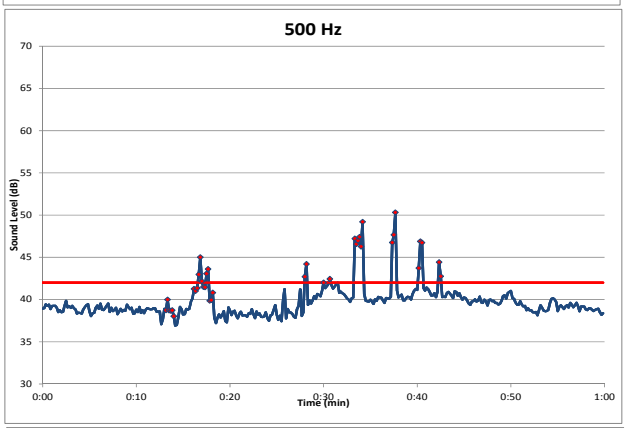

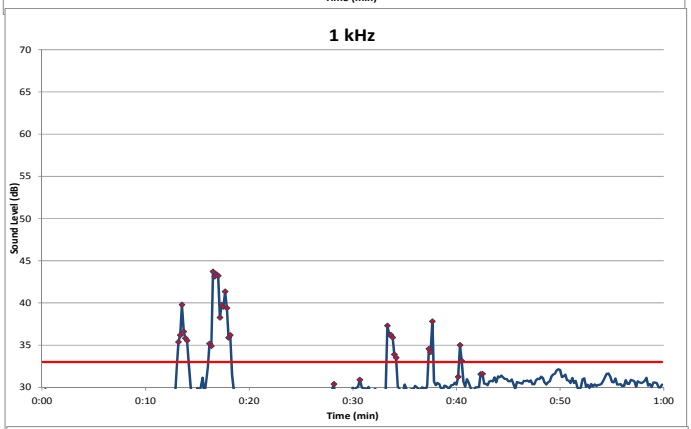

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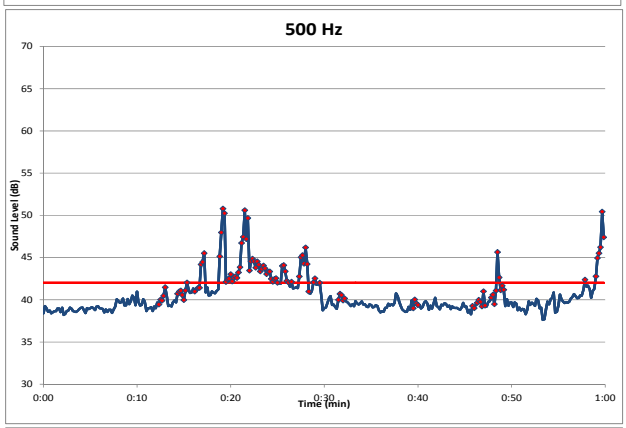

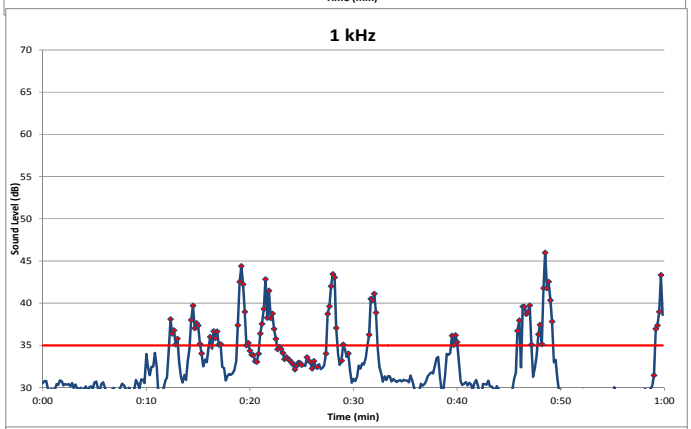

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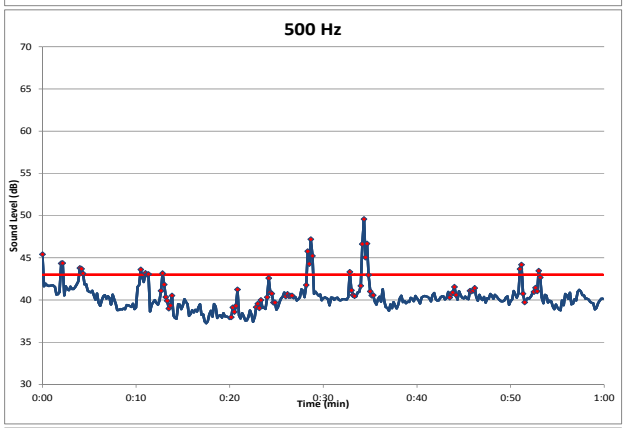

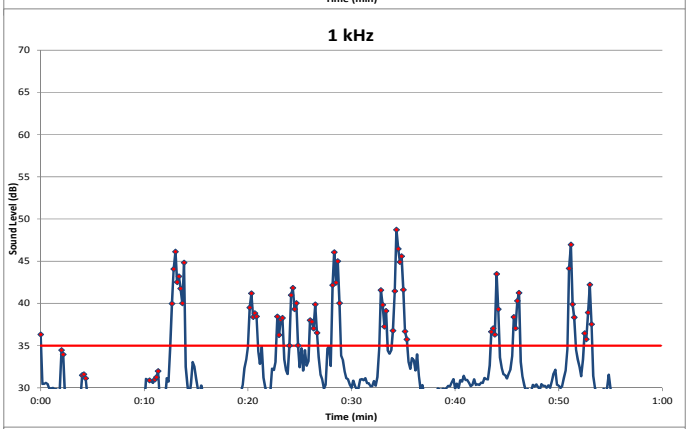

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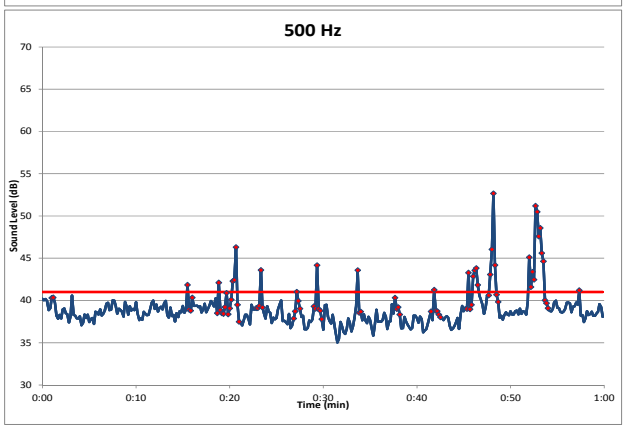

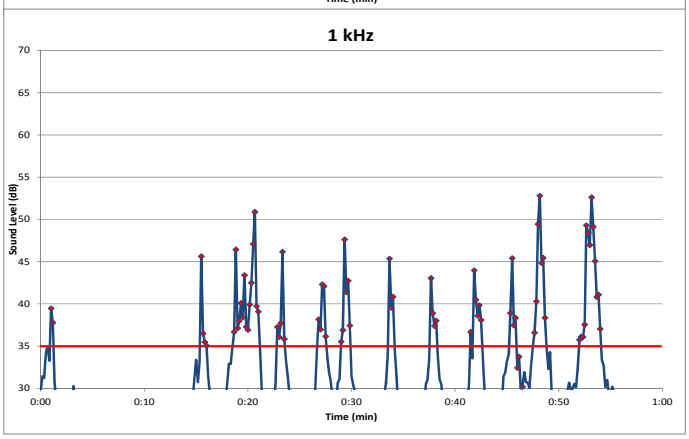

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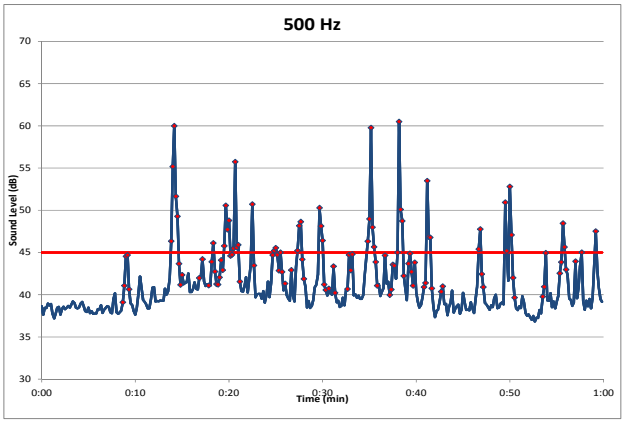

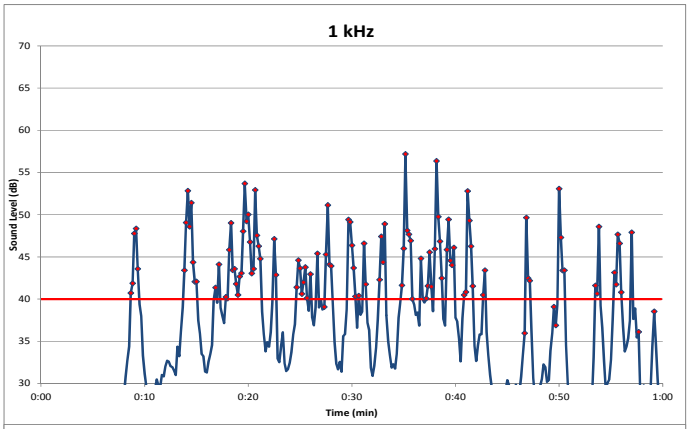

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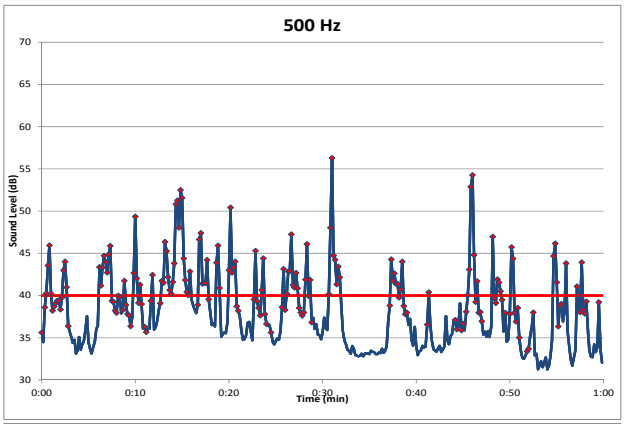

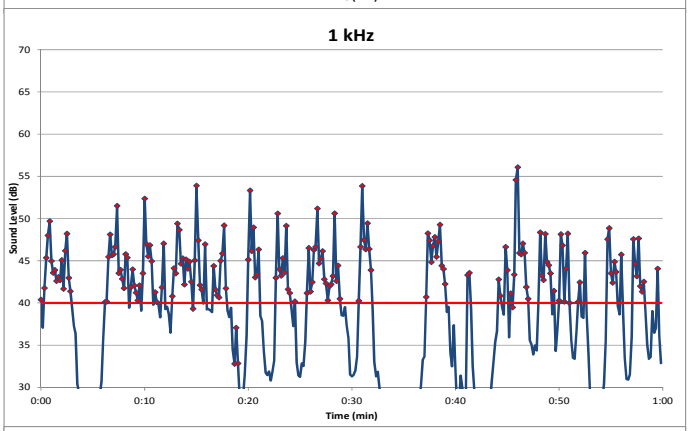

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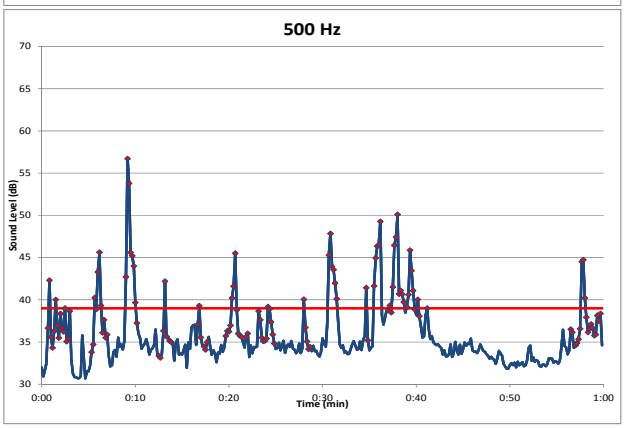

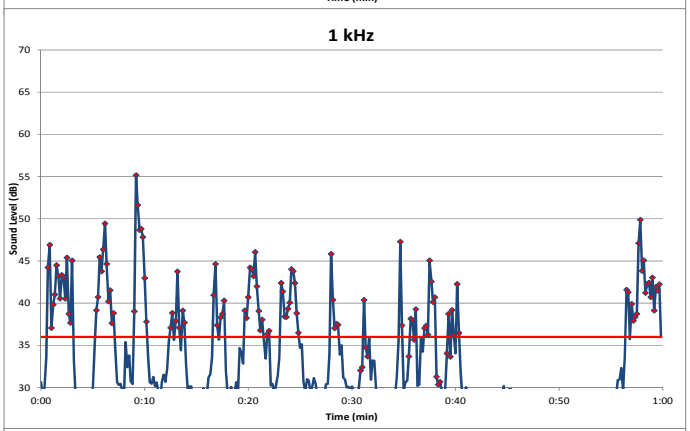

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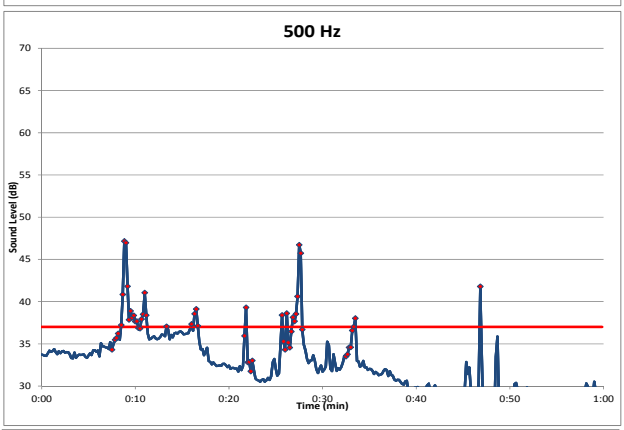

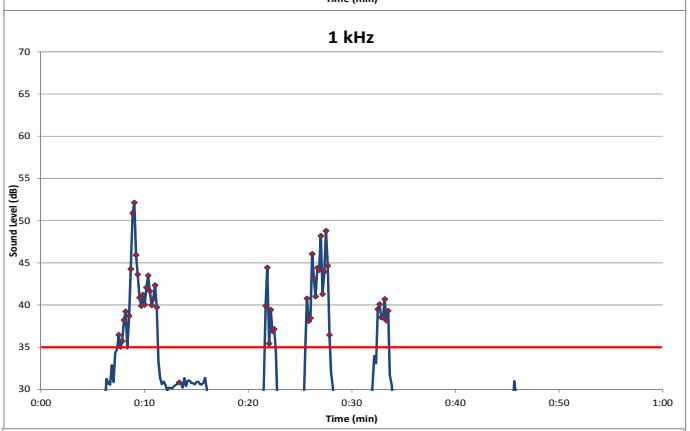

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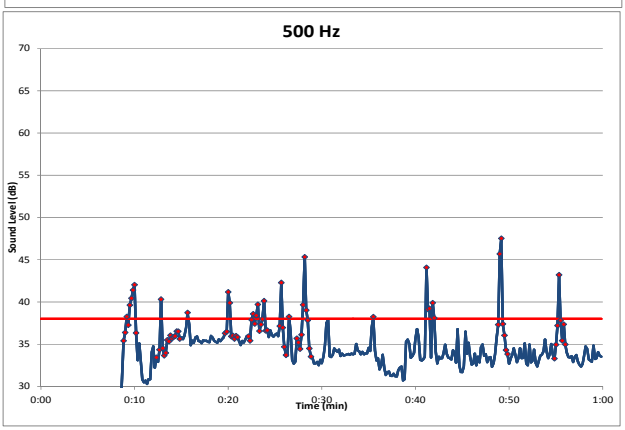

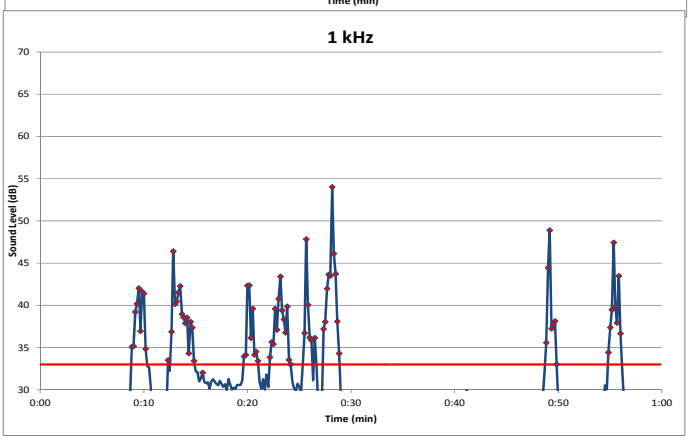

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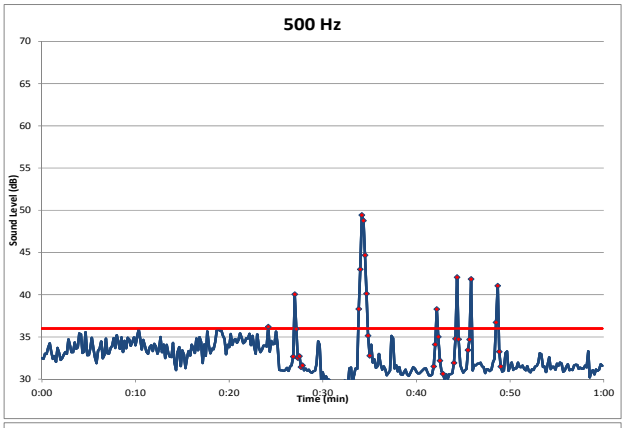

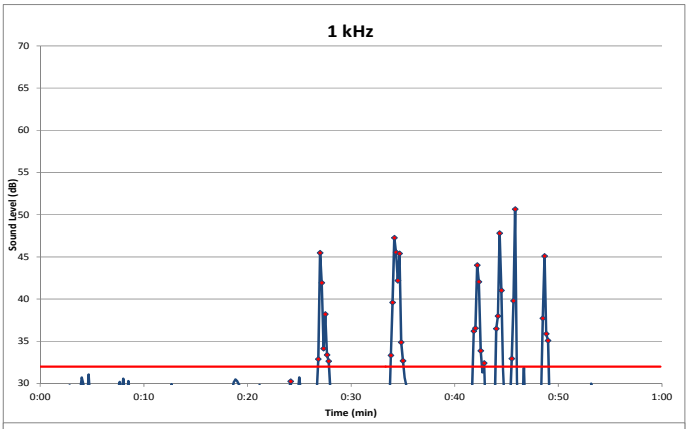

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NOV 3

1:00

daylight savings

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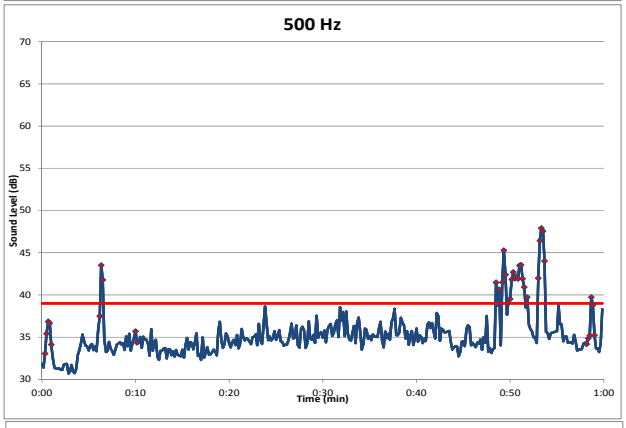

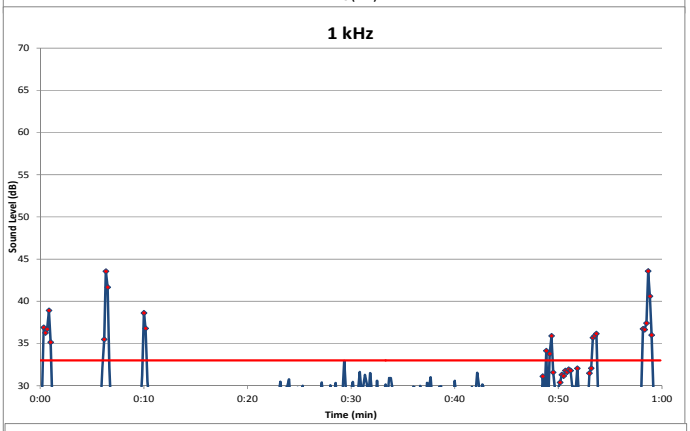

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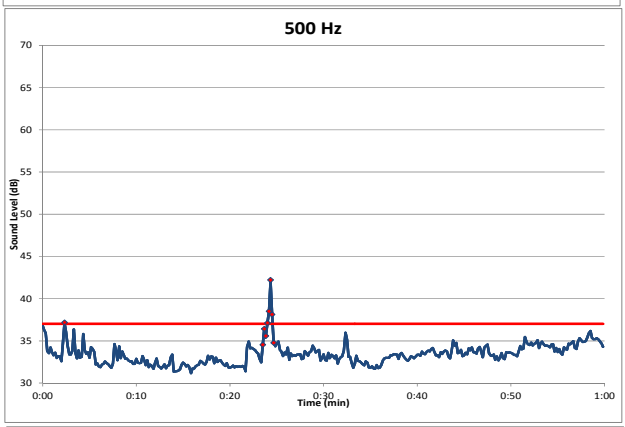

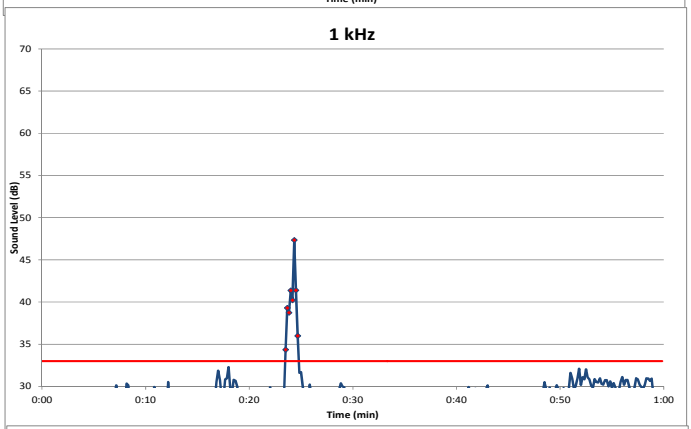

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NOV 3

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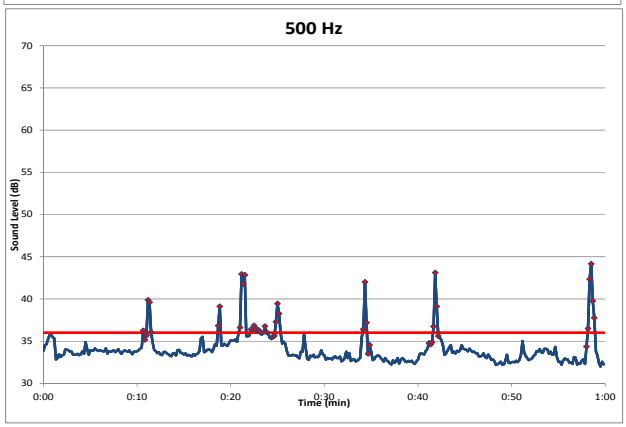

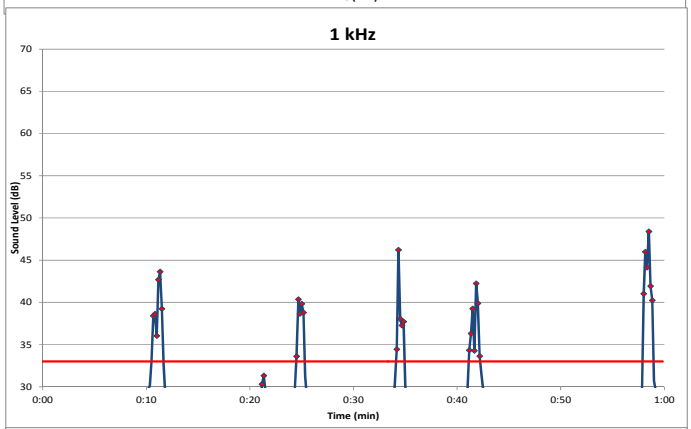

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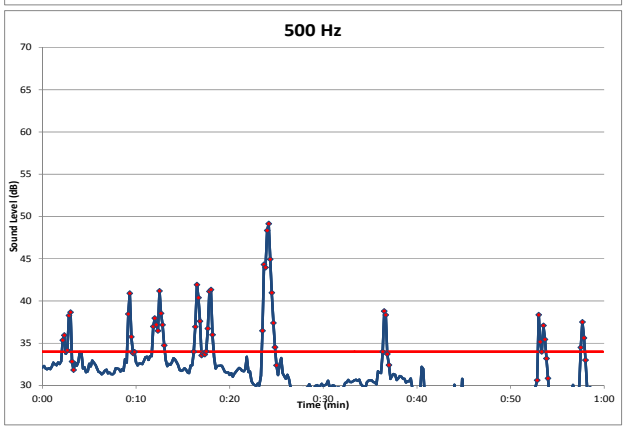

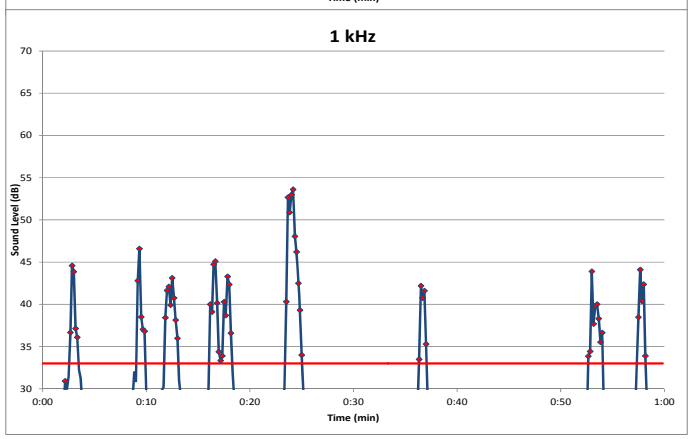

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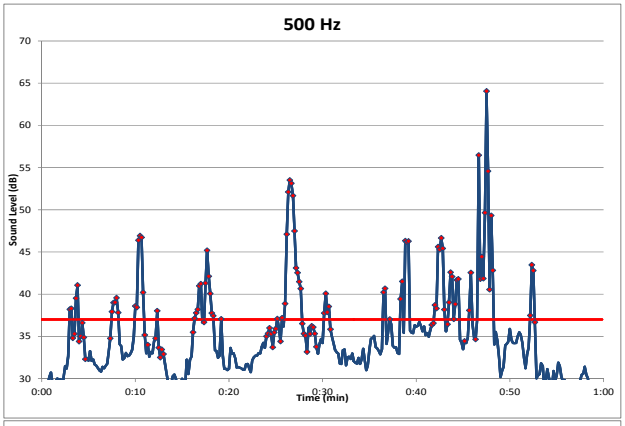

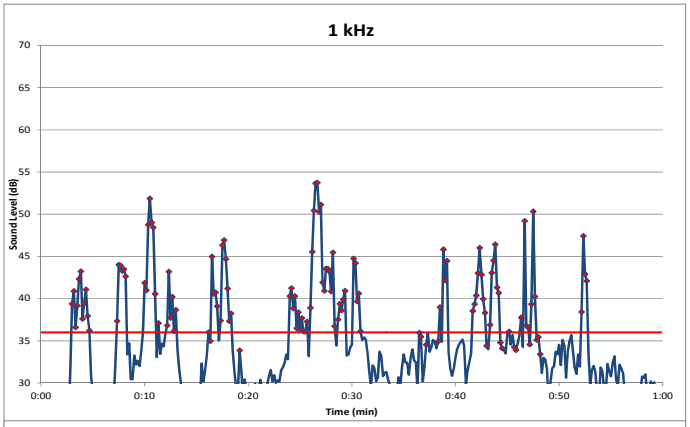

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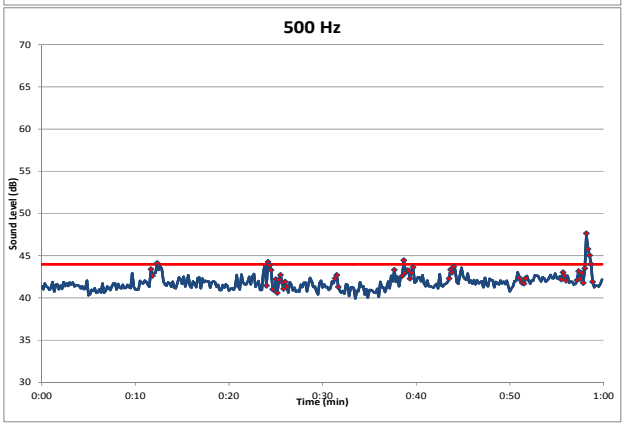

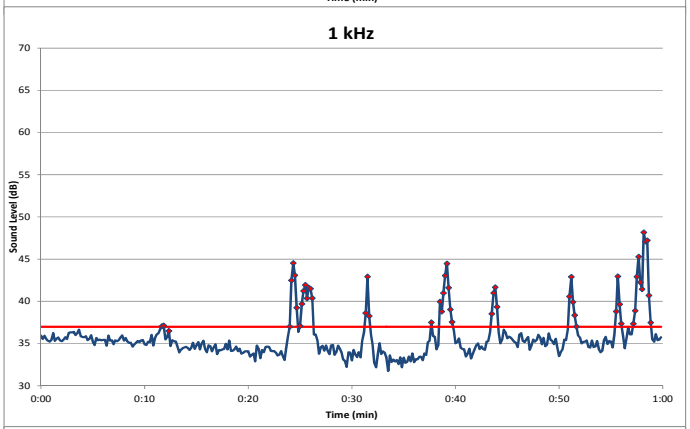

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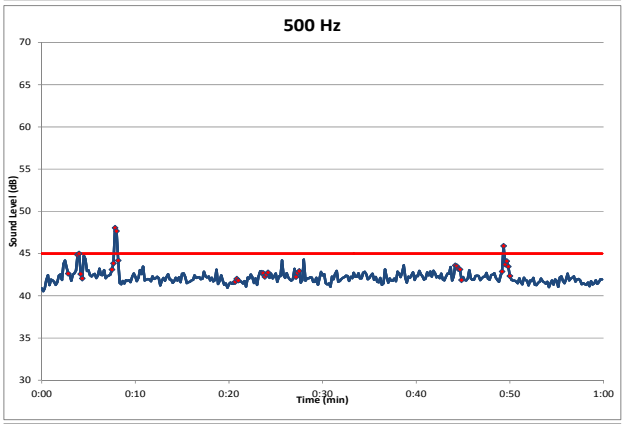

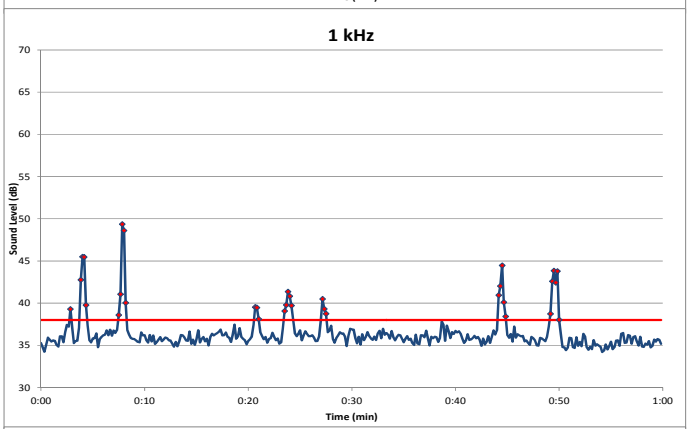

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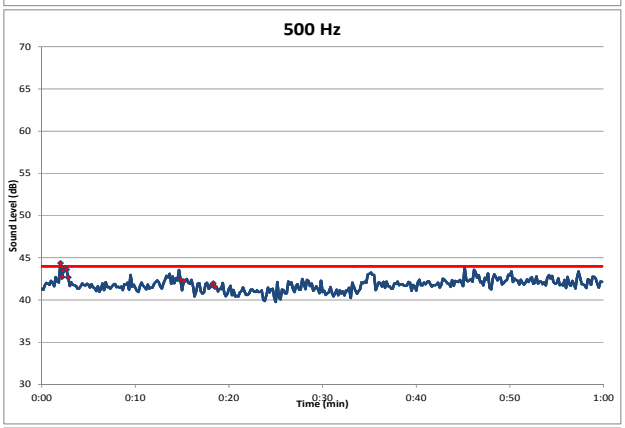

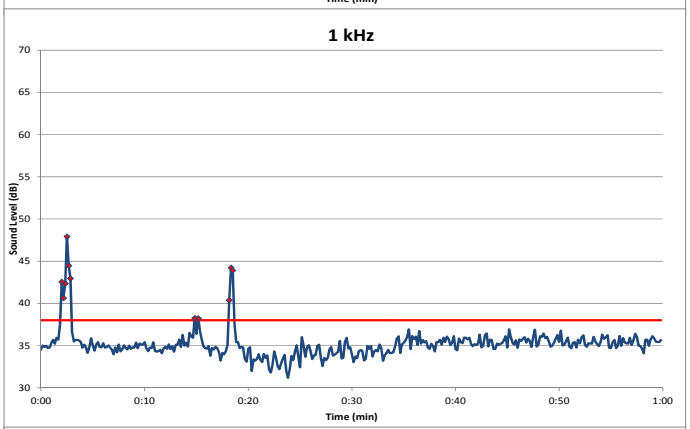

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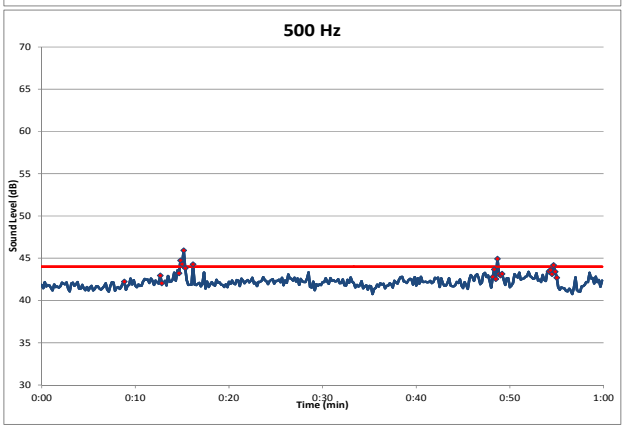

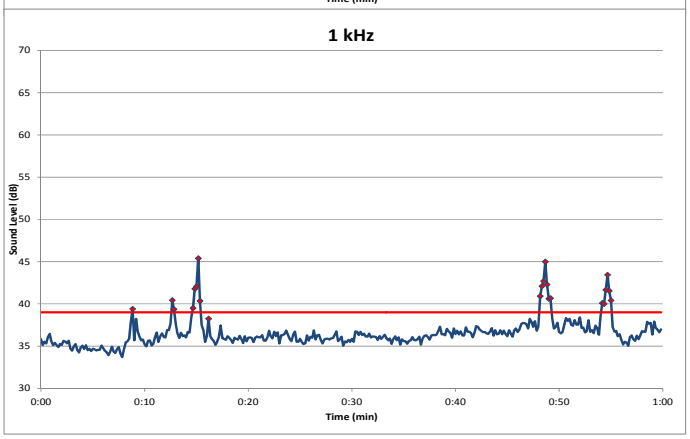

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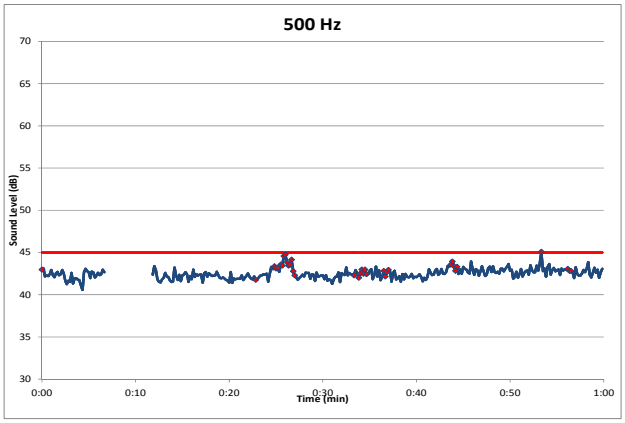

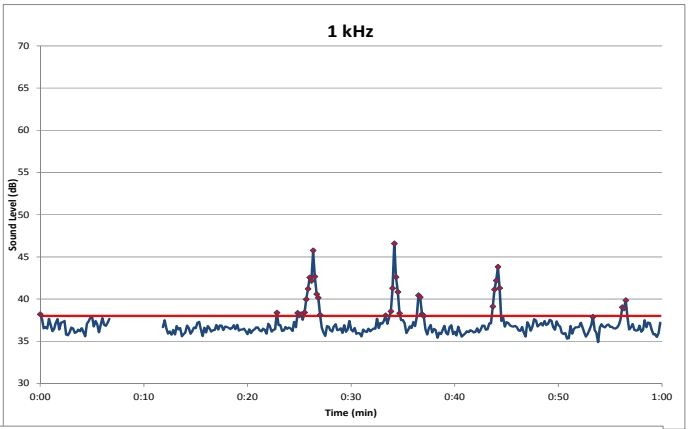

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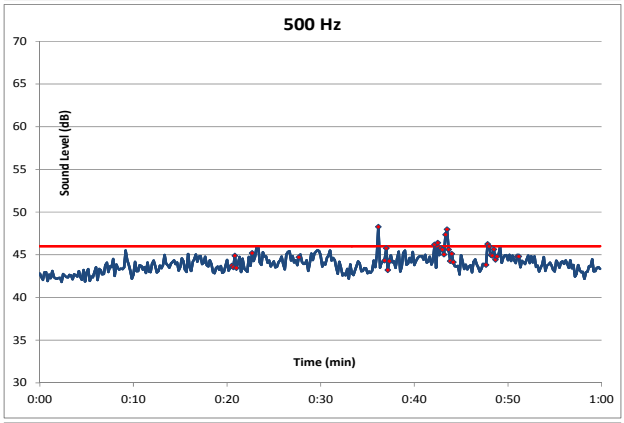

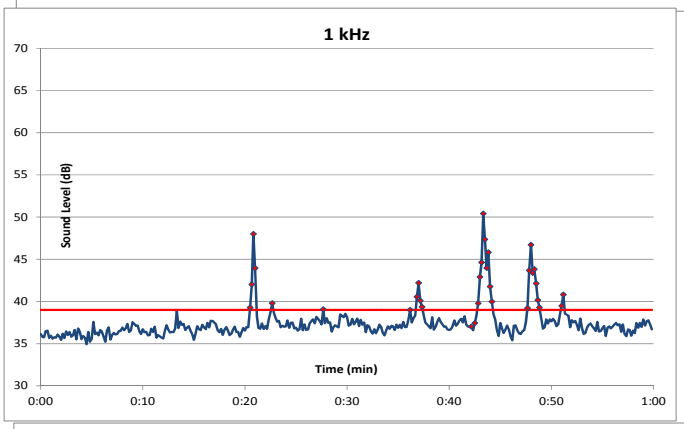

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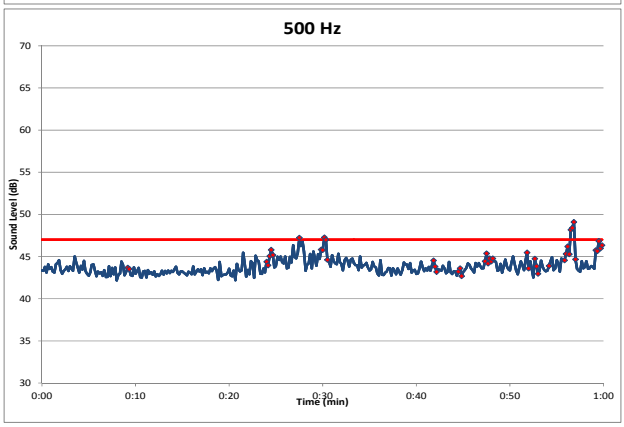

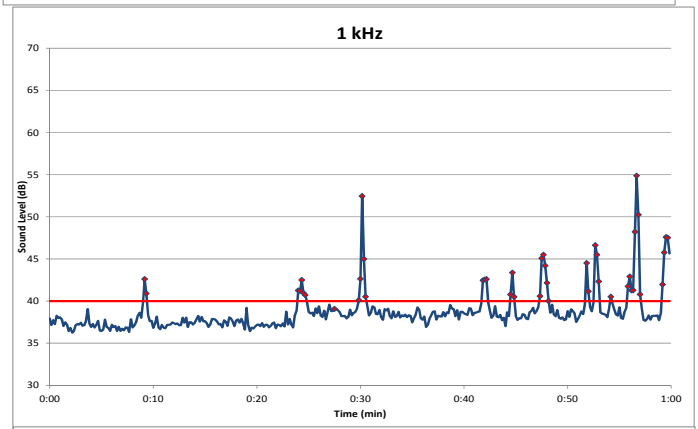

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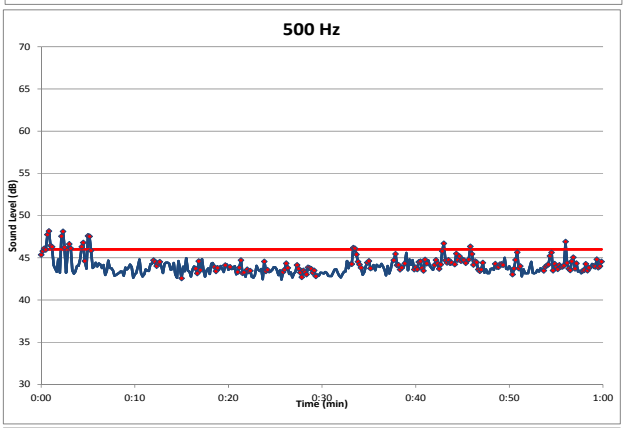

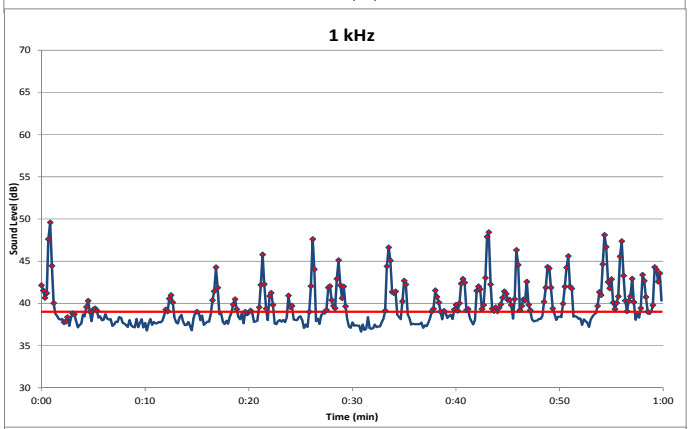

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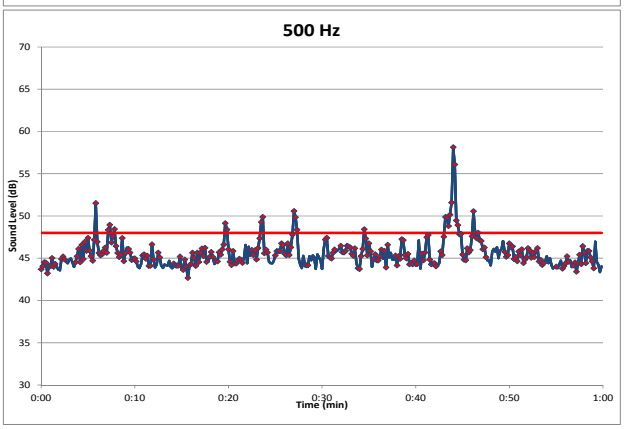

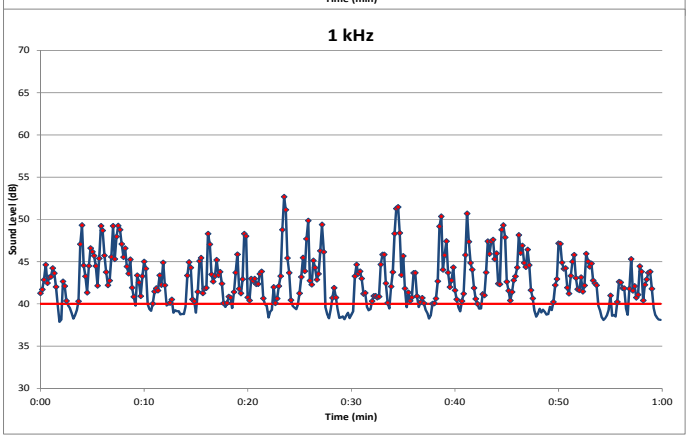

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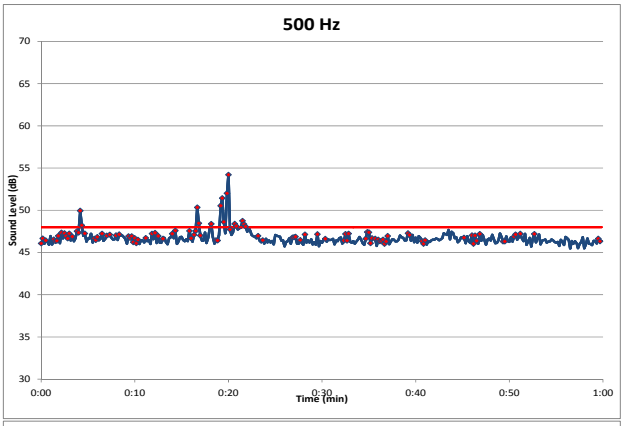

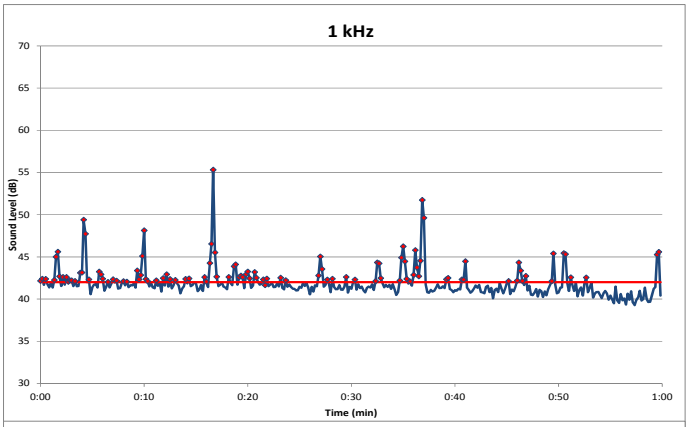

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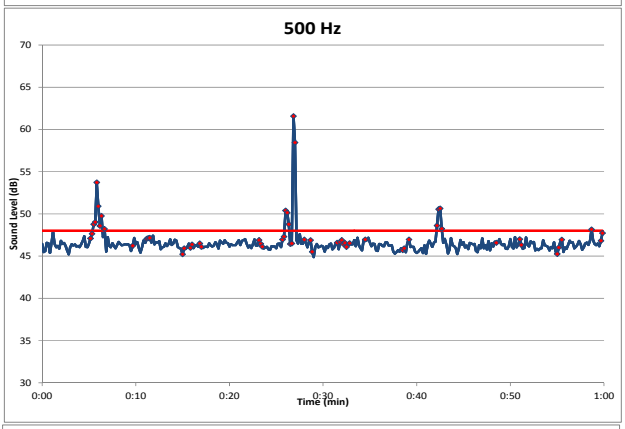

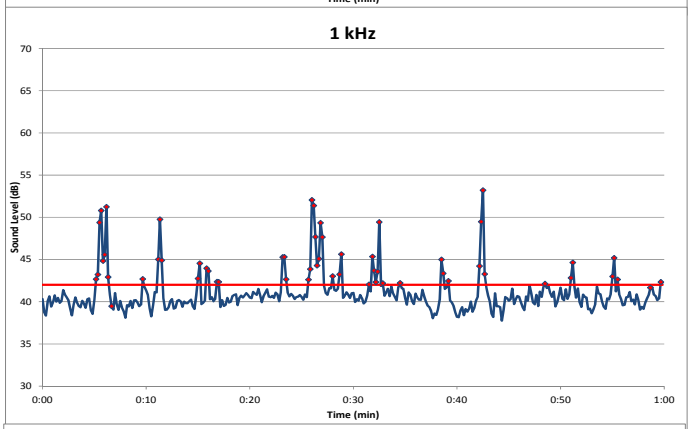

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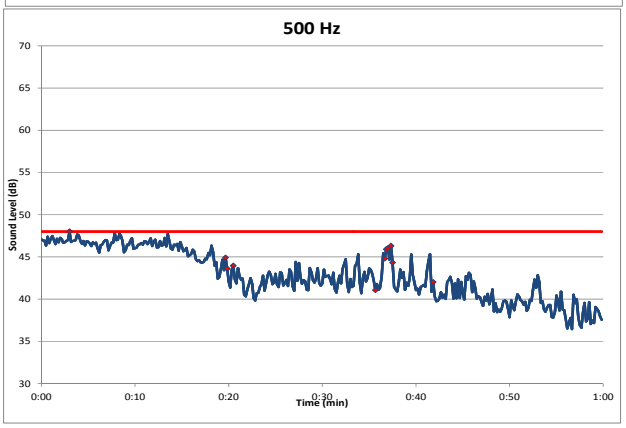

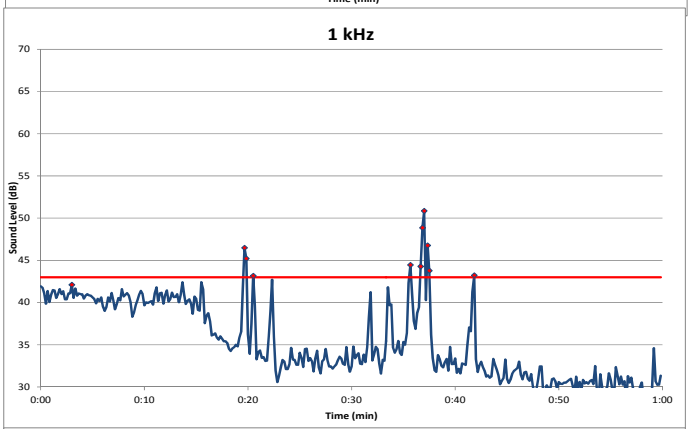

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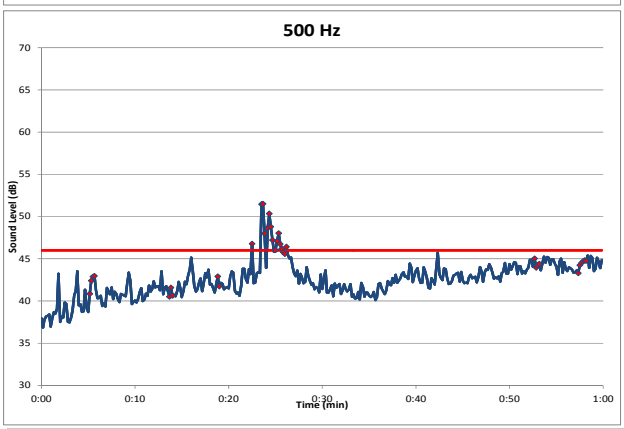

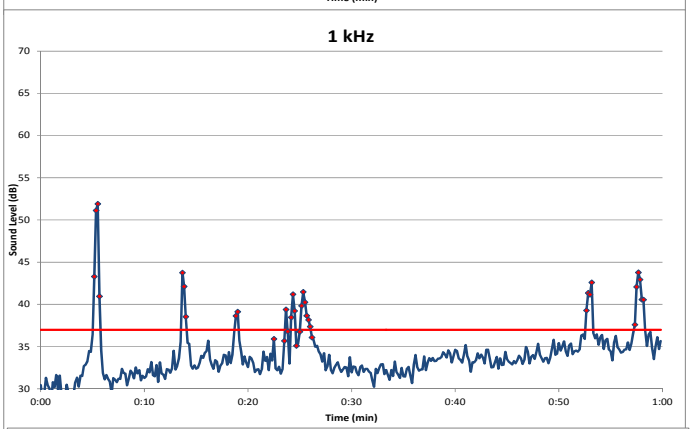

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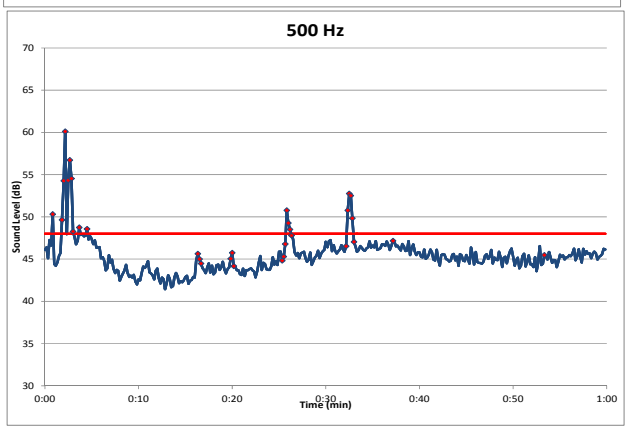

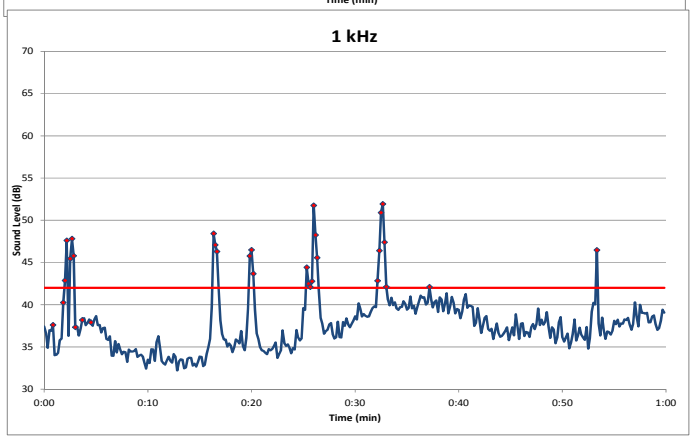

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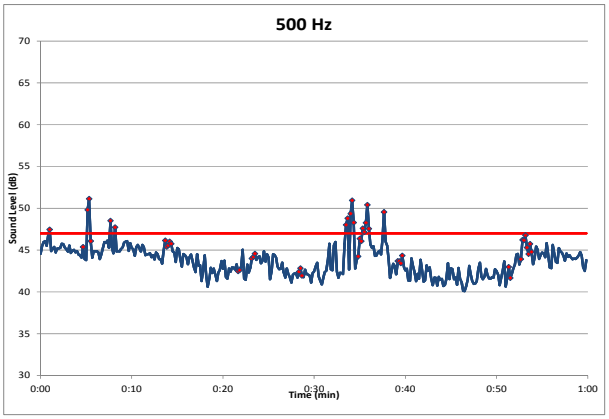

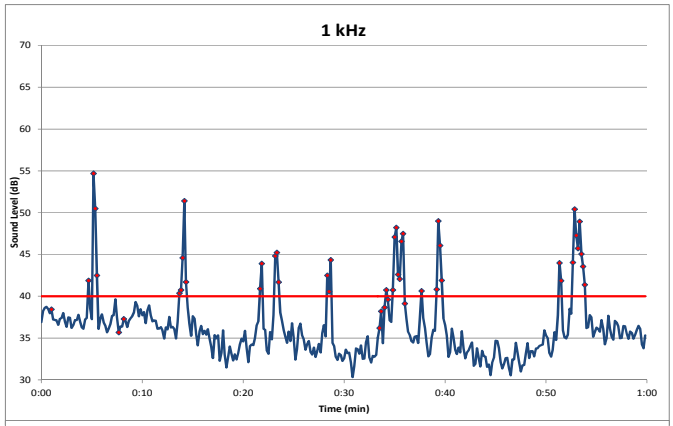

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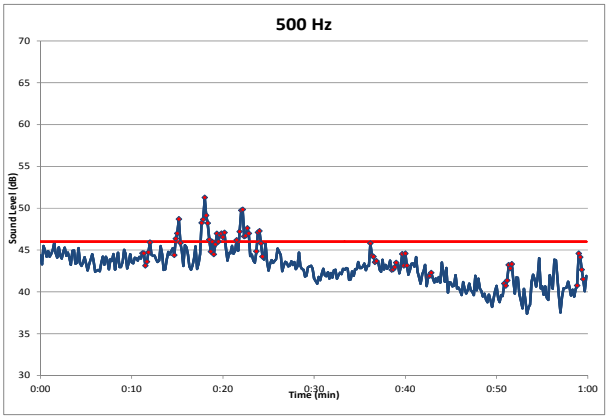

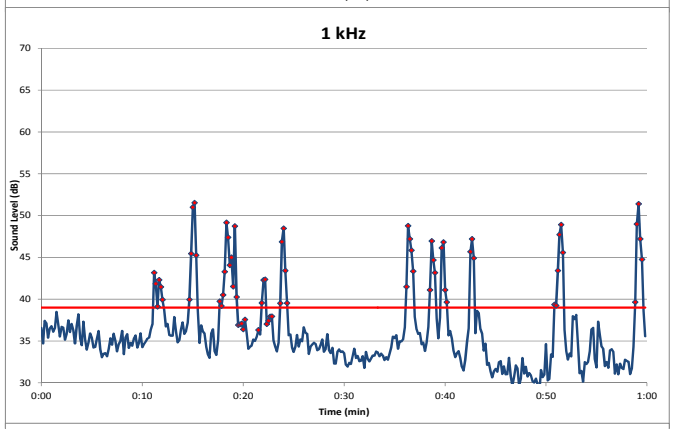

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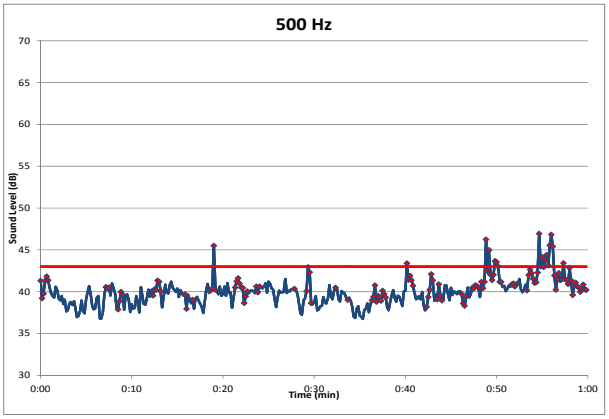

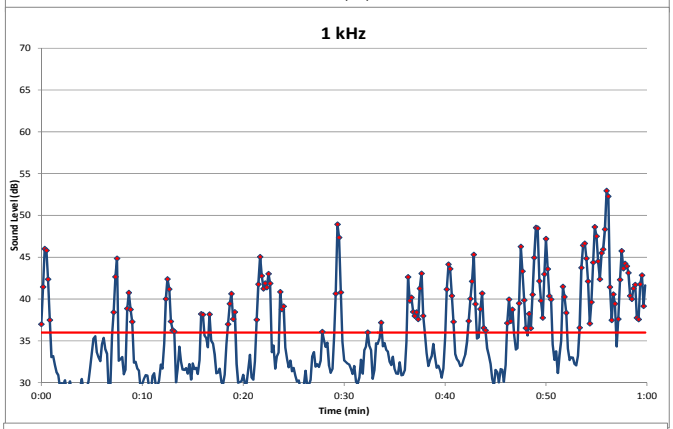

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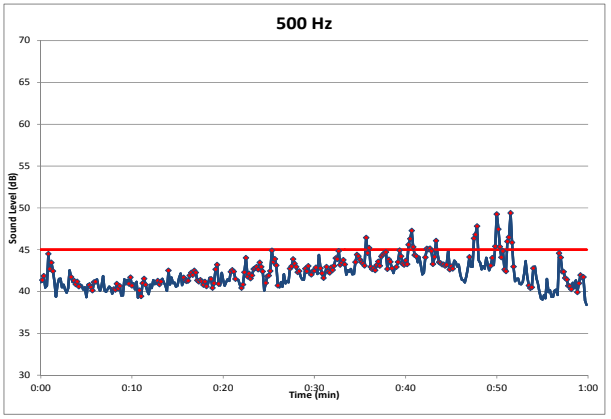

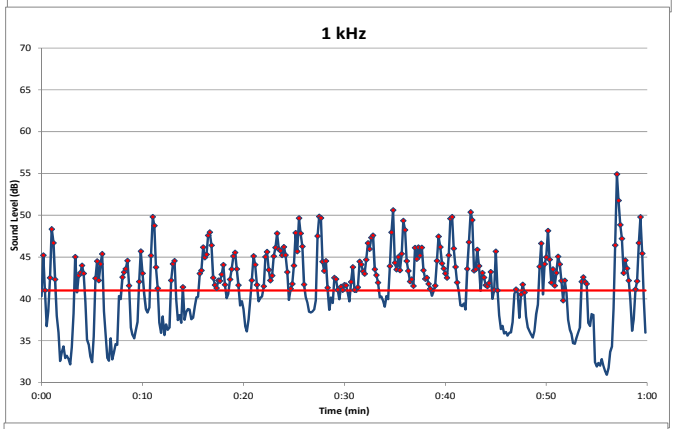

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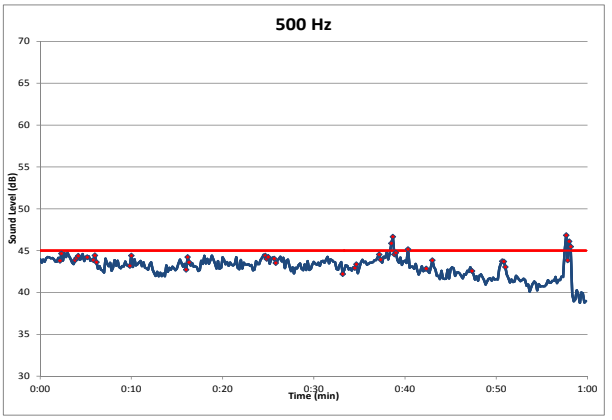

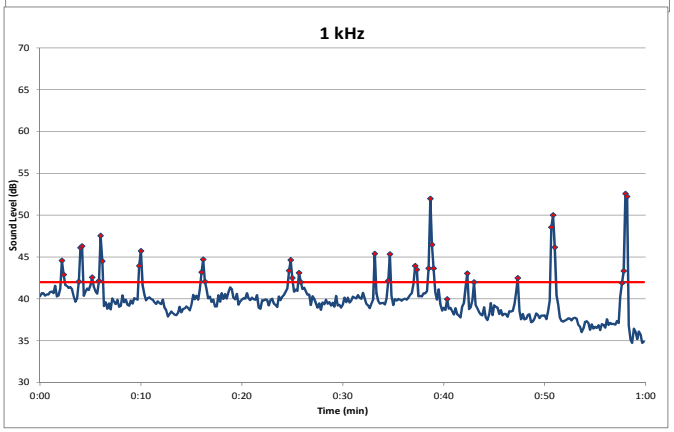

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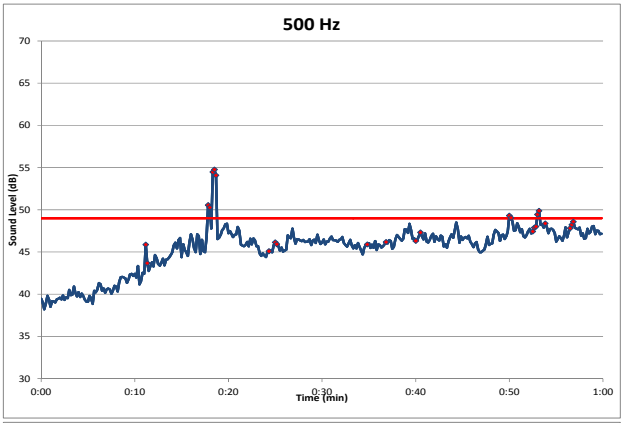

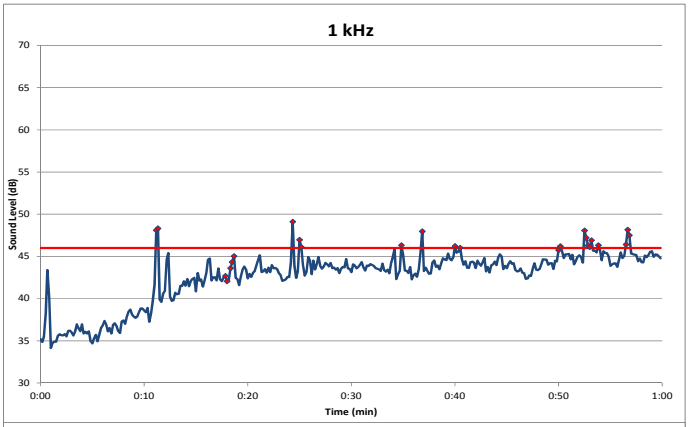

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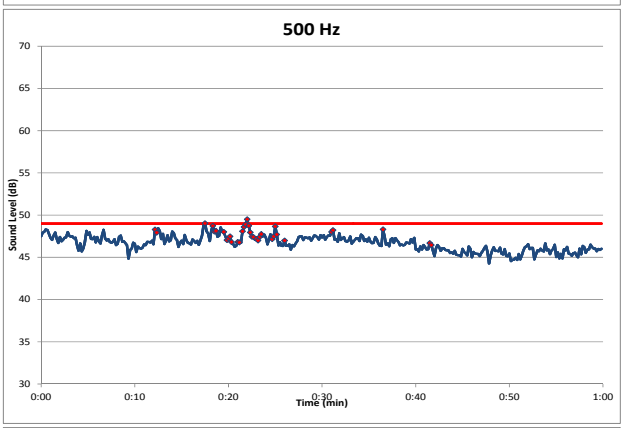

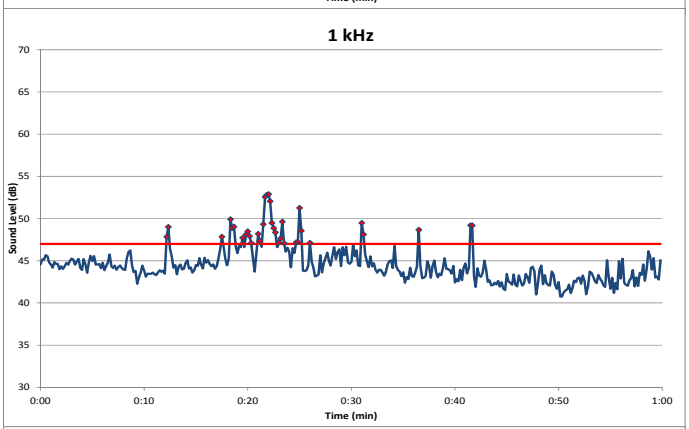

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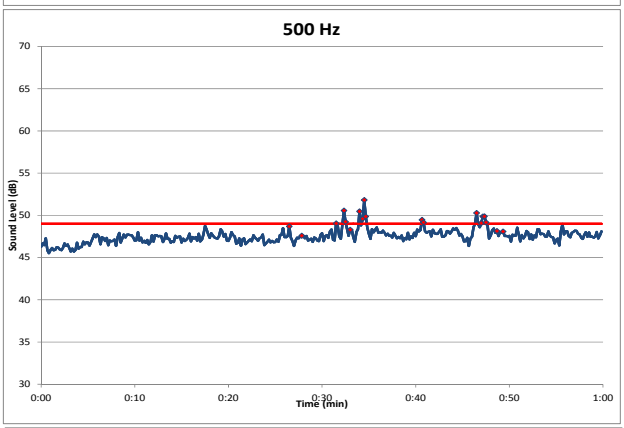

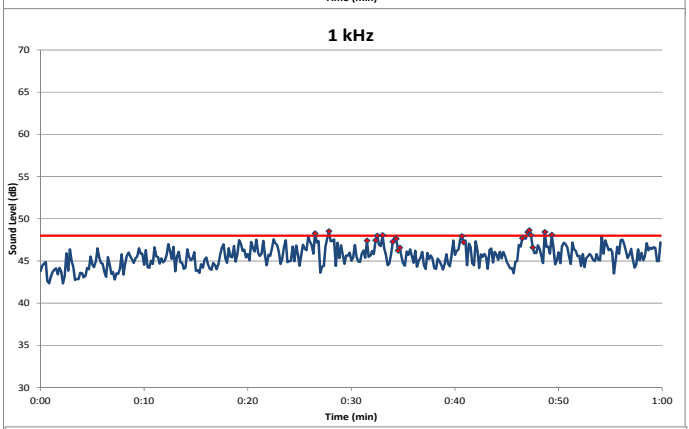

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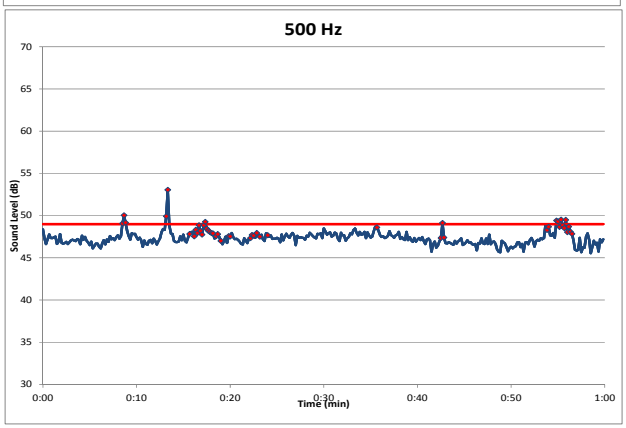

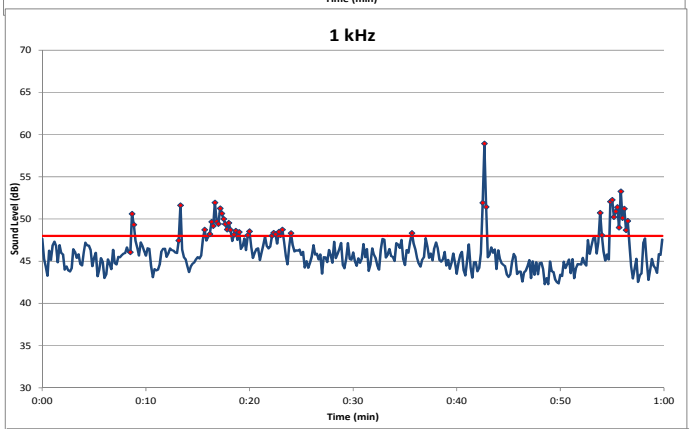

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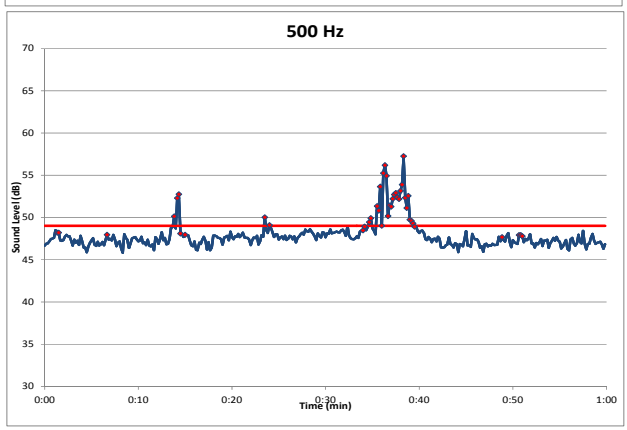

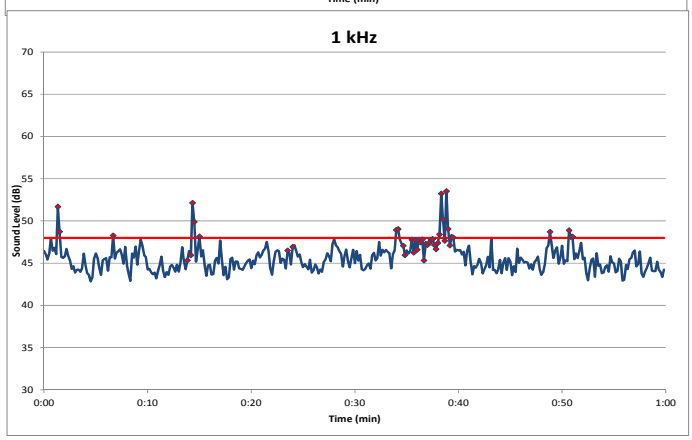

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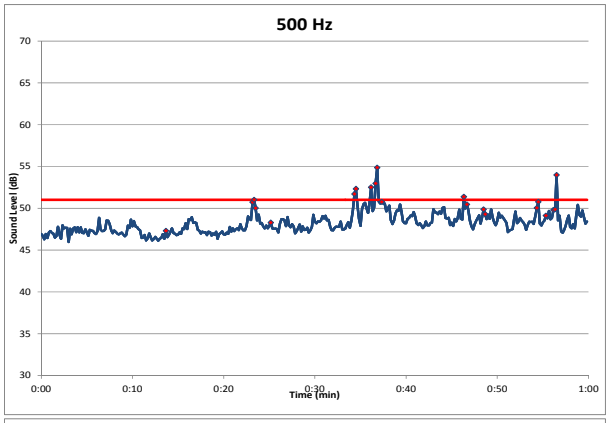

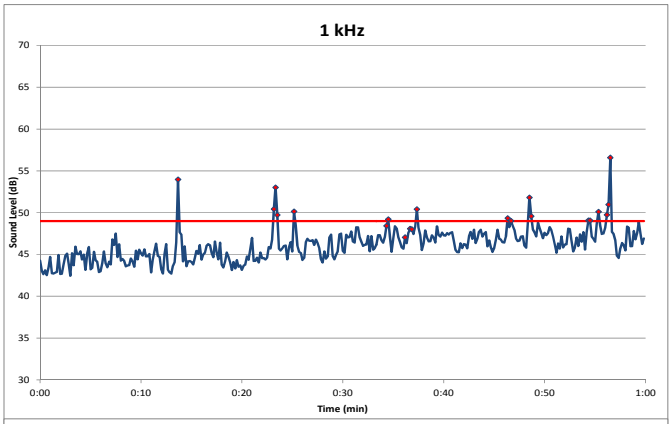

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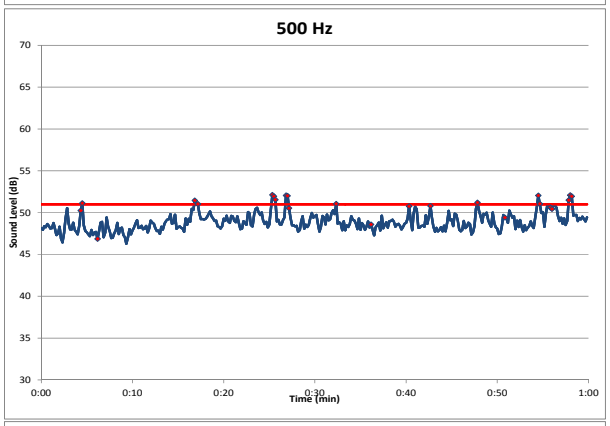

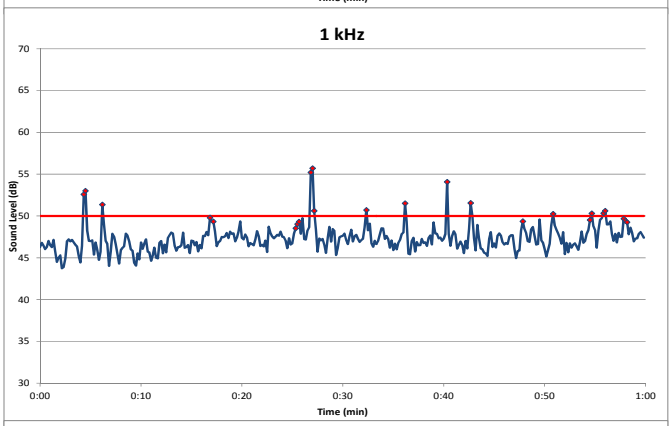

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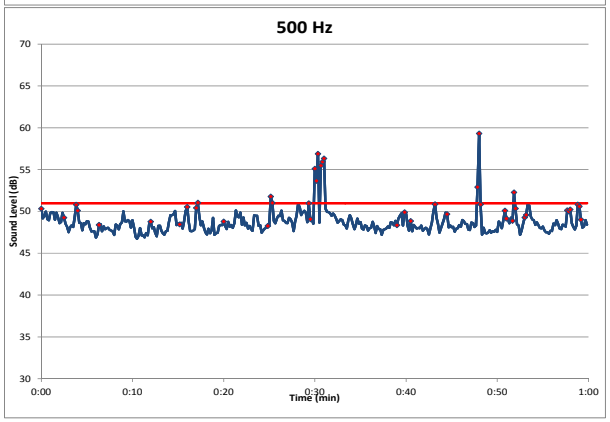

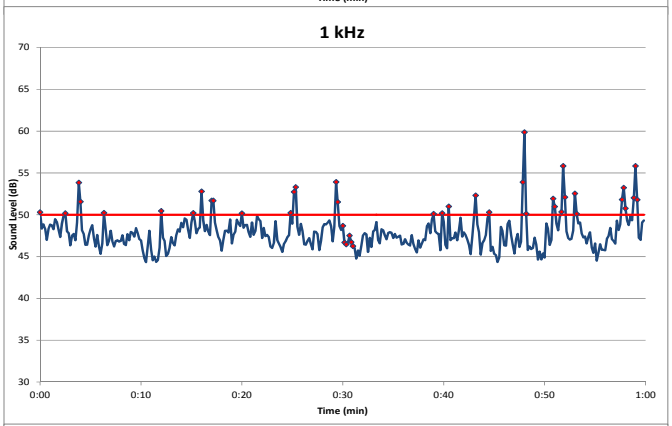

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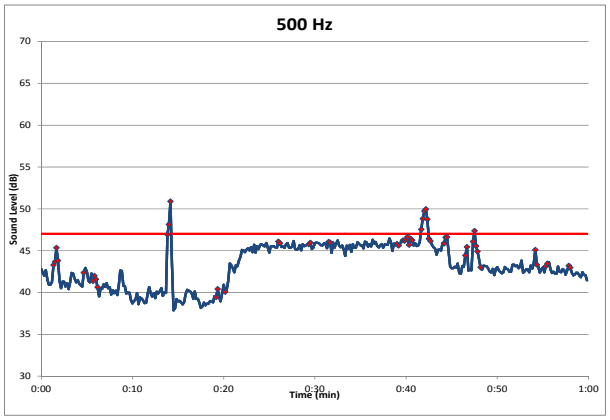

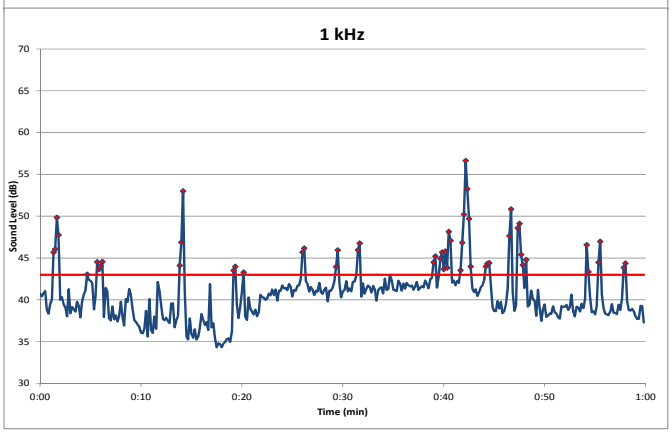

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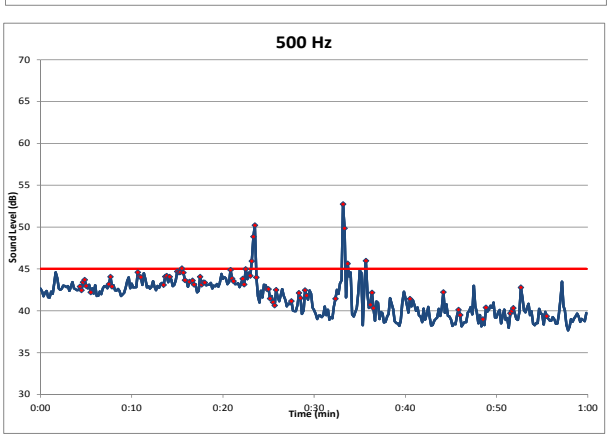

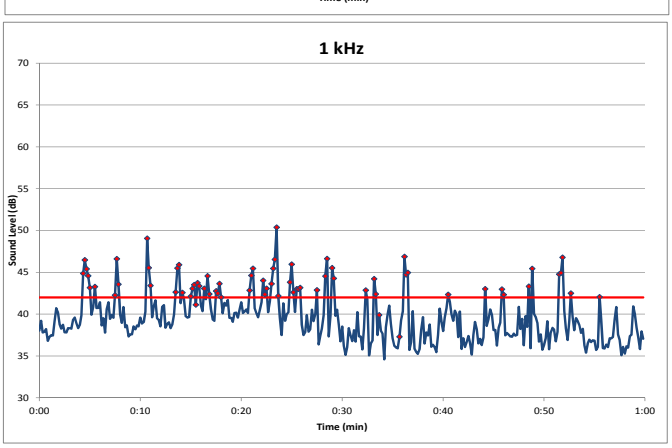

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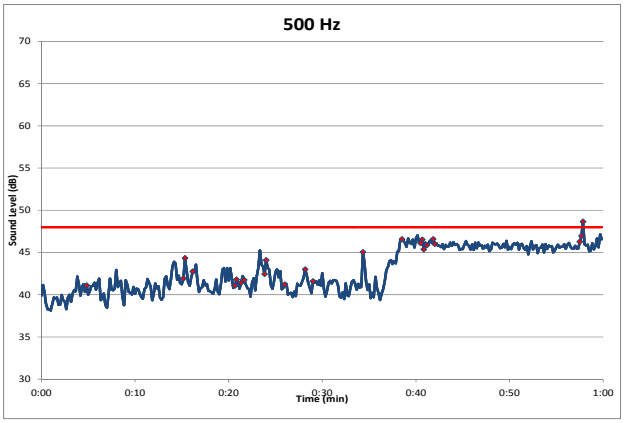

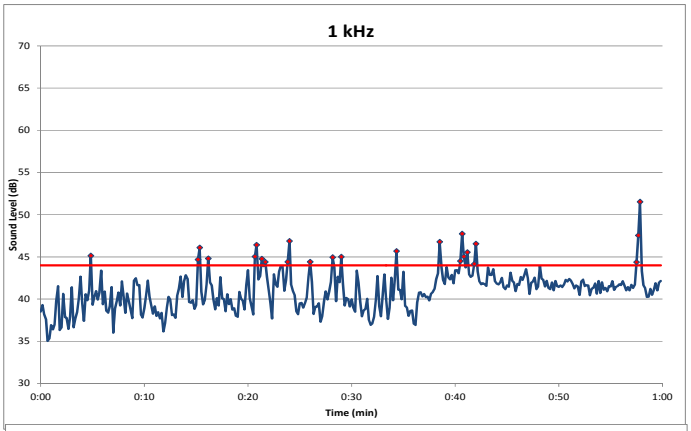

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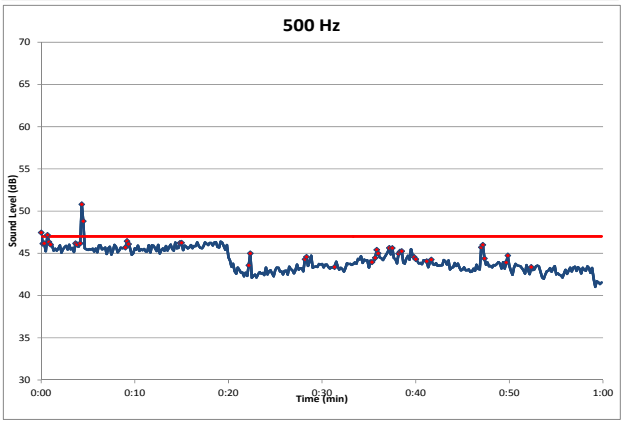

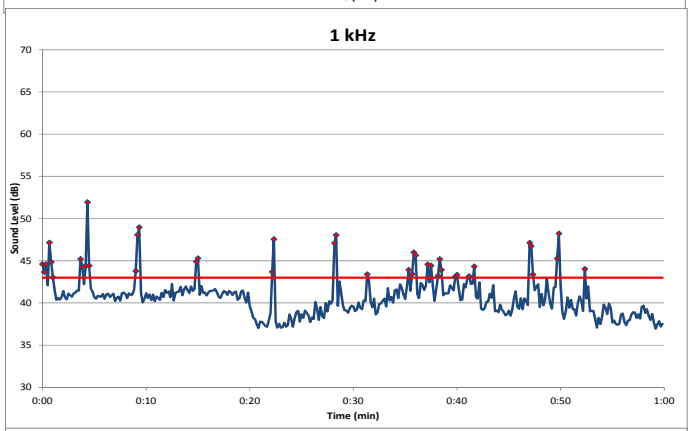

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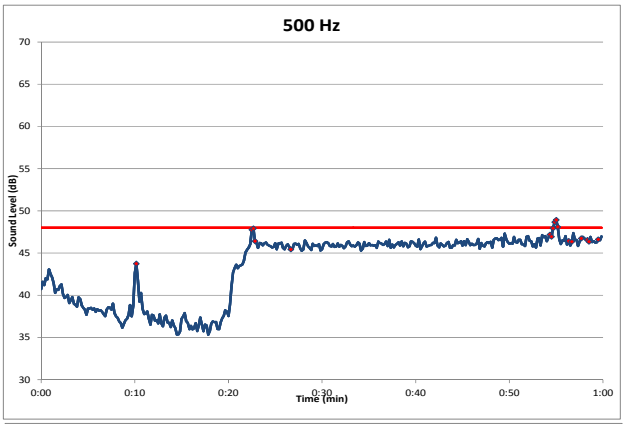

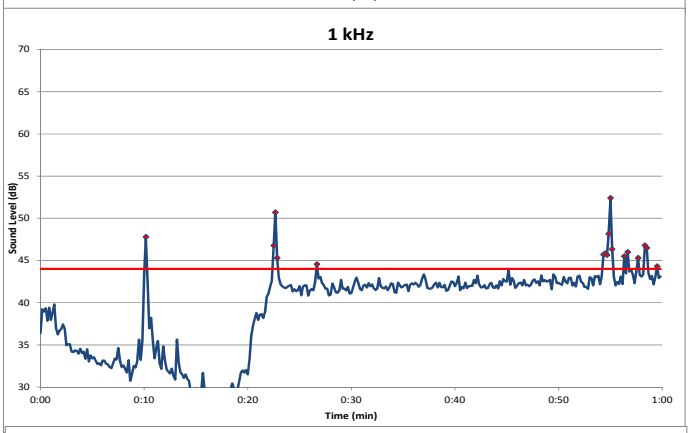

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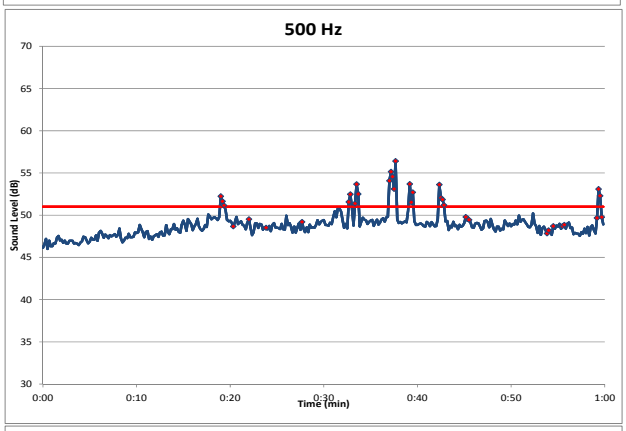

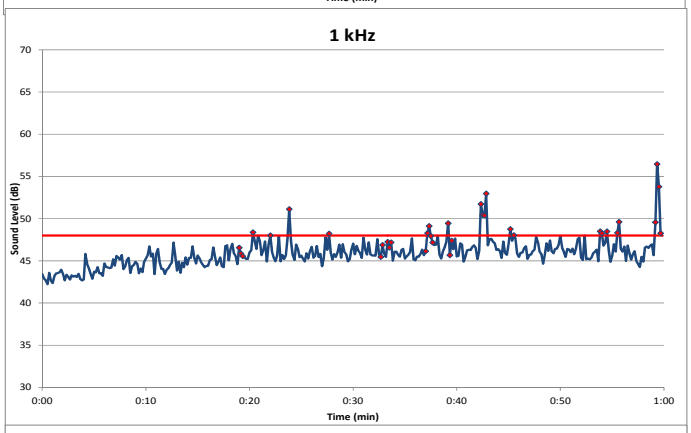

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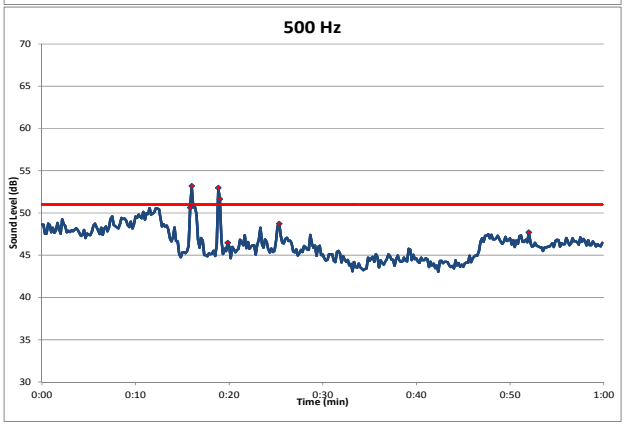

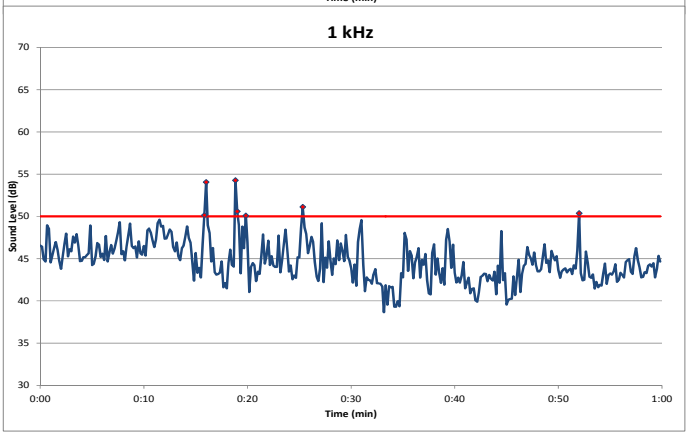

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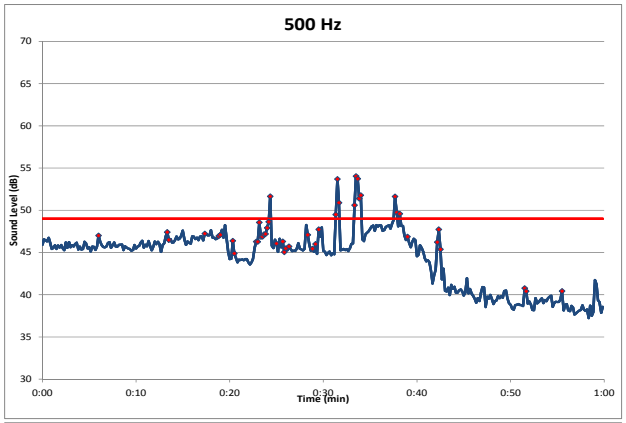

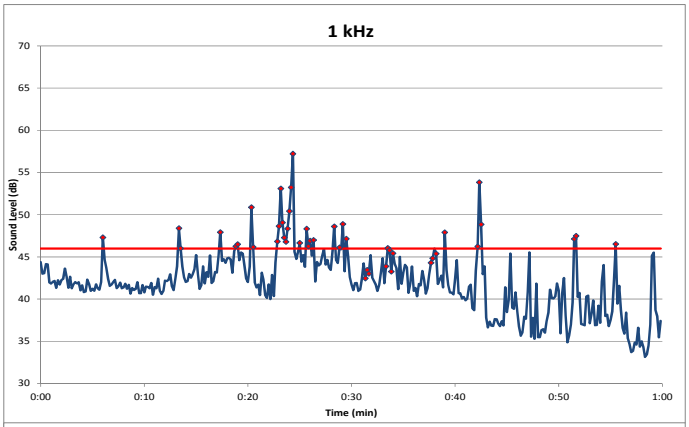

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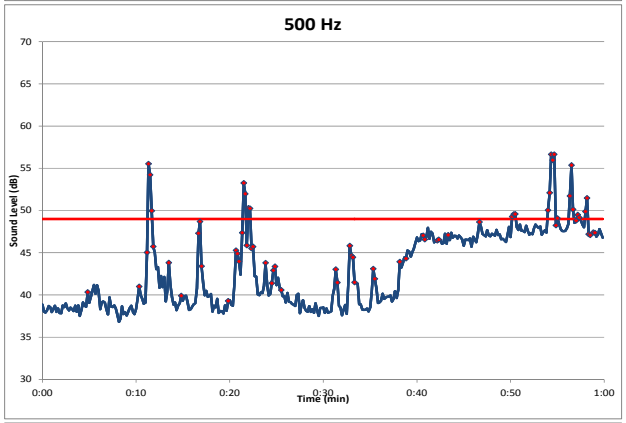

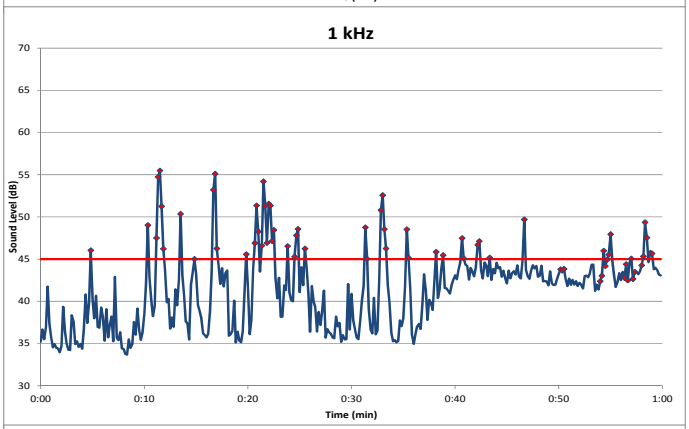

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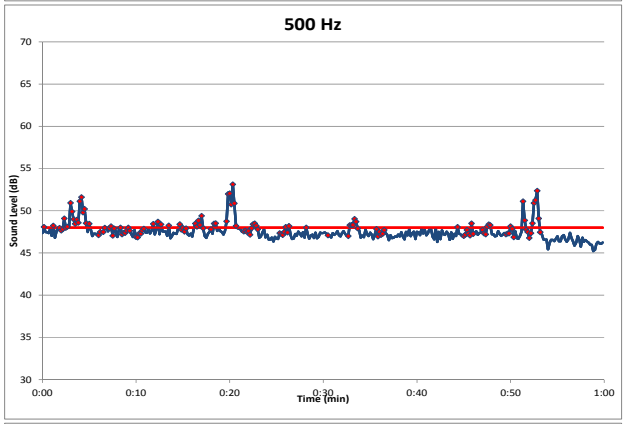

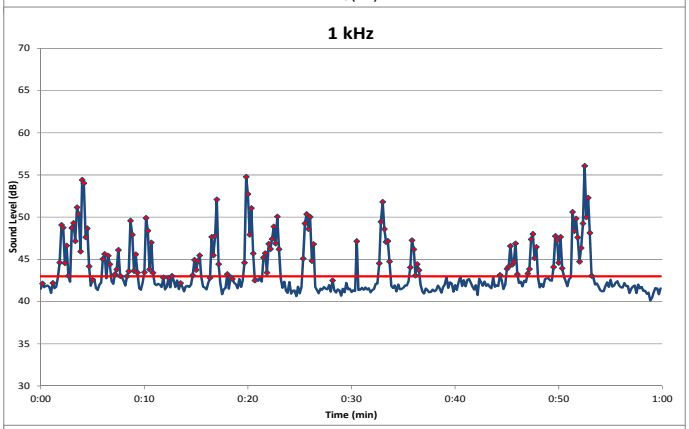

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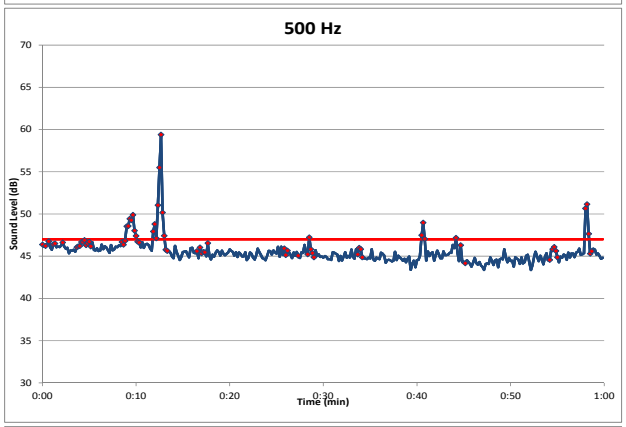

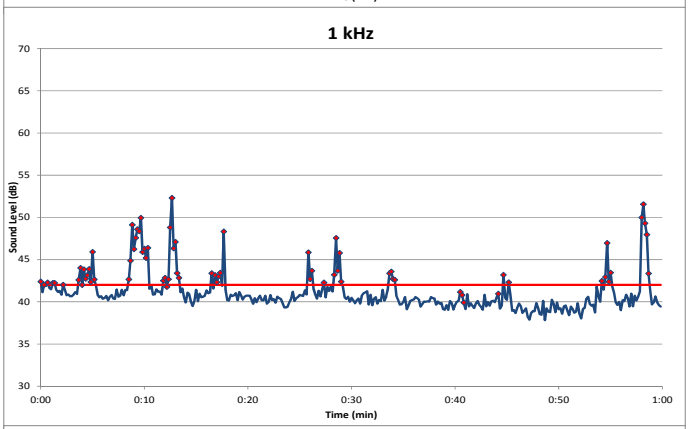

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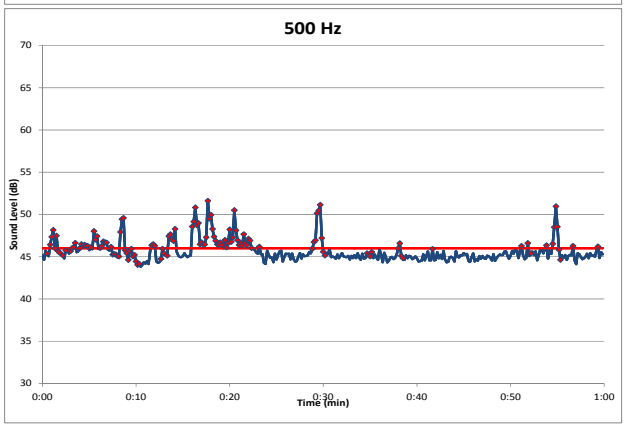

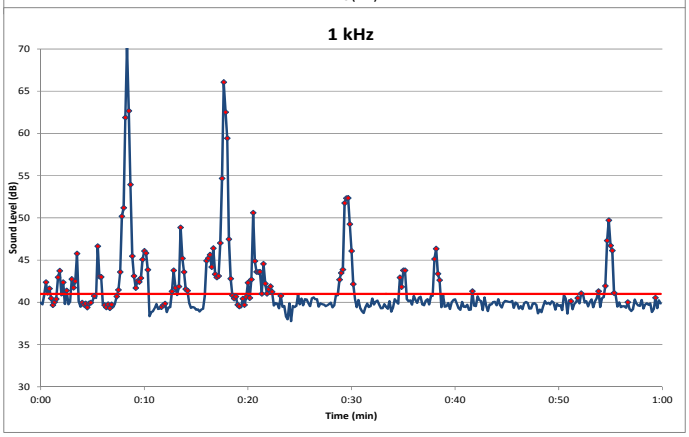

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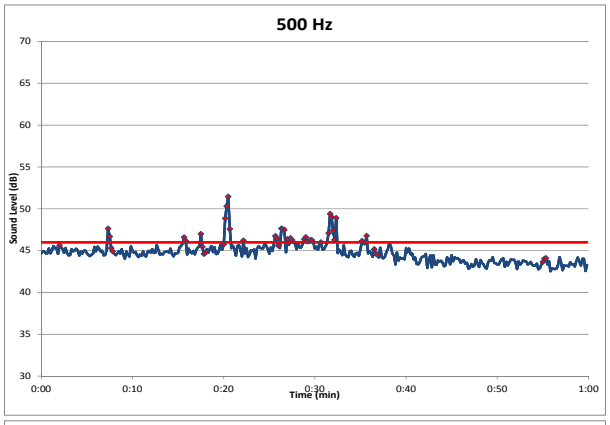

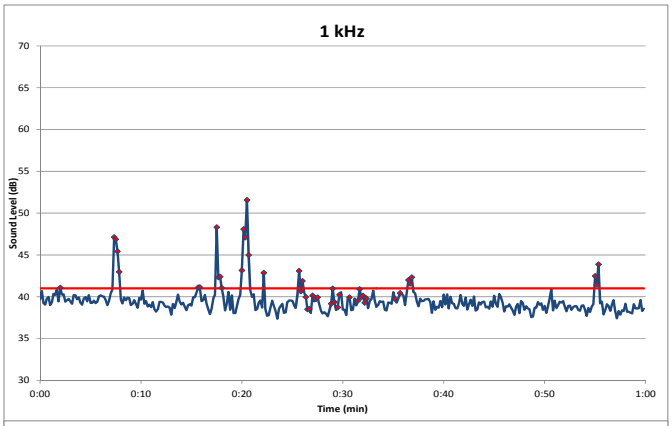

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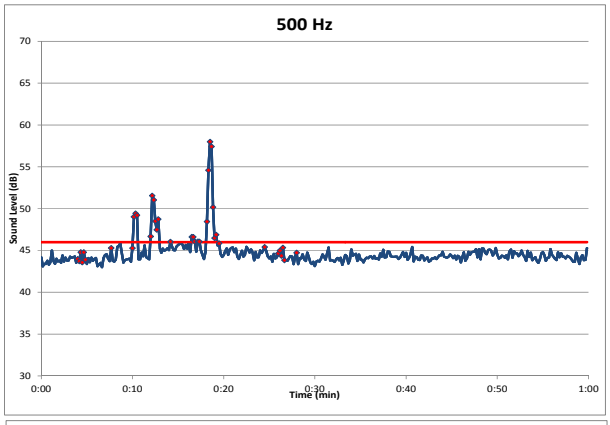

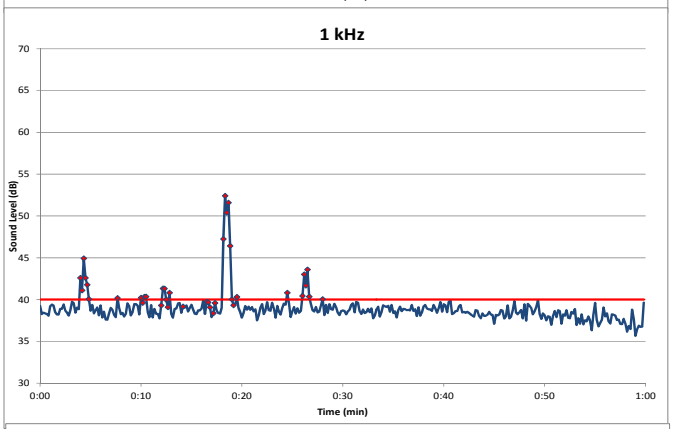

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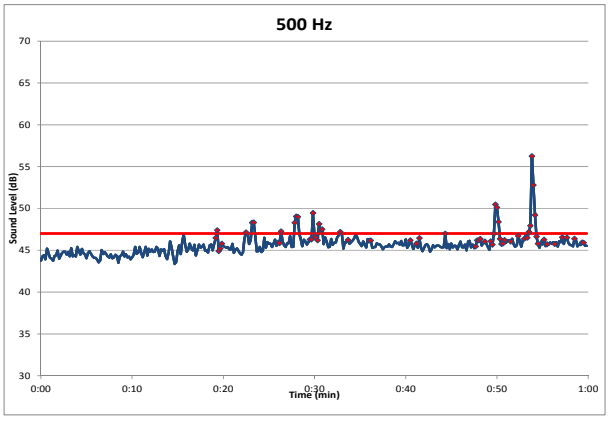

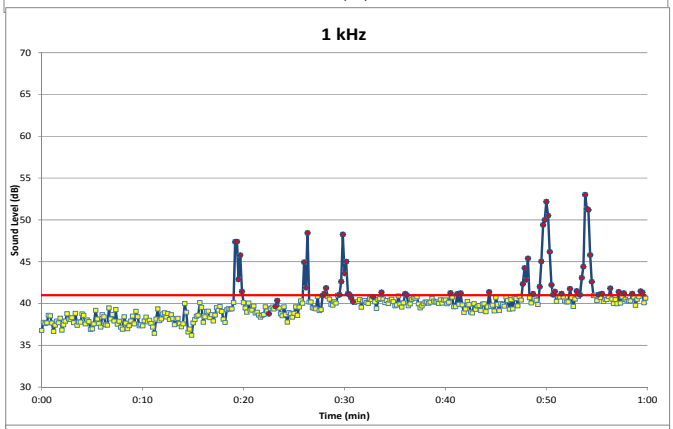

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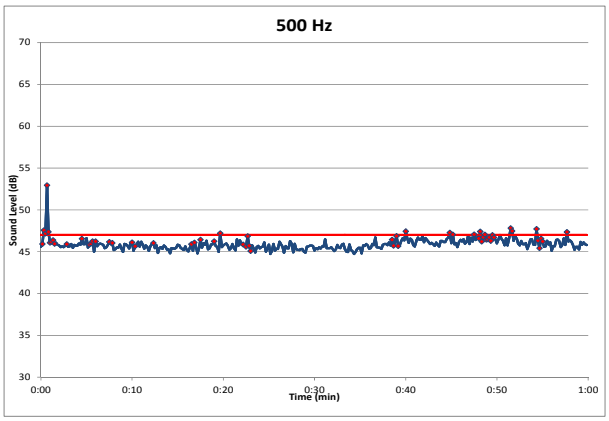

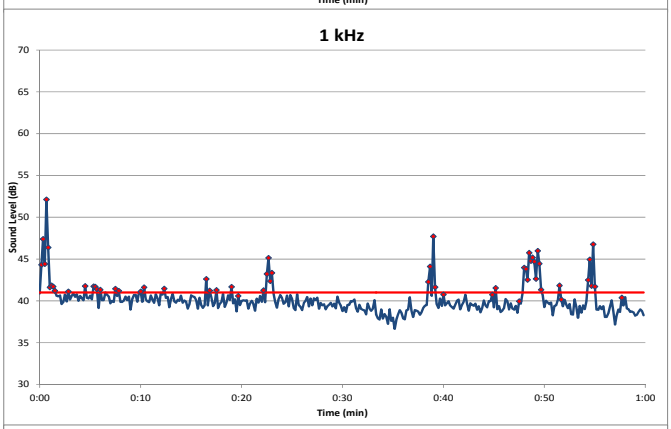

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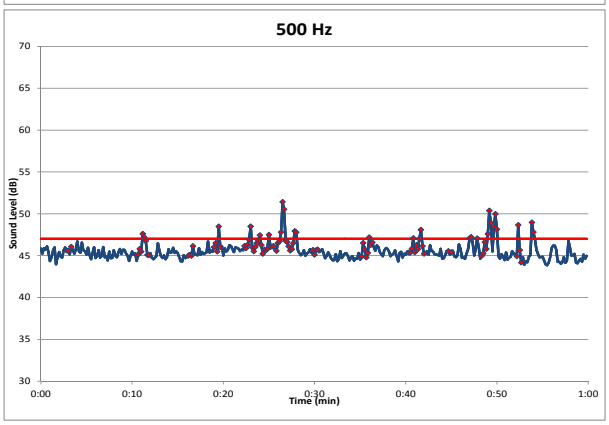

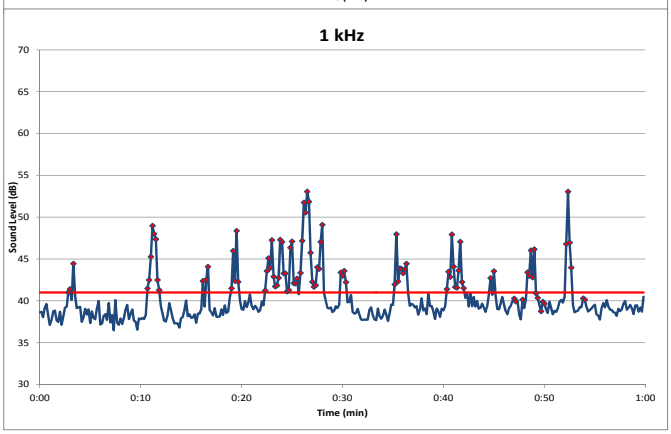

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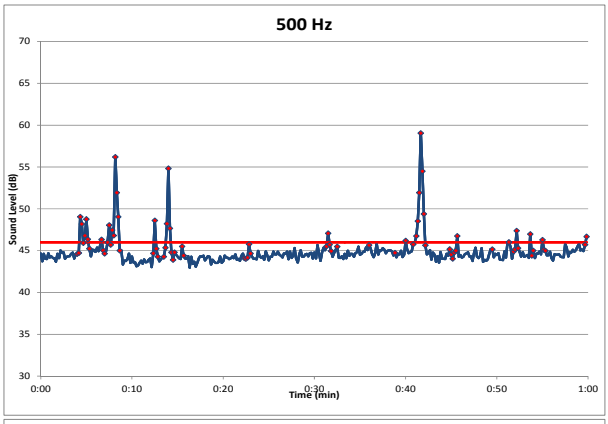

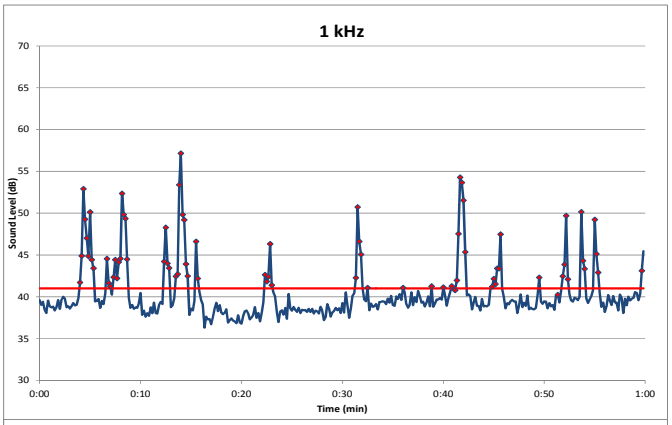

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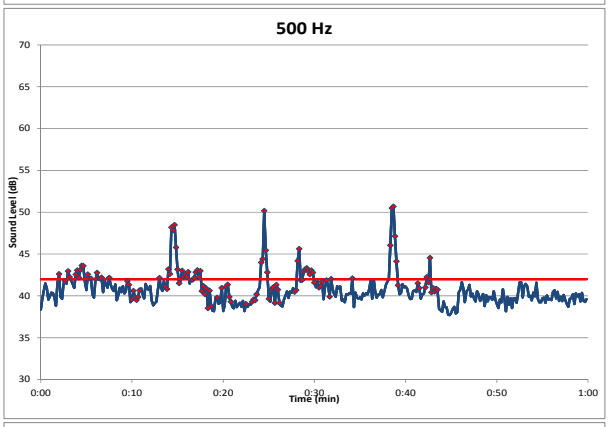

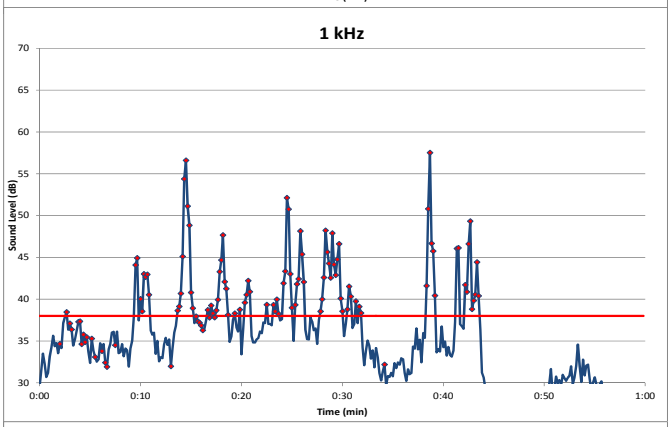

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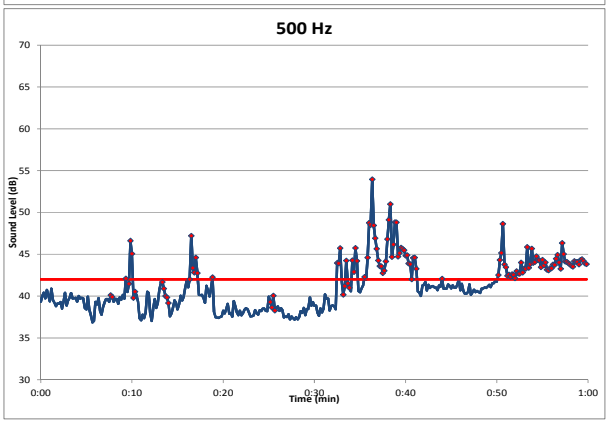

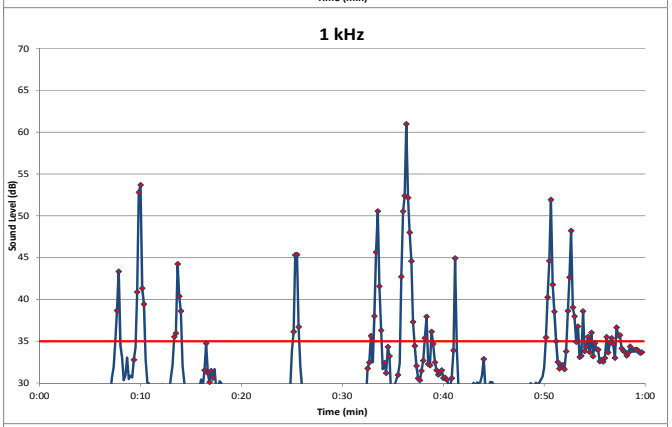

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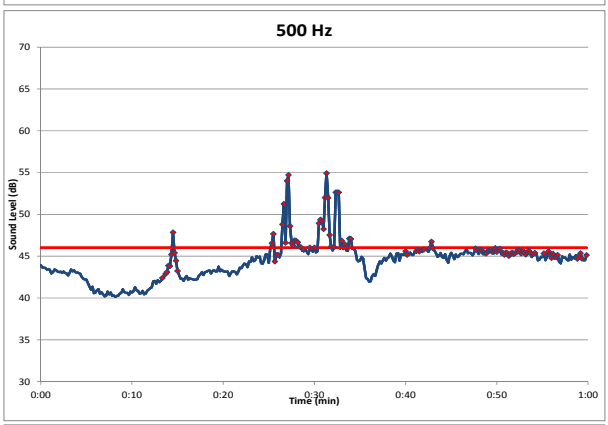

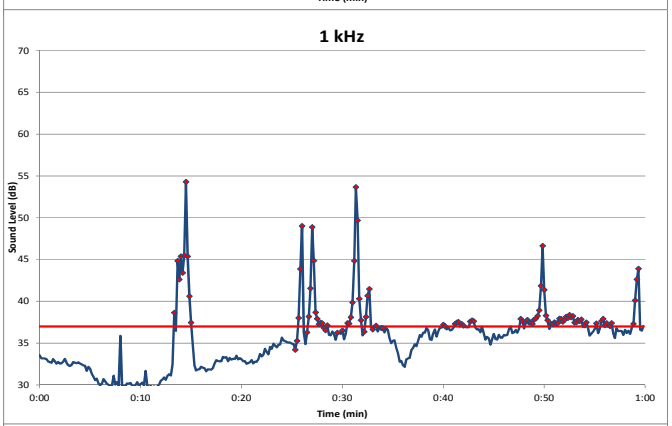

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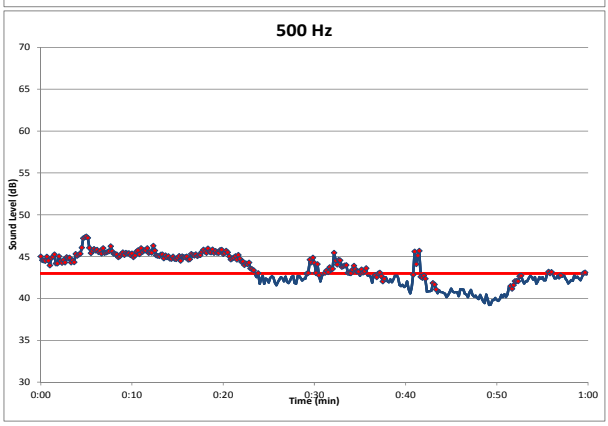

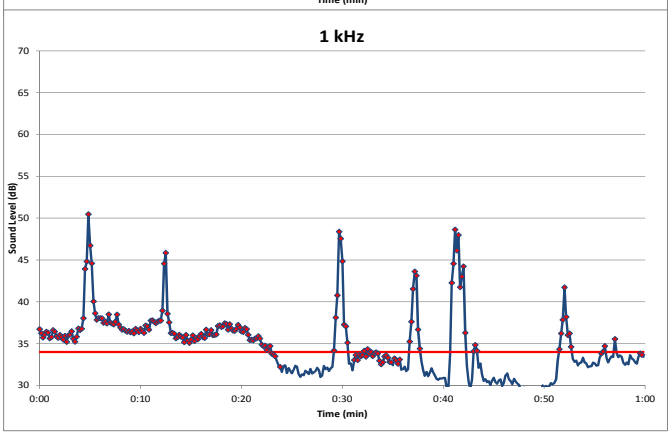

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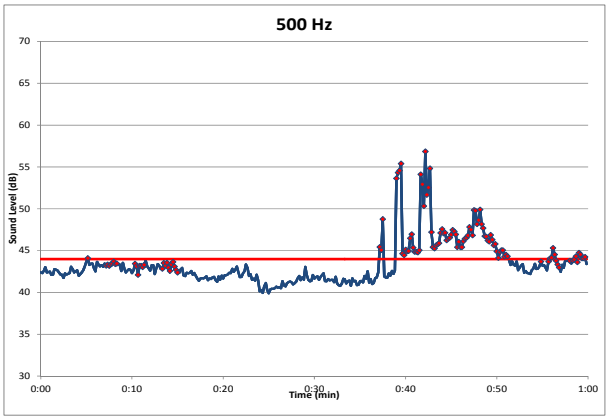

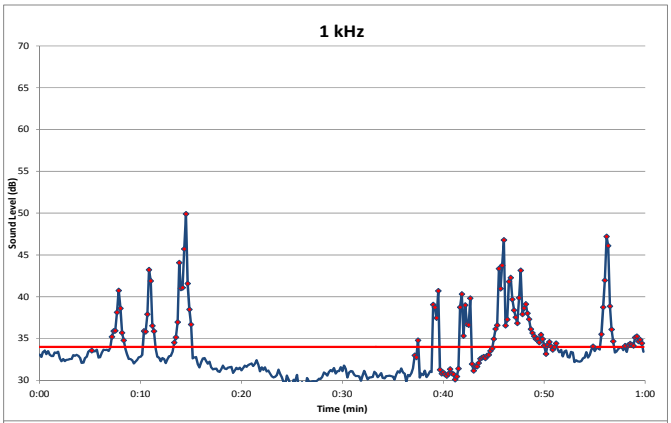

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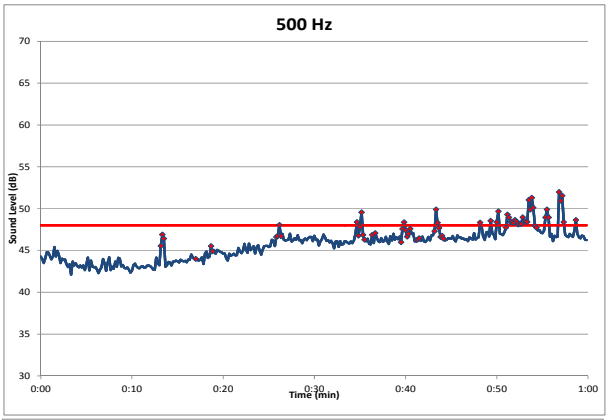

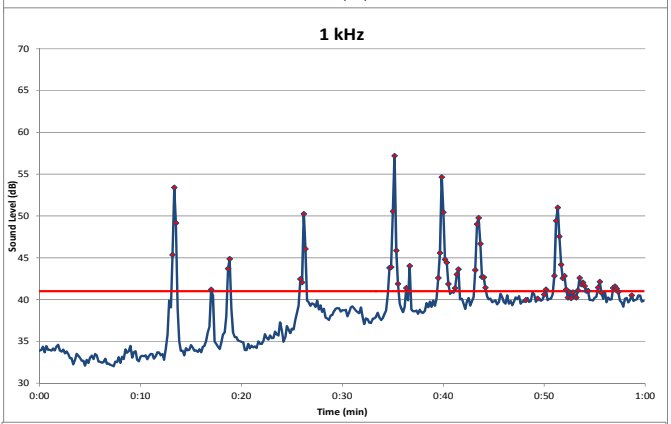

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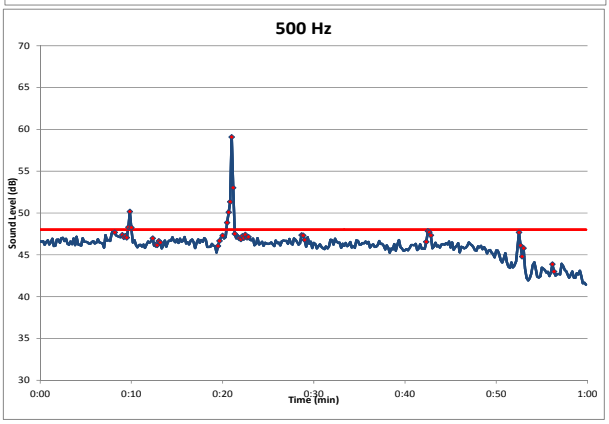

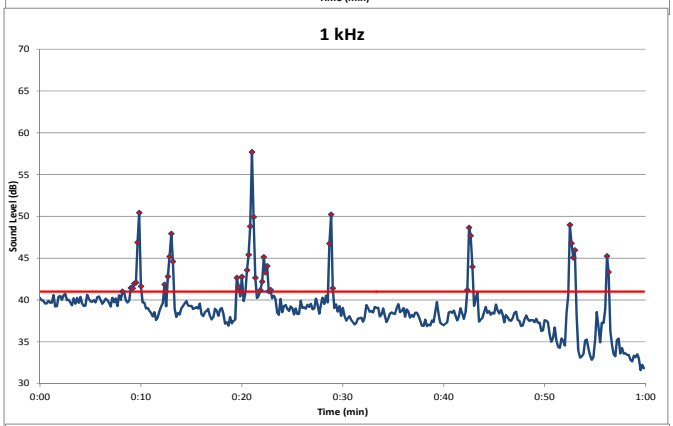

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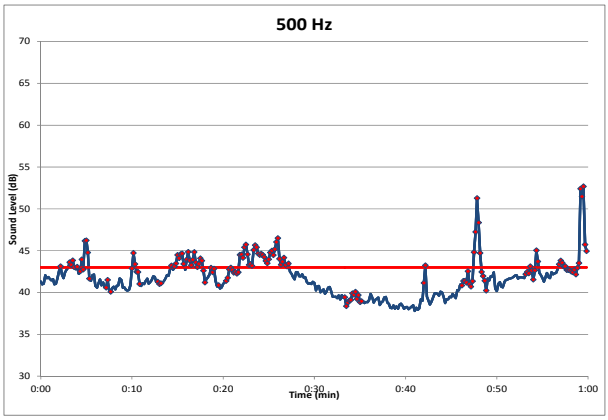

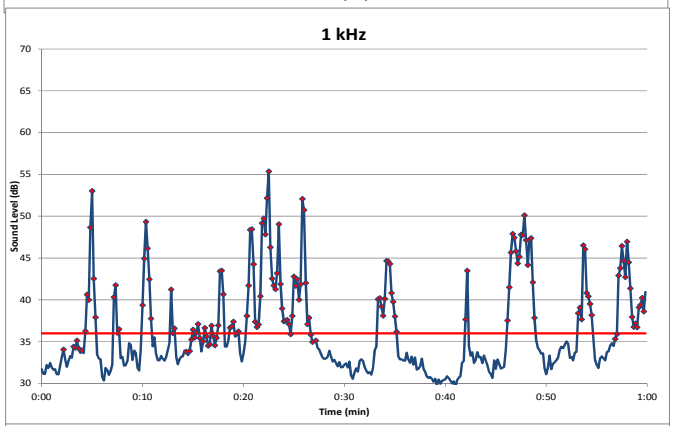

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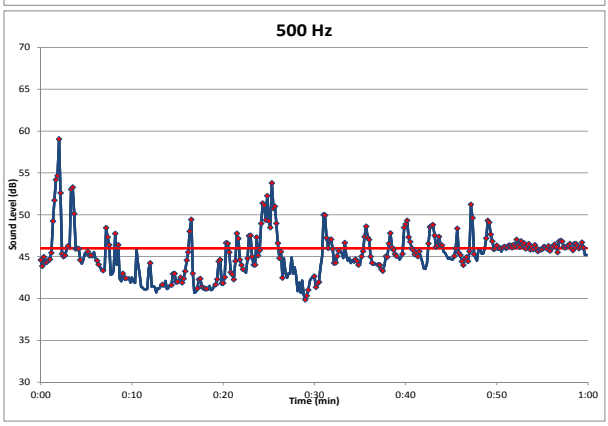

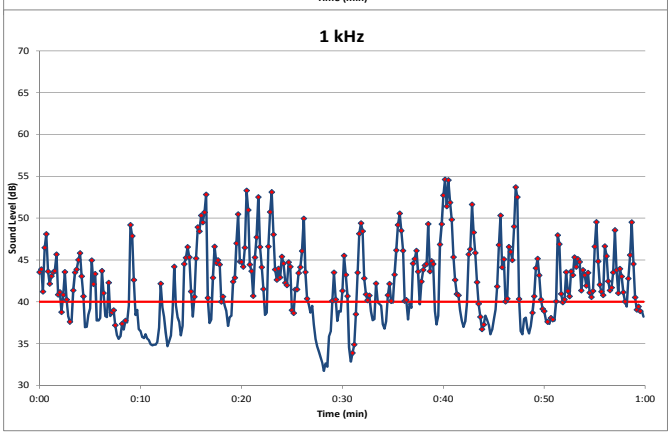

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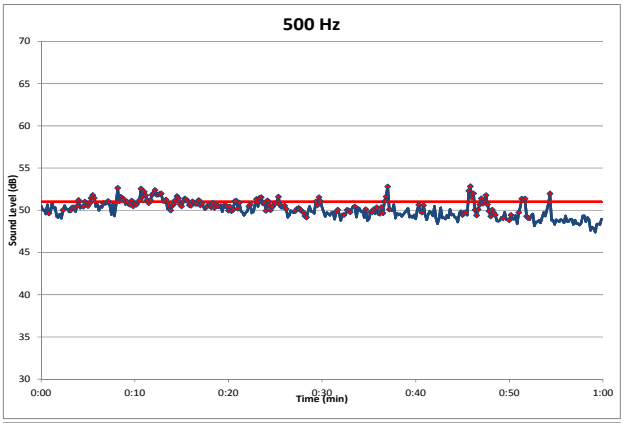

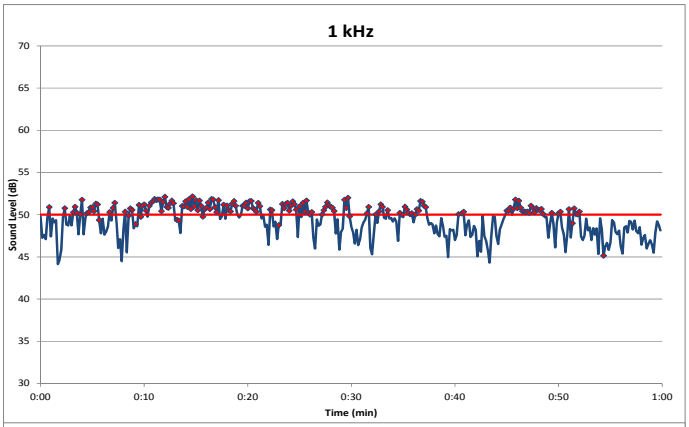

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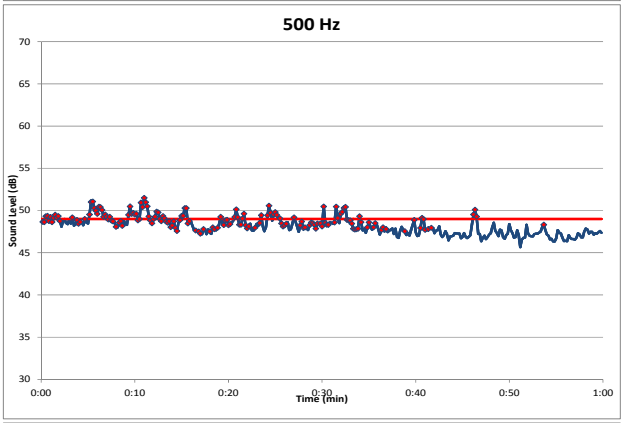

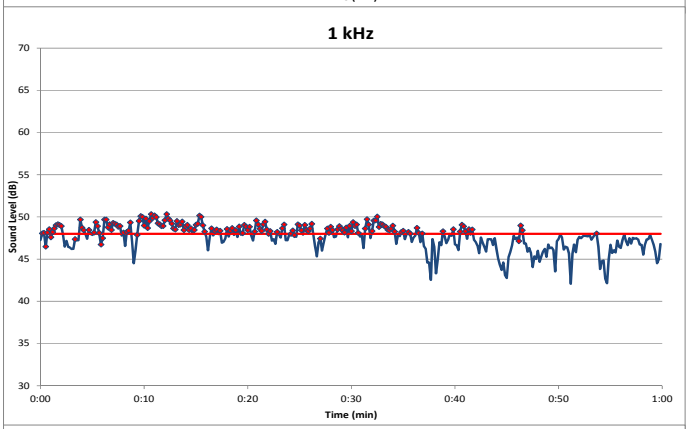

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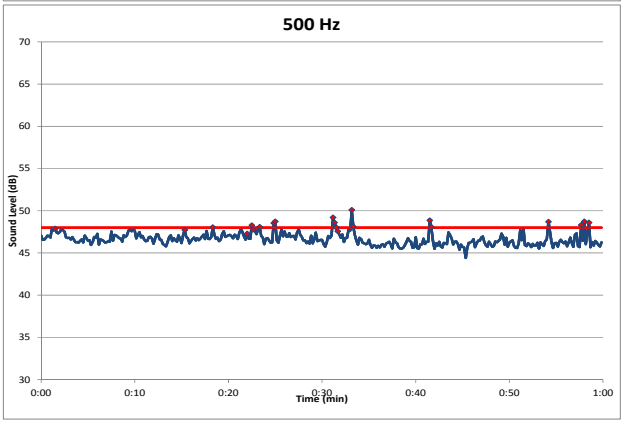

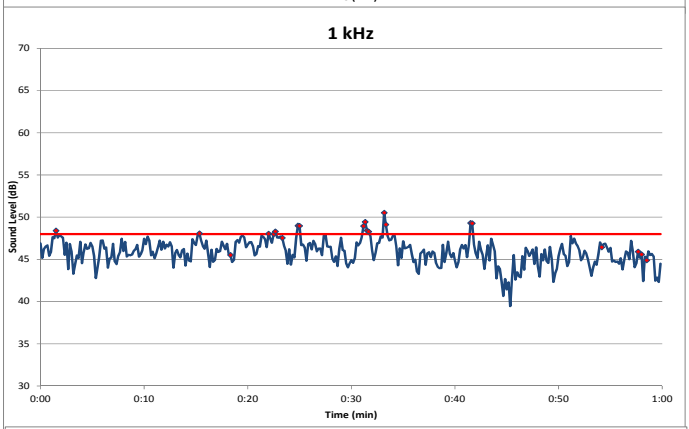

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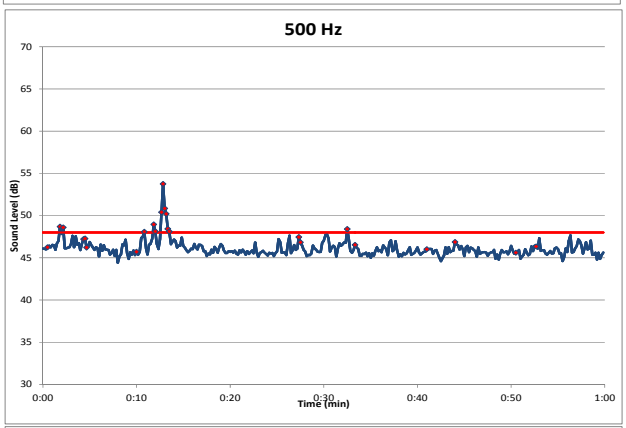

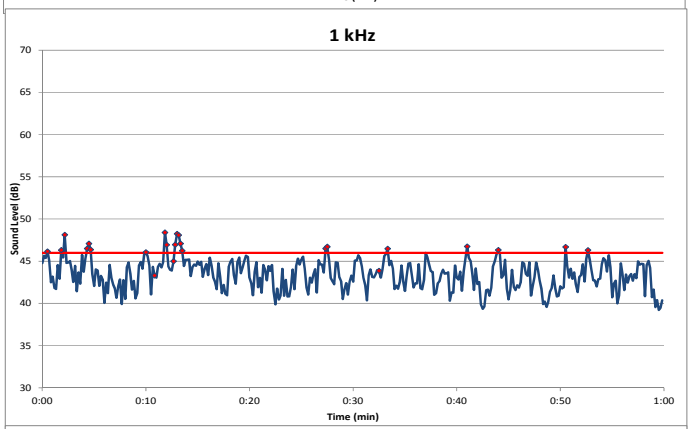

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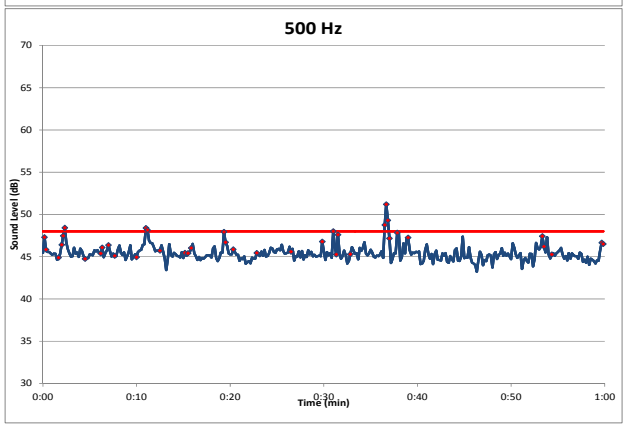

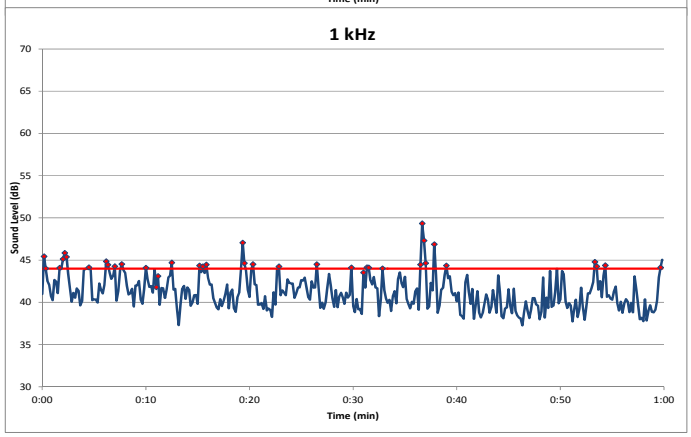

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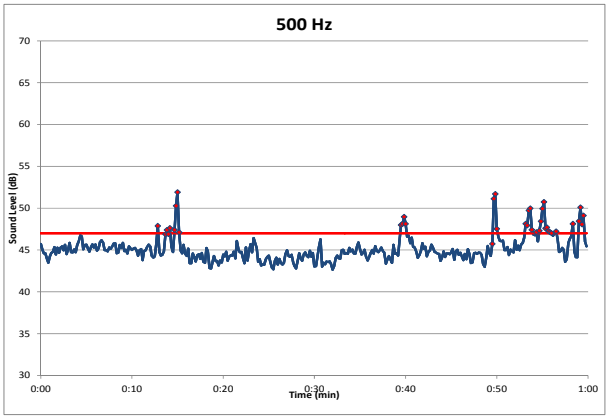

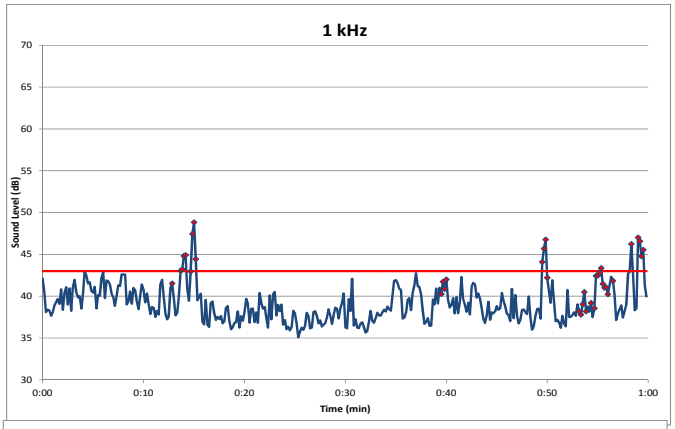

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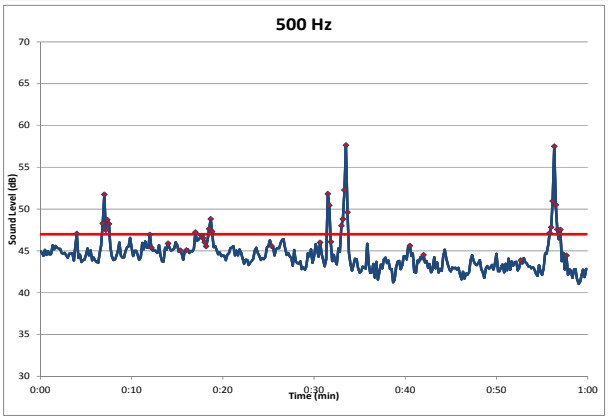

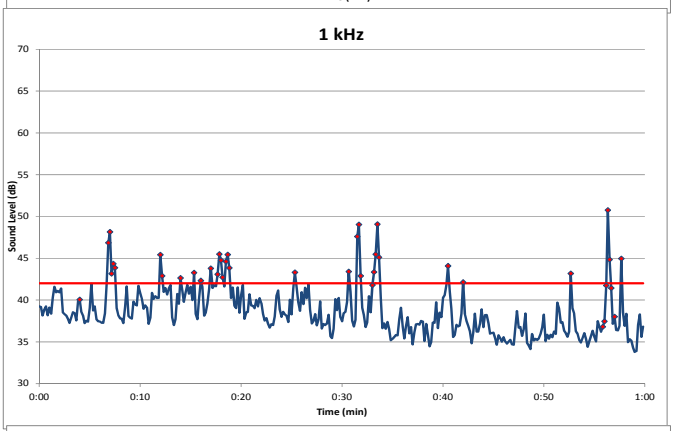

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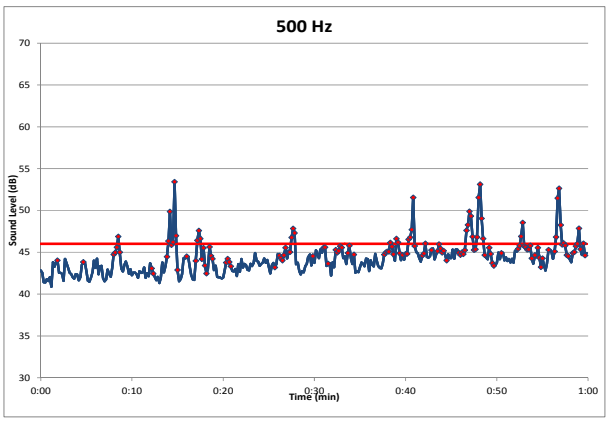

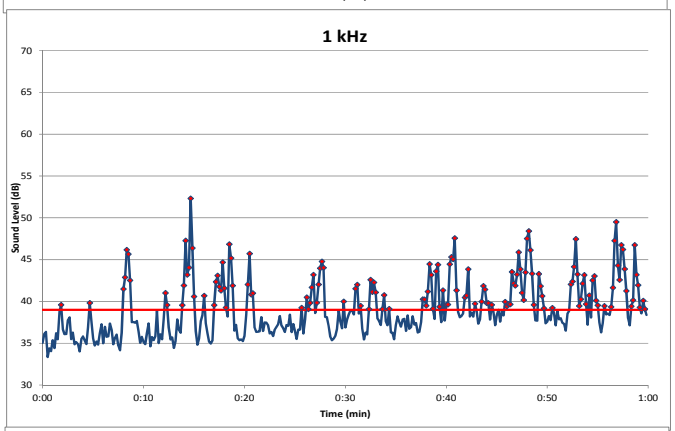

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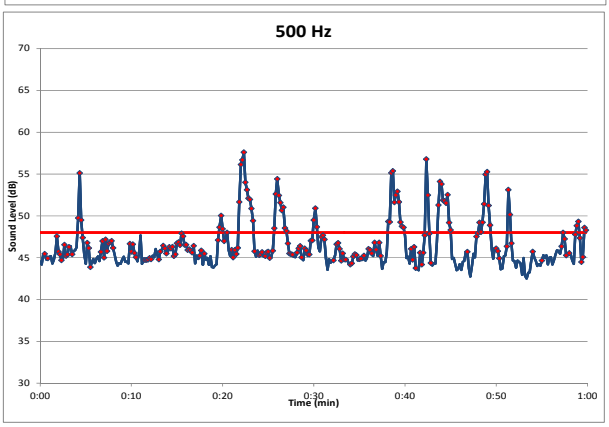

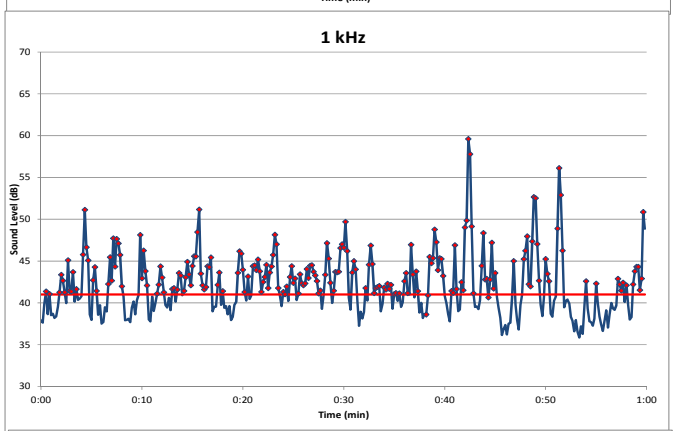

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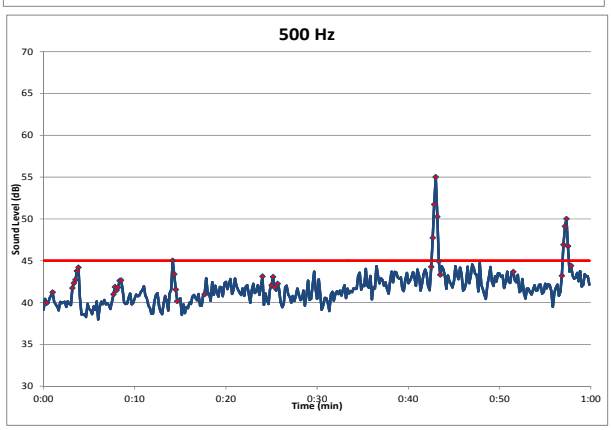

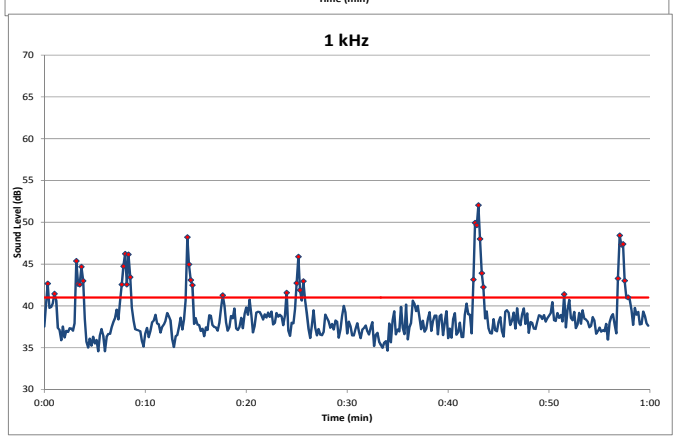

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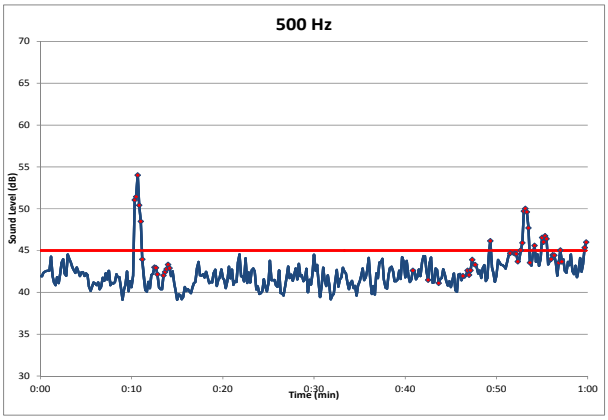

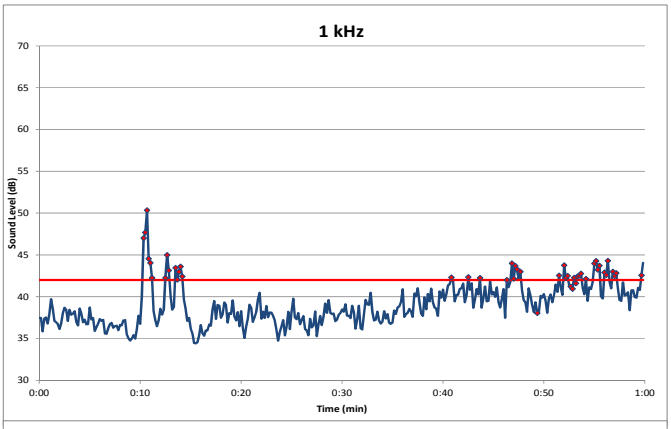

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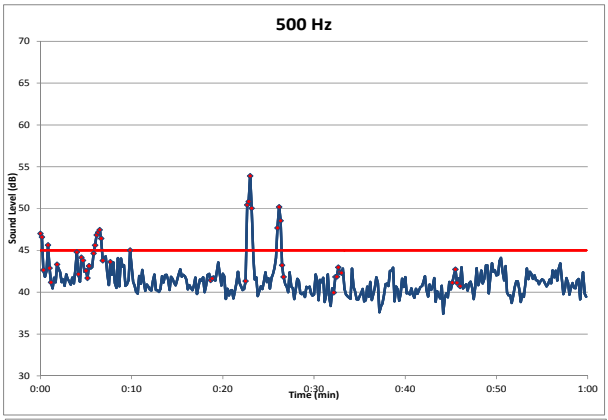

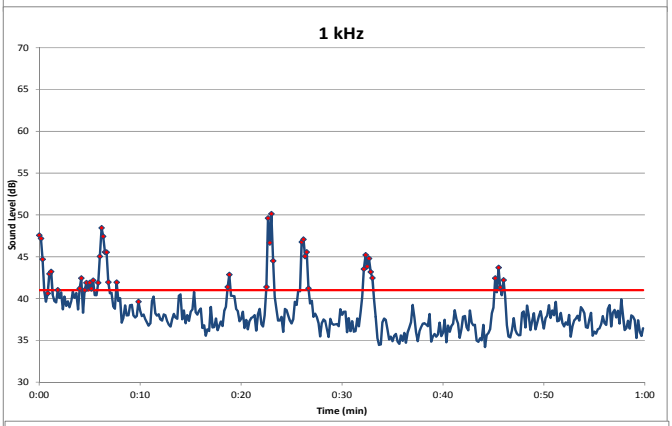

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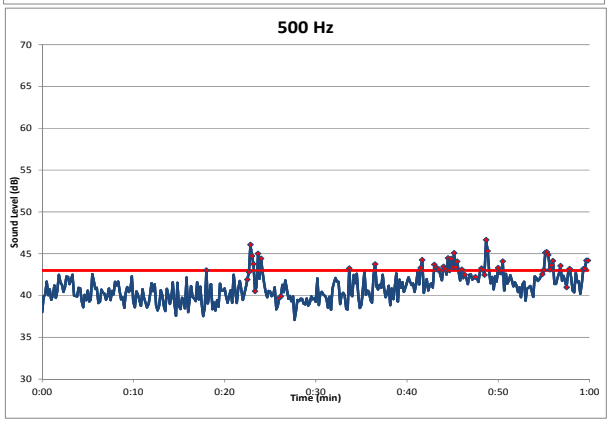

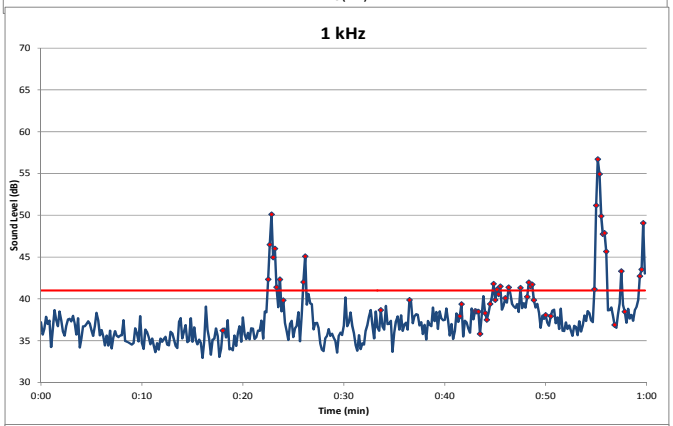

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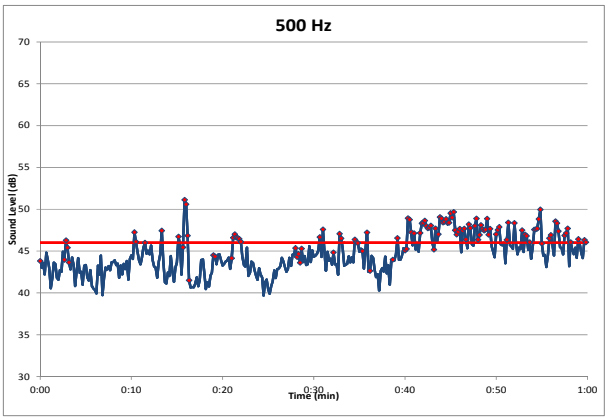

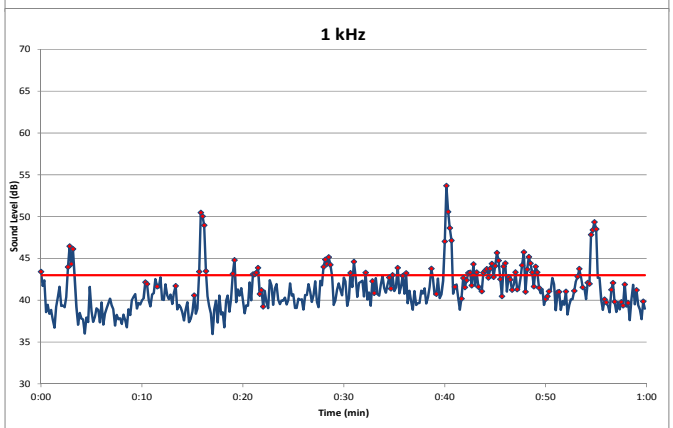

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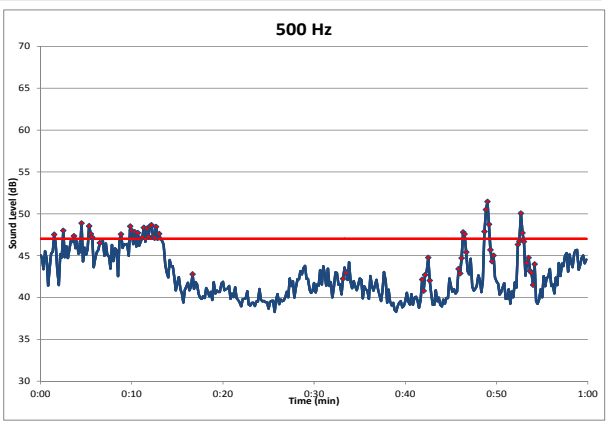

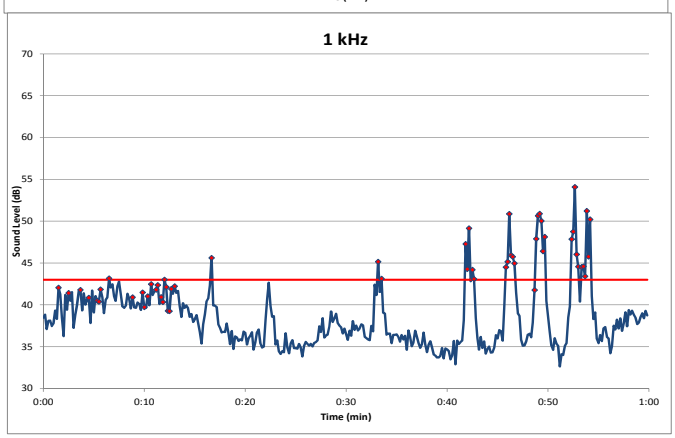

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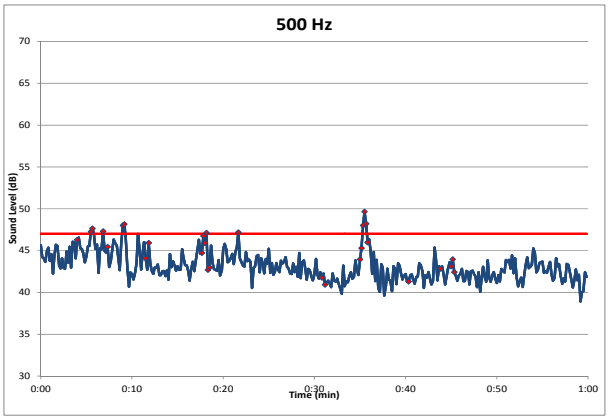

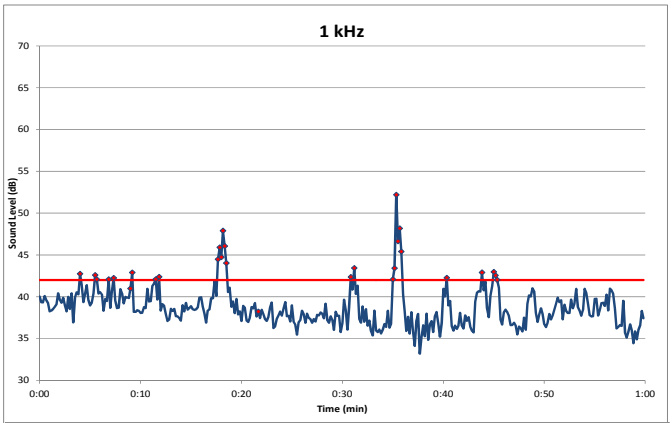

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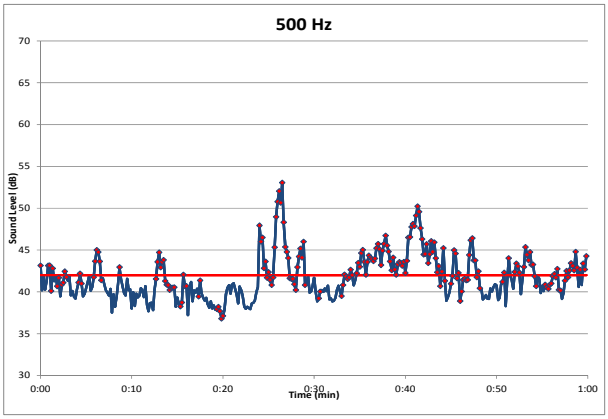

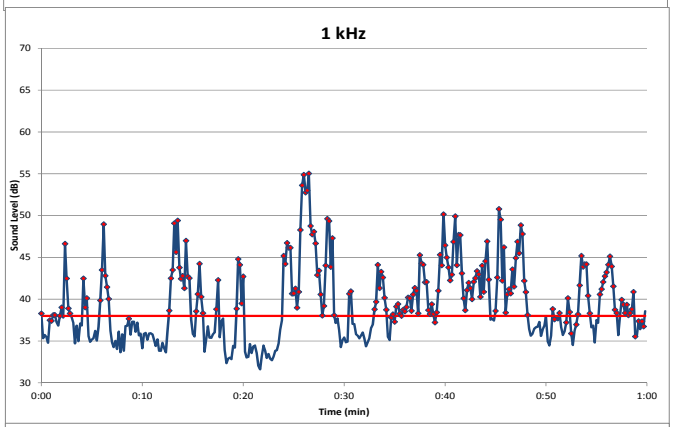

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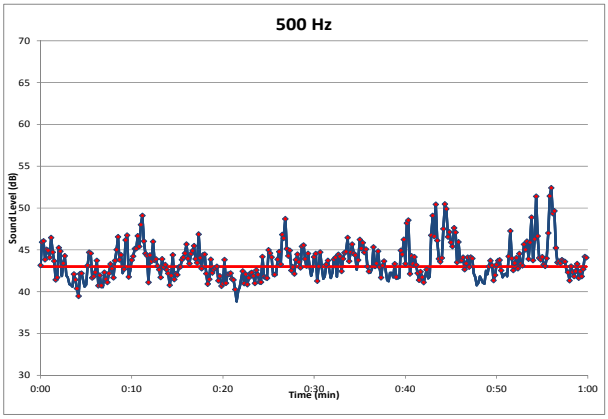

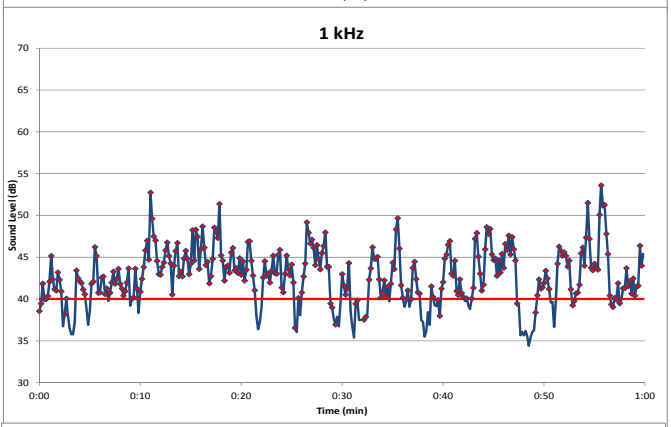

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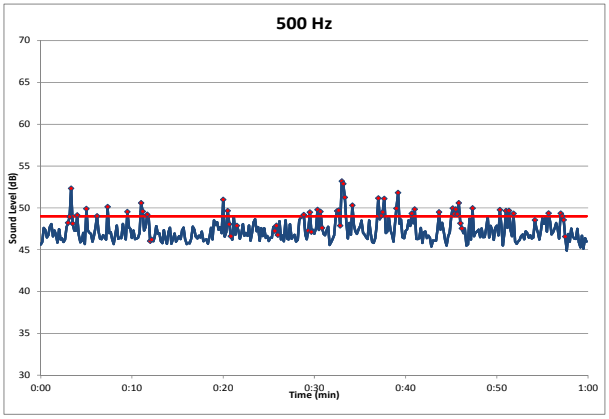

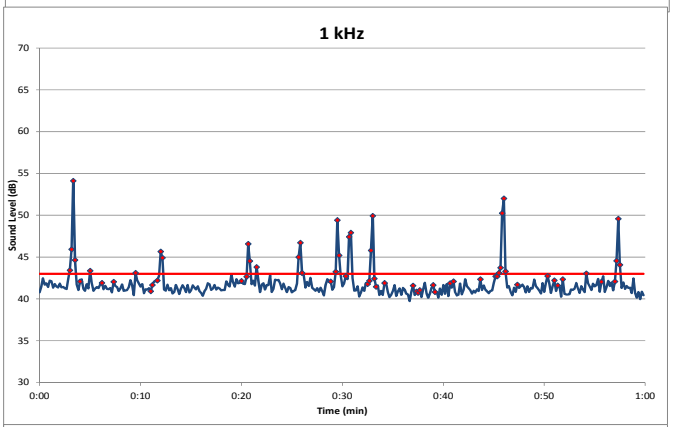

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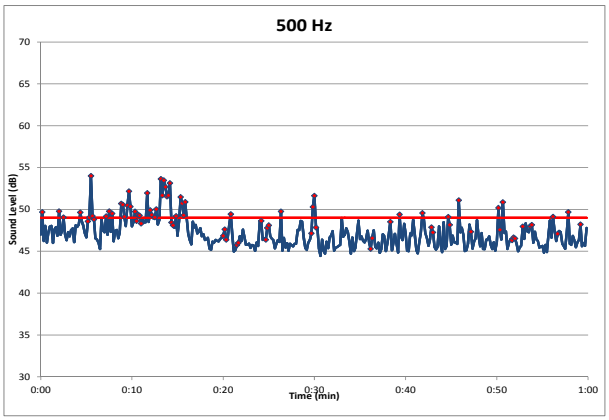

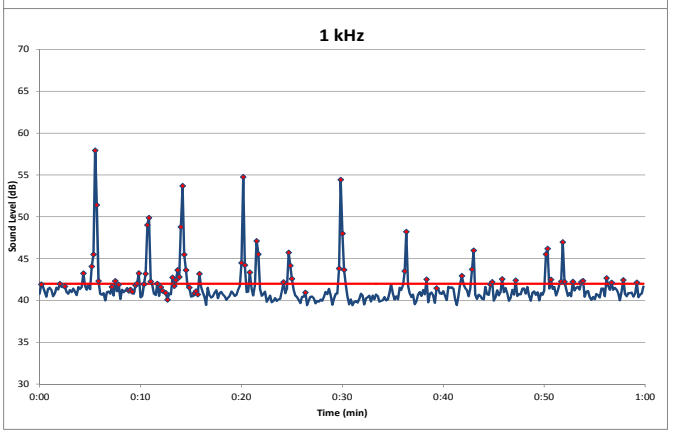

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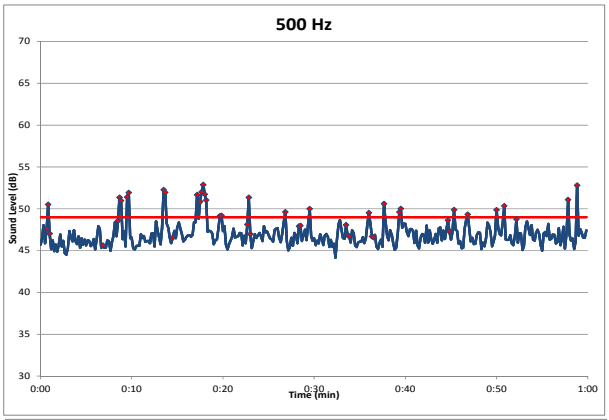

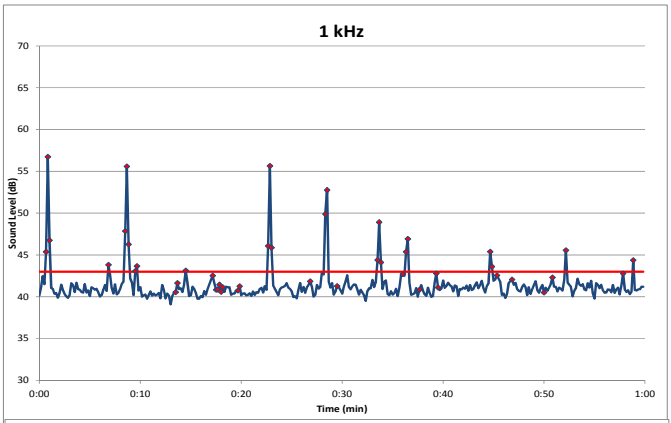

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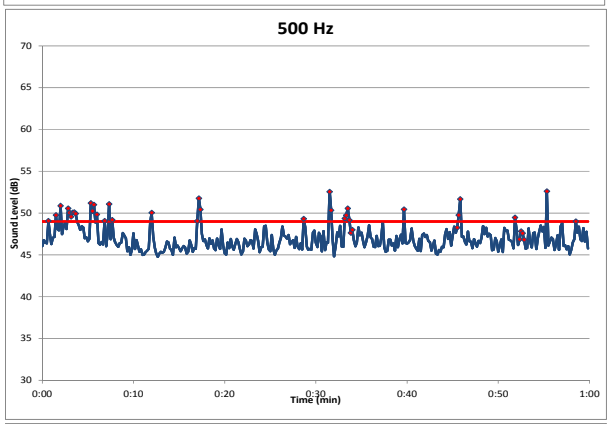

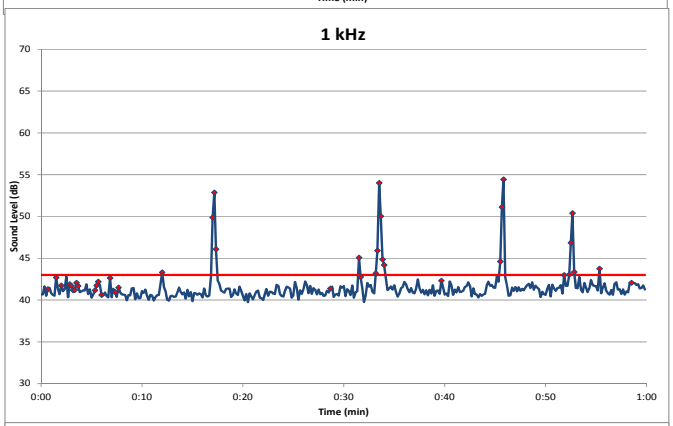

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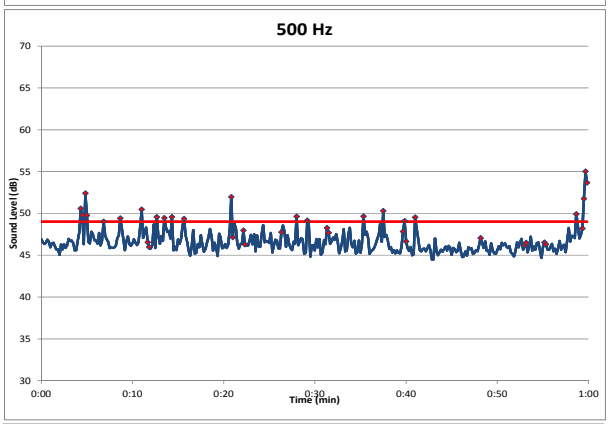

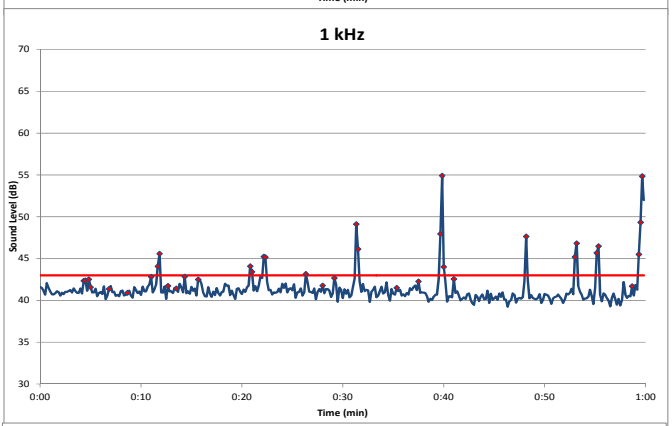

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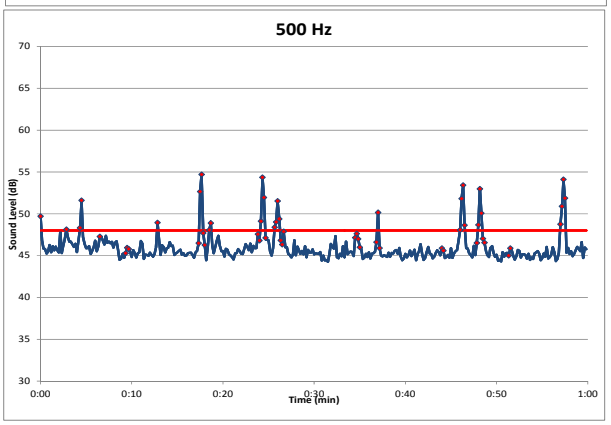

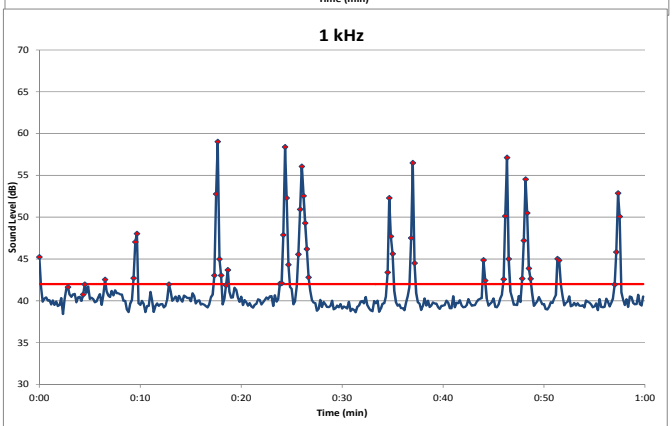

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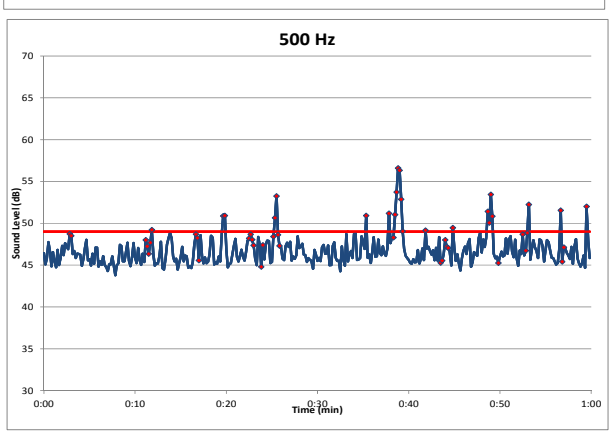

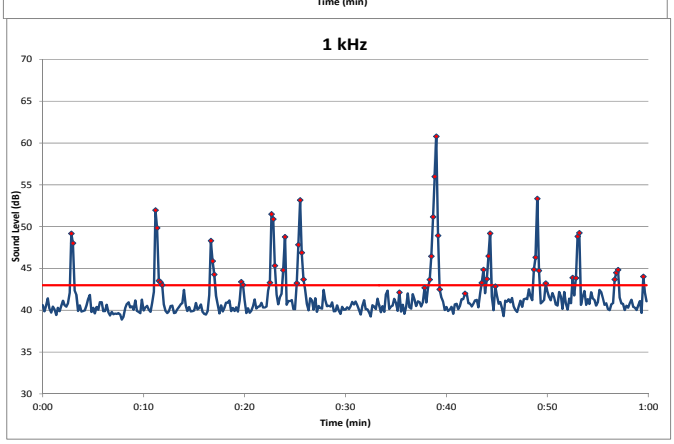

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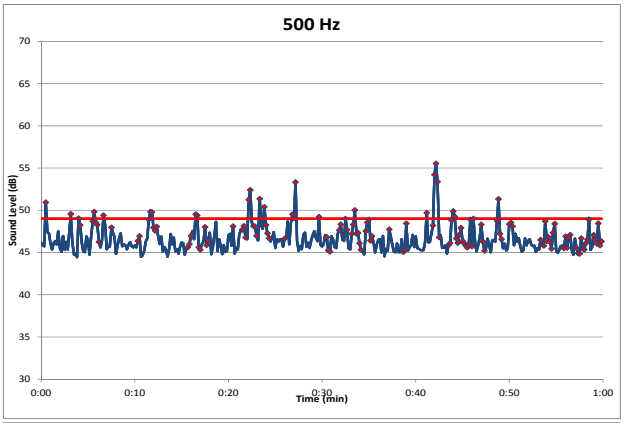

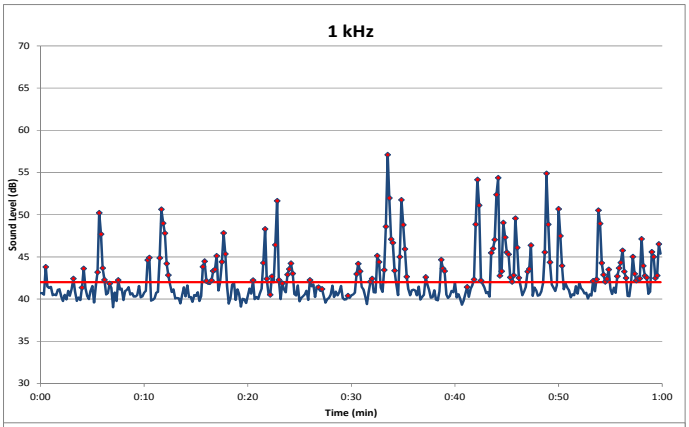

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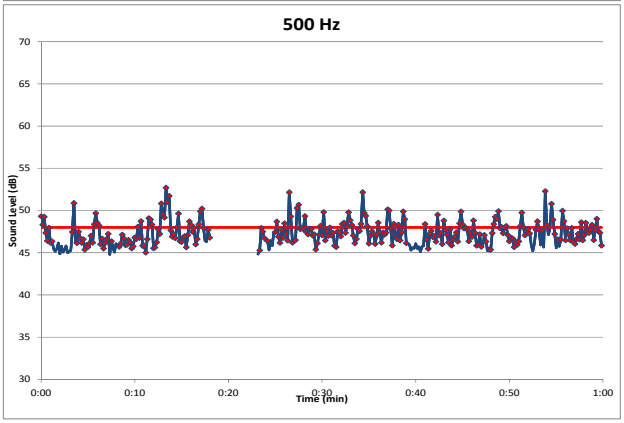

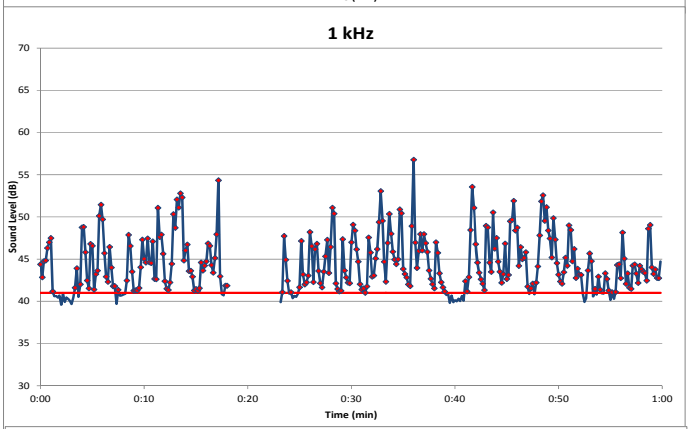

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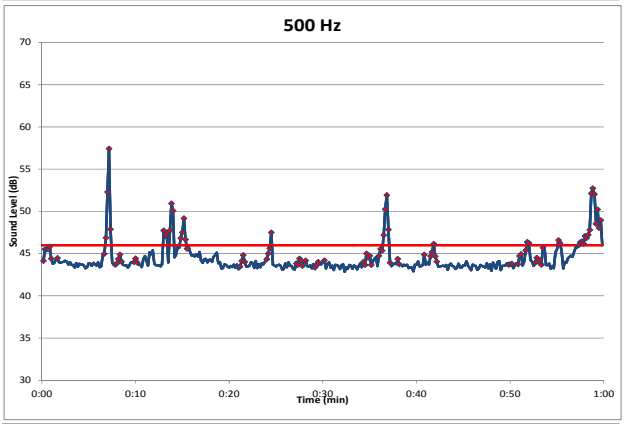

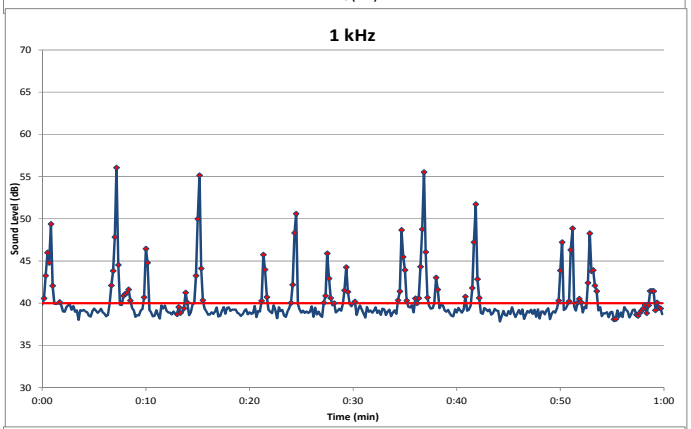

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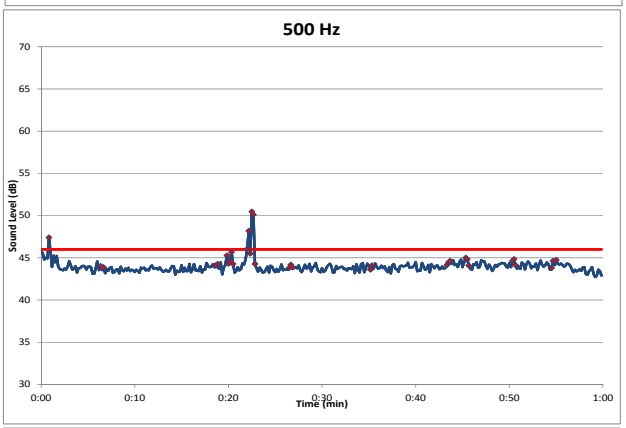

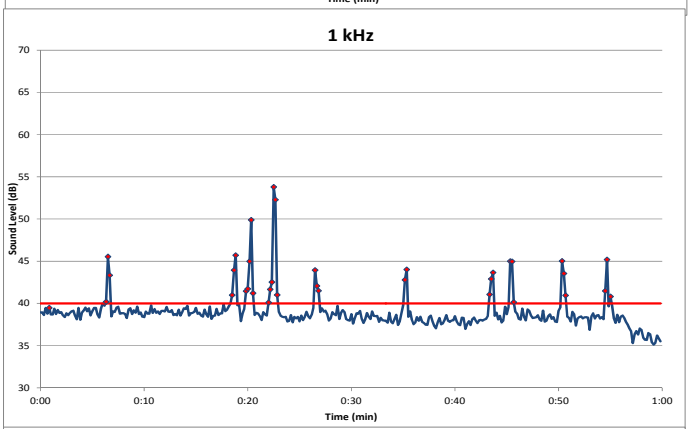

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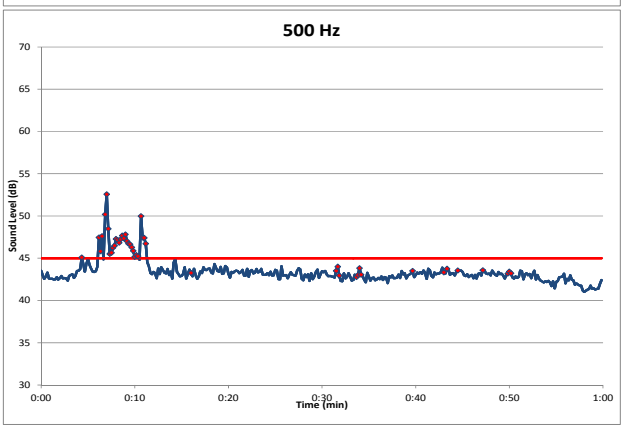

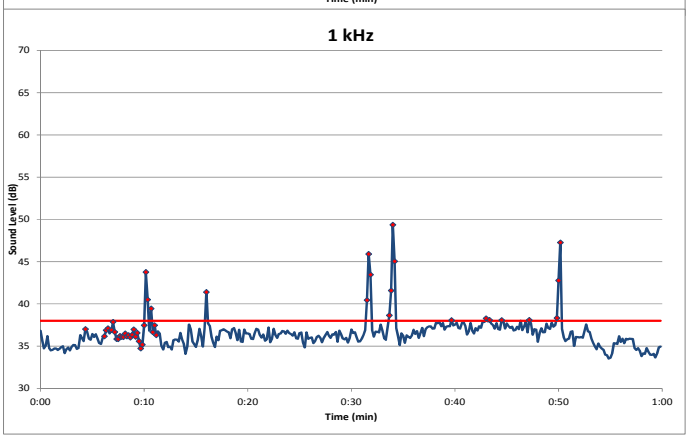

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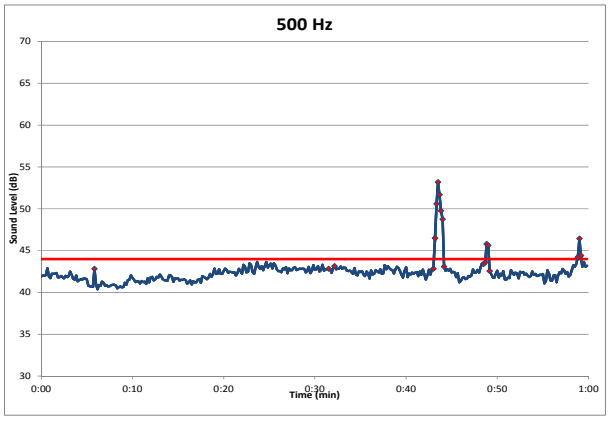

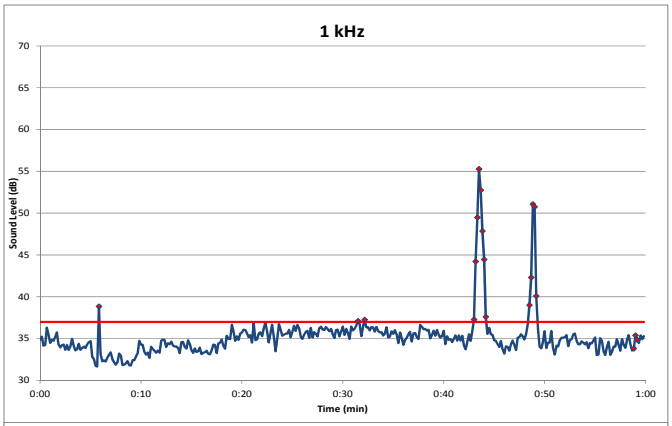

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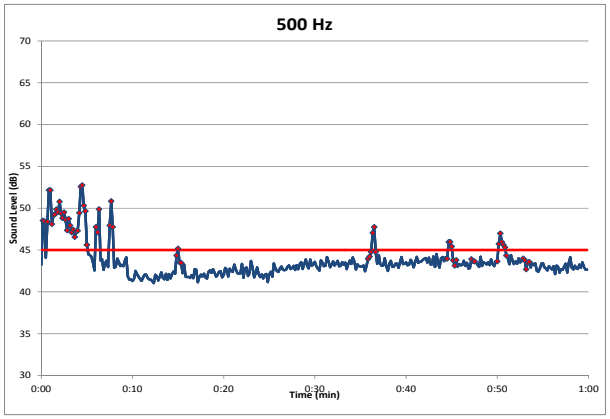

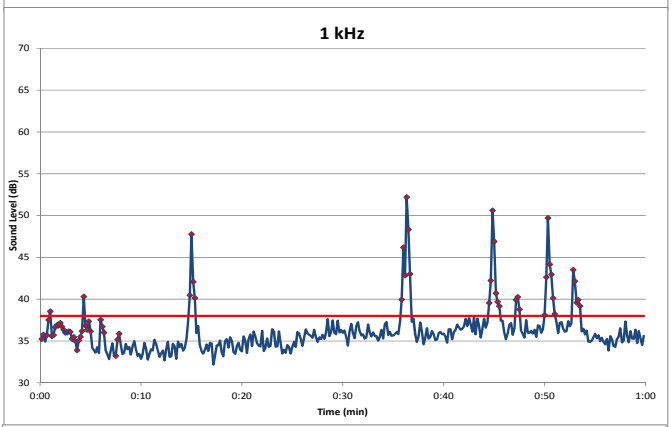

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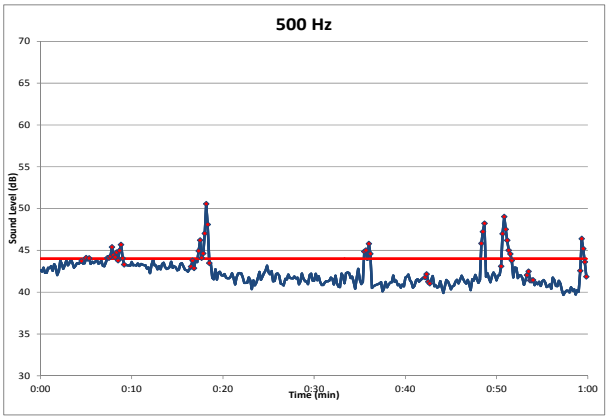

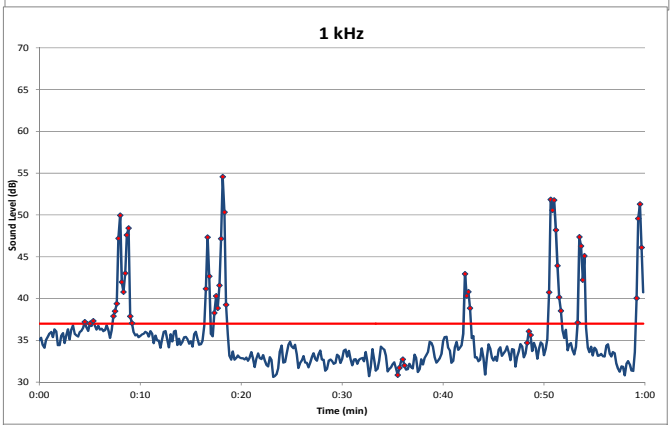

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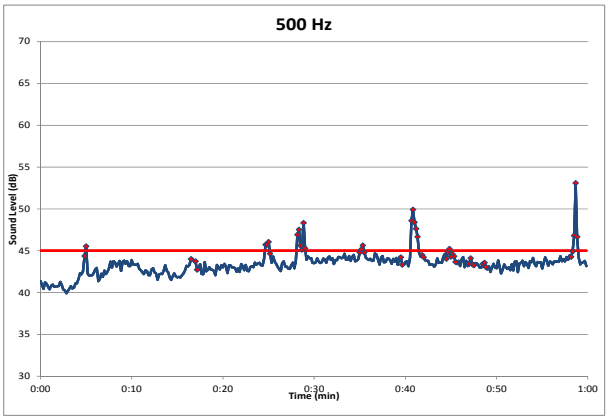

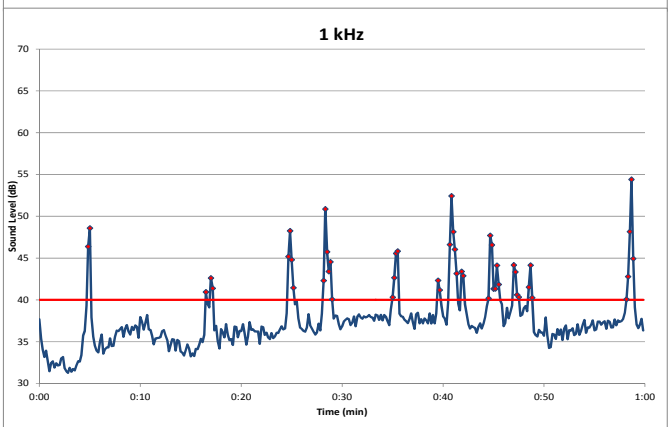

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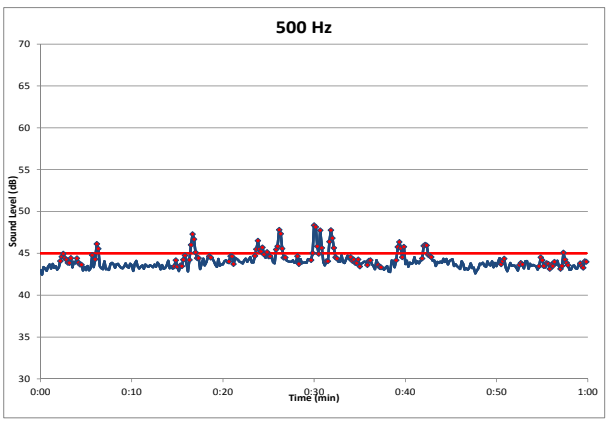

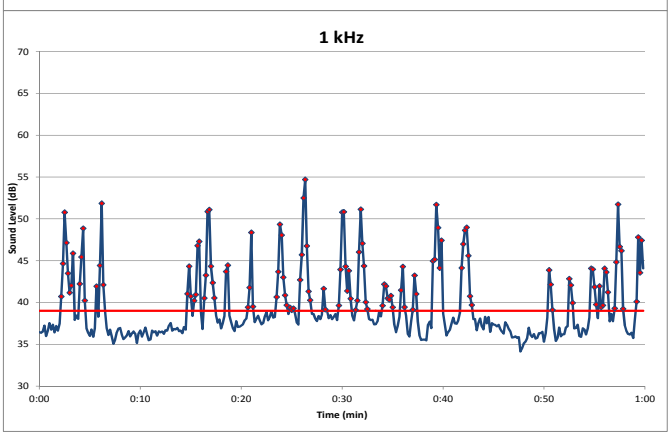

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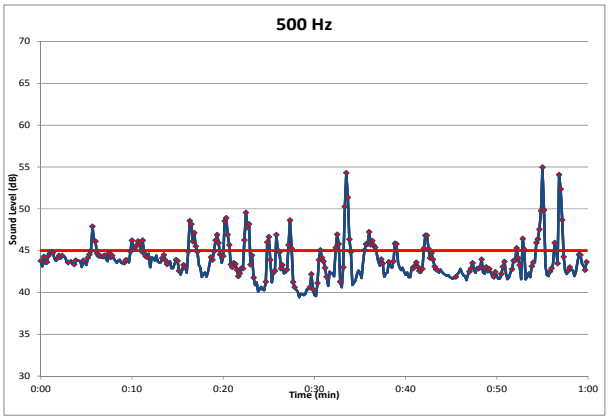

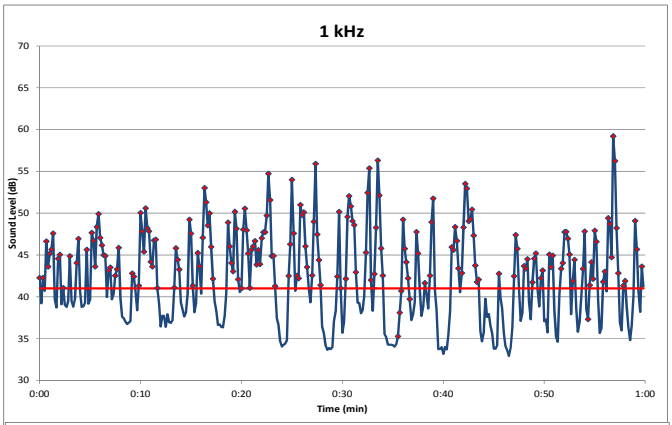

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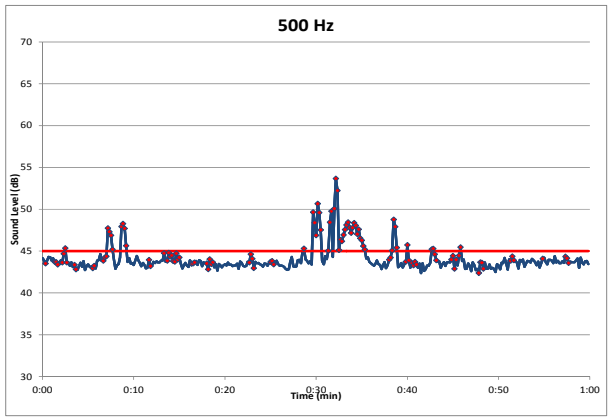

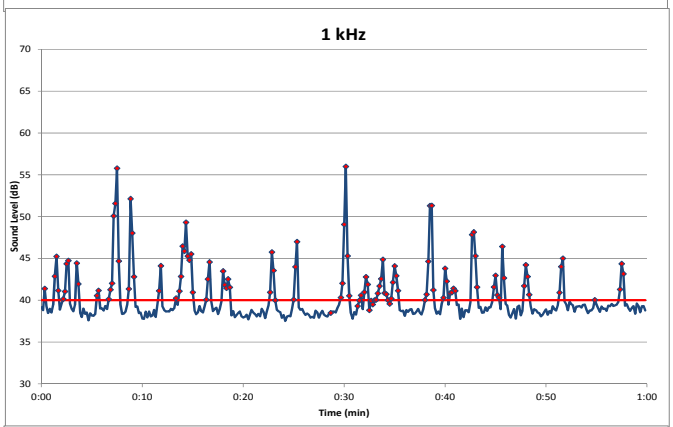

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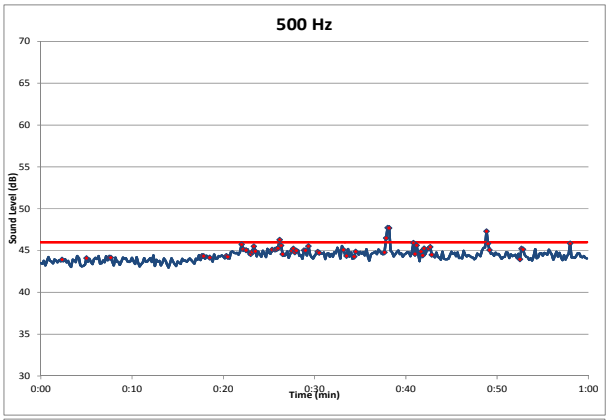

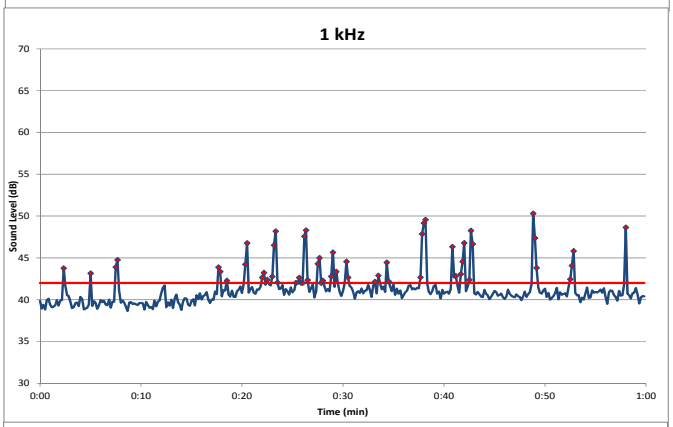

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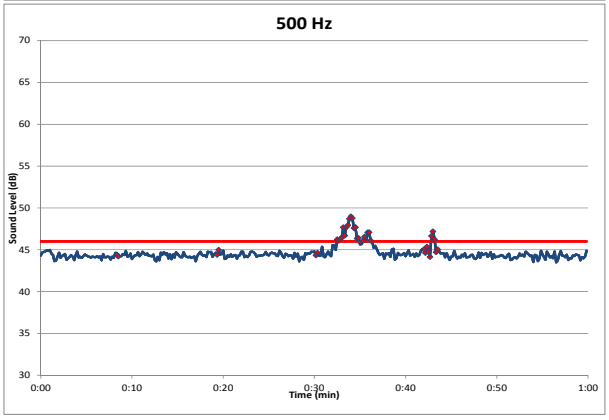

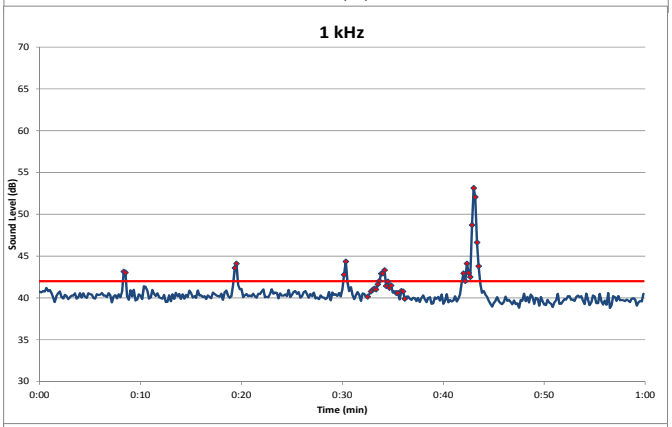

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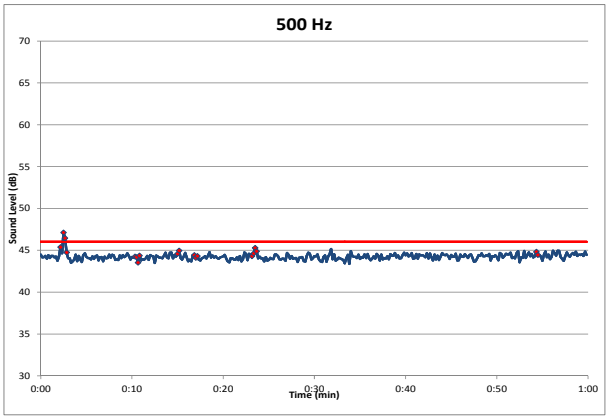

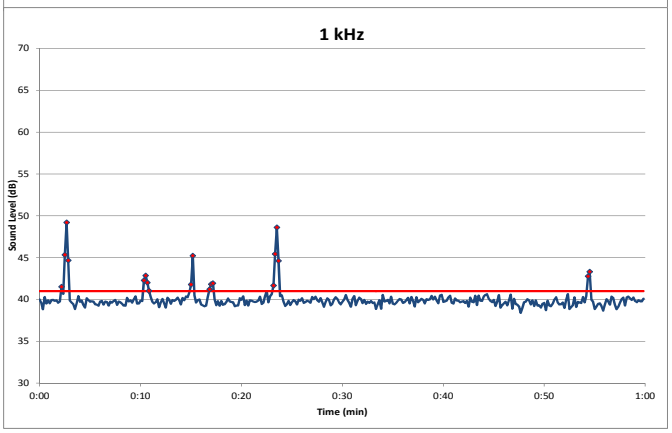

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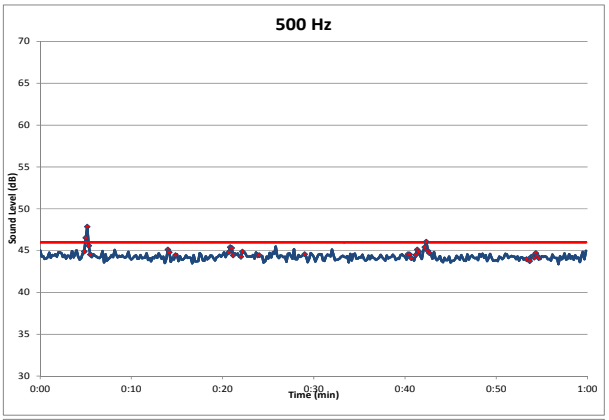

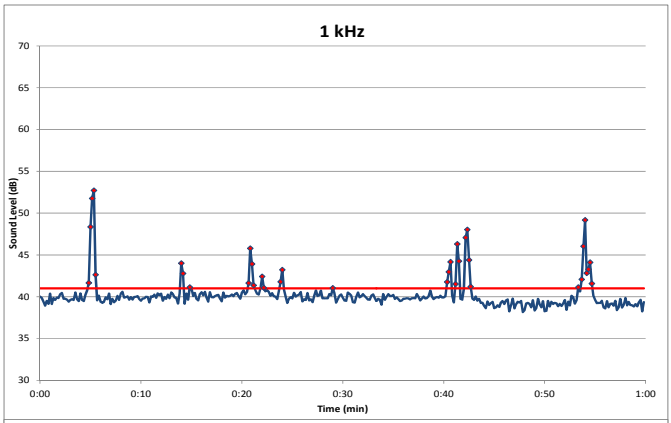

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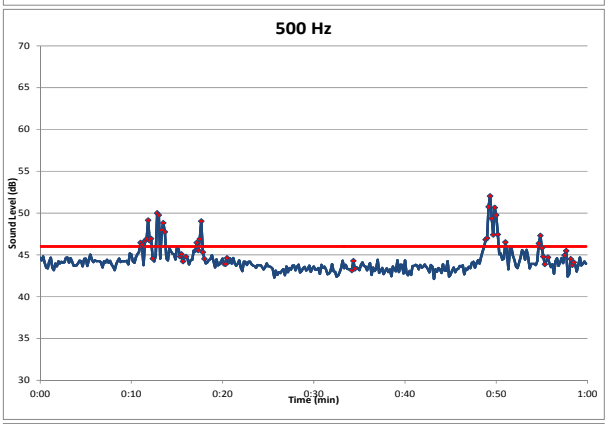

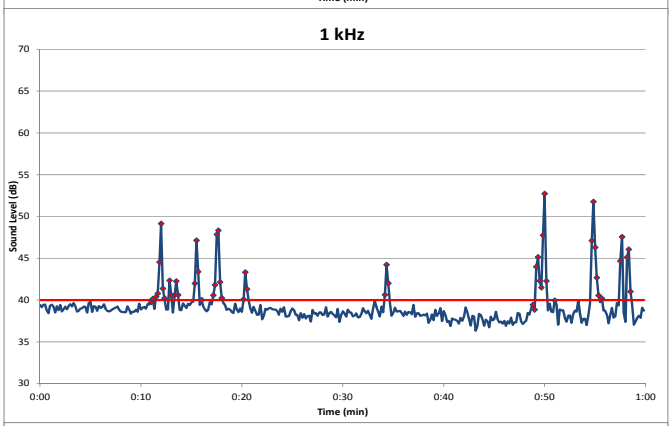

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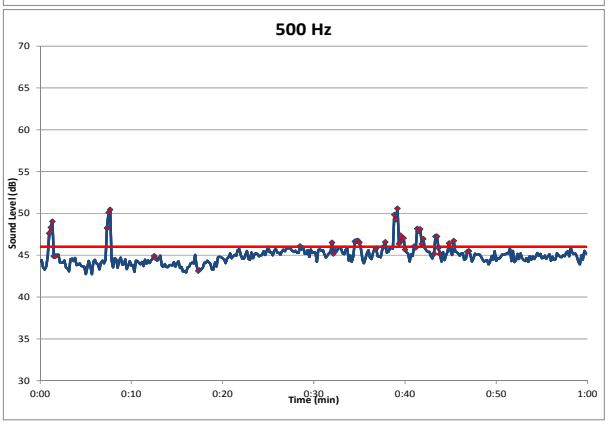

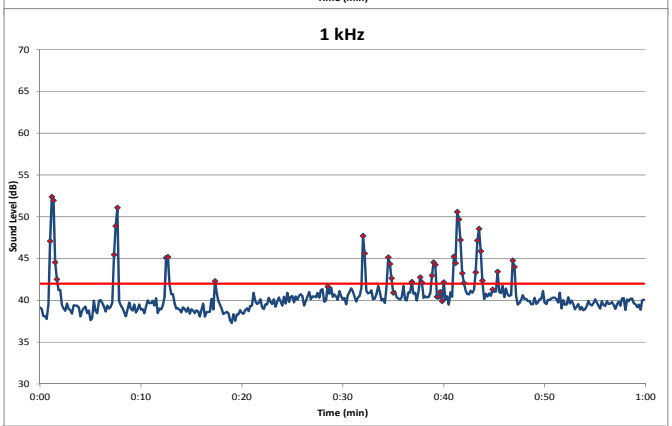

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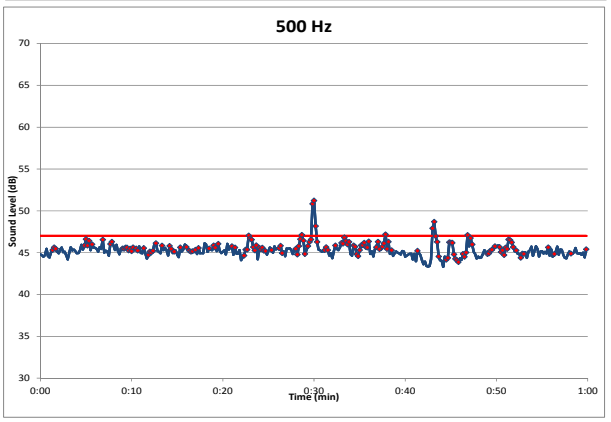

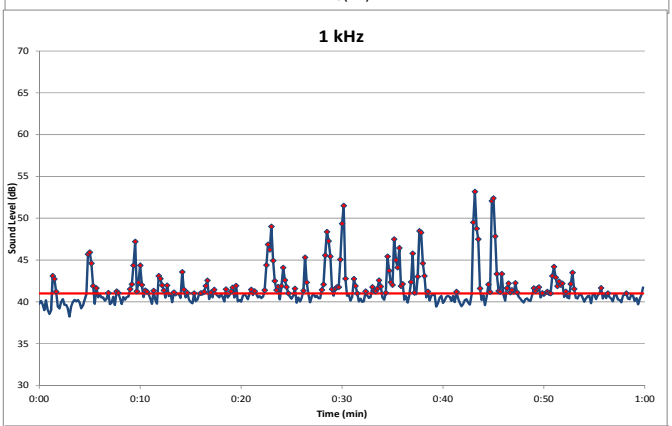

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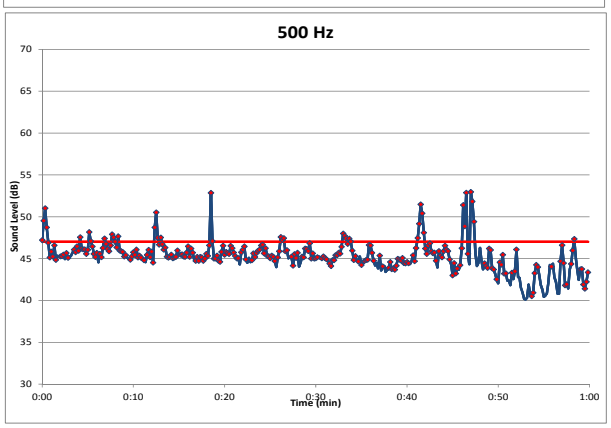

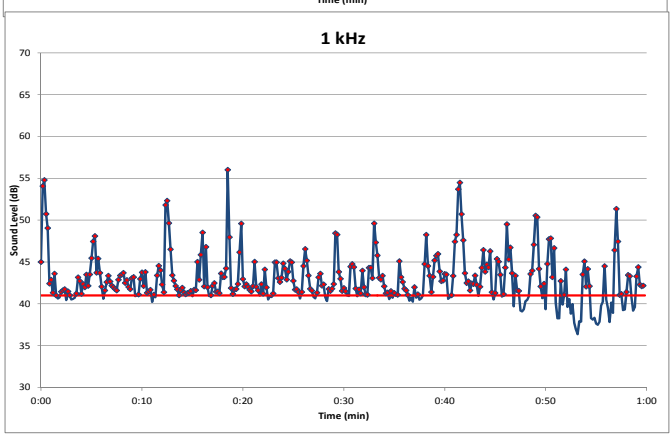

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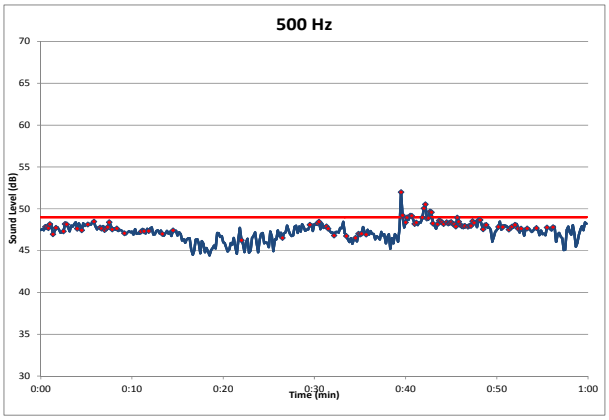

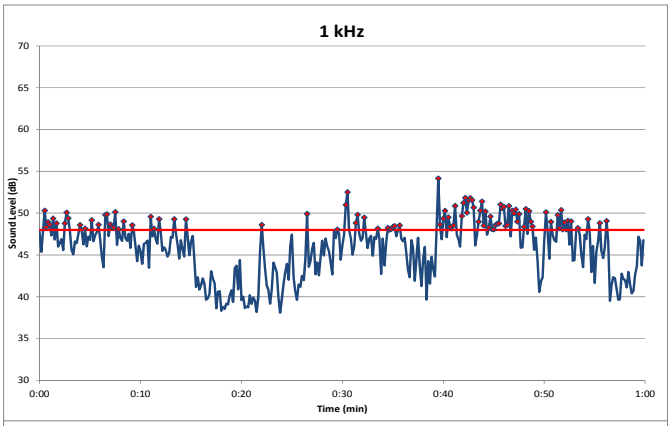

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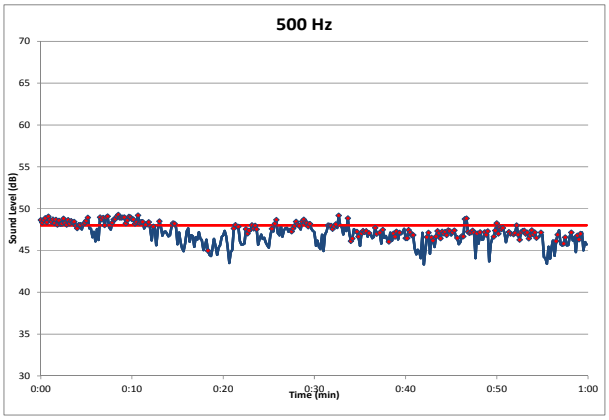

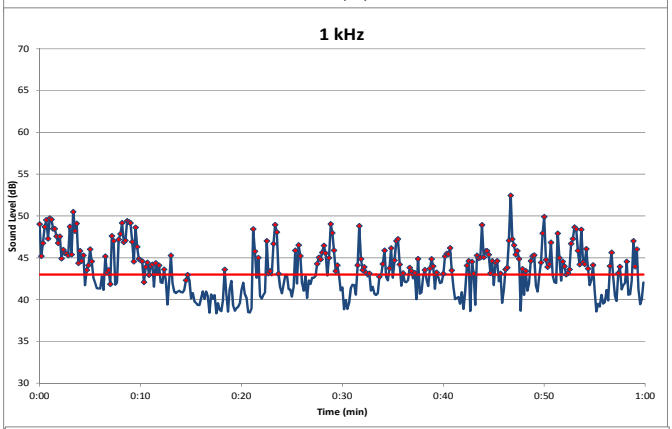

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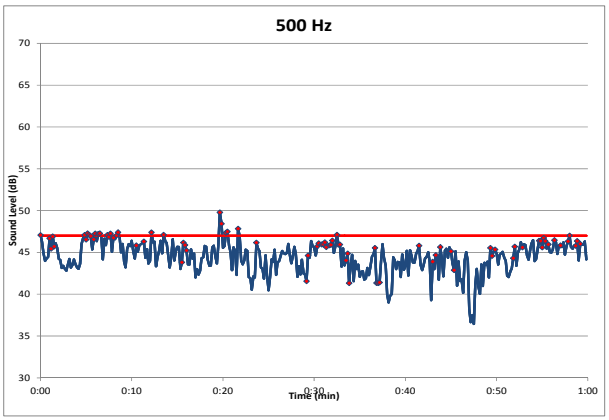

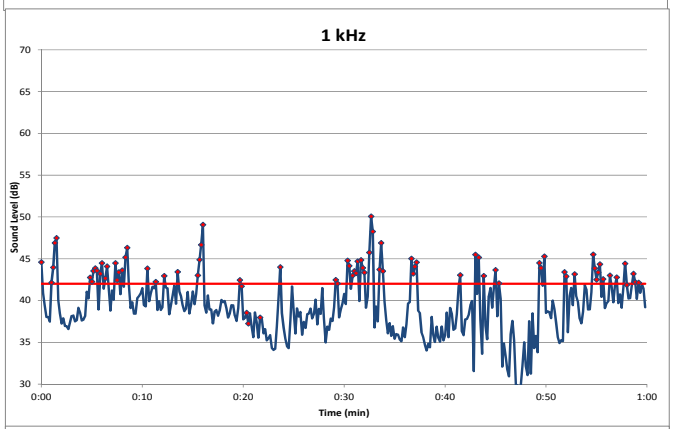

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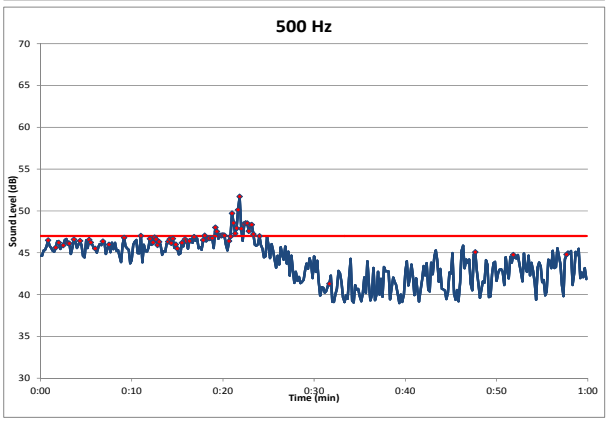

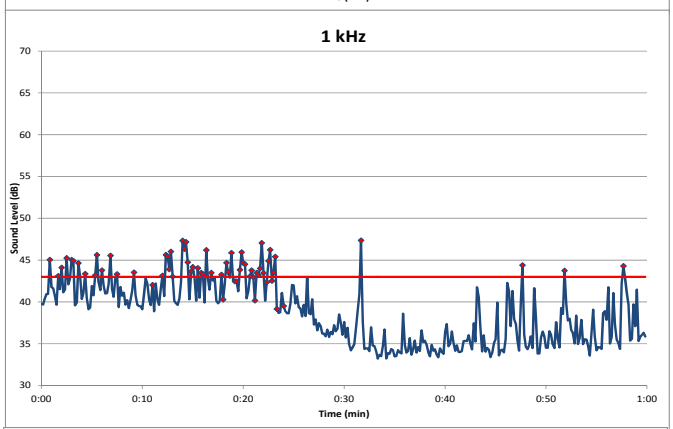

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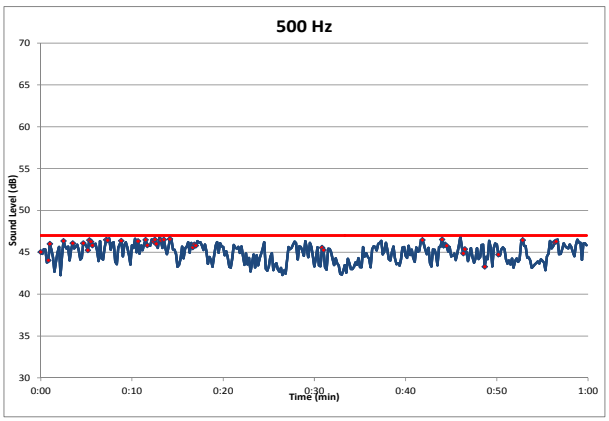

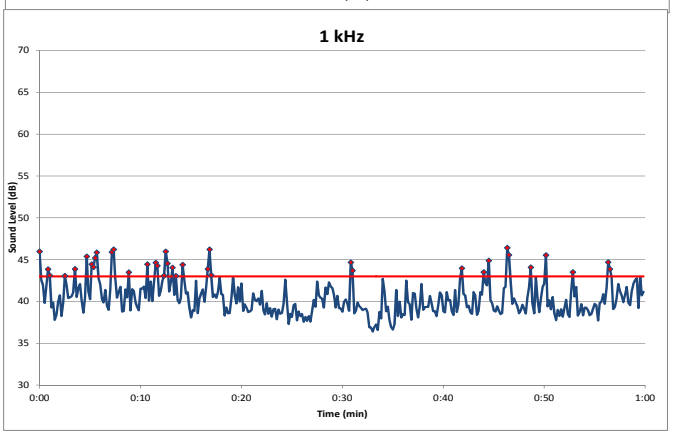

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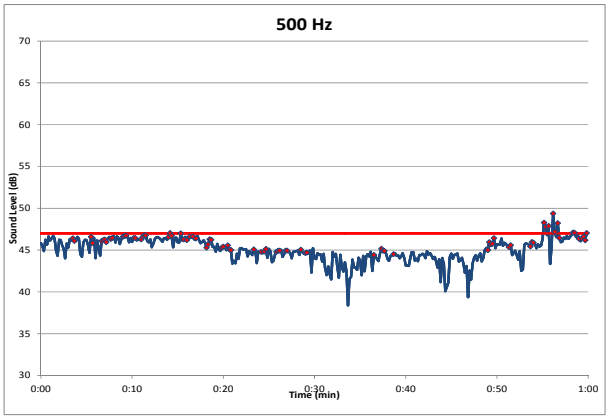

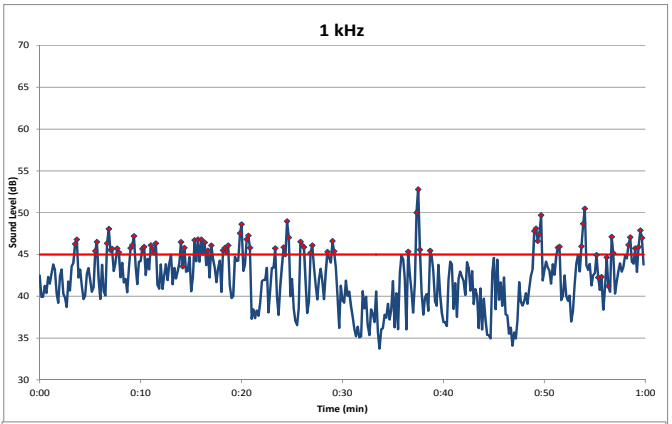

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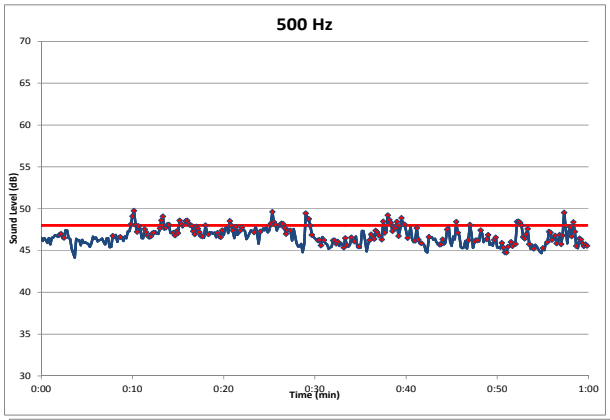

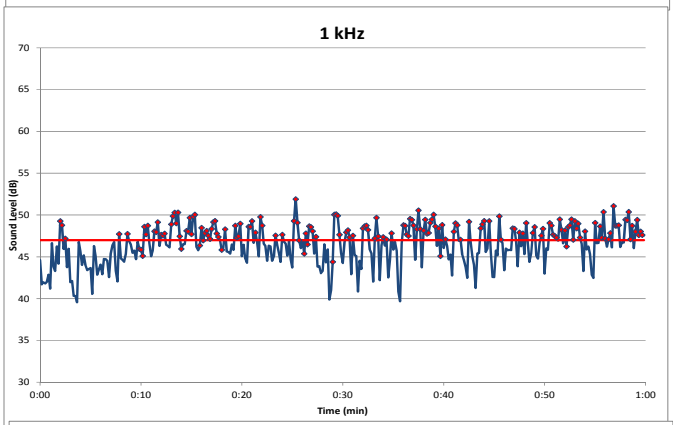

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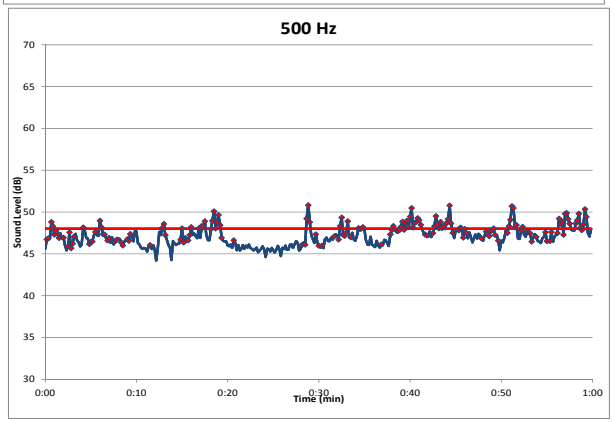

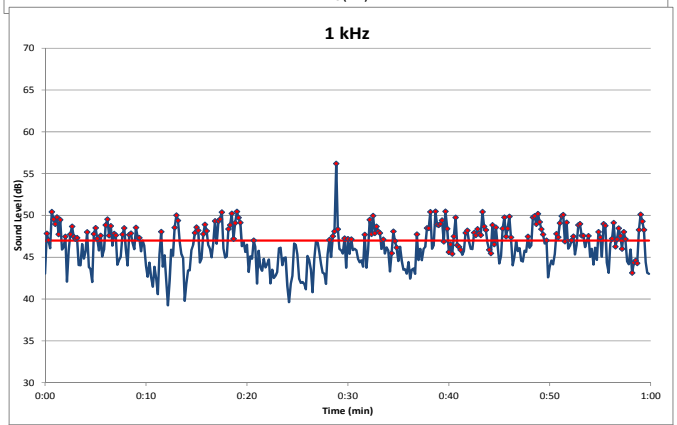

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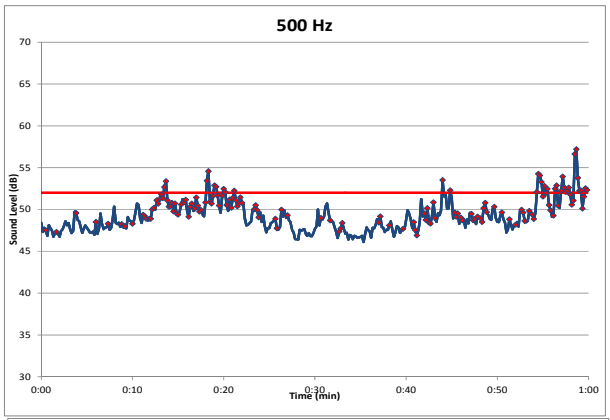

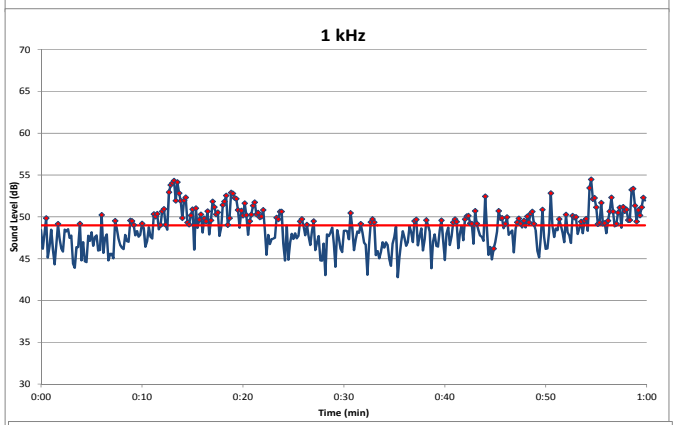

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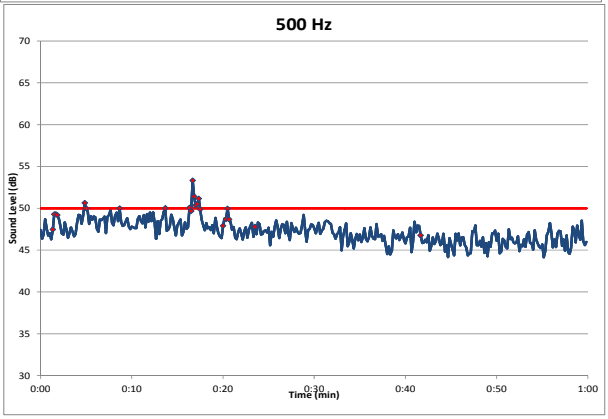

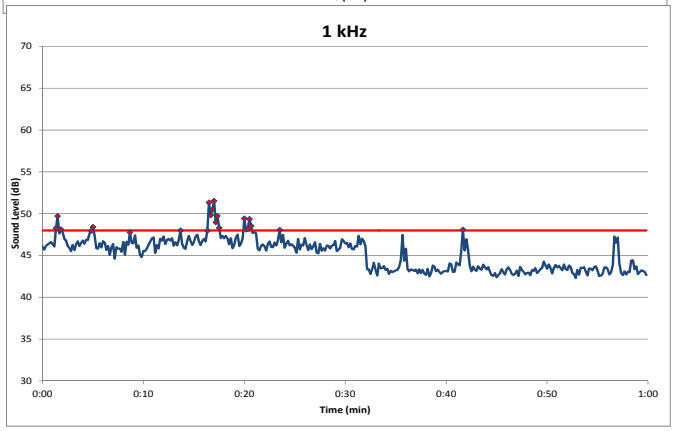

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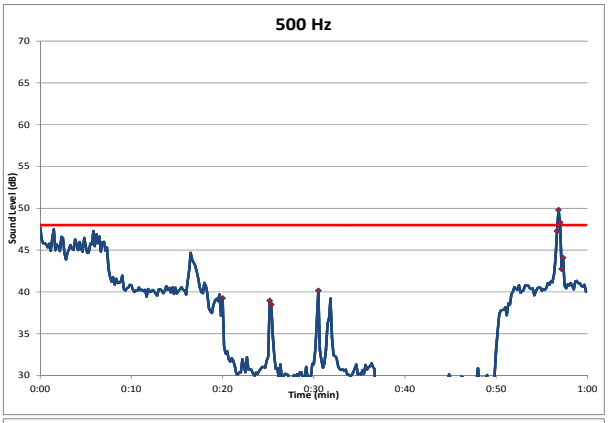

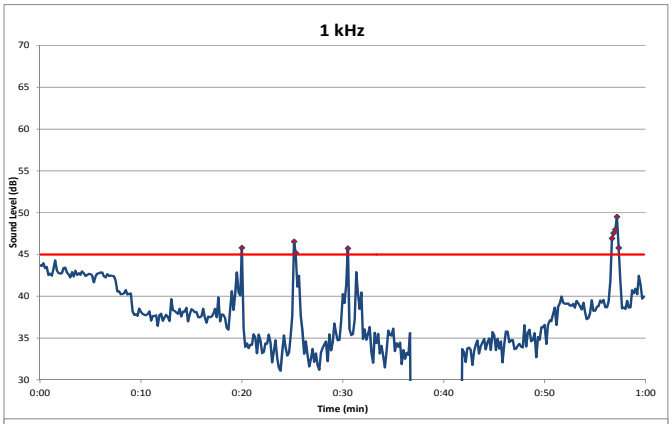

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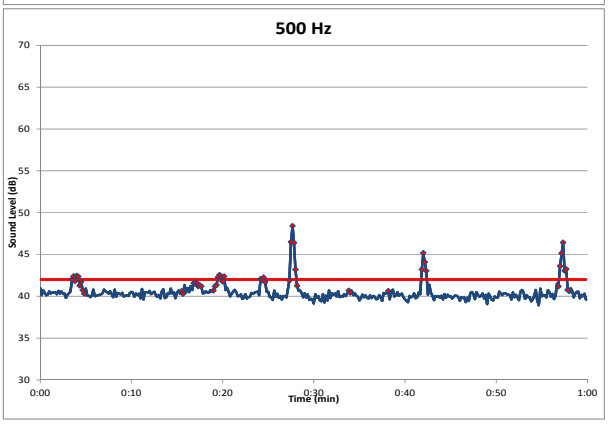

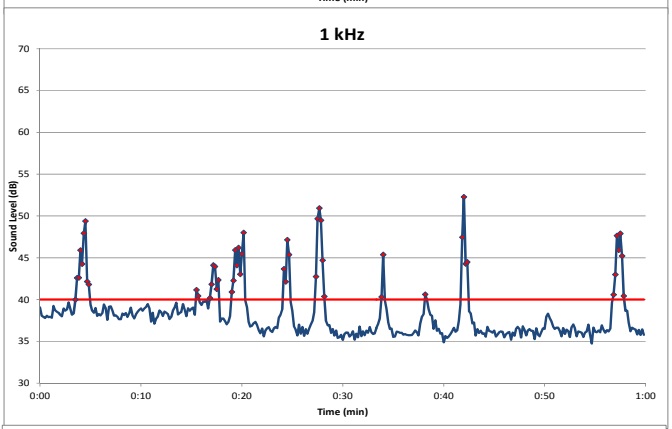

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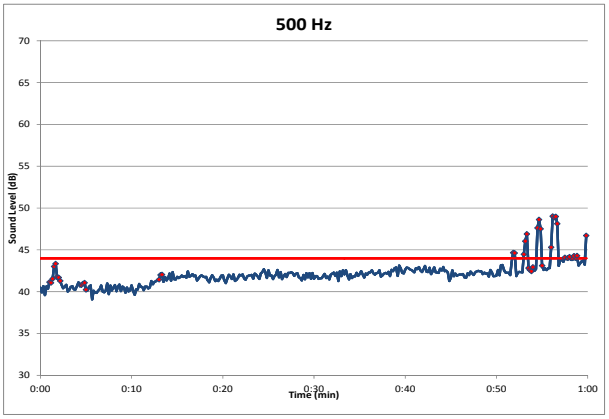

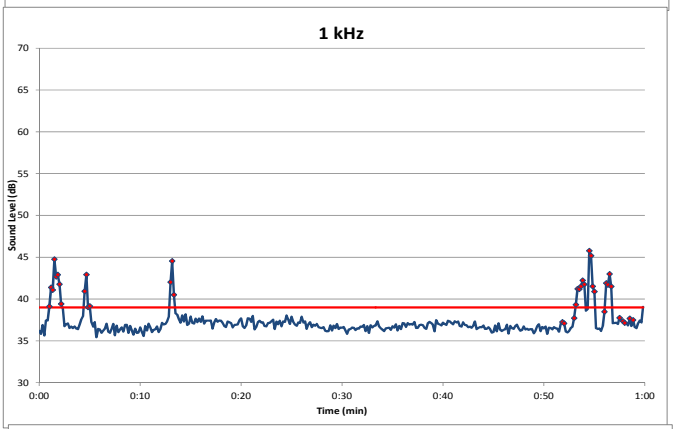

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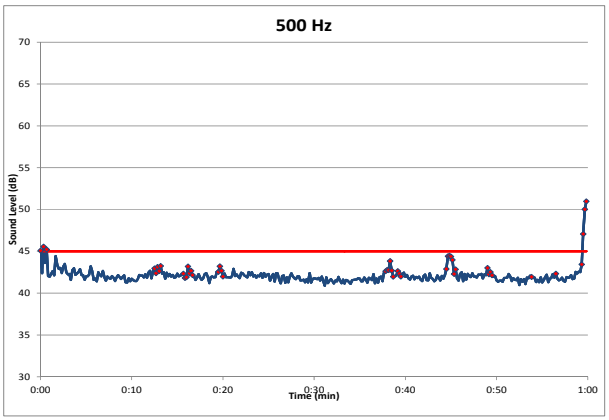

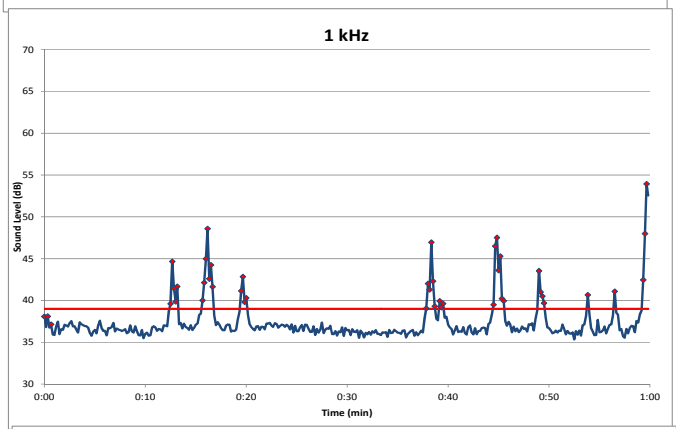

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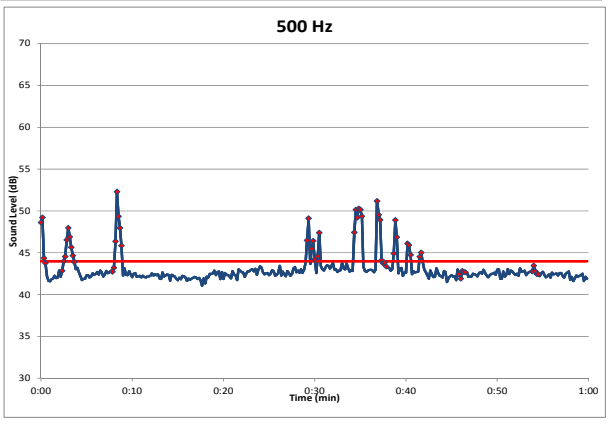

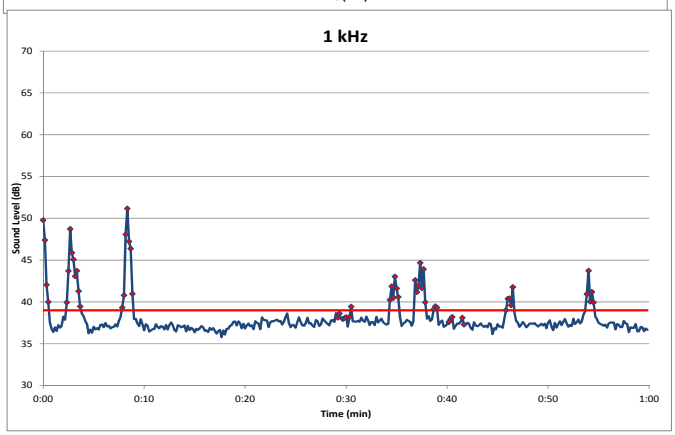

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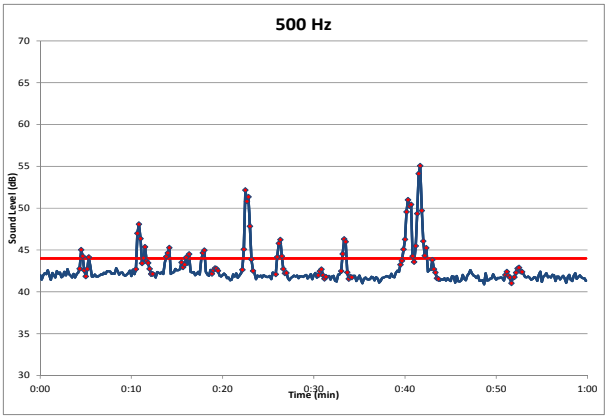

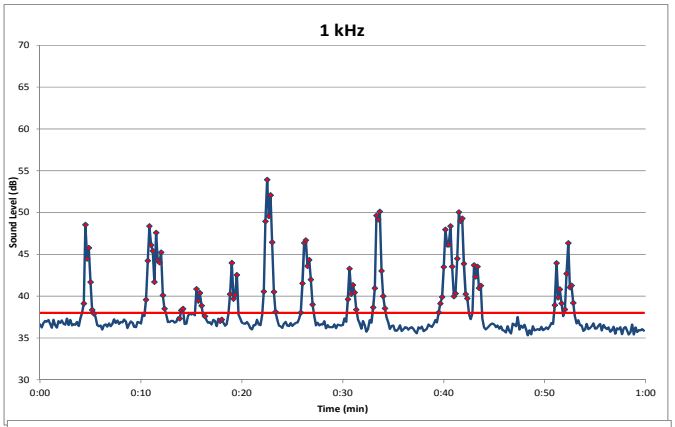

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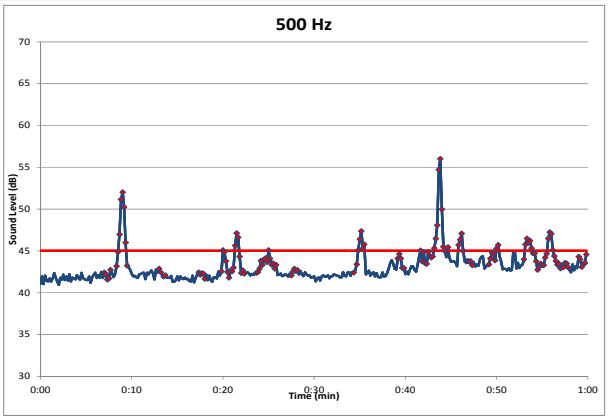

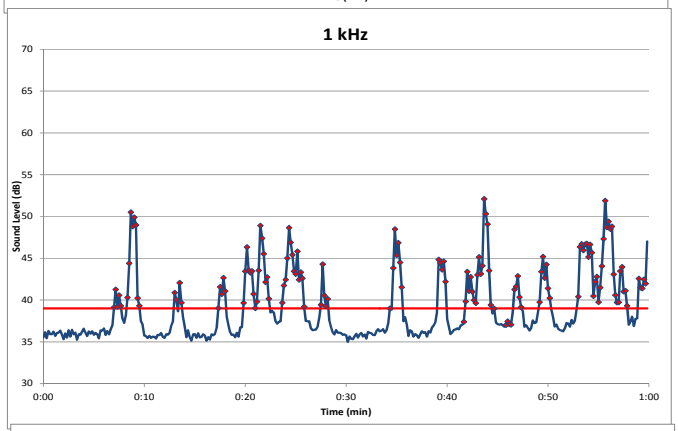

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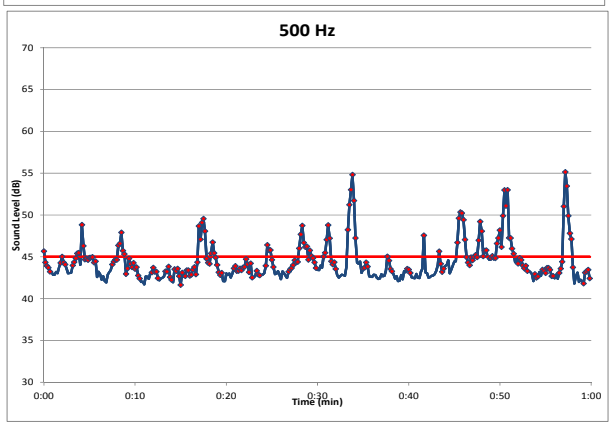

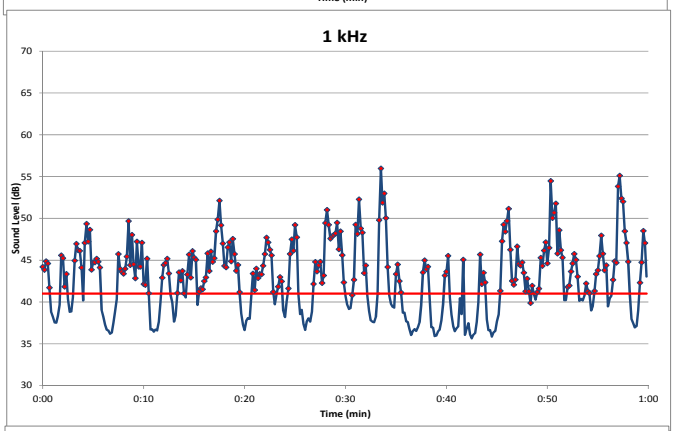

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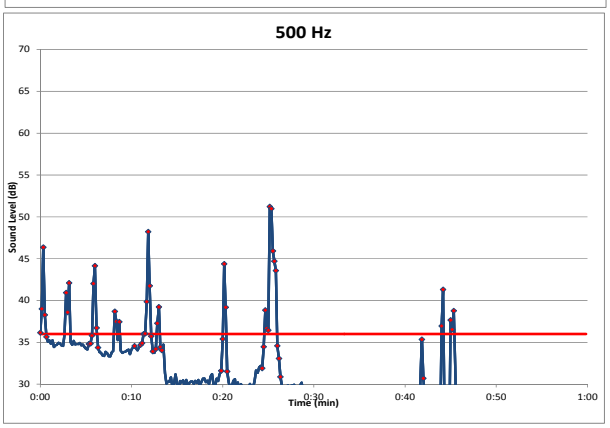

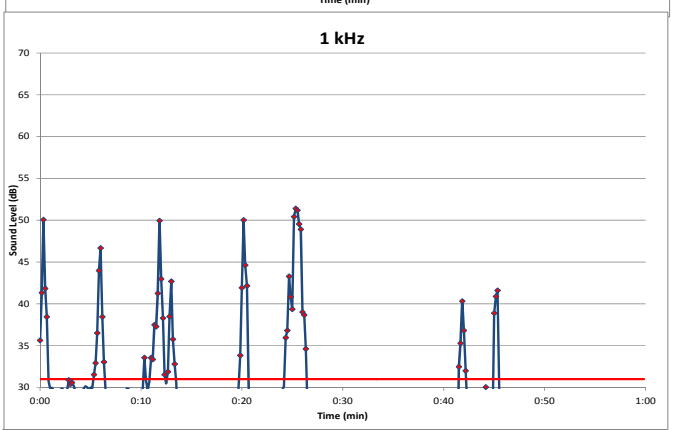

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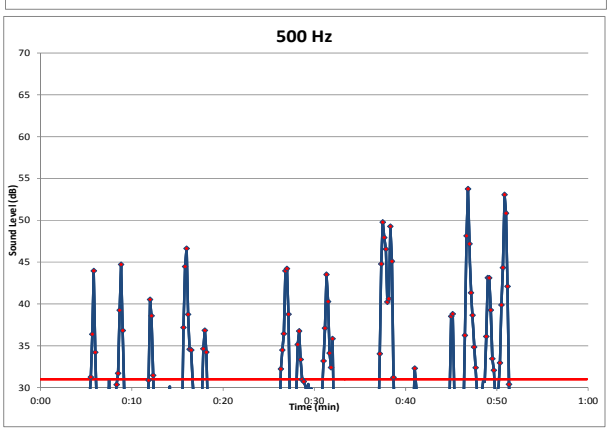

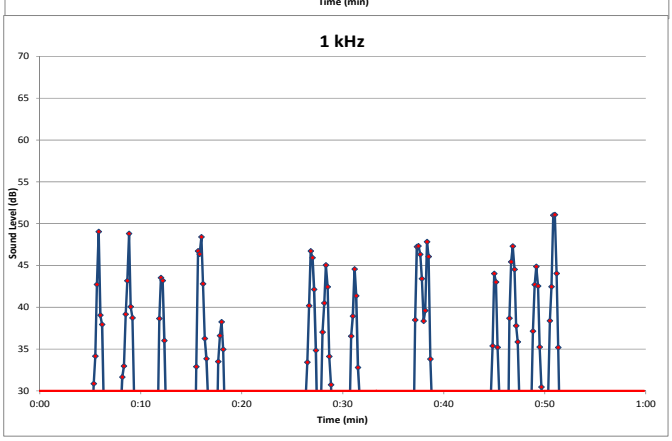

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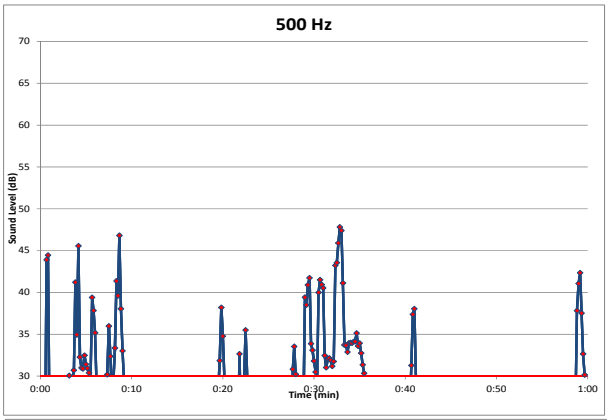

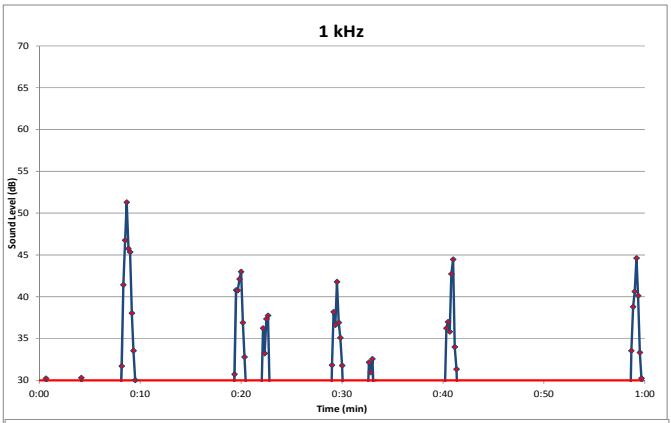

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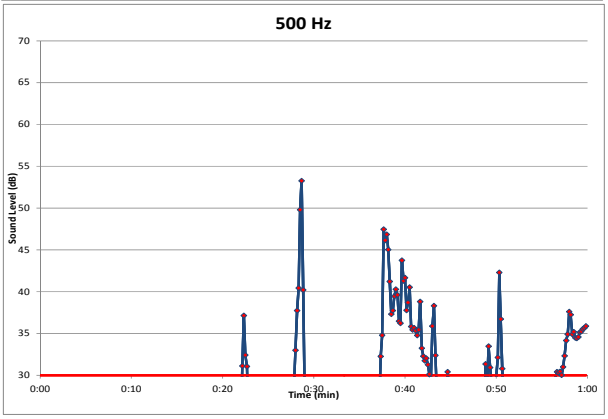

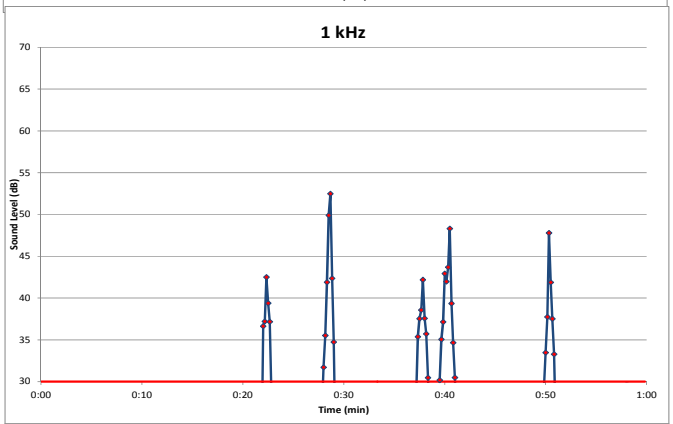

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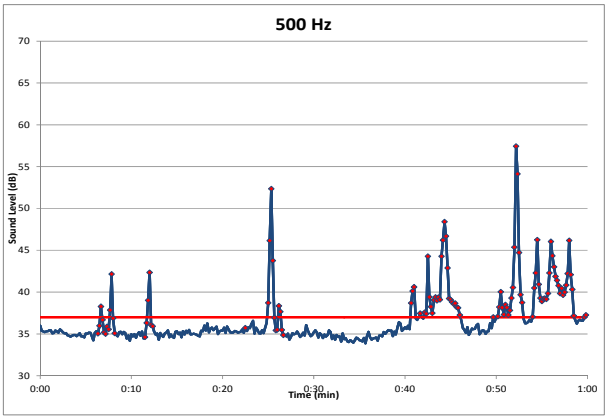

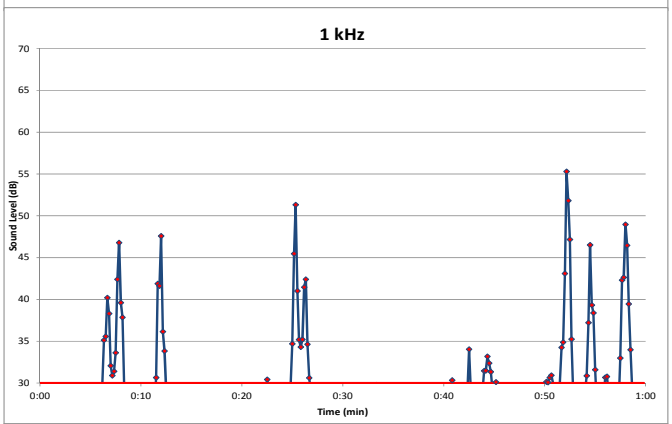

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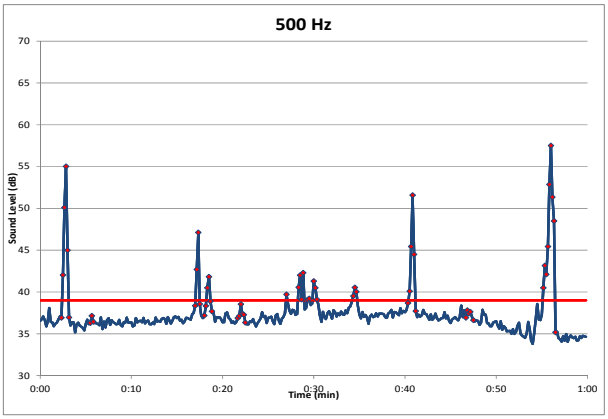

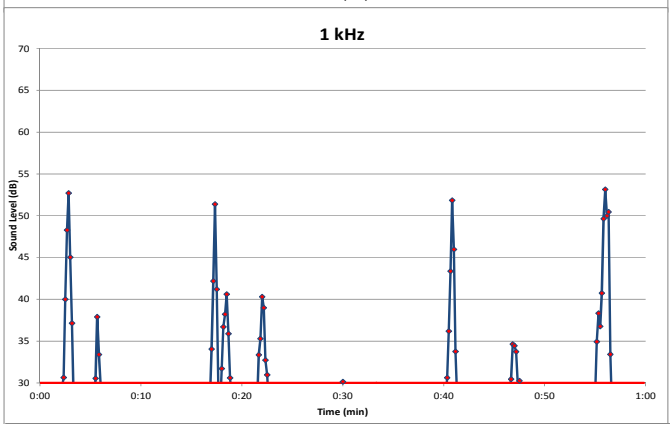

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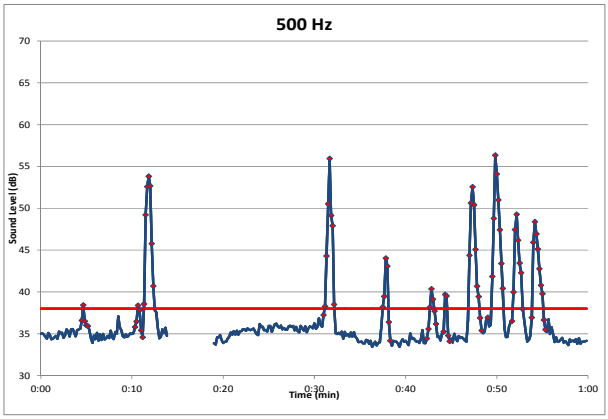

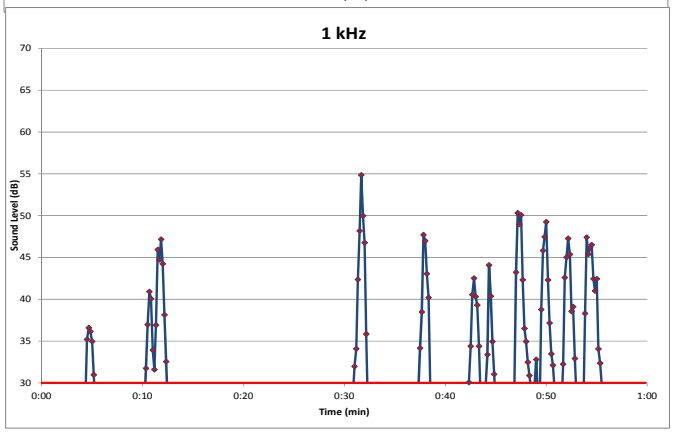

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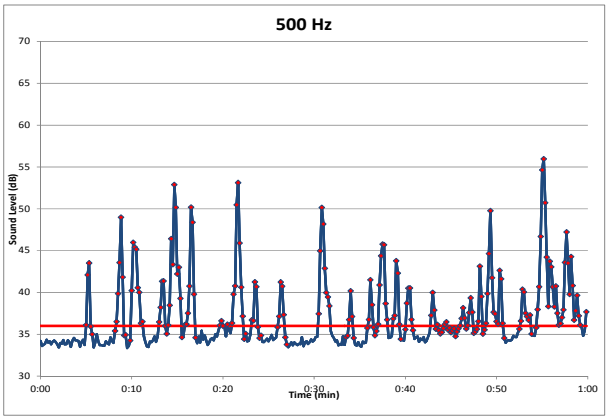

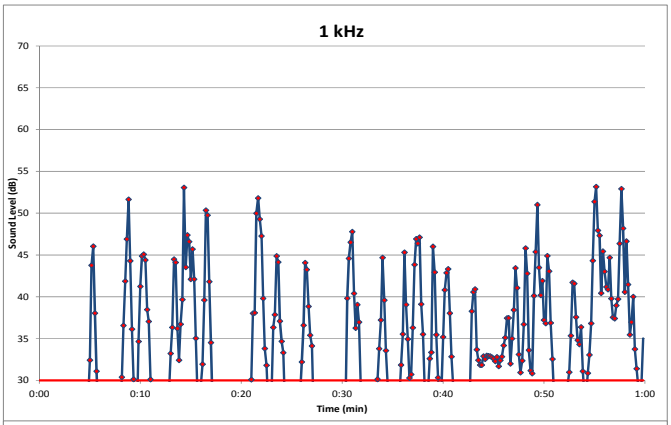

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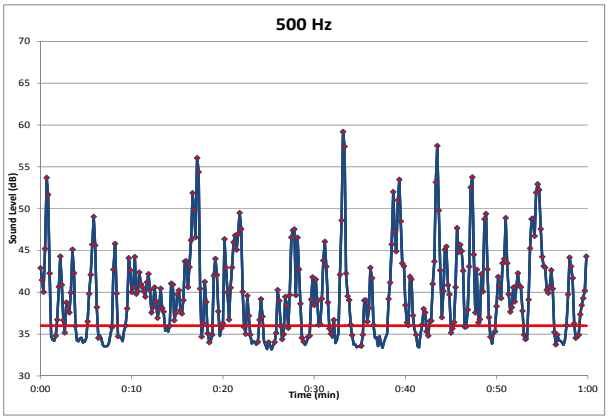

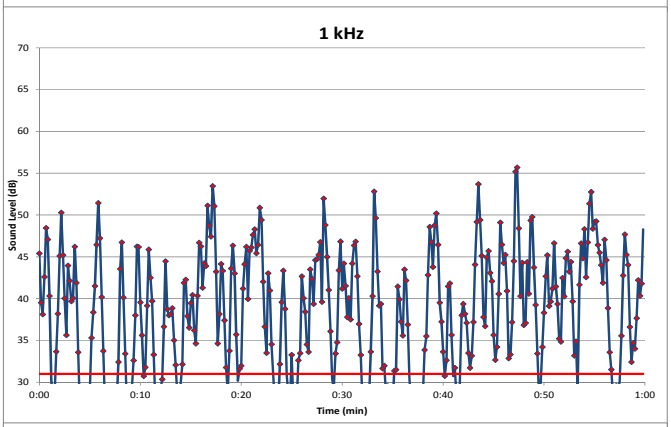

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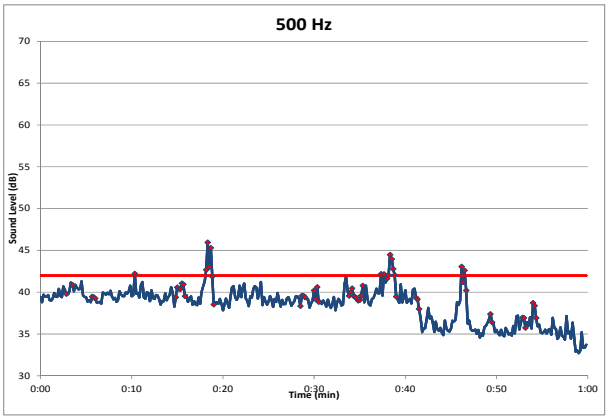

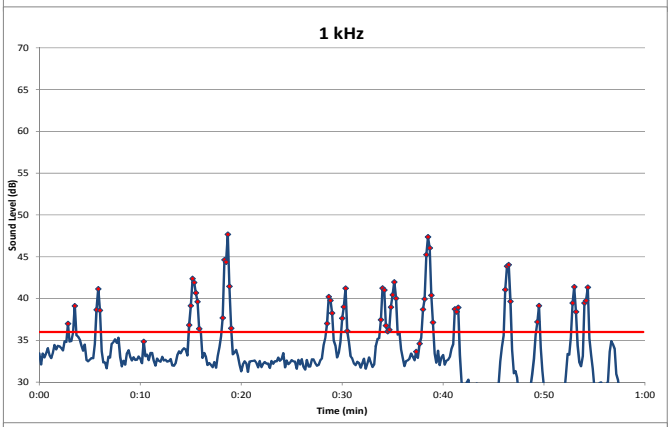

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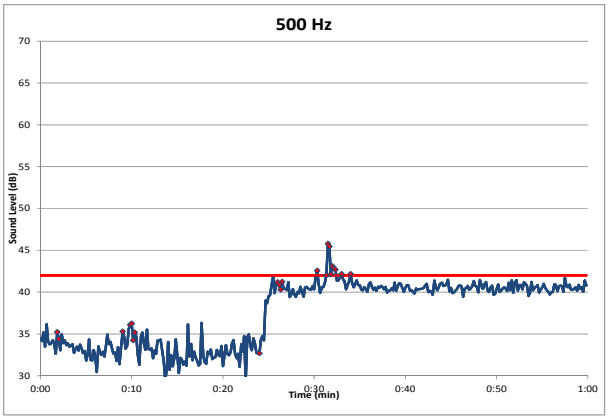

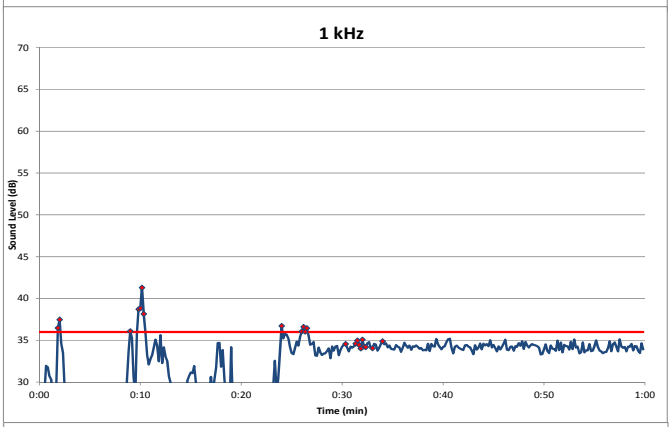

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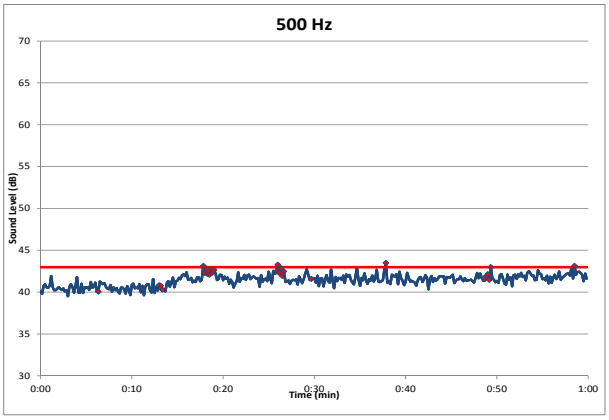

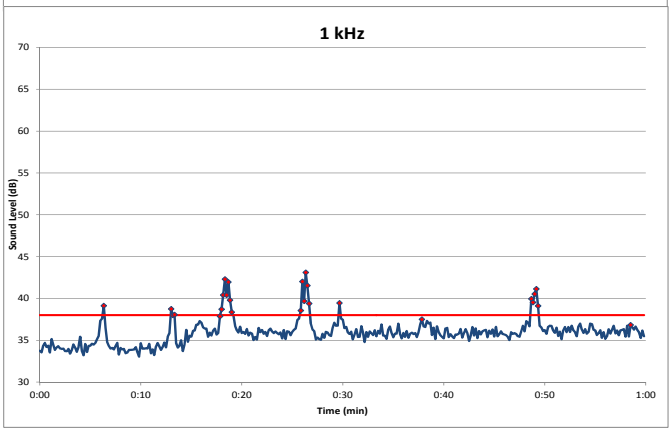

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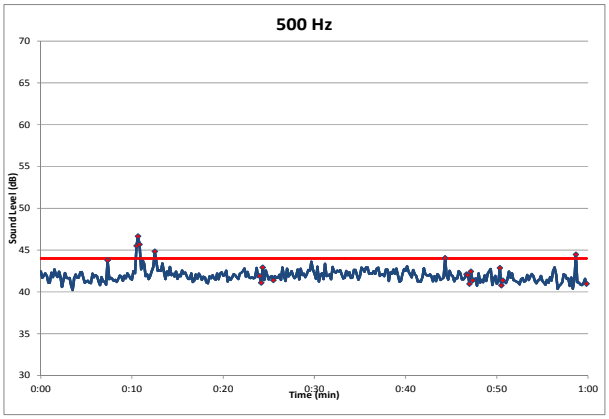

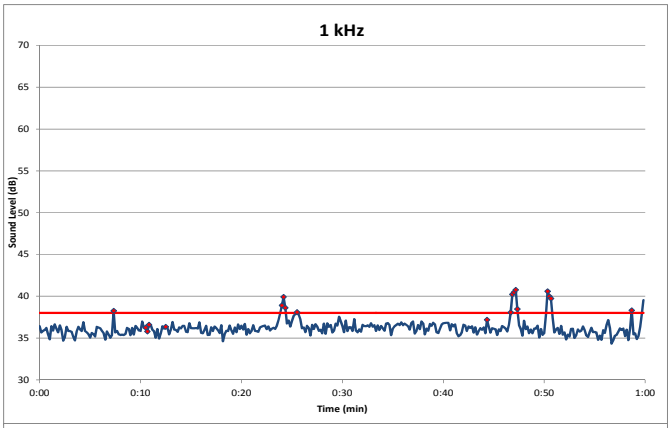

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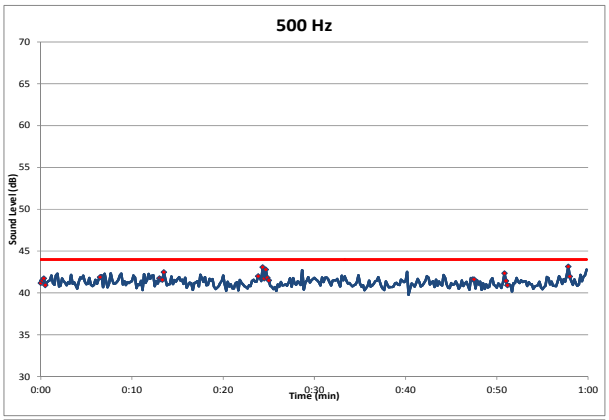

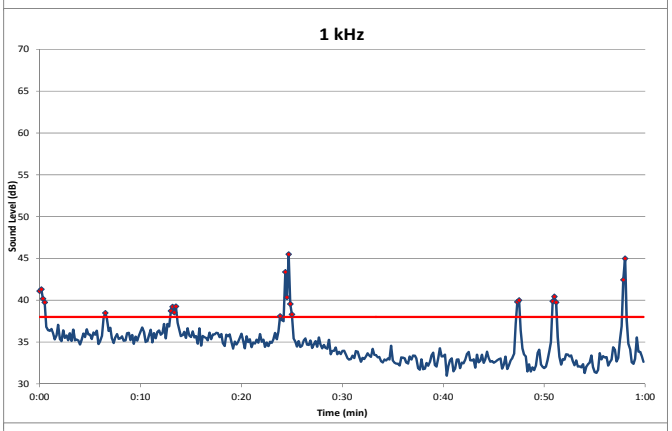

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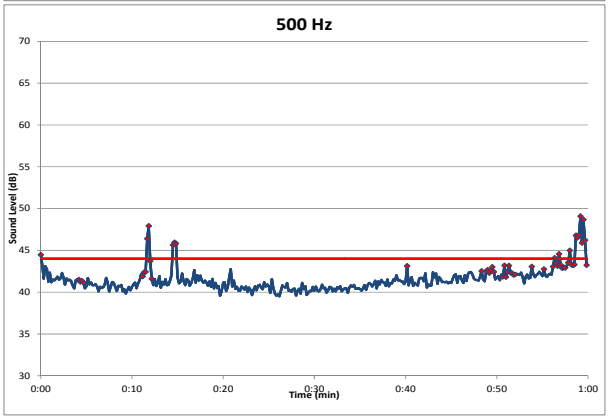

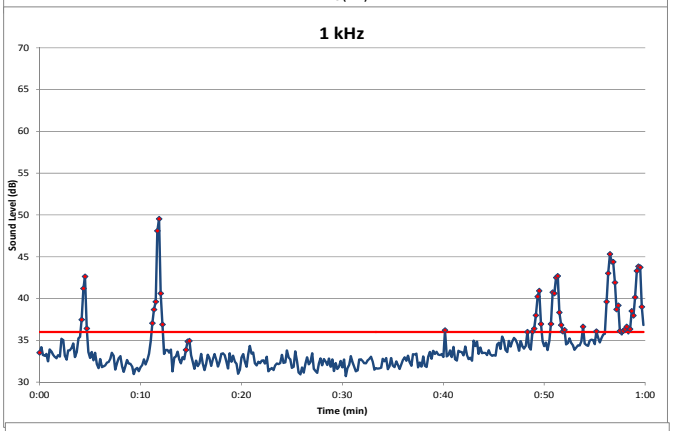

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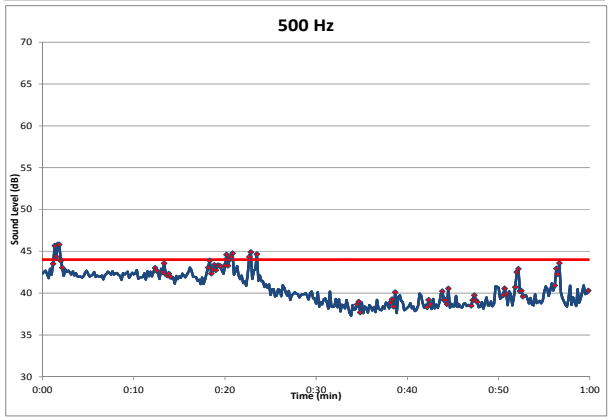

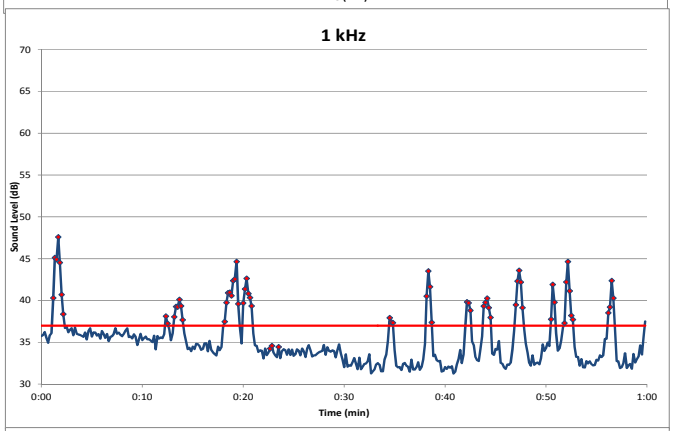

2013

NOV 20

4:00

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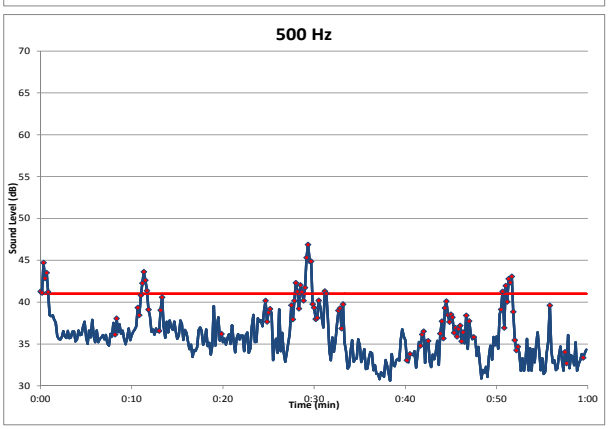

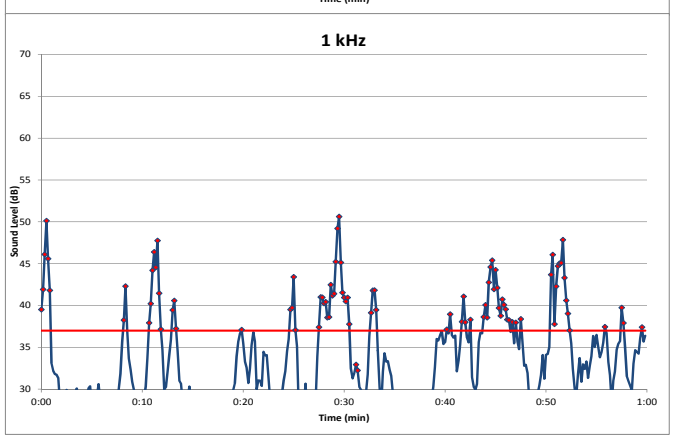

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NOV 20

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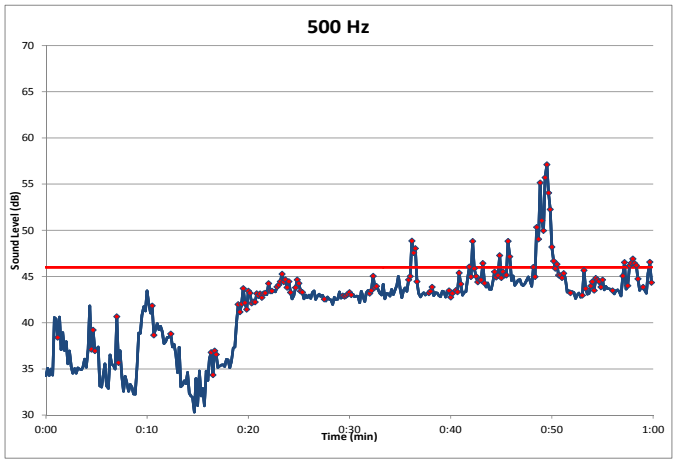

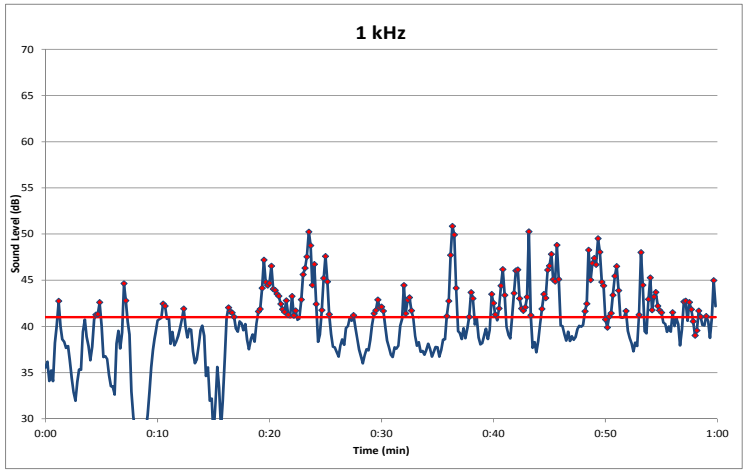

2013

NOV 20

6:00

PRIME 2