ANALYSIS OF EXISTING AND PROPOSED ACOUSTICAL IMPROVEMENTS

to the

ECHO POINT SHOOTING RANGE SITE

Allegan State Game Area, Michigan

for

Department of Natural Resources
Roscommon Customer Service Center
8717 North Roscommon Road
Roscommon, Michigan 48653

by

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November 1, 2021

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INTRODUCTION

This report contains the results of analysis of field measured and computer modeled acoustical data of the existing and proposed acoustical improvements to the Echo Point Shooting Range located in the Allegan State Game Area in Allegan, Michigan. The report includes a summary of baseline ambient sound level measurements made at the site at distances of up to 2 miles from the range in 2016; a summary of sound levels measured during live fire shooting exercises with 3 weapons; a 0.40 caliber handgun, a 12-gauge shotgun and a 0.223 rifle in 2016 and 2021; a 0.357 magnum handgun, 450 Bushmaster and a 0.308 7.62 mm rifle individually loaded added just for the 2021 live fire exercise; computer analysis of "typical day" firearms discharges at the range with the range in its original condition in 2016 and as it currently exists with the first phase of acoustical improvements made to the range.

Noise contours are mapped for the base range design and several design alternatives to show the effects of various noise mitigation options to further reduce sound levels propagating off-site from the range. The acoustical analysis of the range consisted of the use of a "typical day" scenario (1-second sound exposure levels) with 11 people shooting within a 1 second time period: with 4 shooters firing .223 caliber rifles on the 100-yard range; 2 shooters firing a .223 caliber rifle on the 25-yard pistol range; 2 shooters firing 12-gauge Remington shotguns on the 25-yard pistol range; and 3 shooters firing 0.40 caliber handguns on the 25-yard pistol range within a 1 second time period. Computer models using CadnaA software, which is a state-of-the-art, 3-dimensional sound propagation modeling system using methods described in the technical acoustical literature for outdoor sound propagation were analyzed in accordance with ISO 9613. The effects of distance, molecular absorption, barriers, ground surfaces, non-deciduous vegetation and topography on a typical day (50° F, 80% RH) were included in the analysis.

Sound levels from the gunshots were calculated at locations within two miles of the approximate center of the site of the range for the original condition of the range in 2016; for the current condition of the range with the first phase of noise mitigation strategies constructed in 2021; and for additional noise mitigation options designed to further reduce sound levels at near-by properties.

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EXECUTIVE SUMMARY

Acoustical analysis of improvements to the Echo Point Shooting Range at the Allegan State Game Area in Allegan, Michigan located just south of Monroe Road were conducted for 3 conditions. The first is the range in its original condition in 2016 with no noise mitigation systems in place. The second is for the range in its current condition with the first phase of the noise mitigation systems in place in 2021. The third is a series of alternate noise mitigation systems for the range that can be implemented to further reduce sounds from the range propagating off-site.

1. Existing ambient sound levels were measured at 2 locations near potential noise sensitive receivers located near the existing range site from September 26, to October 3, 2016. Existing ambient sound levels at the sites varied from 19 to 72 dBA with average Day-Night Sound Levels (LDN) of 45 to 60 dBA.

2. A live fire exercise was conducted at the existing range site on September 28, 2016. A Conservation Officer fired 3 shots in succession from a 0.40 caliber handgun; a 12 gauge shotgun; and a 0.223 rifle. Acoustical measurements were made at 10 feet (or approximately 3 meters) from the sound source as well as at 16 locations around the existing range site. There were 4 measurement locations, one in each cardinal direction (i.e., north, east, south, and west) at successive distances of ¼ mile, ½ mile, 1 mile and 2 miles from the firing location at the prospective site for the firing range.

3. This experiment was repeated on May 13, 2021, with the current noise mitigation systems in place at the range. Additionally, a 0.357 magnum handgun, a 450 Bushmaster and a 308 7.62 mm rifle individually loaded were added just for the 2021 live fire exercise. The 308 rifle was fired from both the rifle range and the pistol range. Four additional receiver locations were added in the 2021 live fire exercise to at locations of additional noise sensitive receivers.

4. The range in its original condition consisted of a concrete walkway with a few benches located along it. Shooters stood on the walkway and fired into the face of the hill downrange. There were no real side or rear berms, and no sheds present.

5. DNR implemented a number of noise mitigating measures including re-orientation of the direction of fire; the construction of 15 ft. tall side berms, a 15 ft. tall berm downrange of the 25-yard pistol range with a ricochet baffle overhead, a 35 ft. tall berm downrange the 100-yard range with a ricochet baffle overhead and shooting shed enclosures consisting of a sound absorbing canopy and sound absorbing side walls extending approximately 20 ft. in front of the firing lines. These items were all in place during the 2021 measurements.

6. The sound levels measured at 10 feet from the source were generally lower in 2021 than in 2016. This is due to the presence of the shooting sheds. The location of the shooter inside the shed opening reduced sounds propagating in front and to the sides of the shed by approximately 0-7 dB. Measured sound levels were less than this due to the increased distance necessary to place the microphone in 2021 compared to 2016 due to the presence of the sheds. For example, the difference in location of the microphone in 2016 compared to 2021 in the direction of fire resulted in a -10 to -11 dB reduction in sound level alone.

7. Sound reflections off the underside of the angled roof structure towards the rear of the sheds result in less of a reduction in sound level in that direction compared to other directions.

8. The tests with the additional firearms showed that when firearms with louder discharges are used, sounds propagating away from the range will be louder and when firearms with quieter discharges are used sounds propagating away from the range will be quieter.

9. Sound levels at measurement locations away from the range increased at 2 of the 16 locations in 2021 compared to 2016 and decreased at 11 locations. Additionally, there were measurable sounds from the gun shots at 3 locations in 2021 where there were not measurable sounds from gunshots recorded in 2016. The decrease in sound levels is attributed to the construction of the first phase of the noise mitigation plan for the range that included the 15 ft. tall berms on the sides of the range, the construction of the shooting sheds at the firing line of the range and the re-orientation of the range.

10. Consider constructing mitigation features across the rear of the range behind the sheds to further reduce sounds traveling to the north.

11. Variations in background sound levels between the measurement sessions caused by different numbers and types of vehicles on near-by roads, short bursts of breezes and varying insect activity among other items also likely affected the measurements.

12. Noise contours were plotted for a "typical day" with 11 shooters firing within a 1 second time period for the base range conditions.

13. Computer models of noise mitigation options for the range were constructed in CadnaA software including topography, roads, ground cover, coniferous vegetation, re-orientation of the direction of fire, 15 ft. tall side berms, a 15 ft. tall berm downrange of the 25-yard range with a ricochet baffle overhead, a 35 ft. tall berm downrange the 100 yard range with a ricochet baffle overhead, and shed enclosures consisting of a sound absorbing canopy and sound absorbing side walls extending approximately 20 ft. in front of the firing lines for a standard day with 50ºF and 80% relative humidity with wind conditions modeled as downwind with 1 to 11 mph wind.

14. The computer models also showed that 2 locations had an increase in sound levels from 2016 to 2021 as the range is currently constructed.

15. The computer model studies showed that significant additional sound reductions can be achieved with the construction of a berm, wall or berm and wall combination that extends along the length of the existing berms at the sides of the ranges and also continues behind the range between the range and the road. The entry to the range would be to the east of the site with the berms configured to form a baffled entrance.

16. Further development of the shed enclosures at the firing lines with a rear wall (behind the shooters) and sound absorbent treatment is also proposed as an option to further reduce sound levels at locations away from the range.

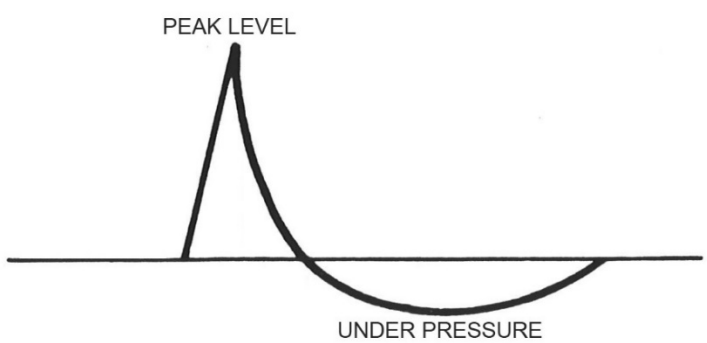
17. The combination of the shed walls and the berm/wall combinations with the baffled entry behind the ranges resulted in the greatest additional sound reductions at many locations.

18. The use of the noise mitigation options should be carefully considered because there are site specific limitations on how much sound level reduction can be obtained at this site for all of the mitigation schemes due to the proximity of residential properties close to the range site to the north, northeast, southeast and south; the large body of sound reflective water, Lake Allegan, to the north; and the face of the hill in the direction of fire that reflects sounds back to the north.

19. It is important to note that sound levels produced at residential receiving properties near the range may be audible above the existing ambient sound levels and may also exceed the sound level limits in the local noise ordinance even with the current and projected reductions in sound levels achieved for the mitigation options for the range.

SOUND LEVELS AND DECIBELS

Sound is defined as a pressure disturbance in the air caused by a vibrating body that is capable of being heard or detected by the human ear. In the case of gun shots, the muzzle blast of the weapon creates the pressure disturbance in the air as an impulsive type of sound. There is a high amplitude peak pressure from the shot followed by an under pressure that propagates away from the gun. The peak sound pressure level is measured at the highest point of the impulsive sound. The average sound pressure level or equivalent continuous sound level (LAeq) of a time-varying sound is defined as the level of an equivalent steady sound at a specific location for the same measurement duration that has the same A-weighted sound energy as the time-varying sound. The LAeq is usually 15 to 20 dB less than the peak sound pressure level for a gun shot. The maximum A-weighted sound level or LAmax is the greatest sound level measured on a sound level meter using fast response of the sound level meter during a designated time duration and an A-weighted filter. The Sound Exposure Level (SEL or LAE) over a stated time period or event is equal to 10 times the logarithm to the base 10 of the ratio of the time integral of the squared A-weighted sound pressure to the product of the reference sound pressure and the reference duration of 1 second.



Sounds are typically measured in decibels. A decibel is 10 times the logarithm to the base 10 of the pressure disturbance in the air compared to the pressure at the threshold of human hearing. Decibels cannot be added directly because they are logarithmic ratios. For example, 2 sounds of 50 decibels each added together result in a sound of 53 dB, not 100 dB. A summary of the way that sounds of different levels are added together is shown in Table 1.

Table 1. Examples of the addition of different sound levels (dBA).

Sound level 1	Sound level 2	Combined sound level	Explanation
50 dBA	50 dBA	53 dBA	When two sounds of equal level are combined, the result is a 3 dB increase in sound level
50 dBA	52 dBA	54 dBA	When one sound is combined with another sound that is 2-3 dB louder than first sound, the combined sound level is 2 dB louder than the louder sound
50 dBA	55 dBA	56 dBA	When one sound is combined with another sound that is 4-7 dB louder than the first sound, the combined sound level is 1 dB louder than the louder sound
50 dBA	60 dBA	60 dBA	When one sound is 10 dB louder than another, the combined sound level is approximately equal to the louder sound level

Differences in sound levels are not perceived by people linearly either. One sound must be 10 dB louder than another sound for it to be heard as approximately twice as loud as the first sound. A sound that is 0 to 1 dB louder than another sound is heard as approximately the same loudness as the first sound. A sound that is 2 to 3 dB louder than another sound is heard as barely louder than the first sound. A sound that is 5 to 6 dB louder than another sound is heard as noticeably louder, but not twice as loud as the first sound. A summary of the perception of the relative loudness of two sounds is shown in Table 2. An acoustic thermometer showing the sound levels associated with different sounds is shown in Figure 2. The sound levels are measured in A-weighted decibels or dBA. An A-weighted decibel is one that has been adjusted so it corresponds to the relative loudness of middle level sounds as they are heard by human listeners. The low frequency or bass sounds are reduced by the A-weighting process and the higher pitch sounds that human ears are more sensitive to are increased slightly by the A-weighting process.

Table 2. Perception of the relative loudness of 2 sounds.

Difference in sound level between two sounds	The louder sound is perceived as ____ the quieter sound
0 to 1 dB	Not noticeably louder than
2-3 dB	Barely noticeably louder than
5-6 dB	Noticeably louder than, but not twice as loud as
10-12 dB	Approximately twice as loud as
15 dB	Approximately three times as loud as
20 dB	Approximately four times as loud as

In general terms, sound levels of 30 to 40 dBA are usually perceived by people as being relatively quiet. Normal conversation measured at approximately 3 feet from the person speaking is 60 to 65 dBA. Cars passing on a street or a residential air-conditioning unit are approximately 65 to 75 dBA. Loud night clubs and amplified music at concerts are often played at levels of 100 to 110 dBA. Peak sound levels from gunshots measured at 10 feet from the source in the direction of fire will be 150 to 165 dBA depending upon the weapon type and ammunition used.

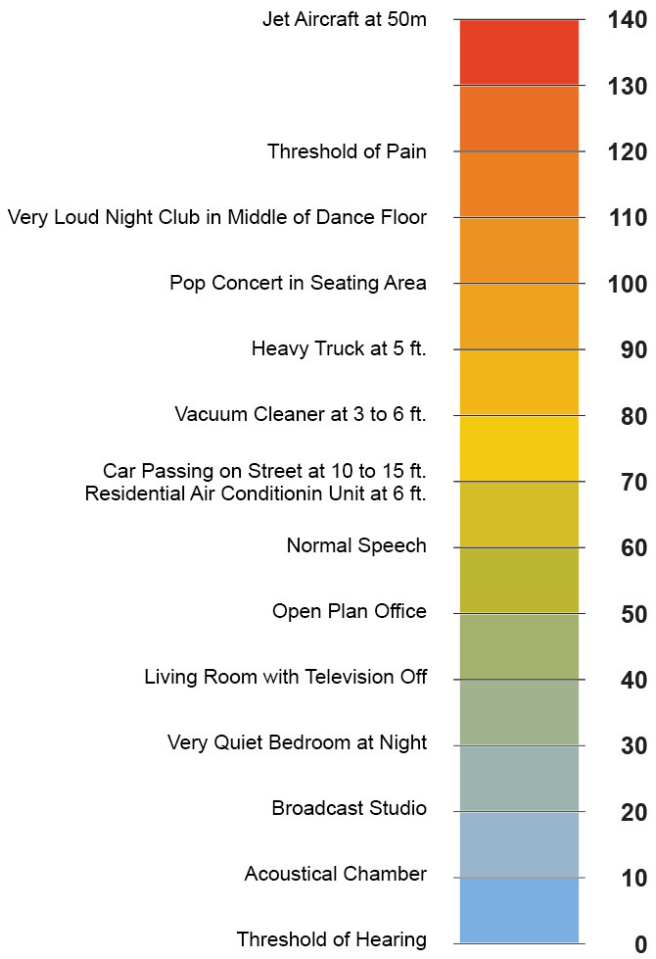


Figure 2. Acoustical thermometer showing the relative loudness in dBA of various sounds.

ACOUSTICAL MEASUREMENTS

Two types of acoustical measurements were taken. Short term measurements of the sounds produced by firearms at the location of the shooter and at distances away from the shooter were conducted at the range for the original condition of the range in 2016 and for the current condition of the range in 2021 after the first phase of noise mitigation systems were implemented. Long term measurements of base line ambient sounds were also made at 2 locations near the site for approximately 1 week in 2016 only.

Short Term Measurements

Short term acoustical measurements of overall-A-weighted, C-weighted and Z-weighted peak, average and maximum sound levels, as well as flat-weighted octave band and 1/3 octave band sound levels produced by firearms discharges were recorded at the existing firing range site. Measurements were also made at 16 receiver locations located at distances of ¼ mile, ½ mile, 1 mile and 2 miles from the range. Four additional measurement locations were added for the measurements taken in 2021 of the current condition of the range. These locations are shown in Figure 3. A table summary and graphs of sound levels measured at each of the receiving locations is included in Appendix C. GPS coordinates of the measurement locations are shown in Appendix G.

The measurements were recorded at the location of the shooter and at 16 locations at increasing distances and varying directions from the site in 2016 and at 20 locations away from the range in 2021. A table summary and graphs of sound levels measured at 10 feet from the shooter is contained in Appendix B. Table summaries and graphs of sound levels measured at distances away from the range are contained in Appendix C. Four Larson Davis Model 831's and a Cesva SC 310 Sound Level Meter were used as the basic instrumentation for the acoustical measurements. The meters meet ANSI Standard S1.4 requirements for Type 1 sound level meters.

The 4 Larson Davis 831 meters were set to measure LAeq, LAmax and flat-weighted octave band sound level data averaged every 1 second during the measurements in addition to LA peak and other metrics. The Cesva SC 310 recorded data every 1 second and every 125 milliseconds. The Larson Davis meters were equipped with standard ½" diameter measurement microphones. The Cesva was equipped with a Gras HD 40 1/4" microphone and associated preamplifier so it could measure high sound pressure levels (up to 190 dB) because it was located close to the guns that were fired during the experiments.

The Larson Davis meters were calibrated with a Larson Davis CAL 200 calibrator prior to testing and tested to within 0.1 dB of calibration after the measurements were complete. The Cesva SC 310 was calibrated with a Norsonic 1251 calibrator prior to testing and tested to within 0.1 dB of calibration after the measurements were complete. The meters were mounted on tripods at approximately 5 ft. above the ground at each measurement location. A windscreen was attached to the microphones for all measurements. The data were stored on the hard drives of the meters and downloaded to computers in our office and analyzed.

Weather readings including dry bulb temperature (°F), relative humidity (%R.H.), barometric pressure (inches of mercury (Hg) and wind speed (m.p.h.) and direction were made with a Kestrel 4000 Pocket Wind Meter from Nielsen Kellerman at each measurement location. These readings are included in Appendix D of this report.

Three rounds in succession were fired from a Sig Sauer P229 0.40 caliber handgun with Federal hollow point; a Remington 870 12-gauge shotgun using Federal 2-3/4" 1 oz. rifled flue; and a Colt M4 223 semi-auto rifle using 0.223 55 grain full metal jacket ammunition at the range while sound levels were recorded with the Cesva meter near the source and with the 4 Larson Davis 831 meters at the receiver locations located at distances away from the range. The sequence of firing was repeated at each of the receiver locations in 2016 and 2021. A Smith and Wesson 0.357 magnum handgun, 450 Bushmaster with Hornady 250-gram loads and a Ruger 308 7.62 mm rifle with American Eagle 150-gram full metal jacket individually loaded were added just for the 2021 live fire exercise. The 308 rifle was fired both from the rifle range and the pistol range.

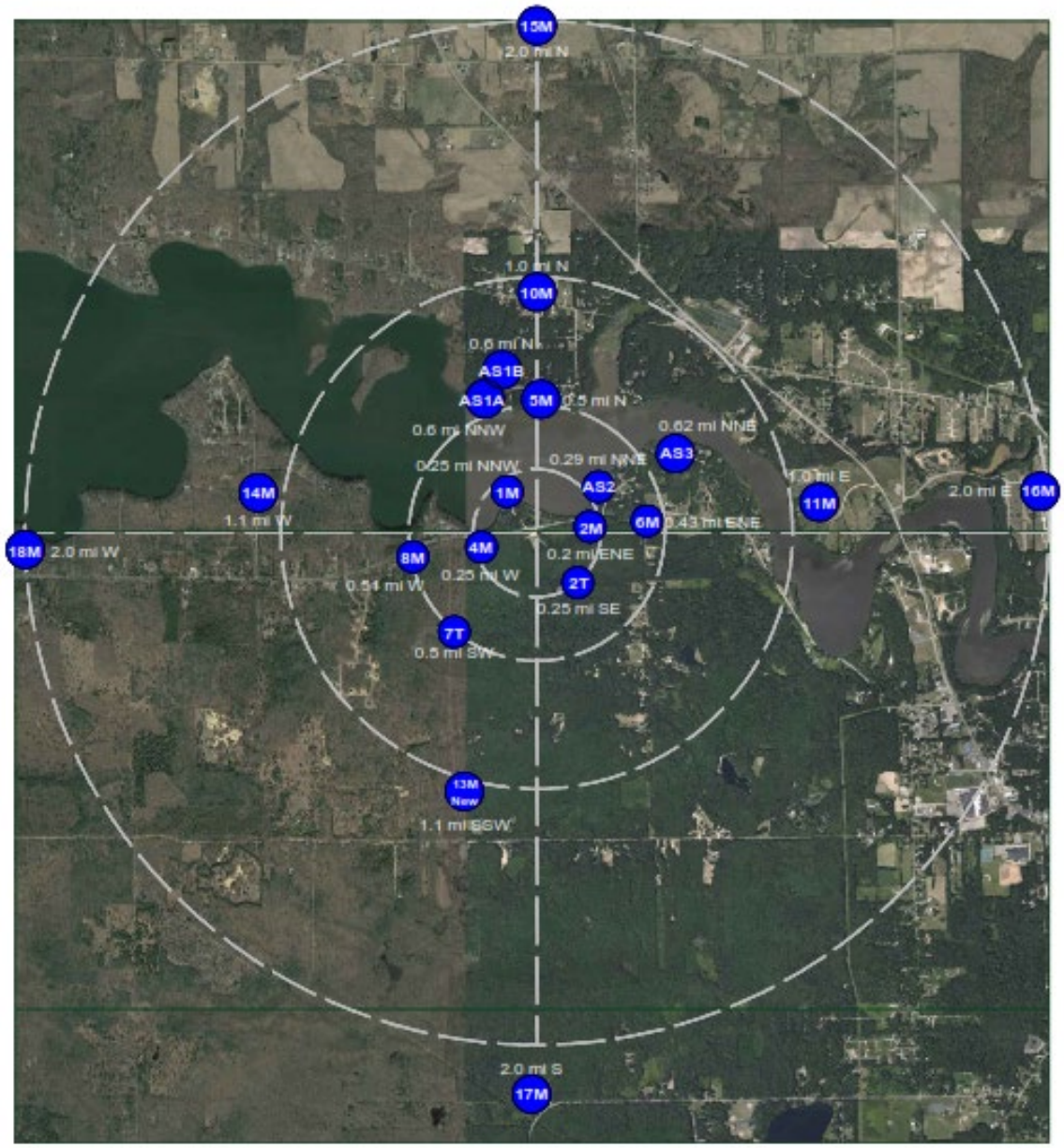


Figure 3. Aerial photograph showing the short- term measurement locations used during the live fire exercises in 2016 and 2021.

Long Term Measurements of Base Line Ambient Sound Levels

Long term measurements of existing ambient sound levels were made for a 1-week time period at 2 locations near the range site with 1 Rion NL-32 and 1 Rion NL-52 integrating sound level meter in 2016 only. The Rion equipment meets ANSI S1.4 requirements for type 1 sound level meters. The meters were set to the fast, A-weighted mode to acquire data. The Rion NL-32 and NL-52 meters were calibrated with a Larson Davis Cal 200 calibrator prior to and after testing. The calibration levels were within ±0.1 dB from the beginning of the measurement period to the end.

The microphones were covered with a wind screen and positioned atop an extension rod approximately 5 ft 6 inches (the height of a standing person) above ground level attached to secure, weather resistant environmental cases. The environmental cases were strapped to a tree at each measurement location. The meters logged acoustical measurement data for 6 and7 days respectively recording sound levels every 1/8 second. The 1/8 second levels were averaged over a 1 minute time period to yield a 1 minute A-weighted Continuous Equivalent Sound Level (LAeq). Graphs illustrating the 1-minute continuous equivalent sound level (LAeq) plotted vs. time for each 6 and 7 day time period are shown in Appendix A. A tabular summary of the data is provided in Appendix A along with an aerial photograph of the area in the vicinity of the range showing the measurement locations, the range of average sound levels (LAeq's) and the LDN during the measurement period. Data were downloaded from the meters to a laptop computer after the measurement time for subsequent analysis.

The Day-Night Average Sound Level (LDN) was calculated from the LAeq data for each day during the measurement period. The LDN is the average of the measurements taken during day time hours from 7:00 a.m. until 10:00 p.m. and the measurements taken during night time hours from 10:00 p.m. until 7:00 a.m. with a 10 dB "penalty" added to sound levels recorded during the night time hours to reflect a greater sensitivity to sounds made during this time period as potentially interfering with people sleeping.

The sound level meters also recorded A-weighted maximum and minimum sound levels, as well as other statistical acoustical data (L05, L10, L50, L90 L95 and SEL). These data are available for review if desired. The L05 is the sound level exceeded for 5% of the measurement time. The L10 is the sound level exceeded for 10% of the measurement time. The L50, L90 and L95 are defined similarly for 50%, 90% and 95% of the measurement time respectively. The SEL is the sound exposure level.

MEASUREMENT RESULTS

Existing Ambient Sound Levels

Existing ambient sound levels were measured at 2 locations near the range site near potential noise sensitive receivers from September 26 to October 3, 2016. Figure A-1 in Appendix A shows an aerial photograph of the area around the existing range with the ambient sound level measurement locations indicated on the site plan. The sound level meters were left unattended during the measurement period. A summary of the measured data is presented in Table A-1 in Appendix A. The data are presented as a range of average sound levels or A-weighted Equivalent Average Sound Levels (LAeq's) and Day Night Average Sound Levels (LDN's). LDN's are usually used as metrics to classify lands for planning purposes. The LAeq's for the ambient sound levels can be compared to the range of sounds produced by firearms discharge in the experiments conducted on site as well as in the computer model studies to determine if the sound levels produced by the firearms are louder than the existing ambient sound levels at locations of interest. Graphs of sound pressure level in dBA plotted vs. time for each day during the measurement period at the site are shown in Appendix A.

1. Existing ambient sound levels at the measurement locations near the Echo Point Shooting Range varied from 19 to 72 dBA with average Day-Night Sound Levels (LDN) of 45 to 60 dBA. Rion 4 was located on the north side of 118th Avenue in the middle of the block to the north of the range. The ambient sounds at the site consisted of light traffic on 115th Avenue; wind blowing through the trees; birds calling; and the sounds of insects. Rion 6 was located to the south of the range near the intersection of 115th Avenue and 39th Street. Ambient sounds at this location included traffic on 115th Avenue; wind blowing through the trees; birds calling; and the sounds of insects.

MEASURED SOUND LEVELS OF FIREARMS

Experiments were conducted at the range in its original condition on September 28, 2016, and in the current condition with the first phase of noise mitigation strategies implemented at the range on May 13, 2021. A Conservation Officer fired 3 shots in succession from a 0.40 caliber handgun; a 12-gauge shotgun; and a 0.223 rifle. A 0.357 magnum handgun, 450 Bushmaster and a 308 7.62 mm rifle individually loaded were added just for the 2021 live fire exercise. The 308 rifle was fired from both the rifle range and the pistol range sheds. Acoustical measurements were made at 10 feet or approximately 3 meters from the sound source in 4 directions (direction of fire, right side of shooter, rear of shooter, left side of shooter) as well as at 16 locations around the proposed range site in 2016 and at 20 locations around the range in 2021. A table summary and graphs of sound levels of gun shots measured at 10 feet from the person shooting during the experiments at the range in 2016 and 2021 is presented in tabular and graphic formats in Appendix B.

There were also 16 measurement locations, one in each cardinal direction (i.e., north, east, south, and west) at successive distances of ¼ mile, ½ mile, 1 mile and 2 miles from the firing location at the firing range made in 2016. Four additional measurement locations, for a total of 20, were added in 2021 to account for specific locations of concern. A summary of LAeq average and LA peak sound levels of gun shots measured at distances away from the existing range is presented in tabular and graphic formats in Appendix C for the Echo Point Shooting Range at Allegan State Game Area.

Figure 4. Photograph of the original Echo Point Shooting Range in 2016. There is just an open range with a concrete paved walkway at the firing line.

Figure 5. The rifle range at the Echo Point Shooting Range as it was in 2016.

Figure 6. Conservation Officer firing at the Echo Point Shooting Range as it existed in 2016. The measurement microphone was located 10 ft. to the side of the shooter in this photograph. There are no obstacles between the shooter and the microphone. The same situation occurred when the microphone was 10 ft. in front of the shooter and 10 ft. behind the shooter in 2016. The direct sound from the gun has a clear path to the microphone. This is compared to the sound path to the microphones for the measurements made in 2021 when the range shed affected the sounds traveling from the firearm to the microphone reducing sound levels.

Summary of Measurements Made at the Source Locations

1. The sound levels measured at 10 feet from the source were generally quieter when measured in 2021 compared to 2016 due to the construction of the initial phase of noise mitigating berms and structures at the range. This included construction of 15 ft. tall berms on the sides of the range; a reorientation of the direction of fire of the range and the construction of the shooting sheds that shooters now stand or sit in with their firearms usually held within the roof and wall envelope of the structure while they fire.

2. The shooting sheds in particular affect the sound levels measured near the shooters. When the original measurements were made in 2016, the firing line consisted of just a paved concrete path with a few concrete tables located along the path. For the measurements taken in 2021, DNR had constructed 2 shooting sheds. The rifle shed oriented towards the longer range has 4 bays. The pistol shed is facing a 15 ft. tall berm and targets down range. The sheds are made of wood with an angled roof. The interior walls and ceiling of some of the shooting bays are lined with a glass fiber sound absorbing material that is currently deteriorating some.

3. Sound levels measured in the direction of fire were -10 to -18 dB quieter in 2021 compared to the measurements of the same guns made in 2016. The reason for this is that in 2021 the measurement microphone was located 10 ft. from the southern edge of the shooting shed because it could not be placed inside the shed. This means that instead of the microphone being 10 ft. from the firearm, it was actually 34 ft. 2 inches from the rifle. The measured sound reduction is attributed to the increased distance between the microphone and the sound source which would be approximately -10 to -11 dB and the sound reduction due to absorption and reflection of sounds within the shed structure which would be the rest of the difference in measured sound level of approximately 0 to -7 dB.

4. Sounds to the right side of the shooter at 10 ft. measured in 2021 were -8 to -20 dB quieter than those measured in 2016. This is attributed to 2 reasons. First is that the microphone could not be located 10 ft. directly to the side of the shooter due to the side walls and tables built into the range shed structure. The microphone was off axis, a little farther to the rear of the shooter in 2021 compared to 2016. Second is that the firearm was held in front of the shooter with the side wall of the bay of the shooting shed acting as a noise barrier to reduce sound levels at the microphone located to the side of the shooter.

Figure 7. Photograph showing a shooter in the rifle bay with the firearm located under the roof structure of the shooting shed and between the side walls of the shed.

Figure 8. Photograph of the 15 ft. tall berms on the sides of the range and behind the targets of the pistol range and the 4 bay rifle shoting shed on the right and the 8 bay pistol shooting shed on the left.

Figure 9. Photograph of the side of the pistol shooting shed. The walls of the shed are constructed of plywood on wood framing. The roof is a metal roof on plywood. The interior wall and roof surfaces of some of the bays are lined with sound absorbent glass fiber batts. The roof overhangs the shooting position. The shooters can sit or stand at the tables and their firearms are under the roof structure and within the walls of the shed when they fire. The depth of the shed in the direction of fire is 24 ft. 2 inches.

Figure 10. Photograph of the rifle range showing the berms on the sides of the range and behind the targets as well as the ricochet baffle above the targets.

5. Sounds measured to the rear of the shooter in 2021 were -3 to -12 dB less than those measured in 2016. There is less reduction of sound propagating to the rear of the shooter compared to the other directions because some of the sounds of the firearms reflect off the angled roof of the shed and are propagated to the rear thereby increasing the sound levels in that direction compared to the front and sides of the shooters.

6. The additional weapons fired in 2021 indicate that when smaller caliber weapons are used, sound levels will decrease and when larger caliber weapons are used, sound levels will increase. For example, the 0.357 magnum handgun was quieter than the 0.40 caliber handgun in all directions. The 450 Bushmaster and 308 rifles were louder than the 0.223 rifles used.

7. This means that sound levels away from the range will increase and decrease depending upon the number of shooters, types of weapons and ammunition fired at the range. However, the insertion loss or sound reduction provided by the existing and proposed noise mitigation features of the range will have the same reduction regardless of the number, type or loudness of the weapon(s) fired.

8. The sound level of the 308-rifle fired from the pistol shed was measured at approximately the same sound levels at the locations near the shed as the 308 rifle fired from the rifle bay.

9. There were significant differences measured in different directions at locations away from the range due to the unique topography of this site and the large body of water behind the range.

Summary of Measurements Made at 1/4 mile, 1/2 mile, 1 mile and 2 miles from the Proposed Range Site

Sound levels increased at 2 of the 16 locations in 2021 compared to 2016 and decreased at 11 locations. Additionally, there were measurable sounds from the gun shots at 3 locations in 2021 where there were not measurable sounds from gunshots recorded in 2016. The decrease in sound levels is attributed to the construction of the first phase of the noise mitigation plan for the range that included the 15 ft. tall berms on the sides of the range, the construction of the shooting sheds at the firing line of the range and the re-orientation of the range. It is necessary to construct mitigation features across the rear of the range behind the sheds to further reduce sounds traveling to the north. Variations in background sound levels between the measurement sessions caused by different numbers and types of vehicles on near-by roads, short bursts of breezes and varying insect activity among other items also likely affected the measurements.

1. Location 1M was approximately 0.2 miles to the north of the range at the boat lunch on Lake Allegan. One second average (LA eq) sound levels were measured at +1 to +3 dB louder for the 0.40 caliber pistol; -1 dB quieter for the shotgun; and +2 to +5 dB louder for the 0.223 rifle in 2021 than in 2016.

2. Location 2M was approximately 0.25 miles to the east of the range on a grass path on the south side of Monroe Road about 200 feet south of the road. One second average (LA eq) sound levels were measured at -7 dB quieter for the 0.40 caliber pistol; -11 dB quieter for the shotgun; and -4 to -9 dB quieter for the 0.223 rifle in 2021 than in 2016.

3. Location 2T was approximately 0.25 miles to the southeast of the range on the snowmobile trail. One second average (LA eq) sound levels were measured at -14 to -15 dB quieter for the 0.40 caliber pistol; -13 to -15 dB quieter for the shotgun; and -11 to -15 dB quieter for the 0.223 rifle in 2021 than in 2016.

4. Location 4M was approximately 0.25 miles west of the range in the right-of way by the residence at 3743 Monroe Road. One second average (LA eq) sound levels were measured at -9 to -10 dB quieter for the 0.40 caliber pistol; -13 to -15 dB quieter for the shotgun; and -11 to -13 dB quieter for the 0.223 rifle in 2021 than in 2016.

5. Location 5M was approximately 0.56 miles to the north of the range on the south side of 3684 118th Avenue near the street. One second average (LA eq) sound levels were measured at -5 to -7 dB quieter for the 0.40 caliber pistol; -11 to -12 dB quieter for the shotgun; and -5 dB quieter for the 0.223 rifle in 2021 than in 2016.

6. Location 6M was approximately 0.5 miles to the east of the range in the right-of-way near 1738 36th Street. One second average (LA eq) sound levels of the 0.40 caliber pistols, shotguns and rifles could not be measured in 2016. The one second average (LA eq) sound levels of the shotguns

were not able to be measured in 2021. The one second average (LA eq) sound levels of the pistols were measured at 49 to 57 dBA in 2021. The one second average (LA eq) sound levels of the rifles were measured at 60 to 65 dBA in 2021. Therefore, it is assumed that sound levels of the gun shots increased at this location in 2021.

7. Location 7T was approximately 0.5 miles to the southwest of the range on the snowmobile trail. One second average (LA eq) sound levels were measured at -19 to -26 dB quieter for the 0.40 caliber pistol; -18 to -26 dB quieter for the shotgun; and -28 to -33 dB quieter for the 0.223 rifle in 2021 than in 2016.

8. Location 8M was approximately 0.5 miles to the west of the range on the right-of-way to the east of the residence at 3804 Monroe Road. One second average (LA eq) sound levels of the guns were not measurable at this location in 2021. Therefore, specific sound reductions cannot be calculated for this location.

9. Location 10M was approximately 1.0 mile to the north of the range on the right-of-way on the north side Allegan Dam Road at 3680. One second average (LA eq) sound levels of the guns were not measurable at this location in 2016. One second average LAeq sound levels of the 0.40 caliber pistol were measured at 48 to 50 dBA; 45 to 51 dBA for the shotguns; and 47 to 50 dBA for the rifles. Therefore, it is assumed that sound levels of the gun shots increased at this location in 2021.

10. Location 11M was approximately 1.0 mile to the east of the range near 3474 Snow Farm Lane. One second average (LA eq) sound levels of the 0.40 caliber pistols and shotguns were not able to be measured in 2016 and 2021. The one second average (LA eq) sound levels were measured at +1 to +3 dB louder for the 0.223 rifle in 2021 than in 2016.

11. Location 13 New was approximately 1.0 mile to the south of the range on the snowmobile trail. One second average (LA eq) sound levels were measured at -15 to -19 dB quieter for the 0.40 caliber pistol; -22 to -24 dB quieter for the shotgun; and -23 to -24 dB quieter for the 0.223 rifle in 2021 than in 2016.

12. Location 14M was approximately 1.0 mile to the west of the range on the right-of-way across the street from 1736 39th Street. One second average (LA eq) sound levels of the guns were not measurable at this location in 2021. Therefore, specific sound reductions cannot be calculated for this location.

13. Location 15M was approximately 2.0 miles to the north of the range off 121st Avenue next to 3723 in a field about 0.17 miles off the road at the bottom of a small hill. One second average (LA eq) sound levels of the guns were not measurable at this location in 2016. One second average LAeq sound levels of the 0.40 caliber pistol were measured at 35 to 38 dBA; 35 to 39 dBA for the shotguns; and 41 to 48 dBA for the rifles. Therefore, it is assumed that sound levels of the gun shots increased at this location in 2021.

14. Location 16M was approximately 2.0 miles to the east of the range near 1726 Signal Point Circle. One second average (LA eq) sound levels of the guns were not measurable at this location in 2016 or 2021. Therefore, specific sound reductions cannot be calculated for this location.

15. Location 17M was approximately 2.0 miles to the south of the range on 113th Avenue where it intersects with 37th Street. The measurement location was about 100 feet down 113th Avenue from the curve where it intersects with 37th Street. One second average (LA eq) sound levels of the guns were not measurable at this location in 2021. Therefore, specific sound reductions cannot be calculated for this location.

16. Location 18M was approximately 2.0 miles to the west of the range on the right-of-way at 4091 Wildwood Drive. One second average (LA eq) sound levels of the guns were not measurable at this location in 2021. Therefore, specific sound reductions cannot be calculated for this location.

17. Location AS 1A was approximately 0.59 miles north of the range at the cul-de-sac at 1838 118th Avenue. One second average LAeq sound levels of the 0.40 caliber pistol were measured at 44 to 46 dBA; 42 to 43 dBA for the shotguns; and 53 to 54 dBA for the rifles.

18. Location AS 1B was approximately 0.65 miles north of the range at the in the parking lot of the residence at 118th Avenue on the north side of the street in front of the studio. One second average LAeq sound levels of the 0.40 caliber pistol were measured at 47 to 52 dBA; 43 to 45 dBA for the shotguns; and 50 to 53 dBA for the rifles.

19. Location AS 2 was approximately 0.29 miles northeast of the range in the back yard of the residence at 3629 Bay View Drive facing the lake and the range. One second average LAeq sound levels of the 0.40 caliber pistol were measured at 65 to 67 dBA; 67 to 69 dBA for the shotguns; and 71 to 73 dBA for the rifles.

20. Location AS 3 was approximately 0.61 miles northeast of the range near the residential property at the west end of 3585 Shoreline Drive. One second average LAeq sound levels of the 0.40 caliber pistol were measured at 49 to 50 dBA; 47 to 48 dBA for the shotguns; and 49 to 51 dBA for the rifles.

THE COMPUTER MODEL STUDIES

Introduction

A computer model study was conducted to study the propagation of sounds from the range in its original configuration in 2016; in its current configuration (2021) with the first phase of noise mitigation systems implemented at the range; and for additional noise mitigation options to further reduce the sounds propagated at distances away from the range. The data are compared to the sound levels measured and calculated for the original configuration of the range in 2016 and for the current configuration of the range (2021). The model was constructed in the CadnaA software package using topographic information from USGS maps. The original configuration of the range consisted of concrete paths with small tables at the firing lines for the 150-yard range, the 100-yard range, and the 50-yard range. The shooters faced the hill to the south and fired in that direction. The current configuration of the range consists of a 100-yard rifle range; a 25-yard pistol range from which rifles, and shotguns may also be fired. The firing range has 15 ft. tall side berms, a 15 ft. tall berm downrange of the 25-yard range with a ricochet baffle overhead, a 35 ft. tall berm downrange in the 100-yard range with a ricochet baffle overhead, and shed enclosures consisting of a sound absorbing roof and side

walls extending approximately 20 ft. in front of the firing lines. The berms on the sides of the ranges stop a short distance behind the firing lines.

Method

1. The analysis assumed a "typical day" with 11 shooters firing within a 1 second time period for the base range conditions with other people on the range getting ready to fire, loading their weapons or talking with each other.

2. The "typical day" had 4 shooters firing .223 caliber rifles on the 100-yard range; 2 shooters firing a .223 caliber rifle on the 25-yard pistol range; 2 shooters firing 12-gauge Remington shotguns on the 25-yard pistol range; and 3 shooters firing 0.40 caliber handguns on the 25-yard pistol range within a 1 second time period. Other people on the range were assumed to be either watching, loading weapons to get ready to fire or pausing between firing during the 1 second time period studied.

3. Octave band sound pressure level data for the firearms were obtained from a report entitled "*Field Measurement of Sound Pressure Levels of Various Firearms,"* published by the Architectural Acoustics Research Group at the University of Florida in 1993 for the National Rifle Association, which includes data for an M-16 rifle with .223 Remington 55 grain power-locked hollow point ammunition; a Remington 12 gauge shotgun; and a 0.40 caliber handgun. A summary of the octave band sound exposure level data for the firearms used in the models is included in Appendix E.

4. Three-dimensional computer models of the site were constructed using AutoCAD software by drawing topographical elevations of the site extending approximately 2 miles from the center of the firing range. The AutoCAD model was imported into CadnaA software which is a state-of-the-art noise propagation modeling software.

5. The computer sound propagation model was used to estimate the average or LAeq sound levels from the gunfire in all directions from the range with the following conditions considered.

    A. Number of shooters: 4 shooters firing .223 caliber rifles on the 100-yard range; 2 shooters firing a .223 caliber rifle on the 25-yard pistol range; 2 shooters firing 12-gauge Remington shotguns on the 25-yard pistol range; and 3 shooters firing 0.40 caliber handguns on the 25-yard pistol range within a 1 second time period. The computer model for the firing range does not include shooters on the150-yard or 50-yard firing, as its original configuration in 2016, since these no longer are present in the current range configuration.

    B. Direction of fire model per for the current range configuration is to the south-southwest. The direction of fire from the original configuration in 2016 was to the south.

    C. The base range, which is the current configuration of the range in 2021, Model A, has 15 ft. tall side berms, a 15 ft. tall berm downrange of the 25-yard pistol range with a ricochet baffle overhead, a 35 ft. tall berm downrange the 100-yard range with a ricochet baffle overhead, and shed enclosures consisting of a sound absorbing canopy and sound absorbing side walls extending approximately 20 ft. in front of the firing lines. The resulting noise contour plot for this model is shown in Figure 3 in Appendix F.

D. Molecular sound absorption for an average day scenario (50° F, 80%R.H.) was used in the base model study. The average day scenario used in the site noise study for the original range in 2016 was 50°F, 50% R.H. The average day scenario of 50° F, 80%R.H. used in the computer model studies for the current range resulted in the highest sound levels at distances away from the range when compared to the sound levels estimated for the original range in 2016 which used an average day scenario of 50° F, 80%R.H .

E. Anomalous excess attenuation (from small scale differences in wind, temperature, and humidity in the air).

F. The topographic features of the site were developed using contour maps obtained from the client and from the United States Geological Survey.

G. CadnaA assumes a downwind condition with wind velocity of 1 to 11 mph.

H. Ground cover was modeled as pavement for paved roads and grass for terrain covered with vegetation.

I. Deciduous trees were not included in the models because the loss of leaves during the Fall and Winter months significantly reduces the insertion loss of stands of deciduous trees.

Model A Current range facility in 2021 with initial phase of noise mitigation options included, as shown in Figure 11.

Model B The height of the side berms of the firing range was increased to 35 ft. tall above grade from the firing line to the end of the range by adding a 20 ft. tall noise barrier wall above the 15 ft. tall side berm. The side berm to the east side of the 100-yard firing line was extended approximately 100 ft. toward the northeast. A concept plan for this experiment is shown in Figure 12.

Model C Model B with the extended side berm, to the east of the 100-yard range, angled toward the northwest to contain the berm within the confines of the property line. A concept plan for this experiment is shown in Figure 13.

Models D + E Studies were conducted for the current firing range facility including a 10 ft. tall rear wall (Model D) and a 20 ft. tall rear wall (Model E) across the firing range facility. A concept plan for this experiment is shown in Figure 14.

Model F The entry to site was relocated to the northeast corner of the site; a 20 ft. tall rear wall with a baffled entry to the range was added behind range; the side berm to the north of the 25-yard pistol range was extended approximately 85 ft. toward the northeast; the side berm to the south of the 100-yard range was extended approximately 105 ft. past the firing line to the northwest; a 20 ft. tall wall above side berms was also included. A concept plan for this experiment is shown in Figure 15.

Model G Two 14 ft. tall noise barrier walls, combined with the features of Model A, were located behind the sheds, leaving a 10 ft. gap between the firing line and the noise barrier wall for access. The rear walls overlap each other to reduce noise propagating behind the firing line while allowing access to the firing lines. A concept plan for this experiment is shown in Figure 16.

Model H The 14 ft. tall noise barrier wall behind the firing shed, discussed in Model G, was combined with the baffled entry, the noise barrier walls on top of the berms and the extended side berms of Model F. A concept plan for this experiment is shown in Figure 17.

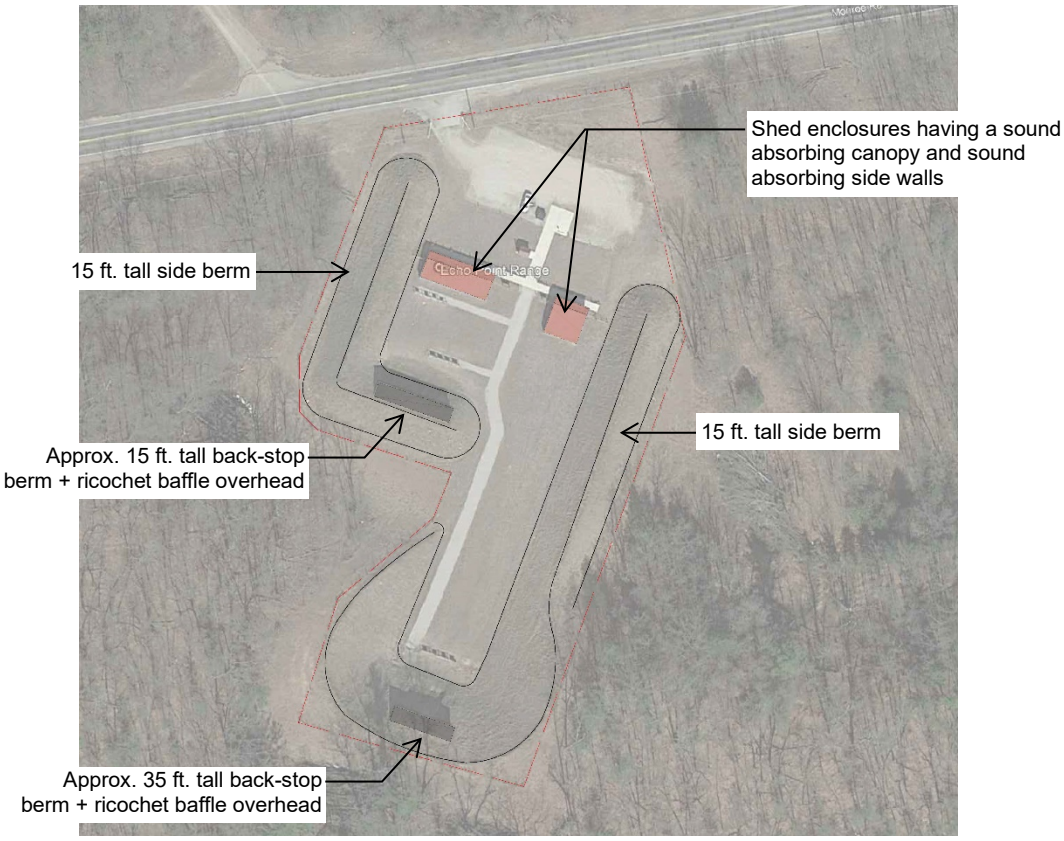


Figure 11. Concept plan diagram of the base range | Model A

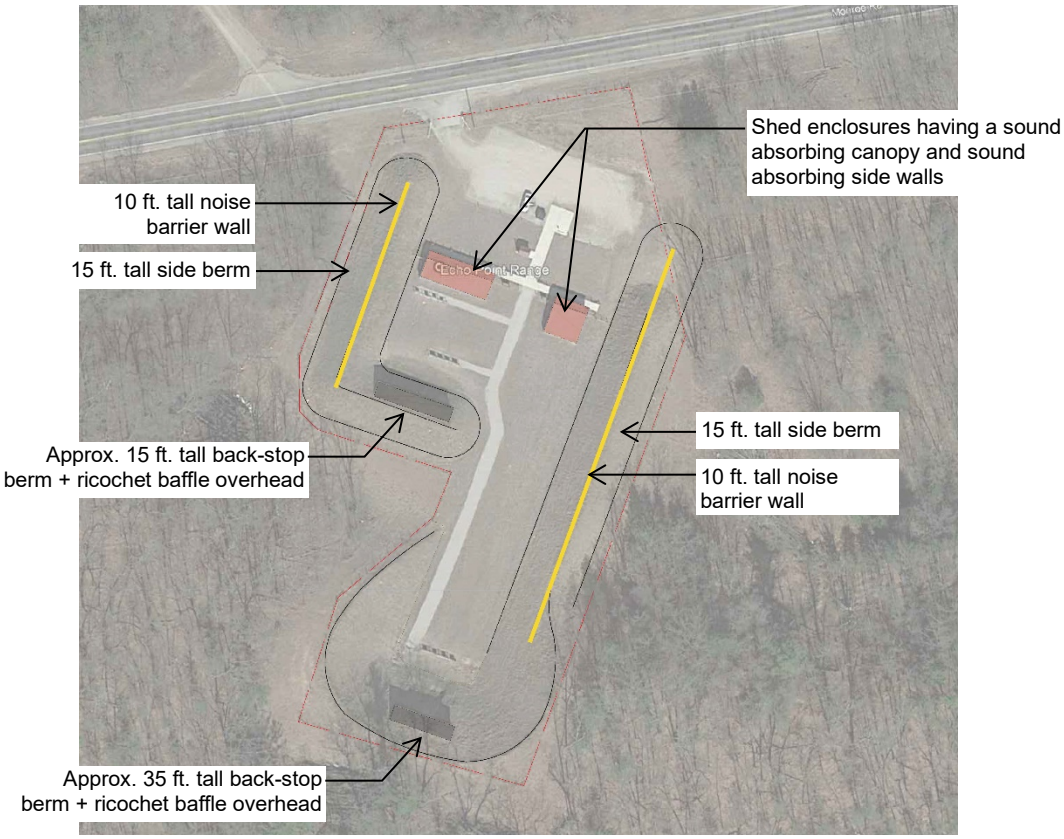


Figure 12. Concept plan diagram of the base range with noise barrier walls above the side berms | Model B

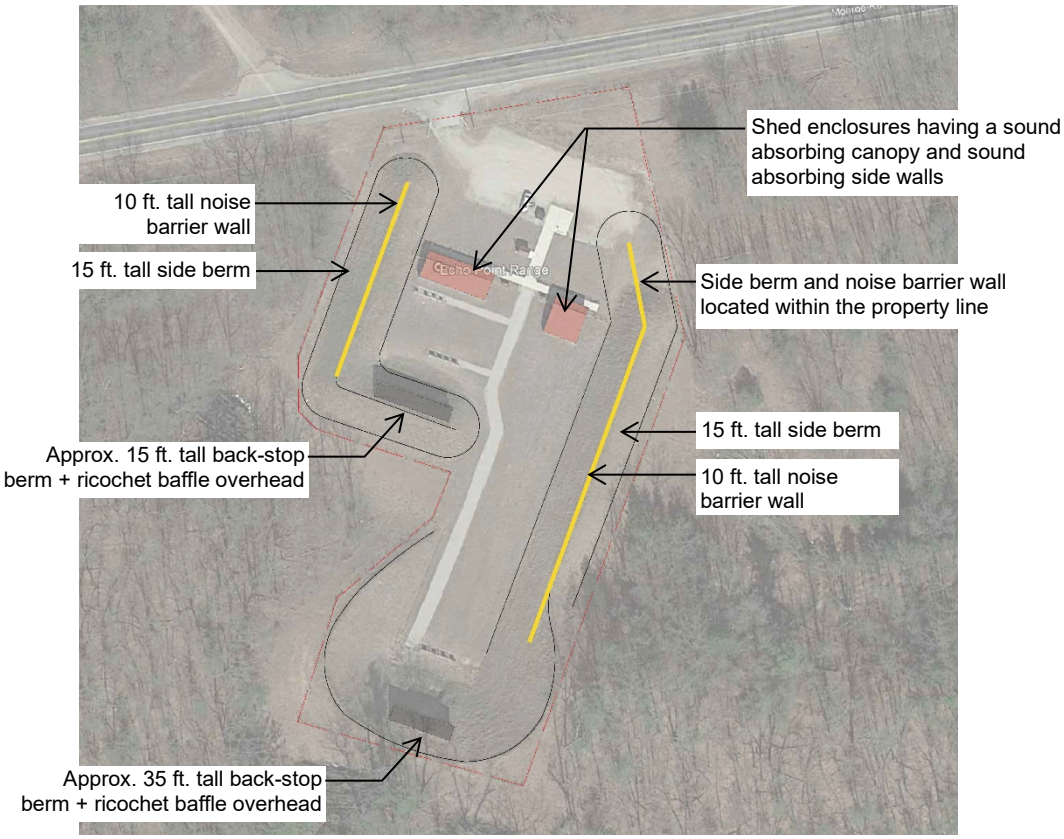


Figure 13. Concept plan diagram of the base range with noise barrier walls above the side berms | Model C

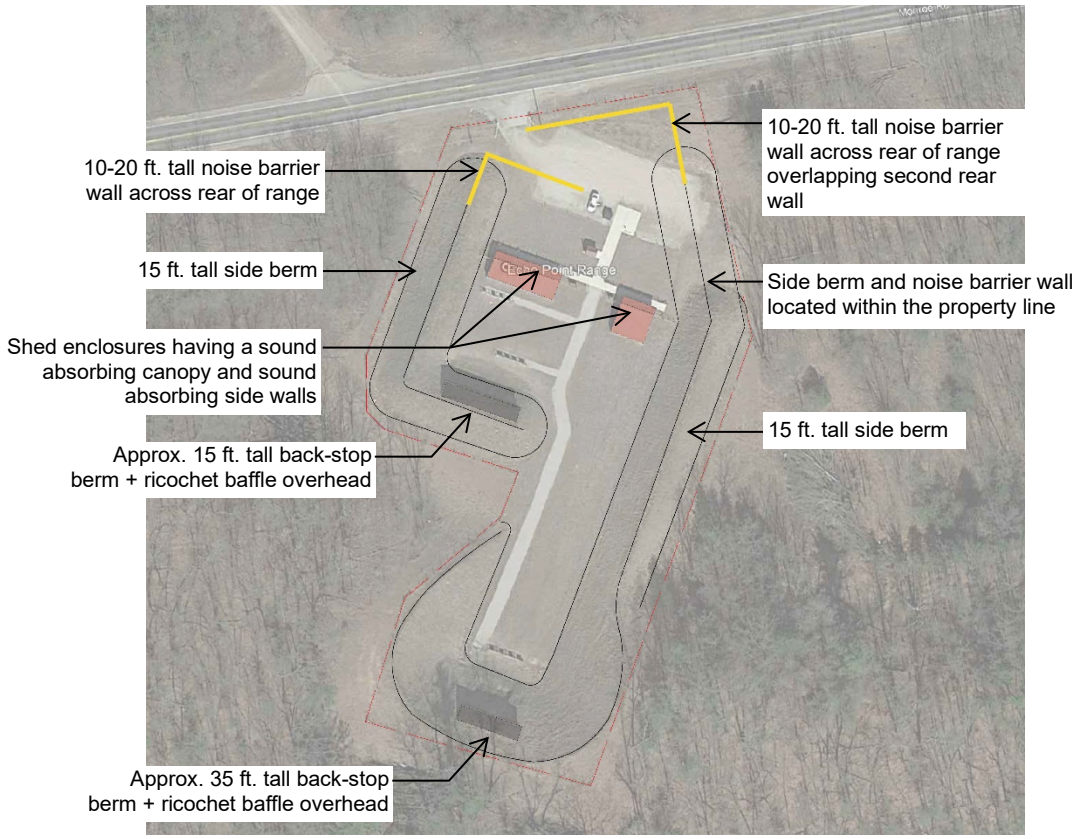


Figure 14. Concept plan diagram of the base range with 10 ft. tall (Model D) and 20 ft. tall (Model E) noise barrier walls across the rear of the firing range facility

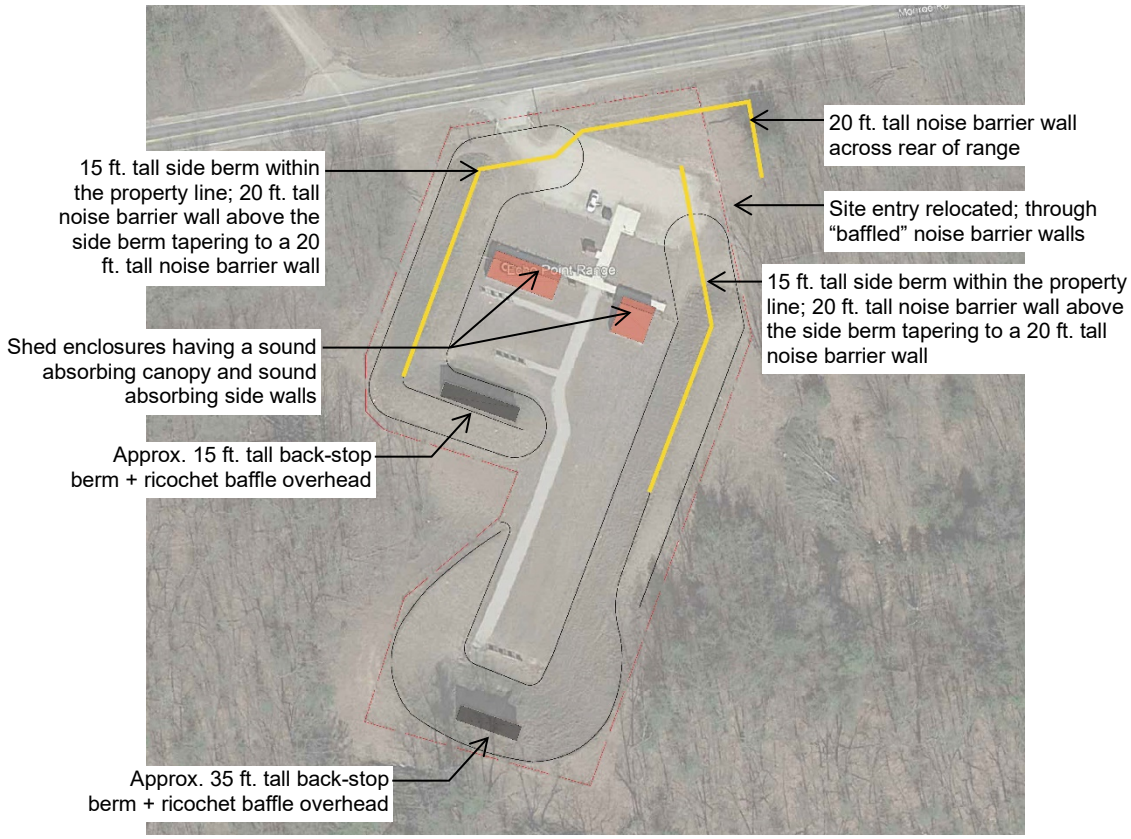


Figure 15 Concept plan diagram of the base range with the site entry relocated to the northeast corner of the site; 20 ft. tall rear walls across the range; and 20 ft. tall noise barrier walls above the side berms | Model F

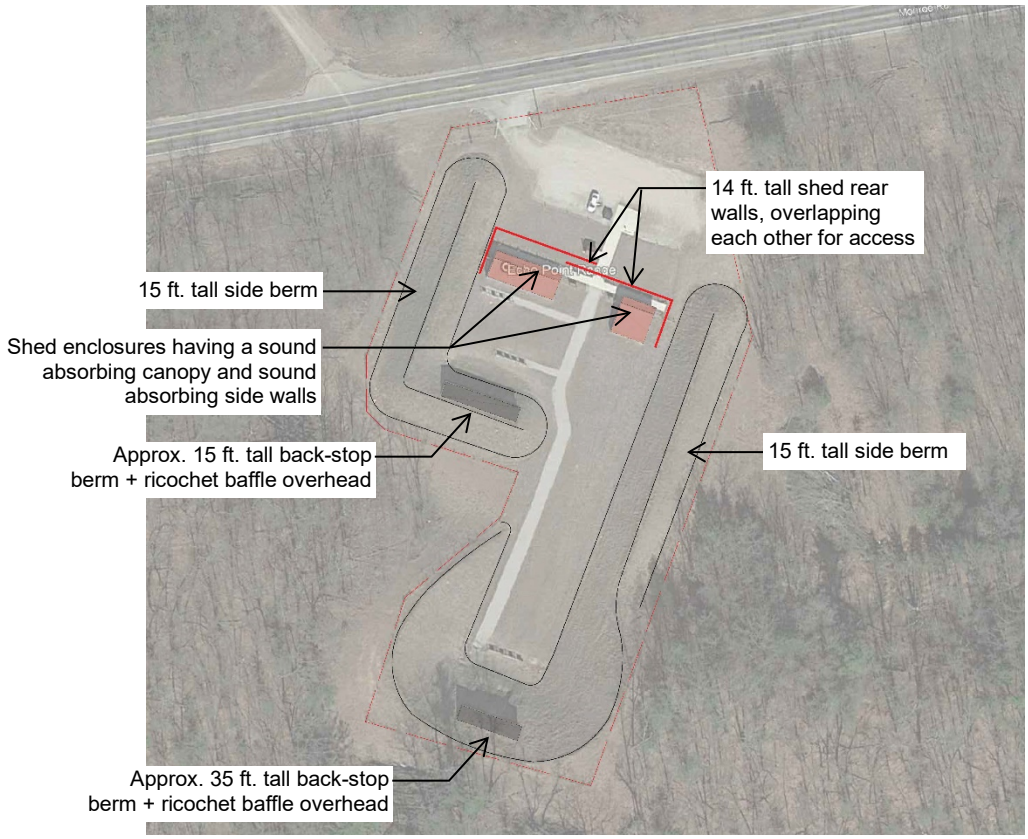


Figure 16. Concept plan diagram of the base range with a 14 ft. tall noise barrier wall behind the sheds | Model G

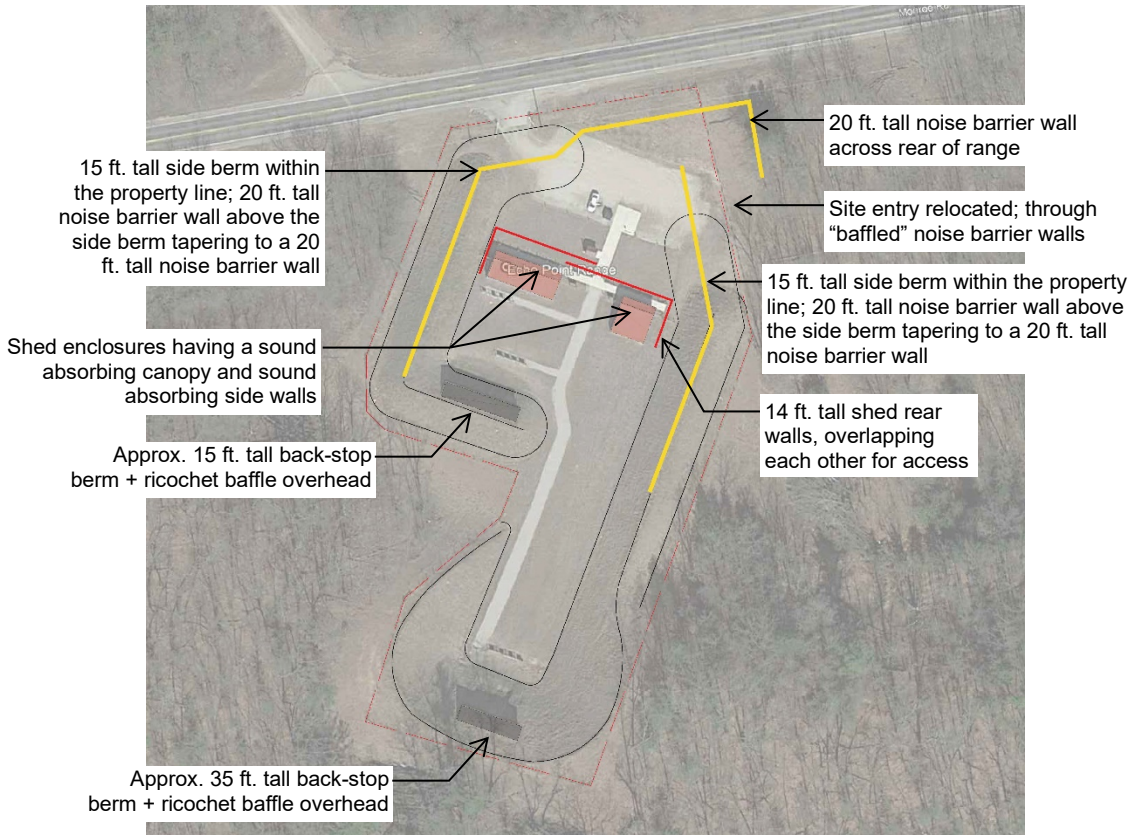


Figure 17. Concept plan diagram of the base range with the site entry relocated to the northeast corner of the site; 20 ft. tall rear walls across the range; 20 ft. tall noise barrier walls above the side berms; and 14 ft. tall noise barriers behind the sheds | Model H

Results of the Computer Model Studies

Figures 3 through 10, in Appendix F, contain scaled maps/aerials of the site and surrounding areas with calculated sound levels at specific locations included for each of the experiments described above.

The sound levels shown on the noise contours in the figures represent the sound exposure level (SEL) or 1 second equivalent continuous sound pressure level (LAeq) at receiver locations around the existing range site for each scenario when 4 shooters firing .223 caliber rifles on the 100-yard range; 2 shooters firing a .223 caliber rifle on the 25-yard pistol range; 2 shooters firing 12-gauge Remington shotguns on the 25-yard pistol range; and 3 shooters firing 0.40 caliber handguns on the 25-yard pistol range within a 1 second time period.

Model A: The computer model showed that the current range facility with the first phase of noise mitigation systems added to the ranges provides a significant reduction of sound levels at many of the noise sensitive receivers when compared to the original firing range configuration prior any renovation in 2016.

The sound levels toward the south of the firing range are estimated to be reduced by -8 dB at receiver R8 located ½ mile to the southwest of the range; -1 dB at receiver R16, which is approximately 1.1

miles toward the south-southwest of the range; and -6 dB at receiver R19 which is approximately 2 miles toward the south of the range.

Sound levels toward the east and west sides of the firing range are estimated to be reduced by -12 dB at receiver R2 located ¼ mile to the west of the range, and at receiver R9 located ½ mile to the west of the range; -17 dB at receiver R4, which is approximately 1/4 mile toward the southeast of the range; -13 dB at receiver R15 which is approximately 1.1 miles toward the west of the range; -9 dB at receiver R6 which is located 0.43 miles to the east-northeast of the range; and -10 dB at receiver R20 which is approximately 2.0 miles toward the west of the range. Sound levels at receivers located behind the firing range, toward the east and west sides of the firing range are estimated to be reduced by -3 dB at receiver R1 located 0.20 miles to the east-northeast of the range; by -15 dB at receiver R13 located 1 mile to the east of the range; and -13 dB at receiver R17, which is approximately 2 miles toward the east of the range. The sound level reduction at these receivers is due to the addition of the 15 ft. tall berms at the sides of the firing range facility and the adjusted orientation of the direction of fire.

The computer model also showed that there is an increase in sound level at noise sensitive receivers toward the rear of the firing range. Sound levels are estimated to be increased by +1 dB at receiver R10, which is approximately 1.60 miles toward the north-northwest of the range; by +2 dB at receiver R5 which is located 0.29 miles to the north-northeast of the range. The increase in sound level at these receivers is mainly due to the adjusted orientation of the firing range. An increase of 1 dB is not generally noticeable to people of normal hearing sensitivities.

Receiver R3 located 0.25 miles to the north-northwest of the range, showed -1 dB reduction in sound levels when compared to the firing range configuration prior any renovation. Compared to the original firing range configuration prior any renovation in 2016, no additional reduction of sound levels was observed at the noise sensitive receivers R7, R11, R12, and R18. This is explained by the fact that noise mitigation systems were not built behind the ranges (to the north).

Model B: When compared to Model A, the addition of 20 ft. tall walls above the 15 ft. tall side berms resulted in an additional reduction of -1 to -2 dB at receivers R1 located 0.20 miles to the east-northeast of the range; R2 located ¼ mile to the west of the range; R4 which is approximately 0.25 miles toward the southeast of the range; R6 located 0.43 miles to the east-northeast of the range; and R9 located ½ mile to the west of the range.

Sound levels are estimated to increase by +2 dB at receiver R8 located ½ mile to the southwest of the range due to addition of the side walls above the berms which reduce noise propagating to the sides, but directs sounds toward the direction of fire where receiver R8 is located. Although the increase in sound level is observed at this location when comparing Model B to Model A, there is a sound level reduction of -5 dB when comparing Model B to the original firing range configuration prior any renovation in 2016.

Compared to Model A, no additional reduction of sound levels was observed at the noise sensitive receivers R3, R5, R7, and R10 through R20.

Model C: When compared to Model B, adjusting the shape of the extended berm to the east side of the 100-yard firing range to be within the property line, the computer model did not show additional sound level reductions at the noise sensitive receivers.

When compared to Model A, the shape of the extended berm resulted in an additional reduction of -1 dB at receiver R1, located 0.20 miles to the east-northeast of the range, at receiver R2, located ¼ mile to the west of the range, and at receiver R6, located 0.43 miles to the east-northeast side of the range; -2 dB at receiver R4, which is approximately 1/4 mile toward the southeast of the range, and at receiver R9 located ½ mile to the west of the range.

When compared to Model A, sound levels are estimated to increase by +2 dB at receiver R8 located ½ mile to the southwest of the range. The sound levels at receiver R8 are estimated to be reduced by -5 dB when comparing Model C to the original firing range configuration prior any renovation in 2016.

No additional reduction of sound levels was observed at the remaining noise sensitive receivers.

Model D: When compared to Model A, the addition of a 10ft. tall wall across the rear of the existing firing range facility resulted in an additional reduction of -10 dB at receiver R1, located 0.20 miles to the east-northeast of the range; -1 dB at receiver R2, located ¼ mile to the west of the range, at receiver R5, which is approximately 0.29 mile toward the north-northeast of the range, at receiver R6, located 0.43 miles to the east-northeast side of the range, and at receiver R18, located 2.0 miles to the north side of the range; -5 dB at receivers R3 and a R7 located 0.25 miles to the north-northwest and 0.50 miles to the north of the range respectively; -2 dB at receiver R4, which is approximately 1/4 mile toward the southeast of the range, at receiver R9 located ½ mile to the west of the range, and at receiver R10 located 1.60 miles to the north-northwest of the range; and -4 dB at receiver R11 located 1.60 miles to the north of the range.

When compared to Model A, sound levels are estimated to be increased by +2 dB at receiver R8 located ½ mile to the southwest of the range. The sound levels at receiver R8 are estimated to be reduced by -5 dB when comparing Model D to the original firing range configuration prior any renovation in 2016.

Compared to Model A, no additional reduction of sound levels was observed at the noise sensitive receivers R12 through R17, R19 and R20.

Compared to the original firing range configuration prior any renovation work in 2016, the estimated reduction of sound levels at the noise sensitive receivers R12 through R17, R19 and R20 varies between 0 to -15 dB.

Model E: When compared to Model A, increasing the height of the rear wall across the existing firing range facility to 20 ft. resulted in an additional reduction of -12 dB at receiver R1, located 0.20 miles to the east-northeast of the range; -2 dB at receiver R2, located ¼ mile to the west of the range, at receiver R4, located 1/4 mile toward the southeast of the range, and at receiver R9 located ½ mile to the west of the range; -7 dB at receiver R3, located 0.25 miles to the north-northwest of the range; -4 dB at receivers R5, located 0.29 miles toward the north-northeast of the range, at receiver R10, located 1.60 miles to the north-northwest of the range and R18, located 2.0 miles to the north of the range; -8 dB at receiver R7, located ½ mile to the north of the range; -6 dB at receiver R11 located 1.60 miles to the north of the range; and -1 dB at receivers R6, R14, R15 and R20.

When compared to Model A, sound levels are estimated to increase by +2 dB at receiver R8 located ½ mile to the southwest of the range. The sound levels at receiver R8 are estimated to be reduced by -5 dB when comparing Model E to the original firing range configuration prior any renovation in 2016.

Compared to Model A, no additional reduction of sound levels was observed at the noise sensitive receivers R12, R13, R16, R17 and R19.

Compared to the original firing range configuration prior any renovation work in 2016, the estimated reduction of sound levels at the noise sensitive receivers R12, R13, R16, R17 and R19 varies between 0 to -15 dB.

Model F: Compared to Model A, by relocating the entry to the site to the northeast corner of the site, providing 20 ft. tall rear walls across the range, and 20 ft. tall noise barrier walls above the side berms, computer model F resulted in an additional reduction of -11 dB at receiver R1, located 0.20 miles to the east-northeast of the range; -2 dB at receiver R2, located ¼ mile to the west of the range, at receiver R4, located 1/4 mile toward the southeast of the range, at receiver R9 located ½ mile to the west of the range, and at receiver R18, located 2.0 miles to the north of the range; -5 dB at receiver R3, located 0.25 miles to the north-northwest of the range, and at receiver R7 located ½ mile to the north of the range; -1 dB at receiver R6 located 0.43 miles to the east-northeast side of the range, at receiver R15, located 1.1 miles to the west of the range, and at receiver R20 located 2 miles to the west of the range; -4 dB at receiver R10 located 1.60 miles to the north-northwest of the range and at receiver R11 located 1.60 miles to the north of the range.

When compared to Model A, sound levels are estimated to increase by +2 dB at receiver R8 located ½ mile to the southwest of the range. The sound levels at receiver R8 are estimated to be reduced by -5 dB when comparing Model F to the original firing range configuration prior any renovation in 2016.

Compared to Model A, no additional reduction of sound levels was observed at the noise sensitive receivers R5, R12, R13, R14, R16, R17 and R19.

Compared to the original firing range configuration prior any renovation work in 2016, the estimated reduction of sound levels at the noise sensitive receivers R5, R12, R13, R14, R16, R17 and R19 varies between 0 to -15 dB.

Model G: The addition of a 14 ft. tall rear wall noise barrier 10 ft. behind the firing lines added to the existing firing range configuration, as described in Model A, resulted in additional reduction of -10 dB at receiver R1, located 0.20 miles to the east-northeast of the range; -2 dB at receiver R2, located ¼ mile to the west of the range, at receiver R4, located 1/4 mile toward the southeast of the range, and at receiver R14, located 1.0 mile to the north of the range; -8 dB at receiver R3, located 0.25 miles to the north-northwest of the range; -7 dB at receiver R5 located 0.29 miles to the north-northeast side of the range, and at receiver R18 located 2 miles to the north of the range; -4 dB at receiver R6, located 0.43 miles to the east-northeast of the range, and at receiver R12 located 0.62 miles to the north-northeast side of the range; -10 dB at receiver R7, located 0.50 miles to the north of the range; -1 dB at receiver R9 located ½ mile to the west of the range; -9 dB at receiver R11 located 1.60 miles to the north of the range; and -6 at receiver R10 located 1.60 miles to the north-northwest of the range.

Compared to Model A, no additional reduction of sound levels was observed at the noise sensitive receivers R8, R13, R15, R16, R17, R19 and R20.

Compared to the original firing range configuration prior any renovation work in 2016, the estimated reduction of sound levels at the noise sensitive receivers R8, R13, R15, R16, R17, R19 and R20 varies between -1 to -15 dB.

Model H: The addition of a 14 ft. tall rear wall noise barrier 10 ft. away from the firing lines added to the firing range configuration described in Model F, resulted in an additional reduction of -14 dB at receiver R1, located 0.20 miles to the east-northeast of the range; -2 dB at receiver R2, located ¼ mile to the west of the range, at receiver R4, located 1/4 mile toward the southeast of the range, and at receiver R20, located 2.0 miles to the west of the range; -10 dB at receiver R3, located 0.25 miles to the north-northwest of the range, and at receiver R18 located 2.0 miles to the north of the range; -12 dB at receiver R5 located 0.29 miles to the north-northeast side of the range; -4 dB at receiver R6, located 0.43 miles to the east-northeast of the range; -16 dB at receiver R7, located 0.50 miles to the north of the range; -3 dB at receiver R9 located ½ mile to the west of the range; -11 dB at receiver R10 located 1.60 miles to the north-northwest of the range; -13 dB at receiver R11 located 1.60 miles to the north of the range; -8 dB at receiver R12, located 0.62 miles to the north-northeast of the range; -7 dB at receiver R14 located 1.0 mile to the north of the range; and -1 dB at receiver R15 located 1.60 miles to the west of the range.

Compared to Model A, no additional reduction of sound levels was observed at the noise sensitive receivers R8, R13, R16, R17 and R19.

Compared to the original firing range configuration prior any renovation work in 2016, the estimated reduction of sound levels at the noise sensitive receivers R8, R13, R16, R17 and R19 varies between -1 to -15 dB.

1. A table summarizing the resulting sound reduction provided by each of the computer model studied is presented in Table 5. The table shows that the following model configurations resulted in more sound reduction compared to the existing firing range configuration (Model A):

    A. Model H: This model resulted in approximately -7 to -16 dB reduction in off-site sound propagation toward the north; -4 to -14 dB toward the east-northeast; 0 to -2 dB toward the direction of fire; and 0 to -3 dB toward the east and west sides of the firing range facility.
    B. Model G: This model resulted in approximately -2 to -10 dB reduction in off-site sound propagation toward the north; -4 to -10 dB toward the east-northeast; 0 to -2 dB toward the direction of fire; and 0 to -2 dB toward the east and west sides of the firing range facility.
    C. Model E: This model resulted in approximately 0 to -8 dB reduction in off-site sound propagation toward the north; -1 to -12 dB toward the east-northeast; -2 to +2 dB toward the direction of fire; and 0 to -2 dB toward the east and west sides of the firing range facility.
    D. Model F: This model resulted in approximately 0 to -5 dB reduction in off-site sound propagation toward the north; -1 to -11 dB toward the east-northeast; -2 to +2 dB toward the direction of fire; and 0 to -2 dB toward the east and west sides of the firing range facility.
    E. Model D: This model resulted in approximately 0 to -5 dB reduction in off-site sound propagation toward the north; -1 to -10 dB toward the east-northeast; -2 to +2 dB toward the direction of fire; and 0 to -2 dB toward the east and west sides of the firing range facility.

F. Models B and C: The computer models with extended side berms to the east of the 100-yard range, and 20 ft. tall noise barrier walls above the side berms, resulted in no additional reduction in off-site sound propagation toward the north; -1 dB toward the east-northeast; -2 to +2 dB toward the direction of fire; and 0 to -2 dB toward the east and west sides of the firing range facility.

Table 5. Summary of estimated reduction of sound levels from various noise mitigation schemes added to the range compared to the original firing range facility prior to any renovation work in 2016.

RECEIVERS		COMPUTER MODEL SCENARIOS (Estimated Insertion Loss Relative to the Former Range)									ORIENTATION RELATIVE TO D.O.F
		2016	A	B	C	D	E	F	G	H	
1	0.20 mi ENE - 2M - old/new	0	-3	-4	-5	-13	-15	-14	-14	-18	SIDE-REAR
2	0.25 mi W - 4M - old/new	0	-12	-14	-14	-14	-14	-14	-14	-15	SIDE-FRONT
3	0.25 mi NNW - 1M - old/new	0	-1	-1	-1	-5	-7	-6	-8	-10	SIDE-REAR
4	0.25 mi SE - 2T old/new	0	-17	-19	-19	-19	-19	-19	-19	-19	SIDE-FRONT
5	0.29 mi - NNE - AS2	0	2	2	2	1	-2	2	-5	-10	REAR
6	0.43 mi ENE - 6M - old/new	0	-9	-10	-10	-10	-10	-10	-13	-14	SIDE
7	0.50 mi N - 5M - old/new	0	0	0	0	-5	-8	-5	-10	-16	REAR
8	0.50 mi SW – 7T - old/new	0	-8	-5	-5	-5	-5	-5	-8	-8	FRONT
9	0.51 mi W - 8M - old/new	0	-12	-14	-14	-14	-14	-14	-12	-15	FRONT-SIDE
10	1.60 mi NNW - AS1A - new	0	1	1	1	-1	-3	-3	-5	-10	REAR
11	1.60 mi N - AS1B - new	0	0	0	0	-4	-6	-4	-9	-13	REAR
12	0.62 mi NNE - AS3	0	0	0	0	0	0	0	-4	-7	SIDE-REAR
13	1.00 mi E - 11M - old/new	0	-15	-15	-15	-15	-15	-15	-15	-15	SIDE
14	1.00 mi N - 10M - old/new	0	-4	-4	-4	-4	-5	-4	-6	-11	REAR
15	1.10 mi W -14M - old/new	0	-13	-13	-13	-13	-14	-14	-13	-14	SIDE-REAR
16	1.10 mi SSW - 13M New - old/new	0	-1	-1	-1	-1	-1	-1	-1	-1	FRONT
17	2.00 mi E - 16M - old/new	0	-13	-13	-13	-13	-13	-13	-13	-14	SIDE
18	2.00 mi N - 15M - old/new	0	0	0	0	-1	-4	-2	-7	-10	REAR
19	2.00 mi S - 17M - old/new	0	-6	-6	-6	-6	-6	-6	-6	-6	FRONT
20	2.00 mi W - 18M - old/new	0	-10	-10	-10	-10	-11	-11	-10	-11	SIDE

Table 6. Summary of estimated reduction of sound levels from various additional noise mitigation schemes compared to the current firing range configuration with the first phase of noise mitigation systems added to the range in 2021 (Model A).

RECEIVERS		COMPUTER MODEL SCENARIOS (Estimated Insertion Loss Relative to Model A)								ORIENTATION RELATIVE TO D.O.F
		A	B	C	D	E	F	G	H	
1	0.20 mi ENE - 2M - old/new	0	-1	-1	-10	-12	-11	-10	-14	SIDE-REAR
2	0.25 mi W - 4M - old/new	0	-1	-1	-1	-2	-2	-2	-2	SIDE-FRONT
3	0.25 mi NNW - 1M - old/new	0	0	0	-5	-7	-5	-8	-10	SIDE-REAR
4	0.25 mi SE - 2T old/new	0	-2	-2	-2	-2	-2	-2	-2	SIDE-FRONT
5	0.29 mi - NNE - AS2	0	0	0	-1	-4	0	-7	-12	REAR
6	0.43 mi ENE - 6M - old/new	0	-1	-1	-1	-1	-1	-4	-4	SIDE
7	0.50 mi N - 5M - old/new	0	0	0	-5	-8	-5	-10	-16	REAR
8	0.50 mi SW – 7T - old/new	0	2	2	2	2	2	0	0	FRONT

RECEIVERS		COMPUTER MODEL SCENARIOS (Estimated Insertion Loss Relative to Model A)								ORIENTATION RELATIVE TO D.O.F
		A	B	C	D	E	F	G	H	
9	0.51 mi W - 8M - old/new	0	-2	-2	-2	-2	-2	-1	-3	FRONT-SIDE
10	1.60 mi NNW - AS1A - new	0	0	0	-2	-4	-4	-6	-11	REAR
11	1.60 mi N - AS1B - new	0	0	0	-4	-6	-4	-9	-13	REAR
12	0.62 mi NNE - AS3	0	0	0	0	0	0	-4	-8	SIDE-REAR
13	1.00 mi E - 11M - old/new	0	0	0	0	0	0	0	0	SIDE
14	1.00 mi N - 10M - old/new	0	0	0	0	-1	0	-2	-7	REAR
15	1.10 mi W -14M - old/new	0	0	0	0	-1	-1	0	-1	SIDE-REAR
16	1.10 mi SSW - 13M New - old/new	0	0	0	0	0	0	0	0	FRONT
17	2.00 mi E - 16M - old/new	0	0	0	0	0	0	0	0	SIDE
18	2.00 mi N - 15M - old/new	0	0	0	-1	-4	-2	-7	-10	REAR
19	2.00 mi S - 17M - old/new	0	0	0	0	0	0	0	0	FRONT
20	2.00 mi W - 18M - old/new	0	0	0	0	-1	-1	0	-2	SIDE

Models G and H are the only models that do not show any increases in sound levels compared to the original range prior to the 2016 construction.

The noise barrier walls, if constructed, should have a Sound Transmission Class or STC rating > 26. The wall should extend from grade to the height above the firing line specified as a solid surface with no unsealed gaps, joints or other potential paths for sound to move through the face of the wall. The wall can be built of any material that meets the required STC rating. This could include PVC walls such as AIL Quick Wall, metal sound barrier walls by Empire, IAC, Soundfighter or other manufacturer, precast concrete walls such as by Permacast or others, chain link fence covered with Acousti Blok, field fabricated concrete masonry units or poured concrete walls or other types of walls that meet the STC rating.

NOISE ORDINANCES

The firing range is located in Valley Township and is within a two-mile radius of Allegan Township.

Allegan Township Ordinance No. 07-02, the Anti-Noise Ordinance, does not include quantitative sound level limits or sound measurement methods for determining the acceptability of sounds of various types and levels. Section II of the Allegan Township Anti-Noise Ordinance states that "no person, firm, or corporation shall cause, create, maintain or operate any unreasonable or improper noise or disturbance, injurious to the health, peace or quiet of the residents and property owners of the Township of Allegan." Firearms and shooting are not specifically mentioned as noise creating activities and are not listed as exceptions to improper noise. However, it is possible that gun-shot noise may be considered a disturbance according to the Allegan Township Anti-Noise Ordinance.

The Noise Ordinance for the Township of Valley is included in Valley Township Noise Ordinance No. 219. Section V, Anti-Noise Regulations Based Upon dB(A) Criteria of the Valley Township Ordinance No. 219. It states that residential zoning districts have a maximum noise level limit of 55 dBA during the daytime hours of 7 a.m. to 10 p.m. and 50 dBA during nighttime hours of 10 p.m. to 7 a.m. The ordinance also states that periodic or repetitive impulse sounds must have sound pressure level limits of 5 dBA less than the noise level limits listed above.

CONCLUSIONS

1. Sound studies were conducted at the existing Echo Point Shooting Range in the Allegan State Game Area to compare measured sound levels during a live fire exercise in the range in its original configuration in 2016 with measurements made in 2021 after the initial phase of noise mitigation options were constructed at the range. Noise mitigation options to further reduce off-site sound levels for the range were investigated in a series of computer model studies.

2. Existing ambient sound levels were measured at 2 locations near potential noise sensitive receivers located near the range from September 26 to October 3, 2016. Existing ambient sound levels (LAeq) at the sites varied from 19 to 72 dBA with average Day-Night Sound Levels (LDN) of 45 to 60 dBA. The lower end of this range of sound levels is typical of relatively quiet sites in natural settings with little anthropocentric sounds. The middle to upper end of the range of measured sound levels are indicative of louder suburban sites or sites with some transportation or commercial activity nearby.

3. Experiments were conducted at the range site on September 28, 2016, and on May 13, 2021. A Conservation Officer fired 3 shots in succession from a 0.40 caliber handgun; a 12-gauge shotgun; and a 0.223 rifle. A 0.357 magnum handgun, 450 Bushmaster and a 308 7.62 mm rifle individually loaded were added just for the 2021 live fire exercise. Acoustical measurements were made at 10 feet or approximately 3 meters from the sound source as well as at 16 locations around the proposed range site. There were 4 measurement locations, one in each cardinal direction (i.e., north, east, south, and west) at successive distances of ¼ mile, ½ mile, 1 mile and 2 miles from the firing location at the range. Four additional measurement locations were added for the measurements in 2021.

4. The sound levels measured at 10 feet from the source were generally lower in 2021 than in 2016 due to the construction of the shooting sheds. The sheds reduced sound levels in the direction of fire and to the sides and also prevented the microphones from being placed in the same location in 2021 as they were originally placed in 2016 due to the configuration of the shed and the location of the shooter within the shed.

5. Sound levels at distances away from the range decreased at 11 of 16 locations between 2016 and 2021 and increased at 2 of the 16 measurement locations as measured during the live fire exercises. Additionally, there were measurable sounds from the gun shots at 3 locations in 2021 where there were not measurable sounds from gunshots recorded in 2016. The decreases in sound levels are attributed to the construction of the shooting sheds, the 15 ft. tall berms on the sides of the range and the other mitigation elements constructed at the range that decrease sound levels at many locations.

6. The increase in sound levels generally occurred to the north because there are no mitigation features in the range to decrease sound levels propagating to the north from the range. The focus of the computer model studies was to evaluate potential noise mitigation options to reduce sound levels for as many locations as possible.

7. A computer model of the range as it currently exists was constructed in CadnaA software including topography; roads; ground cover; coniferous vegetation; 15 ft. tall side berms, a 15 ft. tall berm downrange of the 25-yard range with a ricochet baffle overhead, a 35 ft. tall berm downrange the 100-yard range with a ricochet baffle overhead, and shed enclosures consisting of a sound absorbing roof and side walls extending approximately 20 ft. in front of the firing lines; for a standard day with 50°F and 80% relative humidity with wind conditions modeled as downwind with 1 to 11 mph wind.

8. The computer models also showed that 2 locations had an increase in sound levels from 2016 to 2021 as the range is currently constructed.

9. A series of experiments were conducted to determine additional noise mitigating strategies that could provide increased sound reduction at noise sensitive receivers. The noise mitigation options studied included the following:
    A. Model A: Existing range, as shown in Figure 3.
    B. Model B: Existing range design and 20 ft. tall side walls above the side berms, as shown in Figure 4.
    C. Model C: Model B with the extended side berm, to the east of the 100-yard range, angled toward the northwest to contain the berm within the property line, as shown in Figure 5.
    D. Model D: Existing range design and a 10 ft. tall rear wall across the firing range facility, as shown in Figure 6.
    E. Model E: Existing range design and a 20 ft. tall rear wall across the firing range facility, as shown in Figure 6.
    F. Model F: Existing range and access entry to site relocated to the northeast corner of the site; a 20 ft. tall rear wall with a baffled entry to the range was added behind the range; both side berms were extended and 20 ft. tall noise barrier walls were added above the side berms. A concept plan for this experiment is shown in Figure 7.
    G. Models G: Existing range with a 14 ft. tall rear wall 14 ft. to the north of the firing lines, as shown in Figure 8.
    H. Model H: Model F with a 14 ft. tall rear wall added 14 ft. to the north of the firing lines, as shown in Figure 8.

10. Many of the mitigation options such as extending the side berms and adding a noise barrier wall or berm, reduced sound levels effectively to the north.

11. The computer model studies showed that significant additional sound reductions can be achieved with the construction of a berm, wall or berm and wall combination that extends along the length of the existing berms at the sides of the ranges and also continues behind the range between the range and the road. The entry to the range would be to the east of the site with the berms configured to form a baffled entrance.

12. Further development of the shed enclosures at the firing lines with a rear wall (behind the shooters) and sound absorbent treatment is also proposed as an option to further reduce sound levels at locations away from the range.

13. The combination of the shed walls and the berm/wall combinations with the baffled entry behind the ranges resulted in the greatest additional sound reductions at many locations.

14. The use of the noise mitigation options should be carefully considered because there are site specific limitations on how much sound level reduction can be obtained at this site for all of the mitigation schemes due to the proximity of residential properties close to the range site to the north, northeast, southeast and south; the large body of sound reflective water, Lake Allegan, to the north; and the face of the hill in the direction of fire that reflects sounds back to the north.

15. It is important to note that sound levels produced at residential receiving properties near the range may be audible above the existing ambient sound levels and may also exceed the sound level limits in the local noise ordinance even with the current and projected reductions in sound levels achieved for the mitigation options for the range.

APPENDIX A: SUMMARY AND GRAPHS OF EXISTING AMBIENT SOUND LEVELS MEASURED AT 2 LOCATIONS NEAR THE RANGE IN 2016

Echo Point Allegan 2016 LD Table

Table A-1. Summary table of LAeq and LDN sound levels measured at 2 locations near the existing Echo Point Shooting Range in Allegan, Michigan in 2016.

Rion #	Location	Day	LDN (dBA)	LAeq Range (dBA)
4	Ambient 4	1	54	35-65
4	Ambient 4	2	53	35-66
4	Ambient 4	3	54	37-67
4	Ambient 4	4	54	40-57
4	Ambient 4	5	59	36-63
4	Ambient 4	6	49	34-56
4	Ambient 4	7	50	34-63
6	Ambient 6	1	51	19-65
6	Ambient 6	2	-	26-61
6	Ambient 6	3	51	29-70
6	Ambient 6	4	48	32-59
6	Ambient 6	5	60	27-72
6	Ambient 6	6	45	25-57

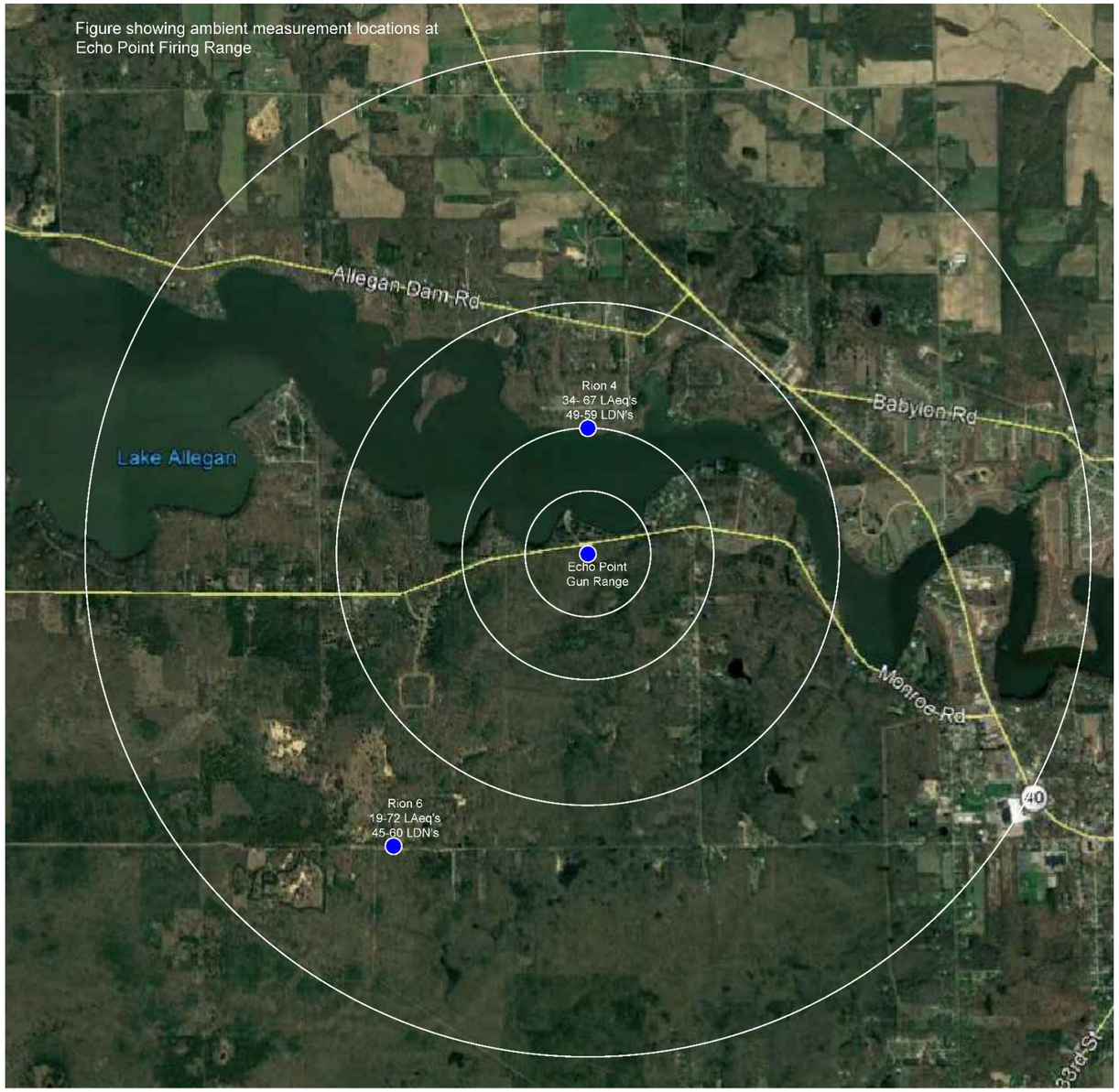
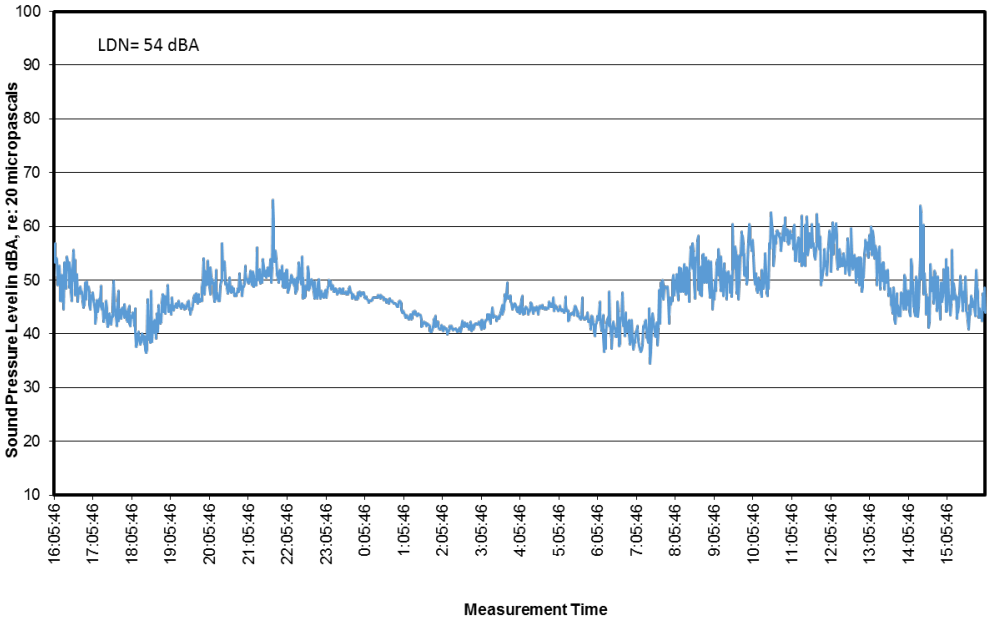


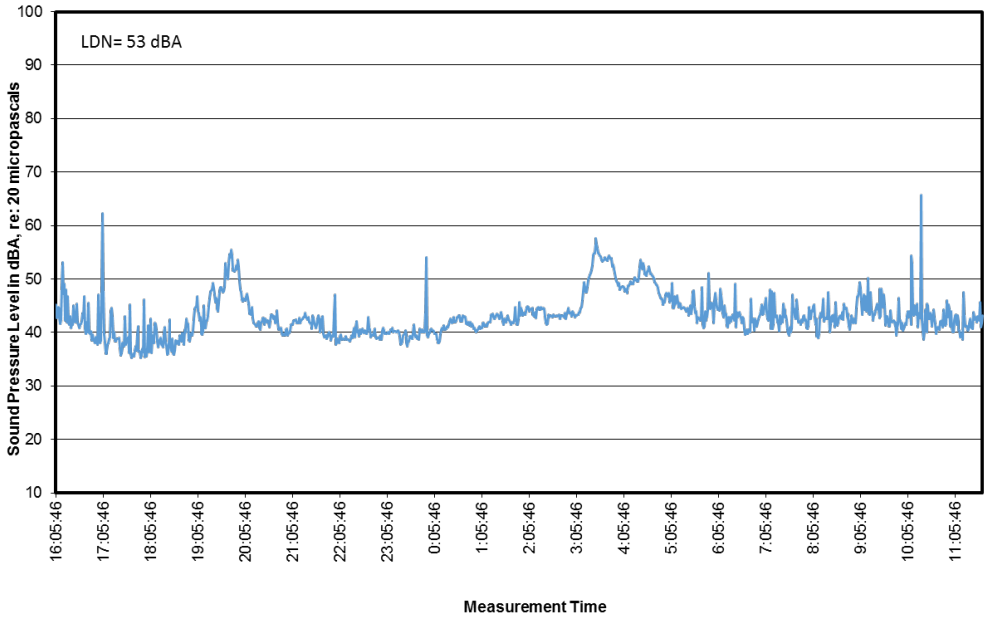
Figure A-1. Aerial photograph showing LA eq and LDN existing ambient sound levels measured at 2 locations near the existing Echo Point Shooting Range Allegan, Michigan in 2016.

Graphs of Average Existing Ambient Sound Levels Measured Near the Existing Range Site in 2016

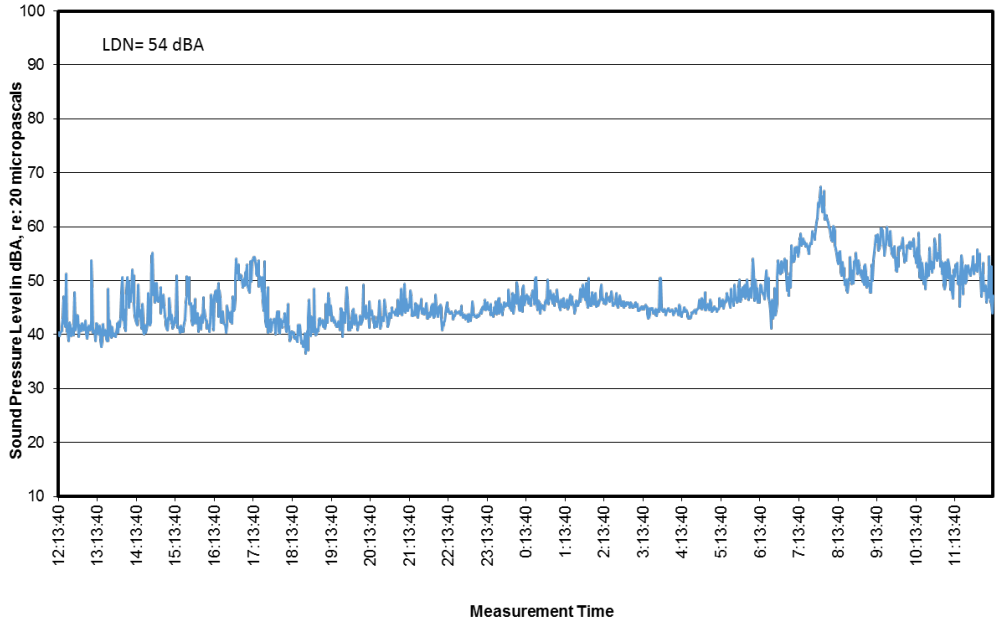
Michigan DNR 2
Location: Rion 4
September 26, 2016 to September 27, 2016



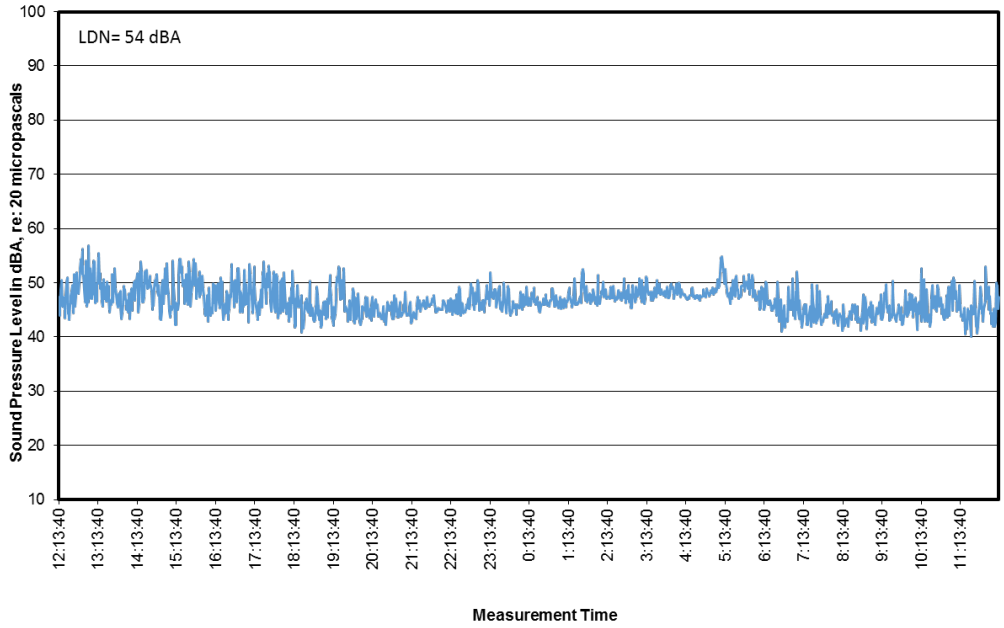
Michigan DNR 2
Location: Rion 4
September 27, 2016 to September 28, 2016



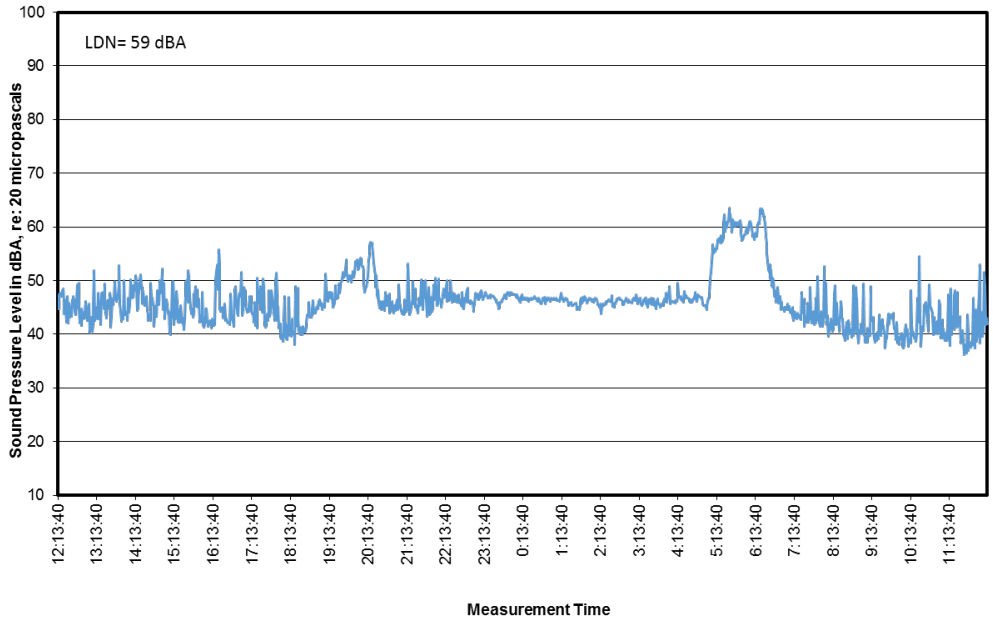
Michigan DNR 2
Location: Rion 4
September 28, 2016 to September 29, 2016



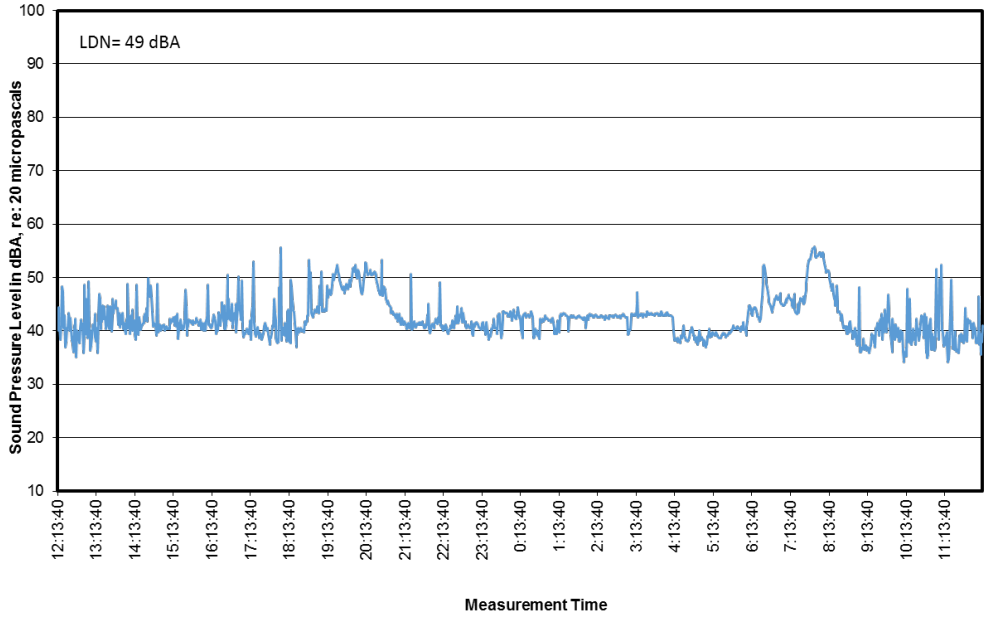
Michigan DNR 2
Location: Rion 4
September 29, 2016 to September 30, 2016



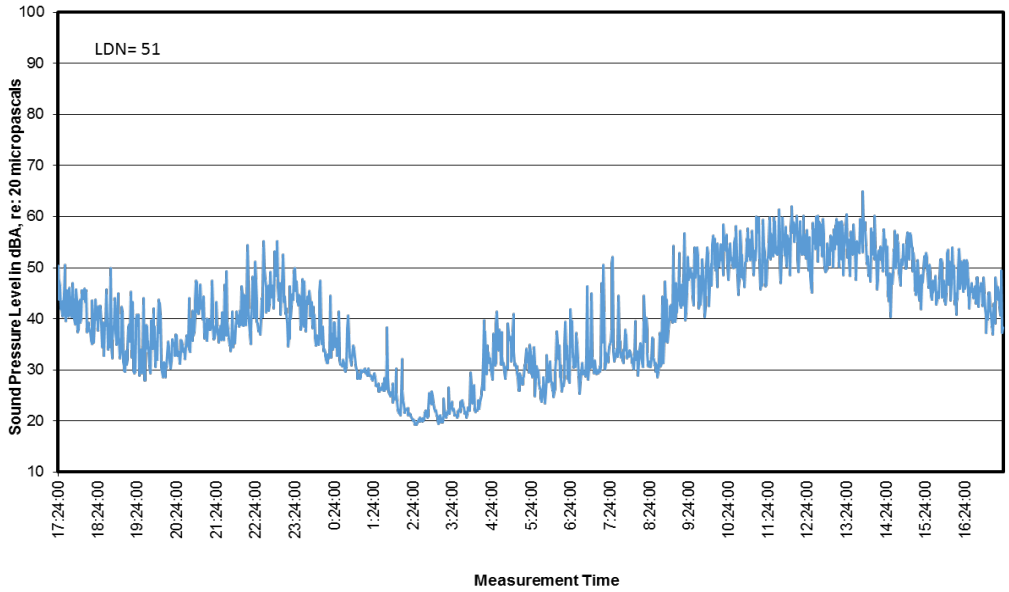
Michigan DNR 2
Location: Rion 4
September 30, 2016 to October 1, 2016



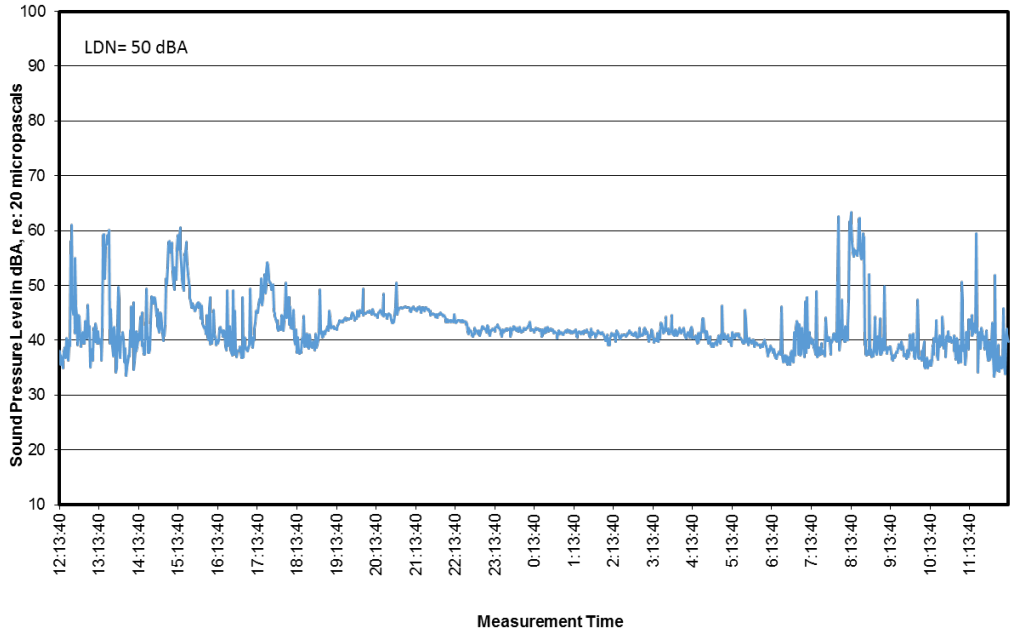
Michigan DNR 2
Location: Rion 4
October 1, 2016 to October 2, 2016



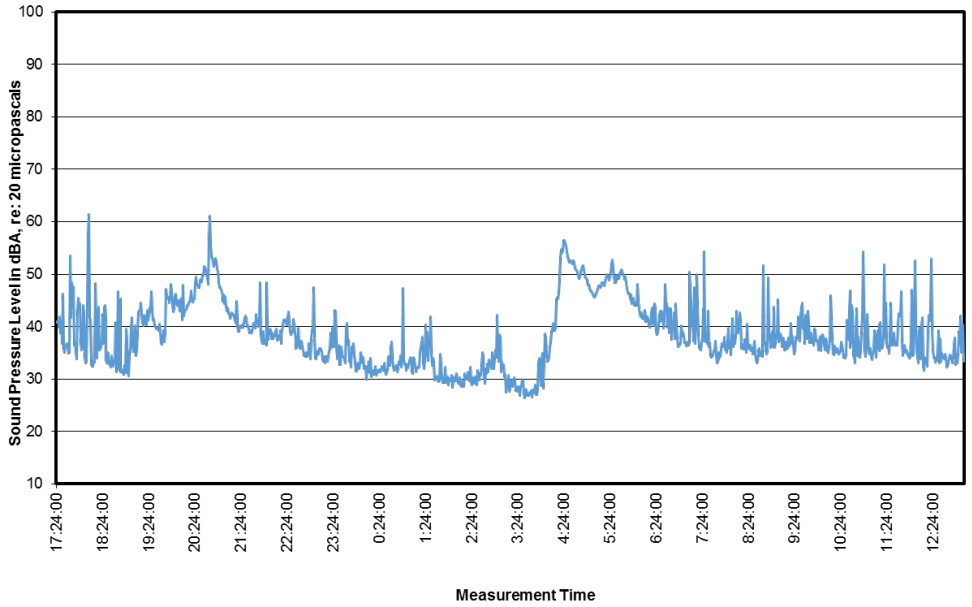
Michigan DNR 2
Location: Rion 6
September 26, 2016 to September 27, 2016



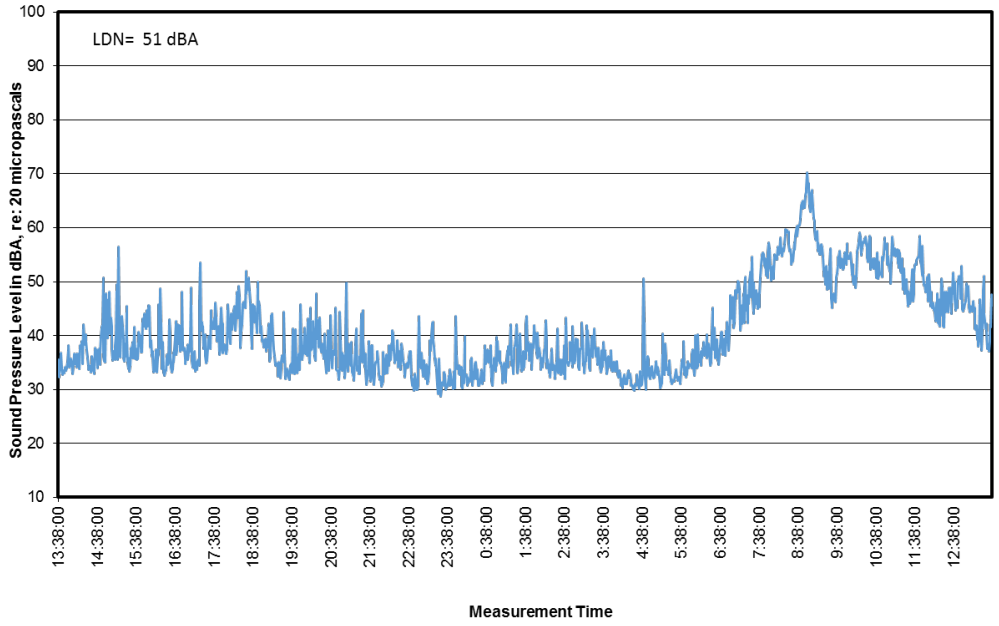
Michigan DNR 2
Location: Rion 4
October 2, 2016 to October 3, 2016



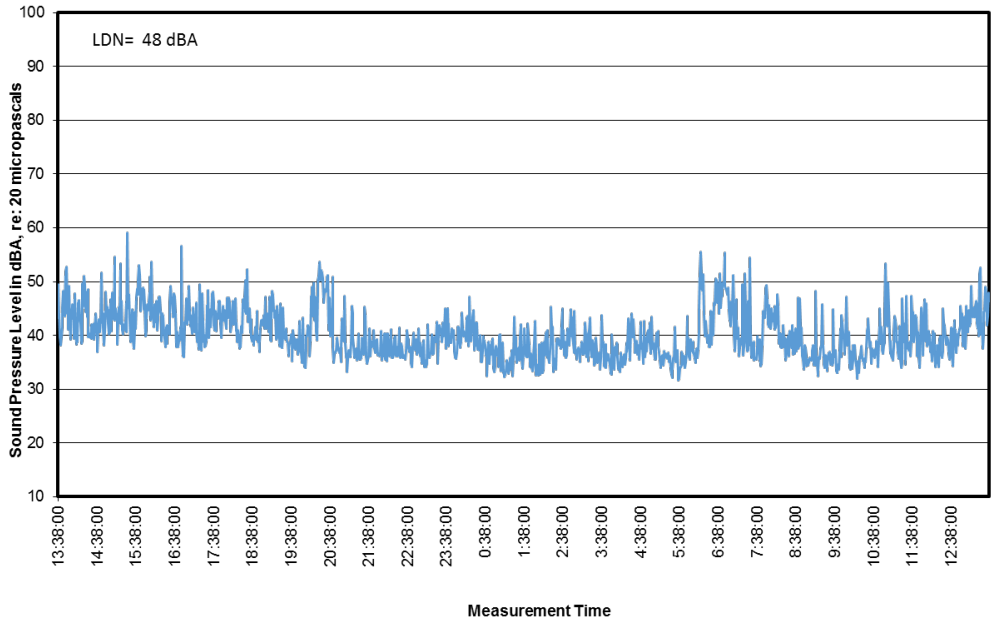
Michigan DNR 2
Location: Rion 6
September 27, 2016 to September 28, 2016



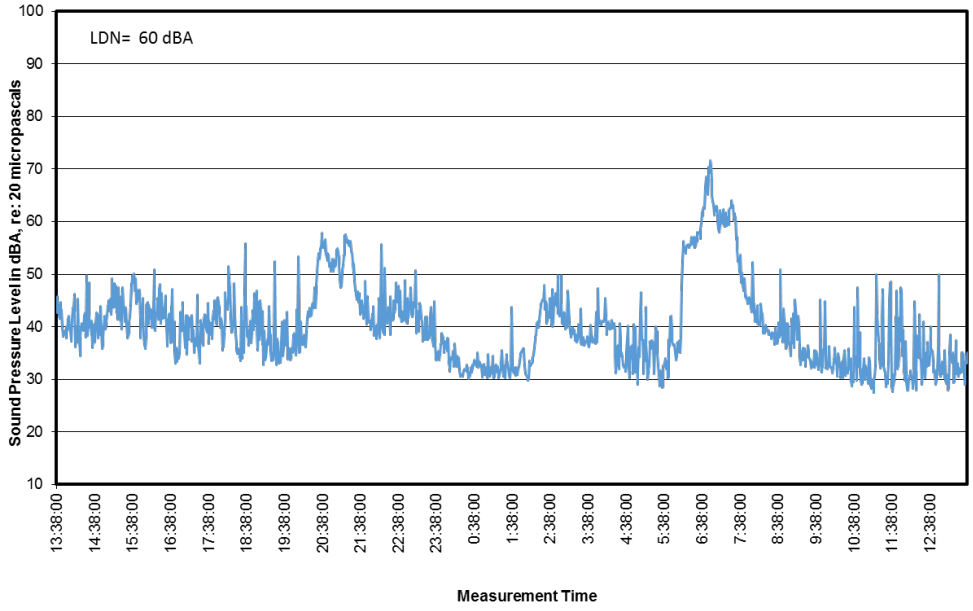
Michigan DNR 2
Location: Rion 6
September 28, 2016 to September 29, 2016



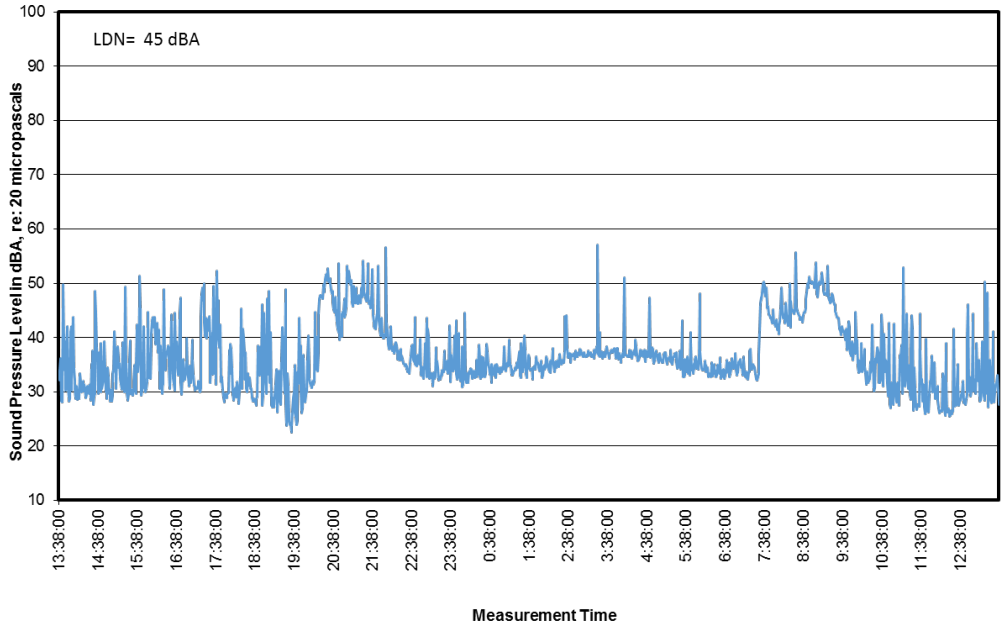
Michigan DNR 2
Location: Rion 6
September 29, 2016 to September 30, 2016



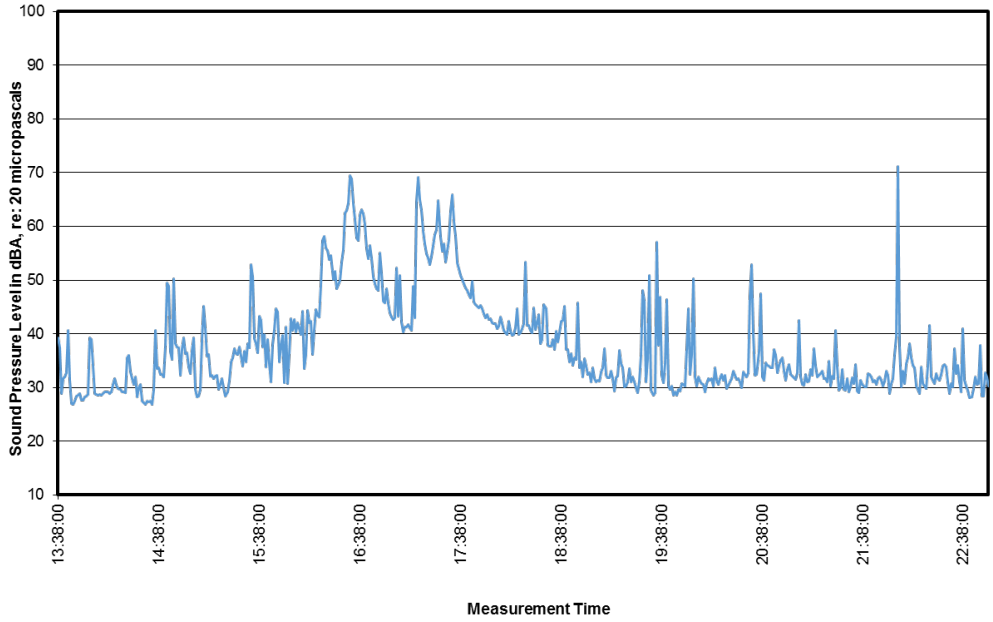
Michigan DNR 2
Location: Rion 6
September 30, 2016 to October 1, 2016



Michigan DNR 2
Location: Rion 6
October 1, 2016 to October 2, 2016



Michigan DNR 2
Location: Rion 6
October 2, 2016



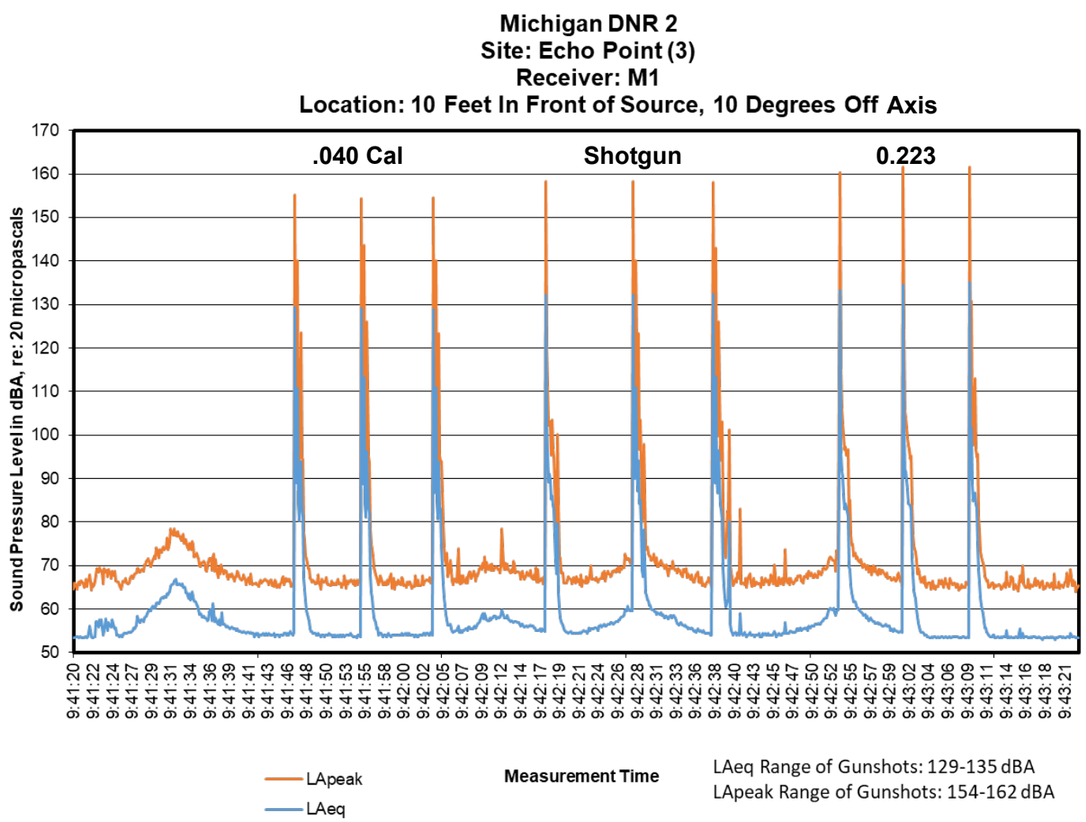
APPENDIX B: GRAPHS OF SOUND LEVELS MEASURED AT 10 FEET FROM THE SOURCE DURING THE LIVE FIRE EXPERIMENTS AT THE RANGE IN 2016 AND 2021

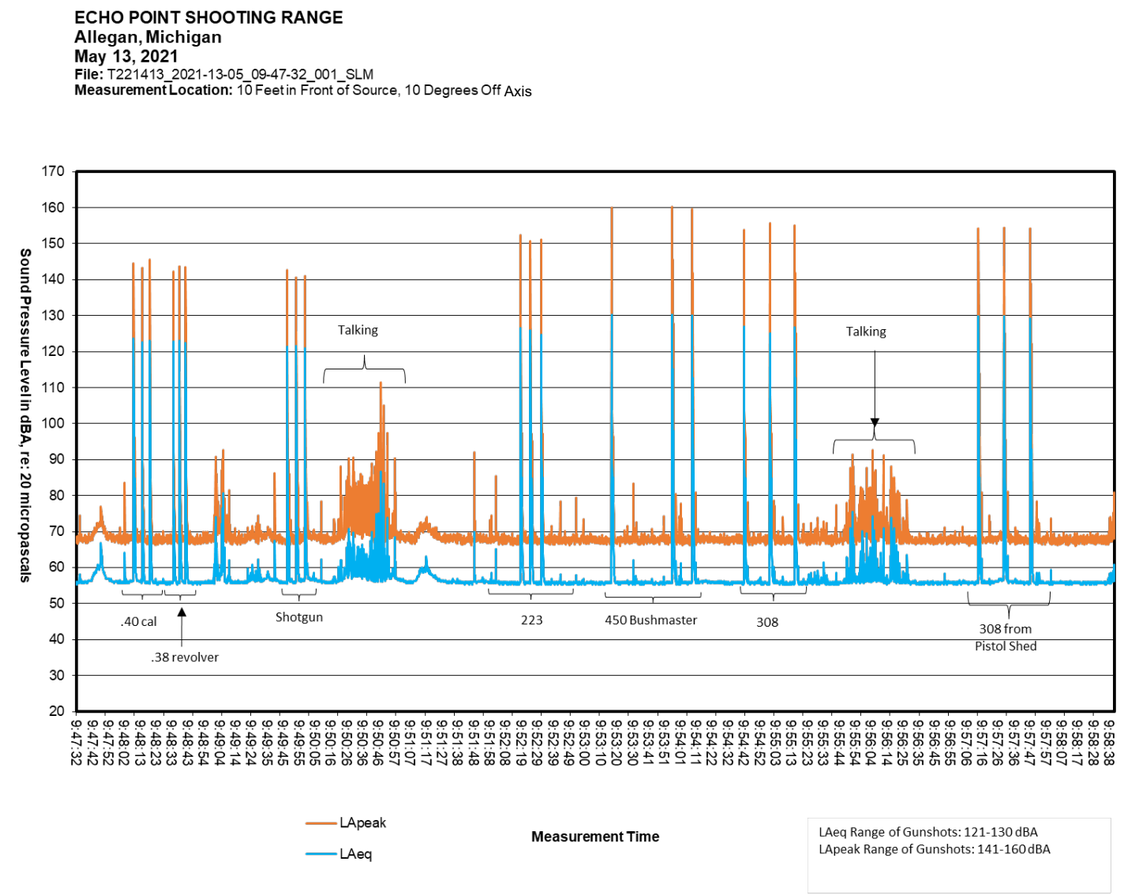
Table B-1. Peak sound pressure levels (dBA) of gun shots near the sound source for guns fired in 2016 and 2021.

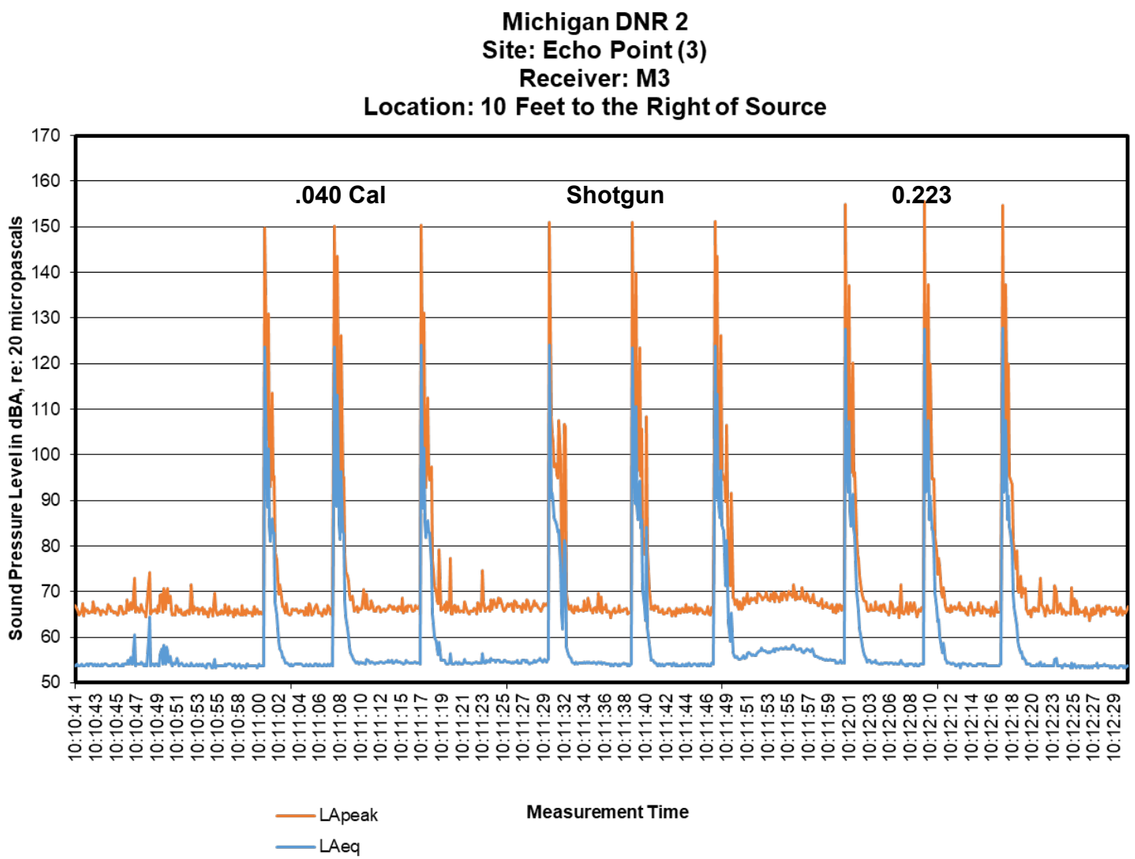
Peak sound pressure levels (dBA) of gun shots near the source									
Location of Microphone	**0.40 Caliber Handgun**			**12 Gauge Shotgun**			**0.223 Caliber Rifle**		
	2016	**2021**	**Difference**	**2016**	**2021**	**Difference**	**2016**	**2021**	**Difference**
10 ft in front of the source and 10 degrees off axis(D.O.F.)	154-155	143-145	**-10 to -11**	158	140-142	**-16 to -18**	160-162	150-152	**-10**
10 ft. to the right of the source	150	140-142	**-8 to -10**	151	135-137	**-14 to -16**	154-155	135-136	**-18 to -20**
10 ft. behind the source	141 to 143	137-138	**-4 to -5**	142	131-134	**-8 to -12**	141	138	**-3**
10 ft. to the left of the source	150	148-149	**-1 to -2**	150	139-143	**-7 to -11**	151	146-147	**-4 to -6**
4 ft. to the right of the source									

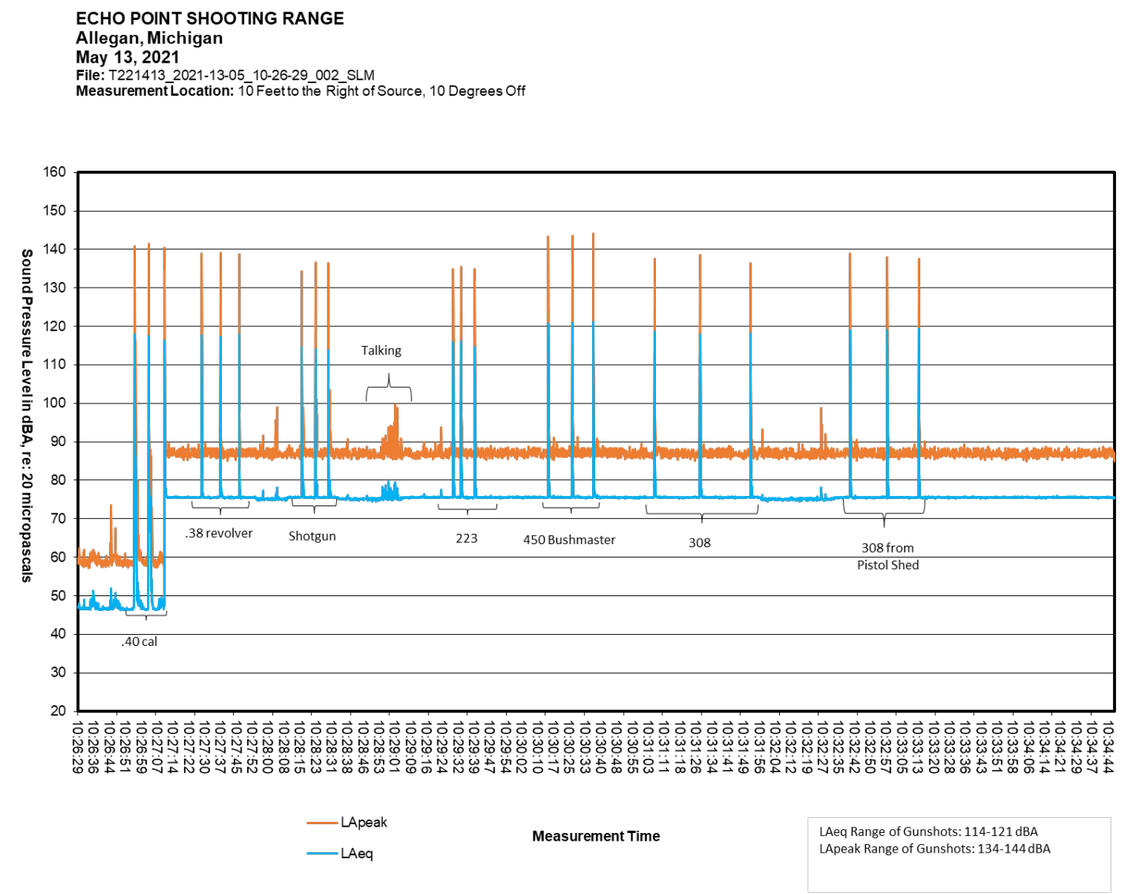
Table B-2. Peak sound pressure levels (dBA) of gun shots near the sound source for guns fired only in 2021.

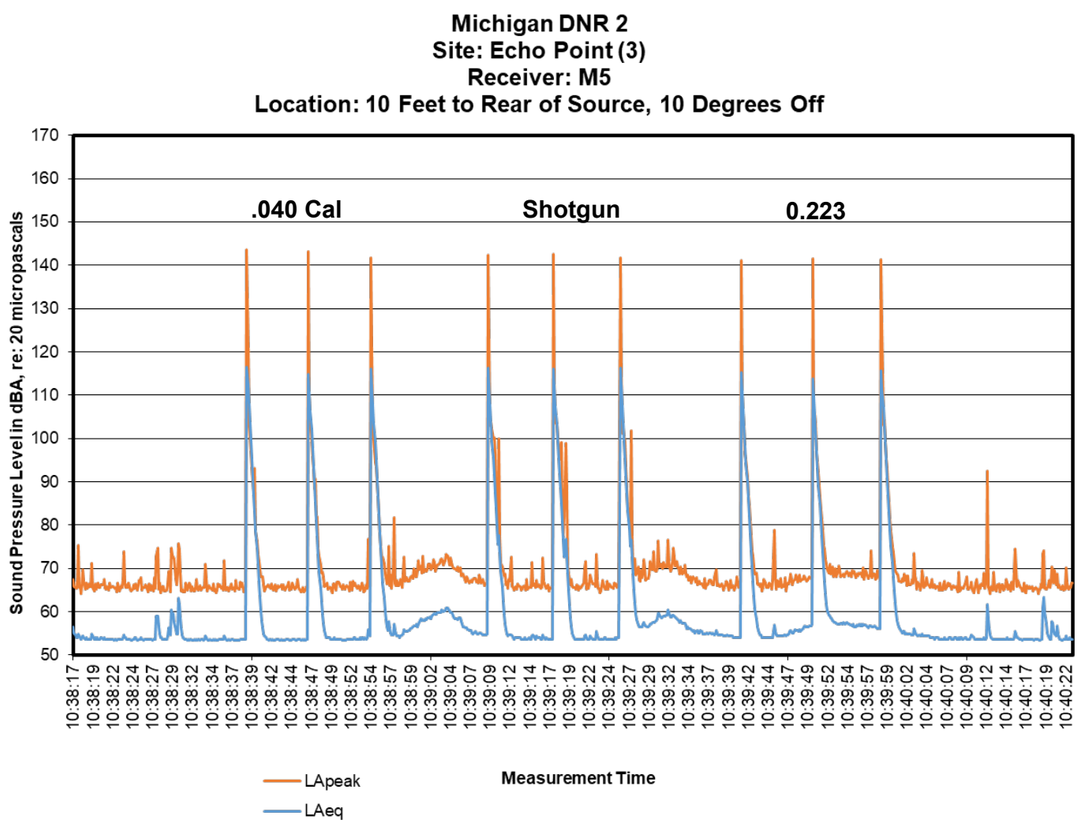
Peak sound pressure levels (dBA) of gun shots near the source				
Location of Microphone	**0.38 Caliber Handgun**	**450 Bushmaster**	**0.308 Rifle**	**0.308 Rifle from Pistol Shed**
	2021	**2021**	**2021**	**2021**
10 ft in front of the source and 10 degrees off axis(D.O.F.)	142-144	160	153-156	153-155
10 ft. to the right of the source	138-139	143-144	137-139	138-139
10 ft. behind the source	137-138	147	139-141	139
10 ft. to the left of the source	148-149	153	149	148-149
4 ft. to the right of the source	148-149	154	147-148	148

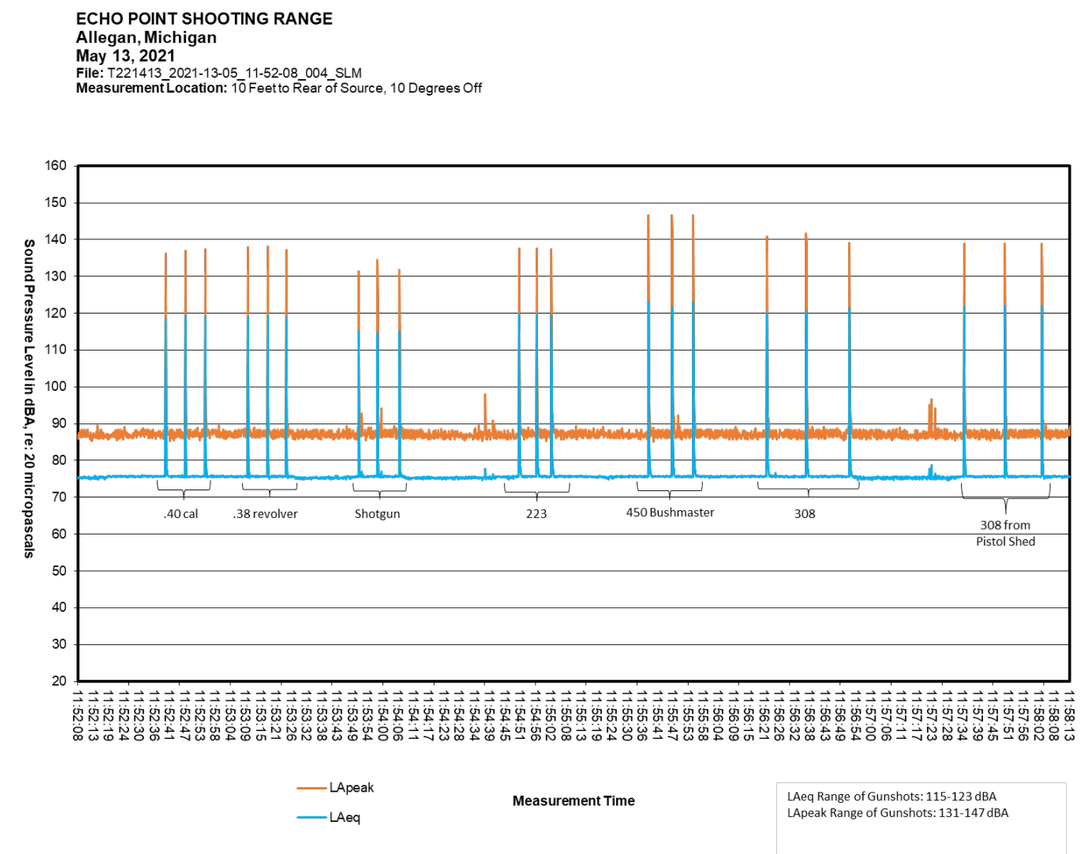

Michigan DNR 2
Site: Echo Point (3)
Receiver: M1
Location: 10 Feet In Front of Source, 10 Degrees Off Axis
.040 Cal
Shotgun
0.223
Sound Pressure Level in dBA, re: 20 micropascals
Measurement Time
LApeak
LAeq
LAeq Range of Gunshots: 129-135 dBA
LApeak Range of Gunshots: 154-162 dBA

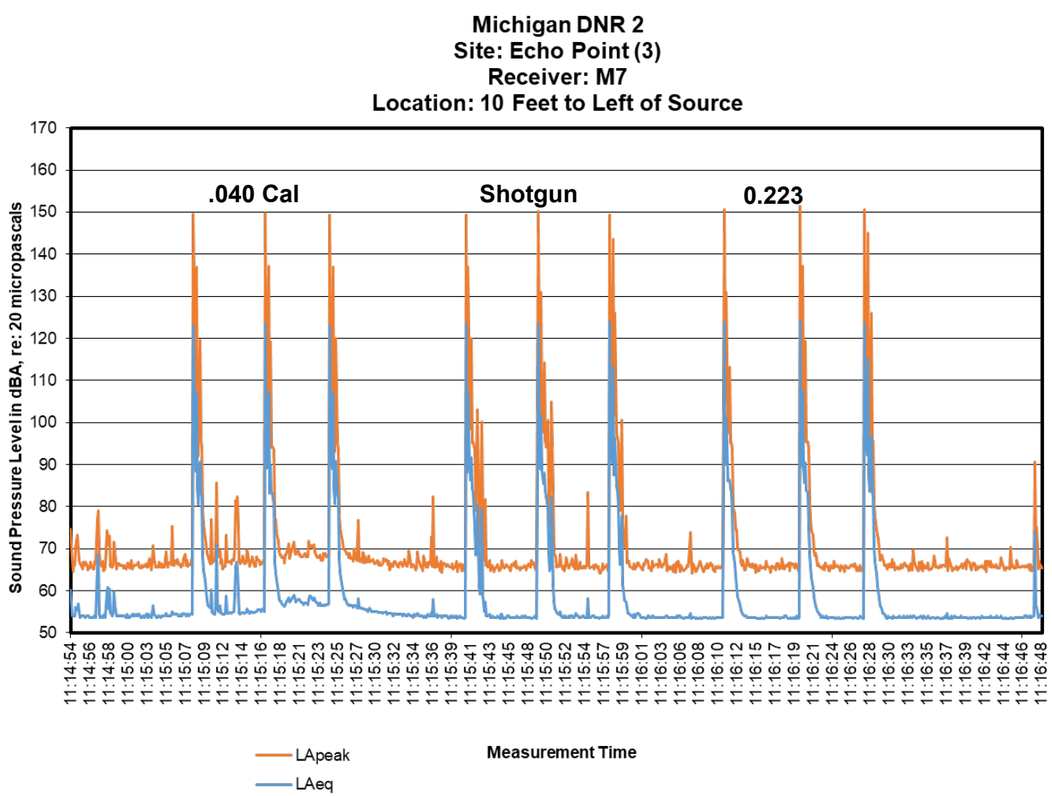

ECHO POINT SHOOTING RANGE
Allegan, Michigan
May 13, 2021
File: T221413_2021-13-05_09-47-32_001_SLM
Measurement Location: 10 Feet in Front of Source, 10 Degrees Off Axis
Talking
Talking
.40 cal
.38 revolver
Shotgun
223
450 Bushmaster
308
308 from Pistol Shed
Sound Pressure Level in dBA, re: 20 micropascals
Measurement Time
LApeak
LAeq
LAeq Range of Gunshots: 121-130 dBA
LApeak Range of Gunshots: 141-160 dBA

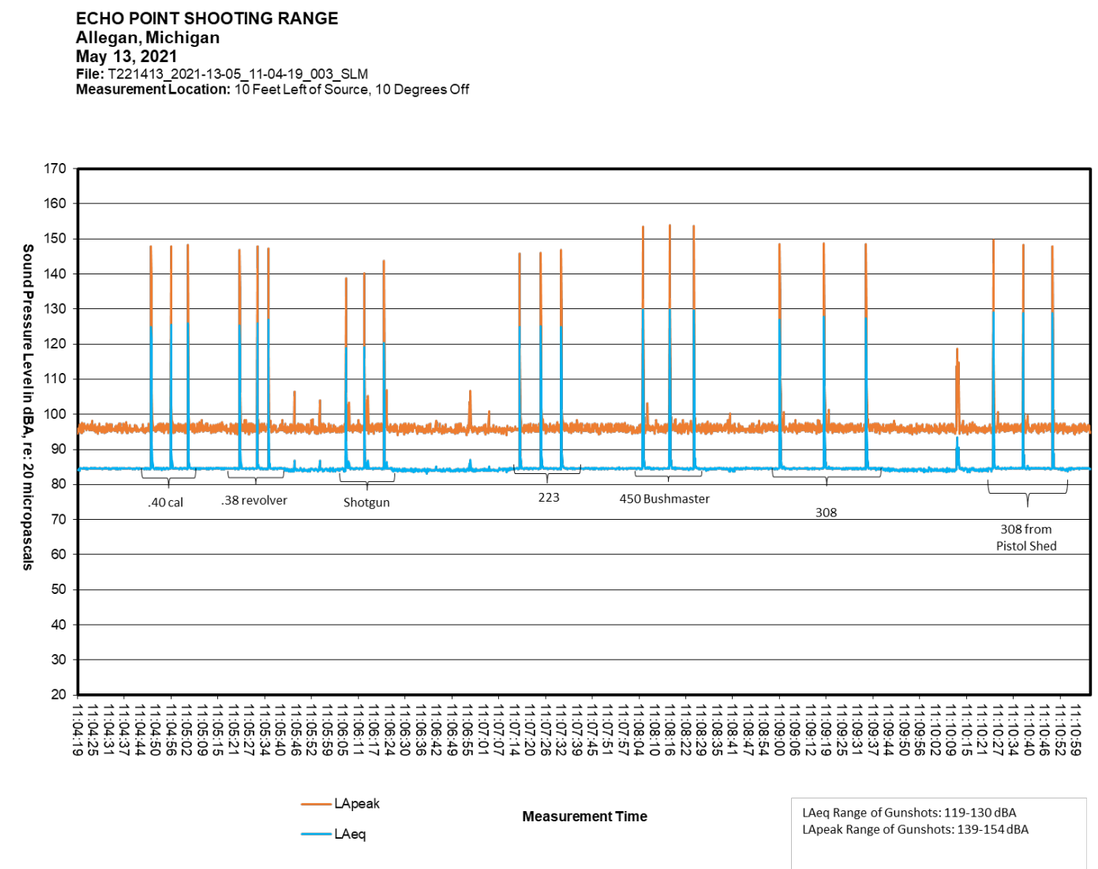

Michigan DNR 2
Site: Echo Point (3)
Receiver: M3
Location: 10 Feet to the Right of Source
.040 Cal
Shotgun
0.223
Sound Pressure Level in dBA, re: 20 micropascals
Measurement Time
LApeak
LAeq


ECHO POINT SHOOTING RANGE
Allegan, Michigan
May 13, 2021
File: T221413_2021-13-05_10-26-29_002_SLM
Measurement Location: 10 Feet to the Right of Source, 10 Degrees Off
Talking
.38 revolver
Shotgun
223
450 Bushmaster
308
308 from Pistol Shed
.40 cal
Sound Pressure Level in dBA, re: 20 micropascals
Measurement Time
LApeak
LAeq
LAeq Range of Gunshots: 114-121 dBA
LApeak Range of Gunshots: 134-144 dBA

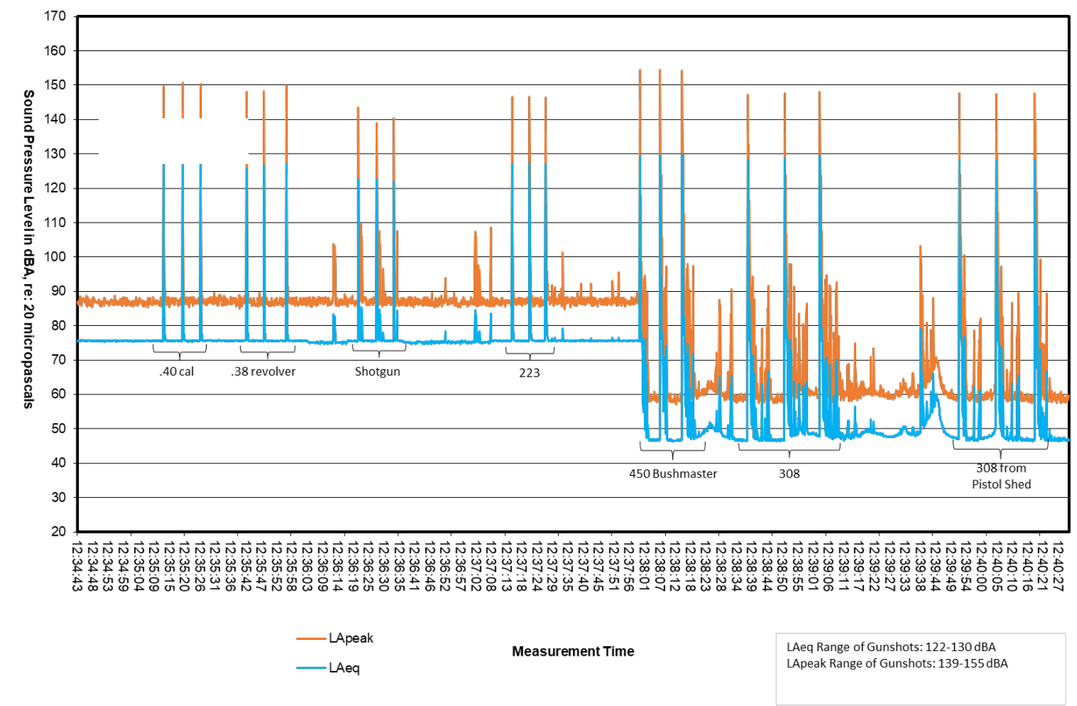

Michigan DNR 2
Site: Echo Point (3)
Receiver: M5
Location: 10 Feet to Rear of Source, 10 Degrees Off
.040 Cal
Shotgun
0.223
Sound Pressure Level in dBA, re: 20 micropascals
Measurement Time
LApeak
LAeq


ECHO POINT SHOOTING RANGE
Allegan, Michigan
May 13, 2021
File: T221413_2021-13-05_11-52-08_004_SLM
Measurement Location: 10 Feet to Rear of Source, 10 Degrees Off
Sound Pressure Level in dBA, re: 20 micropascals
.40 cal
.38 revolver
Shotgun
223
450 Bushmaster
308
308 from Pistol Shed
Measurement Time
LApeak
LAeq
LAeq Range of Gunshots: 115-123 dBA
LApeak Range of Gunshots: 131-147 dBA


Michigan DNR 2
Site: Echo Point (3)
Receiver: M7
Location: 10 Feet to Left of Source
.040 Cal
Shotgun
0.223
Sound Pressure Level in dBA, re: 20 micropascals
Measurement Time
LApeak
LAeq


ECHO POINT SHOOTING RANGE
Allegan, Michigan
May 13, 2021
File: T221413_2021-13-05_11-04-19_003_SLM
Measurement Location: 10 Feet Left of Source, 10 Degrees Off
Sound Pressure Level in dBA, re: 20 micropascals
.40 cal
.38 revolver
Shotgun
223
450 Bushmaster
308
308 from Pistol Shed
Measurement Time
LApeak
LAeq
LAeq Range of Gunshots: 119-130 dBA
LApeak Range of Gunshots: 139-154 dBA

ECHO POINT SHOOTING RANGE
Allegan, Michigan
May 13, 2021
File: T221413_2021-13-05_12-34-43_005_SLM
Measurement Location: 4 Feet to Right of Source, 10 Degrees Off
Notes: Shots Audible



LAeq Range of Gunshots: 122-130 dBA
LApeak Range of Gunshots: 139-155 dBA

APPENDIX C: SUMMARY AND GRAPHS OF SOUND LEVELS MEASURED AT DISTANCES OF APPROXIMATELY ¼ MILE, ½ MILE, 1 MILE AND 2 MILES FROM THE RANGE DURING THE LIVE FIRE EXERCISES IN 2016 AND 2021

Table C.1 Average and Peak Sound Pressure Levels (dBA) Measured at Locations Away from the Range in 2016 and 2021

Pistol							
		Laeq			Lapeak		
Location	Distance	Old	New	Difference	Old	New	Difference
1M	0.2m N	56-57 dBA	57-60 dBA	-1 to -3 dBA	68-71 dBA	69-72 dBA	-1 dBA
2M	0.25m E	72-73 dBA	65-66 dBA	-7 dBA	95-97 dBA	78-80 dBA	-17 dBA
2T	0.25m SE	61-64 dBA	47-49 dBA	-14 to -15 dBA	75 dBA	58-61 dBA	-14 to -17 dBA
4M	0.25m W	59-60 dBA	49-51 dBA	-9 to -10 dBA	72-77 dBA	58-62 dBA	-14 to -15 dBA
5M	0.5m N	52-54 dBA	45-52 dBA	-2 to -7 dBA	62-68 dBA	56-62 dBA	-6 dBA
6M	0.5m E	-	49-57 dBA	-	-	61-66 dBA	-
7T	0.5m SW	57-59 dBA	31-40 dBA	-19 to -26 dBA	73-75 dBA	-	-
8M	0.5 W	54-56 dBA	-	-	68-69 dBA	-	-
10M	1M N	-	48-50 dBA	-	-	56-59 dBA	-
11M	1M E	-	-	-	-	-	-
13 New	1M S	53-60 dBA	38-43 dBA	-15 to -17 dBA	66-76 dBA	-	-
14M	1M W	46 dBA	-	-	60-64 dBA	-	-
15M	2M N	-	35-38 dBA	-	-	-	-
16M	2M E	-	-	-	-	-	-
17M	2M S	48-50 dBA	-	-	59-61 dBA	-	-
18M	2M W	46-48 dBA	-	-	58-61 dBA	-	-

Table C.2 Average and Peak Sound Pressure Levels (dBA) Measured at Location Away from the Range in 2016 and 2021.

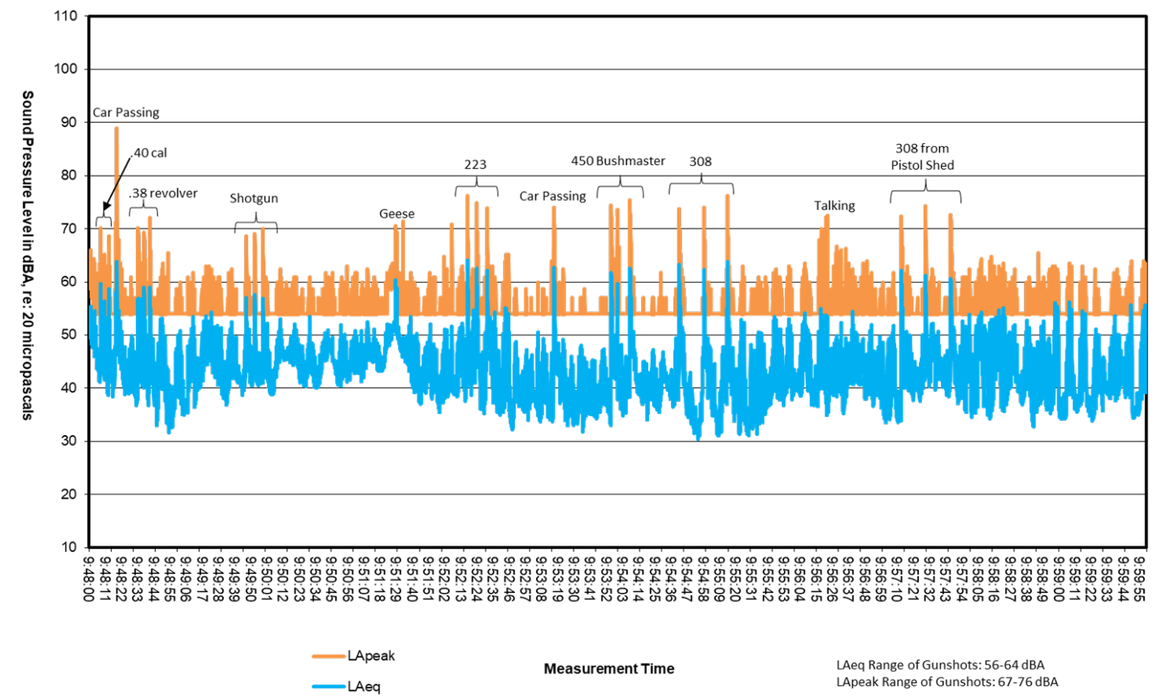
Shotgun							
		Laeq			Lapeak		
Location	Distance	Old	New	Difference	Old	New	Difference
1M	0.2m N	58-59 dBA	57-58 dBA	-1 dBA	70-72 dBA	69-70 dBA	-1 to -2 dBA
2M	0.25m E	73-75 dBA	62-64 dBA	-11 dBA	92-97 dBA	74-76 dBA	-18 to -19 dBA
2T	0.25m SE	61-64 dBA	48-49 dBA	-13 to -15 dBA	74-77 dBA	58-60 dBA	-16 to -17 dBA
4M	0.25m W	62-65 dBA	-	-	73-76 dBA	-	-
5M	0.5m N	57-59 dBA	45-48 dBA	-11 to -12 dBA	68-70 dBA	58 dBA	-10 to -12 dBA
6M	0.5m E	-	-	-	-	-	-
7T	0.5m SW	57-59 dBA	29-33 dBA	-18 to -26 dBA	70-74 dBA	-	-
8M	0.5 W	53-55 dBA	-	-	66-69 dBA	-	-
10M	1M N	-	45-51 dBA	-	-	57-59 dBA	-
11M	1M E	-	-	-	-	-	-
13 New	1M S	62-65 dBA	38-43 dBA	-22 to -24 dBA	75-77 dBA	-	-
14M	1M W	48-49 dBA	-	-	59-65 dBA	-	-
15M	2M N	-	35-39 dBA	-	-	-	-
16M	2M E	-	-	-	-	-	-
17M	2M S	56-58 dBA	-	-	69-70 dBA	-	-
18M	2M W	44-49 dBA	-	-	58-64 dBA	-	-

Table C.3 Average and Peak Sound Pressure Levels (dBA) Measured at Locations Away from the Range in 2016 and 2021.

Rifle							
		Laeq			Lapeak		
Location	Distance	Old	New	Difference	Old	New	Difference
1M	0.2m N	58-59 dBA	60-64 dBA	-2 to -5 dBA	69-71 dBA	72-76 dBA	+3 to +5 dBA
2M	0.25m E	73-78 dBA	68-73 dBA	-5 dBA	97-103 dBA	78-86 dBA	-17 to -19 dBA
2T	0.25m SE	67 dBA	52-56 dBA	-11 to -15 dBA	79-80 dBA	63-69 dBA	-11 to -16 dBA
4M	0.25m W	65 dBA	55-61 dBA	-4 to -10 dBA	79-81 dBA	65-69 dBA	-12 to -14 dBA
5M	0.5m N	57-58 dBA	49-57 dBA	-1 to -8 dBA	68 dBA	61-72 dBA	+4 to +7 dBA
6M	0.5m E	-	56-64 dBA	-	-	65-73 dBA	-
7T	0.5m SW	62-71 dBA	34-42 dBA	-28 to -29 dBA	75-89 dBA	-	-
8M	0.5 W	57-60 dBA	-	-	70-76 dBA	-	-
10M	1M N	-	47-57 dBA	-	-	57-66 dBA	-
11M	1M E	46-47 dBA	45-50 dBA	+1 to +3 dBA	56-59 dBA	56-62 dBA	0 to +3 dBA
13 New	1M S	58-60 dBA	37-45 dBA	-15 to -21 dBA	69-78 dBA	53-56 dBA	-16 to -22 dBA
14M	1M W	50-53 dBA	-	-	65-70 dBA	-	-
15M	2M N	-	41-48 dBA	-	-	53-60 dBA	-
16M	2M E	-	-	-	-	-	-
17M	2M S	51-62 dBA	-	-	64-78 dBA	-	-
18M	2M W	49-52 dBA	-	-	60-68 dBA	-	-

Michigan DNR 2
Site: Echo Point
Receiver Location: 1M
September 28, 2016

Michigan DNR 5
Site: Allegan Echo Point
Receiver Location: 1M
May 13, 2021



0.25 miles NNW of range Boat Launch.

1M – Boat Launch