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February 2, 2018

Ms. Lori Burford
Michigan Department of Natural Resources Shooting Range and Facilities Analyst
Roscommon Customer Service Center
8717 North Roscommon Road
Roscommon, Michigan 48653

Dear Lori:

Enclosed please find one bound and one loose copy of our *Sound Study for the Proposed Firing Ranges* report at the Barry State Game Area in Barry, Michigan. The report contains a summary of baseline ambient sound level measurements made at the 2 sites; a summary of sound levels measured during shooting exercises at each site with 3 weapons; a 0.40 caliber handgun, a 12 gauge shotgun and a 0.223 rifle; and sound levels calculated at locations within two miles of the approximate center of the 2 proposed sites for a firing range with berms on 3 sides and a canopy over the firing line; and several noise mitigation options for the ranges. Rank ordering of the relative magnitude of potential noise impacts for the base range locations; orientation of the direction of fire of the range; and a variety of noise mitigation options for each range location are also presented.

The report contains an executive summary of the results, background information relevant to the acoustical analysis; a description of the methods used to conduct the measurements and analysis; aerial maps showing the measurements and results of the computer analysis; and rank ordering of the relative magnitude of potential noise impacts for the range location, orientation and design alternatives considered.

Please do not hesitate to contact us if you have any questions regarding the findings of our analysis or if we can be of additional assistance in this regard.

Sincerely,
SIEBEIN ASSOCIATES, INC.

Gary W. Siebein, FAIA, FASA
Senior Principal Consultant

SOUND STUDY

for the

PROPOSED SHOOTING RANGE SITES

Barry 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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INTRODUCTION

This report contains the results of a sound study for 2 proposed sites for a new firing range located in the Barry Game Area in Barry, Michigan. The report includes a summary of baseline acoustical measurements taken at 2 locations near each of the proposed sites; a summary of acoustical measurements of firearms discharges at each site at distances of up to 2 miles from the proposed range locations; and computer analysis of “typical day” firearms discharges at each of the sites. Noise contours are mapped for a base range design and several design alternatives to show the effects of various noise mitigation designs at each site. The acoustical analysis of ranges located at each site consisted of the use of a “typical day” scenario (1-second sound exposure levels) with 11 people shooting within a 1 second time period: 5 people firing 0.223 rifles on the 100 yard range, 1 person firing a 0.223 rifle on the 150 yard range; 2 people firing 12 gauge shotguns on the 50 yard range, and 3 people firing 0.40 caliber handguns on the 25 yard range. Computer models using CADNA-A 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. The effects of distance, molecular absorption, barriers, ground surfaces, non-deciduous vegetation and topography on a typical day (50^{o} F, 70% RH) were included in the analysis. Sound levels from the gunshots were estimated at locations within two miles of the approximate center of each site for two different proposed range locations. A rating system was used to rank the relative noise impacts for the range locations, orientations and design features on properties. Alternate configurations of the ranges were studied and rank ordering of the relative magnitude of potential noise impacts of the location, orientation and noise mitigation options for the range on adjoining properties are provided. Budget construction costs for the range noise mitigation features are also provided.

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EXECUTIVE SUMMARY

Sound studies were conducted for one existing shooting range site: Site 1 at the Barry State Game Area located east of North Yankee Springs Road and south of North Middleville Road; and Site 2 which is an alternate site in the Barry State Game Area called Chief Noonday, located south of Chief Noonday Road.

1. Existing ambient sound levels were measured at 2 locations near potential noise sensitive receivers located near each proposed range site from September 27 to October 2, 2016. Existing ambient sound levels at the sites varied from 16 to 79 dBA with average Day-Night Sound Levels (LDN) of 47 to 59 dBA.

2. Experiments were conducted at each proposed range site on September 27 and 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 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 2 prospective sites for the firing range.

3. The sound levels measured at 10 feet from the source were approximately 4 to 5 dB louder in the direction of fire than to the sides and 12-13 dB louder in the direction of fire than behind the shooter for the 0.40 caliber handgun; approximately 6 to 7 dB louder in the direction of fire than to the sides and 13 to 15 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun; and approximately 6 to 8 dB louder in the direction of fire than to the sides and 18 to 20 dB louder in the direction of fire than behind the shooter for the 0.223 rifle.

4. At 62% of the measurement locations at distances of 1 to 2 miles from the proposed range site the sounds of the gun shots could not be measured above the ambient sound levels. Average LAeq, maximum LA max and peak LA peak sound levels were measured at the 16 locations around each of the proposed range sites. The LA max levels were on average 1 dB less than the LAeq levels. The LA peak levels were 12.5 dB louder than the LAeq levels.

5. Measured sound levels were approximately 6 to 15 dB louder in the direction of fire compared to the same distances at the sides of the shooter and 15 to 25 dB louder in the direction of fire than behind the shooter at distances of ¼ and ½ mile from the proposed range location.

6. The average sound decay with distance measured from the proposed range sites was 3 to 5 dB per doubling of distance from the sound source. This was affected by distance and localized conditions of wind, topography, ground cover and vegetation at each site.

7. Computer models of each of the proposed range sites were constructed in CADNA Software including topography, roads, ground cover, coniferous vegetation with the 8 ft. tall berms on the 2 sides of the ranges, a 20 ft. tall berm on the downrange side of the range and an open structure over the firing line for a standard day with 50°F and 70% relative humidity with typical wind speed and direction.

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

9. A point scale was used to assess potential noise impacts that accounted for the sound pressure at each house within a 2 mile radius of each of the proposed range sites and the number of dwellings impacted by the sounds. The sound pressure derived from the average sound level calculated in the noise modeling software was multiplied by the number of dwelling units within each 5 dB group of noise contour lines. For example, if 20 dwellings were located between the 30 and 35 dBA noise contours the points were calculated by the following method. The average sound level in this contour range is 32.5 dBA. The sound pressure associated with this value is 10^(32.5/10). This value was multiplied by the number of dwellings identified in GIS software by DNR staff to arrive at a linear pressure score for these contours. The linear pressure was divided by 100,000 to arrive at a scale that ranged from 494 to 182,395 for the alternatives studied. The values for each of the 5 dB groups of noise contours were added together to reach the cumulative linear pressure score for the scenario. Scenarios with lower numbers of points have lower cumulative noise impacts for the scenario.

10. Two sites and range orientations were initially selected for analysis. Site 1: Barry State Game Area Existing Range Site with the rifle range oriented towards the west-southwest and the shorter range oriented towards the east-southeast; and Site 2: Barry State Game Area Chief Noonday Site with the range oriented towards the south. The computer model analysis of these sites is summarized in Appendix F with 8 ft. tall berms on the 2 down range sides of the range and a 20 ft. tall downrange berm. Site 2 had the lowest linear pressure score of 9,626 followed by Site 1 with a linear pressure score of 71,150. The linear pressure scores decreased for both sites as the heights of the berms surrounding the ranges were increased.

11. Alternate orientations were selected for each range to reduce potential noise impacts to residential properties within 2 miles of each proposed range site. The alternate range orientation to minimize potential noise impacts to residential and noise sensitive receivers was oriented towards the southwest for Site 1: Barry State Game Area Existing Range Site; and oriented towards the east for Site 1; and oriented towards the southwest for Site 2: Barry State Game Area Chief Noonday Site.

12. Site 2 oriented towards the southwest had the lowest linear pressure score of the 5 alternatives followed closely by Site 2 oriented towards the south. The linear pressure scores for the orientations for Site 1, the existing range at the Barry State Game Area, were significantly higher than the linear pressure scores for Site 2 for the base range design with the 8 ft. berm on the 2 sides of the range and a 20 ft. tall berm on the downrange side of the range.

13. Models were tested using 20 ft. tall and 30 ft. tall berms in addition to the 8 ft. tall side berms and 20 ft. tall downrange berm for each of the range sites and orientations. These studies are reported in Appendix G. The lowest scores for a given range and orientation were generally received by the scheme with the tallest berm height. The relative ranking of sites was similar to those previously discussed with Site 2 oriented to the southwest and Site 2 oriented to the south receiving the lowest

linear pressure scores for a given berm height. These sites were followed by Site 1 oriented to the SW with almost 10 times the linear pressure score of the Site 2 ranges. The highest scores for these tests were for all berm heights and orientations at Site 1: the existing range site at the Barry State Game Area.

14. Studies with alternate air temperatures and relative humidities (Appendix H); alternate wind conditions (Appendix I); and the addition of the existing stands of coniferous trees (Appendix J) on the sites verified that the assumptions made in the model studies represented a conservative approach to the noise contour mapping for the proposed range. This means that the mapped noise contours represent a worst case condition in terms of the effects of temperature, humidity, wind and vegetation on the modeled noise contours.

15. Experiments were conducted in computer models of noise mitigation options that could be considered for the ranges if needed in the future. Order of magnitude costs for the mitigation options were also presented in Appendix R. The noise mitigation options studied included raising the height of the down range berms to 20 ft. tall and 30 ft. tall at cost increases of approximately $235,700 for the 20 ft. tall berm compared to the 8 ft. tall berm; and approximately $676,200 for the 30 ft. tall berm compared to the 8 ft. tall berm. These studies are summarized in Appendices F and G.

16. A U-shaped berm built around the rear of the range to reduce sounds spilling to the rear and sides of the range was investigated in computer model studies summarized in Appendix K. The linear pressure score was reduced by 61% to 76% by adding these U-shaped berms that were 20 ft. tall and 30 ft. tall at an incremental cost increase of approximately $113,900 for a total cost increase of $349,600 for the 20 ft. berm scheme and $493,100 for a total cost increase of $1,169,300 for the 30 ft. tall berm scheme over the base range design.

17. Adding solid dividers between each lane in the range building and lining the walls and ceiling of each lane with sound absorbent panels such as Troy Acoustics Troy Board will reduce the linear pressure score at Site 2 by approximately 84% to 86% and by approximately 37% to 52% at Site 1 at a cost of approximately $85,900 as summarized in Appendix L.

18. Additional mitigation options studied included adding solid walls at the sides and rear of the range building lined with the sound absorbent panels; extending the roof of the range building 40 ft. downrange from the firing line and adding a sound absorbent inner lining to the roof; building a U-shaped berm around the rear of the range and raising the height of the berms on all sides to 20 ft. and 30 ft. respectively. These options are described in Appendices M through O. These options reduced the linear pressure score between 37% and 95% compared to the base range with the 8 ft. tall berm on 2 sides and 20 ft. berm downrange and the open range structure depending upon the combination of options selected. Incremental costs for these options varied from approximately $134,500 for adding the side and rear walls of the range building; approximately $309,600 for adding the 40 ft. roof extension; approximately $113,900 for adding the 20 ft. tall U-shaped berm at the rear of the range; approximately $493,100 for adding the 30 ft. tall U-shaped berm at the rear of the range; and approximately $1,613,40 for the combination of all of these options.

19. The use of the noise mitigation options should be carefully considered for a given site because there are site specific limitations on how much reduction in linear pressure score can be obtained at any given site for a specific mitigation scheme.

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 pressure level for a gun shot. The maximum A-weighted sound level or LAmax is the greatest sound level measured using the 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.

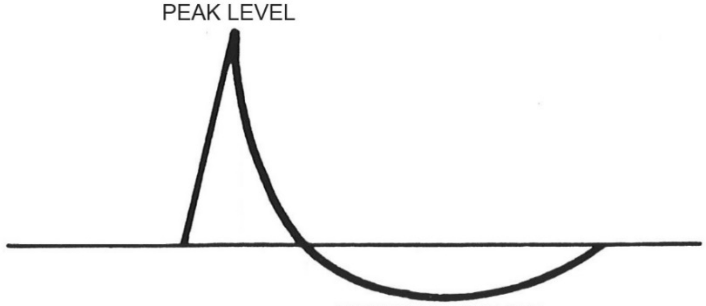


Figure 1. Amplitude or loudness plotted vs time for a typical impulsive sound like a gunshot.

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

Sound level 1	Sound level 2	Combined sound level	Explanation
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 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.

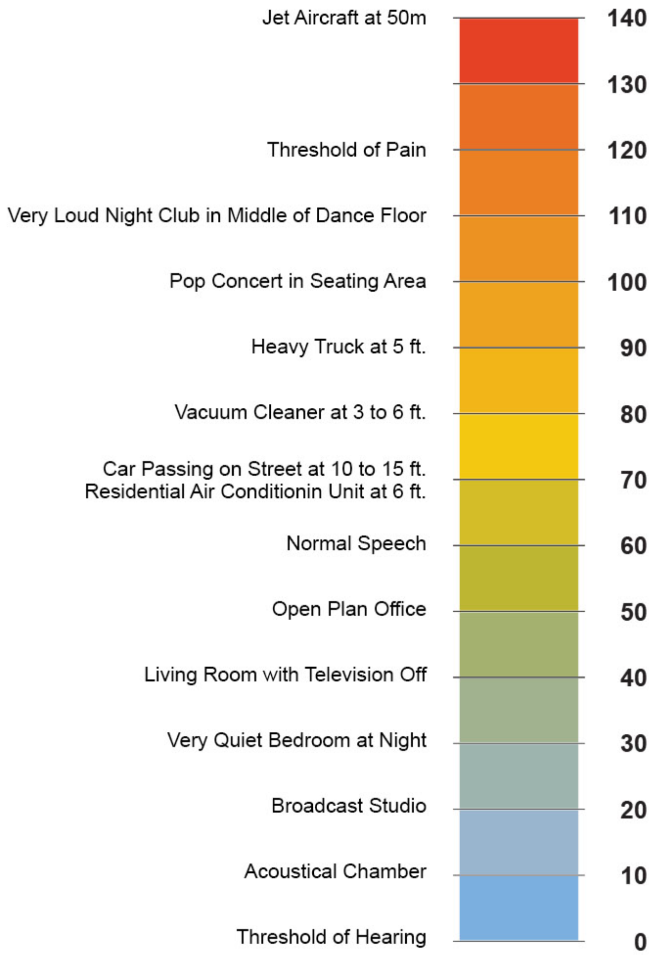


Figure 2. Acoustical thermometer showing the relative loudness in dBA of various sounds.

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 2 sites. Long term measurements of base line ambient sounds were also made at 2 locations at each of the sites for approximately 1 week at each of the four locations.

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 2 proposed firing range sites. Measurements were also made at 16 receiver locations located at distances of ¼ mile, ½ mile, 1 mile and 2 miles from the proposed range sites at locations around the range sites at which the gunshots were audible above the background noise levels and were able to be measured. These locations are shown in Appendices C and D. GPS coordinates of the measurement locations are shown in Appendix Q. Sound levels measured at each of the source locations are shown on diagrams of each site in Appendix B.

The measurements were recorded at the location of the shooter and at 16 locations at increasing distances and varying directions from the site. A summary of sound levels measured at 10 feet from the shooter at each site is contained in Appendix B. Table summaries and aerial photographs of each proposed site and its surroundings showing the sound levels measured at distances away from the range sites are contained in Appendices C and D. Graphs showing average and peak sound levels for each of the measurements are contained in Appendix S. Four Larson Davis Model 831 sound level meters and one 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 (^{o} F), relative humidity (%), barometric pressure (inches of mercury (Hg)), 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 P of this report.

Three rounds in succession were fired from a Sig Sauer P229 0.40 caliber handgun with Federal hollow point ammunition; a Remington 870 12 gauge shotgun using Federal 2-3/4” 1 oz. rifled flue shots; and a Colt M4 223 semi-auto rifle using 0.223 55 grain full metal jacket ammunition at each of the 2 proposed range locations while sound levels were recorded with the Cesva meter near the source and with the 4 Larson Davis 831 meters at the 16 receiver locations located at distances away from each of the proposed range sites. The sequence of firing was repeated at each of the receiver locations and then repeated at each of the sites.

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 each of the proposed range sites with 3 Rion NL-32 and 1 Rion NL-52 integrating sound level meters. The Rion equipment meets ANSI 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 and 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 approximately 7 days 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) and fast maximum A-weighted sound level (LAF max) plotted vs. time for each 7 day time period are shown in Appendix T. A tabular summary of the data is provided in Appendix A along with aerial photographs of the 2 proposed range sites showing the measurement locations and 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 each of the proposed range sites at locations near potential noise sensitive receivers from September 27 and 28, 2016. Figures A-1 and A-2 in Appendix A show an aerial photograph of the area around each proposed range site with the ambient sound level measurement locations indicated on the site plan. The sound level meters were left unattended during the measurement time 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 of 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 each site are shown in Appendix T.

1. Existing ambient sound levels at Range Site 1, the existing range at the Barry State Game Area, varied from 16 to 68 dBA with average Day-Night Sound Levels (LDN) of 52 to 58 dBA. The ambient sound levels at Site 1 consisted of light to moderate traffic on North Yankee Springs Road; the breeze blowing through the trees; birds chirping; and the sounds of insects.

2. Existing ambient sound levels at Range Site 2 Chief Noonday varied from 29 to 79 dBA with average Day-Night Sound Levels (LDN) of 47 to 58 dBA. The ambient sound levels at Site 2 consisted of light to moderate traffic with trucks on South Yankee Springs Road and Chief Noonday Road; the breeze blowing through the trees and grasses; birds chirping; and the sounds of insects.

MEASURED SOUND LEVELS OF FIREARMS

Experiments were conducted at each proposed range site on September 27 and 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 proposed range site. A summary of sound levels of gun shots measured at 10 feet from the person shooting during the experiments at each proposed range site is presented in tabular and diagrammatic 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 2 prospective sites for the firing range. A summary of LAeq average and LA peak sound levels of gun shots measured at distances away from the 2 proposed range sites is presented in tabular and graphic formats in Appendix C for Site 1: Barry State Game Area Existing Range; and Appendix D for Site 2:Barry State Game Area Chief Noonday Site. Graphs of the average and peak sound levels recorded for each measurement are presented in Appendix S.

Summary of Measurements Made at the Source Locations

1. The sound levels measured at 10 feet from the source were approximately 4 to 5 dB louder in the direction of fire than to the sides and 12-13 dB louder in the direction of fire than behind the shooter for the 0.40 caliber handgun; approximately 6 to 7 dB louder in the direction of fire than to the sides and 13 to 15 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun; and approximately 6 to 8 dB louder in the direction of fire than to the sides and 18 to 20 dB louder in the direction of fire than behind the shooter for the 0.223 rifle.

2. The global average difference in LA peak sound levels for all firearms measured at 10 feet from the shooter was 5 to 6 dB less to the sides of the shooter and 16 dB less to the rear of the shooter compared to levels measured in the direction of fire.

3. LA peak sound levels of the 0.40 caliber handgun were measured at 154 dBA to 155 dBA at 10 feet in front of the shooter approximately 10^{o} off the axis of firing. The measured peak sound levels varied from 149 to 151 dBA to the sides of the shooter and 141 to 144 dBA behind the shooter.

4. LA peak sound levels of the 12 gauge shotgun were measured at 156 dBA to 158 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured peak sound levels varied from 149 to 152 dBA to the sides of the shooter and 141 to 144 dBA behind the shooter.

5. LA peak sound levels of the 0.223 rifle were measured at 159 dBA to 162 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured peak sound levels varied from 151 to 156 dBA to the sides of the shooter and 139 to 142 dBA behind the shooter.

6. LAeq average sound levels of the 0.40 caliber handgun were measured at 128 dBA to 129 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured LAeq sound levels varied from 123 to 125 dBA to the sides of the shooter and 115-118 dBA behind the shooter.

7. LAeq average sound levels of the 12 gauge shotgun were measured at 129 dBA to 133 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured LAeq sound levels varied from 122 to 125 dBA to the sides of the shooter and 116-119 dBA behind the shooter.

8. LAeq average sound levels of the 0.223 rifle were measured at 132 dBA to 136 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured LAeq sound levels varied from 124 to 128 dBA to the sides of the shooter and 114-118 dBA behind the shooter.

9. Therefore, the orientation of the direction of fire for the range will have a significant effect on sounds propagated away from the range site. The approximate 5 to 8 dB difference between sound levels propagated in the direction of fire compared to the sides of the shooter would be heard as noticeably quieter by people of normal sensitivities. The 12 to 20 dB difference in sound levels between the direction of fire compared to the rear of the shooter would be heard as ½ to almost ¼ as loud by people of normal sensitivities.

Summary of Measurements Made at 1/4 mile, 1/2 mile, 1 mile and 2 miles from the Two (2) Proposed Range Sites

1. At Site 1, in the existing range in Barry State Game Area, average (LAeq) and peak (LA peak) sound levels measured for the 0.40 caliber handgun at ¼ mile from the proposed range site varied from 55 to 73 dBA LAeq and 65 to 95 dBA LA Peak; 55 to 68 dBA LAeq and 70 to 85 dBA LA peak at ½ mile from the proposed range site; 54 to 57 dBA LAeq and 68 to 79 dBA LA peak at 1 mile from the proposed range site; and were not measurable at 2 miles from the proposed range site.

2. At Site 1, the existing range in the Barry State Game Area, average (LAeq) and peak (LA peak) sound levels measured for the 12 gauge shotgun at ¼ mile from the proposed range site varied from 52 to 76 dBA LAeq and 63 to 89 dBA LA Peak; 53 to 86 dBA LAeq and 64 to 96 dBA LA peak at ½ mile from the proposed range site; 54 to 61 dBA LAeq and 67 to 77 dBA LA peak at 1 mile from the proposed range site; and not measurable at 2 miles from the proposed range site.

3. At Site 1, the existing range in the in Barry State Game Area, average (LAeq) and peak (LA peak) sound levels measured for the 0.223 rifle at ¼ mile from the proposed range site varied from 57 to 74 dBA LAeq and 67 to 91 dBA LA Peak; 58 to 85 dBA LAeq and 67 to 97 dBA LA peak at

½ mile from the proposed range site; 54 to 59 dBA LAeq and 66 to 72 dBA LA peak at 1 mile from the proposed range site; and not measurable at 2 miles from the proposed range site.

4. At Site 2, Chief Noonday, average (LAeq) and peak (LA peak) sound levels measured for the 0.40 caliber handgun at ¼ mile from the proposed range site varied from 55 to 81 dBA LAeq and 67 to 101 dBA LA Peak; 47 to 63 dBA LAeq and 58 to 78 dBA LA peak at ½ mile from the proposed range site; 46 to 48 dBA LAeq and 58 to 59 dBA LA peak at 1 mile from the proposed range site; and 51 dBA LAeq and 63 dBA LA peak at 2 miles from the proposed range site.

5. At Site 2, Chief Noonday, average (LAeq) and peak (LA peak) sound levels measured for the 12 gauge shotgun at ¼ mile from the proposed range site varied from 53 to 75 dBA LAeq and 63 to 89 dBA LA Peak; 51 to 59 dBA LAeq and 60 to 70 dBA LA peak at ½ mile from the proposed range site; 46 to 48 dBA LAeq and 59 to 62 dBA LA peak at 1 mile from the proposed range site; and not measurable at 2 miles from the proposed range site.

6. At Site 2, Chief Noonday, average (LAeq) and peak (LA peak) sound levels measured for the 0.223 rifle at ¼ mile from the proposed range site varied from 53 to 76 dBA LAeq and 62 to 95 dBA LA Peak; 50 to 65 dBA LAeq and 60 to 79 dBA LA peak at ½ mile from the proposed range site; 49 to 50 dBA LAeq and 60 to 63 dBA LA peak at 1 mile from the proposed range site; and 33 to 34 dBA LAeq at 2 miles from the proposed range site.

7. At 62% of the measurement locations at distances of 1 to 2 miles from the proposed range site the sounds of the gun shots could not be measured above the ambient sound levels. These measurements are indicated by an "x" in Table C-1 for Site 1; and Table D-1 for Site 2. The measurements are indicated by a N/A on the aerial photographs showing the measured sound levels in Appendices C and D.

8. Average LAeq, maximum LA max and peak LA peak sound levels were measured at the 16 locations around each of the 2 proposed range sites. The LA max levels were on average 1 dB less than the LAeq levels with a range of 0 to 2 dB because the LAeq measurements were taken at 100 ms. rather than 1 second as in previous studies. The LA peak levels were 12 to 15 dB louder than the LAeq levels for all sites, all locations and all weapon types with a range of 8 to 23 dBA. This smaller difference compared to previous studies was due to the use of 100 ms. averaging for the LA eq.

9. The measurements at Site 1 showed a 1 dB average difference between the LA max and LAeq with a range of 0 to 2 dB and 15 dB average difference between the LA peak and LAeq measurements with a range of 8 to 20 dB.

10. The measurements at Site 2 showed a 1 dB average difference between the LA max and LAeq sound levels with a 0 to 3 dB range and a 12.5 dB difference between the LA peak and LAeq sound levels with a range of 8 to 20 dB.

11. There was a 12 to 15 dB difference between LA peak and LAeq levels for the handgun to the front of the shooter, an 11 to 23 dB difference between LA peak and LAeq levels to the rear of the shooter for the handgun, and a 10 to 23 dB difference at the sides.

12. There was a 10 to 23 dB difference between LA peak and LAeq levels for the shotgun to the front of the shooter, a 5 to 17 dB difference between LA peak and LAeq levels to the rear of the shooter for the shotgun, and a 8 to 23 dB difference at the sides.

13. There was a 10 to 17 dB difference between LA peak and LAeq levels for the .223 rifle to the front of the shooter, a 10 to 19 dB difference between LA peak and LAeq levels to the rear of the shooter for the 0.223 rifle, and a 9 to 19 dB difference at the sides.

14. The average sound decay per doubling of distance from the source was measured at 4 dB for LA peak values at Site 1 and 3 dB for LAeq values at Site 1.

15. The average sound decay for each doubling of distance from the sound source for the LA peak values was 5 dB with 5 dB decay per doubling of distance for the LAeq values at Site 2.

THE COMPUTER MODEL STUDIES

Introduction

A series of computer model studies were designed and executed to study the propagation of sounds from the 2 proposed range sites at distances away from the proposed ranges. The models were constructed in the CADNA-A software package using topographic information from USGS maps and the GIS data base. A series of experiments were conducted to understand the relative differences between a number of variables including the location and orientation of the range, the height of berms, the number of people firing simultaneously (in the same 1 second time period), the configuration of the range structure, the addition of acoustical treatment to the range structure, the effects of different temperatures, wind, the presence of coniferous trees and combinations of these variables. The experiments are described in Appendices F through O. Noise contour plots for each of the options studied are also included in the appendices describing the experiment. The proposed base range design consists of 25 yard, 50 yard, 100 yard and 150 yard ranges surrounded by a berm. The ranges have approximately 8 ft. tall berms on two sides and 20 ft. tall berms downrange. There is an open structure that covers the firing line that has a wood roof/ceiling. The base range design selected by DNR was based on the proposed Michigan DNR range construction for the Grand Traverse County Shooting Range site. A diagram of the base range design is shown in Figure 3.

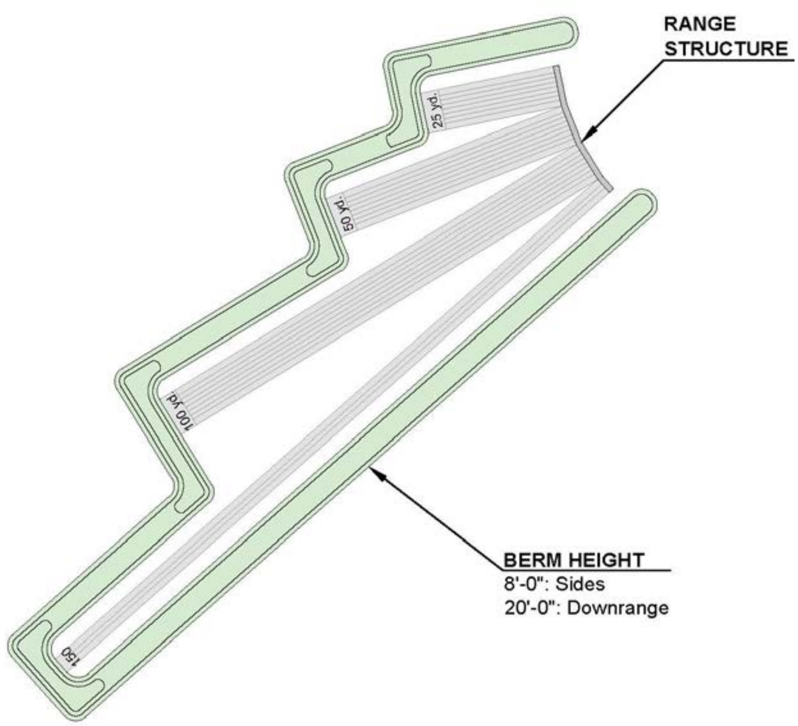


Figure 3. Concept diagram of the base range design.

Method

1. The analysis assumed a “typical day” with 11 shooters firing within a 1 second time period for the base range conditions with possibly up to 8 additional people on the range getting ready to fire, loading their weapons or talking with each other.

2. The “typical day” had 5 shooters firing .223 caliber rifles on the 100 yard range; 1 shooter firing a .223 caliber rifle on the 150 yard range; 2 shooters firing 12 gauge Remington shotguns on the 50 yard range; and 3 shooters firing 0.40 caliber handguns on the 25 yard range within a 1 second time period. The 8 other people on the range were assumed to be either watching, loading their weapons to get ready to fire or pausing in their firing during the 1 second time period studied. 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.

3. The 1 second LAeq data shown in the noise contour maps can be converted to LA max or LA peak data. On average, across all field measurements made in the study, the LA max was approximately 1 dB less than the LAeq with a range of 0 to 2 dB and the LA peak was 12 to 13 dB higher than the LAeq with a range of 8 to 23 dB.

4. Three dimensional computer models of the 2 proposed sites were constructed using AutoCAD software by drawing topographical ground elevations of the two sites extending approximately 2 miles from the approximate center of the firing ranges. The AutoCAD model was imported into CADNA-A software which is a state-of-the-art noise propagation modeling software.

5. The octave band sound pressure level data for the .223 rifles described above was used as the sound source for shooters on the 100 yard and 150 yard range. The octave band sound pressure level data for the 12 gauge Remington shotguns described above was used as the sound source for shooters on the 50 yard range. The octave band sound pressure level data for the 0.40 caliber handguns described above was used as the sound source for shooters on the 25 yard range. The computer sound propagation model was used to estimate the LAeq sound levels from the gunfire in all directions from the range with the following conditions taken into account.

   A. Number of shooters: “Typical day” 1 on the 150 yard range, 5 on the 100 yard range, 2 on the 50 yard range and 3 on the 25 yard range)
   B. Direction of fire relative to the receiver.
   C. The ranges have approximately 8 ft. tall berms on two sides and 20 ft. berms downrange. Subsequent modeling was completed with 20 ft. tall and 30 ft. tall berms in addition to the base range design. These experiments are described in Appendix F for the original sites and range orientations and in Appendix G for the alternate range orientations.

D. Molecular sound absorption for a standard day (50° F, 70%R.H.). Separate experiments were conducted with computer model runs using 70^o F and 50% R.H.; 50^{o}F and 50% R.H.; 32^o F and 50% R.H.; and 0^{o}F and 50% R.H. values to document the range of sound levels that would occur during different seasons of the year. The 50^o F and 50% Relative Humidity condition resulted in the highest sound levels at distances away from the ranges in the series of experiments described above. These experiments are described in Appendix H.
E. Anomalous excess attenuation (from small scale differences in wind, temperature, and humidity in the air).
F. The topographic features of the sites were developed using contour maps obtained from the United States Geological Survey.
G. CADNA-A assumes a downwind condition with wind velocity of 1 – 11 mph. An experiment was also conducted with average and maximum wind speeds and wind directions for each site. This experiment is described in Appendix I.
H. Vegetation (trees) was not included in the analysis. Areas of coniferous trees were added in Experiment 5 described in Appendix J.
I. Ground cover was modeled as pavement for paved roads, water in the lakes and grass for terrain covered with vegetation.
J. 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.
K. Separate computer model runs were conducted with the stands of coniferous trees included in the model and not included in the model to document the change in sound levels calculated at receiver locations due to the effects of coniferous trees. This experiment is described in Appendix J.
L. Noise mitigation options described in the Noise Mitigation section of the report were also modeled. The noise mitigation experiments are described in Appendices K through O.

6. The resulting sound levels at the proposed sites were plotted on scaled maps/aerial photographs of the sites identifying the 2 proposed sites with the initial range orientations as well as for alternate range orientations to the east and southwest for Site 1, and to the southwest for Site 2 in Appendices F and G.

7. A scaled map of the modeled configuration for the base range is shown in Figure 3.

8. The noise mitigation options studied include the following items.
   A. Alternate range orientations to the east and southwest for Site 1 and to the southwest for Site 2 in Appendix G. Concept plans for these arrangements are shown in Figure 4. This experiment is described in Appendix G.
   B. A U-shaped berm was added at the rear of the range at Site 1 with the alternate range orientations of east and southwest; and to the south and to the southwest for Site 2. The berm around the perimeter of the range and the U-shaped berm had heights of 20 ft. and 30 ft. tall and enclosed the back and part of the sides of the range. There is a passage on both sides of the range between the U-shaped berm and the berm protecting the main range that allows people to enter and leave the range. A concept plan for this experiment is shown in Figure 5. This experiment is described in Appendix K.

C. A sound absorbent, acoustical lining was added to the inside of the range structure on the underside of the roof and on the sides of partitions built between the lanes inside the range. A concept plan for this experiment is shown in Figure 6. The experiment was conducted for Site 1 with the alternate range orientations of east and southwest; and to the south and to the southwest for Site 2 with a 20 ft. berm height. The experiment is described in Appendix L.
D. Rear and side walls were added to the range structure at the proposed sites for the alternate range orientations at Site 1; and for the original and alternate range orientations for Site 2. The inside facing of the walls was with a sound absorbent liner. The berm height was 20 ft. A concept plan for this experiment is shown in Figure 7. The experiment is described in Appendix M.
E. A 40 ft. deep extension was added to the roof of the range extending from the firing line down range towards the target area for the 2 proposed sites for the alternate range orientations at Site 1 and for the original and alternate range orientations for Site 2 with a 20 ft. berm height. The underside of the roof extension is covered with a sound absorbent lining. A concept plan for this experiment is shown in Figure 8. The experiment is described in Appendix N.
F. A 30 ft. tall U-shaped berm is added to the rear of the range and a 40 ft. deep extension was added to the roof of the range extending from the firing line down range towards the target area at the three proposed sites for the alternate range orientation with a 20 ft. and 30 ft. berm height. The underside of the roof extension is covered with a sound absorbent lining. A concept plan for this experiment is shown in Figure 9. The experiment is described in Appendix O.

Site 1
Barry State Game Area

Site 2
Chief Noonday

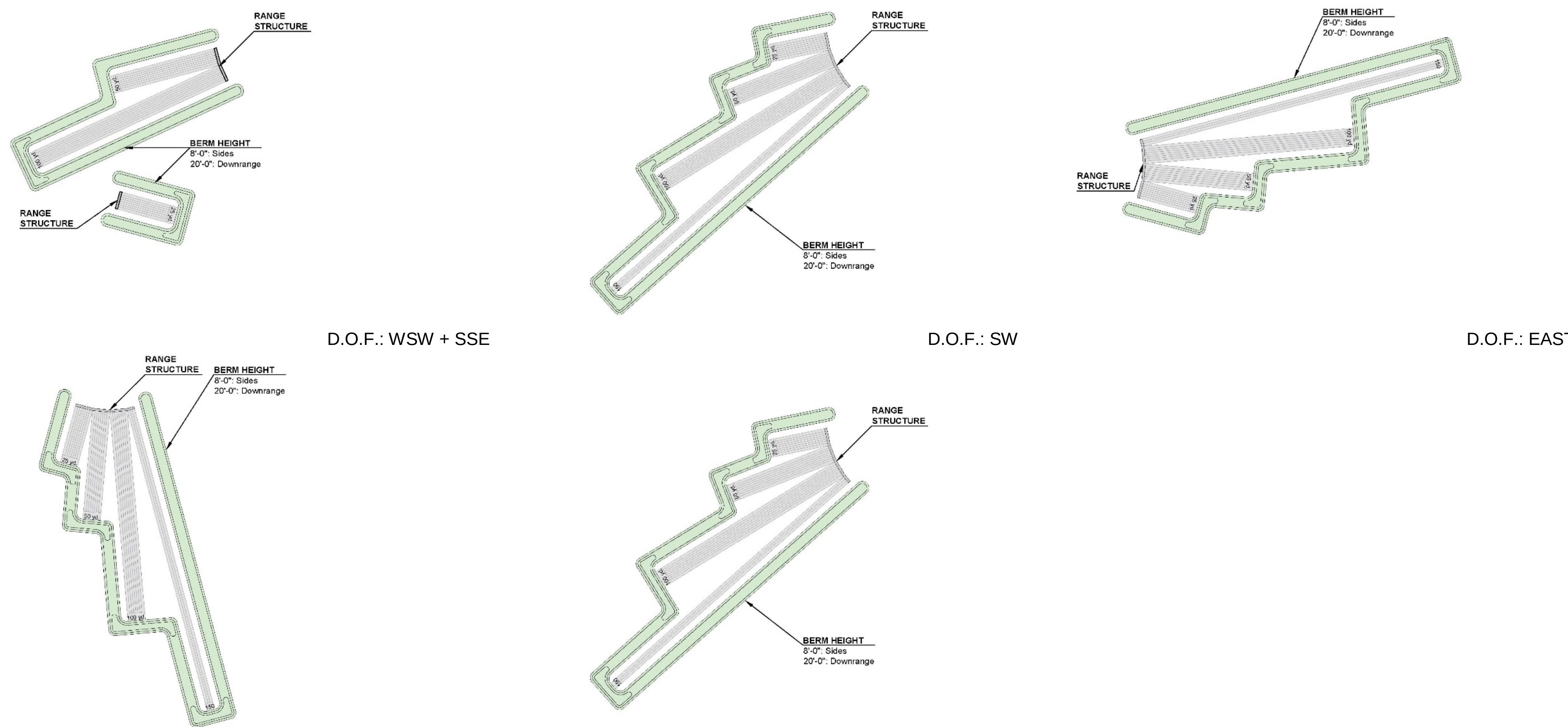


Figure 4.
Concept plans showing the original and alternate range orientations for the 2 range sites.

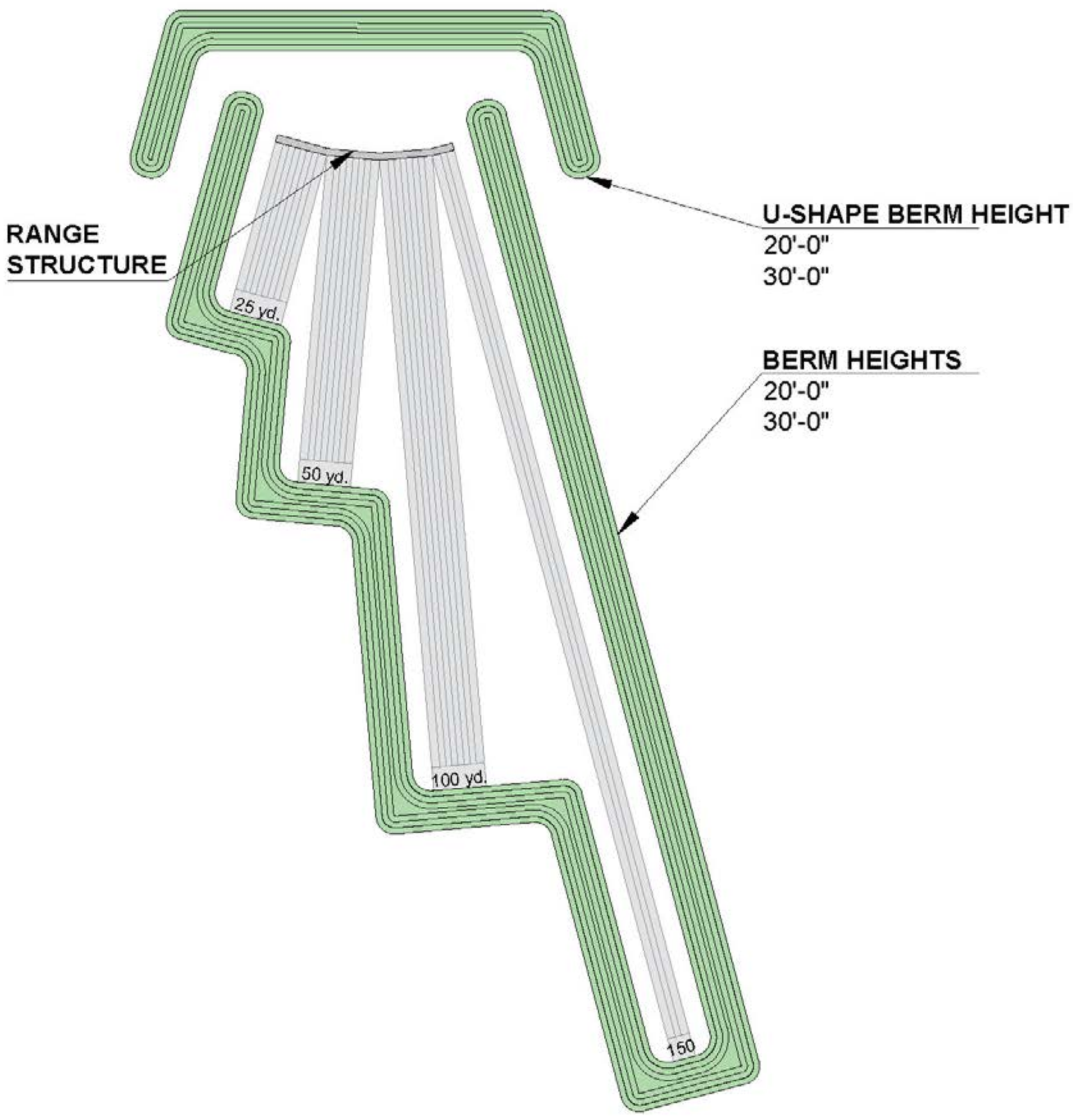


Figure 5. Concept plan showing the U-shaped berm configuration for the range described in Appendix K.

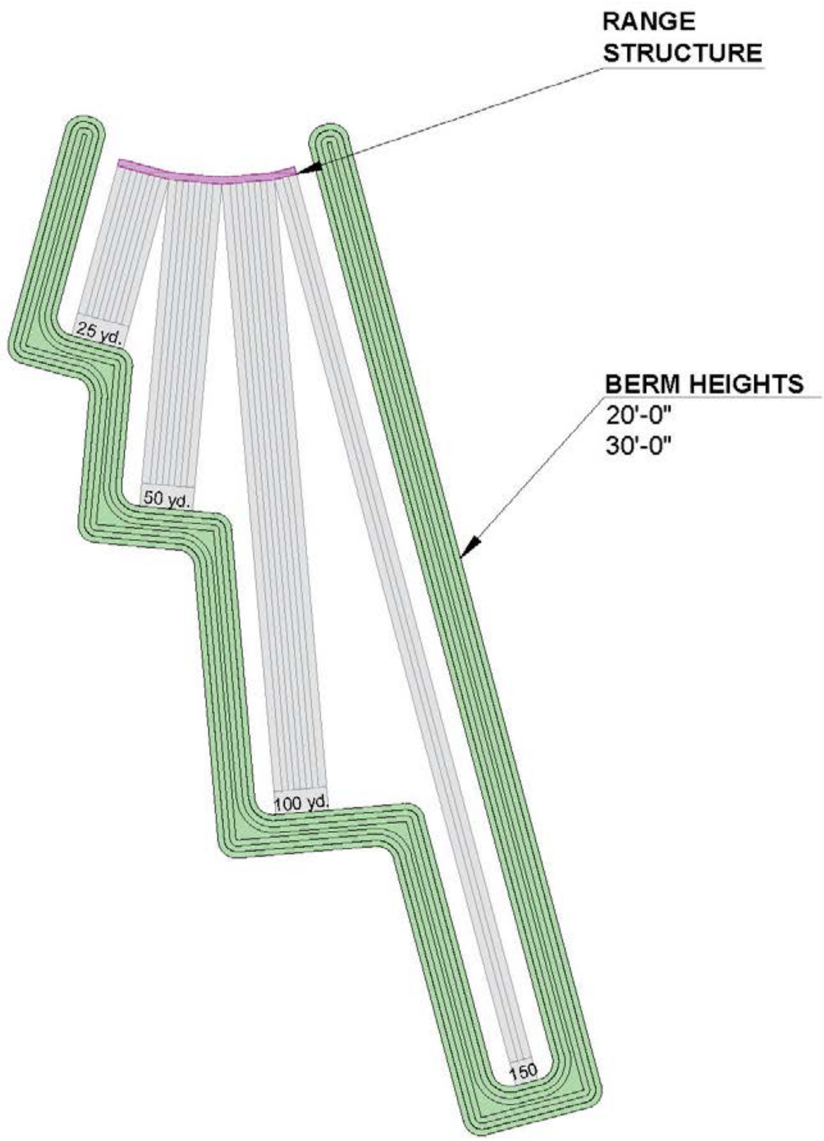


Figure 6. Concept plan for the range structure with interior sound absorbent lining described in Appendix L.

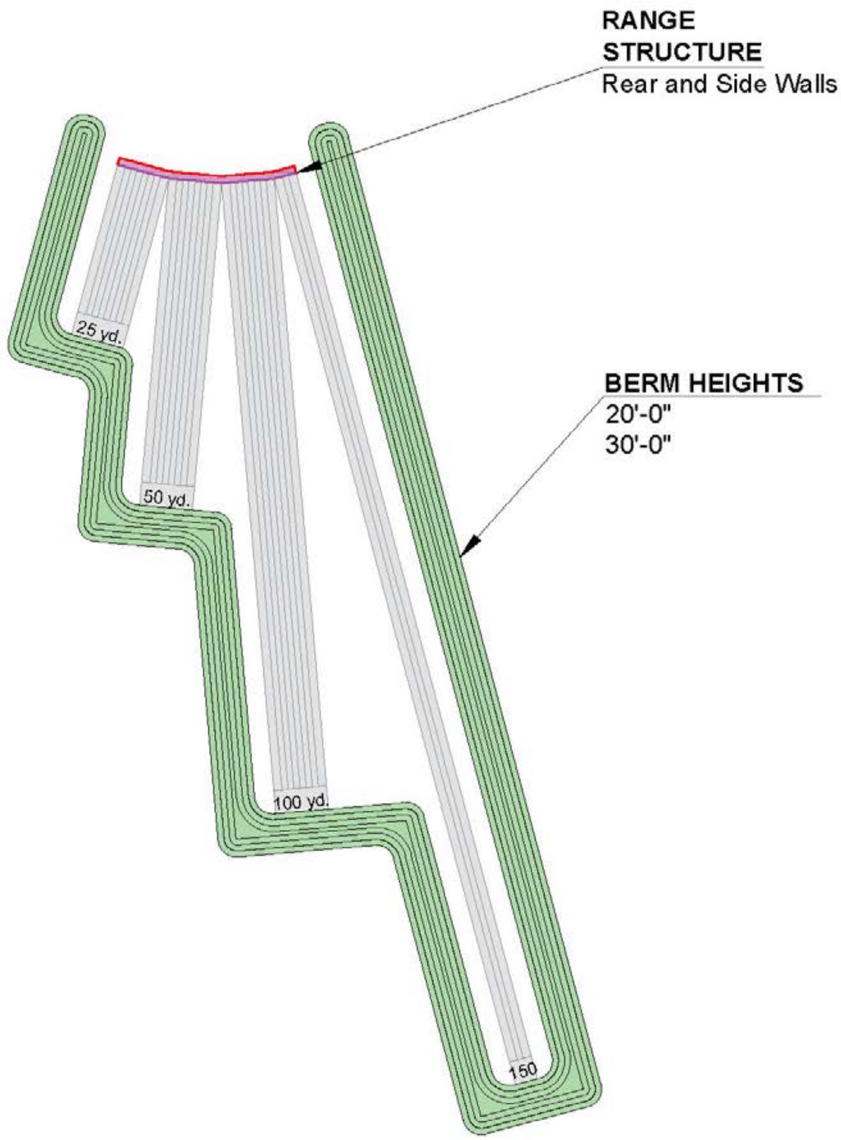


Figure 7. Concept plan for the range structure with the rear and side walls added with the interior sound absorbent lining described in Appendix M.

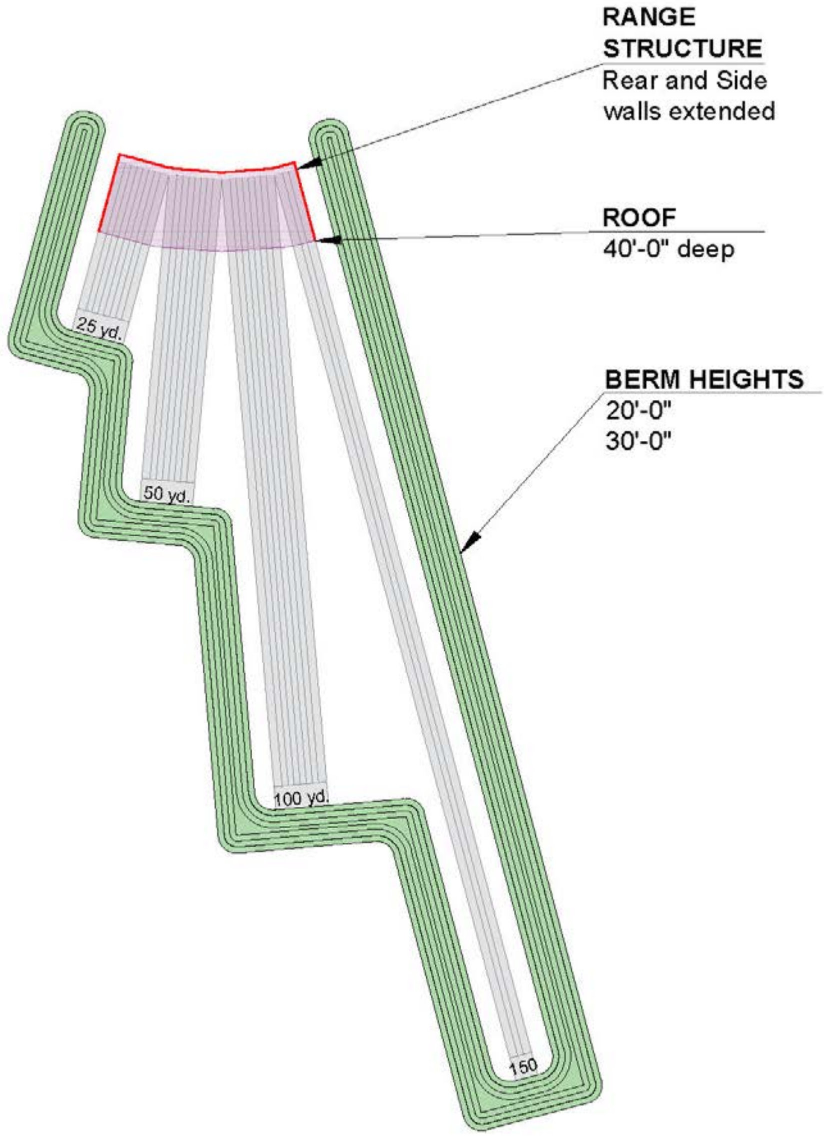


Figure 8. Concept plan for the range structure with the 40 ft. extension of the roof with the rear and side walls added and the interior sound absorbent lining described in Appendix N.

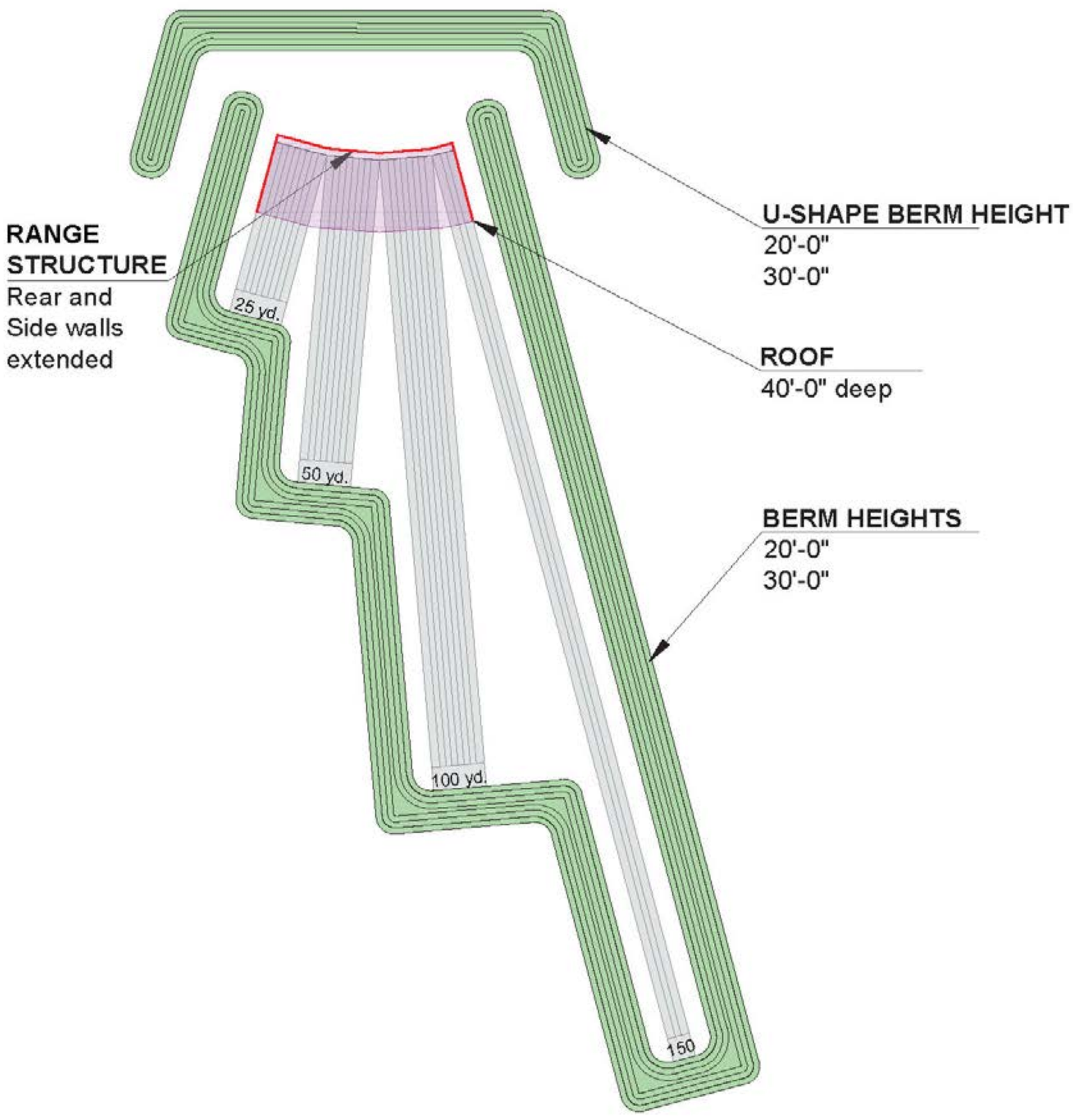


Figure 9. Concept plan showing the range structure with the 40 ft. extension of the roof with the rear and side walls added and the interior sound absorbent lining and a U-shaped berm around the rear of the range described in Appendix O.

RESULTS OF THE COMPUTER MODEL STUDIES

Appendices F through O contain scaled maps/aerials of the 2 proposed sites 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 1 second equivalent continuous sound pressure level (LAeq) at receiver locations around the proposed range sites for each scenario. The sound levels could increase by 10 to 20 dB for receivers downwind of the source and when temperature inversions (warmer air aloft) occur. An experiment was conducted to study the effects of wind speed and direction on the propagation of sounds.

Due to the complexity of the data and the number of options studied, a point system was developed to rank order the various schemes based on the sound pressure and the number of dwellings and other noise sensitive properties that fell within the noise contours produced by each scheme for both ranges. A GIS data base was used by DNR to count the number of dwellings within each of the 5 dB noise contour increments. A sound pressure was calculated for the center of the contour group. For example, 32.5 dBA was the center of the 30 to 35 dBA noise contours. The dB level was converted to a sound pressure by taking 10^(32.5/10). The resulting sound pressure was multiplied by the number of dwelling units located between the 5 dB contour lines. This process was repeated for each of the 5 dB increments of contour lines in the vicinity of the proposed range sites. The total for all of the sound pressures x number of dwellings was then added together for the experiment and divided by 100,000 to reach the total number of points for the scheme on a scale from 494 to 182,395. Scenarios with lower numbers of points have lower cumulative noise impacts for the scenario. The results of the different experiments are described in Appendices F through O with tabular summaries of the schemes studied and the linear pressure points for each scheme.

Two sites and range orientations were initially selected for analysis. Site 1: Barry State Game Area Existing Range Site with the rifle ranges oriented towards the west-southwest and the shorter range oriented towards the east-southeast; and Site 2: Barry State Game Area Chief Noonday Site with the range oriented towards the south. The computer model analysis of these sites is summarized in Appendix F with 8 ft. tall berms on the 2 down range sides of the range and a 20 ft. tall downrange berm. Site 2 had the lowest linear pressure score of 9,626 compared to the linear pressure score of 71,150 for Site 1.

Alternate orientations were selected for each range to reduce potential noise impacts to residential properties within 2 miles of each proposed range site. The alternate range orientations to minimize potential noise impacts to residential and noise sensitive receivers was to the southwest and east for Site 1: Barry State Game Area Existing Range Site; and towards the southwest for Site 2: Barry State Game Area Chief Noonday Site.

Site 2 oriented towards the southwest had the lowest linear pressure score of 6,080 of the 5 alternatives followed closely by the linear pressure score of 9,626 of Site 2 oriented towards the south . The linear pressure scores for the 3 orientations of 71,150 to 182,395 for Site 1 were significantly higher than the linear pressure scores for Site 2 for the base range design with the 8 ft. tall berms on the 2 down range sides of the range and a 20 ft. tall berm on the downrange side of the range.

Experiments were conducted in computer models of noise mitigation options that could be considered for the ranges if needed in the future. Order of magnitude costs for the mitigation options were also presented in Appendix R. The noise mitigation options studied included raising the height of the down range berms to 20 ft. tall and 30 ft. tall at cost increases of approximately $235,700 for the 20 ft. tall berm compared to the base design range consisting of 8 ft. tall side berms and 20 ft. tall downrange berm; and approximately $676,200 for the 30 ft. tall berm compared to the base design range. These studies are summarized in Appendices F and G.

Models were tested using 20 ft. tall and 30 ft. tall berms in addition to the 8 ft. tall side berms and 20 ft. tall downrange berm for each of the range sites and orientations. These studies are reported in Appendix G. The lowest scores for a given range and orientation were generally received by the scheme with the tallest berm height. The relative ranking of sites was similar to those previously discussed with Site 2 oriented to the southwest; Site 2 oriented to the south and Site 1 oriented to the southwest receiving the lowest scores. The highest scores for these tests were for all berm heights and orientations at Site 1: Barry State Game Area Existing Range Site due to the close proximity to multiple noise sensitive receivers.

On average across all models and all scenarios tested, the average decrease in sound level was approximately 4 dB for the 20 ft. tall berm compared to the 10 ft. tall berm and an additional 4 dB for the 30 ft. tall berm compared to the 20 ft. tall berm at distances up to approximately ½ to 1 mile from the range.

The levels to the rear of the range stay relatively consistent from one scenario to the next with the berms only to the sides and down range from the firing line because there is no noise mitigating structure present in the base schemes in that direction. The U-shaped berm option was selected to reduce sounds propagating to the sides and rear of the ranges. This was considered to reduce sounds propagating towards homes to the north of Site 1; and homes to the northeast of Site 2. A U-shaped berm built around the rear of the range to reduce sounds spilling to the rear and sides of the range was investigated in computer model studies summarized in Appendix K. The linear pressure score was reduced by 61% to 76% by adding these U-shaped berms that were 20 ft. tall and 30 ft. tall at an incremental cost increase of approximately $349,600 for the 20 ft. berm scheme and $1,169,300 for the 30 ft. tall berm scheme. Please note that the incremental costs include raising the height of the downrange berms to the same height as the U-shaped berm at the rear of the range.

The typical day modeled with an air temperature of 50^{o} F and a 70% relative humidity resulted in 1 to 16 dB higher sound levels at distances away from the ranges than the other temperature and humidity conditions tested; so this condition was used as the base temperature and relative humidity condition for the computer model studies. Studies with alternate air temperatures and relative humidities (Appendix H); alternate wind conditions (Appendix I); and the addition of the existing stands of coniferous trees (Appendix J) on the sites verified that the assumptions made in the model studies represented a conservative approach to the noise contour mapping for the proposed range. This means that the mapped noise contours represent a worst case condition in terms of the effects of temperature, humidity, wind and vegetation on the modeled noise contours.

Experiments were conducted in computer models of noise mitigation options that could be considered for the ranges if needed in the future. Order of magnitude costs for the mitigation options were also

presented in Appendix R. The noise mitigation options studied included raising the height of the down range berms to 20 ft. tall and 30 ft. tall at cost increases of approximately $235,700 for the 20 ft. tall berm compared to the 8 ft. tall berm; and approximately $676,200 for the 30 ft. tall berm compared to the 8 ft. tall berm. These studies are summarized in Appendices F and G.

Adding solid dividers between each lane in the range building and lining the walls and ceiling of each lane with sound absorbent panels such as Troy Acoustics Troy Board will reduce the linear pressure score at Site 2 by approximately 84% to 86%, and by approximately 37% to 52% at Site 1 at a cost of approximately $85,900 as summarized in Appendix L.

Additional mitigation options studied included adding solid walls at the sides and rear of the range building lined with sound absorbent panels; extending the roof of the range building 40 ft. downrange from the firing line and adding a sound absorbent inner lining to the roof; building a U-shaped berm around the rear of the range and raising the height of the berms on all sides to 20 ft. and 30 ft. respectively. These options reduced the linear pressure score between 37% and 95% compared to the base range with the 8 ft. tall berm on 2 sides and 20 ft. berm downrange and the open range structure depending upon the combination of options selected. Incremental costs for these options varied from approximately $134,500 for adding the side and rear walls of the range building; approximately $309,600 for adding the 40 ft. roof extension; approximately $113,9000 for adding the 20 ft. tall U-shaped berm at the rear of the range; approximately $493,100 for adding the 30 ft. tall U-shaped berm at the rear of the range; and approximately $1,613,400 for the combination of all of these options.

The use of the noise mitigation options should be carefully considered for a given site because there are site specific limitations on how much reduction in linear pressure score can be obtained at any given site for a specific mitigation scheme.

Sound Level Reductions from Noise Mitigation Systems

Site 1: Barry State Game Area Existing Range. If the range will be located at the existing range site in the Barry State Game Area, one option to reduce sounds propagating to the sides and rear of the ranges was to add solid side walls and a rear wall to the range structure which reduced sound levels by approximately 5 dB to 24 dB to the west, north, and south at 1/2 mile to 1 mile from the range with the firing line oriented to the east and by approximately 4 dB to 11 dB to the north, south, and east at 1/2 mile to 1 mile from the range with the firing line oriented to the southwest when compared to the base range design.

A sound level reduction of 5 dB to 10 dB was observed towards the north when the firing line of the range was oriented to the east, and of 11 dB to 14 dB towards the north when the range was oriented to the southwest, due to the extended roof on the range structure and the U-shaped berm behind the shooters at similar distances. There were several instances of a 20 dB decrease in sound level towards the rear of the range with the firing line oriented to the east when the U-shaped berm at the rear of the range and the extended roof on the range structure were included in the design. With the firing line of the range oriented toward the southwest, a sound level reduction of 9 dB to 17 dB was observed toward the rear of the range.

The acoustical lining on the inside surfaces of the range structure and the use of partitions to divide the range structure into individual lanes and lining the dividing walls would reduce sound levels inside the range structure for shooters as well as decrease sound levels by 5 dB to 8 dB propagating toward the north from the range with the firing line oriented to the east; and by 10 dB to 11 dB toward the north from the range with the firing line oriented to the southwest, at distances of 1/2 to 1 mile from the range.

The 40 ft. deep extension of the range structure roof would reduce sound propagation toward the north and south, as a possible alternative to raising the height of the berms in the direction of fire if used in conjunction with raising the height of the berms, to reduce sound levels toward the north and south by approximately 9 dB to 14 dB at distances of 1/2 to 1 mile from the range with the firing line oriented toward the east and by approximately 4 dB to 11 dB at similar distances when the firing line of the range is oriented toward the southwest.

Site 2: Chief Noonday Site at Barry State Game Area. One option to reduce sounds propagating to the sides and rear of the range if it is located in the proposed Chief Noonday site was to add solid side walls and a rear wall to the range structure which reduced sound levels by approximately 6 dB to 13 dB to the north, west and east at 1/2 mile to 1 mile from the range with the firing line oriented to the south and by approximately 3 dB to 22 dB in all directions from the range at 1/2 mile to 1 mile from the range with the firing line oriented to the southwest when compared to the base range design.

A sound level reduction of 7 dB to 13 dB was observed towards the sides when the firing line of the range was oriented to the south, and of 3 dB to 24 dB towards the east and west when the range was oriented to the southwest, due to the extended roof on the range structure and the U-shaped berm behind the shooters at similar distances. There were several instances of a 20 dB decrease in sound level towards the rear of the range with the firing line oriented to the southwest when the U-shaped berm at the rear of the range and the extended roof on the range structure were included in the design. With the firing line of the range oriented toward the southwest, a sound level reduction of 20 dB to 21 dB was observed toward the rear of the range at distances of 1/2 to 1 mile from the range.

The acoustical lining on the inside surfaces of the range structure and the use of partitions to divide the range structure into individual lanes and lining the dividing walls would reduce sound levels inside the range structure for shooters as well as decrease sound levels by 7 dB to 13 dB propagating toward the sides of the range with the firing line oriented to the south; and by 1 dB to 16 dB in all directions from the range with the firing line oriented to the southwest

The 40 ft. deep extension of the range structure roof would reduce sound propagation toward the north, east, and west, as a possible alternative to raising the height of the berms in the direction of fire if used in conjunction with raising the height of the berms, to reduce sound levels toward the sides and the rear of the range by approximately 6 dB to 13 dB at distances of 1/2 to 1 mile from the range with the firing line oriented toward the south and by approximately 3 dB to 22 dB in all directions when the from the range. line of the range is oriented toward the southwest.

Noise Ordinances in the Communities Near the Range Sites

The 2 proposed range sites and the 2 mile radius from which sounds may be audible when discharged at the range sites fall within 4 townships: Irving, Rutland, Thornapple and Yankee Springs. The Barry State Game Area Existing Range Site is located in Yankee Springs Township and is within a two-mile radius of Rutland, Irving, and Thornapple Townships. The Barry State Gaming Area Chief Noonday proposed firing range is located in Rutland Township and is within a two-mile radius of Yankee Springs Township. Both range sites are located within Barry County, Michigan.

Section 2337 of Article 23 of the Barry County Zoning Ordinance limits sounds from gunshots at the property line of a gun club to less than 60 decibels. Section 2705 of Article 27 of the Barry County Zoning Ordinance limits sounds from gunshots to 55 decibels at residential property lines.

Section 22-108 of Chapter 22 of the Thornapple Code of Ordinances states that "no person shall create any loud noises or use any loudspeaker, sound amplifier or other electrical or mechanical device intended to increase the volume of sound at any place or places within the township in such a manner as to disturb unnecessarily and without reasonable cause the quiet, comfort or repose of any reasonable person or persons between the hours of 12:00 a.m. and 7:00 a.m."

Part 81, Section 4.a.3 of the Yankee Springs Township Noise Control and Public Nuisance Ordinance states that "noises emanating from the discharge of firearms are excluded, providing the discharge of the firearms was authorized under Michigan law and all local ordinances".

Noise ordinances for Rutland Township and Thornapple Township do not include quantitative sound level limits or sound measurement methods for determining the acceptability of sounds of various types and levels. In the absence of a local noise ordinance with quantitative sound level limits, an analysis of the noise contour maps for each of the design alternatives could be undertaken relative to criteria based on sound level limits contained in typical community noise ordinances. Many noise ordinances have sound level limits of 55 to 60 dBA during daytime hours and 50 to 55 dBA during nighttime hours at residential receiving property lines.

The analysis showed that residential properties are located within noise contours greater than 50 dBA LAeq for all the range configurations studied at Site 1 Barry SGA and Site 2 Chief Noonday. There are approximately 289 structures within the 50 to 60 dBA noise contours, and approximately 175 structures within noise contours greater than 60 dBA at Site 1 Barry SGA. At Site 2, Chief Noonday, there are 169 structures within the 50 to 60 dBA noise contours, and approximately 121 structures within noise contours greater than 60 dBA.

Providing side and rear wall enclosures and 20 ft. tall berms on the three downrange sides of the range is estimated to reduce the number of impacted structures to approximately 152 at Barry SGA with the range oriented toward the southwest; and to approximately 98 with the extended roof on the range structure and the U-shaped berm behind the shooters with the range oriented toward the southwest. However, due to the close proximity of the range location to neighboring residential properties, there are still approximately 125 to 130 structures within noise contours greater than 60 dBA with these noise mitigation schemes.

Providing side and rear wall enclosures and 20 ft. tall berms on the three downrange sides of the range is estimated to reduce the number of impacted structures within the 50 to 60 dBA noise contours to approximately 90 at the Chief Noonday site with the range oriented toward the southwest; and to approximately 67 with the extended roof on the range structure and the U-shaped berm behind the shooters with the range oriented toward the southwest. For any given noise mitigation scheme, there are still approximately 30 to 50 additional impacted structures within noise contours greater than 60 dBA.

CONCLUSIONS

Sound studies were conducted for two range sites in the Barry State Game Area. The 2 sites are options for the location of a new firing range in the Barry State Game Area. Site 1 is located at the site of the existing range in the Barry State Game Area located east of North Yankee Springs Road and south of North Middleville Road with the shooters facing west-southwest on the rifle ranges and east-southeast at the shorter range. Site 2 is an alternate site in the Barry State Game Area called Chief Noonday, located south of Chief Noonday Road, with the shooters facing south.

1. Existing ambient sound levels were measured at 2 locations near potential noise sensitive receivers located near each proposed range site from September 28 to October 2, 2016. Existing ambient sound levels at Site 1 at the existing range site at the Barry State Game Area varied from 16 to 68 dBA with average Day-Night Sound Levels (LDN) of 52 to 58 dBA. The ambient sound levels at Site 1 consisted of light to moderate traffic on North Yankee Springs Road; the breeze blowing through the trees; birds chirping; and the sounds of insects.

2. Existing ambient sound levels at Site 2, Chief Noonday, varied from 29 to 79 dBA with average Day-Night Sound Levels (LDN) of 47 to 58 dBA. The ambient sound levels at Site 2 consisted of light to moderate traffic with trucks on South Yankee Springs Road and Chief Noonday Road; the breeze blowing through the trees and grasses; birds chirping; and the sounds of insects.

3. The lower end of the range of the ambient 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.

4. Experiments were set up at each proposed range site on September 27, 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 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 2 prospective sites for the firing range.

5. The sound levels measured at 10 feet from the source were approximately 4 to 5 dB louder in the direction of fire than to the sides and 12 to 13 dB louder in the direction of fire than behind the

shooter for the 0.40 caliber handgun; approximately 6 to 7 dB louder in the direction of fire than to the sides and 13 to 15 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun; and approximately 6 to 8 dB louder in the direction of fire than to the sides and 18 to 20 dB louder in the direction of fire than behind the shooter for the 0.223 rifle.

6. At 62% of the measurement locations at distances of 1 to 2 miles from the proposed range site the sounds of the gun shots could not be measured above the ambient sound levels. This means that when only a few shooters will be using the proposed range, that sounds may not be heard at many of the residential locations at these distances in the vicinity of both of the proposed range sites.

7. Average LAeq, maximum LA max and peak LA peak sound levels were measured at the 16 locations around each of the proposed range sites. The LA max levels were on average 1 dB less than the LAeq levels. The LA peak levels were 12.5 dB louder than the LAeq levels.

8. Measured sound levels were approximately 6 to 15 dB louder in the direction of fire compared to the same distances at the sides and 15 to 25 dB louder in the direction of fire than behind at distances of ¼ and ½ mile from the proposed range location. This means that the orientation of the direction of fire of the range is an important decision.

9. The average sound decay with distance measured from the proposed range sites was 3 to 5 dB per doubling of distance from the sound source. This was affected by distance and localized conditions of wind, topography, ground cover and vegetation at each site.

10. Computer models of each of the proposed range sites were constructed in CADNA-A software including topography, roads, ground cover, coniferous vegetation with the 8 ft. tall berms on 2 sides of the ranges, 20 ft. tall berms on the downrange side of the range and an open structure over the firing line for a standard day with 50^{o} F and 70% relative humidity with typical wind speed and direction.

11. Noise contours were plotted for a “typical day” with 11 people shooting within a 1 second time period: 5 people firing 0.223 rifles on the 100 yard range, 1 person firing a 0.223 rifle on the 150 yard range; 2 people firing 12 gauge shotguns on the 50 yard range, and 3 people firing 0.40 caliber handguns on the 25 yard range within a 1 second time period for the base range conditions. Eight (8) other people who were not shooting were also assumed to be on the range.

12. A point scale was used to assess potential noise impacts that accounted for the sound pressure at each house within a 2 mile radius of each of the proposed range sites and the number of dwellings impacted by the sounds. The sound pressure derived from the average sound level calculated in the noise modeling software was multiplied by the number of dwelling units within each 5 dB group of noise contour lines. For example, if 20 dwellings were located between the 30 and 35 dBA noise contours the points were calculated by the following method. The average sound level in this contour range is 32.5 dBA. The sound pressure associated with this value is 10^(32.5/10). This value was multiplied by the number of dwellings identified in GIS software by DNR staff to arrive at a linear pressure score for these contours. The linear pressure was divided by 100,000 to arrive at a scale that ranged from 494 to 182,395 for the alternatives studied. The values for each of the 5 dB groups of noise contours were added together to reach the cumulative linear pressure score

for the scenario. Scenarios with lower numbers of points have lower cumulative noise impacts for the scenario.

13. Two sites and range orientations were initially selected for analysis: Site 1: Barry State Game Area Existing Range with the rifle ranges oriented towards the west-southwest and the shorter range oriented towards the east-southeast; and Site 2: Chief Noonday with the range oriented towards the south. The computer model analysis of these sites is summarized in Appendix F for the "typical day" scenario with 8 ft. tall berms on the 2 down range sides of the range and a 20 ft. tall berm on the downrange side of the range. Site 2 had the lowest linear pressure score followed by Site 1 with a linear pressure score that was approximately 7 times the Site 2 score for both scenarios.

14. Alternate orientations were selected for each range to reduce potential noise impacts to residential properties within 2 miles of each proposed range site. The alternate range orientation to minimize potential noise impacts to residential and noise sensitive receivers was to the south west and to the east for Site 1: Barry State Game Area Existing Range; and towards the southwest for Site 2: Chief Noonday.

15. Site 2 oriented towards the southwest had the lowest linear pressure score of 6,080 of the 5 alternatives followed closely by Site 2 oriented towards the south with a linear pressure score of 9,626 for the base range design with an 8 ft. tall berm on the 2 sides of the range, a 20 ft. tall berm on the downrange side of the range and an open structure over the firing line. The three options for the base range design at Site 1 has linear pressure scores that were 7 to 19 times higher than the linear pressure scores for Site 2.

16. Models were tested using 20 ft. tall and 30 ft. tall berms in addition to the 8 ft. tall berms for each of the range sites and orientations. These studies are reported in Appendix G. The lowest linear pressure scores for a given range and orientation were generally received by the scheme with the tallest berm height. The relative ranking of sites was similar to those previously discussed with Site 2: Chief Noonday oriented to the southwest; and Site 2 oriented towards the south receiving the lowest scores. The highest scores for these tests were for all berm heights and orientations at Site 1: Barry State Game Area Existing Range.

17. Studies with alternate air temperatures and relative humidities (Appendix H); alternate wind conditions (Appendix I); and the addition of the existing stands of coniferous trees (Appendix J) on the sites verified that the assumptions made in the model studies represented a conservative approach to the noise contour mapping for the proposed range. This means that the mapped noise contours represent a worst case condition in terms of the effects of temperature, humidity, wind and vegetation on the modeled noise contours. The typical day modeled with an air temperature of 50^{o} F and a 70% relative humidity resulted in 1 dB to 8 dB higher sound levels at distances away from the range located at Site 1 Barry SGA; and 1 dB to 16 dB higher sound levels at distances away from the range located at Site 2 Chief Noonday.

18. Experiments were conducted in computer models of noise mitigation options that could be considered for the ranges if needed in the future. Order of magnitude costs for the mitigation options were also presented in Appendix T. The noise mitigation options studied included raising the height of the down range berms to 20 ft. tall and 30 ft. tall at cost increases of approximately

$235,700 for the 20 ft. tall berm compared to the 8 ft. tall berms on the sides; and approximately $676,200 for the 30 ft. tall berm compared to the 8 ft. tall berms on the sides of the range. These studies are summarized in Appendices F and G.

19. A U-shaped berm built around the rear of the range to reduce sounds spilling to the rear and sides of the range was investigated in computer model studies summarized in Appendix K. The linear pressure score was reduced by 61% to 76% by adding these U-shaped berms that were 20 ft. tall and 30 ft. tall at an incremental cost increase of approximately $349,600 for the 20 ft. berm scheme and $1,169,600 for the 30 ft. tall berm scheme.

20. Adding solid dividers between each lane in the range building and lining the walls and ceiling of each lane with sound absorbent panels such as Troy Acoustics Troy Board will reduce the linear pressure score at Site 2 by 84% to 86% and by approximately 37% to 52% at Site 1 at a cost of approximately $85,900 as summarized in Appendix L.

21. Additional mitigation options studied included adding solid walls at the sides and rear of the range building lined with sound absorbent panels; extending the roof of the range building 40 ft. downrange from the firing line and adding a sound absorbent inner lining to the roof; building a U-shaped berm around the rear of the range and raising the height of the berms on all sides to 20 ft. and 30 ft. respectively. These options reduced the linear pressure score between 37% and 95% compared to the base range with the 8 ft. tall berms on the sides of the range and the 20 ft. tall berm on the downrange side of the range depending upon the combination of options selected. Incremental costs for these options varied from approximately $134,500 for adding the side and rear walls of the range building; approximately $309,600 for adding the 40 ft. roof extension; approximately $32,900 for adding the 10 ft. tall U-shaped berm at the rear of the range; approximately $113,900 for adding the 20 ft. tall U-shaped berm at the rear of the range; approximately $493,100 for adding the 30 ft. tall U-shaped berm at the rear of the range; and approximately $1,613,400 for the combination of all of these options.

22. The use of the noise mitigation options should be carefully considered for a given site because there are site specific limitations on how much reduction in linear pressure score can be obtained at any given site for a specific mitigation scheme.

APPENDIX A: SUMMARY OF EXISTING AMBIENT SOUND LEVELS MEASURED AT 2 LOCATIONS NEAR EACH OF THE 2 PROPOSED RANGE SITES

Table A-1. Summary table of LAeq and LDN sound levels measured at 2 locations near each of the 2 proposed range sites.

Rion #	Location	Day	LDN (dBA)	LAeq Range (dBA)
1	Ambient 1	1	50	22-63
1	Ambient 1	2	48	23-70
1	Ambient 1	3	56	30-67
1	Ambient 1	4	56	35-79
1	Ambient 1	5	58	31-70
1	Ambient 1	6	50	30-67
1	Ambient 1	7	45	29-63
2	Ambient 2	1	39	14-51
2	Ambient 2	2	36	12-50
2	Ambient 2	3	44	25-57
2	Ambient 2	4	43	27-51
2	Ambient 2	5	46	22-55
2	Ambient 2	6	40	22-52
2	Ambient 2	7	34	16-50
3	Ambient 3	1	56	24-72
3	Ambient 3	2	56	24-62
3	Ambient 3	3	58	32-68
3	Ambient 3	4	57	38-60
3	Ambient 3	5	57	33-62
3	Ambient 3	6	52	31-62
3	Ambient 3	7	55	25-64
5	Ambient 5	1	53	35-90
5	Ambient 5	2	47	35-77
5	Ambient 5	3	53	36-75
5	Ambient 5	4	52	40-68
5	Ambient 5	5	55	40-67
5	Ambient 5	6	50	40-64

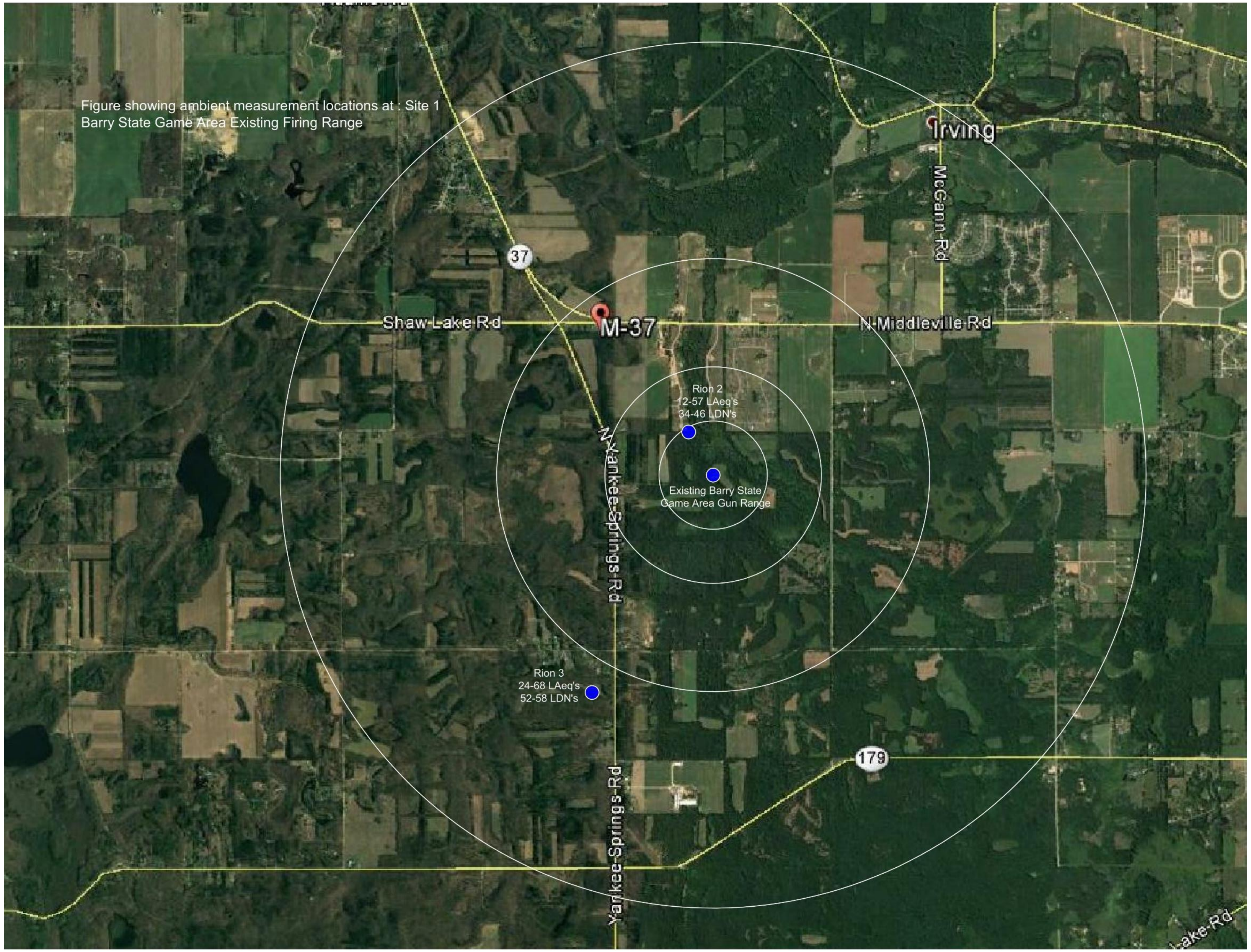


Figure A-1. Aerial photograph showing LAeq and LDN existing ambient sound levels measured at 2 locations near proposed range Site 1: Barry State Game Area Existing Range Site.

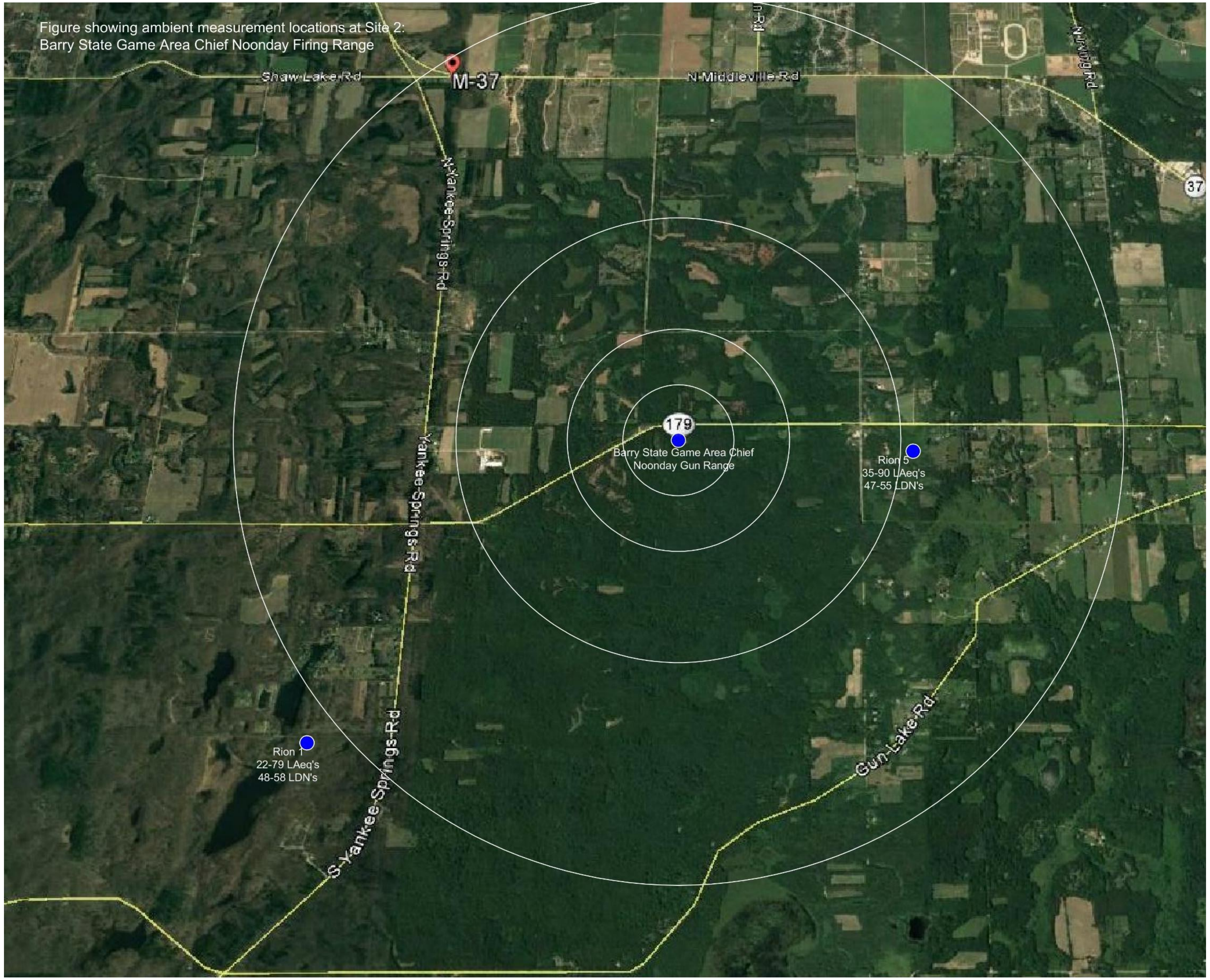


Figure A-2. Aerial photograph showing LA eq and LDN existing ambient sound levels measured at 2 locations near proposed range Site 2: Barry State Game Area Chief Noonday Site.

APPENDIX B: SUMMARY OF SOUND LEVELS MEASURED AT 10 FEET FROM THE SOURCE DURING THE EXPERIMENTS AT EACH PROPOSED RANGE SITE WITH LIVE FIREARMS DISCHARGES

Table B-1. Summary table of LAeq and LA peak sound levels made at 10 feet from the person shooting during the live fire experiments conducted at each of the proposed range sites.

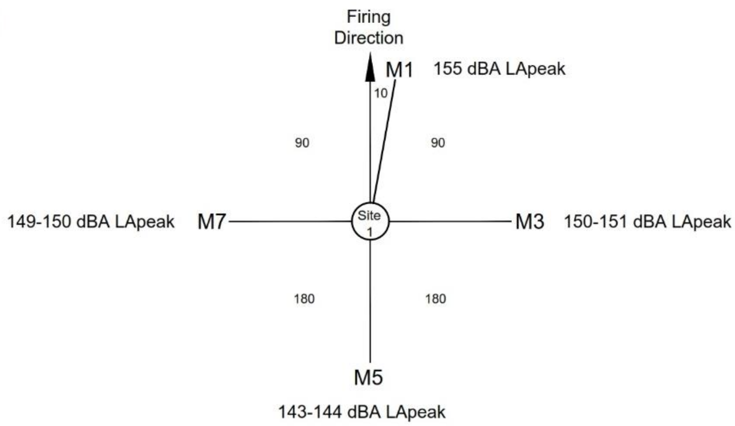
Gun	Site	Receiver	Shot 1		Shot 2		Shot 3	
			LAeq	LApeak	LAeq	LApeak	LAeq	LApeak
40	1	M1	129	155	129	155	129	155
12 gauge	1	M1	129	156	129	156	129	156
223	1	M1	132	159	132	159	132	159
40	1	M3	124	151	124	151	124	150
12 gauge	1	M3	124	151	122	151	125	151
223	1	M3	126	153	127	155	124	154
40	1	M5	115	144	117	143	x	x
12 gauge	1	M5	117	143	117	142	119	144
223	1	M5	117	141	116	140	118	141
40	1	M7	125	150	124	149	124	149
12 gauge	1	M7	125	152	122	151	124	150
223	1	M7	128	155	128	155	128	155
40	2	M1	129	155	128	154	128	154
12 gauge	2	M1	131	157	131	158	131	158
223	2	M1	135	162	135	162	136	162
40	2	M3	124	150	124	150	124	150
12 gauge	2	M3	123	151	124	151	124	151
223	2	M3	126	153	126	154	126	154
40	2	M5	118	144	115	141	117	143
12 gauge	2	M5	117	142	118	141	117	142
223	2	M5	117	139	116	140	116	139
40	2	M7	125	151	124	151	125	150
12 gauge	2	M7	125	152	124	151	124	152
223	2	M7	126	154	126	153	127	155

Table B-2. Summary of differences in LApeak sound levels vs. direction for the 3 types of weapons used in the live fire experiments conducted at each of the proposed range sites measured at 10 feet from the person shooting.

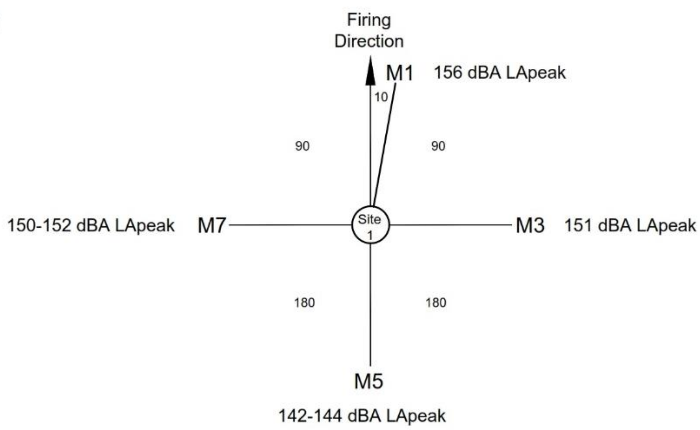
Direction	Site	.40 Caliber Handgun	12 ga Shotgun	0.223 Rifle
Front to side	1	4	5	4
	2	4	7	9
AVERAGE		**4**	**6**	**7**
Front to rear	1	12	13	18
	2	11	16	23
AVERAGE		**12**	**15**	**20**
Front to back side	1	6	5	4
	2	4	6	8
AVERAGE		**5**	**5**	**6**

Site 1: Barry

0.40 caliber Pistol



12 gauge Shotgun



0.223 Rifle

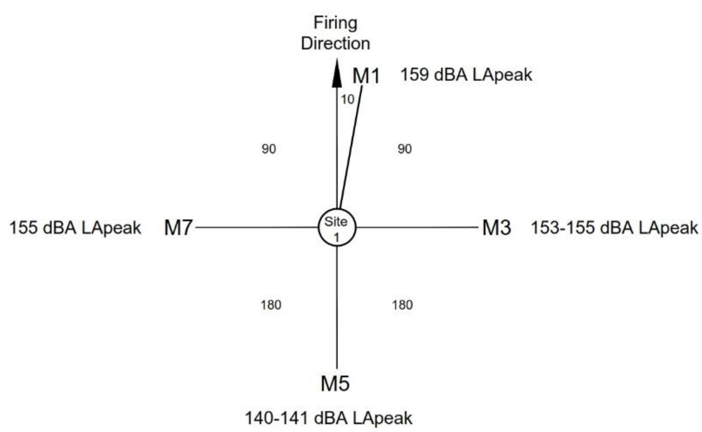
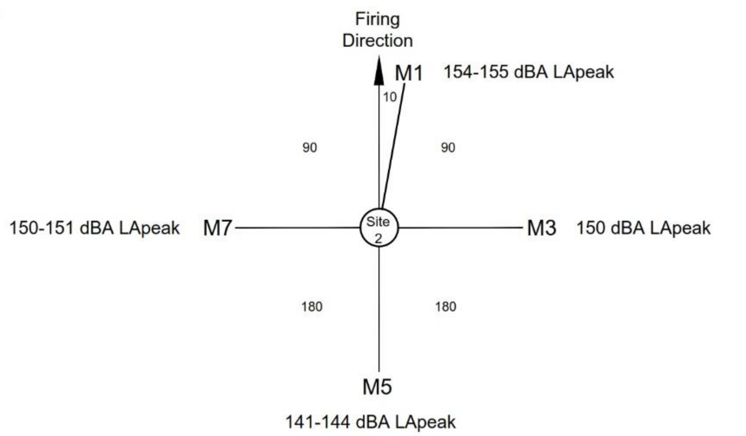


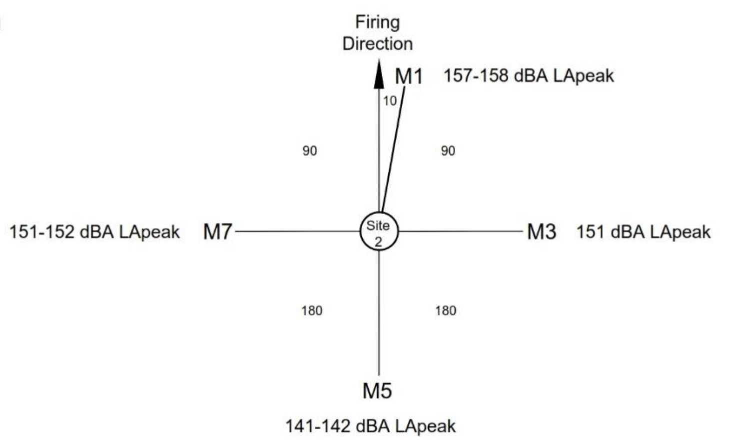
Figure B-1. Diagrams of measured LA peak sound levels (dBA) measured at 10 feet from the person shooting at Proposed Site 1: Barry State Game Area Existing Range Site.

Site 2: Chief Noonday

0.40 caliber Pistol



12 gauge Shotgun



0.223 Rifle

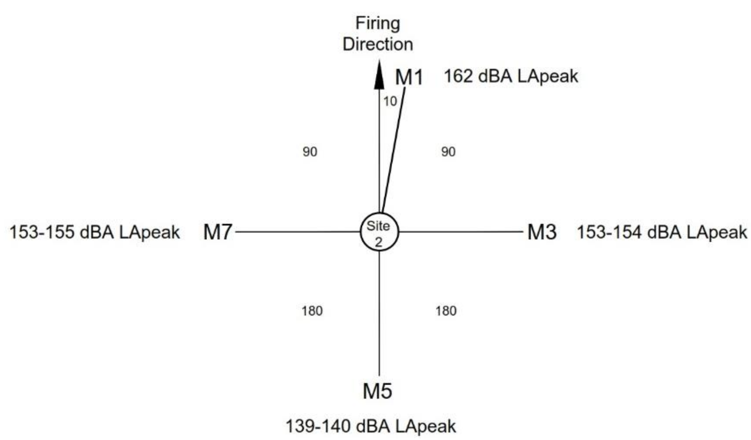


Figure B-2. Diagrams of measured LA peak sound levels (dBA) measured at 10 feet from the person shooting at Proposed Site 2: Barry State Game Area Chief Noonday Range Site.

APPENDIX C: SUMMARY OF SOUND LEVELS MEASURED AT DISTANCES of APPROXIMATELY ¼ MILE, ½ MILE, 1 MILE and 2 MILES FROM THE PROPOSED RANGE SITE 1: BARRY STATE GAME AREA EXISTING RANGE SITE, DURING THE EXPERIMENTS WITH LIVE FIREARMS DISCHARGES

Table C-1. Summary table of LAeq, LA max and LA peak sound levels made at distances of approximately ¼ mile, ½ mile, 1 mile and 2 miles from proposed range Site 1: Barry State Game Area Existing Range Site during the live fire experiments with the shooter firing towards the west-southwest.

Gun	Source	Receiver	Shot 1			Shot 2			Shot 3		
			LAeq	LApeak	LAFmax	LAeq	LApeak	LAFmax	LAeq	LApeak	LAFmax
40	**1**	**1B**	73	94	71	72	86	69	73	95	72
12 gauge	**1**	**1B**	72	83	71	71	88	71	70	85	68
223	**1**	**1B**	69	82	68	71	82	70	68	83	69
40	**1**	**3B**	70	90	69	68	86	66	67	84	65
12 gauge	**1**	**3B**	74	89	73	76	88	75	70	86	68
223	**1**	**3B**	73	89	72	71	85	70	74	91	72
40	**1**	**4B**	60	72	59	62	72	60	60	72	59
12 gauge	**1**	**4B**	66	77	63	65	77	63	60	82	59
223	**1**	**4B**	63	76	61	66	79	64	63	76	61
40	**1**	**5B**	55	69	54	56	67	54	55	66	54
12 gauge	**1**	**5B**	53	64	53	53	64	52	52	63	52
223	**1**	**5B**	57	69	57	63	74	63	58	73	57
40	**1**	**6B**	64	82	62	68	85	66	62	76	60
12 gauge	**1**	**6B**	61	72	60	63	79	61	59	72	81
223	**1**	**6B**	60	76	60	59	74	59	59	69	59
40	**1**	**7B**	57	71	56	60	77	58	58	72	57
12 gauge	**1**	**7B**	65	80	63	62	75	62	62	74	61
223	**1**	**7B**	64	80	63	62	75	62	62	73	62
40	**1**	**8B**	57	72	56	55	70	54	61	79	59
12 gauge	**1**	**8B**	64	81	62	55	77	54	53	64	52
223	**1**	**8B**	58	74	57	59	72	57	60	74	57
40	**1**	**9B**	x	x	x	x	x	x	x	x	x
12 gauge	**1**	**9B**	86	96	86	86	96	85	84	95	84
223	**1**	**9B**	83	94	83	85	97	85	82	91	81
40	**1**	**10B 1**	54	66	54	54	65	54	56	70	55
12 gauge	**1**	**10B 1**	56	67	55	56	67	56	56	67	55
223	**1**	**10B 1**	56	68	55	54	66	54	55	66	54
40	**1**	**11B**	54	68	54	57	79	56	56	69	55
12 gauge	**1**	**11B**	57	70	56	61	77	59	54	67	54
223	**1**	**11B**	56	69	55	59	72	57	55	67	53
40	**1**	**12B**	x	x	x	x	x	x	x	x	x

Gun	Source	Receiver	Shot 1			Shot 2			Shot 3		
			LAeq	LApeak	LAFmax	LAeq	LApeak	LAFmax	LAeq	LApeak	LAFmax
12 gauge	1	12B	x	x	x	x	x	x	x	x	x
223	1	12B	x	x	x	x	x	x	x	x	x
40	1	13B	x	x	x	x	x	x	x	x	x
12 gauge	1	13B	x	x	x	x	x	x	x	x	x
223	1	13B	x	x	x	x	x	x	x	x	x
40	1	16B	x	x	x	x	x	x	x	x	x
12 gauge	1	16B	x	x	x	x	x	x	x	x	x
223	1	16B	x	x	x	x	x	x	x	x	x
40	1	17B	x	x	x	x	x	x	x	x	x
12 gauge	1	17B	x	x	x	x	x	x	x	x	x
223	1	17B	x	x	x	x	x	x	x	x	x
40	1	18B	x	x	x	x	x	x	x	x	x
12 gauge	1	18B	x	x	x	x	x	x	x	x	x
223	1	18B	x	x	x	x	x	x	x	x	x
40	1	19B	x	x	x	x	x	x	x	x	x
12 gauge	1	19B	x	x	x	x	x	x	x	x	x
223	1	19B	x	x	x	x	x	x	x	x	x

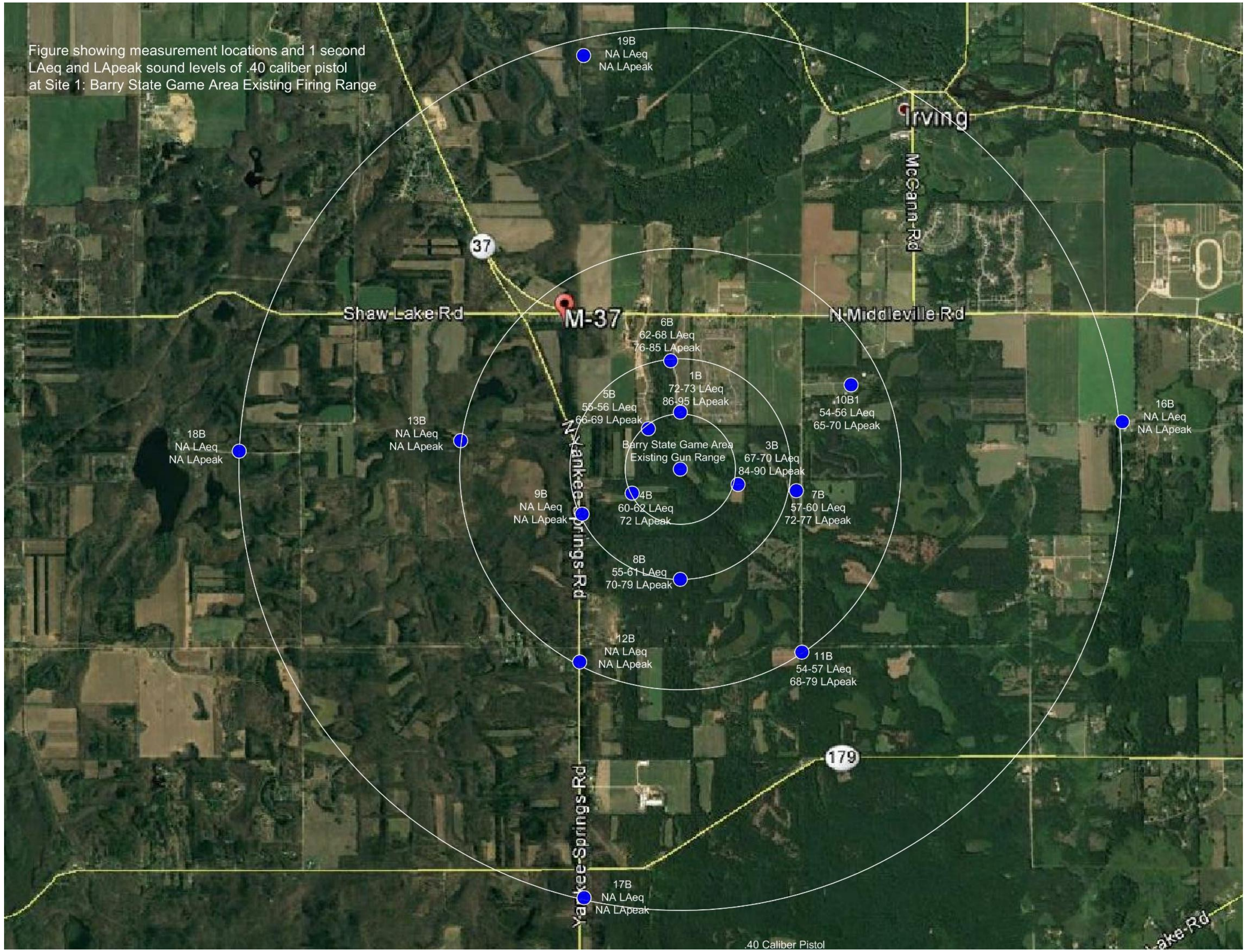


Figure C-1. Aerial photograph showing measured LAeq and LA peak sound levels produced by a 0.40 caliber handgun measured at distances of approximately ¼ mile, ½ mile, 1 mile and 2 miles from proposed range Site 1: Barry State Game Area Existing Range Site, with the shooter firing towards the west-southwest.

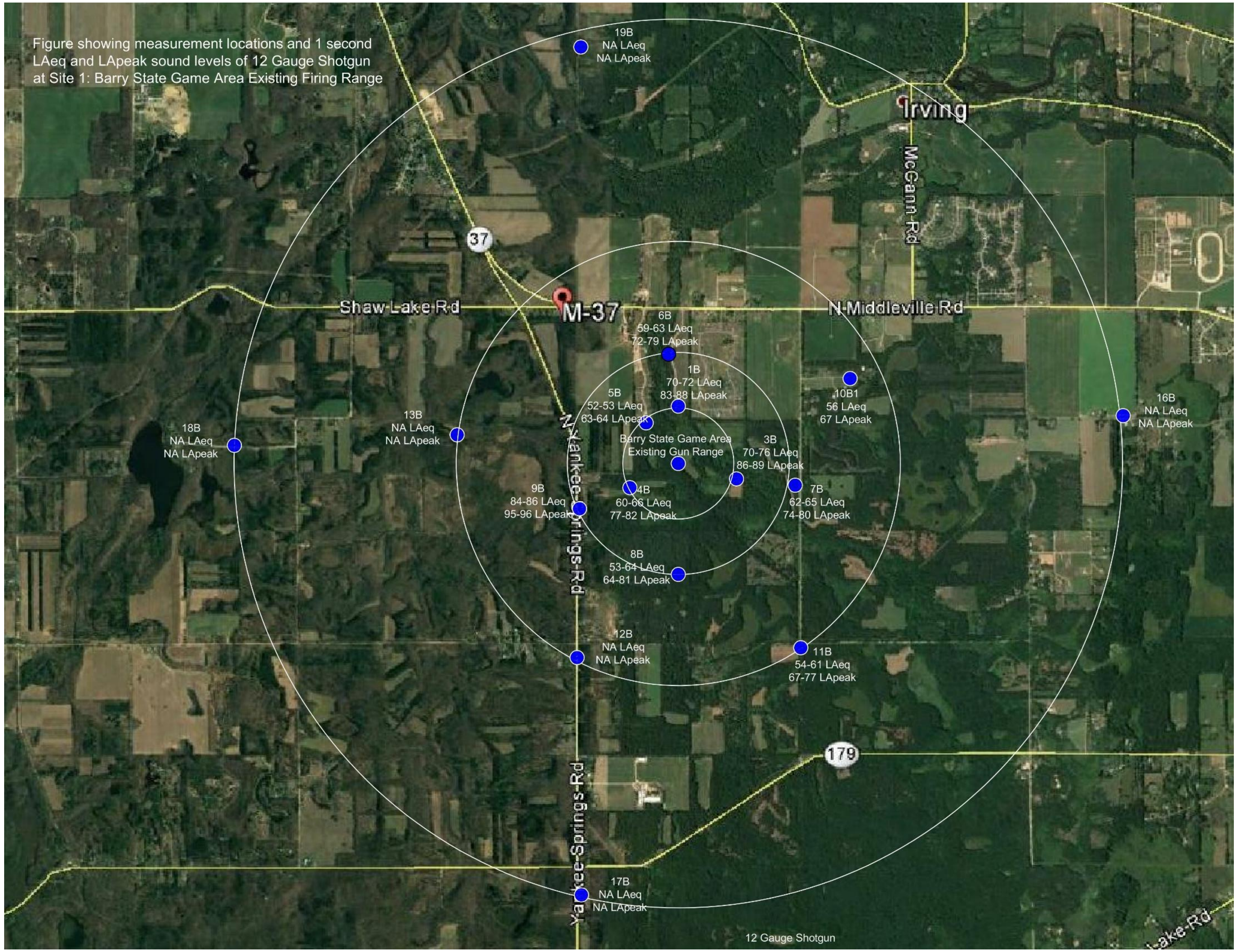


Figure C-2. Aerial photograph showing measured LAeq and LA peak sound levels produced by a 12 gauge shotgun measured at distances of approximately ¼ mile, ½ mile, 1 mile and 2 miles from proposed range Site 1: Barry State Game Area Existing Range Site, with the shooter firing towards the west-southwest.

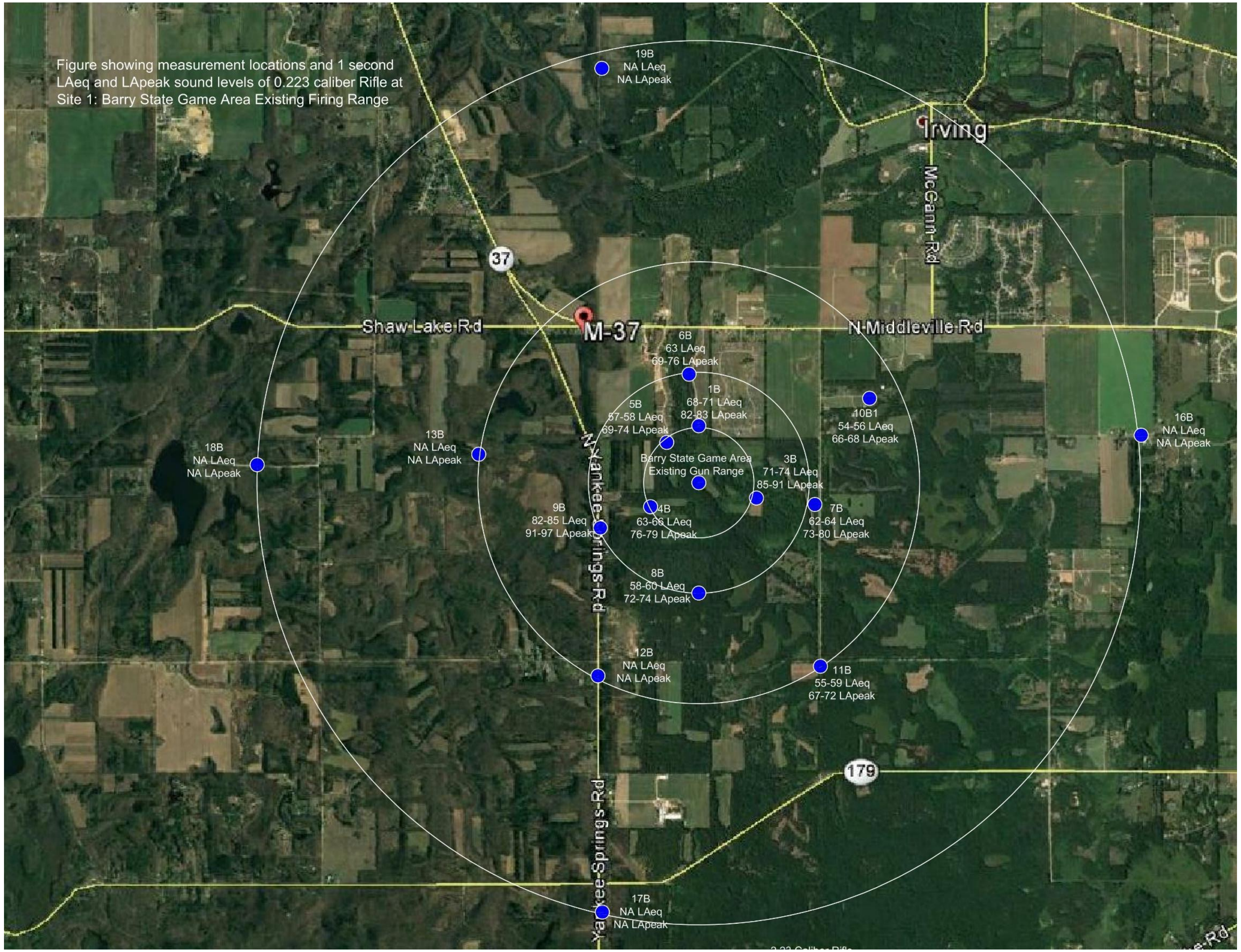


Figure C-3. Aerial photograph showing measured LAeq and LA peak sound levels produced by a 0.308 rifle measured at distances of approximately ¼ mile, ½ mile, 1 mile and 2 miles from proposed range Site 1: Barry State Game Area Existing Range Site, with the shooter firing towards the west-southwest.

APPENDIX D: SUMMARY OF SOUND LEVELS MEASURED AT DISTANCES of APPROXIMATELY ¼ MILE, ½ MILE, 1 MILE and 2 MILES FROM THE PROPOSED RANGE SITE 2: BARRY STATE GAME AREA CHIEF NOONDAY SITE, DURING THE EXPERIMENTS WITH LIVE FIREARMS DISCHARGES

Table D-1. Summary table of LAeq, LA max and LA peak sound levels made at distances of approximately ¼ mile, ½ mile, 1 mile and 2 miles from proposed range Site 2: Barry State Game Area Chief Noonday Site during the live fire experiments with the shooter firing towards the south.

Gun	Source	Receiver	Shot 1			Shot 2			Shot 3		
			LAeq	LApeak	LAFmax	LAeq	LApeak	LAFmax	LAeq	LApeak	LAFmax
40	2	1p	55	67	54	55	67	55	56	67	56
12 gauge	2	1p	60	72	59	58	75	57	60	70	60
223	2	1p	60	71	59	57	69	57	56	67	56
40	2	2p alt	73	90	71	71	90	69	81	101	79
12 gauge	2	2p alt	72	84	70	71	84	71	75	89	74
223	2	2p alt	70	83	68	76	95	74	75	90	73
40	2	3p	57	71	56	56	70	55	56	71	55
12 gauge	2	3p	56	67	55	59	71	58	57	71	57
223	2	3p	61	74	59	61	73	58	60	73	59
40	2	4p alt	54	65	53	55	66	55	52	64	52
12 gauge	2	4p alt	53	63	53	53	65	53	53	63	53
223	2	4p alt	55	68	55	53	64	52	53	62	52
40	2	5p	51	68	51	51	64	51	51	62	50
12 gauge	2	5p	51	62	51	58	69	58	58	69	58
223	2	5p	60	72	60	59	72	59	56	67	56
40	2	6p 1	58	71	55	63	78	61	61	75	58
12 gauge	2	6p 1	56	67	55	65	70	56	59	71	58
223	2	6p 1	61	74	59	65	79	62	63	76	61
40	2	7p	47	58	47	48	58	47	49	60	49
12 gauge	2	7p	52	60	51	51	62	50	51	70	51
223	2	7p	51	60	50	50	62	50	51	62	51
40	2	8p 1	x	x	x	x	x	x	x	x	x
12 gauge	2	8p 1	51	63	51	x	x	x	53	63	52
223	2	8p 1	52	69	52	x	x	x	58	70	58
40	2	9p	x	x	x	x	x	x	x	x	x
12 gauge	2	9p	x	x	x	x	x	x	x	x	x
223	2	9p	x	x	x	x	x	x	x	x	x
40	2	10p 1	x	x	x	x	x	x	x	x	x
12 gauge	2	10p 1	x	x	x	x	x	x	x	x	x
223	2	10p 1	x	x	x	x	x	x	x	x	x

Gun	Source	Receiver	Shot 1			Shot 2			Shot 3		
			LAeq	LApeak	LAFmax	LAeq	LApeak	LAFmax	LAeq	LApeak	LAFmax
40	2	11p	48	59	46	46	58	45	46	59	45
12 gauge	2	11p	46	59	45	48	62	48	48	61	48
223	2	11p	49	61	48	50	60	48	49	63	49
40	2	12p	x	x	x	x	x	x	x	x	x
12 gauge	2	12p	x	x	x	x	x	x	x	x	x
223	2	12p	x	x	x	x	x	x	x	x	x
40	2	13p	x	x	x	x	x	x	x	x	x
12 gauge	2	13p	x	x	x	x	x	x	x	x	x
223	2	13p	x	x	x	x	x	x	x	x	x
40	2	14p 1 alt	x	x	x	x	x	x	x	x	x
12 gauge	2	14p 1 alt	x	x	x	x	x	x	x	x	x
223	2	14p 1 alt	56	68	55	57	67	56	57	69	56
40	2	15p	51	63	51	x	x	x	x	x	x
12 gauge	2	15p	x	x	x	x	x	x	x	x	x
223	2	15p	x	x	x	x	x	x	x	x	x
40	2	16p 1	x	x	x	x	x	x	x	x	x
12 gauge	2	16p 1	x	x	x	x	x	x	x	x	x
223	2	16p 1	x	x	x	x	x	x	x	x	x

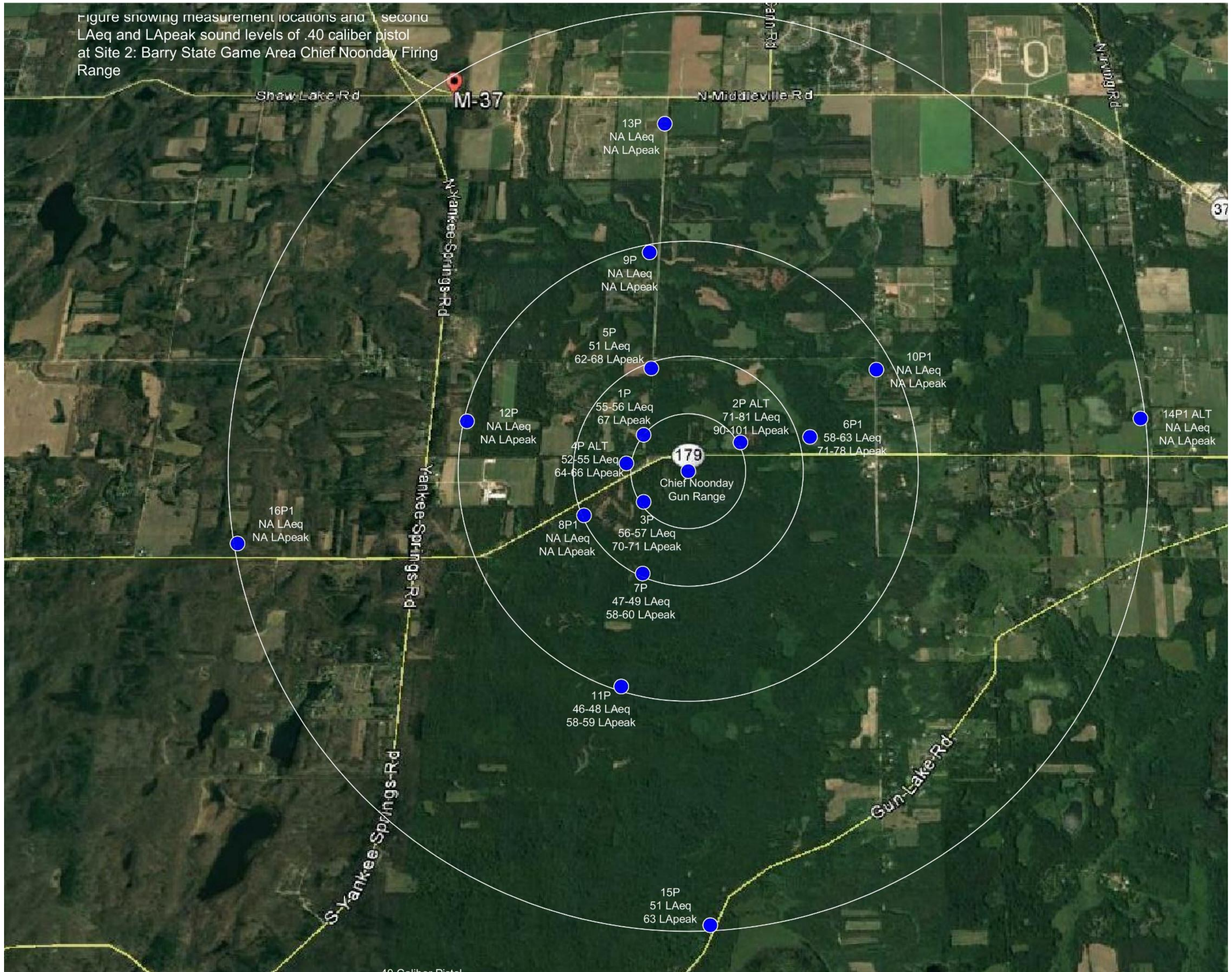


Figure D-1. Aerial photograph showing measured LAeq and LA peak sound levels produced by a 0.40 caliber handgun measured at distances of approximately ¼ mile, ½ mile, 1 mile and 2 miles from proposed range Site 2: Barry State Game Area Chief Noonday Site, with the shooter firing towards the south.

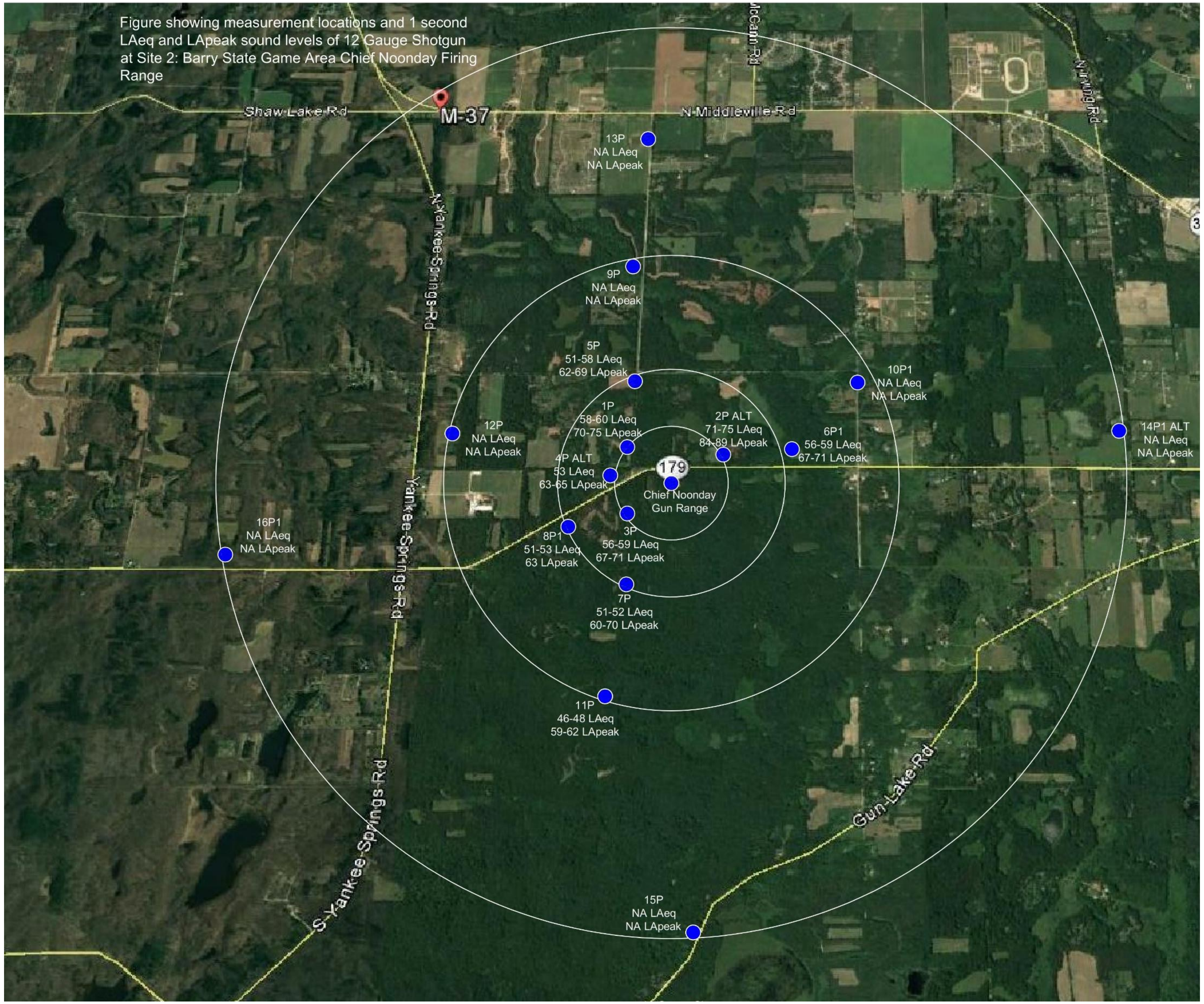


Figure D-2. Aerial photograph showing measured LAeq and LA peak sound levels produced by a 12 gauge shotgun measured at distances of approximately ¼ mile, ½ mile, 1 mile and 2 miles from proposed range Site 2: Barry State Game Area Chief Noonday Site, with the shooter firing towards the south.