SIEBEIN ASSOCIATES, INC.
Consultants in Architectural & Environmental Acoustics
625 NW 60th Street, Suite C Gainesville, Florida 32607
Telephone: (352) 331-5111 Facsimile: (352) 331-0009
Website: www.siebeinacoustic.com

October 6, 2017

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 of 2 Sites for the Proposed Firing Range* report for the proposed shooting range in Marquette County, 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

Marquette County, 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 to be located in Marquette County, 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" and "busy day" firearms discharges at each of the sites for range. 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 1 person firing a 0.223 rifle on the 300 yard range; 1 person on the 40 yard range shooting a 12 gauge shotgun; and one person on the 25 yard range firing a 0.40 caliber handgun in the same 1 second period of time. The "busy day" scenario had 1person on the 50 yard, 200 yard and 300 yard ranges each firing a 0.223 rifle; 1 person on the 40 yard range firing a 12 gauge shotgun; and 2 people on the 25 yard range each firing a 0.40 caliber handgun in the same 1 second period of time. Computer models using CadnaA software, which is a state-of-the-art, 3-D 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, 80% 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.

Table of Contents

Appendix G: Computer Model Study 2: Alternate Range Orientations at the 2 Proposed Range Sites with Typical Day and Busy Day Scenarios and Different Berm Heights

Appendix H: Computer Model Study 3: Alternate Temperature and Relative Humidity Conditions for Sites 1 and 2 with the Base Range Orientation with the Typical Day Scenario

Appendix I: Computer Model Study 4: Alternate Wind Conditions for Sites 1 and 2 with the Base Range Orientation with the Typical Day Scenario and a 20 ft. tall berm

Appendix J: Computer Model Study 5: Coniferous Vegetation Added at Sites 1 and 2 with the Base Range Orientation for the Typical Day Scenario with a 20 ft. tall berm

Appendix K: Computer Model Study 6: U-Shaped Berm at the Rear of the Range Added at Sites 1 and 2 with the Base and Alternate Range Orientations for the Typical and Busy Day Scenario with a 20 ft. and 30 ft. tall berm

Appendix L: Computer Model Study 7: Sound Absorbing Material Added to the Inside of the Range Structure at Sites 1 and 2 with the Base and Alternate Range Orientations for the Typical and Busy Day Scenarios with a 20 ft. tall berm

Appendix M: Computer Model Study 8: Side and Rear Walls Added to the Range Structure at Sites 1 and 2 with the Base and Alternate Range Orientations for the Typical and Busy Day Scenarios with a 20 ft. tall berm

Appendix N: Computer Model Study 9: A 40 ft. Deep Extension Was Added to the Range Structure in the Direction of Fire at Sites 1 and 2 with the Base and Alternate Range Orientations for the Typical and Busy Day Scenarios with a 20 ft. tall berm

Appendix O: Computer Model Study 10: A 40 ft. Deep Extension was Added to the Range Structure in the Direction of Fire and a Rear Berm was Added at Sites 1 and 2 with Base and Alternate Range Orientations for the Typical and Busy Day Scenarios with 20 ft. and 30 ft. tall berms

Appendix P: Summary of Weather Conditions During the Acoustical Measurements Made at Each of the Proposed Range Sites

Appendix Q: List of GPS Locations for the Measurement Locations of the Existing Ambient Sound Levels and the Sounds of Firearms Experiments

Appendix R: Concept Cost Estimates for Noise Mitigation Options for the Ranges

Appendix S: Graphs of Average and Peak Sound Levels Measured During the Firearms Experiments at Distances Away from the 2 Proposed Range Sites

Appendix T: Graphs of Average Sound Levels Measured at Locations Near Each of the 2 Proposed Range Sites

Appendix U: Staffing and Qualifications

EXECUTIVE SUMMARY

Sound studies were conducted for two proposed shooting range sites: Site 1 at the Marquette County Road Commission Area located north of County Road Ng and west of County Road 480; and Site 2 which is the Sands West site located just east of County Road Nc in Marquette County, Michigan.

EXISTING AMBIENT SOUND LEVELS

Existing ambient sound levels were measured at 2 locations near potential noise sensitive receivers located near each proposed range site from May 30 to June 6, 2017. Existing ambient sound levels at the sites varied from 8 to 81 dBA with average Day-Night Sound Levels (LDN) of 36 to 60 dBA.

FIRING RANGE EXPERIMENTS

Experiments were conducted at each proposed range site on May 31, 2017. Three Conservation Officers fired 5 shots in succession from 0.40 caliber handguns in 5 separate bursts separated by a short pause between each burst. This was followed by one officer firing 2 single shots from the handgun with a short pause between each shot. The 3 officers then fired 3 shots each in five separate bursts with short pauses between each burst with a 12 gauge shotgun. One officer then fired 2 single shots with the shotgun with a short pause between each shot. The 3 officers then fired 5 shots each in 5 separate busts with short pauses between each burst with 0.223 rifles. Then one officer fired 2 single shots with the 0.223 rifle with a short pause between each shot. Acoustical measurements were made at 10 feet or approximately 3 meters from the sound sources as well as at 16 locations around the proposed range sites. There were 16 measurement locations per site; 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.

DIRECTIONALITY COMPARISON: SOURCE

The sound levels measured at 10 feet from the source were approximately 5 to 6 dB louder in the direction of fire than to the sides and 10 to 11 dB louder in the direction of fire than behind the shooter for the 0.40 caliber handgun; approximately 8 to 10 dB louder in the direction of fire than to the sides and 12 to 14 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun; and approximately 7 to 11 dB louder in the direction of fire than to the sides and 15 to 16 dB louder in the direction of fire than behind the shooter for the 0.223 rifle.

AUDIBILITY OF SHOTS DURING EXPERIMENT

At 52% 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.

GLOBAL ACOUSTIC METRIC COMPARISON: LAMax vs LAeq vs LApeak

Average LAeq, LA max and LA peak sound levels were measured at the 16 locations around each of the proposed range sites. The LA max levels were on average 2 to 5 dB louder than the LAeq levels. The LA peak levels were 16 to 22 dB louder than the LAeq levels.

GLOBAL DIRECTIONALTIY COMPARISON

Measured sound levels were between 11 dB louder and 19 dB quieter in the direction of fire compared to the same distances at the sides of the shooter and 5 dB louder and 17 dB quieter in the direction of fire than behind the shooter compared to the same distances from the proposed range locations. This was affected by the variations in topography, vegetation, distances from the site and direction of the measurement locations compared to the direction of fire.

GLOBAL SOUND DECAY WITH DISTANCE
The average sound decay with distance measured from the proposed range sites was 7 to 11 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.

COMPUTER MODEL STUDIES

BASE RANGE CONDITION
Computer models of each of the proposed range sites were constructed in CADNA Software including topography, roads, ground cover, coniferous vegetation with the 10 ft. tall berms on 3 sides of the ranges and an open structure over the firing line for a standard day with 50°F and 80% relative humidity with typical wind speed and direction.

"TYPICAL DAY" vs "BUSY DAY" SCENARIOS
Noise contours were plotted for a "typical day" scenario (1-second sound exposure levels) with 1 person firing a 0.223 rifle on the 300 yard range; 1 person on the 40 yard range shooting a 12 gauge shotgun; and one person on the 25 yard range firing a 0.40 caliber handgun in the same 1 second period of time and a "busy day" scenario had one person on the 50 yard, 200 yard and 300 yard ranges each firing a 0.223 rifle; one person on the 40 yard range firing a 12 gauge shotgun; and 2 people on the 25 yard range each firing a 0.40 caliber handgun in the same 1 second period of time or the base range conditions.

POINT SCALE RANKING SYSTEM
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 18 to 4,816 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.

ORIGINAL SITE AND RANGE ORIENTATION
Two sites and range orientations were initially selected for analysis. Site 1: Marquette County Road Commission site with the range oriented towards the north; and Site 2: Sands West with the range oriented towards the north. The computer model analysis of these sites is summarized in Appendix F with 10 ft. tall berms on the 2 down range sides of the range and a 20 ft. tall downrange berm. Site 1: MCRC had the lowest linear pressure score that was approximately ½ of the linear pressure score for Site 2: Sands West.

ALTERNATE RANGE ORIENTATIONS

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 north-northwest for Site 1: Marquette County Road Commission; and towards the northwest and southwest for Site 2: Sands West.

Site 1 oriented towards the north-northwest had the lowest linear pressure score of the 5 alternatives followed closely by Site 1 oriented towards the north and the northwest and north orientations for Site 2 for the base range design with the 10 ft. berm on the 3 down range sides of the range. The linear pressure score for Site 1 oriented to the NNW was 25% less than the linear pressure score for site 1 oriented to the N. The linear pressure score for Site 2 oriented to the NW was almost 30% higher than the linear pressure score for Site 1 oriented to the N.

ALTERNATE RANGE ORIENTATIONS WITH DIFFERENT BERM HEIGHTS

Models were tested using 20 ft. tall and 30 ft. tall berms in addition to the 10 ft. tall side berms and 20 ft. tall downrange berm for each of the range sites and orientations. These studies are reported in Appendices F and 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 1 oriented to the NNW and N with linear pressure scores of 562 and 442 respectively with 30 ft. tall berms. Order of magnitude costs for the mitigation options were also presented in Appendix R. The approximate cost for adding the 30 ft. berms is $670,900. The linear pressure scores were 926 for Site 1 oriented to the NNW and 850 for Site 1 oriented to the N with 20 ft. berms. The approximate cost for adding the 20 ft. tall berms is $233,900. The linear pressure scores for Site 2: Sands West oriented to the NW were 1,188 with the 30 ft. berms and 1,483 with the 20 ft. berms. The linear pressure scores for these scenarios are respectively 270% and 335% higher than the linear pressure score for Site 1: MCRC oriented to the NNW with the 30 ft. berms.

ALTERNATE RANGE WEATHER AND VEGETATION CONDITIONS

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.

U-SHAPED BERM OPTION

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 31% to 70% by adding these U-shaped berms that were 20 ft. tall and 30 ft. tall at an incremental cost increase of approximately $345,200 for the 20 ft. berm scheme and $1,160,100 for the 30 ft. tall berm scheme.

SOLID DIVIDERS BETWEEN LANES OPTION
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 1 by approximately 73% to 89% and by approximately 87% to 90% at Site 2 at a cost of approximately $83,500 for the partitions and sound absorbent material and $233,900 for raising the berm height to 20 ft. tall, for a total cost of $319,200 as summarized in Appendix L.

ADDITIONAL NOISE MITIGATION OPTIONS AND COSTS
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 reduced the linear pressure score between 50% and 97% compared to the base range with the 10 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 $133,500 for adding the side and rear walls of the range building; approximately $307,100 for adding the 40 ft. roof extension; approximately $111,300 for adding the 20 ft. tall U-shaped berm at the rear of the range; approximately $489,200 for adding the 30 ft. tall U-shaped berm at the rear of the range; and approximately $1,600,700 for the combination of all of these options.

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 on a sound level meter using fast response of the sound level meter during a designated time duration and an A-weighted filter. The Sound Exposure Level (SEL or LAE) over a stated time period or event is equal to 10 times the logarithm to the base 10 of the ratio of the time integral of squared A-weighted sound pressure to the product of the reference sound pressure and the reference duration of 1 second.

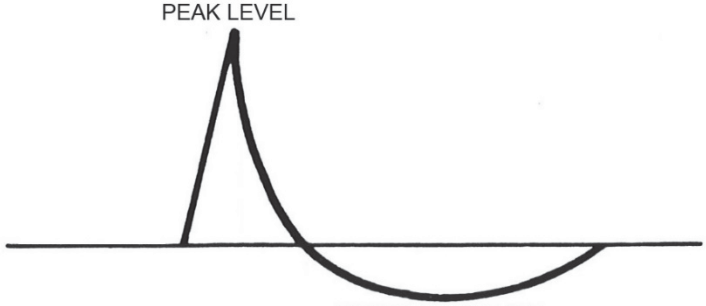

Figure 1. Amplitude or loudness plotted vs time for a typical gunshot.

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
50 dBA	55 dBA	56 dBA	When one sound is combined with another sound that is 4-7 dB louder than the first sound, the combined sound level is 1 dB louder than the louder sound
50 dBA	60 dBA	60 dBA	When one sound is 10 dB louder than another, the combined sound level is approximately equal to the louder sound level

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

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

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

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

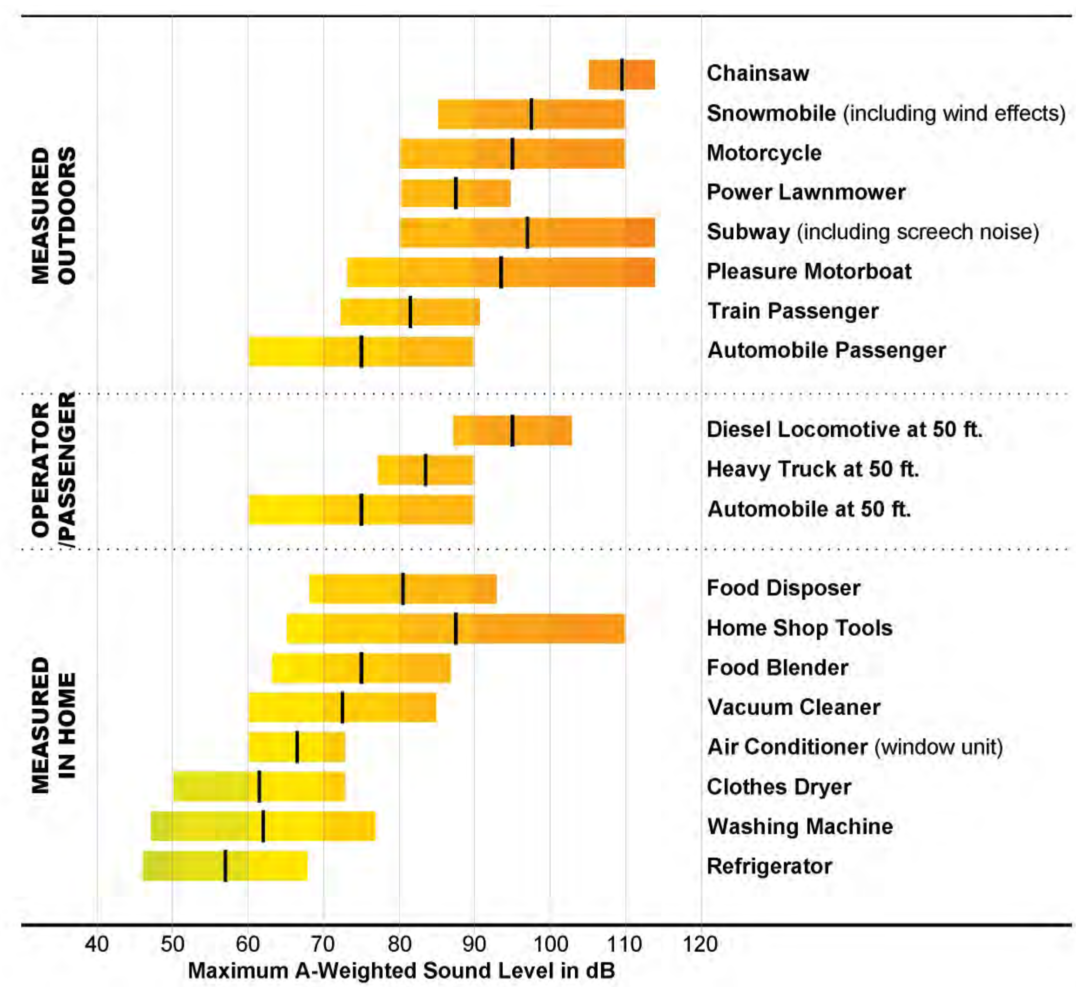

Figure 2. Acoustical thermometer showing the relative loudness in dBA of various sounds.

ACOUSTICAL MEASUREMENTS

Two types of acoustical measurements were taken. Short term measurements of the sounds produced by firearms at the location of the shooter and at distances away from the shooter were conducted at each of the 2 sites. Long term measurements of base line ambient sounds were also made at 2 locations at each of the 2 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 able to be measured.

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.

INSTRUMENTATION
A Larson Davis Model 831 and a Cesva SC 310 Sound Level Meter were used as the basic instrumentation for the acoustical measurements. The meters meet ANSI Standard S1.4 requirements for Type 1 sound level meters.

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

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

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

WEAPONS MEASURED

The weapons used in the testing included a Sig Sauer P229 0.40 caliber handgun with Smith and Wesson 0.40 caliber 180 grain full metal jacket ammunition; a Remington 870 12 gauge shotgun using 12 gauge 2-3/4" 26 grain ammunition; and a Colt M4 5.56 mm 223 semi-auto rifle using Remington 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 4 Rion NL-32 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 meters were calibrated with a Larson Davis Cal 200 calibrator prior to and after testing. The calibration levels were within ±0.1 dB from the beginning of the measurement period to the end.

The microphones were covered with a wind screen and positioned atop an extension rod approximately 5 ft 6 inches (the height of a standing person) above ground level attached to secure, weather resistant environmental cases. The environmental cases were strapped to a tree at each measurement location. The meters logged acoustical measurement data for 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 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 meter 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 distances near potential noise sensitive receivers from May 31 to June 6, 2017. 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 for the ambient sound levels can be compared to the range of sounds produced by firearms discharge in the experiments conducted on site as well as in the computer model studies to determine if the sound levels produced by the firearms are louder than the existing ambient sound levels at locations of interest. Graphs of sound pressure level in dBA plotted vs. time for each day during the measurement period at each site are shown in Appendix T.

1. Existing ambient sound levels at Range Site 1 at the Marquette County Road Commission site varied from 8 to 77 dBA with average Day-Night Sound Levels (LDN) of 36 to 55 dBA. The ambient sound levels at Site 1 consisted of light to moderate traffic on County Road 553; the breeze blowing through the trees; birds chirping; and the sounds of insects.

2. Existing ambient sound levels at Range Site 2 Sands West varied from 18 to 81 dBA with average Day-Night Sound Levels (LDN) of 41 to 60 dBA. The ambient sound levels at Site 2 consisted of light to moderate traffic with trucks on County Road N-B; the breeze blowing through the trees and grasses; distant dogs barking; birds chirping; and the sounds of insects.

MEASURED SOUND LEVELS OF FIREARMS

Experiments were conducted at each proposed range site on May 31, 2017. Conservation Officers fired shots in succession from a 0.40 caliber handgun; a 12 gauge shotgun; and a 0.223 rifle. The sequence of fire began with the 3 Conservation Officers firing 5 shots in succession from 0.40 caliber handguns in 5 separate bursts separated by a short pause between each burst. This was followed by one officer firing 2 single shots from the handgun with a short pause between each shot. The 3 officers then fired 3 shots each in five separate bursts with short pauses between each burst with a 12 gauge shotgun. One officer then fired 2 single shots with the shotgun with a short pause between each shot. The 3 officers then fired 5 shots each in 5 separate busts with short pauses between each burst with 0.223 rifles. Then one officer fired 2 single shots with the 0.223 rifle with a short pause between each shot. 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 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: Marquette County Road Commission; and Appendix D for Site 2: Sands West. 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

DIRECTIONALITY COMPARISON

0.40 Caliber Handgun

The sound levels measured at 10 feet from the source were approximately 5 to 6 dB louder in the direction of fire than to the sides and 10 to 11 dB louder in the direction of fire than behind the shooter for the 0.40 caliber handgun.

12 Gauge Shotgun

The sound levels measured at 10 feet from the source were approximately 8 to 10 dB louder in the direction of fire than to the sides and 12 to 14 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun.

0.223 Rifle

The sound levels measured at 10 feet from the source were approximately 7 to 11 dB louder in the direction of fire than to the sides and 15 to 16 dB louder in the direction of fire than behind the shooter for the 0.223 rifle.

DIRECTIONALITY COMPARISON: LA peak

Global

The global average difference in LA peak sound levels for all firearms measured at 10 feet from the shooter was 7 to 9 dB less to the sides of the shooter and 13 dB less to the rear of the shooter compared to levels measured in the direction of fire.

0.40 Caliber Handgun

LA peak sound levels of the 0.40 caliber handgun were measured at 146 dBA to 156 dBA at 10 feet in front of the shooter approximately 10º off the axis of firing. The measured peak sound levels varied from 140 to 150 dBA to the sides of the shooter and 138 to 145 dBA behind the shooter.

12 Gauge Shotgun

LA peak sound levels of the 12 gauge shotgun were measured at 144 dBA to 159 dBA at 10 feet in front of the shooter approximately 10º off the axis of firing. The measured peak sound levels varied from 139 to 149 dBA to the sides of the shooter and 135 to 146 dBA behind the shooter.

0.223 Rifle

LA peak sound levels of the 0.223 rifle were measured at 157 dBA to 162 dBA at 10 feet in front of the shooter approximately 10º off the axis of firing. The measured peak sound levels varied from 146 to 154 dBA to the sides of the shooter and 139 to 147 dBA behind the shooter.

DIRECTIONALITY COMPARISON: LAeq

The LAeq or average sound levels measured at 10 feet from the source were approximately 6 to 7 dB louder in the direction of fire than to the sides and 11 dB louder in the direction of fire than behind the shooter for the 0.40 caliber handgun; approximately 9 to 10 dB louder in the direction of fire than to the sides and 13 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun; and approximately 7 to 10 dB louder in the direction of fire than to the sides and 15 dB louder in the direction of fire than behind the shooter for the 0.223 rifle.

Global

The global average difference in LAeq average sound levels for all firearms measured at 10 feet from the shooter was 7 to 9 dB less to the sides and 13 dB less to the rear compared to levels measured in the direction of fire.

0.40 Caliber Handgun

LAeq average sound levels of the 0.40 caliber handgun were measured at 108 to 124 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured LAeq sound levels varied from 104 to 118 dBA to the sides of the shooter and 105 to 113 dBA behind the shooter.

12 Gauge Shotgun

LAeq average sound levels of the 12 gauge shotgun were measured at 104 to 124 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured LAeq sound levels varied from 105 to 115 dBA to the sides of the shooter and 102 to 111 dBA behind the shooter.

0.223 Rifle

LAeq average sound levels of the 0.223 rifle were measured at 121 to 130 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured LAeq sound levels varied from 112 to 123 dBA to the sides of the shooter and 106 to 114 dBA behind the shooter.

RANGE ORIENTATION DISCUSSION

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 8 dB difference between sound levels propagated in the direction of fire compared to the sides of the shooter would be heard as ½ as loud by people of normal sensitivities. The 11 to 14 dB difference in sound levels between the direction of fire compared to the rear of the shooter would be heard as 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

ACOUSTIC METRIC COMPARISON

SITE 1

0.40 CALIBER HANDGUN

At Site 1: the Marquette County Road Commission site 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 71 to 90 dBA LA Peak; 48 to 60 dBA LAeq and 60 to 81 dBA LA peak at ½ mile from the proposed range site; 40 to 60 dBA LAeq and 57 to 73 dBA LA peak at 1 mile from the proposed range site; and 34 to 44 dBA LAeq and 50 to 63 dBA LA peak at 2 miles from the proposed range site.

12 GAUGE SHOTGUN

At Site 1, 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 68 dBA LAeq and 71 to 89 dBA LA Peak; 43 to 58 dBA LAeq and 57 to 76 dBA LA peak at ½ mile from the proposed range site; 35 to 48 dBA LAeq and 47 to 70 dBA LA peak at 1 mile from the proposed range site; and 38 to 46 dBA LAeq 51 to 62 dBA LA peak at 2 miles from the proposed range site.

0.223 RIFLE

At Site 1, average (LAeq) and peak (LA peak) sound levels measured for the 0.223 rifle at ¼ mile from the proposed range site varied from 52 to 77 dBA LAeq and 64 to 91 dBA LA Peak; 42 to 61 dBA LAeq and 58 to 81 dBA LA peak at ½ mile from the proposed range site; 43 to 57 dBA LAeq and 55 to 78 dBA LA peak at 1 mile from the proposed range site; and 37 to 49 dBA LAeq and 51 to 65 dBA LA peak at 2 miles from the proposed range site.

SITE 2

0.40 CALIBER HANDGUN

At Site 2: Sands West 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 50 to 74 dBA LAeq and 72 to 102 dBA LA Peak; 38 to 66 dBA LAeq and 58 to 94 dBA LA peak at ½ mile from the proposed range site; 38 to 53 dBA LAeq and 61 to 85 dBA LA peak at 1 mile from the proposed range site; and 48 to 51 dBA LAeq and 61 to 66 dBA LA peak at 2 miles from the proposed range site.

12 GAUGE SHOTGUN

At Site 2, average (LAeq) and peak (LA peak) sound levels measured for the 12 gauge shotgun at ¼ mile from the proposed range site varied from 44 to 75 dBA LAeq and 65 to 105 dBA LA Peak; 41 to 66 dBA LAeq and 57 to 89 dBA LA peak at ½ mile from the proposed range site; 38 to 51 dBA LAeq and 55 to 74 dBA LA peak at 1 mile from the proposed range site.

0.223 RIFLE

At Site 2 average (LAeq) and peak (LA peak) sound levels measured for the 0.223 rifle at ¼ mile from the proposed range site varied from 51 to 82 dBA LAeq and 72 to 110 dBA LA Peak; 42 to 67 dBA LAeq and 59 to 91 dBA LA peak at ½ mile from the proposed range site; 42 to 52 dBA LAeq and 57 to 73 dBA LA peak at 1 mile from the proposed range site; and 34 to 52 dBA LAeq and 48 to 71 dBA LA peak at 2 miles from the proposed range site.

AUDIBILITY OF MEASUREMENTS

At 52% of the measurement locations at distances of 1 to 2 miles from the proposed range sites the sounds of the gun shots could not be measured above the ambient sound levels. These measurements are indicated by dashes (- -) in Tables C-1 through C-3 for Site 1; and Tables D-1 through D-3 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.

GLOBAL ACOUSTIC METRIC COMPARISON

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 3 to 4 dB louder than the LAeq levels. The LA peak levels were 19 to 20 dB louder than the LAeq levels for all sites, all locations and all weapon types.

SITE 1

The measurements at Site 1 showed a 2 to 3 dB average difference between the LA max and LAeq with a range of 1 to 5 dB and a 16 to 17 dB average difference between the LA peak and LAeq measurements with a range of 13 to 23 dB.

SITE 2

The measurements at Site 2 showed a 4 to 5 dB average difference between the LA max and LAeq with a range of 1 to 6 dB and a 21 to 22 dB average difference between the LA peak and LAeq measurements with a range of 14 to 29 dB.

0.40 CALIBER HANDGUN

SITE 1

Measurements at Site 1 showed a 1 to 5 dB difference between LA max and LAeq levels for the 0.40 caliber handgun to the front of the shooter a 2 to 4 dB difference between LA max and LAeq levels to the rear of the shooter, and a 2 to 3 dB difference at the sides. This was affected by variations in the distances from the site and direction of the measurement locations compared to the direction of fire.

Measurements at Site 1 showed a 14 to 23 dB difference between LA peak and LAeq levels for the 0.40 caliber handgun to the front of the shooter, a 17 to 21 dB difference between LA peak and LAeq levels to the rear of the shooter for the handgun, and an 15 to 17 dB difference at the sides.

SITE 2

Measurements at Site 2 showed a 4 to 6 dB difference between LA max and LAeq levels for the 0.40 caliber handgun to the front of the shooter a 4 to 5 dB difference between LA max and LAeq levels to the rear of the shooter, and a 1 to 5 dB difference at the sides. This was affected by variations in the distances from the site and direction of the measurement locations compared to the direction of fire.

Measurements at Site 2 showed a 21 to 25 dB difference between LA peak and LAeq levels for the 0.40 caliber handgun to the front of the shooter, a 21 to 25 dB difference between LA peak and LAeq levels to the rear of the shooter for the handgun, and a 14 to 15 dB difference at the sides.

12 GAUGE SHOTGUN

SITE 1

Measurements at Site 1 showed a 2 to 3 dB difference between LA max and LAeq levels for the 12 gauge shotgun to the front of the shooter a 2 to 5 dB difference between LA max and LAeq levels to the rear of the shooter, and a 1 to 3 dB difference at the sides. This was affected by variations in the distances from the site and direction of the measurement locations compared to the direction of fire.

Measurements at Site 1 showed a 15 to 19 dB difference between LA peak and LAeq levels for the 12 gauge shotgun to the front of the shooter, a 16 to 22 dB difference between LA peak and LAeq levels to the rear of the shooter for the shotgun, and an 13 to 17 dB difference at the sides.

SITE 2

Measurements at Site 2 showed a 4 to 6 dB difference between LA max and LAeq levels the 12 gauge shotgun to the front and rear and a 1 to 6 dB difference at the sides. This was affected by variations in the distances from the site and direction of the measurement locations compared to the direction of fire.

Measurements at Site 2 showed an 18 to 25 dB difference between LA peak and LAeq levels for the 12 gauge shotgun to the front of the shooter, a 20 to 29 dB difference between LA peak and LAeq levels to the rear of the shooter for the shotgun, and an 15 to 27 dB difference at the sides.

0.223 RIFLE

SITE 1

Measurements at Site 1 showed a 2 to 4 dB difference between LA max and LAeq levels for the 0.223 rifle to the front and rear of the shooter and a 1 to 3 dB difference at the sides. This was affected by variations in the distances from the site and direction of the measurement locations compared to the direction of fire.

Measurements at Site 1 showed a 14 to 20 dB difference between LA peak and LAeq levels for the 0.223 rifle shotgun to the front of the shooter and a 14 to 19 dB difference between LA peak and LAeq levels to the rear and sides of the shooter for the rifle.

SITE 2

Measurements at Site 2 showed a 4 to 5 dB difference between LA max and LAeq levels the 0.223 rifle to the front of the shooter a 3 to 5 dB difference between LA max and LAeq levels to the rear of the shooter, and a 2 to 6 dB difference at the sides. This was affected by variations in the distances from the site and direction of the measurement locations compared to the direction of fire.

Measurements at Site 2 showed a 19 to 24 dB difference between LA peak and LAeq levels for the 0.223 rifle to the front of the shooter, an 18 to 26 dB difference between LA peak and LAeq levels to the rear of the shooter for the rifle, and a 16 to 26 dB difference at the sides.

DIRECTIONALITY COMPARISON

SITE 1

LA Peak

Measured LA peak sound levels at Site 1 were approximately 5 dB quieter to 4 dB louder in the relative direction of fire at ¼ mile compared to the same distances at the back side of the shooter and 7 dB quieter to 1 dB louder in the relative direction of fire compared to the rear of the shooter at ¼ mile. This is due to proposed range site and the measurement locations at ¼ mile were located in a depression or "bowl" formed by the topography. Also, the measurement location to the front of the proposed range was not directly in front of the direction of fire. The LA peak levels were 6 to 17 dB quieter in the direction of fire compared to the near side and 8 to 16 dB quieter compared to the rear at ½ mile from the proposed range location. LA peak levels were 2 dB quieter in the direction of fire compared to the near side and 9 to 14 dB quieter compared to the rear at 1 mile from the proposed range location. The measurement locations in the direction of fire at ½ mile and 1 mile were shielded by topography whereas the measurement locations to the sides and rear were at similar elevations to the proposed range location. The measurement locations were slightly off-axis from the direction of fire. Also, variations occurred in the distances from the proposed range location and direction of the measurement locations compared to the direction of fire at different distances.

LAeq

Measured LAeq sound levels at Site 1 were approximately 3 to 13 dB quieter in the relative direction of fire at ¼ mile compared to the same distances at the back side of the shooter and 0 to 7 dB quieter in the relative direction of fire compared to the rear of the shooter at ¼ mile. The LAeq levels were 6 to 17 dB quieter in the direction of fire compared to the near side and 8 to 16 dB quieter compared to the rear at ½ mile from the proposed range location. LAeq levels were 2 dB quieter in the direction of fire compared to the near side and 9 to 14 dB quieter compared to the rear at 1 mile from the proposed range location.

SITE 2

LA Peak

Measured LA peak sound levels at Site 2 were approximately 21 to 28 dB quieter in the direction of fire at ¼ mile compared to the same distance at the near side of the shooter, 19 to 25 dB quieter in the direction of fire compared to the rear of the shooter at ¼ mile and 2 dB quieter to 4 dB louder in the direction of fire compared to the back side of the shooter at ¼ mile. This may be due to the vegetation between the proposed range site and the measurement locations at ¼ mile. The LA peak levels were 0 to 10 dB louder in the relative direction of fire compared to the near side at ½ mile, 0 to 6 dB louder in the relative direction of fire compared to the rear at ½ mile and 20 to 28 dB louder in the relative direction of fire compared to the back side at ½ mile from the proposed range location. The LA peak levels were 0 to 12 dB louder in the relative direction of fire compared to the near side at 1 mile and 6 dB quieter to 11 dB louder in the relative direction of fire compared to the rear at 1 mile from the proposed range location. The measurement locations at ½ mile, 1 mile and 2 miles were off-axis from the direction of fire so the measurement locations to the front of the proposed range were not directly in front of the direction of fire and the measurement locations to the sides and rear were to directly to the sides and rear of the direction of fire. Also, variations occurred in the distances from the proposed range location and direction of the measurement locations compared to the direction of fire at different distances. The topography in the relative direction of fire slopes upward while the topography behind the proposed range slopes downward.

LAeq

Measured LAeq sound levels at Site 2 were approximately 14 to 21 dB quieter in the direction of fire at ¼ mile compared to the same distance at the near side of the shooter, 14 to 18 dB quieter in the direction of fire compared to the rear of the shooter at ¼ mile and 0 to 2 dB louder in the direction of fire compared to the back side of the shooter at ¼ mile. The LAeq levels were 1 dB quieter to 9 dB louder in the relative direction of fire compared to the near side at ½ mile, 2 dB quieter to 8 dB louder in the relative direction of fire compared to the rear at ½ mile and 13 to 18 dB louder in the relative direction of fire compared to the back side at ½ mile from the proposed range location. The LAeq levels were 1 dB quieter to 2 dB louder in the relative direction of fire compared to the near side at 1 mile and 2 to 4 dB louder in the relative direction of fire compared to the rear at 1 mile from the proposed range location.

SOUND DECAY WITH DISTANCE

SITE 1

The average sound decay for each doubling of distance from the sound source for the LA peak values was 8 dB with 7 dB decay per doubling of distance for the LAeq values at Site 1. This was affected by the variations in topography, vegetation, distances from the site and direction of the measurement locations compared to the direction of fire.

SITE 2

The average sound decay for each doubling of distance from the sound source for the LA peak values was 11 dB with 8 dB decay per doubling of distance for the LAeq values at Site 2. This was affected by the variations in topography, vegetation, distances from the site and direction of the measurement locations compared to the direction of fire.

AVERAGE DIFFERENCE IN MEASUREMENTS

SITE 1

LAeq

At Site 1: MCRC the average difference in LAeq measurements for successive bursts was 9 dB for the 0.40 caliber handgun with a range of 4 to 13 dB; the average difference in LAeq measurements was 8 dB for the 12 gauge shotgun with a range of 2 to 16 dB; and average difference in LAeq measurements was 9 dB for the 0.223 rifle with a range of 2 to 14 dB.

LApeak

At Site 1: MCRC the average difference in LA peak measurements for successive bursts was 13 dB for the 0.40 caliber handgun with a range of 7 to 20 dB; the average difference in LA peak measurements was 11 dB for the 12 gauge shotgun with a range of 2 to 19 dB; and average difference in LA peak measurements was 11 dB for the 0.223 rifle with a range of 6 to 21 dB.

LAmax

At Site 1: MCRC the average difference in LA max measurements for successive bursts was 8 dB for the 0.40 caliber handgun with a range of 5 to 12 dB; the average difference in LA max measurements was 7 dB for the 12 gauge shotgun with a range of 1 to 15 dB; and average difference in LA max measurements was 8 dB for the 0.223 rifle with a range of 4 to 13 dB.

SITE 2
LAeq
At Site 2: SANDS the average difference in LAeq measurements for successive bursts was 10 dB for the 0.40 caliber handgun with a range of 4 to 16 dB; the average difference in LAeq measurements was 11 dB for the 12 gauge shotgun with a range of 7 to 19 dB; and average difference in LAeq measurements was 10 dB for the 0.223 rifle with a range of 7 to 16 dB.

LApeak
At Site 2: SANDS the average difference in LA peak measurements for successive bursts was 14 dB for the 0.40 caliber handgun with a range of 5 to 24 dB; the average difference in LA peak measurements was 15 dB for the 12 gauge shotgun with a range of 7 to 24 dB; and average difference in LA peak measurements was 14 dB for the 0.223 rifle with a range of 9 to 20 dB.

LAmax
At Site 2: SANDS the average difference in LA max measurements for successive bursts was 10 dB for the 0.40 caliber handgun with a range of 3 to 17 dB; the average difference in LA max measurements was 11 dB for the 12 gauge shotgun with a range of 5 to 16 dB; and average difference in LA max measurements was 10 dB for the 0.223 rifle with a range of 6 to 16 dB.

THE COMPUTER MODEL STUDIES

Introduction

A series of computer model studies were designed and executed to study the propagation of sounds from the proposed range sites at each of the 2 locations at distances away from the proposed ranges. The models were constructed in the CadnaA 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 and 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, 40 yard, 50 yard, 100 yard, 200 yard and 300 yard ranges surrounded by a berm. The ranges have approximately 10 ft. high berms on three sides. 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 Marquette County Shooting Range site. A diagram of the base range design is shown in Figure 3.

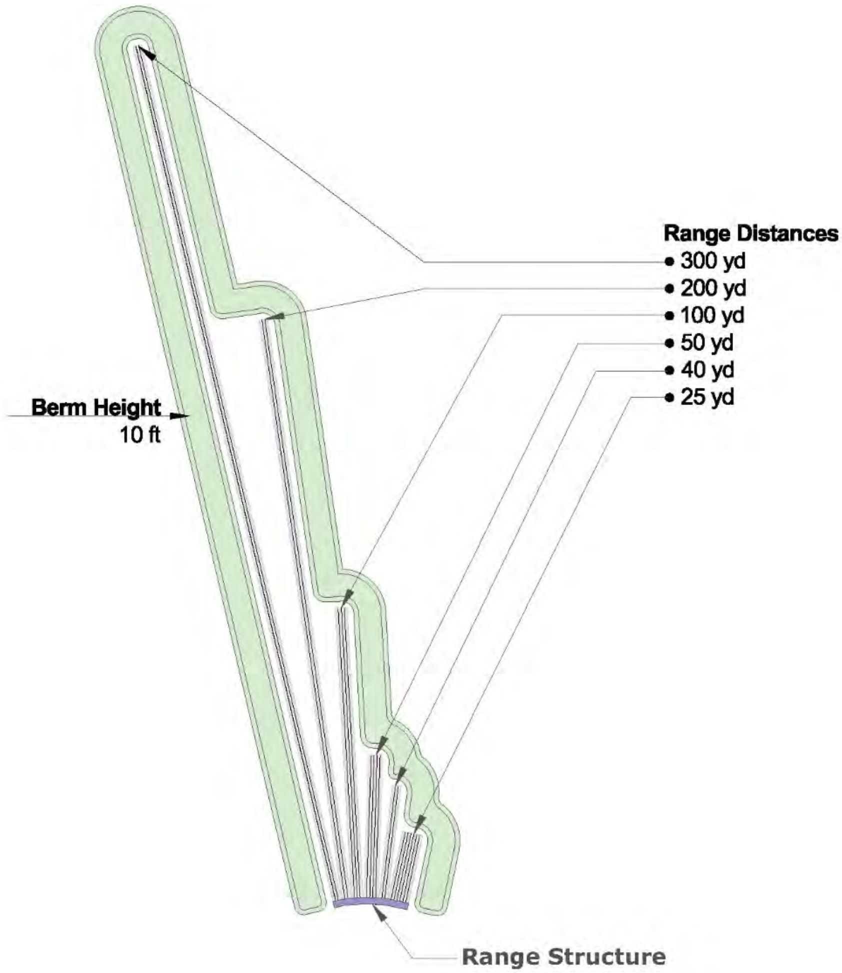

Figure 3. Concept diagram of the base range design.

Method

1. The analysis assumed a "typical day" with 3 shooters firing within a 1 second time period for the base range conditions with up to 13 additional people on the range getting ready to fire, loading their weapons or talking with each other.

2. The "typical day" had 1 person firing a 0.223 rifle on the 300 yard range; 1 person on the 40 yard range shooting a 12 gauge shotgun; and one person on the 25 yard range firing a 0.40 caliber handgun in the same 1 second period of time. The 13 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.

3. The "busy day" scenario had one person on the 50 yard, 200 yard and 300 yard ranges each firing a 0.223 rifle; one person on the 40 yard range firing a 12 gauge shotgun; and 2 people on the 25 yard range each firing a 0.40 caliber handgun in the same 1 second period of time or the base range conditions.

4. 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.

5. 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 3 to 4 dB higher than the LAeq with a range of 1 to 6 dB and the LA peak was 19 to 20 dB higher than the LAeq with a range of 13 to 29 dB.

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

7. The octave band sound pressure level data for the .223 rifles described above was used as the sound source for shooters on the 50 yard, 200 yard and 300 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 40 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 person firing a 0.223 rifle on the 300 yard range; 1 person on the 40 yard range shooting a 12 gauge shotgun; and one person on the 25 yard range firing a 0.40 caliber handgun in the same 1 second period of time.
   B. “Busy day” - one person on each of the 50 yard, 200 yard and 300 yard ranges each firing a 0.223 rifle; one person on the 40 yard range firing a 12 gauge shotgun; and 2 people on the 25 yard range each firing a 0.40 caliber handgun in the same 1 second period of time or the base range conditions.
   C. Direction of fire relative to the receiver.
   D. The ranges have approximately 10 ft. tall berms on the three downrange sides. 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.
   E. Molecular sound absorption for a standard day (50° F, 80% 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 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.
   F. Anomalous excess attenuation (from small scale differences in wind, temperature, and humidity in the air).
   G. The topographic features of the 2 sites were developed using contour maps obtained from the United States Geological Survey.

H. CadnaA assumes a downwind condition with wind velocity of 1 – 11 mph. An experiment was also conducted with an average and maximum wind speed and wind direction for each site. This experiment is described in Appendix I.
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.

8. The resulting sound levels for each of the three 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 north-northwest for Site 1, and to the northwest and southwest for Site 2 in Appendices F and G.

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

10. The noise mitigation options studied include the following items:
    A. Alternate range orientations to the north-northwest for Site 1, and to the northwest and 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 north-northwest; to the south and to the northwest and 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 Site 1 with the alternate range orientations of north-northwest; and to the northwest and 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 2 proposed sites for the alternate range orientation at Site 1; 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 original and alternate range orientations at Sites 1 and 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 with the 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 two proposed sites for the original and 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.

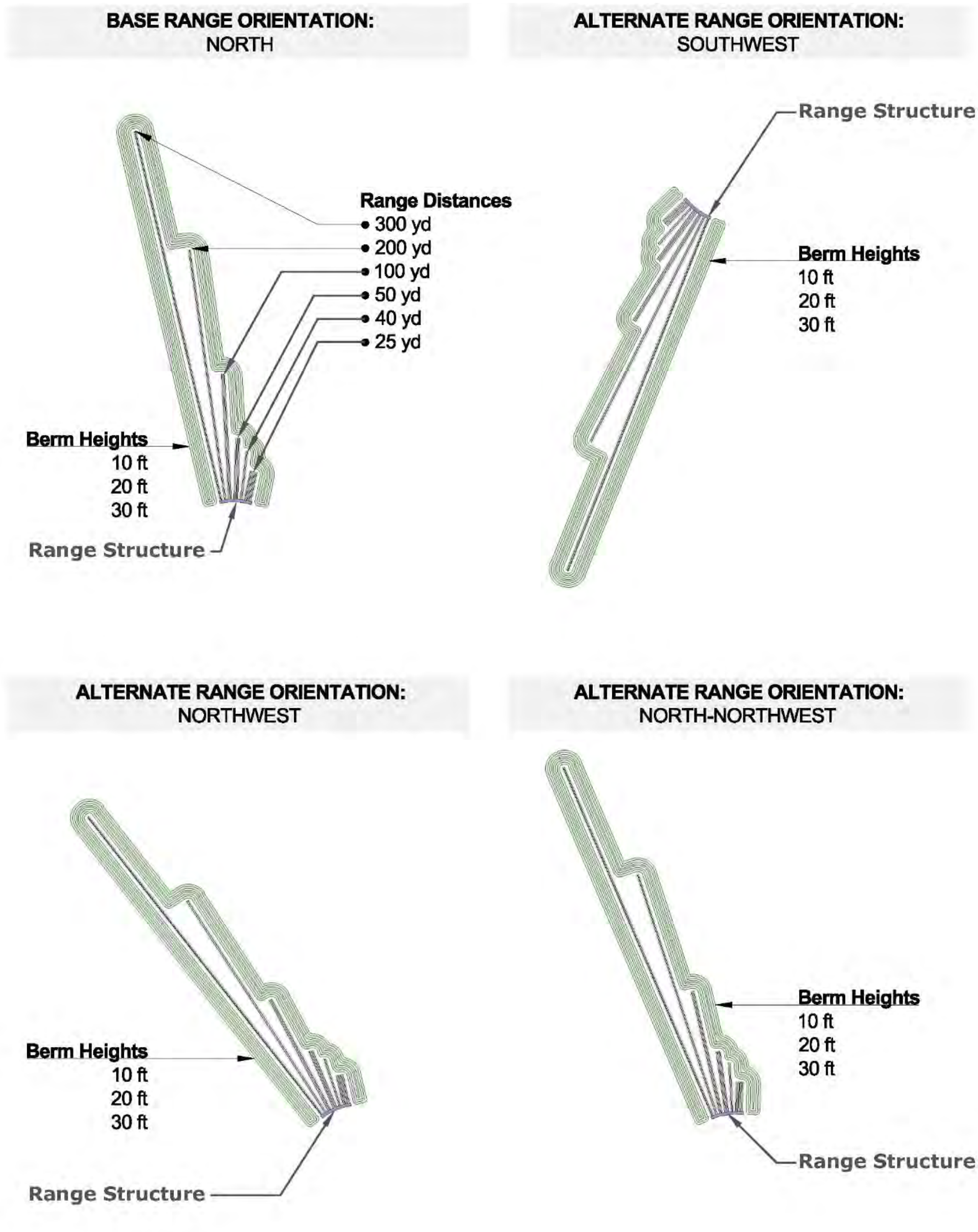

Figure 4. Concept plans showing the original and alternate range orientations for the 2 proposed range sites.

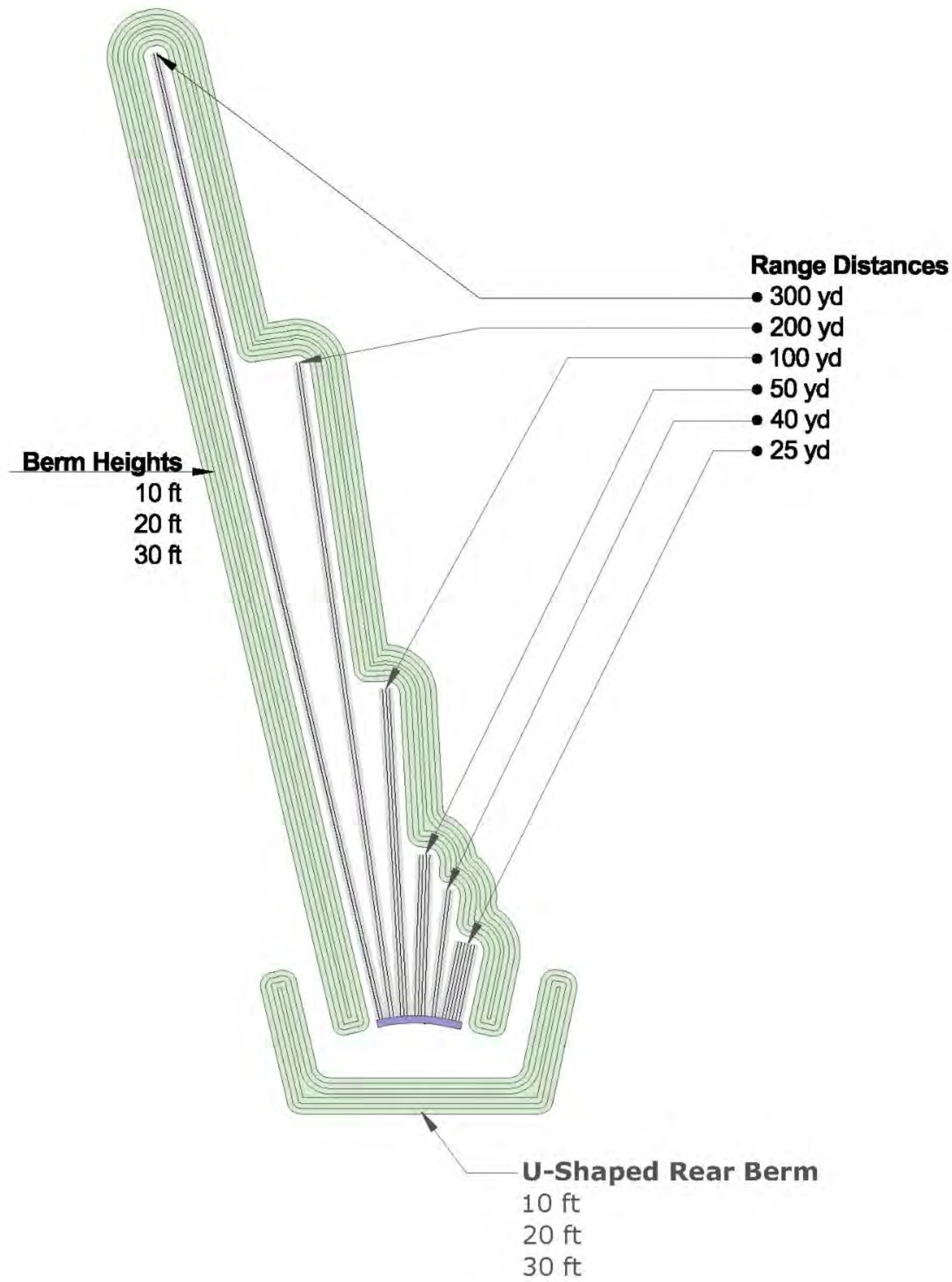

Figure 5. Concept plan showing the U-shaped berm configuration for the range described in Appendix K.

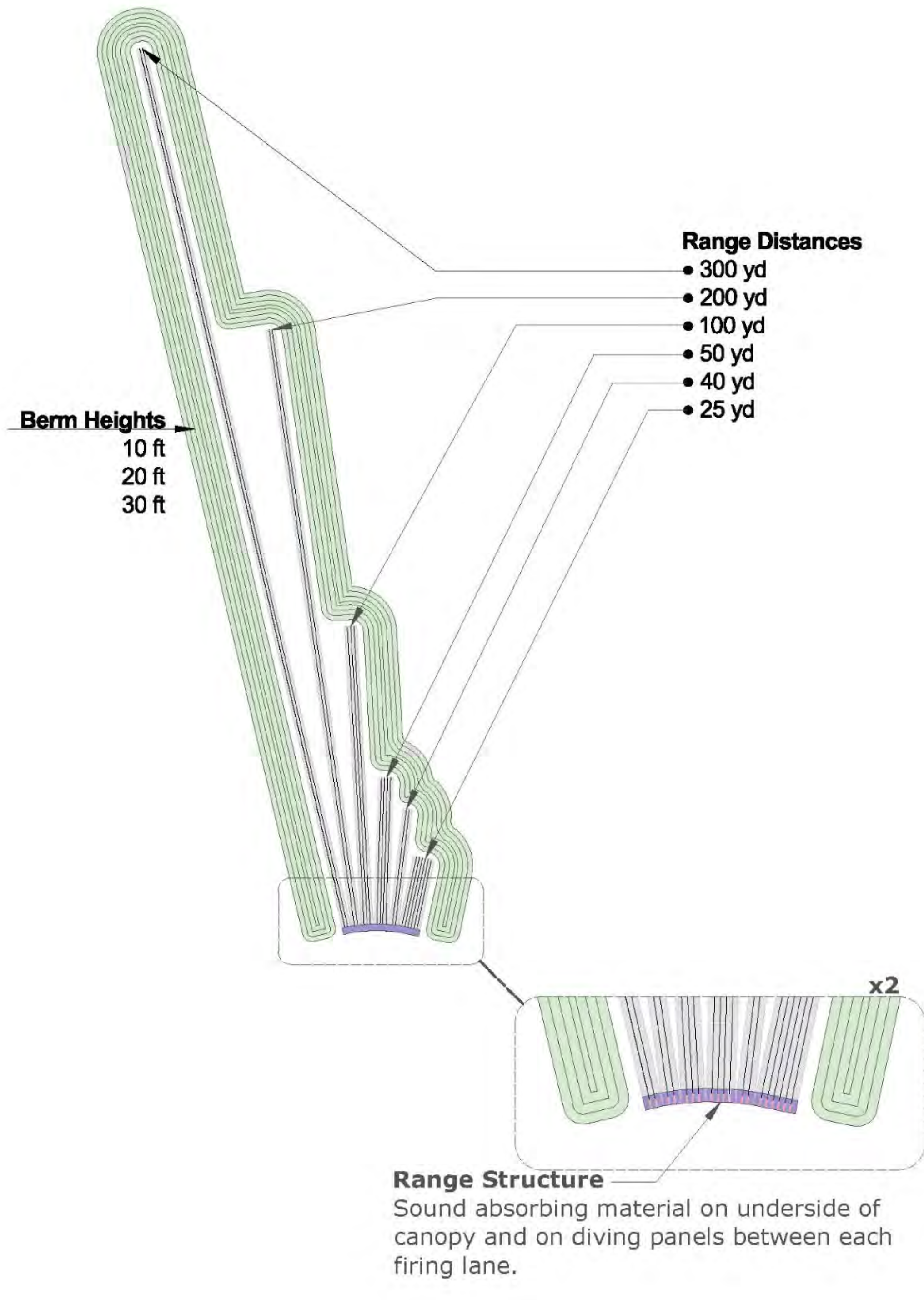

Figure 6. Concept plan for the range structure with interior sound absorbent lining described in Appendix L.

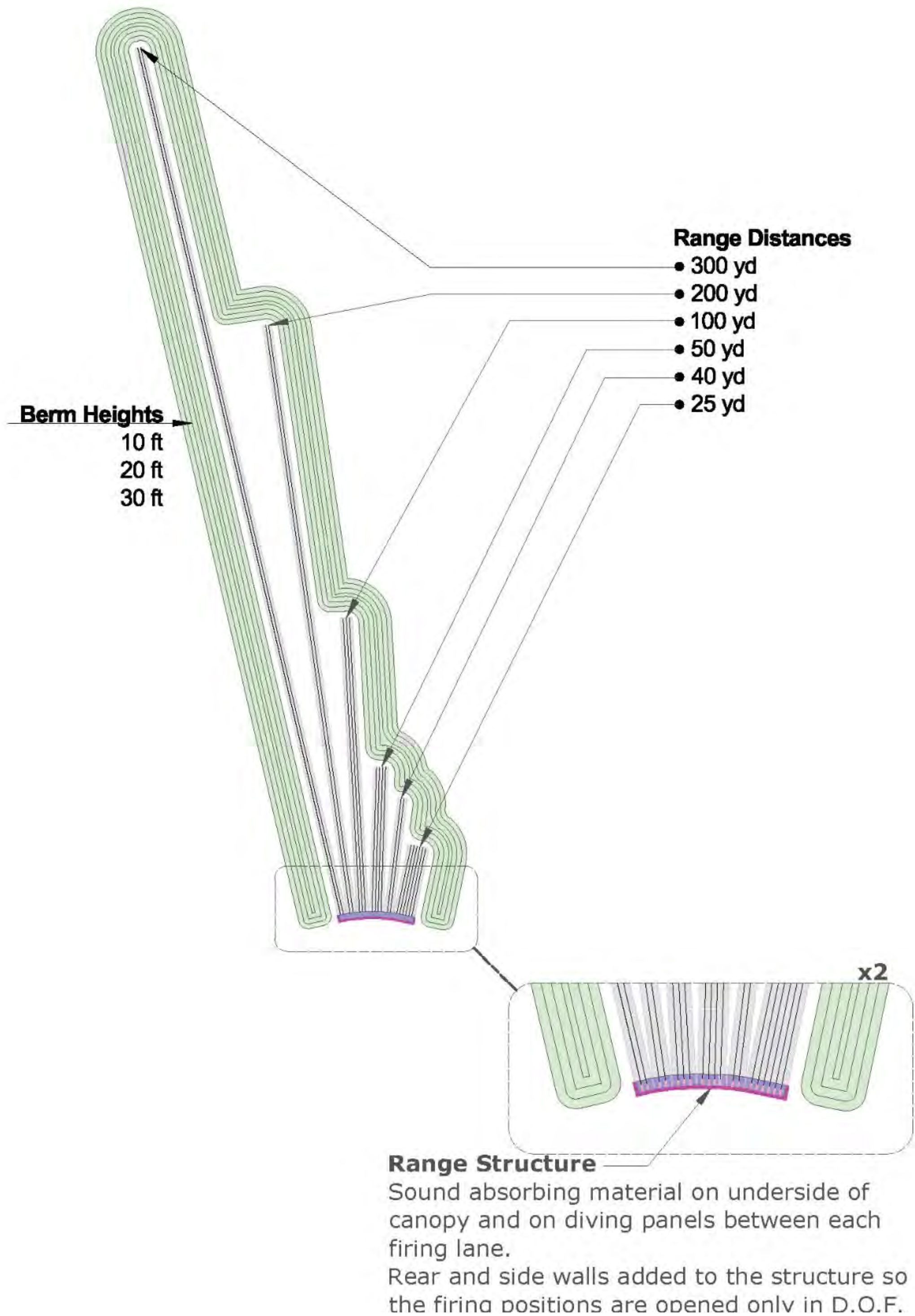

Figure 7. Concept plan for the range structure with the rear and side walls added with the interior sound absorbent lining described in Appendix M.

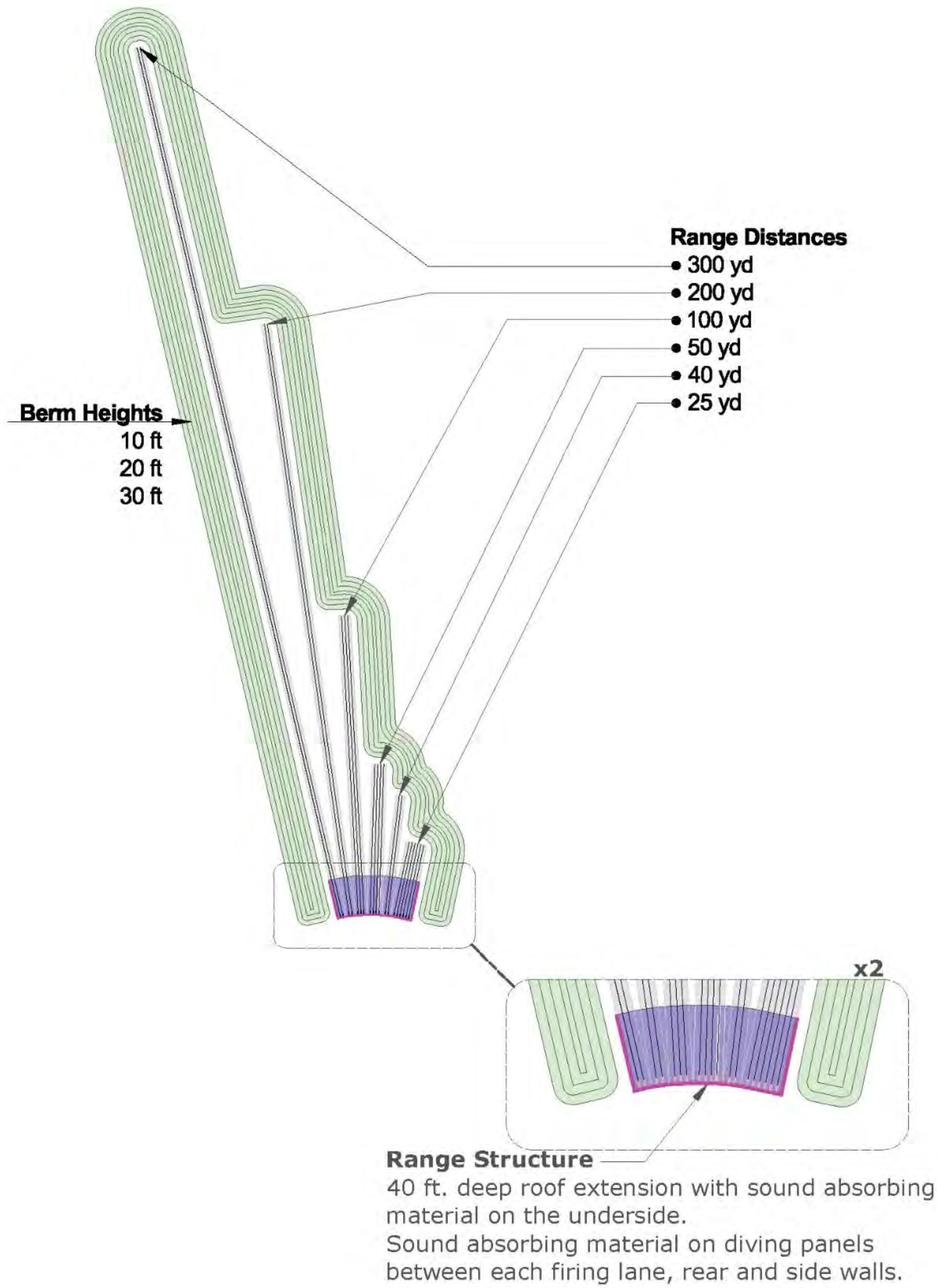

Figure 8. Concept plan for the range structure with the 40 ft. extension of the roof with the rear and side walls added and the interior sound absorbent lining described in Appendix N.

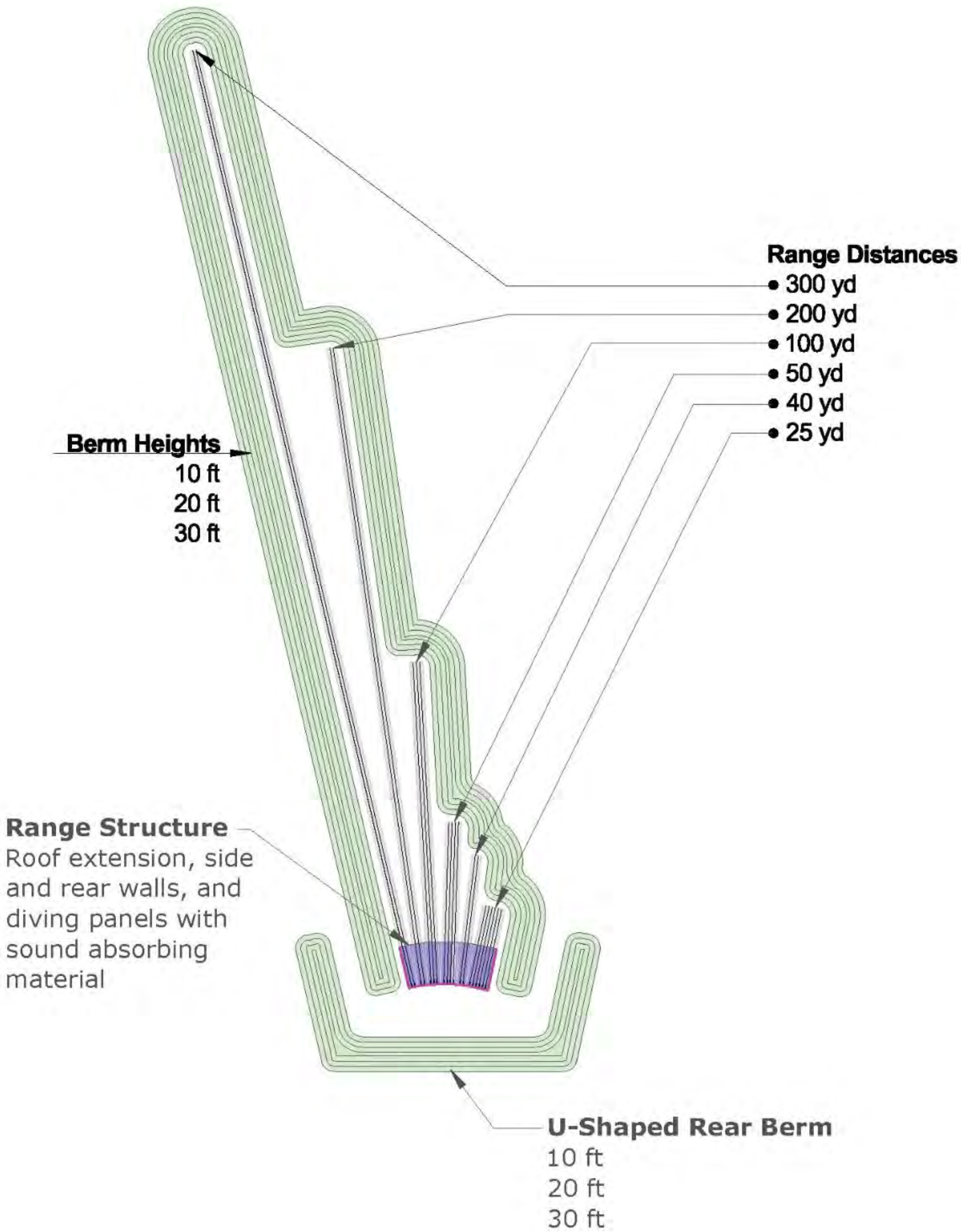

Figure 9. Concept plan showing the range structure with the 40 ft. extension of the roof with the rear and side walls added and the interior sound absorbent lining and a U-shaped berm around the rear of the range described in Appendix O.

RESULTS OF THE COMPUTER MODEL STUDIES

Appendices F through O contain scaled maps/aerials of the 3 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 sound exposure level (SEL) or 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.

POINT RANKING SYSTEM

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 sensitive properties that fell within the noise contours produced by the range. 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 18 to 4,816. 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.

BASE RANGE CONDITIONS

Two sites and range orientations were initially selected for analysis. Site 1: MCRC with the range oriented towards the north; and Site 2: Sands West with the range oriented towards the north. The computer model analysis of these sites is summarized in Appendix F with 10 ft. tall berms on the three downrange sides. Site 1 had linear pressure score of 1,235 that was approximately ½ of the linear pressure score for the base range design at Site 2: Sands West.

ALTERNATE RANGE ORIENTATIONS

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 north-northwest for Site 1: MCRC; and towards the northwest and southwest for Site 2: Sands West.

The range at Site 1 oriented towards the north-northwest had the lowest linear pressure score of 927 of the 5 alternatives with the base range design. This linear pressure score was approximately 25% less than the linear pressure score for the base range design at Site 1 oriented to the north. The range at Site 2: Sands West oriented to the NW had a 30% higher linear pressure score than the range at Site 1 oriented to the N. The linear pressure scores at the other 2 orientations for Site 2 were 200% and almost 400% higher than the linear pressure score for the base range at Site 1 oriented to the N. The relative ranking of the ranges for “typical day” scenarios were identical to the rankings for the “busy day” scenarios.

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 $233,900 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 $670,900 for the 30 ft. tall berm compared to the base design range. These studies are summarized in Appendices F and G.

BERM HEIGHT STUDY
Models were tested using 20 ft. tall and 30 ft. tall berms in addition to the 10 ft. tall side berms on the three downrange sides 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 and orientations was similar to those previously discussed with Site 1 oriented to the north and Site 1 oriented to the north-northwest having the lowest linear pressure scores of the alternatives examined of 442 and 562 respectively.

The highest scores for these tests were for all berm heights and orientations at Site 2: Sands West of 1,188 to 4,816 due to the close proximity to multiple noise sensitive receivers and the higher number of noise sensitive receivers within 2 miles of the approximate center of the proposed range site when compared to the number of noise sensitive receivers within a 2 mile radius of Site 1.

On average across all models and all scenarios tested, the average decrease in sound level was approximately 1 to 2 dB for the 20 ft. tall berm compared to the 10 ft. tall berm and an additional 1 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 biggest reductions in sound levels as the height of the berms is increased occur close to the range. At ½ to 1 mile and at 2 miles, the sound reductions get relatively small. Therefore, if there are a lot of homes near the range, raising the berm height can result in large sound reductions at the nearest homes that need the greatest reductions. At greater distances from the range, the sound reductions from increasing the height of the berms are limited. So, if there are a lot of homes farther away from the range, raising the height of the berms does not provide significant sound reductions. Therefore, the increased berm height should be implemented for carefully considered situations.

U-SHAPED BERM STUDY
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 south of Site 1 and homes to the south and southeast 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 31% to 70% by adding these U-shaped berms that were 20 ft. tall and 30 ft. tall at an incremental cost increase of approximately $345,200 for the 20 ft. berm scheme and $1,160,100 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.

ALTERNATE RANGE WEATHER/VEGETATIVE CONDITIONS

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.

SOLID DIVIDERS BETWEEN LANE STUDY

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 1 by approximately 73% to 89% and by approximately 87% to 90% at Site 2 at a cost of approximately $85,300 for adding the partitions and sound absorbent material to the range structure and $233,900 for raising the berms to 20 ft. high for a total cost increase compared to the base range of $319,200 as summarized in Appendix L.

ADDITIONAL NOISE MITIGATION OPTIONS

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 reduced the linear pressure score between 50% and 97% compared to the base range with the 10 ft. tall berm on the three downrange sides and the open range structure depending upon the combination of options selected. Incremental costs for these options varied from approximately $133,500 for adding the side and rear walls of the range building; approximately $307,100 for adding the 40 ft. roof extension; approximately $111,300 for adding the 20 ft. tall U-shaped berm at the rear of the range; approximately $489,200 for adding the 30 ft. tall U-shaped berm at the rear of the range; and approximately $1,600,700 for the combination of all of these options.

A second 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 0 to 7dB at distances of 1 to 2 miles in the direction of fire from the range and by 6 to 15 dB towards the rear of the range.

There was also an additional 7 dB decrease in sound level on average attributed to the extended roof on the range structure and the U-shaped berm behind the shooters at similar distances towards the front of the range. There was a 7 to 15 decrease in sound level towards the rear of the range when the U-shaped berm at the rear of the range and the extended roof on the range structure were included in the design.

EXISTING CONDITIONS

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. For example, the increases in berm height and in the roof overhang of the range structure did not reduce sounds as much at 1 to 2 mile distances from the range structure as they did at distances closer to the ranges.

NOISE ORDINANCES

The Marquette County Road Commission (MCRC) site and the Sands Township site are both located in Sands Township in Marquette County, Michigan. The MCRC site is located within a two-mile radius of Negaunee and Richmond Townships. The Sands Township site is not within a two-mile radius of any other township.

Marquette County does not have a noise ordinance. According to County staff, noise is regulated at the level of the individual townships.

Noise ordinances for Sands and Negaunee Townships 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 was 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. There are approximately 5 residential properties near the MCRC range site and 15 residential properties near the Sands West range site located within the 55 to 60 LAeq noise contours for the base range design. There are 8 residential properties near the MCRC range site and 112 residential properties near the Sands West range site located between the 50 to 55 dBA contours for the base range design. This means that the MCRC site will impact fewer residences than the Sands site at these sound pressure levels as shown by the noise contour lines in the computer model studies.

The Noise Control Ordinance for the Sands Township is included in Ordinance Number 53 of the General Law Township of Sands in Marquette County, Michigan. Section 4: General Prohibited Noise, sub-section A of the Sands Township Noise Control Ordinance states that “It shall be unlawful for any person or entity to make, maintain, or continue, or cause to be made or continued, any excessive, unnecessary, unnatural, repeated, prolonged or unusually loud noise, or any noise which annoys or disturbs or injures or irritates or unreasonably impairs the comfort, repose, health, or peace of another, within the limits of the General Law Township of Sands.” However, Section 6: Exceptions, sub-section E states that the noise prohibitions do not apply to “Noise emanating from the discharge of firearms providing that such discharge is otherwise authorized under Michigan law or local ordinances.”

Negaunee Township does not have a noise ordinance or noise-specific zoning ordinances.

The Richmond Township Noise and Public Nuisance Ordinance states in sub-section A, General regulation of Section 2: Noise Regulations that “it shall be unlawful for any person to make or continue, or cause to be made or continued, any excessive, or unnecessary or unusually loud noise or any noise which either annoys, disturbs, injures, or endangers the comfort, repose, health, peace or safety of others within the limits of the Township.”

This noise ordinance information is displayed in Table 3.

Table 3. Table showing the applicable noise ordinances and which sites they pertain to.

Applicable Noise Ordinances	SITES	
	Sands	MCRC
Marquette County	No noise ordinance. According to County staff, noise is regulated at the level of the individual townships.	
Sands Township	The Noise Control Ordinance for the Sands Township is included in Ordinance Number 53 of the General Law Township of Sands in Marquette County, Michigan. Section 4: General Prohibited Noise, sub-section A of the Sands Township Noise Control Ordinance states that "It shall be unlawful for any person or entity to make, maintain, or continue, or cause to be made or continued, any excessive, unnecessary, unnatural, repeated, prolonged or unusually loud noise, or any noise which annoys or disturbs or injures or irritates or unreasonably impairs the comfort, repose, health, or peace of another, within the limits of the General Law Township of Sands." However, Section 6: Exceptions, sub-section E states that the noise prohibitions do not apply to "Noise emanating from the discharge of firearms providing that such discharge is otherwise authorized under Michigan law or local ordinances."	
Negaunee Township	N/A	No noise ordinance or noise-specific zoning ordinances
Richmond Township	N/A	The Richmond Township Noise and Public Nuisance Ordinance states in sub-section A, General regulation of Section 2: Noise Regulations that "it shall be unlawful for any person to make or continue, or cause to be made or continued, any excessive, or unnecessary or unusually loud noise or any noise which either annoys, disturbs, injures, or endangers the comfort, repose, health, peace or safety of others within the limits of the Township."

CONCLUSIONS

Sound studies were conducted for two proposed shooting range sites: Site 1 at the Marquette County Road Commission Area located north of County Road Ng and west of County Road 480; and Site 2 which is the Sands West site located just east of County Road Nc in Marquette County, Michigan.

EXISTING AMBIENT CONDITIONS

Existing ambient sound levels were measured at 2 locations near potential noise sensitive receivers located near each proposed range site from May 30 to June 6, 2017. Existing ambient sound levels (LAeq) at the sites varied from 8 to 81 dBA with average Day-Night Sound Levels (LDN) of 36 to 60 dBA. The lower end of this range of sound levels is typical of relatively quiet sites in natural settings with little anthropocentric sounds. The middle to upper end of the range of measured sound levels are indicative of louder suburban sites or sites with some transportation or commercial activity nearby.

EXPERIMENT SETUP

Experiments were set up at each proposed range site on May 31, 2017. Three Conservation Officers fired 3 shots in succession from a 0.40 caliber handgun; a 12 gauge shotgun; and a 0.223 rifle. The sequence of fire included each of the 3 Conservation Officers firing 5 shots in succession from 0.40 caliber handguns in 5 separate bursts separated by a short pause between each burst. This was followed by one officer firing 2 single shots from the handgun with a short pause between each shot. The 3 officers then fired 3 shots each in five separate bursts with short pauses between each burst with a 12 gauge shotgun. One officer then fired 2 single shots with the shotgun with a short pause between each shot. The 3 officers then fired 5 shots each in 5 separate busts with short pauses between each burst with 0.223 rifles. Then one officer fired 2 single shots with the 0.223 rifle with a short pause between each shot.

SOUND LEVELS MEASURED AT 10' FROM THE SOURCE
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 3 prospective sites for the firing range.

The sound levels measured at 10 feet from the source were approximately 5 to 6 dB louder in the direction of fire than to the sides and 10 dB louder in the direction of fire than behind the shooter for the 0.40 caliber handgun; approximately 8 to 9 dB louder in the direction of fire than to the sides and 13 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun; and approximately 7 to 10 dB louder in the direction of fire than to the sides and 16 dB louder in the direction of fire than behind the shooter for the 0.223 rifle.

AUDIBILITY OF EXPERIMENT
At 52% 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 the proposed range sites.

GLOBAL ACOUSTIC METRIC COMPARISON
Average LAeq, maximum LA max and peak LA peak sound levels were measured at 16 locations around each of the proposed range sites. The LA max levels were on average 2 to 5 dB louder than the LAeq levels. The LA peak levels were 16 to 22 dB louder than the LAeq levels.

DIRECTIONALITY COMPARISON
Measured sound levels were between 11 dB louder and 19 dB quieter in the direction of fire compared to the same distances at the sides of the shooter and 5 dB louder and 17 dB quieter in the direction of fire than behind the shooter compared to the same distances from the proposed range locations. This was affected by the variations in topography, vegetation, distances from the site and direction of the measurement locations compared to the direction of fire.

SOUND DECAY WITH DISTANCE
The average sound decay with distance measured from the proposed range sites was 7 to 11 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.

3-D ACOUSTIC MODEL
Computer models of each of the proposed range sites were constructed in CadnaA Software including topography, roads, ground cover, coniferous vegetation with the 10 ft. tall berms on 3 sides of the ranges and an open structure over the firing line for a standard day with 50^{o} F and 80% relative humidity with typical wind speed and direction.

TYPICAL DAY vs BUSY DAY SCENARIOS

Noise contours were plotted for a "typical day" with 3 shooters firing within a 1 second time period and a "busy day" with 6 shooters firing within a 1 second time period for the base range conditions. Other people would likely be at the range for both of these conditions, but not firing within the same 1 second period of time.

POINT SCALE RANKING METHOD

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 18 to 4,816 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.

SITE 1 vs SITE 2 RANKING

Two sites and range orientations were initially selected for analysis. Site 1: Marquette County Road Commission with the range oriented towards the north; and Site 2: Sands West with the range oriented towards the north. The computer model analysis of these sites is summarized in Appendix F for the "typical day" and "busy day" scenarios with 10 ft. tall berms on the 3 down range sides of the range. Site 1 had the lowest linear pressure score followed by Site 2 with with a linear pressure score that was double the Site 1 score.

TYPICAL DAY vs BUSY DAY RANKING

The "typical day" scenario had approximately 1/3 of the linear pressure score or 4 dB less than the scores for the "busy day" scenario. This means that off-site sound levels will be higher when more people fire their weapons in the same 1 second periods of time.

20' vs 30' BERM RANKING

The ranking of the initial 2 sites and range orientations remained consistent for the "busy day" scenario when alternate berm heights of 20 ft. and 30 ft. were modeled. The scenario with the 20 ft. tall berms had approximately 78% of the linear pressure score as the base range design. The scenario with the 30 ft. tall berms had approximately 60% of the linear pressure score as the base range design.

ALTERNATE RANGE ORIENTATIONS

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 northwest for Site 1: Marquette County Road Commission; and towards the north-northwest and to the northwest and the southwest for Site 2: Sands West.

Site 1 oriented towards the north-northwest had the lowest linear pressure score of the 5 alternatives followed closely by Site 1 oriented towards the north and the northwest and north orientations for Site 2 for the base range design with the 10 ft. berm on the 3 down range sides of the range. The linear pressure score for Site 1 oriented to the NNW was 25% less than the linear pressure score for site 1 oriented to the N. The linear pressure score for Site 2 oriented to the NW was almost 30% higher than the linear pressure score for Site 1 oriented to the N.

BERM HEIGHT STUDY

Models were tested using 20 ft. tall and 30 ft. tall berms in addition to the 10 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 1 oriented to the NNW and N with linear pressure scores of 562 and 442 respectively with 30 ft. tall berms. Order of magnitude costs for the mitigation options were also presented in Appendix R. The approximate cost for adding the 30 ft. berms is $670,900. The linear pressure scores were 926 for Site 1 oriented to the NNW and 850 for Site 1 oriented to the N with 20 ft. berms. The approximate cost for adding the 20 ft. tall berms is $233,900. The linear pressure scores for Site 2: Sands West oriented to the NW were 1,188 with the 30 ft. berms and 1,483 with the 20 ft. berms. The linear pressure scores for these scenarios are respectively 270% and 335% higher than the linear pressure score for Site 1: MCRC oriented to the NNW with the 30 ft. berms.

ALTERNATIVE WEATHER/VEGETATION CONDITIONS

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.

U-SHAPED BERM STUDY

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 31% to 70% by adding these U-shaped berms that were 20 ft. tall and 30 ft. tall at an incremental cost increase of approximately $345,200 for the 20 ft. berm scheme and $1,160,100 for the 30 ft. tall berm scheme.

SOLID DIVIDERS BETWEEN LANES STUDY

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 1 by approximately 73 to 89% and by approximately 87% to 90% at Site 2 at a cost of approximately $83,500 for the partitions and sound absorbent material and $233,900 for raising the berm height to 20 ft. tall for a total cost of $319,200 as summarized in Appendix L.

ADDITIONAL NOISE MITIGATION OPTIONS

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 reduced the linear pressure score between 50% and 97% compared to the base range with the 10 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 $133,500 for adding the side and rear walls of the range building; approximately $307,100 for adding the 40 ft. roof extension; approximately $111,300 for adding the 20 ft. tall U-shaped berm at the rear of the range; approximately $489,200 for adding the 30 ft. tall U-shaped berm at the rear of the range; and approximately $1,600,700 for the combination of all of these options.

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	Rion 1	1	45	25-58
1	Rion 1	2	NA	25-55
1	Rion 1	3	48	22-58
1	Rion 1	4	48	22-66
1	Rion 1	5	50	23-70
1	Rion 1	6	55	20-77
1	Rion 1	7	46	23-58
2	Rion 2	1	43	21-53
2	Rion 2	2	NA	18-54
2	Rion 2	3	39	9-44
2	Rion 2	4	39	8-44
2	Rion 2	5	39	11-60
2	Rion 2	6	36	10-47
2	Rion 2	7	38	8-46
3	Rion 3	1	43	20-62
3	Rion 3	2	NA	20-62
3	Rion 3	3	46	18-57
3	Rion 3	4	44	18-56
3	Rion 3	5	48	23-73
3	Rion 3	6	44	20-53
3	Rion 3	7	49	20-79
4	Rion 4	1	43	18-63
4	Rion 4	2	NA	17-66
4	Rion 4	3	46	18-63
4	Rion 4	4	45	19-64
4	Rion 4	5	46	18-73
4	Rion 4	6	41	18-61
4	Rion 4	7	60	18-81