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December 11, 2015

Mr. Dan Lord
Facilities, Operations and Support Systems Manager
Finances and Operations Division
Department of Natural Resources
525 West Allegan
P.O. Box 30028
Lansing, Michigan 48933

Dear Dan:

Enclosed please find one bound and one loose copy of our *Environmental Acoustic Assessment of 3 Sites for a Proposed Firing Range* report for the proposed Shooting Ranges in Grand Traverse County, Michigan. The report contains a summary of baseline ambient sound level measurements made at the 3 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 0.308 rifle; and sound levels calculated at locations within two miles of the approximate center of the 3 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

ENVIRONMENTAL ACOUSTIC ASSESSMENT

for the

PROPOSED SHOOTING RANGE SITES

Grand Traverse County, Michigan

for

Department of Natural Resources

525 West Allegan
P.O. Box 30257
Lansing, Michigan 48933

by

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INTRODUCTION

This report contains the results of an environmental acoustical assessment for 3 proposed sites for a new firing range located in Grand Traverse 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 ranges. 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 3 people shooting within a 1 second time period: 1 person firing a rifle on the 100 yard range, 1 person firing a shotgun on the 50 yard range, and 1 person firing a handgun on the 25 yard range; and a "busy day" scenario (1-second sound exposure levels) with 6 people shooting within a 1 second time period: with 2 people firing rifles on the 100 yard range, 2 people firing shotguns on the 50 yard range, and 2 people firing handguns on the 25 yard range. Computer models using CADNA-A software which is a state-of-the-art, 3-dimensional sound propagation modeling system using methods described in the technical acoustical literature for outdoor sound propagation were analyzed. The effects of distance, molecular absorption, barriers, ground surfaces, non-deciduous vegetation and topography on a typical day (50^o F, 70% RH) were included in the analysis. Sound levels from the gunshots were estimated at locations within two miles of the approximate center of each site for three 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 or the relative magnitude of potential noise impacts of the location, orientation and noise mitigation options for the range on adjoining properties are provided. Budget construction costs for the range noise mitigation features are also provided.

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EXECUTIVE SUMMARY

Three options for the location of a new firing range in Grand Traverse County, Michigan were investigated. Site 1 is located in Whitewater Township north of Diagonal Road at T27N R9W Section 33. Site 2 is located in Union Township south of Jackpine Road at T26N R9W Section 13. Site 3 is located in Fife Lake Township southeast of Bowen Road at T25N R9W Section 27.

1. Existing ambient sound levels were measured at 2 locations near potential noise sensitive receivers located near each proposed range site from September 1-7, 2015. Existing ambient sound levels at the sites varied from 16 to 82 dBA with average Day-Night Sound Levels (LDN) of 39 to 61 dBA.

2. Experiments were conducted at each proposed range site on September 1-2, 2015. A Conservation Officer fired 3 shots in succession from a 0.40 caliber handgun; a 12 gauge shotgun; and a 0.308 rifle. Acoustical measurements were made at 10 feet or approximately 3 meters from the sound source as well as at 16 locations around the proposed range site. There were 4 measurement locations, one in each cardinal direction (i.e., north, east, south, and west) at successive distances of ¼ mile, ½ mile, 1 mile and 2 miles from the firing location at the 3 prospective sites for the firing range.

3. The sound levels measured at 10 feet from the source were approximately 7 to 8 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 0.40 caliber handgun; approximately 11 dB louder in the direction of fire than to the sides and 17 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun; and approximately 12 dB louder in the direction of fire than to the sides and 23 dB louder in the direction of fire than behind the shooter for the 0.308 rifle.

4. At 42% of the measurement locations at distances of 1 to 2 miles from the proposed range site the sounds of the gun shots could not be measured above the ambient sound levels. Average LAeq, maximum LA max and peak LA peak sound levels were measured at the 16 locations around each of the proposed range sites. The LA max levels were on average 3 to 4 dB louder than the LAeq levels. The LA peak levels were 17 to 19 dB louder than the LAeq levels.

5. Measured sound levels were approximately 10 dB louder in the direction of fire compared to the same distances at the sides of the shooter and 20 dB louder in the direction of fire than behind the shooter at distances of ¼ and ½ mile from the proposed range location.

6. The average sound decay with distance measured from the proposed range sites was 6 to 17 dB per doubling of distance from the sound source. This was affected by distance and localized conditions of wind, topography, ground cover and vegetation at each site.

7. Computer models of each of the proposed range sites were constructed in CADNA Software including topography, roads, ground cover, coniferous vegetation with the 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 70% relative humidity with typical wind speed and direction.

8. 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.

9. A point scale was used to assess potential noise impacts that accounted for the sound pressure at each house within a 2 mile radius of each of the proposed range sites and the number of dwellings impacted by the sounds. The sound pressure derived from the average sound level calculated in the noise modeling software was multiplied by the number of dwelling units within each 5 dB group of noise contour lines. For example, if 20 dwellings were located between the 30 and 35 dBA noise contours the points were calculated by the following method. The average sound level in this contour range is 32.5 dBA. The sound pressure associated with this value is 10^(32.5/10). This value was multiplied by the number of dwellings identified in GIS software by DNR staff to arrive at a linear pressure score for these contours. The linear pressure was divided by 100,000 to arrive at a scale that ranged from 0.4 to 46.5 for the alternatives studied. The values for each of the 5 dB groups of noise contours were added together to reach the cumulative linear pressure score for the scenario. Scenarios with lower numbers of points have lower cumulative noise impacts for the scenario.

10. Three sites and range orientations were initially selected for analysis. Site 1: Whitewater Township with the range oriented towards the north; Site 2: Union Township with the range oriented towards the east; and Site 3: Fife Lake with the range oriented towards the southwest. 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 Site 3 a distant third with a linear pressure score that was 4 times the Site 1 score for both scenarios.

11. The "typical day" scenario had approximately ½ of the linear pressure score or 3 dB less than the scores for the "busy day" scenario.

12. The ranking of the initial 3 sites and range orientations remained consistent for the "busy day" scenario when alternate berm heights of 20 ft. and 30 ft. were modeled. The scores for sites 1 and 2 were mixed for the "typical day" scenario.

13. 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: Whitewater Township; towards the northeast for Site 2: Union Township; and towards the northwest for Site 3: Fife Lake Township.

14. Site 1 oriented towards the northwest had the lowest linear pressure score of the 6 alternatives followed closely by Site 1 oriented towards the north and the 2 orientations for Site 2 for the base range design with the 10 ft. berm on the 3 down range sides of the range. Both options for the base range design at Site 3 were scored at almost twice to 4 times the scores for the other sites. There was a slightly different ranking for the "typical day" scenarios than for the "busy day" scenarios.

15. Models were tested using 20 ft. tall and 30 ft. tall berms in addition to the 10 ft. tall berms 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 northwest; Site 2 oriented to the northeast and Site 1 oriented to the north receiving the lowest scores. The highest scores for these tests were for all berm heights and orientations at Site 3: Fife Lake for both the “typical day” and “busy day” scenarios.

16. 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.

17. Experiments were conducted in computer models of noise mitigation options that could be considered for the ranges if needed in the future. Order of magnitude costs for the mitigation options were also presented in Appendix T. The noise mitigation options studied included raising the height of the down range berms to 20 ft. tall and 30 ft. tall at cost increases of approximately $223,600 for the 20 ft. tall berm compared to the 10 ft. tall berm; and approximately $641,300 for the 30 ft. tall berm compared to the 10 ft. tall berm. These studies are summarized in Appendices F and G.

18. 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 50% to 60% by adding these U-shaped berms that were 20 ft. tall and 30 ft. tall at an incremental cost increase of approximately $300,400 for the 20 ft. berm scheme and $1,078,100 for the 30 ft. tall berm scheme.

19. Adding solid dividers between each lane in the range building and lining the walls and ceiling of each lane with sound absorbent panels such as Troy Acoustics Troy Board will reduce the linear pressure score at Site 2 by almost 50% and by approximately 11% at Site 1 at a cost of approximately $83,500 as summarized in Appendix L.

20. 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 75% compared to the base range with the 10 ft. tall berm on 3 sides of the range and the open range structure depending upon the combination of options selected. Incremental costs for these options varied from approximately $150,500 for adding the side and rear walls of the range building; approximately $296,600 for adding the 40 ft. roof extension; approximately $31,200 for adding the 10 ft. tall U-shaped berm at the rear of the range; approximately $108,000 for adding the 20 ft. tall U-shaped berm at the rear of the range; approximately $468,000 for adding the 30 ft. tall U-shaped berm at the rear of the range; and approximately $1,525,200 for the combination of all of these options.

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

SOUND LEVELS AND DECIBELS

Sound is defined as a pressure disturbance in the air caused by a vibrating body that is capable of being heard or detected by the human ear. In the case of gun shots, the muzzle blast of the weapon creates the pressure disturbance in the air as an impulsive type of sound. There is a high amplitude peak pressure from the shot followed by an under pressure that propagates away from the gun. The peak sound pressure level is measured at the highest point of the impulsive sound. The average sound pressure level or equivalent continuous sound level (LAeq) of a time-varying sound is defined as the level of an equivalent steady sound at a specific location for the same measurement duration 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 time averaging 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.

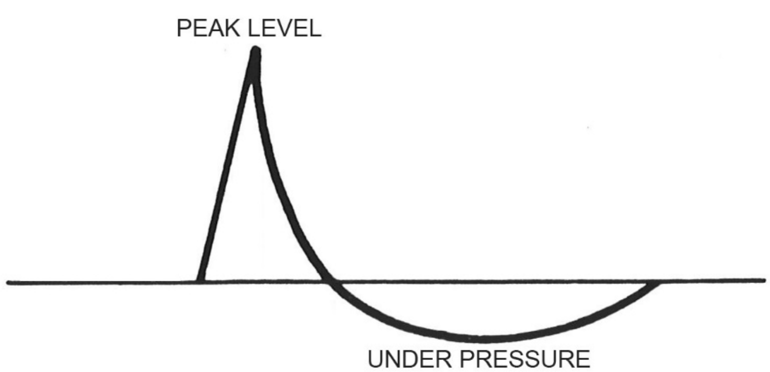

Figure 1. Amplitude or loudness plotted vs time for a typical gunshot.

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

The 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.

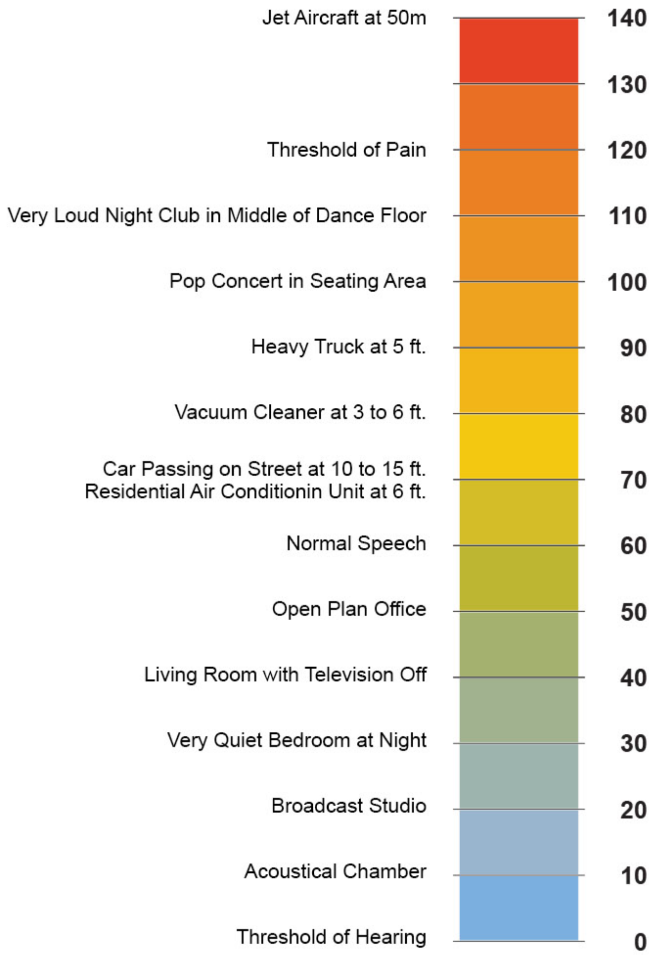

Figure 2. Acoustical thermometer showing the relative loudness in dBA of various sounds.

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 3 sites. Long term measurements of base line ambient sounds were also made at 2 locations at each of the 3 sites for approximately 1 week at each of the six 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 3 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. These locations are shown in Appendix A. GPS coordinates of the measurement locations are shown in Appendix S. Sound levels measured at each of the receiving locations are shown on aerial photographs of each site in Appendix A and in graph form in Appendix V.

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, D and E. Graphs showing average and peak sound levels for each of the measurements are contained in Appendix U. 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 2 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 a tripod at approximately 5 ft. above the ground at each measurement location. A windscreen was attached to the microphones for all measurements. The data were stored on the hard drives of the meters and downloaded to computers in our office and analyzed.

Weather readings including dry bulb temperature (^{o} F), relative humidity (%), barometric pressure (inches of mercury (Hg) 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 R of this report.

Three rounds in succession were fired from a Sig Sauer P229 0.40 caliber handgun with Smith and Wesson 180 grain full metal jacket bullets; a Remington 870 12 gauge shotgun using LE 133 ¾" buckshot; and a Ruger 77 rifle using 0.308 Win 150 grain full metal jacket boat tail ammunition at each of the 3 proposed range locations while sound levels were recorded with the Cesva meter near the source and with the 2 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 3 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 6 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 V. A tabular summary of the data is provided in Appendix A along with aerial photographs of the 3 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 September 1-7, 2015. Figures A-1, A-2 and A-3 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 V.

1. Existing ambient sound levels at Range Site 1 in Whitewater Township varied from 18 to 72 dBA with average Day-Night Sound Levels (LDN) of 39 to 59 dBA. The ambient sound levels at Site 1 consisted of light to moderate traffic on Supply Road, Williamsburg Rd, and Broomhead Road; logging operations and logging trucks traveling near the site; occasional vehicles traveling on the dirt and gravel roads near the site; the breeze blowing through the trees; birds chirping; and the sounds of insects.

2. Existing ambient sound levels at Range Site 2 in Union Township varied from 16 to 77 dBA with average Day-Night Sound Levels (LDN) of 39 to 61 dBA. The ambient sound levels at Site 2 consisted of light to moderate traffic on Supply Road and Fife Lake Road; occasional vehicles traveling on the dirt and gravel roads near the site; occasional recreational motorized bikes and 4-wheelers traveling on the dirt roads near the site; the breeze blowing through the trees and grasses; birds chirping; and the sounds of insects.

3. Existing ambient sound levels at Range Site 3 in Fife Lake varied from 16 to 81 dBA with average Day-Night Sound Levels (LDN) of 48 to 56 dBA. The ambient sound levels at Site 3 consisted of traffic with trucks on Routes U.S. 131 and County Road 113 in the distance; wind blowing through the trees; birds calling; and the sounds of insects.

MEASURED SOUND LEVELS OF FIREARMS

Experiments were conducted at each proposed range site on September 1-2, 2015. A Conservation Officer fired 3 shots in succession from a 0.40 caliber handgun; a 12 gauge shotgun; and a 0.308 rifle. Acoustical measurements were made at 10 feet or approximately 3 meters from the sound source as well as at 16 locations around the proposed range site. A summary of sound levels of gun shots measured at 10 feet from the person shooting during the experiments at each proposed range site is presented in tabular and diagrammatic formats in Appendix B.

There were also 16 measurement locations, one in each cardinal direction (i.e., north, east, south, and west) at successive distances of ¼ mile, ½ mile, 1 mile and 2 miles from the firing location at the 3 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 3 proposed range sites is presented in tabular and graphic formats in Appendix C for Site 1: Whitewater Township; Appendix D for Site 2: Union Township; and Appendix E for Site 3: Fife Lake. Graphs of the average and peak sound levels recorded for each measurement are presented in Appendix U.

Summary of Measurements Made at the Source Locations

1. The sound levels measured at 10 feet from the source were approximately 7 to 8 dB louder in the direction of fire than to the sides of the shooter and 16 dB louder in the direction of fire than behind the shooter for the 0.40 caliber handgun; approximately 11 dB louder in the direction of fire than to the sides of the shooter and 17 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun; and approximately 12 dB louder in the direction of fire than to the sides of the shooter and 23 dB louder in the direction of fire than behind the shooter for the 0.308 rifle.

2. The global average difference in LA peak sound levels for all firearms measured at 10 feet from the shooter was 10 dB less to the sides of the shooter and 19 dB less to the rear of the shooter compared to levels measured in the direction of fire.

3. LA peak sound levels of the 0.40 caliber handgun were measured at 153 dBA to 158 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured peak sound levels varied from 144 to 150 dBA to the sides of the shooter and 137-141 dBA behind the shooter.

4. LA peak sound levels of the 12 gauge shotgun were measured at 157 dBA to 160 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured peak sound levels varied from 144 to 149 dBA to the sides of the shooter and 140-142 dBA behind the shooter.

5. LA peak sound levels of the 0.308 rifle were measured at 163 dBA to 165 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured peak sound levels varied from 148 to 155 dBA to the sides of the shooter and 140-143 dBA behind the shooter.

6. The LAeq or average sound levels measured at 10 feet from the source were approximately 8 to 9 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 0.40 caliber handgun; approximately 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 12 gauge shotgun; and approximately 12 dB louder in the direction of fire than to the sides and 19 dB louder in the direction of fire than behind the shooter for the 0.308 rifle.

7. The global average difference in LAeq average sound levels for all firearms measured at 10 feet from the shooter was 10 dB less to the sides and 17 dB less to the rear compared to levels measured in the direction of fire.

8. LAeq average sound levels of the 0.40 caliber handgun were measured at 129 dBA 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 117 to 123 dBA to the sides of the shooter and 111-114 dBA behind the shooter.

9. LAeq average sound levels of the 12 gauge shotgun were measured at 129 dBA to 132 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured LAeq sound levels varied from 116 to 121 dBA to the sides of the shooter and 118-121 dBA behind the shooter.

10. LAeq average sound levels of the 0.308 rifle were measured at 135 dBA to 137 dBA at 10 feet in front of the shooter approximately 10^o off the axis of firing. The measured LAeq sound levels varied from 121 to 126 dBA to the sides of the shooter and 115-118 dBA behind the shooter.

11. 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 10 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 17 to 19 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 Three (3) Proposed Range Sites

1. At Site 1 in Whitewater Township 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 48-52 dBA LAeq and 62 to 80 dBA LA Peak; 33 to 52 dBA LAeq and 33 to 76 dBA LA peak at ½ mile from the proposed range site; 33 to 41 dBA LAeq and 57 to 70 dBA LA peak at 1 mile from the proposed range site; and 31 to 40 dBA LAeq and 56 to 58 dBA LA peak at 2 miles from the proposed range site.

2. At Site 1 in Whitewater Township average (LAeq) and peak (LA peak) sound levels measured for the 12 gauge shotgun at ¼ mile from the proposed range site varied from 44-59 dBA LAeq and 58 to 79 dBA LA Peak; 34 to 50 dBA LAeq and 56 to 72 dBA LA peak at ½ mile from the proposed range site; 33 to 44 dBA LAeq and 57 to 65 dBA LA peak at 1 mile from the proposed range site; and 29 to 40 dBA LAeq at 2 miles from the proposed range site.

3. At Site 1 in Whitewater Township average (LAeq) and peak (LA peak) sound levels measured for the 0.308 rifle at ¼ mile from the proposed range site varied from 49-61 dBA LAeq and 63 to 85 dBA LA Peak; 35 to 57 dBA LAeq and 56 to 84 dBA LA peak at ½ mile from the proposed range site; 32 to 51 dBA LAeq and 57 to 76 dBA LA peak at 1 mile from the proposed range site; and 33 to 40 dBA LAeq and 60 to 63 dBA LA peak at 2 miles from the proposed range site.

4. At Site 2 in Union Township 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 47-67 dBA LAeq and 61 to 99 dBA LA Peak; 35 to 58 dBA LAeq and 57 to 84 dBA LA peak at ½ mile from the proposed range site; 41 to 50 dBA LAeq and 57 to 68 dBA LA peak at 1 mile from the proposed range site; and 29 to 34 dBA LAeq at 2 miles from the proposed range site.

5. At Site 2 in Union Township average (LAeq) and peak (LA peak) sound levels measured for the 12 gauge shotgun at ¼ mile from the proposed range site varied from 41-71 dBA LAeq and 60 to 101 dBA LA Peak; 36 to 56 dBA LAeq and 56 to 82 dBA LA peak at ½ mile from the proposed range site; 43 to 48 dBA LAeq and 56 to 72 dBA LA peak at 1 mile from the proposed range site; and 31 to 38 dBA LAeq at 2 miles from the proposed range site.

6. At Site 2 in Union Township average (LAeq) and peak (LA peak) sound levels measured for the 0.308 rifle at ¼ mile from the proposed range site varied from 48-76 dBA LAeq and 66 to 105 dBA LA Peak; 37 to 60 dBA LAeq and 58 to 86 dBA LA peak at ½ mile from the proposed range site; 32 to 47 dBA LAeq and 58 to 73 dBA LA peak at 1 mile from the proposed range site; and 33 to 34 dBA LAeq at 2 miles from the proposed range site.

7. At Site 3 in Fife Lake Township 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 53-62 dBA LAeq and 73 to 85 dBA LA Peak; 41 to 49 dBA LAeq and 56 to 64 dBA LA peak at ½ mile from the proposed range site; 34 to 43 dBA LAeq and 56 to 61 dBA LA peak at 1 mile from the proposed range site; and 41 to 42 dBA LAeq and 60 to 62 dBA LA peak at 2 miles from the proposed range site.

8. At Site 3 in Fife Lake Township average (LAeq) and peak (LA peak) sound levels measured for the 12 gauge shotgun at ¼ mile from the proposed range site varied from 50-59 dBA LAeq and 70 to 82 dBA LA Peak; 40 to 49 dBA LAeq and 56 to 73 dBA LA peak at ½ mile from the proposed range site; 36 to 42 dBA LAeq and 57 to 69 dBA LA peak at 1 mile from the proposed range site; and 41 to 43 dBA LAeq and 56 to 61 dBA LA peak at 2 miles from the proposed range site.

9. At Site 3 in Fife Lake Township average (LAeq) and peak (LA peak) sound levels measured for the 0.308 rifle at ¼ mile from the proposed range site varied from 55-63 dBA LAeq and 77 to 83 dBA LA Peak; 45 to 48 dBA LAeq and 58 to 64 dBA LA peak at ½ mile from the proposed range site; 33 to 46 dBA LAeq and 56 to 68 dBA LA peak at 1 mile from the proposed range site; and 43 to 44 dBA LAeq and 57 to 62 dBA LA peak at 2 miles from the proposed range site.

10. At 42% of the measurement locations at distances of 1 to 2 miles from the proposed range site the sounds of the gun shots could not be measured above the ambient sound levels. These measurements are indicated by an “x” in Table C-1 for Site 1; Table D-1 for Site 2 and Table E-1 for Site 3. The measurements are indicated by a N/A on the aerial photographs showing the measured sound levels in Appendices C, D and E.

11. Average LAeq, maximum LA max and peak LA peak sound levels were measured at the 16 locations around each of the 3 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 24 dB louder than the LAeq levels for all sites, all locations and all weapon types.

12. The measurements at Sites 1 and 3 showed a 3 dB average difference between the LA max and LAeq with a range of 0 to 6 dB and 18 dB average difference between the LA peak and LAeq measurements with a range of 11 to 37 dB.

13. The measurements at Site 2 showed a 5 dB average difference between the LA max and LAeq sound levels with a 0 to 6 dB range and a 22 dB difference between the LA peak and LAeq sound levels with a range of 13 to 32 dB.

14. Measurements at Site 3 showed a 6 dB difference between LA max and LAeq levels for handguns to the front of the shooter, and a 3 to 4 dB difference between LA max and LAeq levels to the sides and rear of the shooter for the handgun.

15. There was a 24 dB difference between LA peak and LAeq levels for the handgun to the front of the shooter, a 16 dB difference between LA peak and LAeq levels to the rear of the shooter for the handgun, and an 18 dB difference at the sides.

16. Measurements at Site 3 showed a 4 dB difference between LA max and LAeq levels for shotguns to the front and rear of the shooter, and a 1.5 to 3 dB difference between LA max and LAeq levels to the sides of the shooter for the shotgun.

17. There was a 22 dB difference between LA peak and LAeq levels for the shotgun to the front of the shooter, a 21 dB difference between LA peak and LAeq levels to the rear of the shooter for the shotgun, and a 17 dB difference at the sides.

18. Measurements at Site 3 showed a 2 to 3.5 dB difference between LA max and LAeq levels for the .308 rifle to the front of the shooter, and a 3 to 4 dB difference between LA max and LAeq levels to the sides and rear of the shooter with the .308 rifle.

19. There was a 19 dB difference between LA peak and LAeq levels for the .308 rifle to the front of the shooter, a 16 dB difference between LA peak and LAeq levels to the rear of the shooter for the 0.308 rifle, and a 17 dB difference at the sides.

20. Measured LA peak sound levels at Site 1 were approximately 11 to 12 dB louder in the direction of fire compared to the same distances at the sides of the shooter; 11 to 16 dB louder compared to the back side of the shooter; and 15 to 19 dB louder compared to the rear of the shooter at ¼ mile. The LA peak levels were 16 to 17 dB louder in the direction of fire compared to the side and 16 to 23 dB louder compared to the rear at ½ mile from the proposed range location.

21. Measured LAeq sound levels at Site 1 were approximately 5 to 7 dB louder in the direction of fire compared to the same distances at the side of the shooter; 8 to 13 dB louder compared to the back side of the shooter; and 10 to 13 dB louder compared to the rear of the shooter at ¼ mile. The LAeq sound levels were 13 to 14 dB louder in the direction of fire compared to the side of the shooter and 6 to 15 dB louder compared to the rear of the shooter at ½ mile from the proposed range location. The differences were 3 to 8 dB louder in the direction of fire than to the sides of the shooter and 4 to 13 dB louder in the direction of fire compared to the rear of the shooter at 1 mile from the proposed range location.

22. Measured LA peak sound levels at Site 2 were approximately 0 to 12 dB louder in the direction of fire compared to the same distances at the side of the shooter; 0 to 12 dB louder compared to the back side of the shooter; and 1 to 6 dB louder compared to the rear of the shooter at ¼ mile.

23. Measured LAeq sound levels at Site 2 were approximately 18 to 27 dB louder in the direction of fire compared to the same distances at the side of the shooter; -1 to 12 dB louder compared to the back side of the shooter; and 16 to 25 dB louder compared to the rear of the shooter at ¼ to ½ mile distance.

24. The average sound decay per doubling of distance from the source was measured at 6 dB for LA peak values at Site 1 and 7 dB for LAeq values at Site 1.

25. The average sound decay for each doubling of distance from the sound source for the LA peak values was 13 dB with 11 dB decay per doubling of distance for the LAeq values at Site 2.

26. The average sound decay for each doubling of distance from the sound source for the LA peak values was 15 dB with 17 dB decay per doubling of distance for the LAeq values at Site 3.

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 3 locations at distances away from the proposed ranges. The models were constructed in the CADNA-A software package using topographic information from USGS maps and the GIS data base. A series of experiments were conducted to understand the relative differences between a number of variables including the location and orientation of the range, the height of berms, the number of people firing simultaneously (in the same 1 second time period), the configuration of the range structure, the addition of acoustical treatment to the range structure, the effects of different temperatures, wind and coniferous trees and combinations of these variables. The experiments are described in Appendices F through P. Noise contour plots for each of the options studied are also included in the appendices describing the experiment. The proposed base range design consists of 25 yard, 50 yard and 100 yard ranges surrounded by a berm. The ranges have approximately 10 ft. high berms on three sides (downrange and the two 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 recent Michigan DNR range construction projects and recommendations of range layout from the National Rifle Association. A diagram of the base range design is shown in figure 3.

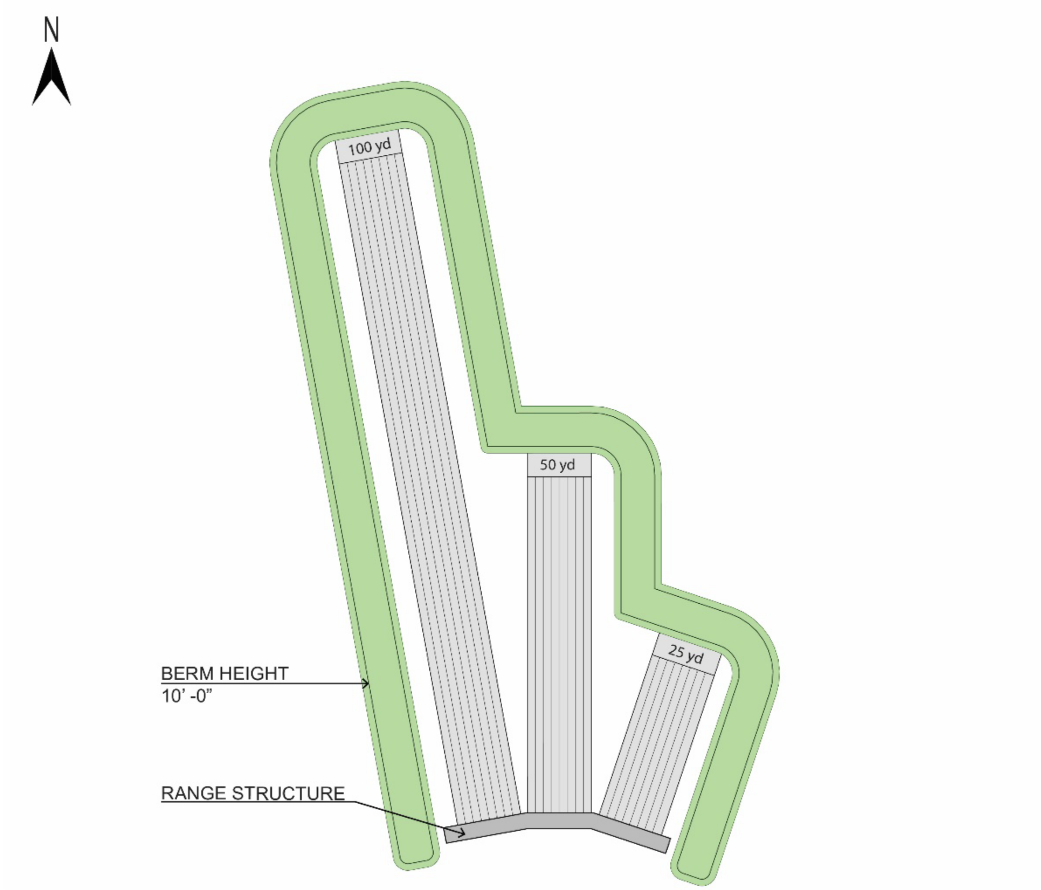

Figure 3. Concept diagram of the base range design.

Method

1. The analysis assumed two typical operating conditions: 1. a "typical day" where 3 people fired their weapons within a 1 second time period with possibly up to 3 additional people on the range getting ready to fire, loading their weapons or talking with each other; and; and 2. a "busy day" where 6 people fired their weapons within a 1 second time period and perhaps 6 other people were also on the range waiting to fire, loading their weapons or talking with each other.

2. The "typical" day had 1 shooter firing a .223 caliber rifle on the 100 yard range; 1 shooter firing a 12 gauge Remington shotgun on the 50 yard range; and 1 shooter firing a 0.40 caliber handgun on the 25 yard range within a 1 second time period. The 3 other people on the range were assumed to be either watching, loading their weapons to get ready to fire or pausing in their firing during the 1 second time period studied. Octave band sound pressure level data for the firearms were obtained from a report entitled "*Field Measurement of Sound Pressure Levels of Various Firearms,"* published by the Architectural Acoustics Research Group at the University of Florida in 1993 for the National Rifle Association, which includes data for an M-16 rifle with .223 Remington 55 grain power-locked hollow point ammunition; a Remington 12 gauge shotgun; and a 0.40 caliber handgun. A summary of the octave band sound exposure level data for the firearms used in the models is included in Appendix Q.

3. The “busy” day had 2 shooters firing .223 caliber rifles on the 100 yard range; 2 shooters firing 12 gauge Remington shotguns on the 50 yard range; and 2 shooters firing 0.40 caliber handguns on the 25 yard range within a 1 second time period. The 6 other people on the range were assumed to be either watching, loading their weapons to get ready to fire or pausing in their firing during the 1 second time period studied. Octave band sound data for the firearms were obtained from the report cited in item 2 above.

4. 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 2 to 5 dB and the LA peak was 17 dB higher than the LAeq with a range of 16 to 24 dB.

5. Three dimensional computer models of the 3 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 CADNA-A software which is a state-of-the-art noise propagation modeling software.

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

   A. Number of shooters: “Typical day” (1 on each of the 100, 50 and 25 yard ranges)
      “Busy day” (2 on each of the 100, 50 and 25 yard ranges)
   B. Direction of fire relative to the receiver.
   C. The ranges have approximately 10 ft. tall berms on three sides (downrange and the two sides). Subsequent modeling was completed with 20 ft. tall and 30 ft. tall berms in addition to the 10 ft. tall berms. These experiments are described in Appendix F for the original sites and range orientations and in Appendix G for the alternate range orientations.
   D. Molecular sound absorption for a standard day (50° F, 70%R.H.). Separate experiments were conducted with computer model runs using 70^{o} F and 50% R.H.; 50^{o}F and 50% R.H.; 32^{o} F and 50% R.H.; and 0 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 70% Relative Humidity condition resulted in the highest sound levels at distances away from the ranges in the series of experiments described above, so this was used as the base condition for the computer models. These experiments are described in Appendix H.
   E. Anomalous excess attenuation (from small scale differences in wind, temperature, and humidity in the air).
   F. The topographic features of the 3 sites were developed using contour maps obtained from the United States Geological Survey.

G. CADNA-A assumes a downwind condition with wind velocity of 1 – 11 mph. An experiment was also conducted with a 6 m.p.h. wind speed from the southwest which is the yearly average wind speed and direction for the area. This experiment is described in Appendix I.
H. Vegetation (trees) was not included in the analysis. Areas of coniferous trees were added in Experiment 5 described in Appendix J.
I. Ground cover was modeled as pavement for paved roads, water in the lakes and grass for terrain covered with vegetation.
J. Deciduous trees were not included in the models because the loss of leaves during the Fall and Winter months significantly reduces the insertion loss of stands of deciduous trees.
K. Separate computer model runs were conducted with the stands of coniferous trees included in the model and not included in the model to document the change in sound levels calculated at receiver locations due to the effects of coniferous trees. This experiment is described in Appendix J.
L. Noise mitigation options described in the Noise Mitigation section of the report were also modeled. The noise mitigation experiments are described in Appendices K through P.

7. The resulting sound levels for each of the three proposed sites were plotted on scaled maps/aerial photographs of the sites identifying the "typical day" and "busy day" scenarios for the 3 proposed sites with the initial range orientations as well as for alternate range orientations to the northwest for Site 1, to the northeast for Site 2 and to the northwest for Site 3 in Appendices F and G.

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

9. The noise mitigation options studied include the following items.
   A. Alternate range orientations to the northwest for Site 1, to the northeast for Site 2 and to the northwest for Site 3 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 Sites 1 and 2 with the alternate range orientation of northwest for Site 1 and northeast for Site 2 as shown in Figure 5 for the busy day scenario. The berm around the perimeter of the range and the U shaped berm had heights of 10 ft., 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. This experiment is described in Appendix K. This experiment was not conducted for Site 3 because the initial analysis indicated that Site 3 had greater potential noise impacts for the base range design than Sites 1 and 2.
   C. A sound absorbent, acoustical lining was added to the inside of the range structure on the underside of the roof and on the sides of partitions built between the lanes inside the range. A concept plan for this experiment is shown in Figure 6. The experiment was conducted for the ranges with the alternate orientations at sites 1 and 2 for the busy day scenario with a 10 ft. berm height. The experiment is described in Appendix L.

D. Rear and side walls were added to the range structure at Sites 1 and 2 for the alternate range orientations for the busy day scenario. The inside facing of the walls was with a sound absorbent liner. The berm height was 10 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 at Sites 1 and 2 for the alternate range orientation with the busy day scenario and a 10 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 Sites 1 and 2 for the alternate range orientation with the busy day scenario and a 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.
G. The 30 ft. tall U-shaped berm and 40 ft. deep roof extension is added to the original and alternate range orientations at Sites 1, 2 and 3 for the typical day and busy day scenarios with 10 ft., 20 ft. and 30 ft. tall berms. The concept plan for this experiment is shown in Figure 9. The experiment is described in Appendix P.

Figure 4. Concept plans showing the original and alternate range orientations for the 3 range sites.

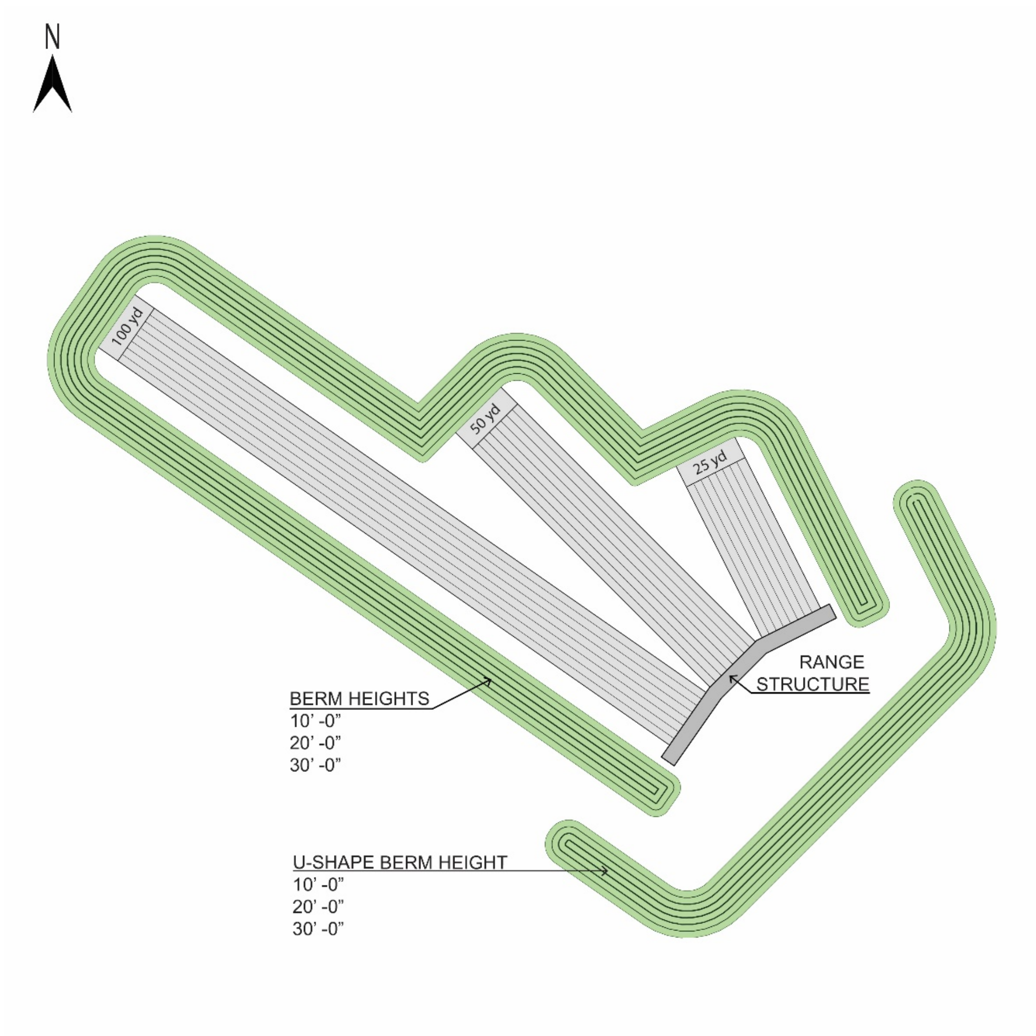

Figure 5. Concept plan showing the U-shaped berm configuration for the range described in Appendix K.

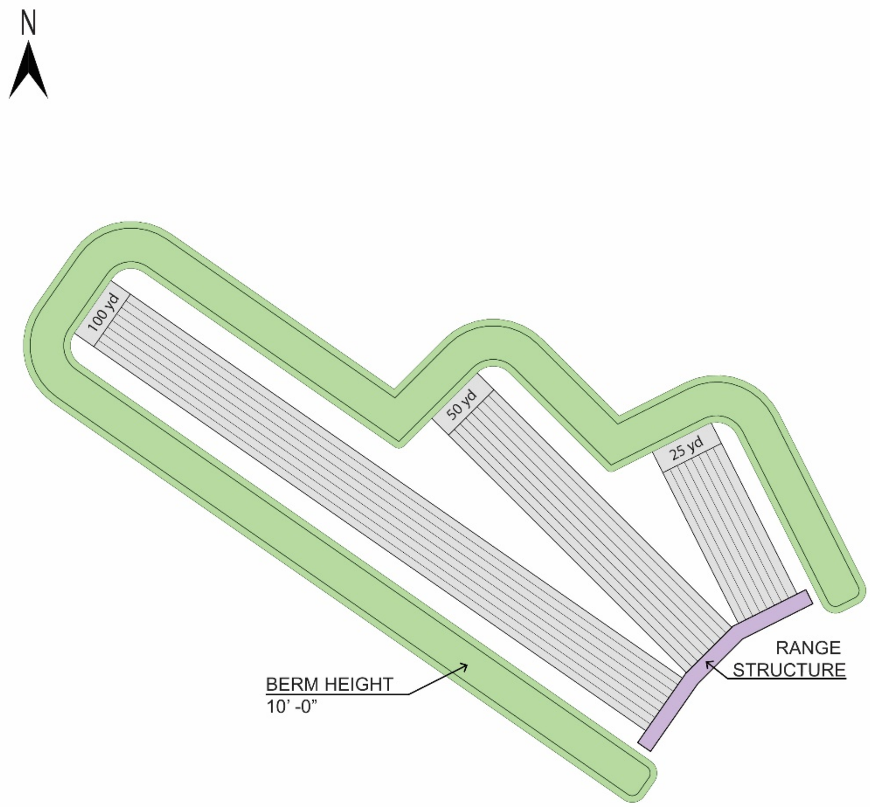

Figure 6. Concept plan for the range structure with interior sound absorbent lining described in Appendix L.

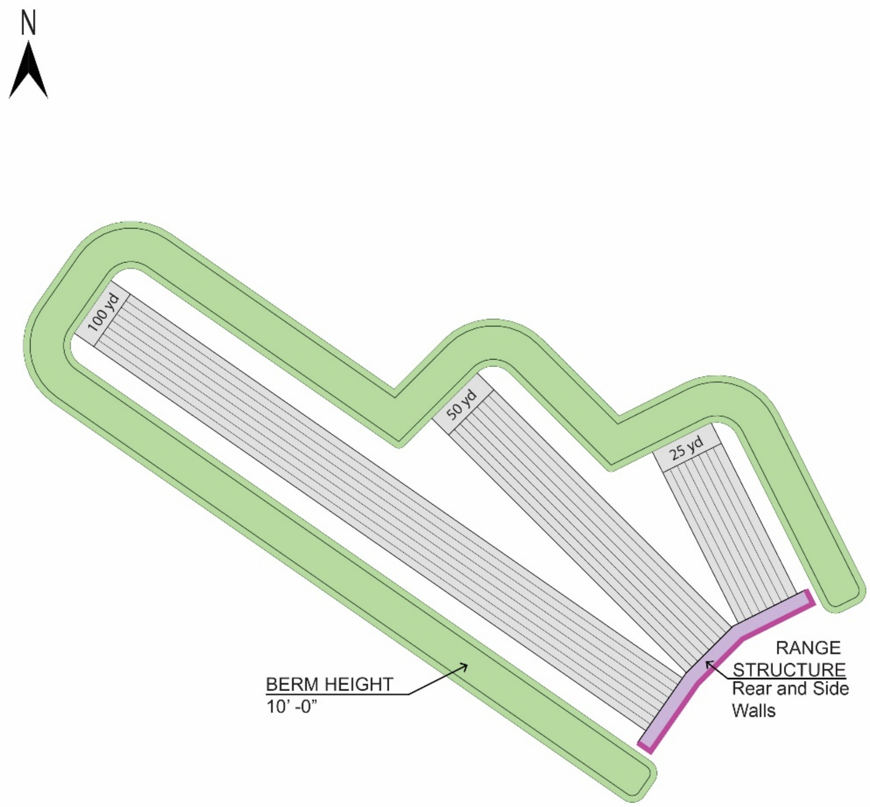

Figure 7. Concept plan for the range structure with the rear and side walls added with the interior sound absorbent lining described in Appendix M.

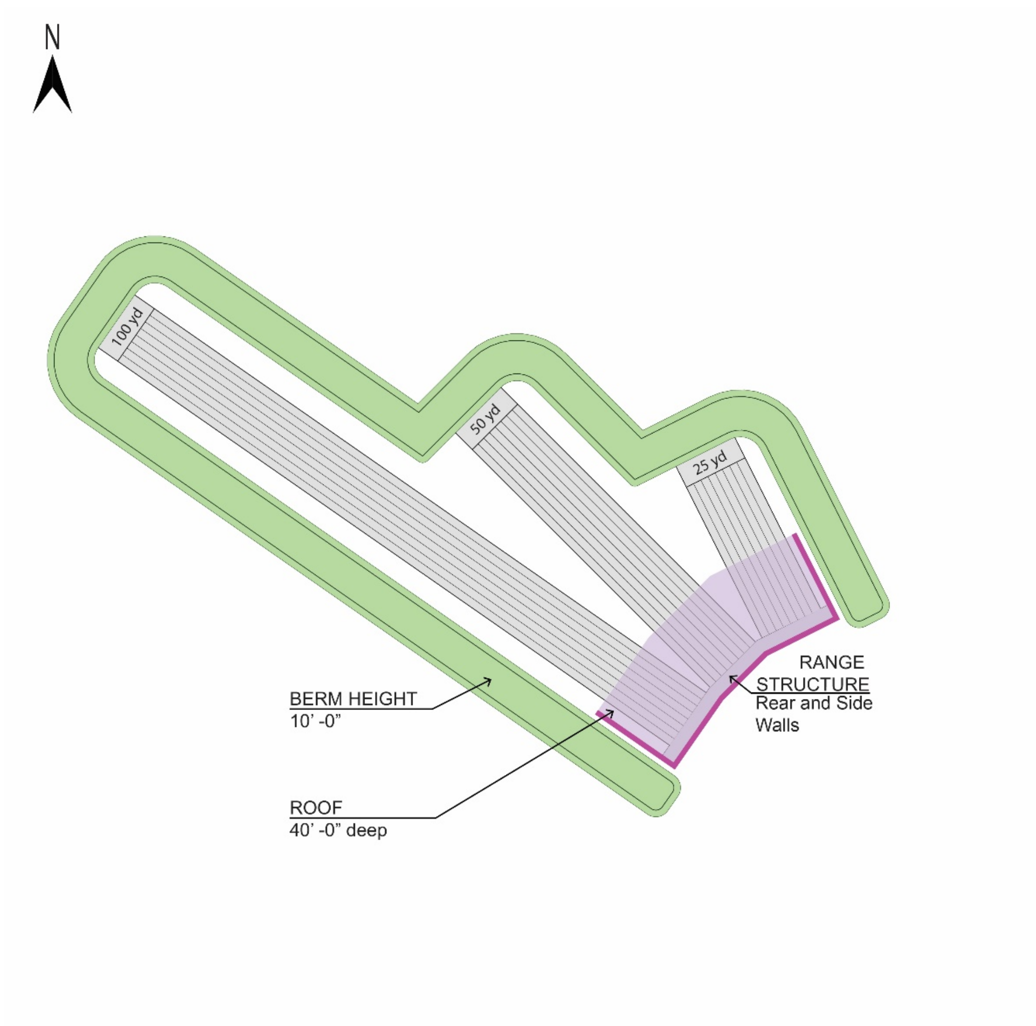

Figure 8. Concept plan for the range structure with the 40 ft. extension of the roof with the rear and side walls added and the interior sound absorbent lining described in Appendix N.

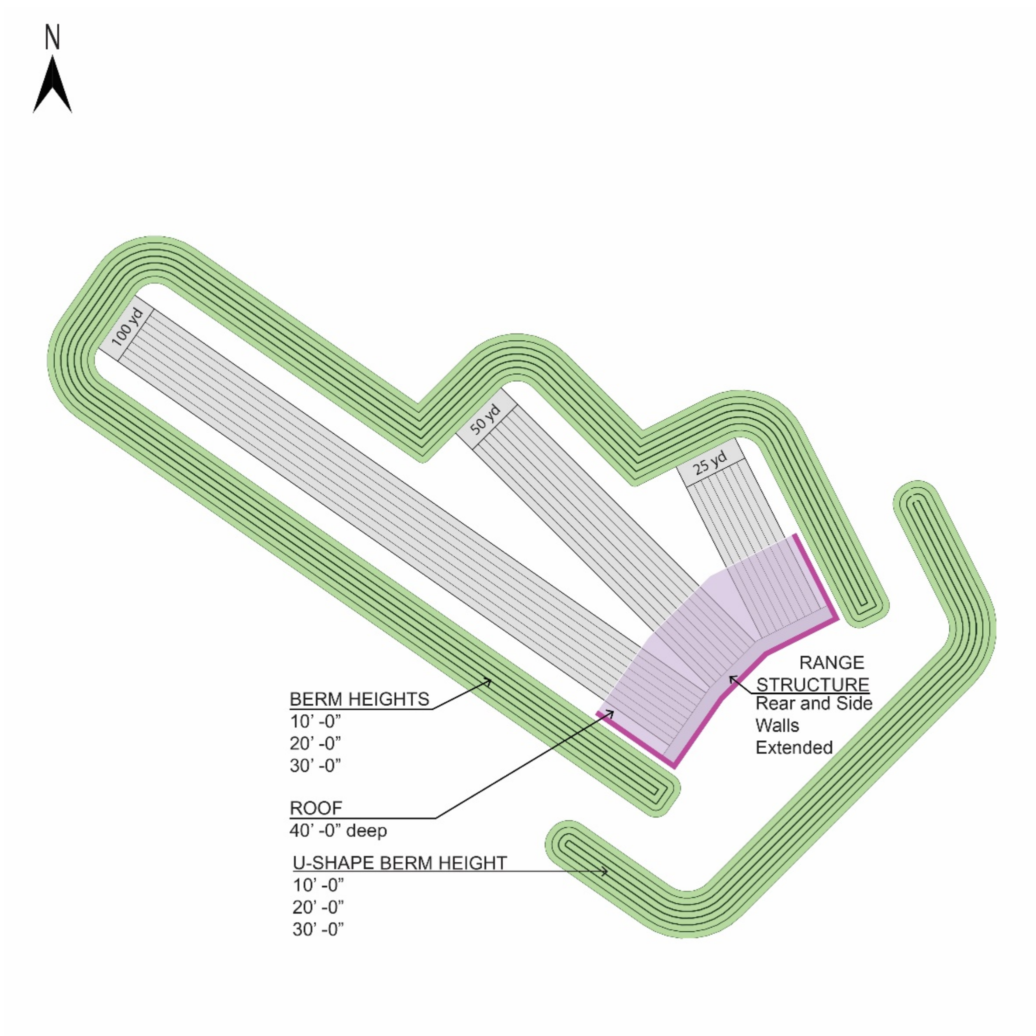

Figure 9. Concept plan showing the range structure with the 40 ft. extension of the roof with the rear and side walls added and the interior sound absorbent lining and a 30 ft. tall U-shaped berm around the rear of the range described in Appendices O and Appendix P.

RESULTS OF THE COMPUTER MODEL STUDIES

Appendices F through P 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 maps also show the 2 “Ambient” locations at each of the 3 sites where long term ambient sound levels were measured.

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 the “typical day” and “busy day” scenarios. The sound levels could increase by 10 to 20 dB for receivers downwind of the source and when temperature inversions (warmer air aloft) occur. An experiment was conducted to study the effects of wind speed and direction on the propagation of sounds.

Due to the complexity of the data and the number of options studied, a point system was developed to rank order the various schemes based on the sound pressure and the number of dwellings and other 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 0.4 to 46.5. 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 P with tabular summaries of the schemes studied and the linear pressure points for each scheme.

Three sites and range orientations were initially selected for analysis. Site 1: Whitewater Township with the range oriented towards the north; Site 2: Union Township with the range oriented towards the east; and Site 3: Fife Lake with the range oriented towards the southwest. 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 Site 3 a distant third with a linear pressure score that was 4 times the Site 1 score for both scenarios.

The sound levels for the busy day scenario were generally 3 dB higher than the sound levels for the typical day scenario due to the increase in the number of shooters for each weapon type on the range. The “typical day” scenario had approximately ½ of the linear pressure score or 3 dB less than the scores for the “busy day” scenario.

The ranking of the initial 3 sites and range orientations remained consistent for the “busy day” scenario when alternate berm heights of 20 ft. and 30 ft. were modeled. The scores for sites 1 and 2 were mixed for the “typical day” scenario.

Alternate orientations were selected for each range to reduce potential noise impacts to the largest number of residential properties and noise sensitive receivers within 2 miles of each proposed range once the patterns of sound propagation were identified in the computer models. A northwest orientation was considered to orient the range away from homes to the southwest and north at Site 1 as well as away from the quiet area to the northeast. A northeast orientation was considered to orient the range away from homes to the northwest and southeast at Site 2. A northwest orientation was considered to orient the range away from homes to the southwest at Site 3.

Site 1 oriented towards the northwest had the lowest linear pressure score of the 6 alternatives followed closely by Site 1 oriented towards the north and the 2 orientations for Site 2 for the base range design with the 10 ft. berm on the 3 down range sides of the range. Both options for the base range design at Site 3 were scored at almost twice to 4 times the scores for the other sites. There was a slightly different ranking for the "typical day" scenarios than 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 T. The noise mitigation options studied included raising the height of the down range berms to 20 ft. tall and 30 ft. tall at cost increases of approximately $223,600 for the 20 ft. tall berm compared to the 10 ft. tall berm; and approximately $641,300 for the 30 ft. tall berm compared to the 10 ft. tall berm. These studies are summarized in Appendices F and G.

Models were tested using 20 ft. tall and 30 ft. tall berms in addition to the 10 ft. tall berms 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 northwest; Site 2 oriented to the northeast and Site 1 oriented to the north receiving the lowest scores. The highest scores for these tests were for all berm heights and orientations at Site 3: Fife Lake for both the "typical day" and "busy day" scenarios.

On average across all models and all scenarios tested, the average decrease in sound level was approximately 5 dB for the 20 ft. tall berm compared to the 10 ft. tall berm and an additional 5 dB for the 30 ft. tall berm compared to the 20 ft. tall berm at distances up to approximately ½ to 1 mile from the range.

The levels to the rear of the range stay relatively consistent from one scenario to the next with the berms only to the sides and down range from the firing line because there is no noise mitigating structure present in the base schemes in that direction. The U-shaped berm option was selected to reduce sounds propagating to the sides and rear of the ranges. This was considered to reduce sounds propagating towards homes to the southwest and southeast at Site 1 and the quiet area to the northeast; homes to the northwest and southeast at Site 2; and homes to the northeast at Site 3. 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 50% to 60% by adding these U-shaped berms that were 20 ft. tall and 30 ft. tall at an incremental cost increase of approximately $300,400 for the 20 ft. berm scheme and $1,078,100 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.

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 -2 to -5 dB at distances of 1 to 2 miles from the range.

The typical day modeled with an air temperature of 50^{o} F and a 70% relative humidity resulted in 1 to 14 dB higher sound levels at distances away from the ranges than the other temperature and humidity conditions tested; so this condition was used as the base temperature and relative humidity condition for the computer model studies. Studies with alternate air temperatures and relative humidities (Appendix H); alternate wind conditions (Appendix I); and the addition of the existing stands of coniferous trees on the sites (Appendix J) verified that the assumptions made in the model studies represented a conservative approach to the noise contour mapping for the proposed range. This means that the mapped noise contours represent a worst case condition in terms of the effects of temperature, humidity, wind and vegetation on the modeled noise contours. The linear pressure scores for the sites tested all decreased when these alternate conditions were used in the models.

There was also an additional 5 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 5 to 10 decrease with several instances of almost a 20 dB 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.

The acoustical lining on the inside surfaces of the range structure and the use of partitions to divide the range structure into individual lanes and lining the dividing walls would reduce sound levels inside the range structure for shooters as well as decrease sound levels by 0 to 8 dB propagating away from the range at distances of 1 to 2 miles from the range. Adding solid dividers between each lane in the range building and lining the walls and ceiling of each lane with sound absorbent panels such as Troy Acoustics Troy Board will reduce the linear pressure score at Site 2 by almost 50% and by approximately 11% at Site 1 at a cost of approximately $83,500 as summarized in Appendix L.

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 75% compared to the linear pressure score of the base range with the 10 ft. tall berm on 3 sides depending upon the combination of options selected. Incremental costs for these options varied from approximately $150,500 for adding the side and rear walls of the range building; approximately $296,600 for adding the 40 ft. roof extension; approximately $31,200 for adding the 10 ft. tall U-shaped berm at the rear of the range; approximately $108,000 for adding the 20 ft. tall U-shaped berm at the rear of the range; approximately $468,000 for adding the 30 ft. tall U-shaped berm at the rear of the range; and approximately $1,525,200 for the combination of all of these options. The 40 ft. deep extension of the range structure roof would reduce sound propagation in the direction of fire as a possible alternative to raising the height of the berms in the direction of fire if used in conjunction with raising the height of the berms to reduce sound levels in the direction of fire by approximately 2 to 5 dB at distances of 1 to 2 miles from the range.

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 for Whitewater Township; Union Township; and Fife Lake Township do not include quantitative sound level limits or sound measurement methods for determining the acceptability of sounds of various types and levels. In the absence of a local noise ordinance with quantitative sound level limits, an analysis of the noise contour maps for each of the design alternatives 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. No residential properties are located within the 55 to 60 LAeq noise contours for any of the range locations and configurations studied. No residential properties were located in the 50 to 55 dBA contours for the base range designs at Sites 1 and 2. One to eleven homes were located in the 50 to 55 dB LAeq noise contours at Site 3.

The Noise Ordinance for Township of Whitewater, Grand Traverse County is included in Ordinance Number 39 of the Whitewater Township Ordinances. Ordinance 39 prohibits any noise disturbances, which by reason of its volume, intensity, location, or time of day impairs the health, welfare, or peace of another person of normal human sensibilities.

The Anti-Noise and Anti Nuisance Ordinance is included in Part 60 of the Union Charter Township, MI Code of Ordinances. Section 3.0 of Part 60 of the Union Charter Township, Michigan Code of Ordinances states that excessive noises and nuisances in the Township starting at 11:00 p.m. on Sunday through Thursday night and starting at 11:30 p.m. on Friday and Saturday night until 5:00 a.m. the following mornings are in violation of the Ordinance.

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

CONCLUSIONS

Three options for the location of a new firing range in Grand Traverse County, Michigan were investigated. Site 1 is located in Whitewater Township north of Diagonal Road, with the shooters facing north. Site 2 is located in Union Township south of Jackpine Road, with the shooters facing east. Site 3 is located in Fife Lake Township southeast of Bowen Road, with the shooters facing southwest.

1. Existing ambient sound levels were measured at 2 locations near potential noise sensitive receivers located near each proposed range site from September 1-7, 2015. Existing ambient sound levels (LAeq) at the sites varied from 16 to 82 dBA with average Day-Night Sound Levels (LDN) of 39 to 61 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.

2. Experiments were set up at each proposed range site on September 1-2, 2015. A Conservation Officer fired 3 shots in succession from a 0.40 caliber handgun; a 12 gauge shotgun; and a 0.308 rifle. Acoustical measurements were made at 10 feet or approximately 3 meters from the sound source as well as at 16 locations around the proposed range site. There were 4 measurement locations, one in each cardinal direction (i.e., north, east, south, and west) at successive distances of ¼ mile, ½ mile, 1 mile and 2 miles from the firing location at the 3 prospective sites for the firing range.

3. The sound levels measured at 10 feet from the source were approximately 7 to 8 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 0.40 caliber handgun; approximately 11 dB louder in the direction of fire than to the sides and 17 dB louder in the direction of fire than behind the shooter for the 12 gauge shotgun; and approximately 12 dB louder in the direction of fire than to the sides and 23 dB louder in the direction of fire than behind the shooter for the 0.308 rifle.

4. At 42% 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 all 3 of the proposed range sites.

5. Average LAeq, maximum LA max and peak LA peak sound levels were measured at the 16 locations around each of the proposed range sites. The LA max levels were on average 3 to 4 dB louder than the LAeq levels. The LA peak levels were 17 to 19 dB louder than the LAeq levels.

5. Measured sound levels were approximately 10 dB louder in the direction of fire compared to the same distances at the sides and 20 dB louder in the direction of fire than behind at distances of ¼ and ½ mile from the proposed range location. This means that the orientation of the direction of fire of the range is an important decision.

6. The average sound decay with distance measured from the proposed range sites was 6 to 17 dB per doubling of distance from the sound source. This was affected by distance and localized conditions of wind, topography, ground cover and vegetation at each site.

7. Computer models of each of the proposed range sites were constructed in CADNA Software including topography, roads, ground cover, coniferous vegetation with the 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 70% relative humidity with typical wind speed and direction.

8. 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.

9. A point scale was used to assess potential noise impacts that accounted for the sound pressure at each house within a 2 mile radius of each of the proposed range sites and the number of

dwellings impacted by the sounds. The sound pressure derived from the average sound level calculated in the noise modeling software was multiplied by the number of dwelling units within each 5 dB group of noise contour lines. For example, if 20 dwellings were located between the 30 and 35 dBA noise contours the points were calculated by the following method. The average sound level in this contour range is 32.5 dBA. The sound pressure associated with this value is 10^(32.5/10). This value was multiplied by the number of dwellings identified in GIS software by DNR staff to arrive at a linear pressure score for these contours. The linear pressure was divided by 100,000 to arrive at a scale that ranged from 0.4 to 46.5 for the alternatives studied. The values for each of the 5 dB groups of noise contours were added together to reach the cumulative linear pressure score for the scenario. Scenarios with lower numbers of points have lower cumulative noise impacts for the scenario.

10. Three sites and range orientations were initially selected for analysis. Site 1: Whitewater Township with the range oriented towards the north; Site 2: Union Township with the range oriented towards the east; and Site 3: Fife Lake Township with the range oriented towards the southwest. 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 Site 3 a distant third with a linear pressure score that was 4 times the Site 1 score for both scenarios.

11. The “typical day” scenario had approximately ½ of the linear pressure score or 3 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.

12. The ranking of the initial 3 sites and range orientations remained consistent for the “busy day” scenario when alternate berm heights of 20 ft. and 30 ft. were modeled. The scores for sites 1 and 2 were mixed for the “typical day” scenario.

13. 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: Whitewater Township; towards the northeast for Site 2: Union Township; and towards the northwest for Site 3: Fife Lake Township.

14. Site 1 oriented towards the northwest had the lowest linear pressure score of the 6 alternatives followed closely by Site 1 oriented towards the north and the 2 orientations for Site 2 for the base range design with the 10 ft. berm on the 3 down range sides of the range. Both options for the base range design at Site 3 were scored at almost twice to 4 times the scores for the other sites. There was a slightly different ranking for the “typical day” scenarios than for the “busy day” scenarios.

15. Models were tested using 20 ft. tall and 30 ft. tall berms in addition to the 10 ft. tall berms 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 northwest; Site 2 oriented to the northeast and site 1 oriented to the north

receiving the lowest scores. The highest scores for these tests were for all berm heights and orientations at Site 3: Fife Lake for both the "typical day" and "busy day" scenarios.

16. 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 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.

17. Experiments were conducted in computer models of noise mitigation options that could be considered for the ranges if needed in the future. Order of magnitude costs for the mitigation options were also presented in Appendix T. The noise mitigation options studied included raising the height of the down range berms to 20 ft. tall and 30 ft. tall at cost increases of approximately $223,600 for the 20 ft. tall berm compared to the 10 ft. tall berm; and approximately $641,300 for the 30 ft. tall berm compared to the 10 ft. tall berm. These studies are summarized in Appendices F and G.

18. 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 50% to 60% by adding these U-shaped berms that were 20 ft. tall and 30 ft. tall at an incremental cost increase of approximately $300,400 for the 20 ft. berm scheme and $1,078,100 for the 30 ft. tall berm scheme.

19. Adding solid dividers between each lane in the range building and lining the walls and ceiling of each lane with sound absorbent panels such as Troy Acoustics Troy Board will reduce the linear pressure score at Site 2 by almost 50% and by approximately 11% at Site 1 at a cost of approximately $83,500 as summarized in Appendix L.

20. 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 75% compared to the base range with the 10 ft. tall berm on 3 sides depending upon the combination of options selected. Incremental costs for these options varied from approximately $150,500 for adding the side and rear walls of the range building; approximately $296,600 for adding the 40 ft. roof extension; approximately $31,200 for adding the 10 ft. tall U-shaped berm at the rear of the range; approximately $108,000 for adding the 20 ft. tall U-shaped berm at the rear of the range; approximately $468,000 for adding the 30 ft. tall U-shaped berm at the rear of the range; and approximately $1,525,200 for the combination of all of these options.

21. 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.