CONWAY & OWEN

Project Report

Date: November 1, 2018

To: Lane Rivenbark
Nutter & Associates
360 Hawthorne Lane
Athens, GA 30606

Re: US Forestry Service / Union County
Shooting Range Noise Acoustical Analysis
Blairsville, GA
C&O #: 18322

From: Chuck Dowd, P.E.
Conway & Owen, Inc

Cc: File

Conway & Owen has developed the following information as an analysis of the firearms noise that is predicted for the proposed US Forestry Service- Union County shooting range located on GA Hwy 180. The intent of this report is to determine the sound level that would be experienced in areas near the shooting range due to gunfire that would occur during typical use of the range.

The proposed shooting range complex would consist of a 200 Yard Rifle Range and a 50 Yard Pistol Range. The proposed shooting range is located in the National Forest near the intersection of GA Hwy 180 and USFS Road 292 southeast of Blairsville, GA. The range layout concept is reproduced in Appendix 4. A graded elevation of 2355' was assumed for the completed shooting range.

The general analysis approach will be to start with typical firearm sound level data. Separate calculations will be generated for the different shooting range types. The various attenuation factors will then be applied to these sound levels in order to determine a resulting sound level at the property line or other selected location. The primary attenuation factors consist of the following: sound spreading due to distance, barrier effects that interrupt line of sight, and the direction of shooting.

After the attenuation factors have been subtracted from the initial source level, the resulting sound level will then be compared against the allowable sound level. The allowable sound level will be determined based on a threshold that is not expected to create a state of annoyance for a typical listener. Sound levels above the threshold level at the selected prediction locations may result in complaints from the residents who live at these locations.

Sound levels will be presented as Sound Pressure Level (SPL) in decibels. An "A" weighting (noted as "dBA") is often applied to these levels to better match the mechanism of human hearing since this hearing mechanism is not as sensitive to lower frequency sounds. The "A" weighting also simplifies the taking of field

measurements by reducing the contribution of wind noise and operator movement. Sound levels of short duration events such as gunshots are often measured with a very fast sound level meter response specialized for measuring impulse signals. Measurements are taken in dBA (I) using the "Impulse" setting and will typically be higher than the dBA (F) measurements taken on the "Fast" setting for the same gunshot due to the faster response time of the meter.

The radiation pattern of the sound generated by the firearm discharge is directional and places the loudest sound in the direction that the muzzle is pointed. This effect tends to be more pronounced for firearms with longer barrels. Table 3 in the Appendix lists the directional characteristics for a typical rifle, shotgun, and handgun.

Table 1 below lists the Sound Pressure Level (SPL) generated by typical firearms. This data was measured at a distance of 10 meters (32.8 feet) and was measured in the direction that the muzzle is aimed (Reference 5). Similar levels are provided in Reference 4. The typical sound level used for a pistol is an average of various types. Levels of other types of sound sources are provided in Appendix 3 for comparison.

TABLE 1- AVERAGE SOUND PRESSURE LEVELS GENERATED IN THE MUZZLE DIRECTION

FIREARM TYPE	SOUND PRESSURE LEVEL (SPL) AT 32.8 FT.
Rifle (Mauser 96, 6.5 mm cart.)	126 dBA(I)
Shotgun (12 ga., 2.75" shell)	127 dBA(I)
Pistol	115 dBA (I)

The proposed shooting range location and all of the sound prediction locations are outside of the city limits of Blairsville. There does not appear to be a local noise ordinance in place other than State of Georgia Statute 41-1-9. This statute basically states that a shooting range only has to be in compliance with any regulations or ordinances that were in place on the day that the range commenced operation. Without a local governing ordinance in place, evaluation criteria will be based on the predicted sound levels that would be expected to generate annoyance and complaints from the local residents. The threshold of annoyance is dependent on the background noise levels of the area in question. Lower background noise levels will cause the gunfire sounds to be more prominent and therefore will generate a heightened sense of annoyance among the neighbors.

Annoyance threshold information is available from the following sources:

- British Building Research Establishment (Reference 1) states that "Annoyance is less likely to occur at a mean shooting noise level (mean SNL) below 55 dBA and highly likely to occur at a mean shooting noise level (mean SNL) above 65 dBA. The likelihood of annoyance at levels within this range will depend upon local circumstances." These values are measured with a fast response on the sound level meter.

- Reference 2 provides sound level regulations from Norway, Sweden, Finland, and Denmark that are very similar to the 55-65 dBA range noted above.
    - Reference 4 provides a conversion for any measurements taken on the sound level meter using an impulse response weighting. This

reference equates the 55-65 dBA (F) range to approximately the range from 60 dBA (I) to 70 dBA (I).

The factors to consider in selecting a threshold value are:

- The locality and general background noise levels- assumed to be relatively low due to the location.
- Day(s) of the week that shooting is to occur- typically 4-7 days per week.
- At what time(s) of day shooting is to occur- daytime only.
- Intensity of shooting, the number of shooting days/year- expected to be greater than 28 days/year.

One other common threshold determination technique is to add 10 dB to the typical background noise measured at the location rather than using the 55-65 dBA range. The background noise level can be predicted but typically requires a site noise survey to accurately quantify. The background noise level will also vary from location to location and with time depending on factors such as proximity to highways or other noise sources. Therefore, background noise measurements averaged over a minimum of one hour per location are required in order to achieve accurate results.

Because the Union County Shooting Range will be located in a rural setting, it is recommended that the lower end of the annoyance criteria be selected. The result is a project threshold criterion of 55 dBA or 60 dBA (I). The attenuation required at the property line or other selected prediction location can then be determined by subtracting this threshold from the Table 1 values as shown in Table 2.

TABLE 2- MINIMUM REQUIRED SOUND ATTENUATION

FIREARM TYPE	ATTENUATION REQUIRED AT PREDICTION LOCATION*
Rifle	66 dB
Shotgun	67 dB
Pistol	55 dB

*Attenuation necessary to reduce SPL to 55 dBA max.

Note that the permissible sound levels described above represent daytime levels only. It is typical to see a reduction in permissible levels at night (after 10:00 pm) due to the lower background noise levels that would be present. Residents would also be sleeping at night which would increase the probability of annoyance if they are disturbed. Often an intermediate evening value will be set for the time between 7:00 pm and 10:00 pm. It is our understanding that the shooting range will operate during daytime hours only and therefore there is no requirement to compare against a lower sound level threshold for evening and nighttime hours.

The next step in the analysis process is to define and determine a value to the factors that are available to provide the required attenuation. Analysis of the various attenuation factors follows the process identified in International Standards Organization (ISO) 9613-2 (Reference 6) as described in Appendix 1.

CALCULATIONS AND OBSERVATIONS

Results of predicted sound levels in dBA at Location 1 through Location 13 are listed in Table 3 for the proposed rifle and pistol ranges. Figure 1 maps these locations.

Levels below 55 dBA would not be expected to produce annoyance and these values are highlighted in the table with a green color. On the other hand, annoyance response to levels above 65 dBA would be expected and these values are indicated with a red color. Levels between 55 dBA and 65 dBA form an uncertainty range and are identified with an orange color.

Specific conclusions are as follows:

- For the Pistol Range, predicted sound levels are in the Green category for all locations except for Location 1 which is at the range entrance. The area of Highway 180 near the range is expected to be in the Red category.

- For the Rifle Range, predicted sound levels are in the Green category for all locations except Location 1, Location 3, and Location 4A. Location 1 is on Highway 180 as described above. Location 3 and Location 4A are on the Appalachian Trail with sound levels at the low end of the Orange category.

- The orientation of the shooting range to the southeast places the majority of prediction locations and residences to the back side of the range. This helps to reduce the sound levels since the loudest sound is in the shooting direction. The only prediction locations on the forward side of the range are Location 3 and Location 4 on the Appalachian Trail.

- The natural terrain of the valley where the proposed range will be located provides additional noise control. Figure 2 is a snapshot view from Google Earth looking to the southwest and west. The depressed area around the firing line enhances this effect and helps to reduce the ability of the Highway 180 corridor (Soapstone Gap) to provide a line of sight sound transmission path. This geometry helps to shield residents to the southwest of the range from shooting noise.

- The Appalachian Trail located to the southeast of the range is more exposed to shooting noise than are the residents to the southwest. This is due to the relatively short distance between the range and locations 3, 4, and 4A as can be seen in Figure 1. Also, these locations are oriented in the muzzle direction from the shooting range so the directional attenuation is minimal. The intervening hills between the Trail and these locations do provide some sound screening. This screening is apparent from the Google Earth snapshot shown in Figure 3. Location 4 benefits from the Trail having dropped below the back side of the ridgeline in this location as shown in Google Earth.

- Actual sound levels will vary somewhat with meteorological conditions. Levels will decrease when wind blows from the listening location towards the shooting range and will increase when strong winds blow from the shooting range towards the listening location.

- Increasing the range grade level from 2355’ to 2370’ produces a minimal difference in the predicted sound levels. Levels at Location 6 increase by approximately 1 dB, levels at other locations increase by smaller amounts. Reducing grade level to 2340’ produces a minimal difference, other than Locations 6 and 7 which see sound levels reduced by 4 dB and 8 dB

respectively. This change reduces line of sight sound transmission down the Hwy 180 corridor. Predicted levels were already low at these two locations.

ANALYSIS SUMMARY

Predicted sound levels are generally in the Green category; exceptions are:

1. The area of Highway 180 near the range (Location 1) will receive significant amounts of sound energy and drivers will hear the shots.

2. Levels of shooting noise will approach the Orange level on the Appalachian Trail. These levels will drop quickly as the intervening hills block the line of sight and as the Trail slopes down the back side of the ridge away from the shooting ranges.

3. Levels of shooting noise are in the Red category at Turkey Pen Mtn. and Turkey Pen Gap due to the limited distance (2000'-2500') and the shooting direction. Levels will be reduced on the back side of the mountain due to sound shadowing.

TABLE 3- PREDICTED SOUND LEVELS IN dBA

POINT	LOCATION DESCRIPTION	RIFLE RANGE	PISTOL RANGE
1	Highway 180- Range Entrance	77	75
2	Hwy 180- One Mile NE of Range	54	48
3	Appalachian Trail- Nearest Point East of Range	61	51
4	Appalachian Trail- Nearest Point Southeast of Range	47	37
4A	Ridgeline near Appalachian Trail- Southeast of Range	58	49
5	Houses- Cedar Mountain View Rd south of Hwy 180	32	27
6	Houses- Jonas Mtn Rd near Hwy 180	39	35
7	Houses- Walnut Springs Rd	44	40
8	Houses- Old Toll Rd and Hwy 180	38	34
9	Houses- Intersection of Hwy 180 and Burt Nix Rd	42	39
10	Houses- Fain Bridge Rd northeast of Town Creek School Rd	41	38
11	Houses- Fain Bridge Rd & Schultz Rd southwest of Range	35	33
12	Houses- Fain Bridge Rd & Heck of a Dr Way	22	20
13	Houses- Brackett Rd & Tom Place west of Range	33	32
14	Turkey Pen Mountain Summit	76	67
15	Turkey Pen Gap at Stream Buffer	70	59

Table 3 Notes

1. Cell color legend is as follows: Green= Below 55 dBA, annoyance not expected. Orange= 55 dBA to 65 dBA annoyance uncertainty region. Red= Above 65 dBA, annoyance expected.

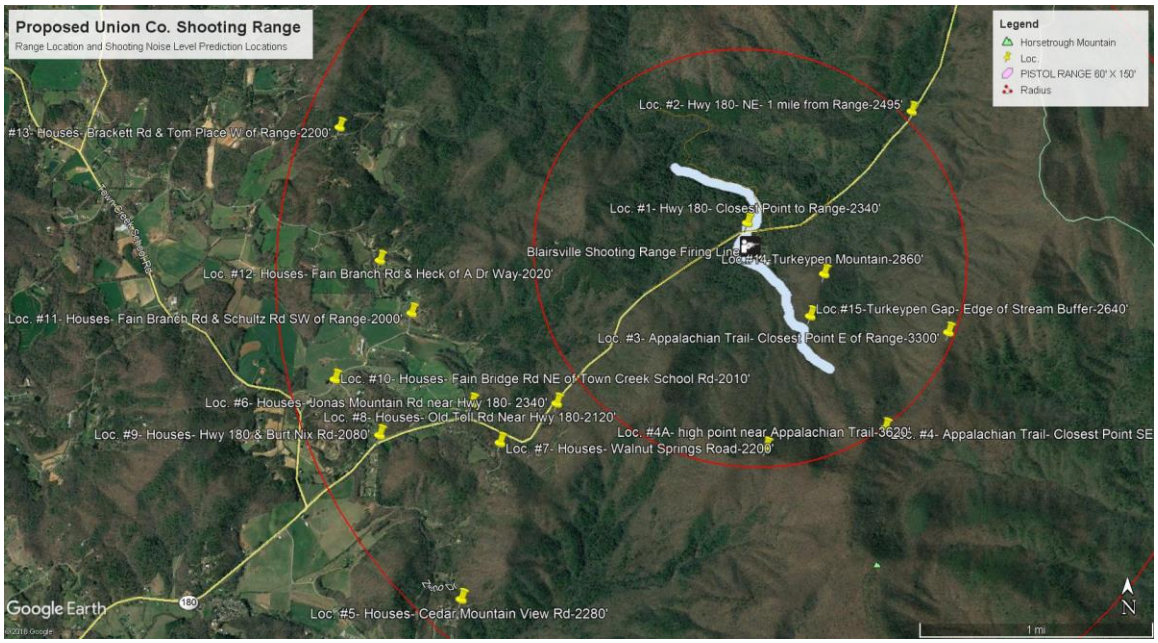


FIGURE 1- SHOOTING RANGE VICINITY MAP- RANGE LOCATION (SHOOTER ICON), PREDICTION LOCATIONS (YELLOW PINS), 1 MILE & 2 MILE RADIUS CIRCLES (RED CIRCLES).

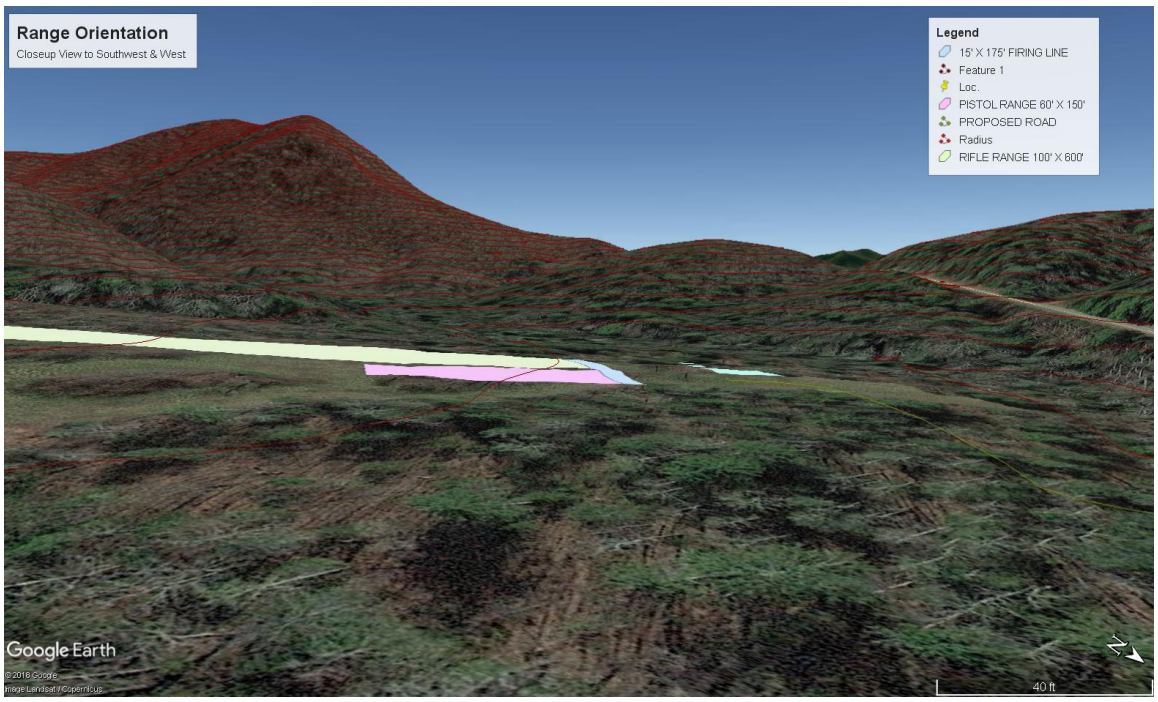


FIGURE 2- SHOOTING RANGE LOCATION IN A NATURAL VALLEY.

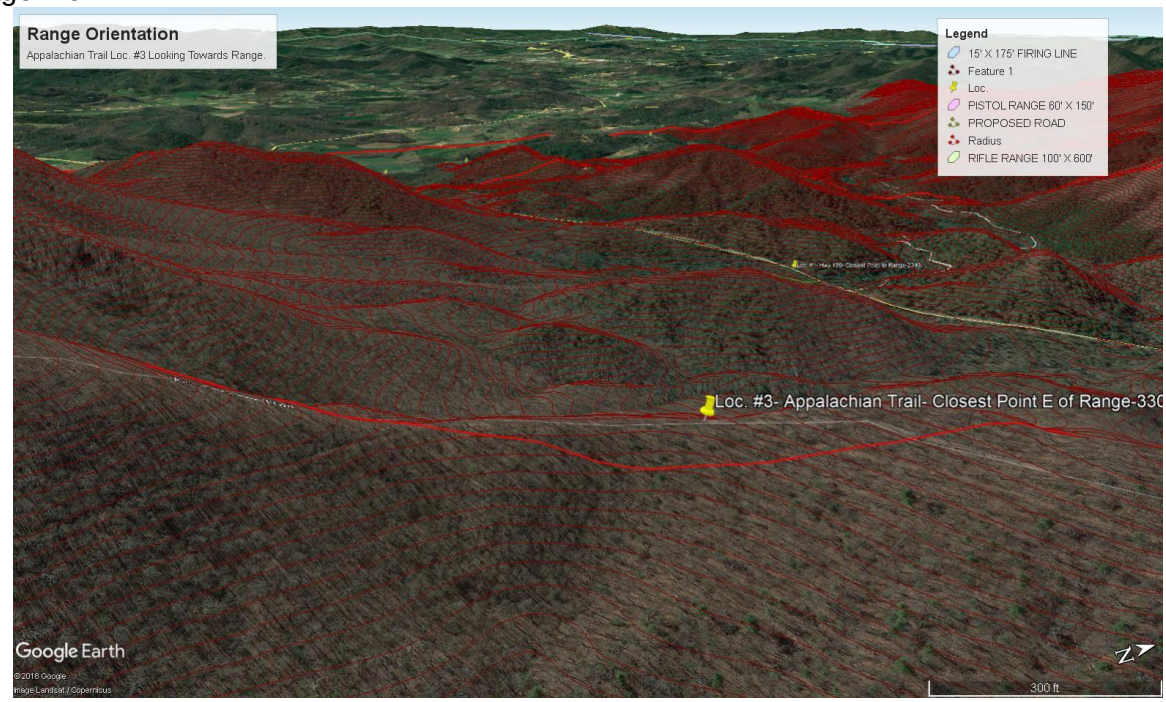


FIGURE 3- LINE OF SIGHT TO RANGE POSITION FROM LOCATION #3.

REFERENCES

1. "Clay Target Shooting, Guidance on the Management and Control of Noise, Public Consultation Draft, November 1997", Chartered Institute of Environmental Health, (CIEH), British Shooting Sports Council, Clay Pigeon Shooting Association. Research conducted by Building Research Establishment.

2. "Propagation, Measurement, and Assessment of Shooting Noise", Timo Markula Master's Thesis, Helsinki University of Technology, Helsinki, Finland, May 2006.

3. "Reduction of Shooting Noise on Clay Target Shooting", Association of European Sporting Ammunition Manufacturers (AFEMS), May 2012.

4. "Acoustics- Noise from Shooting Ranges- Part 3: Guidelines for Sound Propagation Calculations", International Standards Organization (ISO) 17201-3, First Edition, February 1, 2010.

5. "Shooting Ranges and Sound", Royal Canadian Mounted Police IM/IT Business Solutions, March 1999.

6. "Acoustics- Attenuation of Sound During Propagation Outdoors- Part 2: General Method of Calculation", International Standards Organization (ISO) 9613-2, First Edition, December 15, 1996.

7. Google Earth Satellite Imagery Software, www.google.com/earth.

8. United States Department of Agriculture Natural Resources Conservation Service website: https://www.wcc.nrcs.usda.gov/ftpref/downloads/climate/windrose/georgia/ Click on the .gif file for a selected city and month. The Wind Rose graphic shows the wind speed and direction.

APPENDIX 1- DESCRIPTION OF ATTENUATION FACTORS

Attenuation Factor #1- Range Berms (Barrier)

The projectile berms (safety barriers) that are located around the rifle and pistol ranges will provide sound attenuation for receiving locations in the forward direction. A berm provides sound attenuation by forcing the sound up and over the berm so that the sound energy has to travel a longer pathway to reach the receiver. The variables in the sound attenuation calculation are the height of the berm, the distance from the source to the berm, and the distance from the receiver to the berm. The amount of attenuation is also frequency dependent. Gunfire consists of a wide range of frequencies but the output is greatest in the 500 Hz region. The output is reduced at lower frequencies and somewhat reduced at higher frequencies as well.

The attenuation of the berm behind the target (the forward berm) is affected by the length of the range. The distance to the receiver is a factor as well. The calculations also assume that the firearm is placed 5' above the ground and that the receiver's ear is 5' above the ground. Finally, the length of the berms must be sufficient so that the amount of attenuation is not reduced by sound traveling around the side of the berm. Attenuation values are prorated in the calculations if the length of the berm is not sufficient.

Also of note is that trees should not be placed at the top of the berm. These trees may provide a small amount of sound attenuation but they can also re-direct the sound energy back down on the receiver side of the berm so that the berm is not as effective.

Attenuation Factor #2- Firearm Orientation (Directionality-D)

The second attenuation factor is the orientation of the firearm to the listener or prediction location. As stated previously, the sound radiation is greatest in the muzzle direction and is attenuated to the sides and rear of the firearm. Attenuation values for sound energy output to the sides and rear of the firearm are indicated in Table 3. These values are taken from measurements provided in Reference 3. For all ranges, this report assumes that firearms are being used by responsible shooters who are operating under supervision and who are following standard shooting guidelines.

TABLE 4- DIRECTIONALITY OF FIREARM MUZZLE RADIATION

FIREARM	MUZZLE (DOWNRANGE)	TO SIDE (90º)	TO REAR (180º)
Handgun	0 dB	-4 dB	-8 dB
Rifle	0 dB	-10 dB	-18 dB
Shotgun	0 dB	-17 dB	-23 dB

Attenuation Factor #3- Distance (Geometric Spreading)
This is the most important attenuation factor and it is the physical distance from the firearm to the listener or prediction location. The attenuation is due to the sound energy spreading out with distance, an effect known as the "inverse square law". This factor provides 6 dB of loss for each doubling of distance from the source.

Attenuation Factor #4- Atmospheric Absorption
Air provides a relatively minor amount of sound absorption. This factor is frequency dependent and is affected by temperature and humidity. Higher frequencies are attenuated significantly at greater distances, especially when humidity levels are low. Therefore, sound levels and tone will vary somewhat with meteorological conditions present at the time of the gunshot.

Attenuation Factor #5- Ground Effect
Ground effect is due to the interaction of ground reflections with the passing sound wave. The ground effect is primarily due to the ground properties at the source and receiver positions. The ground effect attenuation is greater if the ground is porous and is covered with grass and other vegetation. This effect will be reduced during the times when the ground is frozen during the winter months or when the sound energy passes over a body of water.

Attenuation Factor #6- Terrain (Barrier)
The sixth attenuation factor is the terrain that exists between the range and the receiver or prediction location. This factor would generally come into play only if a ridge is located between the range and the receiver (measurement location) position.

The ridge functions as a barrier or berm to provide sound attenuation. A barrier provides sound attenuation by forcing the sound up and over the barrier so that the sound energy has to travel a longer pathway to reach the receiver. For the Union County range, terrain is an attenuation factor for all locations except for Location 1. This geometry has been included in the calculations for these locations.

Attenuation Factor #7- Other (Vegetation/Foliage)
The final attenuation factor is the presence of tall vegetation or trees that would completely block the view between the range and the receiver (listener) or prediction location. The value is frequency dependent but can be estimated to be approximately 1 dB for a 60' depth of vegetation increasing to a maximum limit of 10 dB for a 600' depth of medium-dense woods. Attenuation beyond approximately 10 dB will not be achieved in the field due to flanking paths and other factors. Rolling terrain will also reduce the effectiveness of foliage as the depressed areas of the sound path will provide limited attenuation since line of sight passes above the trees. A vegetation-free area around either the shooting position or the receiver position will reduce the amount of sound absorption as will a loss of foliage in the winter months.

Due to the high degree of rolling terrain and limited quantity of evergreen trees at this site, foliage factors are limited and have not included in this analysis. Note that any available foliage attenuation will increase slightly if the area of land to be cleared around the shooting location is minimized.

Wind Considerations (Meteorological)

Another factor that can affect propagation of sound is wind direction. When wind is present, sound carries farther in the direction the wind is blowing and is attenuated when traveling against the wind. For this range location, there is no evidence of prevailing wind direction and strength significant enough to bias the calculations in that direction. Current wind data is available in Reference 8 but is limited to metropolitan areas.

APPENDIX 2- SAMPLE CALCULATION FOR A SPECIFIC LOCATION

The following table lists the various attenuation factors used to predict the sound level at an example location, Location 3 with the gunshot occurring on the rifle range.

The calculations begin with gunshot sound power levels in octave frequency bands. The sound power levels are available in Reference 3 and provide similar sound levels to Reference 4 and Reference 5. The octave band analysis approach is used since some of the factors are frequency dependent.

The octave band values are summed to produce a broadband value, which for the Location 3 prediction is 56.0 dBA as shown in the table below. The broadband values are converted to dBA-F by adding 5.0 dB to give the value included in Table 3. This approach simplifies comparison with measurements made on a standard sound level meter and with the annoyance threshold levels described in this report.

TABLE 5- ATTENUATION FACTORS FOR LOCATION 3, RIFLE

Cross section for receiver Loc3 (Id=-5633) and source Rifle (Id=151)

L(wr)	110.36	118.56	125.16	129.06	130.36	129.26	126.86	123.66	121.06
A(ground)	-5.83	-5.83	-5.83	-5.83	-5.83	-5.83	-5.83	-5.83	-5.83
A(barrier)	4.79	4.80	4.84	4.90	5.03	5.28	5.73	6.51	7.75
A(veg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A(sit)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A(bld)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A(air)	0.04	0.17	0.62	1.96	4.47	7.69	14.82	40.74	140.60
A(geo)	75.08	75.08	75.08	75.08	75.08	75.08	75.08	75.08	75.08
D(i)	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32	-1.32
C(meteo)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L(p)	34.96	43.02	49.13	51.62	50.29	45.72	35.74	5.84	-97.85

56.00

Height	Source	Per	LAeq	32	63	125	250	500
1.50	Rifle	1	56.00	34.96	43.02	49.13	51.62	50.29

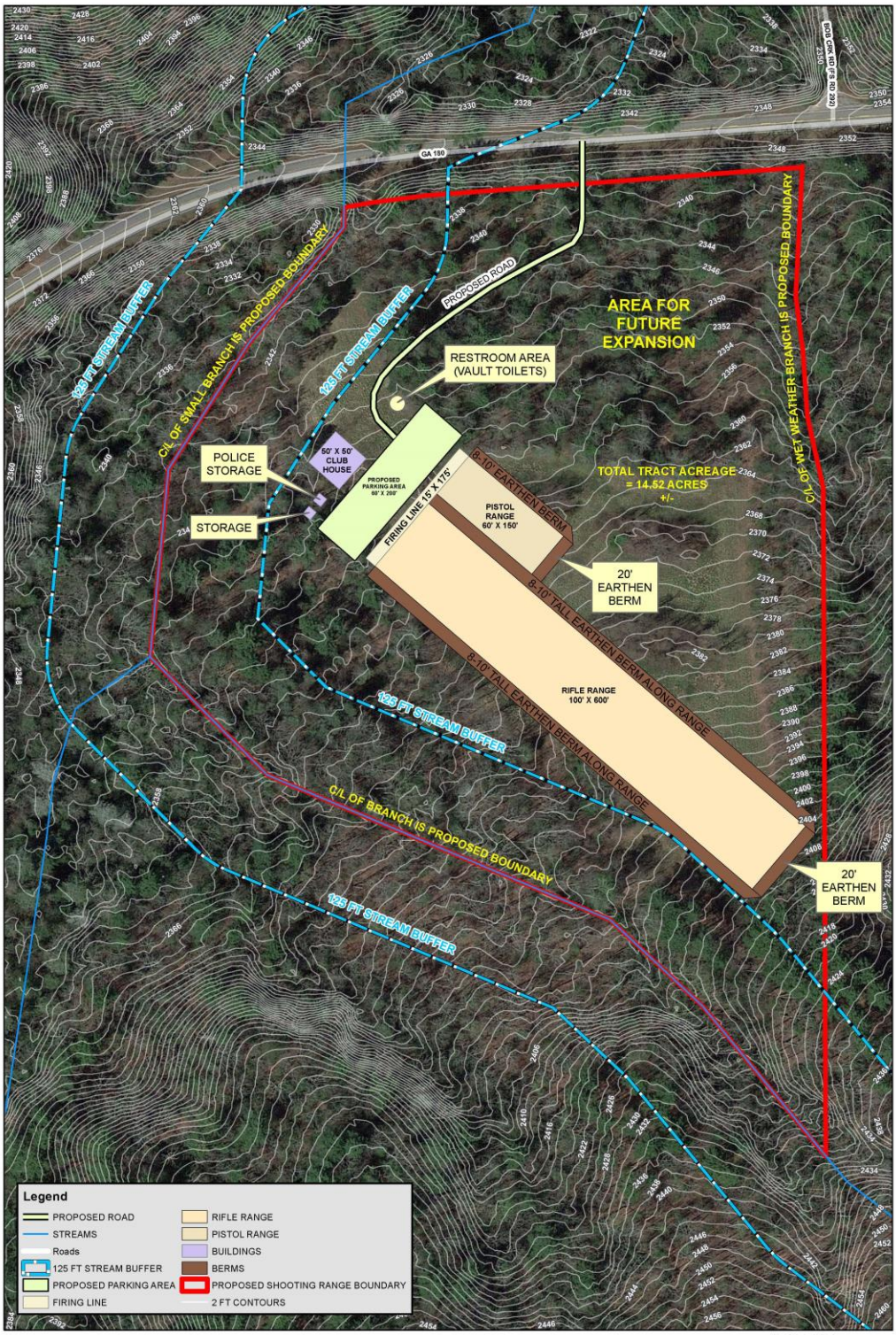
1000	2000	4000	8000
45.72	35.74	5.84	-97.85

APPENDIX 3- RANGES OF LEVELS FOR COMMON SOUNDS

The table below from Reference 9 provides a listing of sound levels in decibels with "A" scale frequency weighting for a number of common interior and exterior sound sources.

SOUND SOURCE DESCRIPTION	SOUND LEVELS
Quiet Residence	30-45
Quiet Street	40-50
Quiet Air Conditioning Outlet at 3'	40-50
Automobile Cabin (30 mph, windows closed)	50-60
150' from Dense Traffic	55-70
Business Office	60-70
Quiet Talker at 3'	60-65
Loud Talker at 3'	70-80
Automobile Cabin (60-85 mph, windows closed)	65-75
Edge of Busy Highway	70-80
School Cafeteria	75-90
Business Machines at 3'	75-85
Aircraft Cabin	85-95
Airplane 3000' Overhead	75-80
Aircraft Cabin	85-95

APPENDIX 4- LAYOUT CONCEPT FOR PROPOSED SHOOTING RANGE



1 inch = 100 feet

PROPOSED SHOOTING RANGE LOCATION
GA HWY 180 E NEAR USFS RD 292
UNION COUNTY, GEORGIA

END OF REPORT