Soundscape Engineering
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Noise Transmission Assessment of FPD Training Grounds, Lockport, Illinois

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11 March 2025

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Executive Summary

The proposed Lockport Township FPD Training Grounds and Outdoor Range will be located in the Lockport Fire Protection District on West Division Street in Lockport, Illinois, adjacent to the Stateville Correctional Center. The outdoor firing range would be surrounded by 24’ tall berms on three sides and a 20.5’ tall absorptive sound barrier on the north side. The firing range has been designed to accommodate a maximum of 15 shooters using handguns and AR-15 rifles.

We have modeled the propagation of sound emitted from rifle and handgun use at the proposed firing range to the surrounding residential properties, with and without the planned mitigation, although we have shifted the proposed barrier 10 feet to the west to improve mitigation to the residences northwest of the range. Our analysis shows that levels transmitted to the surrounding properties will be reduced by 2-12 dB with the mitigation measures, depending on location.

The maximum impulsive levels (LAI_{max}) transmitted from a rifle at the firing range to the nearest residential properties, located approximately 2,200 feet northwest of the site, are predicted to be 58 dBA without mitigation. With the berms and absorptive sound barrier in place, LAI_{max} levels at these properties are expected to be 46 dBA. Levels transmitted from a handgun at the firing range to the same location are expected to be 57 dBA without mitigation and 45 with mitigation.

LAI_{max} sound levels from rifles transmitted to residences located 4,500 feet to the south are predicted to be 58 dBA without mitigation and 50 dBA with the berms/barrier.

At the library and closest residences to the southwest of the site (located approximately 5,000 feet to the southwest) the predicted LAImax sound levels from a rifle are 48 dBA without mitigation and 41 dBA with the berms and absorptive sound barrier in place.

Predicted noise levels are based on our assumption of stable weather conditions and ground conditions in warmer weather. Temperature inversions, wind speed and direction, and seasonal ground effects can all influence the noise levels significantly.

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List of Abbreviated Terms

dB	Decibel
dBA	A-weighted Decibels
IPCB	Illinois Pollution Control Board
L_1	The sound level during 1% of the measurement period, closer to the maximum
L_{10}	The sound level during 10% of the measurement period, closer to the maximum
L_{90}	The sound level exceeded during 90% of the measurement period, closer to the minimum
LAF_{max}	Maximum A-weighted SPL using a fast detector
LAI_{max}	Maximum A-weighted impulsive sound level
LA_{eq}	Equivalent continuous sound level (A-weighted)
L_{eq}	Equivalent continuous sound level (unweighted)
SPL	Sound Pressure Level
STC	Sound Transmission Class
NRC	Noise Reduction Coefficient

1.0 Introduction

Soundscape Engineering has completed a sound study for the proposed Lockport Township FPD Training Grounds and Outdoor Range located in the Lockport Fire Protection District on West Division Street in Crest Hill, Illinois, adjacent to the Stateville Correctional Center. As shown below in Figure 1, the outdoor firing range would be surrounded by 24' tall berms on three sides with a 20.5' tall absorptive sound barrier on the north side.

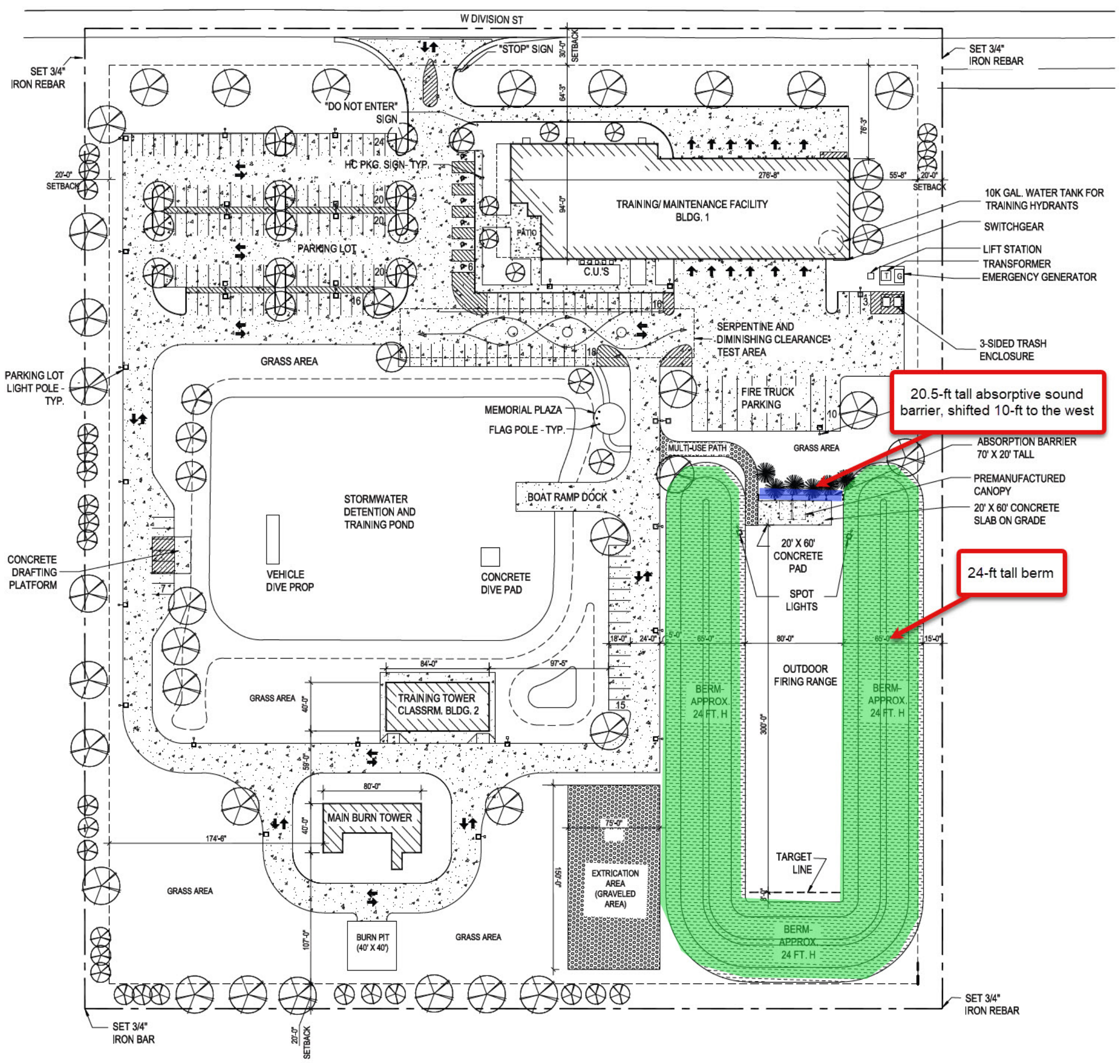

Figure 1: Site Plan for the Lockport Township FPD Training Grounds, Lockport, IL

The outdoor firing range is being designed to accommodate a maximum of 15 shooters. Most of the training would be with handguns, but it is anticipated that AR-15 rifles would be used as well. The design team has been asked to assess sound transmission to the nearby residential properties. The distances to the nearest residential areas are shown in the zoning map below (Figure 2).

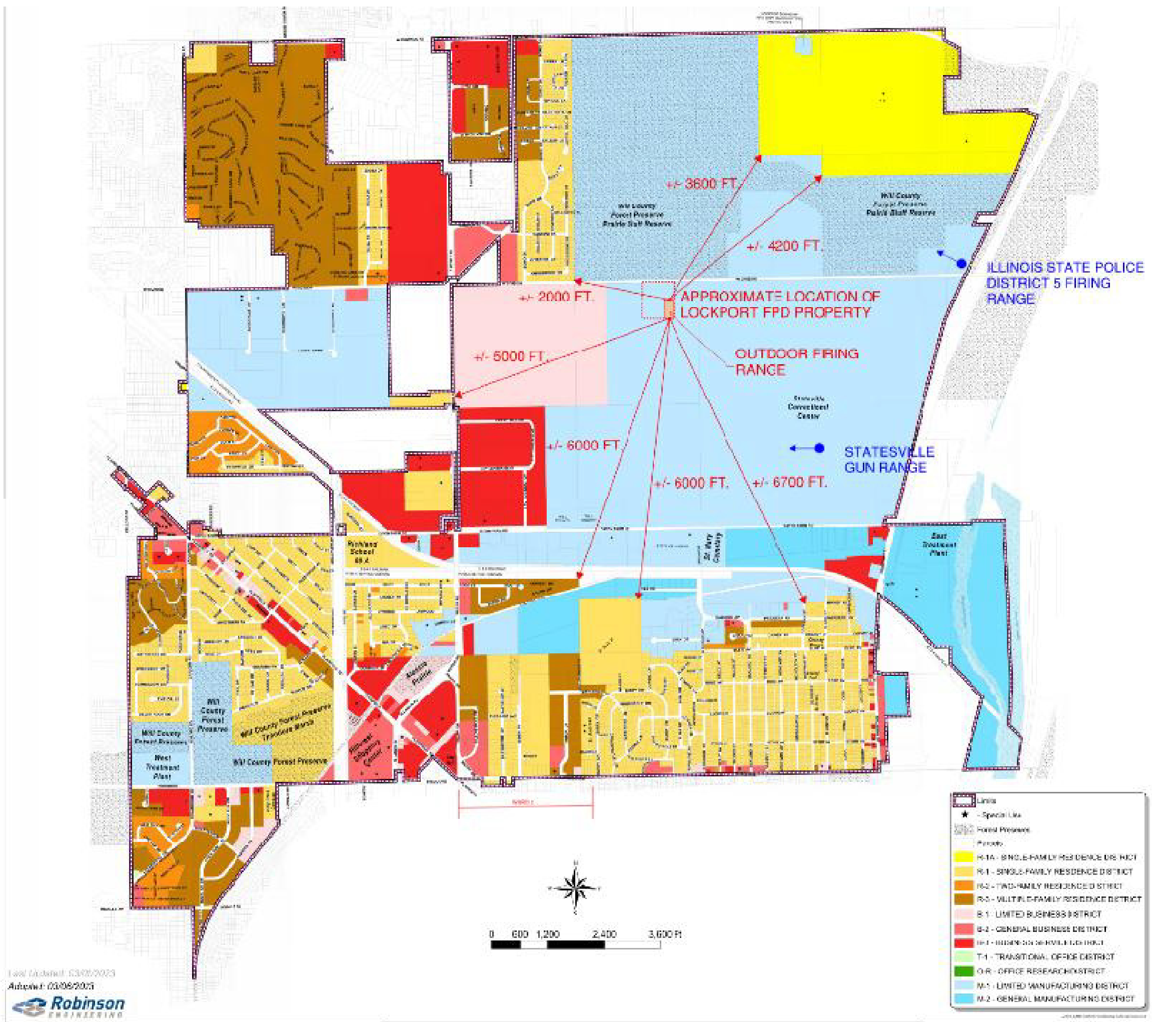

Figure 2: Location of Firing Range with Respect to Nearby Residential Areas

Soundscape has been retained to assess the expected sound transmission to nearby communities within Crest Hill, with and without the planned earthen berms and sound barrier wall.

2.0 Background Information

Outdoor firing ranges are a potential source of noise transmission to the surrounding community. Noise from firearms such as handguns and rifles is characterized as impulsive due to the quick muzzle blast of the weapon and the resulting high amplitude pressure wave. The overall equivalent continuous sound level (LA_{eq}) may not be affected significantly by short-duration impulsive noises from the firing range, however the maximum impulsive noise levels (LAI_{max}) from the gunshots will be noticeably louder, depending on the firing direction and weapon used.

With such highly impulsive noise levels, unmitigated firing ranges can affect residents within a large distance. The findings from this noise transmission study will demonstrate the effectiveness of the proposed mitigation – the berms and sound barrier wall – in reducing firing range noise transmission to the neighbors.

2.1 Terminology

There is a brief glossary of pertinent acoustics terminology in Appendix A.

2.2 Noise Target

Per 740 ILCS 130/5, firearm ranges operated by a governmental entity are exempt from any ordinances governing the noise or sound emissions from normal use of a firearm range. Since the proposed firing range will be operated by the Lockport Township FPD, we understand that it is exempt from noise ordinances. However, we understand that the operators wish to reduce the noise levels transmitted to nearby properties in an effort to be good neighbors.

3.0 Modeled Noise Transmission

3.1 <u>Noise-sensitive Receptors</u>

The sensitive receptors for noise from the firing range were identified as thirteen residential and community spaces surrounding the proposed firing range. As shown in Figure 3, the closest of these homes is approximately 2,200 feet from the planned location of the firing range.

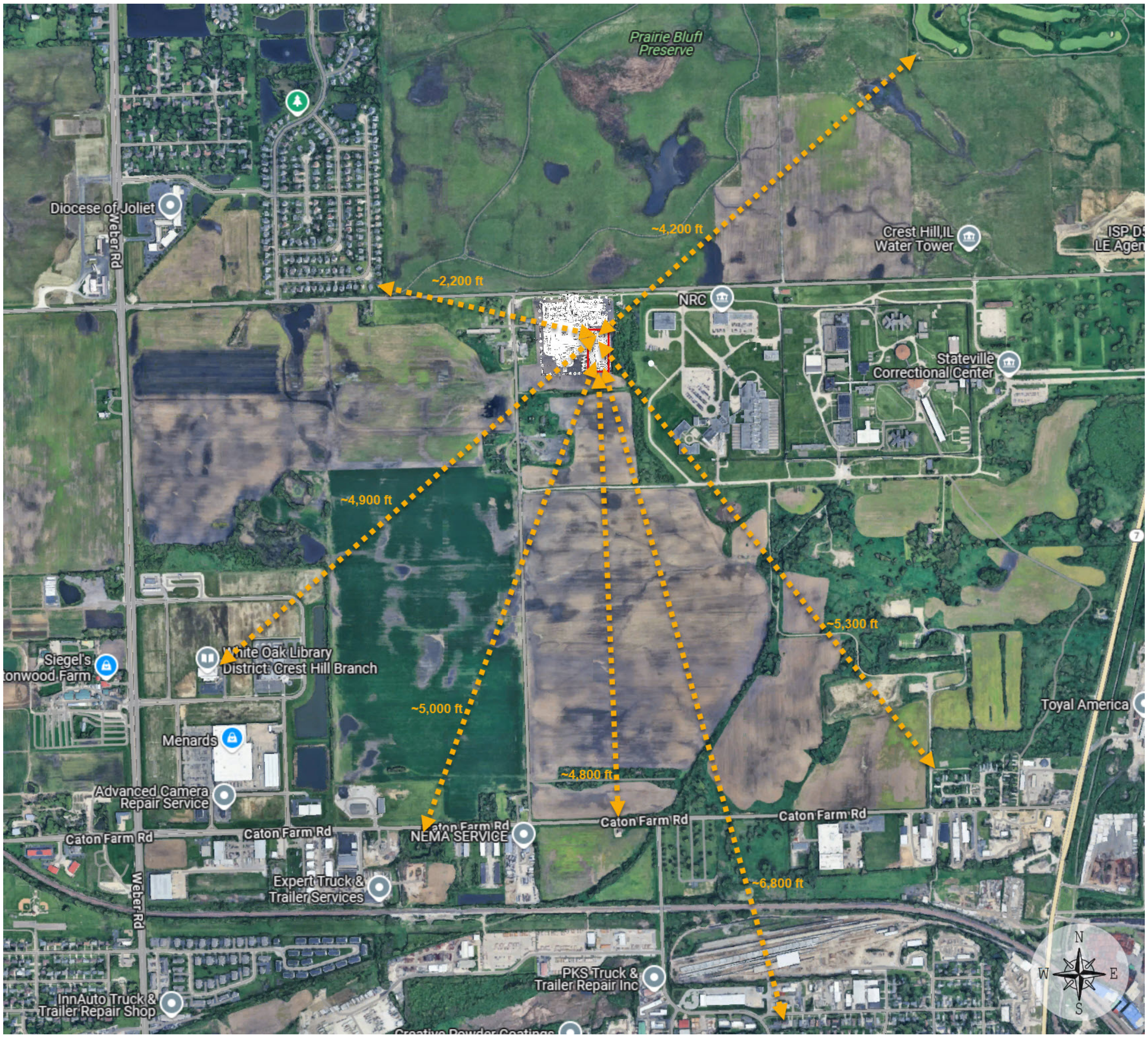

Figure 3: Aerial View Showing Sensitive Receptors

3.2 Firing Range Source Levels

Soundscape has previously measured firearm noise for other projects, which have included handguns and rifle sound levels. The data are directly applicable to this project. Octave band levels measured at a distance of 6 feet in front of a rifle and handgun are shown in Figure 4.

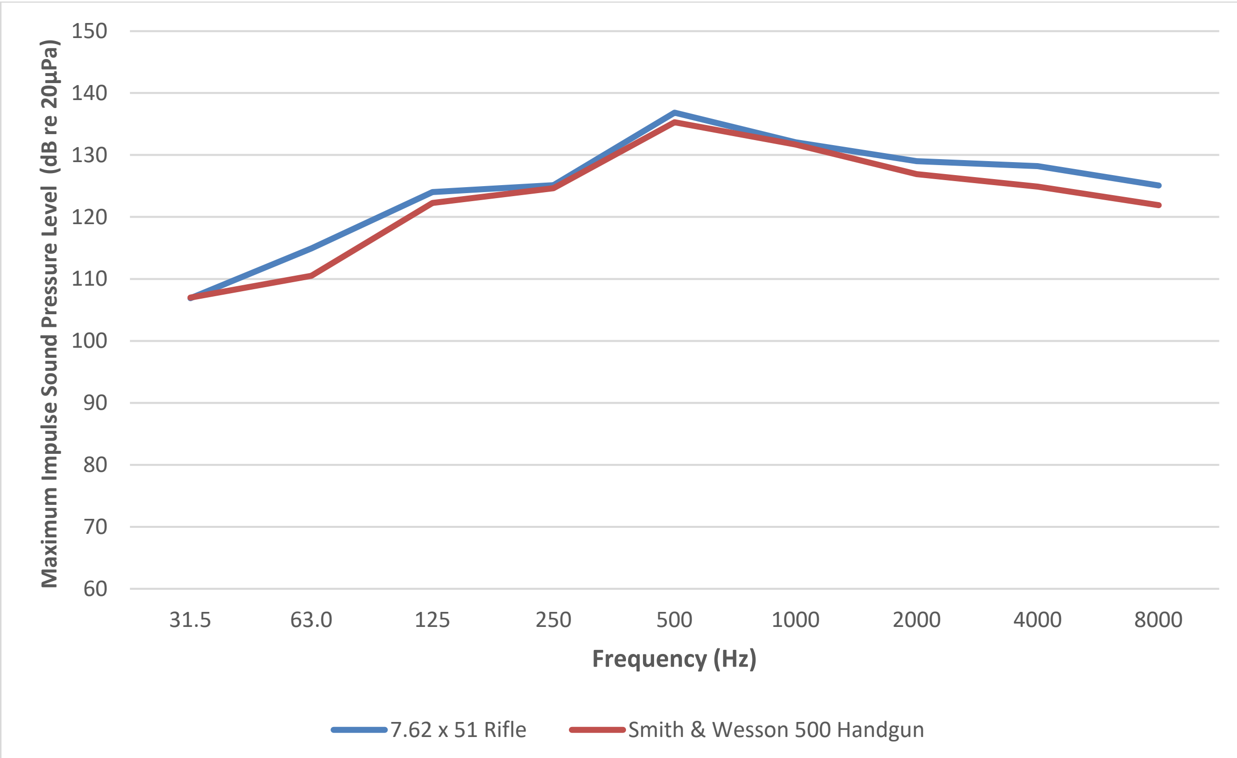

Figure 4: Measured LZI_{max} at 6-ft in Front of Muzzle

There are also many research reports and noise studies published with test data available for different types of firearms, which show similar results to our measurement data shown above.

The directivity pattern of gunshot noise produced by a typical rifle was obtained from a research report from the RCMP, [1] as shown in Figure 5, and was used to set up the rifle noise source in our model. In comparison to the levels measured for a rifle, pistol noise levels are approximately 6 dB quieter at the muzzle and 3 dB louder to the rear of the shooter.

[1] Royal Canadian Mounted Police, "Shooting Ranges and Sound."

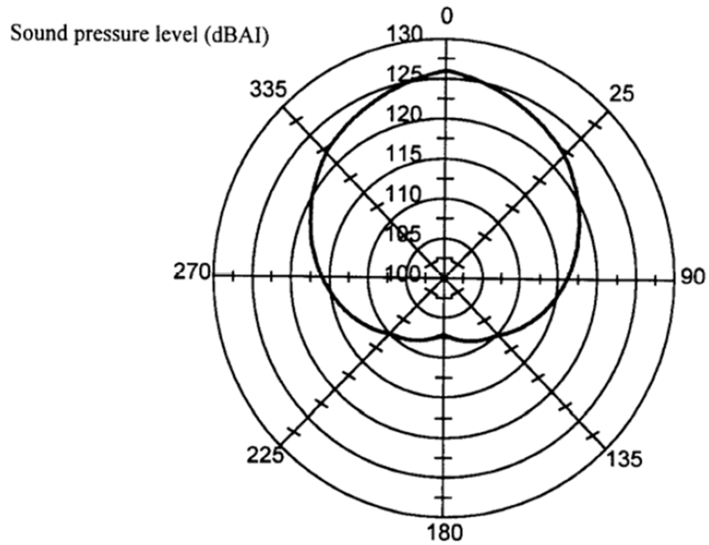

Figure 5: Directivity of Typical Rifle as Measured at 10-m

3.3 Firing Range Noise Modeling with SoundPLAN

The commercially available and widely used computer software, SoundPLAN, was employed to develop a 3-D noise model of the firing range site and its surroundings. This model included inputs to represent the planned firing range, the surrounding buildings, the area's topography, and the planned berms and noise barrier. The sound propagation across the site and surrounding area was calculated within the model to determine the expected noise levels at selected receiver locations.

Figure 6, below, presents an aerial view of the Crest Hill area surrounding the proposed firing range, as modeled in SoundPLAN. In the model, the red asterisk marks the noise source, representing the firing range. The yellow numbers indicate the sound receivers, which are positioned 5 feet above ground at the closest residential (along with the library and golf course) property lines.

Maximum impulsive noise levels were modeled from a single firearm (rifle and handgun) located at the center of the concrete pad, with the muzzle directed to the south. We have provided results separately for the rifle and handgun noise, with and without the planned mitigation, in the following section.

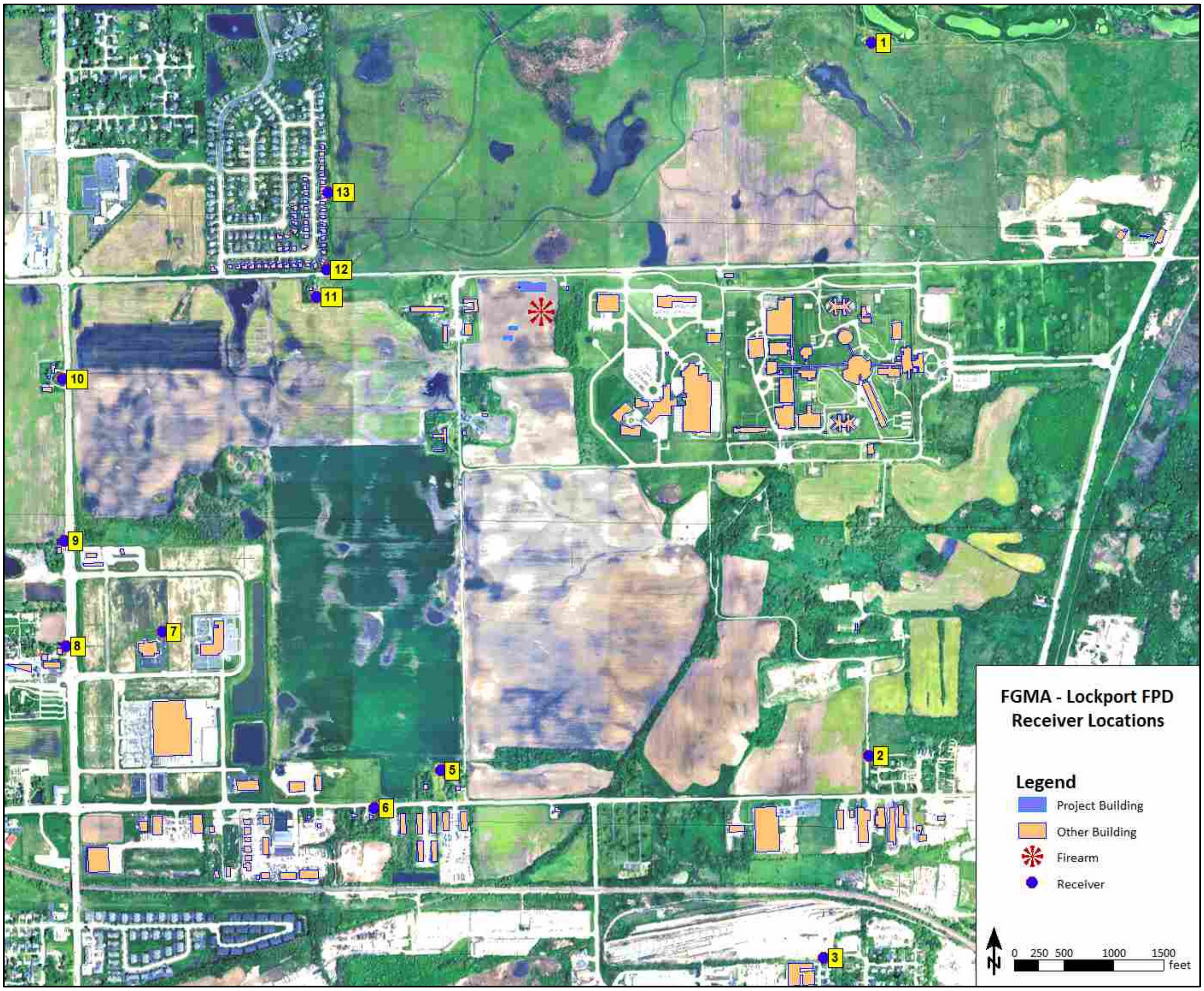

Figure 6: 2-D Aerial View from the SoundPLAN Model

3.4 Sound Absorption Barrier

The planned mitigation includes a 20.5-ft tall acoustical wall along the north side of the concrete pad. The wall was modeled with NRC 0.65 absorption on the south face of the wall. We have assume that the wall will have a minimum STC of 25. Although the site plan (Figure 1) shows the noise barrier located adjacent to the eastern side of the berm, we have shifted its location 10 feet to the west in order to better mitigate the transmitted noise levels to residences directly northwest of the range.

3.5 Ground Effects

Ground cover influences the sound propagation, especially near the source and receiver. Harder surfaces such as concrete, pavement, hard soil, and water provide little attenuation while softer, porous surfaces such as grass, vegetation, or snow will attenuate more sound over long distances. The attenuation is also frequency-dependent. In general, the softer ground types will attenuate more sound in the 250 Hz frequency band than at other frequencies. Taller vegetation can also provide some sound attenuation; however it must be a larger, dense forest before any significant effects can be measured.

The ground effects can also vary seasonally. While we have modeled the firing range in warmer weather conditions, colder weather can affect sound propagation significantly. As mentioned above, snow can provide a porous surface that will attenuate more noise and noise levels will be reduced at locations far from the firing range. At other times when the ground is frozen solid, with no snow on the ground, the hard ground will not provide significant attenuation and levels at distant receivers can increase by 5 – 20 dB, depending on distance.

In our analysis we assumed the ground effects based on warmer weather conditions; pavement and concrete surfaces were modeled as harder, reflective ground and the open field areas were modeled as partially soft ground to represent the absorption provided by some vegetation (i.e., grasses and field crops). We also assumed that there were no dense forests in the immediate area to provide any volume attenuation.

3.6 Wind and Temperature Effects

For noise that travels long distances, such as that from a firing range, wind and temperature variations can affect the bending of sound waves in the atmosphere, which can influence the transmitted noise levels. Wind speed and temperature change with altitude and these gradients can cause sound waves to travel faster or slower.

Outdoor sound is not only affected by wind speed, but also its direction, especially over distances greater than 150 feet. Sounds measured downwind may increase by a few dB while sounds measured upwind or side-wind can drop by 20 dB or more, depending on the distance and wind speeds. Turbulent or gusty wind can also reduce the measured sound levels.

Air temperatures at ground level tend to be warmer than the air at higher altitudes. When there is a "temperature inversion," such as on a clear night, the temperature at the ground surface may be lower than at altitude and sound waves will be reflected back to the earth's surface and can increase noise levels at large distances (1/2 mile or more) by several dB.

Our model of the firing range assumed stable weather conditions, with low winds and no influence from temperature inversions.

4.0 Modeled Firing Range Noise

The predicted noise levels due to a rifle and a handgun at the nearest sensitive receiver locations with and without the mitigation in place are provided below in Table 1. With the berms and noise barrier in place, levels are expected to be reduced by 2 – 12 dB, depending on location relative to the firing range.

Table 1: Comparison of Expected Noise Levels at Selected Receiver Locations, With and Without Mitigation

Receiver #	Rifle		Handgun		Improvement Due to Berms & Wall
	LAI_{max} (dBA) Without Mitigation	LAI_{max} (dBA) With Mitigation	LAI_{max} (dBA) Without Mitigation	LAI_{max} (dBA) With Mitigation	(dBA)
1 (Golf Course)	35	28	38	32	7
2	49	45	44	40	4
3	53	42	49	38	11
4	44	42	39	37	2
5	58	50	53	45	8
6	49	42	44	37	7
7 (Library)	48	41	42	36	7
8	43	38	38	33	5
9	48	41	42	36	7
10	53	41	48	36	12
11	56	48	53	45	8
12 (Nearest Residence)	58	46	57	45	12
13	54	45	55	46	9

A noise contour map helps to visualize the expected noise levels for the surrounding neighborhood due to the proposed firing range. Figure 7 and Figure 8 show predicted LAI_{max} levels from a rifle and handgun, respectively, without any mitigation in place. Notice that gunfire is directional, so more sound would transmit downrange than uprange. In addition, intervening buildings provide shielding in some areas. Figure 9 and Figure 10 show the predicted levels from a rifle and handgun with the berms and noise barrier in place. Figure 11 and Figure 12 show a closer view of the noise contours due to a rifle in the immediate area around the firing range.

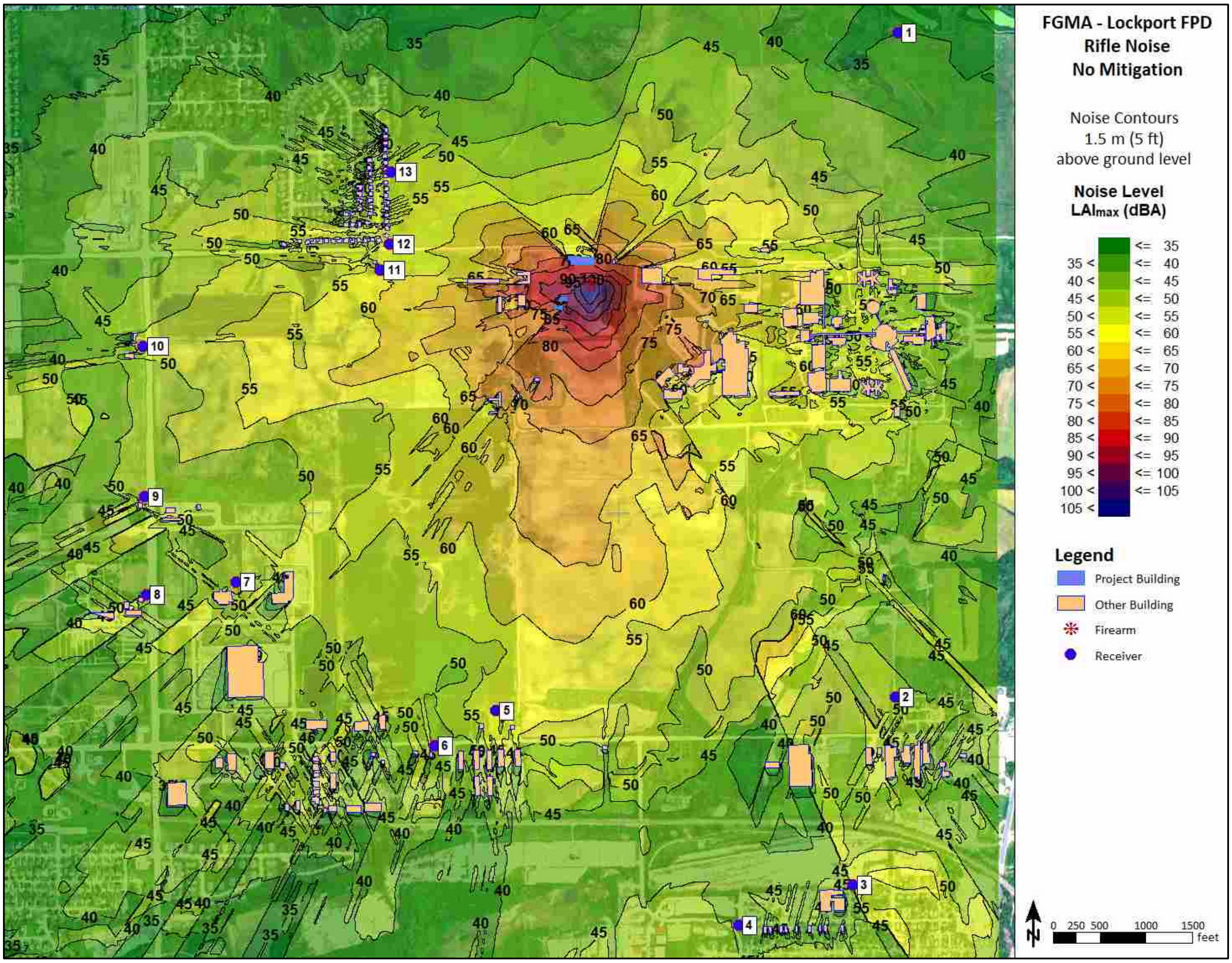

Figure 7: Noise Contour Map of Predicted Rifle Noise Transmission to Surrounding Areas, *Without* Mitigation

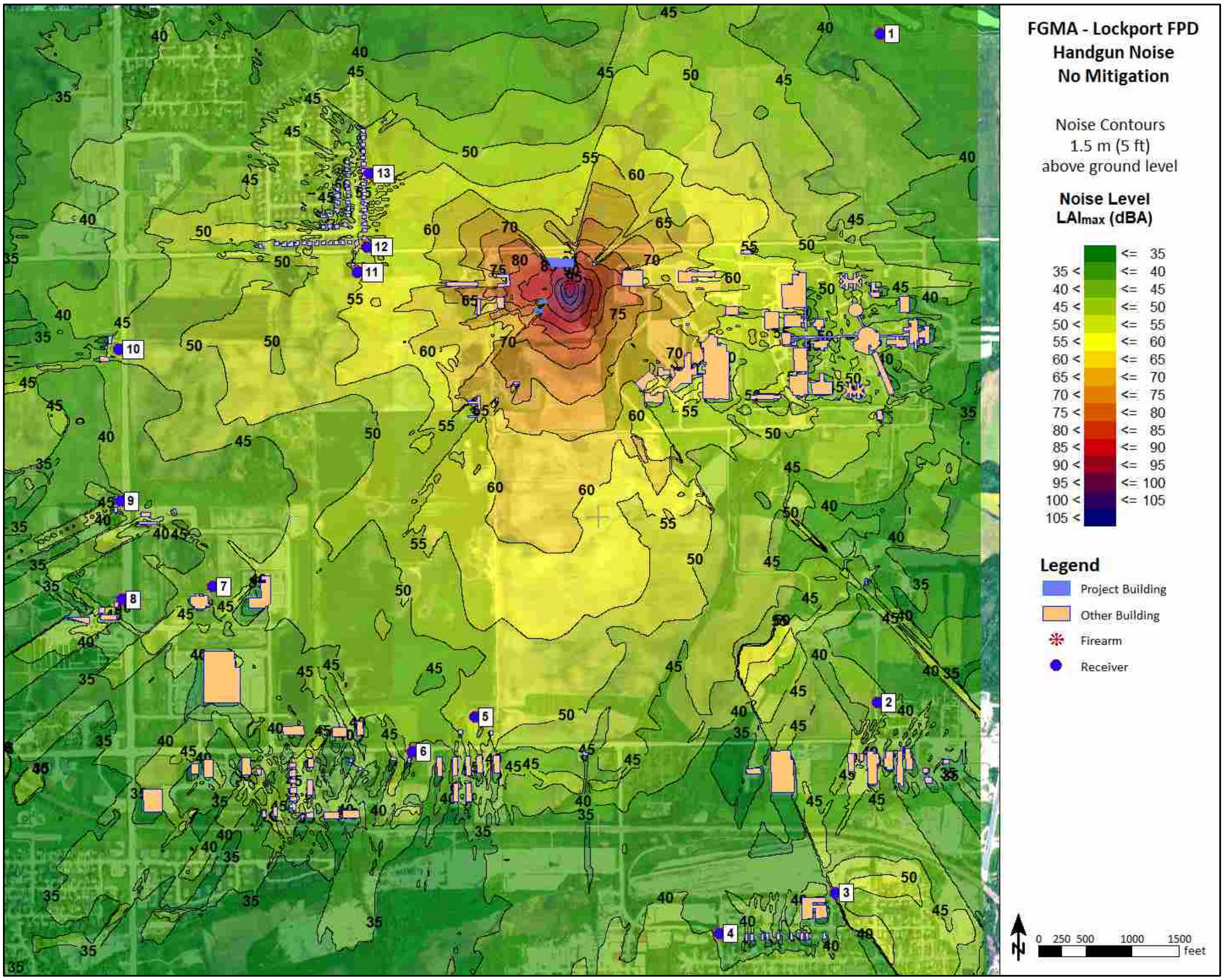

Figure 8: Noise Contour Map of Predicted Handgun Noise Transmission to Surrounding Areas, *Without* Mitigation

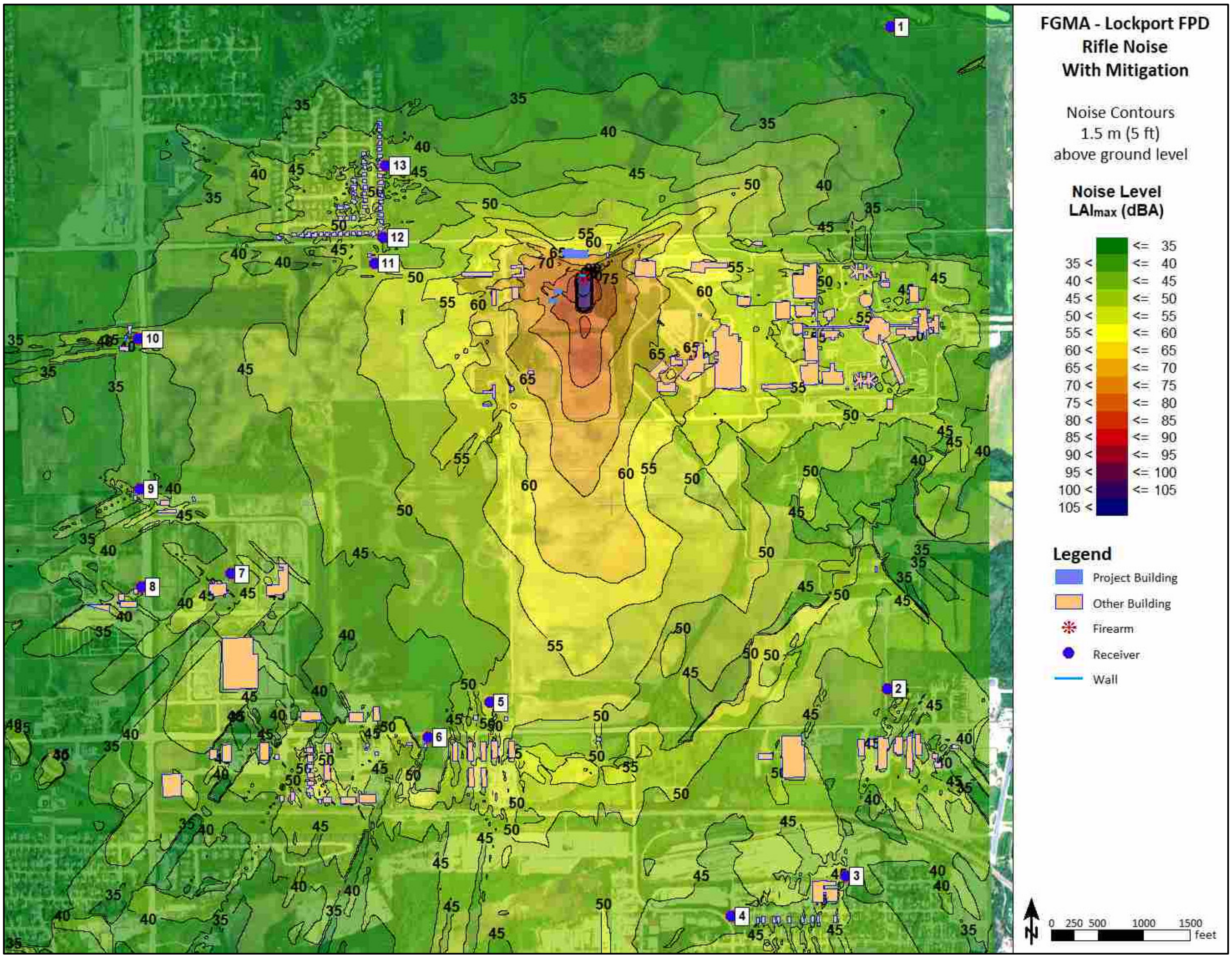

Figure 9: Noise Contour Map of Predicted Rifle Noise Transmission to Surrounding Areas,
***With* Berms and Barrier**

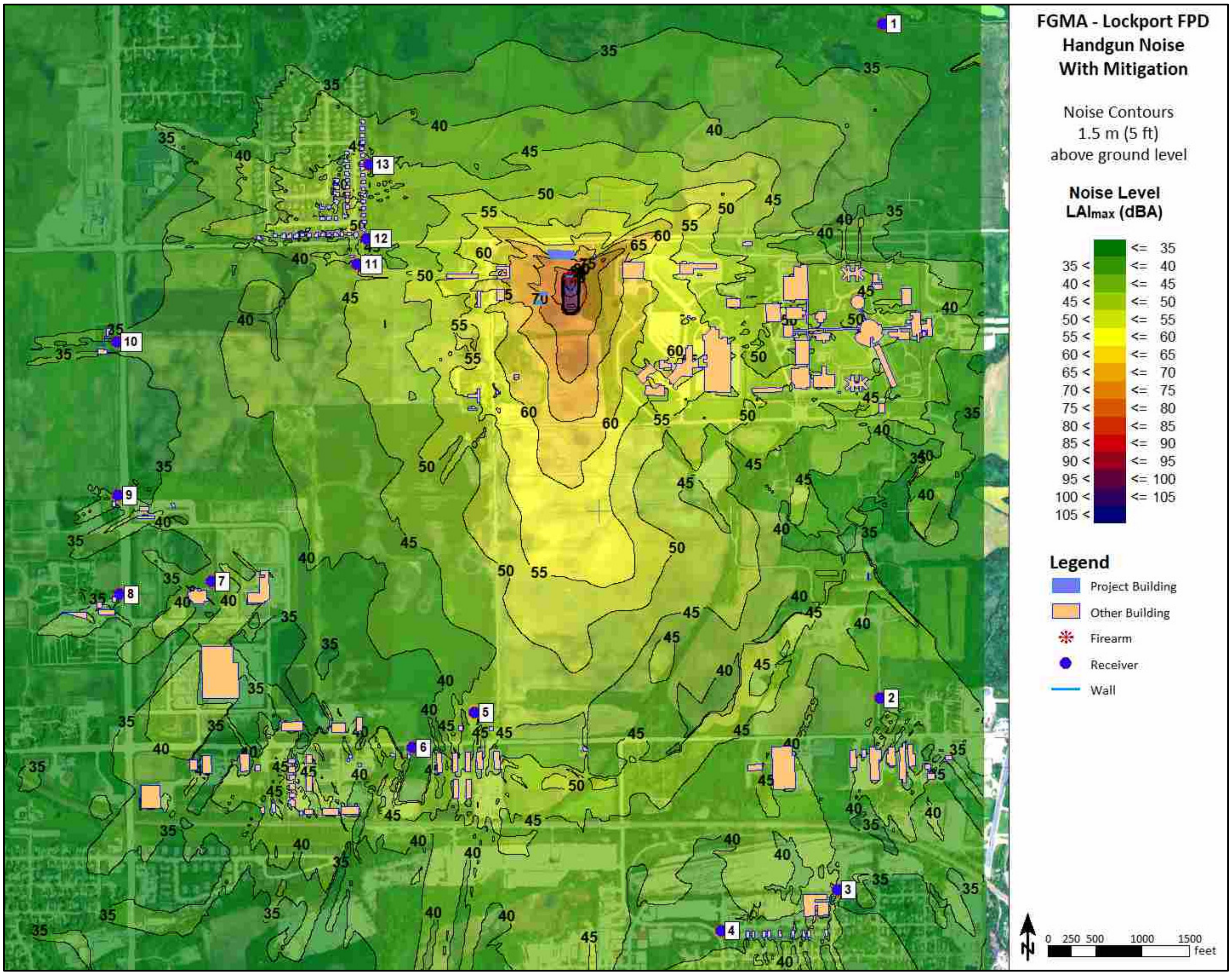

Figure 10: Noise Contour Map of Predicted Handgun Noise Transmission to Surrounding Areas, *With* Berms and Barrier

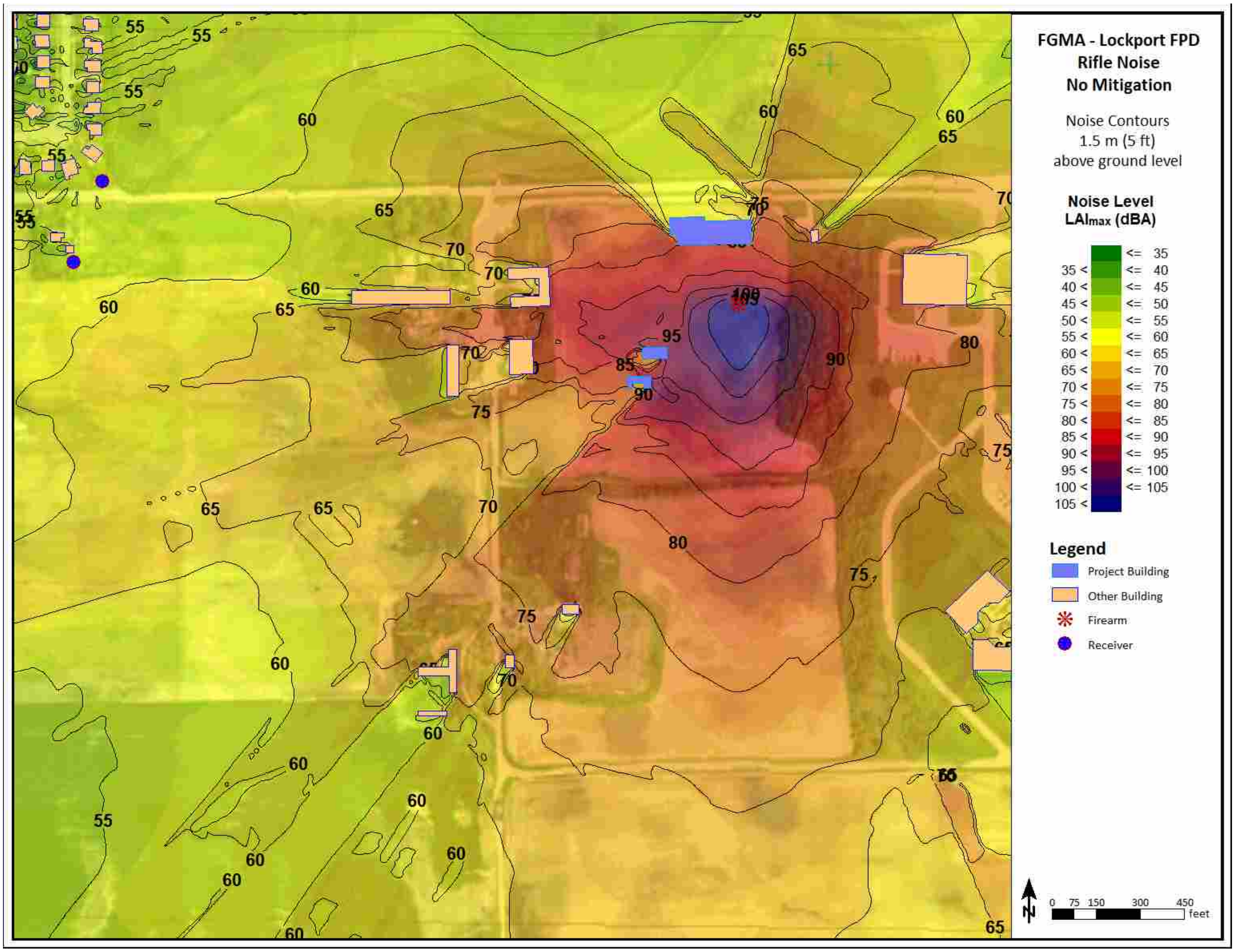

Figure 11: Noise Contour Map of Predicted Rifle Noise Transmission Near Project Site, *Without* Mitigation

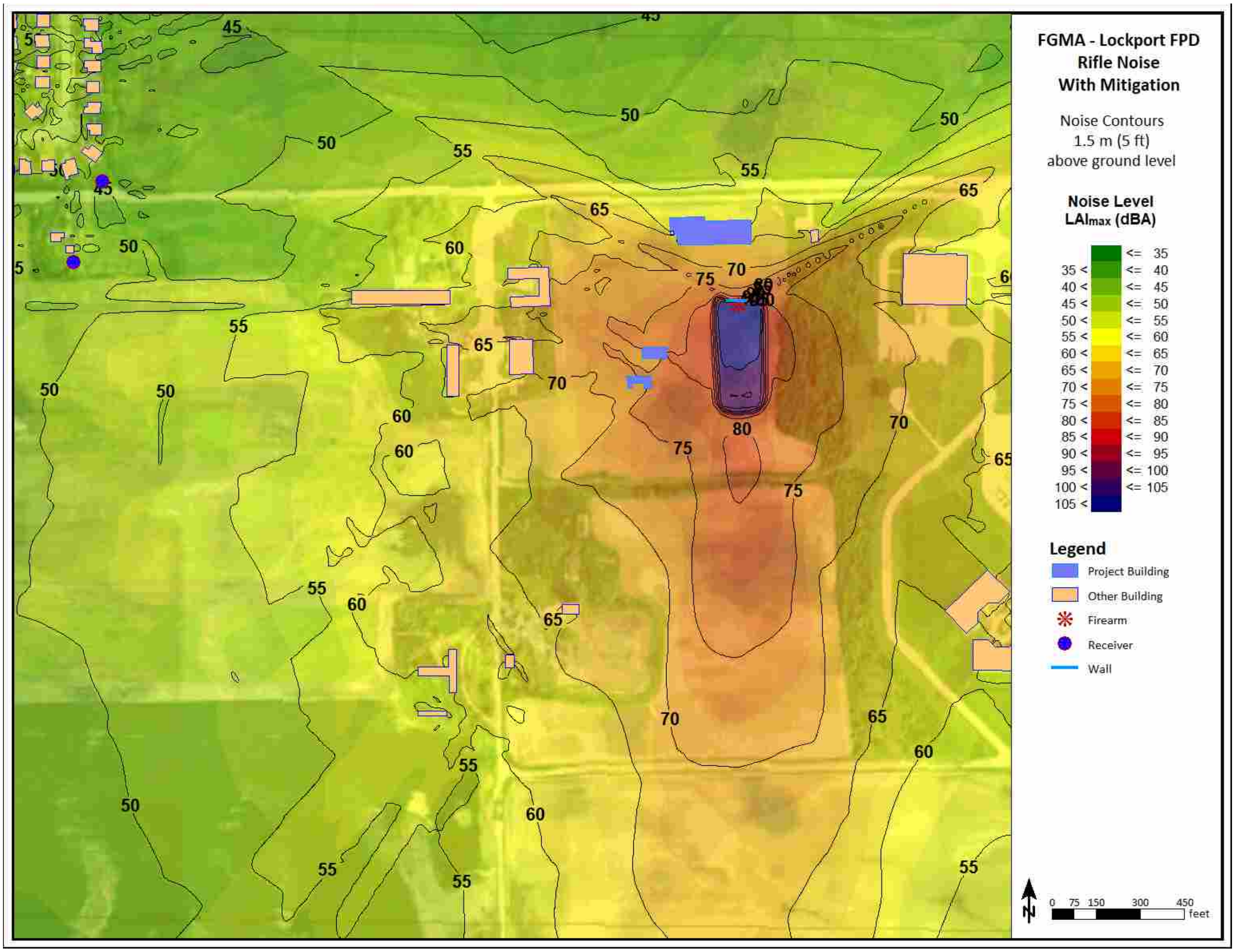

Figure 12: Noise Contour Map of Predicted Rifle Noise Transmission Near Project Site,
***With* Berms and Barrier**

5.0 Conclusions

We have modeled the propagation of sound emitted from rifle and handgun use at the proposed firing range to surrounding residential properties. Our analysis shows that levels transmitted to the surrounding residential properties will be reduced by 2-12 dB with the planned 24-foot tall berm and 20.5-foot tall absorptive sound barrier (STC≥25, NRC≥0.65), which was shifted 10 feet to the west in our model to improve mitigation for the residences northwest of the range.

The maximum impulsive levels (LAI_{max}) transmitted from a rifle at the firing range to the nearest residential properties, located approximately 2,200 feet northwest of the site, are predicted to be 58 dBA without mitigation. With the berms and absorptive sound barrier in place, LAI_{max} levels at these properties are expected to be 46 dBA. Levels transmitted from a handgun at the firing range to the same location are expected to be 57 dBA without mitigation and 45 with mitigation.

LAI_{max} sound levels from rifles transmitted to residences located 4,500 feet to the south are predicted to be 58 dBA without mitigation and 50 dBA with the berms/barrier.

At the library and closest residences to the southwest of the site (located approximately 5,000 feet to the southwest) the predicted LAImax sound levels from a rifle are 48 dBA without mitigation and 41 dBA with the berms and absorptive sound barrier in place.

Predicted noise levels are based on our assumption of stable weather conditions and ground conditions in warmer weather. Temperature inversions, wind speed and direction, and seasonal ground effects can all influence the noise levels significantly.

Appendix A: Acoustical Terminology

Sound level is measured in units called decibels (abbreviated dB). Decibels are logarithmic rather than linear quantities and thus a doubling of the sound level does not translate to a mathematical doubling of decibels. Also, the human ear does not interpret a doubling of sound energy (two sources instead of one) as a doubling of loudness. The logarithmic nature of dB and the human subjective perception of relative sound levels result in the following approximate rules for judging increases in sound.

- 3 dB sound level increase or decrease - just noticeable
  (the addition of one identical sound source to an existing source)
- 5 dB sound level increase or decrease - clearly perceptible and is often considered significant
  (the addition of two identical sound sources to an existing source)
- 10 dB sound level increase or decrease - perceived as twice as loud/half as loud
  (the addition of nine identical sound sources to an existing source)

These perceived changes in the sound level are mostly independent of the absolute sound level. That is, a 35 dB sound will be perceived as twice as loud as a 25 dB sound, and a 60 dB sound will be perceived as twice as loud as a 50 dB sound.

Audible sound occurs over a wide frequency range, from low pitched sounds at approximately 20 hertz (Hz) to high pitched sounds at 20,000 Hz. These frequencies are commonly grouped into octave bands or 1/3 octave bands. Building mechanical systems generally produce noise in the 63 Hz to 1000 Hz octave bands, with the lower frequency noise generated by large fans. Speech is predominantly contained in the 250 Hz to 2000 Hz octave bands.

A-weighted sound level - Humans do not hear equally well at all frequencies. We are especially poor at hearing low frequency sound and are best at hearing sound in the frequency range of speech. A microphone does not have these same characteristics. Therefore, when sound is being measured to determine how well people will be able to hear it, a "weighting" or microphone-to-human correction factor is applied to the sound level measured using a microphone. The most common weighting is the "A-weighting" and the resulting sound level is expressed in A-weighted decibels (dBA). This weighting reduces the low frequency sound, slightly increases the sound at the dominant frequencies of speech, and slightly lowers the sound level at high frequencies.

Equivalent Sound Level (L_{eq}) is essentially the average sound level in an environment. However, the L_{eq} is not a simple arithmetic average of the sound level over time, but is a logarithmic average of the sound energy level over a period of time. L_{eq} can be measured for any time period, but is typically measured for some increment or fraction of an hour such as 15 minutes, 1 hour, or 24 hours. Steady ounds, such as fan noise, can be accurately measured for much shorter periods of time, such as 30 to 60 seconds.

Maximum sound level (L_{max}) is the highest sound level that occurs during a measurement period.

Slow Time Response or Slow Time Weighting is a measurement setting that uses a time constant of 1 second. This setting is most appropriate when the sound level being measured does not fluctuate much. Fan and condensing unit noise are examples of sounds that do not fluctuate much. Some regulations, ordinances, and standards call for a slow response setting regardless of the type of sound source.

Fast Time Response or Fast Time Weighting is a measurement setting that uses a time constant of 125 milliseconds. This setting is most appropriate when the sound level being measured fluctuates quickly, but is also often used as a default setting. Music and speech are examples of sounds that fluctuate quite a bit. Some regulations, ordinances, and standards call for a fast response setting regardless of the type of sound source.

Impulse Time Weighting is a measurement setting that uses a time constant of 32 milliseconds. This setting is most appropriate when the sound level being measured is extremely short. Gunfire and similar impulsive sounds should be measured with the impulse time weighting.

While the **time response setting** will not affect the average sound level (L_{eq}) measurement result, it will affect the maximum sound level (L_{max}) and minimum sound levels (L_{min}) measurement results. For example, if measuring the sound level of music, the fast time weighting will result in higher L_{max} results. When presenting an L_{max} or L_{min} result, the time weighting, impulse, fast, or slow, should be specified.

Statistical sound levels, as they are most often called, quantify the sound level exceeded during a period of time. For example, the L_{90} sound level is the sound level exceeded during 90% of the measurement period. If the measurement period is 60 minutes long, then the L_{90} is the sound level exceeded during 54 minutes. It is generally lower than the average sound. The L_{90} is generally considered to be the "background" sound level, the baseline level that is present most of the time. Another commonly used statistical level is the L_{10}. The L_{10} is the sound level exceeded during only 10% of the measurement period. If the measurement period is 60 minutes long, then L_{10} is the sound level exceeded during only 6 minutes of the measurement period. L_{10} can be used to quantify the fluctuating sound levels in an environment. L_1 is often used as the maximum sound level for analysis in the design of fitness centers and other facilities where music and amplified speech could disturb adjacent spaces.

The **ambient or background sound level** often refers to the indoor or outdoor sound level without the sound source of interest but with other sounds that contribute to the level. For example, if the sound level of an outdoor condensing unit is being assessed, the extraneous sound of traffic and other mechanical equipment should also be measured to determine if it affects the measurement of the condensing unit. If it does, then a correction factor can be applied.

Sound Transmission Class (STC) is a single number rating of the amount of sound blocked by a material or assembly (a window glazing unit, door, wall, floor-ceiling assembly). This metric is measured in a laboratory under ideal conditions. STC is a single number reduction calculated from the measured one-third octave band spectrum. This metric is mathematically normalized and can be compared other partitions or test data. STC is most appropriately used to assess the ability of a material or partition to block sound in the frequency range of speech. The original sound transmission test reports should be consulted when the sound source contains low frequencies, such as music or mechanical noise. A higher number indicates better performance.

Noise Reduction Coefficient (NRC) is basically the percentage of incident sound that is absorbed by a material. Theoretically, NRC 1.0 (100% of sound absorbed) is the best performance achievable, but manufacturers do sometimes publish test results with NRC's greater than 1.0. Because of the way the test is performed in the acoustical lab and the calculation procedure, NRC's are sometimes higher than 1.0. NRC is a single number rating derived by averaging the measured absorption coefficients for the 250 Hz, 500 Hz, 1,000 Hz, and 2,000 Hz octave bands. It is intended to represent the sound absorption provided by a material in the dominant frequency range of human speech. Most manufacturers of sound absorbing acoustical products provide the NRC for their products. NRC is mostly used as a convenient means of comparing the acoustical performance of products.