Noise Attenuation Guidelines

Prepared for the Flint Hills Regional Council

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<u>Executive Summary</u>

This document provides noise attenuation guidelines for the areas in the Flint Hills region surrounding Fort Riley. The Joint Land Use Study (JLUS) update from 2017 includes compatibility analysis and recommendations to address noise concerns.

Noise Attenuation Guidelines includes a discussion of the noise criteria, general guidelines for noise attenuation, and two levels of noise attenuation, “Level A” and “Level B”. Each level of attenuation describes building components to achieve suggested Sound Transmission Class (STC) ratings. Though in no means exhaustive, the example construction assemblies should help the reader better understand what inherently can make a building façade more resistant to noise intrusion. A summary of the recommended STC ratings are shown below.

	Level A Attenuation	Level B Attenuation	Typical Construction
Walls	STC-45	STC-50+	STC-40
Roof	STC-45	STC-50+	STC-40
Windows/ Doors	STC-35	STC-40+	STC-25

The *Noise Attenuation Guidelines* are developed and offered as a public service to provide noise control measures for lowering sound transmission into buildings from exterior noise sources, namely noise propagating from military training exercises within the Fort Riley military base to neighboring communities. The use of these guidelines does not guarantee complete sound isolation, due to varied human perception of noise and the unique characteristics of low-frequency noise. The use of these guidelines is completely voluntary.

An appendix is included at the end of the *Noise Attenuation Guidelines*, offering further information on general sound terminology and related information.

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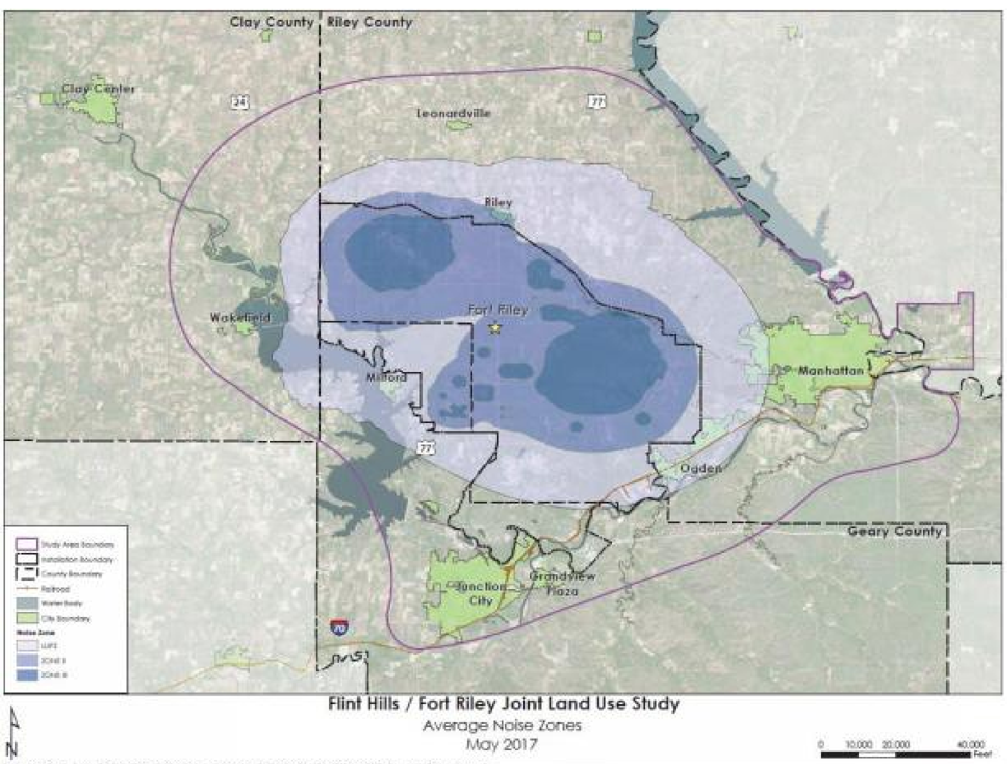
1. Criteria

This report fulfills JLUS Section 7.8.6 Noise Recommendation 6: “Conduct a Noise Study using an acoustic consultant to determine appropriate methods of noise attenuation or other minimization strategies.”

The Fort Riley Joint Land Use Study Update (JLUS) includes several maps of noise zones for areas surrounding the installation. The map shown below highlights the areas for the JLUS Study Area Boundary: Land Use Planning Zone (LUPZ), Noise Zone II, Noise Zone III. The JLUS uses Concussion-Weighted-Day-Night Average Sound Level (CDNL) to model the noise zones surrounding Fort Riley. Noise from small arms weapons firing, demolition, large arms weapons firing, and rotary-wing aircraft can be heard throughout the study area. Environmental factors, especially wind direction, can have a significant impact on sound levels. Please refer to the JLUS for additional details about these noise zones and environmental factors that impact noise (Section 6.8) and other noise recommendations including coordination with municipal planning documents, real estate disclosures, education for builders and community, etc. (Sections 7.8.1 to 7.8.10).



The table below shows the CDNL noise levels in each noise zone and the LUPZ. Noise Zone I and the LUPZ state that land use is compatible. Noise Zone II is normally incompatible. Noise Zone III is incompatible -- nearly the entirety of Noise Zone III is located on base. Within LUPZ, buildings should incorporate all elements of Sound Attenuation Level A described in following sections. Within the Noise Zone II, buildings should incorporate all elements of Sound Attenuation Level B described in the following sections.

TABLE 6.8.C NOISE ZONES AND SENSITIVE LAND USE COMPATIBILITY

Noise Zone	Noise Limits			Land Use Compatibility Level	Recommended Noise Attenuation Level
	Aviation	Impulsive	Small Arms		
LUPZ	60-65 dB	57-62 dB	N/A	Compatible	A
Zone I	<65 dB	<62 dB	<87 dB	Compatible	None
Zone II	65-75 dB	62-70 dB	87-104 dB	Normally Incompatible	B
Zone III	>75 dB	>70 dB	>104 dB	Incompatible	Incompatible

When establishing acoustic criteria, it is important to note that different people have varying sensitivity to noise. In addition, some building uses require quieter indoor sound levels, such as schools or hospitals. The recommended noise measures are intended to provide guidelines to achieve acceptable indoor sound levels for people with normative hearing and average noise-sensitivity. In general, the mitigation strategies documented in this report reflect a noise criterion for interior spaces to be an average (L_{EQ}) sound level of 45 dBA or less and 60 dBC or less for any occupied space. These noise levels from external noise sources will still be noticeable above the general ambient noise environment inside most buildings (from HVAC usage, for example), but they should be acceptable for most occupants while being practical to achieve with conventional and available construction materials.

It is important to note that these noise attenuation measures will not block all sound – particularly low-frequency sound ("bass"), vibration, and resulting repercussions. In fact, the low-frequency pressure waves generated during Fort Riley activities will continue to be heard (or felt) and no amount of noise control measures will provide an appreciable benefit in attenuation. Sound will still be heard inside the buildings, but it will be attenuated to generally more acceptable levels in the mid-to-high frequencies, which should result in generally less disturbing noise levels.

Research relating to perception of noise is an ongoing study in field of acoustics. Significant published data is available for broadband sounds and perception of changes in levels of dBA (see the table below). However, fewer research findings are available for perception of low frequency noise, which utilizes the C-weighting system (dBC).

Change in Sound Level	**Perceived change to ear**
1 to 2 dBA	Not perceptible
3 to 4 dBA	Just noticeable
5 to 9 dBA	Clearly noticeable
10 dBA	***Twice (or half) as loud***

For people or building types which are more sensitive to noise, it may be beneficial to increase to higher levels of noise attenuation to ensure occupant comfort satisfaction. For example, a building in the LUPZ is recommended to follow Noise Attenuation Level A, but if the occupant is more sensitive to noise than average, the building could be constructed following Level B for additional attenuation. The appropriate noise attenuation level should be determined based on location and occupant sensitivity.

2. General Recommendations

Regardless of the noise attenuation level desired, there are several general planning recommendations that can help improve the acoustic environment inside all buildings. The recommendations in this section should be implemented where possible on all projects within the Study Area.

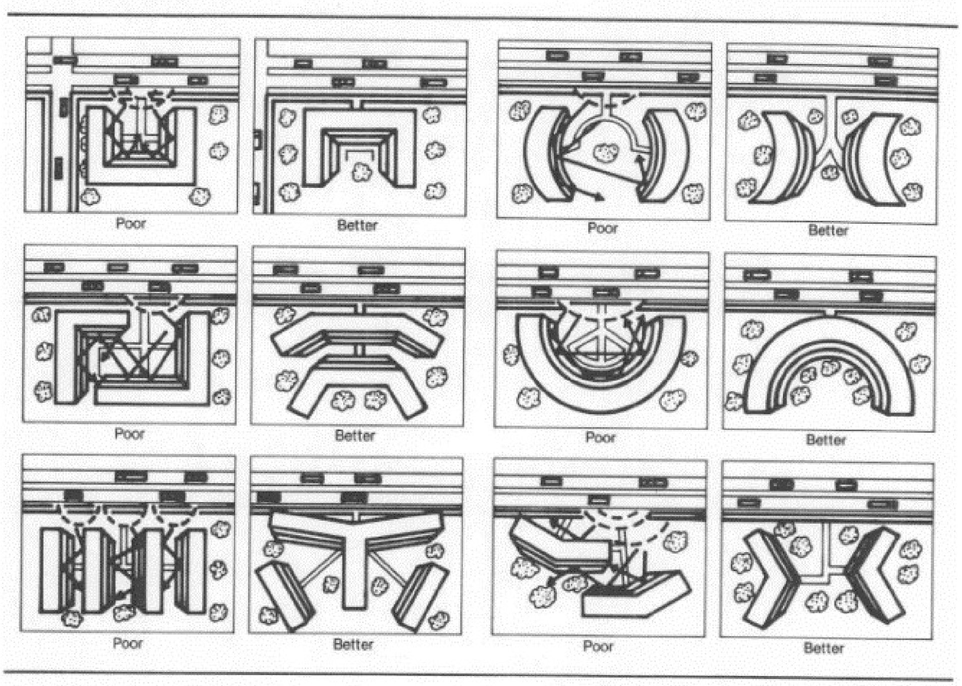
a. *Site Selection*

Sound levels decrease the farther away a building is located from a sound source. If the building will be located on a large site, consider choosing a site plan which locates the building as far away from the Fort Riley noise sources as possible. Also, consider natural features on the site which will influence the sound levels. Site topography and hills can reflect or block sound (although to a much lesser extent in the extended low-frequencies), depending on the relative location and orientation of a building. Dense forests of minimum ¼ mile thick can provide a noise barrier effect. It is of note, however, that general landscaping, such as bushes, trees, plants, etc., does not have an appreciable benefit for noise control.

b. *Building Orientation*

Project layout and building orientation can enable reflected sound energy to increase or decrease the sound level inside buildings. Sound reflects off hard surfaces and can cause increase sound levels. Concave surfaces facing a sound source will focus the sound energy and result in higher sound levels. Convex surfaces will reflect sound away from the rest of the building and result in lower sound levels. In general, choose geometry that does not focus the sound coming from Fort Riley. The optimal orientation will vary depending on the building location relative to the Fort Riley noise sources. The following figure is from HUD *The Noise Guidebook* Chapter 4 and shows examples of poor and better building orientations with the noise source at the top of each diagram. Considering acoustics and noise control during site planning will help decrease the overall sound levels.

Figure 14
Orientation of Buildings on Sites



c. *Architectural Space Planning*

Exterior walls facing towards Fort Riley will have more exposure to noise than exterior walls facing away from the noise sources. When deciding the layout and space planning for a building, consider which spaces may be more sensitive to noise, such as bedrooms, living rooms, executive offices, or conference rooms. Spaces which are more noise sensitive should face away from the noise sources. Spaces which are less noise sensitive, such as storage or utility rooms, can be placed on the façade exposed to the loudest sound levels to act as noise buffer to living-area rooms.

d. *Noise Barriers*

Noise barriers can be an effective way to block sound and can result in a noticeable decrease in sound level (6 to 10 decibels, mid-to-high frequencies). When selecting a noise barrier, it is important to consider both the barrier geometry and material. Like the concept of blocking light with a shade, the goal of a noise barrier is to block the line-of-sight between the sound source and receiver.

To achieve the correct geometry, the location, height, and length of a barrier are critical. In general, locate the noise barrier as close as possible to the building and/or occupied outdoor area. The farther the barrier is located away from the building, the larger in height and length it will have to be to fully block the line-of-sight.

One rule of thumb is the barrier dimensions should >2.5 times the wavelength of the lowest frequency desired for attenuation. Wavelength depends on environmental factors such as temperature, but in general the approximate wavelengths of sound 63 Hz, 125 Hz, and 250 Hz are 18 feet, 9 feet, and 4.5 feet, respectively. The size of barrier required for low frequency attenuation may not be feasible for all buildings. However, mid to high frequency attenuation can be achieve with the noise barrier dimensions detailed below.

The height of the barrier depends on the relative topography of the sound source and receiver. To minimize the required length, a barrier may wrap around in a U-shape to achieve similar geometry to block line-of-sight. In general, for mid-high frequency noise, a noise barrier should follow these guidelines:

- Location: within 50’ of the building, closer is better
- Height: minimum of 2’ above occupants head on highest level, higher if the building is at lower elevation than Fort Riley
- Length: minimum 25’ beyond each side of the building or a minimum length which will block the line of sight from occupied areas to Fort Riley noise sources, whichever is greater.

Noise barriers can be constructed with a wide variety of materials. Materials must have enough mass to block sound from transmitting through the barrier. For best performance, noise barriers should have a surface weight of 2.5 lbs./sq. ft. or greater. This can be achieved with ¾” exterior grade plywood, 16-gauge sheet metal, ½” thick HardiBacker, or ½” thick Durock Cement Board, or equivalent material. Alternatively, several manufacturers have noise barriers panels that meet this surface weight recommendation. Ensure appropriate structural and wind load considerations are incorporated in the design of any noise barriers. As with all construction, check with the local jurisdictions to ensure any proposed noise barrier will comply with applicable codes or ordinances.

Noise barrier effect is also possible using existing hills and topography on site if they block the line of sight. Other site features such as earth berms, outbuildings, and storage sheds may also have some noise barrier properties. Trees in general particularly deciduous species, are poor noise barriers, because the branches and leaves are not very dense. For trees to be effective noise barriers, there must be at least ¼ mile of dense forest area.

e. *Sound Flanking Paths*

Sound transmits through all components of a building façade. Sound flanking paths are areas of a building which may have gaps, seams, or penetrations that are “weak links” for sound transmission. These flanking paths greatly reduce the performance of the overall assembly. A relatively small 0.5% open area can decrease the assembly STC by 8 points or more.

As a best practice, all gaps should be ¼” or less. Seal all penetrations and gaps air tight with acoustical sealant, and stagger seams of all building sheet materials.

Some installers leave a gap between the framing for windows and doors. Ensure all gaps are filled with batt insulation or foam backer rod and sealed with acoustical sealant. Window frames should be caulked in place, and a continuous bead of silicone sealant should be applied around the entire perimeter of the window glass to limit vibration and rattling. Where the walls meet the roof, rim joists are often a flanking path for sound. Ensure that all rim joists are insulated and sealed air tight.

Buildings typically have several ventilation openings for HVAC, exhaust fans, chimneys, dryer vents, etc. These openings should be located on the façade or roof with the openings pointed away from the sound source. They should also not be located near any noise sensitive area.

f. *HVAC Systems*

To achieve the noise attenuation Levels A and B, closed windows with tight weatherproofing is required. For maximum sound attenuation, outdoor air supply must be included in the HVAC systems, in lieu of relying on opening windows for fresh air. This helps to ensure the sound isolation performs properly with no sound flanking paths or air leaks in the building façade.

g. *Ambient Noise*

In certain buildings, the ambient noise level is very quiet. This results in any intruding noise to be significantly noticeable above the low interior noise level. One option to mask the sound is to increase the ambient background noise level, so the intrusive sounds are less noticeable and disturbing to the occupants. Occupants can typically be accustomed to constant, broadband ambient noise levels. Occupants are much less likely to be accustomed to tonal or intermittent sounds. Several ways to increase the ambient noise level in buildings is to use HVAC noise, sound masking systems, or “white noise” machines. Keeping a fan running provides a constant ambient noise level in the building. HVAC noise can be optimized to be constant broadband noise at a level of 35 to 40 dBA. This range provides a good balance between being quiet enough to meet interior noise criterion and providing a steady ambient noise environment to help mask exterior sounds. Permanently installed sound masking systems are available from several manufacturers and consist of small sound emitters installed in the ceiling with constant pink noise playing, frequency-tuned to a comfortable level. Stand alone “white noise machines” are also available for purchase from many manufacturers, and many include this feature in common household components, such as alarm clocks. These can be switched on/off and the sound level can be adjusted to provide masking in one room.

h. *Acoustical Consultants*

The noise recommended attenuation levels provided in this document are generic and intended for typical building construction near Fort Riley Noise Zones. Each project is unique and can have distinct solutions for noise control. For site-specific recommendations, and for more nuanced projects, the services of an acoustical consultant should be considered. These experts can help identify the appropriate noise criteria, attenuation recommendations, plan review, and construction details to ensure the building achieves the desired indoor acoustic environments. A list of consultants and more information about choosing a consultant is available from the National Council of Acoustic Consultants at www.ncac.com.

3. Noise Attenuation Levels – A and B

Noise Attenuation Level A

This is the first tier of enhanced noise attenuation and is intended for buildings located within the LUPZ area surrounding Fort Riley. Additionally, it may be used for buildings located outside the LUPZ if there are occupants or space uses which are more noise sensitive than average buildings, such as schools or healthcare facilities. All items below and the general recommendations in the previous section should be followed to achieve the recommended noise attenuation for the composite building façade.

a. Walls (Minimum STC-45)

   To improve wall STC ratings, several strategies can be implemented including increasing the mass of the materials, more airspace, staggered/ double stud configurations, and/or resilient clips. Ensure that there is minimum 3" thick unfaced, glass fiber, batt insulation in the wall cavity. A sample list of common building façade materials is shown below and is by no means exhaustive:

   - Stucco – exterior grade stucco, made of cement, sand, and water, applied at 5/8" thickness with wire mesh and ½" OSB substrate, 2x4 with batt insulation, ½" gypsum board: STC-45

   - Brick – 4" thick face brick with full mortar, with 2x4 wood framing, batt insulation, and ½" gypsum board: STC-48

   - CMU – 8x8x16" 3-cell lightweight concrete masonry units: STC-45

b. Roof (STC-45)

   Ensure there is a minimum of 6" (R-19) thick batt insulation in the roof assembly to isolate sound from vertical noise sources such as helicopters.

c. Windows (Minimum STC-35)

The windows are one of the most critical elements in the whole façade. There is great potential for flanking paths and poor performance in the windows. The edge condition becomes important when the glazing is upgraded. Fixed picture widows typically have better seals and less sound flanking than operable single or double hung windows. If aluminum frames are provided, ensure they are insulated around the full perimeter.

- 1” thick Insulated Glazing Units, ¼” glass, ½” air space, ¼ glass: STC-35

- Laminated glass – ¼” overall (1/8” glass, .030 PVB, 1/8” glass): STC-35

- Adding a pane of glass to the existing window frame is a potential option. Ensure there is minimum 1” air space and seal in place an additional pane of minimum 1/8” glass to create an insulated window unit. STC-45+

d. Doors (Minimum STC-35)

High quality weather-stripping is required to achieve this acoustic performance out of a door assembly. Triple Fin Gaskets such as Pemko S773 perform well.

- Solid Core Wood Door with perimeter triple fin gaskets and neoprene door bottom: STC-35

- Solid-core wood door 1-3/4” with aluminum storm door with glazing: STC-34

Noise Attenuation Level B

This is the second tier of enhanced noise attenuation and is intended for buildings located within the Noise Zone II area surrounding Fort Riley. Additionally, it may be used for buildings located outside Noise Zone II if there are occupants or space uses which are more noise sensitive than average buildings, such as schools or healthcare facilities. All items below and the general recommendations in the previous section should be followed to achieve the recommended noise attenuation for the composite building façade. This section includes recommendations to meet the Noise Attenuation Level B, and a few assemblies to go beyond this noise criteria.

a. Walls (Minimum STC-50)

- Double Brick – two rows of 4” face brick mortared together, with 2” air space and metal ties: STC-50
- CMU – 8x8x18” 3-cell lightweight concrete masonry units (34 lbs./block) with expanded mineral loose fill insulation: STC-51
- Cast-in-place concrete – 6” thick: STC-57
- Stucco with Resilient Channel – 7/8” Stucco, No. 15 Felt building paper and 1” wire mesh, 2x4 studs spaced 16” O.C., 3-½” glass fiber building insulation, resilient channel, ½” gypsum board: STC-56

b. Roof (Minimum STC-50)

Ensure there is minimum 9” to 12” (R-30 to R-48) batt insulation in the roof plenum and suspend the top floor ceiling with resilient clips or resilient channel. Heavier roof finishes such as terra cotta, clay, or slate tiles will also improve the overall STC.

c. Windows (Minimum STC-40)

The windows will most likely be the limiting factor for the composite STC performance for the whole façade. It is important to select excellent sound isolation windows for any building in Level B Noise Attenuation.

- 5/8” thick laminated – composed of 3/8” glass, 0.030” PVB laminate layer, ¼” glass: STC-40

- Laminated Insulated – 1-1/8” overall, composed of 1” insulated glazing unit (¼” glass, ½” air space, ¼” glass), .030” PVB laminate layer, 1/8” glass: STC-40

- Triple Insulating – 1-7/8” overall, composed of ¼” glass, ½” airspace, ¼” glass, ½” airspace, ¼” glass: STC-40

- Extra air space in a Laminated Insulated assembly: 4-7/8” overall – composed of ¼” glass, .030” PVB laminate layer, 1/4” glass, 4” airspace, 3/8” glass: STC-49

d. Doors (Minimum STC-40)

To achieve the required door performance a rated sound isolating door with insulated or mortared framing is required. The following manufacturers make single doors that are rated for STC-40 or higher:

- Ceco “Sound-Tech Express”
- Curries Assa Abloy
- Eggers Industries “Soundwood”
- Lockmasters

Alternatively, an entry vestibule with minimum 2 doors will meet STC-40 or higher.

4. Noise Attenuation Levels of Typical Conventional Construction

This section describes several typical conventional building construction types. It is intended to be used as a reference to compare standard construction to the increased Noise Attenuation Levels A and B.

a. Walls (STC-40)

In general, rigid insulation does very little to increase the STC rating. Therefore, any exterior construction with rigid insulation and no batt insulation will perform poorly in STC ratings.

- Stucco with 1.5" thick EPS Insulation and 19/32" OSB Plywood, wood stud, ½" gypsum board: STC-42

- 4" Hollow CMU – 4x8x16" 3-cell lightweight concrete masonry units: STC-40

- 12" Hollow CMU – 12x8x16" 3-cell lightweight concrete masonry unit: STC-39

b. Roof (STC-40)

Roof construction sound isolation varies drastically according to attic space height, insulation levels (R-value), as well as the type of roofing used.

- Asphalt roofing shingles on appropriate waterproof membrane, ½" OSB substrate, 4' tall attic space with R-11, one-layer drywall at ceiling: STC-40

- Asphalt roofing shingles on appropriate waterproof membrane, 1/2" OSB substrate, 7' tall attic space with R-30 insulation, one-layer drywall at ceiling: STC-45

- Wood shakes on appropriate waterproof membrane, ½" OSB substrate, 4' tall attic space with R-22, one-layer drywall at ceiling: STC-42

- Wood shakes on appropriate waterproof membrane, ½" OSB substrate, 2' tall attic space with R-11, one layer drywall at ceiling: STC-33

c. Windows (STC-25)

- Casement and awning windows, 3'x4' – glazed double strength, cranked shut: STC-24

- Single / Double Hung 3'x5' – Single panel, 7/16" glazed insulating glass: STC-26

- Picture window 6'x5' – glazed double strength single panel: STC-29

d. Doors with weather stripping (STC-25)

- Hollow-core wood door, 1-¾" thick: STC-20

- Solid-core wood door, 1-¾" thick: STC-27

- Steel-faced door 1- ¾" with rigid polyurethane core: STC-26

- Sliding glass door with ¾" insulated glass (2 layers 1/8" tempered glass): STC-28

end of Noise Attenuation Guidelines

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NOISE ATTENUATION GUIDELINES

APPENDIX

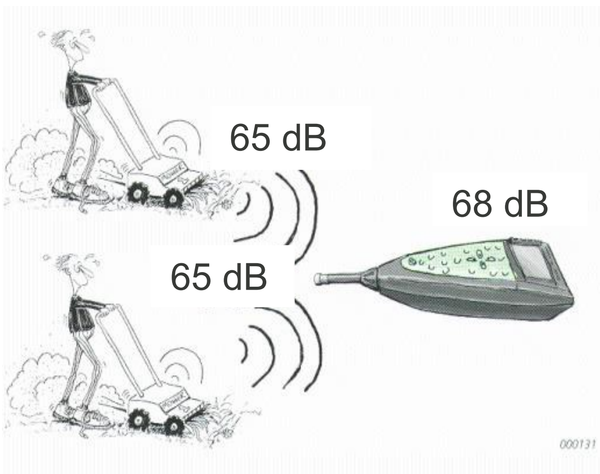
FLINT HILLS REGION, KANSAS

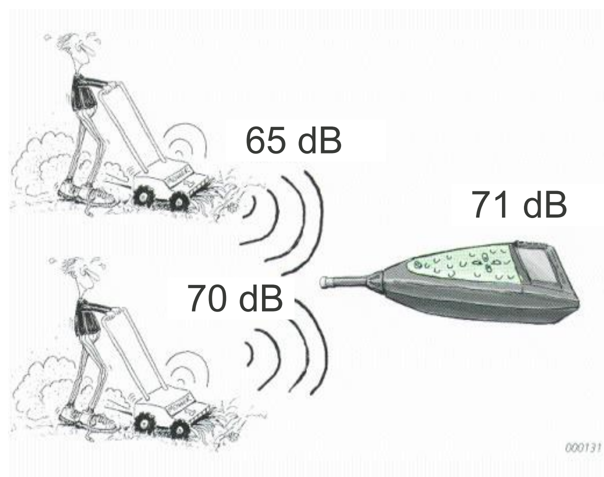
June 17, 2019

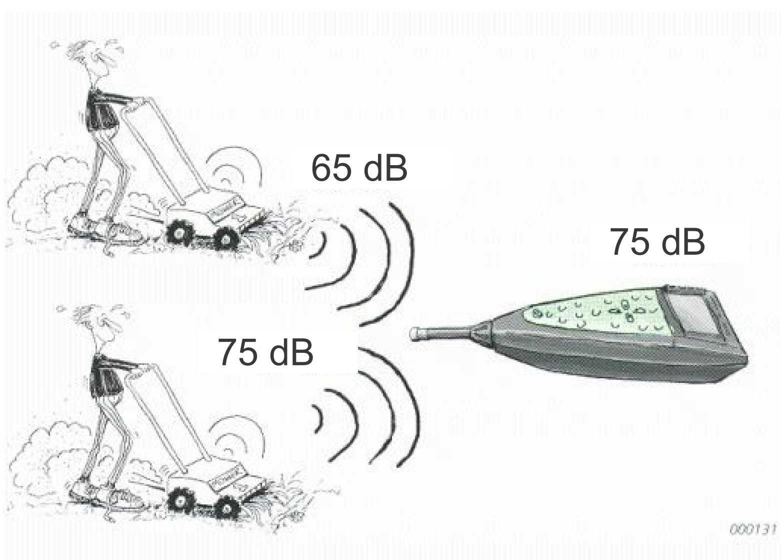
TYPICAL SOUND LEVELS	SPL dBA
Threshold of Pain	130
Rock Concert	120
75-Piece Orchestra	110
Auto Horn 10’ Away	100
Noisy Urban Street	90
Truck Passing By	80
Car Passing By	70
Conversation	60
Average Office	50
Quiet Office	40
Unoccupied Office	30
Whisper	20
Rustling Leaves	10
Threshold of Hearing	0

CHANGE IN SOUND LEVEL	PERCEIVED CHANGE TO EAR
1 – 2 dBA (or STC)	Not Perceptible
3 – 4 dBA (or STC)	Just Noticeable
5 – 9 dBA (or STC)	Clearly Noticeable
10 dBA (or STC)	Twice (or Half) As Loud
20 dBA (or STC)	Four-fold (or one-quarter) as Loud

When Two Decibel Levels Differ By	Add the Following Number to the Higher Value
0-1 dB	3 dB
2-3 dB	2 dB
4-9 dB	1 dB
10 dB or More	0 dB







STC Ratings Descriptor

The most common metric used to define sound transmission through building elements is Sound Transmission Class (STC), and this rating is used in the *Noise Attenuation Guidelines* document. This is a single number rating that assesses the sound isolation performance of construction elements.

The higher the STC, the better the sound isolation. Sound isolation is a function of mass per unit area, stiffness, structural separation, and damping in the material. The more mass a floor or wall assembly has, the higher the STC rating.

Note that there is another metric, the Outdoor-Indoor Transmission Class (OITC), which specifically addresses sound transmission from outdoor noise sources. However, STC is much more widely known and understood by building construction professionals (such as contractors) and finding published OITC data for manufacturers products can be arduous. Therefore, the STC rating is exclusively used in the *Noise Attenuation Guidelines*.

It should be noted, low-frequency noise is the most difficult frequency range to attenuate. Assemblies with the same STC number may not have the same low-frequency sound isolation performance.

STC RATING	SUBJECTIVE DESCRIPTION OF AUDIBILITY BETWEEN AREAS
30	Sentences clearly understood at normal speaking levels
40	Speech can be heard with some effort; individual words and occasional phrases heard
50	Loud speech can be heard with effort; Music still easily heard
60	Loud speech essentially inaudible; Music heard faintly, though bass (low-frequency) notes still clearly audible
70	Loud music faintly heard, mostly in the low frequencies
75	Most noises effectively blocked

Acoustical Terms

Definitions for the acoustical terms used in this document are provided below.

dBA The sound level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner like the response of the human ear and gives good correlation with subjective reactions to noise.

dBC The sound level in decibels as measured on a sound level meter using the C-weighting filter network. The C-weighting filter is used for low-frequency noise measurements or for louder sound sources. As the overall sound level gets higher, the human ear response flattens out across all frequencies.

L_{EQ} Equivalent sound energy level. The sound level correctly corresponding to steady-state sound level containing the same total energy as a time-varying signal over a given sample period.

DNL Day night average sound level. The average equivalent A-weighted sound level during a 24-hour day, obtained after the addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m.

CDNL Concussion-Weighted-Day-Night average sound level. This metric is specific to the JLUS to account for the low frequency sounds. The average equivalent C-weighted sound level during a 24-hour day, obtained after the addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m.

CNEL Community noise exposure level. The average equivalent A-weighted sound level during a 24-hour day, obtained after addition of 5 decibels to sound levels in the evening from 7 P.M. to 10 p.m. and after addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m.

OITC Outdoor-Indoor Transmission Class. A single number rating of sound isolation between indoor and outdoor environments. This rating is based on the difference of A-weighted between sound pressure levels.

STC Sound Transmission Class. A single number rating of sound isolation of an assembly. This rating is based on a curve fit method, which incorporates sound pressure levels across a range of frequencies.

Additional Resources

The following documents provide additional details and recommendations for noise definitions, criteria, and attenuation. Please refer to these documents or contact an acoustical consultant for additional details.

a. Flint Hills/ Fort Riley Joint Land Use Study (JLUS) Update August 2017 http://flinthillsregion.org/projects/flint-hills-fort-riley-joint-land-use-study-jlus

b. Department of Housing and Urban Development (HUD) – The Noise Guidebook https://www.hud.gov/sites/documents/DOC_16419.PDF

c. Federal Highway Administration (FHWA) – Noise Standard 23 CFR 772 https://www.fhwa.dot.gov/environMent/noise/regulations_and_guidance/frule772.cfm

d. California Green Building Code – CCR, Title 24, Part 11 – CALGreen https://www.green-technology.org/calgreen/images/CALGreen_2013.pdf

e. National Council of Acoustical Consultants http://ncac.com/resources/directory/

f. Additional resources are available for specific building types such as schools, hospitals, and multifamily residential.