Soundscape Engineering
Practical Solutions from Professional Engineers

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Subject: Belle Tire – Naperville, Illinois
Sound Propagation Report

Dear Chris:

Soundscape Engineering LLC has measured the ambient sound level at the future Belle Tire site and an existing Belle Tire location. The results of the New Hudson measurements were superimposed on the Naperville site plan, and the levels compared to the Naperville Noise Ordinance. Recommendations are presented in this report for sound mitigation to minimize the levels at the east property line.

Executive Summary

- The primary recommended mitigation measure is an interior partition to close off the alignment bays from the tire changing bays, where the louder tools are used. This interior partition will significantly reduce sound from the tire changing bays at the east property line.
- An extension of the exterior wall at the northeast corner of the building is a secondary recommendation that further reduces the sound level at the east property line in the vicinity of the residence.
- An acoustical barrier in the form of a property line fence or wall will also mitigate the radiated sound.
- When the average sound level measured over a 10 minute period at an existing store is used in the sound propagation model, we predict the Naperville Noise Ordinance is met for the daytime level along the entire east property line. The nighttime level is met at locations near the residence.
- When the sound level of the loudest tool (a large grinder) is isolated (i.e., not averaged over a longer period of time with the other sounds) and used in the sound propagation model, we predict the Naperville Noise Ordinance is met for the daytime level.

Background

Belle Tire is proposing to construct a new store at a location at 1126 Ogden Ave, Naperville, Illinois. A special use permit is required to operate at this location. To the east and southeast is a single-family residential neighborhood as shown in Figure 1. Commercial properties are in the other directions.
In an effort to reduce sound emanating from the store wherever possible, the Naperville location will be Belle Tire's first new store with quieter electric and battery operated equipment. It is using a new quieter electric tire mounting machine at 30567 Milford Road, New Hudson, Michigan location, and proposes the same machine for Naperville. Additionally, quieter battery-operated air wrenches will be used in Naperville.

The maximum allowable sound levels per the Naperville ordinance are given in Figure 2. The Land Use category refers to the property generating the sound, in this case categorized as Commercial. The Belle Tire hours of operation will fall entirely within the ordinance daytime category of 7:00 a.m. to 7:00 p.m. except for the 7:00 p.m. to 8:00 p.m. hour on Mondays and Thursdays when the store is open late. Per the ordinance, the emanating sound level from Belle Tire cannot exceed 62 dBA during daytime hours and 55 dBA during the nighttime hour. These levels must be met at the property line of the parcel from which the sound is generated.

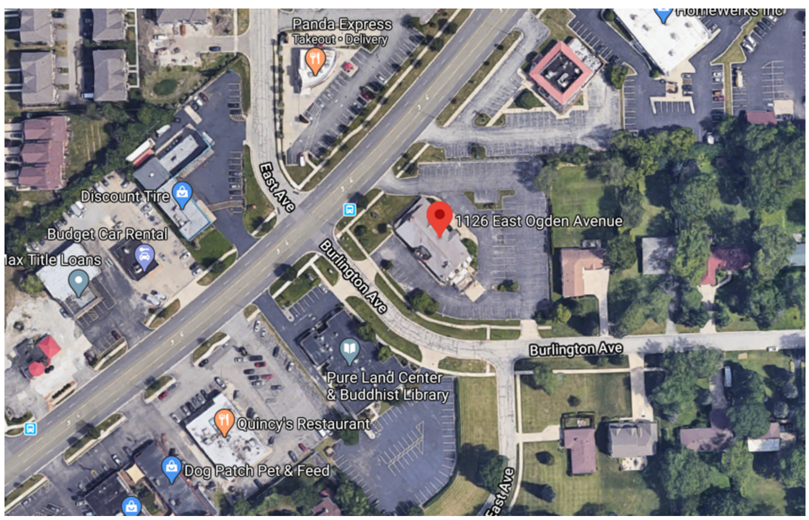

Figure 1: Proposed Naperville Belle Tire Location

Land Use	7:00 a.m. To 7:00 p.m.	7:00 p.m. To 7:00 a.m.
Residential	55 dBA	50 dBA
Commercial	62 dBA	55 dBA
Light industrial	70 dBA	70 dBA
Industrial	80 dBA	80 dBA

Figure 2: Naperville Noise Ordinance Limits

Acoustics Terminology

A glossary of acoustical terminology is appended to this report in case you wish to refer to it while reading the report.

Instrumentation

An NTi Audio model XL2-TA acoustic analyzer with model MC230 microphone and model MA220 preamp was used for all measurements reported here. This system is Class 1 Type Approved, meeting the requirements of IEC 61672 and ANSI S1.4. The system was field checked to verify its calibration.

Measurement Procedure

Soundscape visited the proposed Naperville Belle Tire location and an existing Belle Tire location in New Hudson, Michigan to establish typical sound levels.

Naperville Measurements

Soundscape measured the existing ambient sound level in Naperville, Illinois. Measurements took place on June 16th, 2020 starting at 7:00 pm. A ten-minute measurement was taken at each of the locations shown in Figure 3. The "SLM" (i.e., sound level meter) labels correspond to the data record and are used for reference internally at our company.

Figure 3: Proposed Naperville Belle Tire Layout

New Hudson Measurements

Soundscape visited the New Hudson, Michigan Belle Tire location on June 17th and July 13th to measure the sound level during operation. Measurements began at 3:00 pm on Wednesday, June 17th. During this visit, the technicians used pneumatic air wrenches. The second visit occurred on Monday, July 13th at 9:00 am and the technicians used battery-powered wrenches. Measurements were taken at five points for a minimum of 10 minutes. Measurement locations are shown in Figure 4. The distance away from the building at the New Hudson store are the same distance as the distance between the building and property lines in Naperville. The measurement locations relative to the building are numbered the same for both properties so that they can be directly compared.

In addition to the property line measurements, comparison measurements at close range were taken of the traditional pneumatic socket wrench and a battery-powered socket wrench.

Figure 4: New Hudson Measurement Locations Overlayed on the Naperville Locations

Figure 5: View from Location 1

Measurement Results

Various sound sources were recorded during the measurements including, but not limited to, grinders, air compressors, mechanical wrenches, and banging on metal. The results of the 10 minute A-weighted sound level (designated as LAeq) for all measurement locations are presented in Table 1. The LAeq is the average level over the duration of the measurement period. As expected, Location 1 (outside the eight tire changing garage bays), is the loudest measurement point. The garage sound influenced Locations 2 and 3 also because the entire garage and storage area were open to each other. In other words, the sound generated in the tire changing area radiated into the alignment area and out the open doors on that side of the building.

Table 1: Measurement Summary - LAeq

Location	Naperville Ambient	New Hudson - Visit 1	New Hudson - Visit 2
1	62	74	65
2	55	60	58
3	51	62	58
4	52	65	62
5	51	66	64

During the first visit, the level at Location 1 was significantly louder due to extended periods of grinding and banging sounds that did not occur during the second visit. Location 4 and 5 sound levels were driven significantly by traffic levels.

The measured average sound level at Location 1 exceeds the Naperville noise ordinance. Locations 2 and 3 are predicted to exceed 62 dBA with the use of a grinder (see analysis in following section). All locations exceed the nighttime noise ordinance of 55 dBA due to garage-generated sound.

Measured Sound Source Levels

During the 10 minute measurements, different tools were used. We isolated these sound sources for each measurement and location. Not all tools were recorded at all locations due to the typical workflow at the store. Table 2 presents the average sound level (LAeq) of each type of sound source measured during the first and second visits. Descriptions of each isolated sound source is as follows:

- Powered Wrench – Tool to take tires on and off vehicles
    - Visit 1 – Pneumatic powered
    - Visit 2 – Battery powered
- Large Grinder – Loud full-spectrum sound, disc approximately 4-6” in diameter
- Small Grinder – Higher pitch sound source, disc approximately 2” in diameter
- Banging – Any instance of metal on metal impact sound
- Compressed air – Using the compressed air nozzle to spray clean an object
- Garage general sound – Unidentifiable tool sound from garage bays
- Self-service Air Station – Beep and alarm that emits from the tire fill station located on the north side of the New Hudson Bell Tire
- NC – Not Captured, the sound source was not captured during the measurement

Table 2: Sound Source Levels of Individual Tools

		Visit 1	Visit 2
	Sound Source	**LAeq**	**LAeq**
Location 1	Large Grinder	85	70
	Wrench	68	67
	Banging	NC*	69
	Compressed Air	NC*	72
Location 2	Large Grinder	58	58
	Small Grinder	63	NC*
	Wrench	61	57
	Banging	63	66
Location 3	Large Grinder	NC*	58
	Small Grinder	65	NC*
	Wrench	62	58
	Banging	61	61
	Compressed Air	NC*	58
Location 4	Garage General	66	NC*
	Self-service Air Station	NC*	59
Location 5	Self Service Air Station	NC*	64

*NC - Not Captured

The large grinder was used consistently during the first visit. During the second visit, the large grinder was used sporadically and less overall.

It should be emphasized that these levels are for specific tools over a short period of time (fractions of a minute) and not the level for use over a longer period of time. We are examining these levels because in our experience, when law enforcement is called to a site, only a short measurement is captured. If the measurement happens to be taken while the loudest tool is in use, then that level is often used to determine whether the business is in violation of the ordinance.

Pneumatic and Electric Wrench Sound Levels

A measurement of a pneumatic powered wrench and a battery power wrench taking on/off tire lug nuts were taken at 3 feet from the tool. The results are shown in octave bands in Figure 6. The battery-powered wrench is approximately 2 dB quieter than the pneumatic wrench. While this difference is not generally considered a perceptible difference, it was subjectively observed that the battery-powered wrench was considered a less annoying sound than the standard "whorl sound" of a pneumatic tool. This is mainly due to the lower levels in the mid-frequency octave bands, which can be seen in the graph at 250, 500 and 1000 Hz.

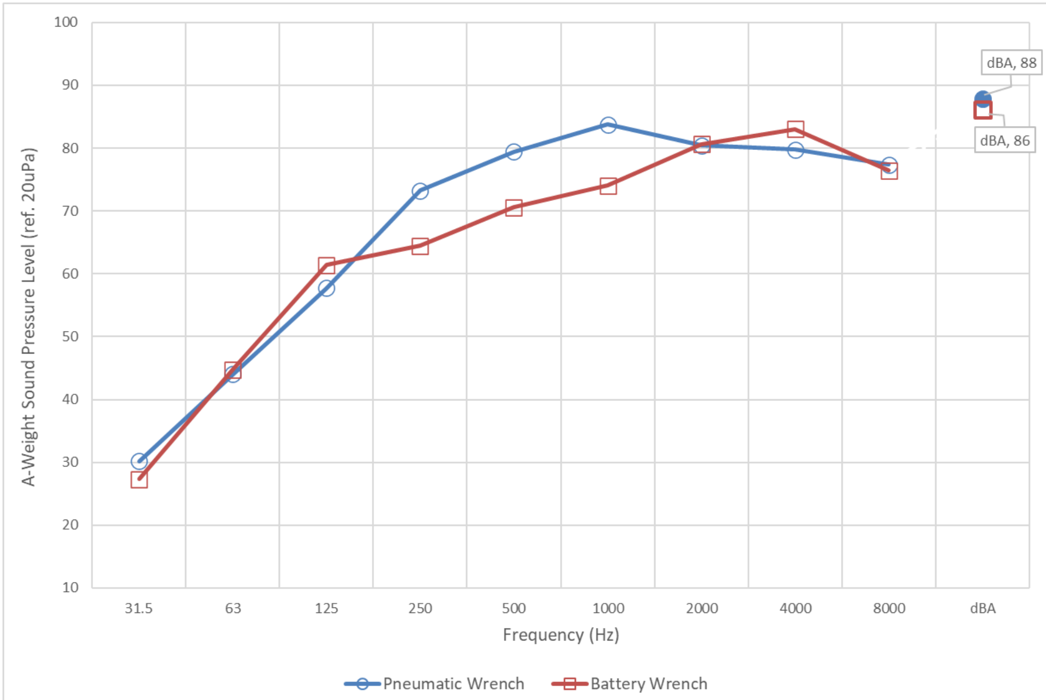

Figure 6: Measured Sound Pressure Level of Pneumatic and Battery Powered Wrenches

Sound Propagation Modeling and Recommendations

Large Grinder as a Sound Source

To determine an appropriate mitigation plan for the Belle Tire Naperville store, the future on-site sound levels were predicted with 3D sound modeling software and the measured data of sound sources expected on-site. SoundPLAN is the software package, and it is used by many acoustics consultanting firms.

The model was used to determine the sound transmission from the garage bays to the surrounding residential properties. The large grinder level measured during the first visit was used to calibrate the model. The sound propagation output helps visualize the impact of Belle Tire Naperville to the surrounding property lines. This tool was the loudest and therefore represents the worst-case scenario. A 3-decibel safety factor was applied to the calculations to account for variations between locations and tool variation. The following numbered sections present the sound propagation results of three modeled scenarios and predicted sound propagation improvements.

1. **As Designed / Standard Store Layout**

   Figure 7 presents the sound levels at specific points for the large grinder with no mitigation and all bay doors open, which is typical for ventilation on a hot day. Figure 8 shows the sound propagation of the sound from the north tire bay and east alignment bay garage doors. The different sound levels are represented by various colors as defined by the key on the right of the image. The predicted levels for the large grinder at the east property line exceed the ordinance.

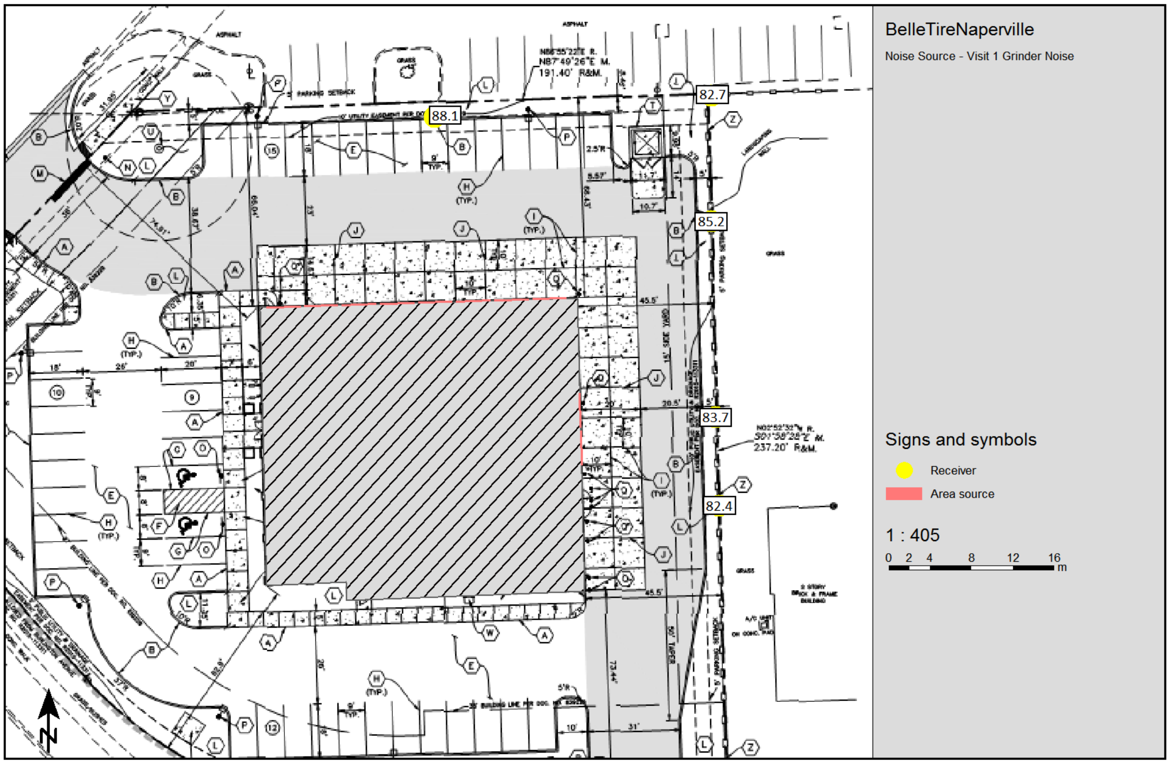

Figure 7: Sound Level - Unmodified Standard Store Design

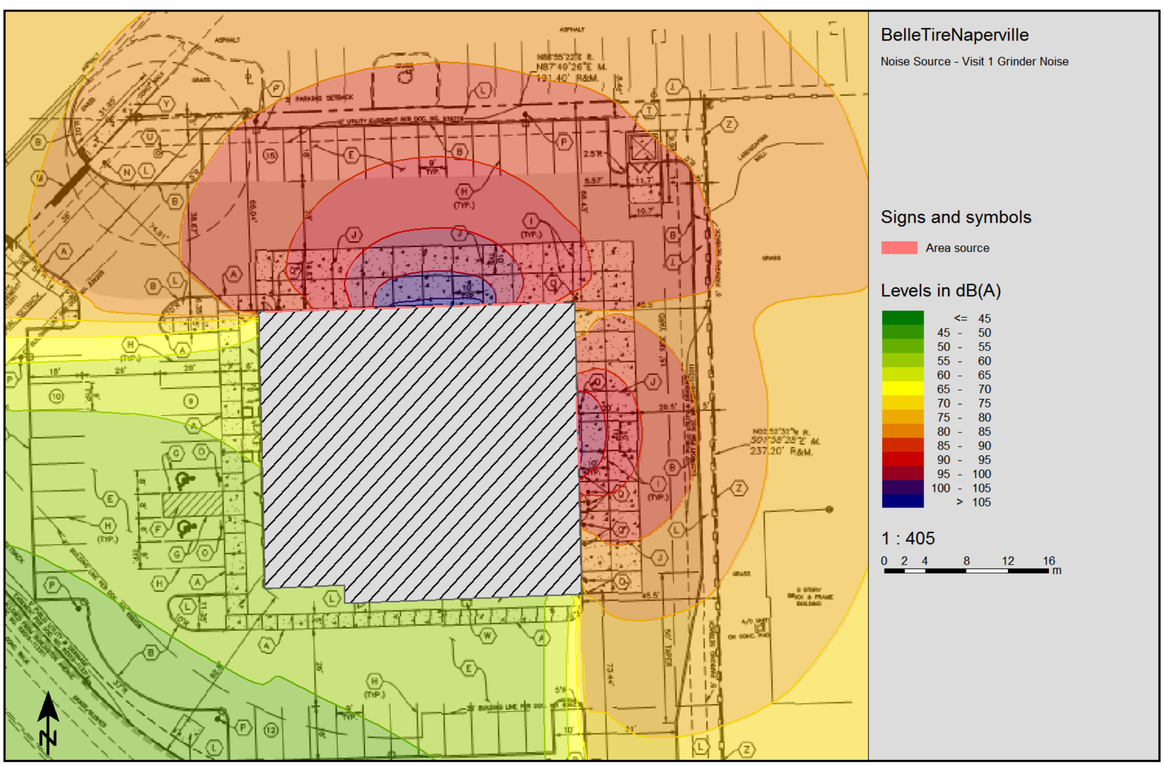

Figure 8: Sound Propagation – Unmodified Standard Store Design

2. Addition of an Interior Wall between Main Garage and Alignment Bays

We understand that there will be no grinding and banging activity in the alignment bays. Therefore, to prevent sound from passing from the main garage bays to the alignment bays, we recommend erecting a wall to separate the two areas. This wall should be full height on all three sides of the alignment area and sealed to the underside of the deck with acoustical caulk. Please refer to Appendix B for further construction details. The minimum sound isolation rating of the wall between bays should be STC 28. This rating can be accomplished by a single layer of 5/8" regular weight Type X or Type C gypsum board or a stud wall with gypsum board on each side. Insulation is not required in the stud cavities. The predicted sound level and propagation improvement are shown in Figure 10 and Figure 11.

The newly enclosed volume will need to be assessed by a mechanical engineer to make sure the proper amount of supply air is served to the space. A return transfer duct should have 1-inch thick internal acoustical duct liner, two elbows without turning vanes, and a minimum of 4 feet of straight duct between the elbows. Locate the transfer duct on the storage side of the alignment bays farthest from the tire changing bays.

Additionally, the louver on the alignment side of the building should ideally be relocated from the east side of the building or have a similar amount of acoustically lined ductwork associated with it as described for the transfer duct. Figure 9 has images of this louver from the outside and inside of the building.

Self-closing doors with seals should be installed for access between the main garage area and the alignment bays. Rubber bulb seals are preferred, but brush seals can be used if necessary. Automatic door bottoms are not required.

With the addition of the interior wall, a significant sound reduction is predicted at the residential property line near the residence. The predicted levels nearly meet the daytime ordinance requirement, though the levels at the northeast corner are still significantly higher than the ordinance.

Figure 9: Garage Louver in Exterior Wall

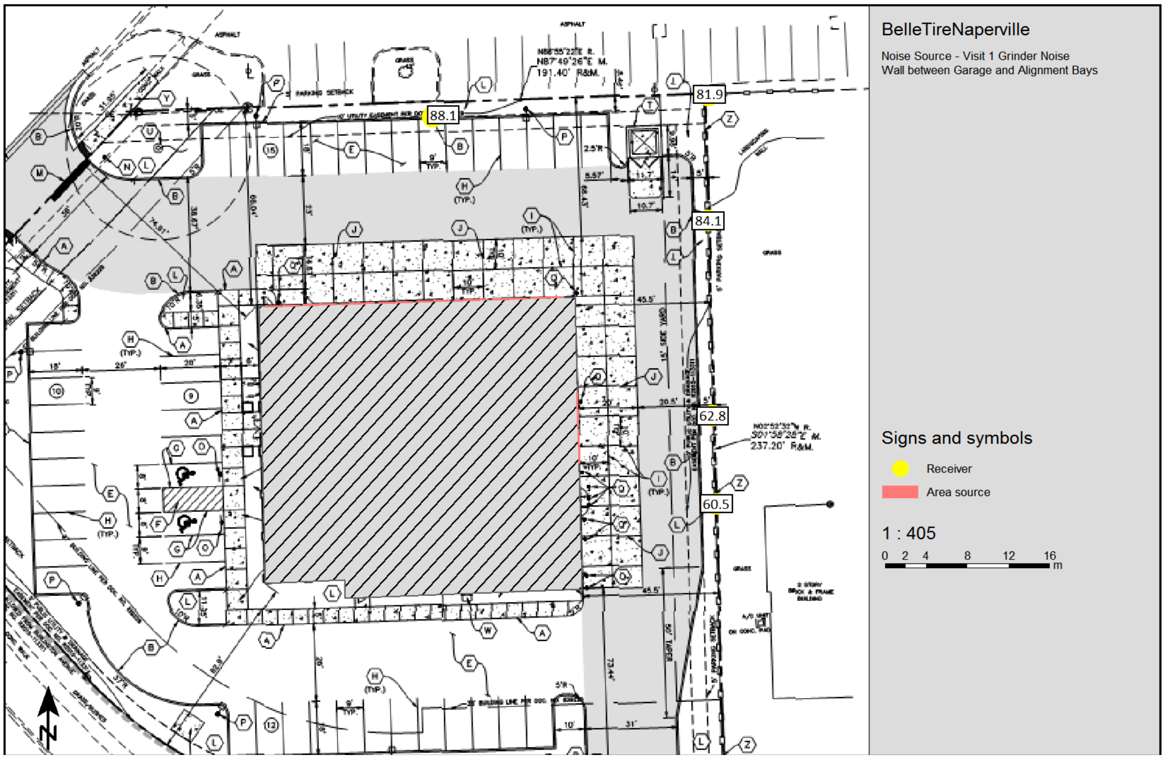

Figure 10: Sound Levels – Interior Wall between Tire Changing Bays and Alignment Bays

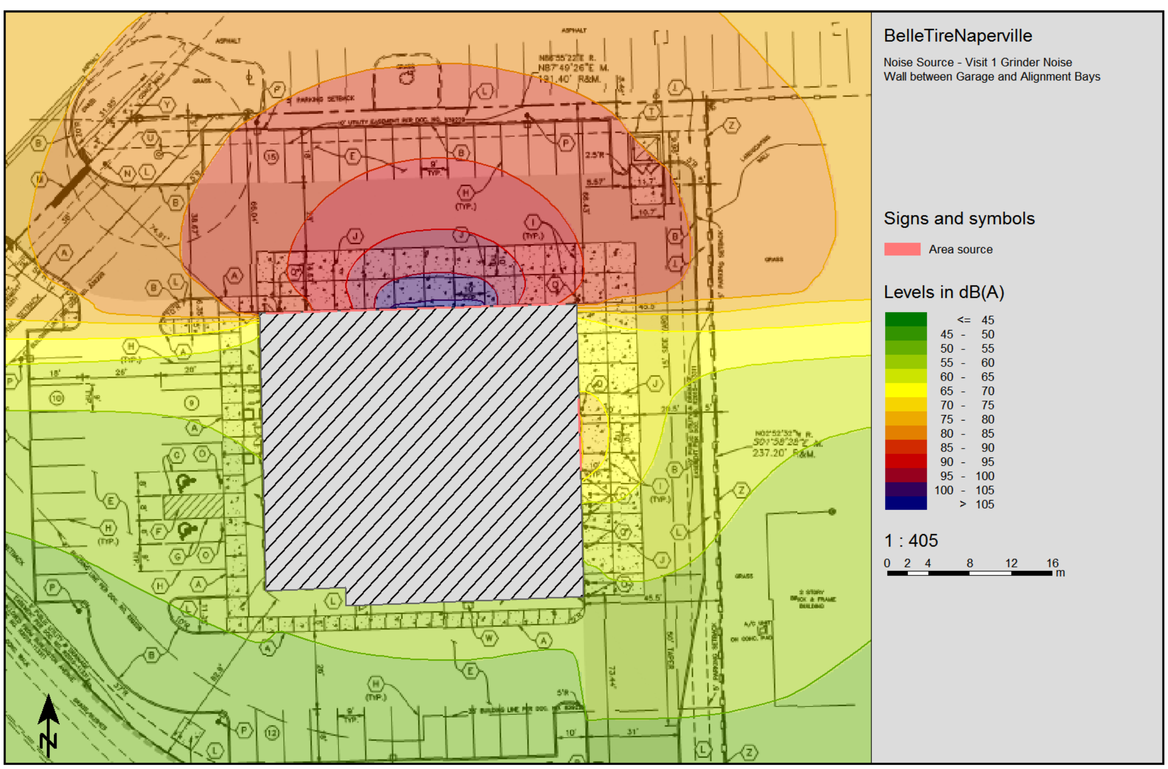

Figure 11: Sound Propagation – Interior Wall between Tire Changing Bays and Alignment Bays

3. Addition of Exterior and Interior Walls

For further incremental improvement to meet the daytime ordinance limits near the residence, we recommend extending the east exterior wall on the northeast corner of the building to act as a barrier to the sound. The wall should extend approximately 2 feet above the top elevation of the garage doors. We understand that this wall can only extend 8 feet from the building to allow proper clearance for firefighting and delivery trucks. Figure 12 shows the 3D acoustics model of the future building with the extended wall at the northeast corner.

The minimum sound isolation performance of the exterior wall extension at northeast corner should be STC 33.

Figure 13 and Figure 14 present the predicted sound levels and propagation with the addition of the interior alignment bay wall and northeast corner exterior wall extension. The exterior wall will help reduce sound to the majority of the residential property line except for the extreme northeast corner of the Belle Tire lot.

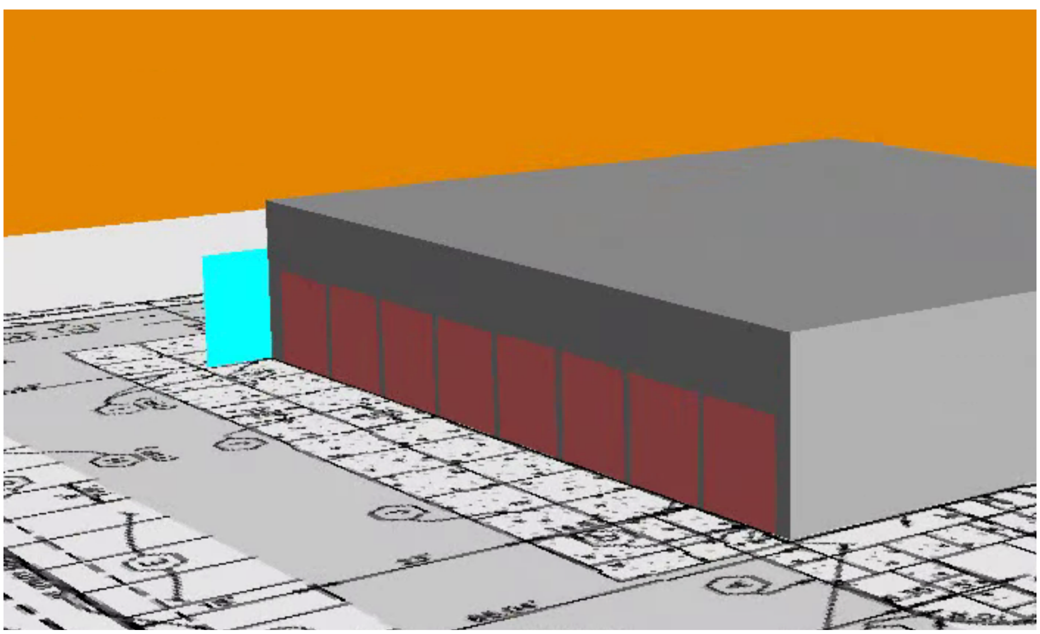

Figure 12: SoundPlan 3D View - Wall at Northeast Corner

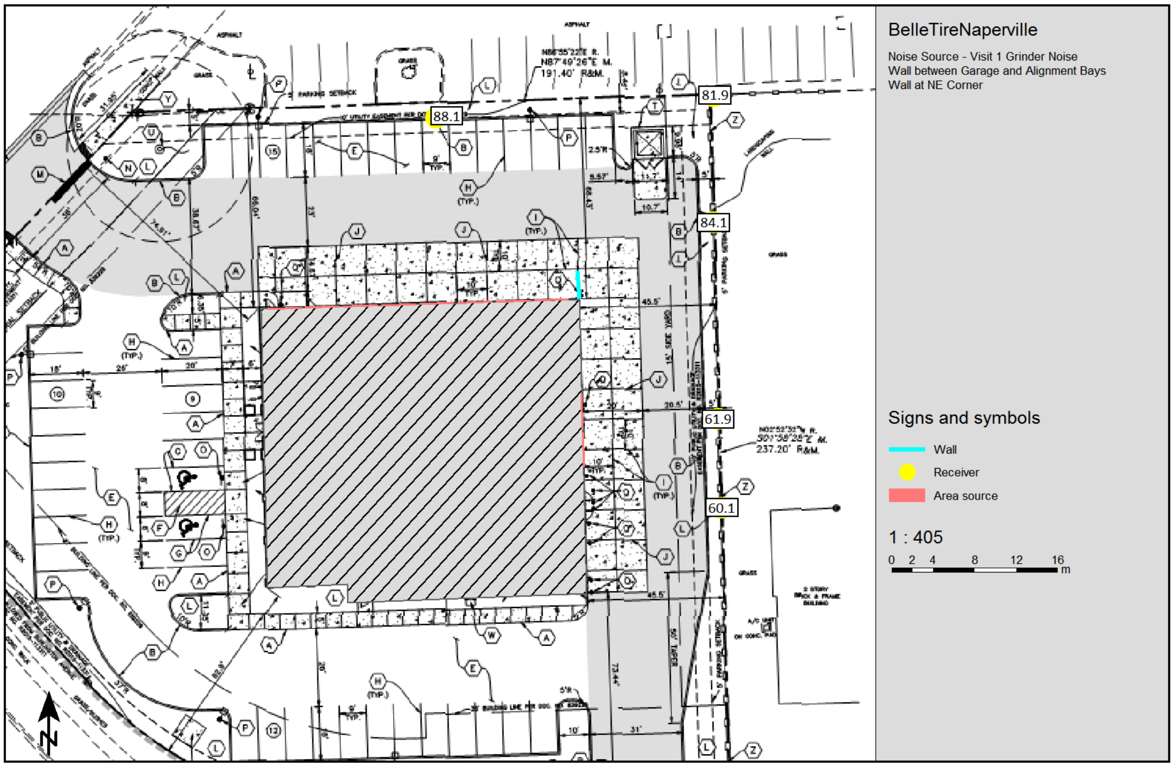

Figure 13: Sound Levels - Walls at Alignment Bay and Northeast Corner

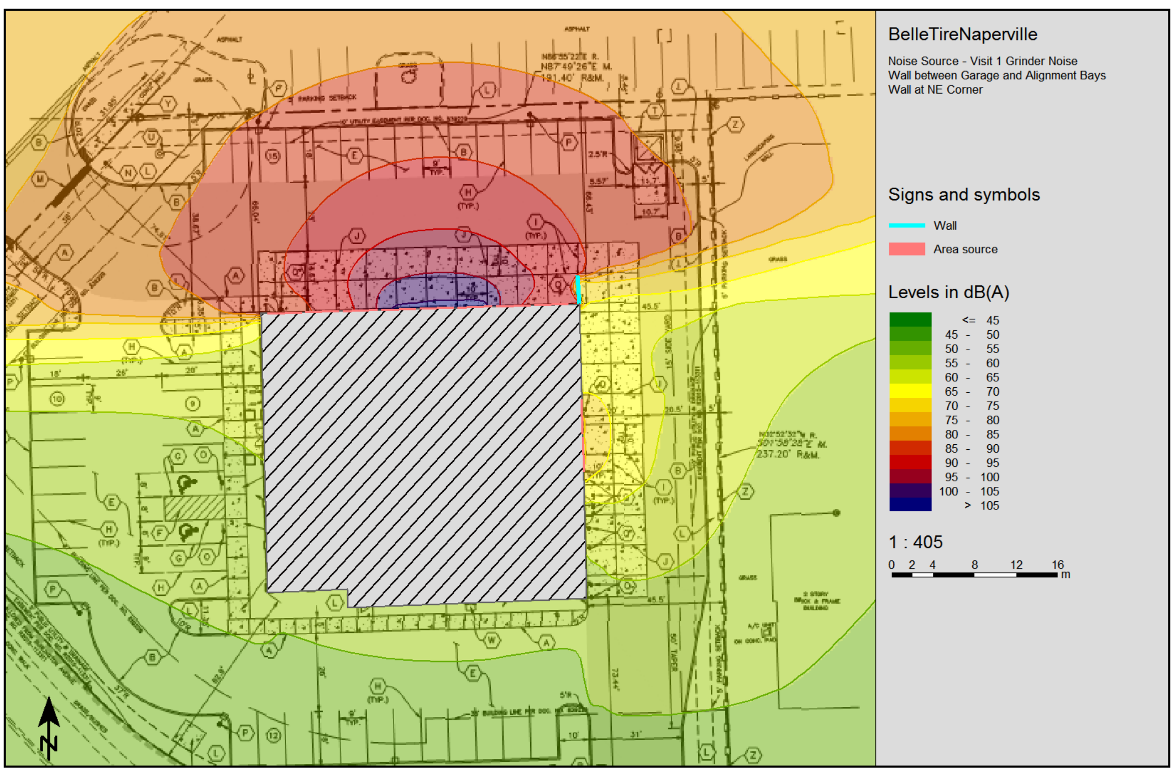

Figure 14: Sound Propagation - Walls at Alignment Bay and Northeast Corner

4. Addition of Exterior and Interior Walls plus Property Line Acoustical Barrier

To address reducing the sound level at the northwest corner of the residential property, a replacement fence can be constructed as an acoustical barrier to mitigate the sound. Other points on the residential property will also benefit from this acoustical barrier.

The effectiveness of an acoustical barrier depends mainly on its height, but another parameter is the ability of the material to prevent sound from penetrating through. In general, the sound blocking performance of the material needs to be STC 33 or higher. This is easily accomplished by masonry. Wood, metals and plastics need to be evaluated to verify that their thicknesses will perform well. For example, slats in a wood fence may be ¾" thick typically, but to obtain the maximum performance, a thickness of 1-½" is recommended. However, the reduction in performance for the thinner boards is only a slight 1 dB when going from a nominal 2x to a 1x board. A discussion of barrier design and materials can be found in Appendix B.

Our recommendations for the acoustical barrier are as follows.

- We recommend a 6 foot high wooden fence or masonry wall. Both will perform the same as long as the STC rating of the material is STC 33 or higher. This is because the sound going over the barrier will be greater than the sound going through the barrier for a material with this performance.

- For wood fencing, it is imperative that no gaps exist between the slats. We recommend high quality kiln dried tongue and groove wood slats or panels. The preferred board thickness is 1-1/2" inches, but a ¾" thick board can be used if a 1 dBA reduction in performance is acceptable.

- For ease and expediency of installation, manufacturers make purpose-built acoustical barrier panel systems that meet these requirements. A few manufacturers are listed below.

    - Noise Barriers LLC
      https://www.noisebarriers.com

    - Sound Fighter Systems
      https://www.soundfighter.com

Note that a narrow row of screening vegetation does not provide a measurable amount of sound reduction unlike popularly believed. However, it could psychologically provide a perceived reduction for the residents by blocking the line of sight.

The performance for the configuration with the interior wall, exterior wall extension, and the property line fence is provided in Figure 15 and Figure 16. An overview of the model with the exterior wall and the property line acoustical barrier is shown in Figure 17.

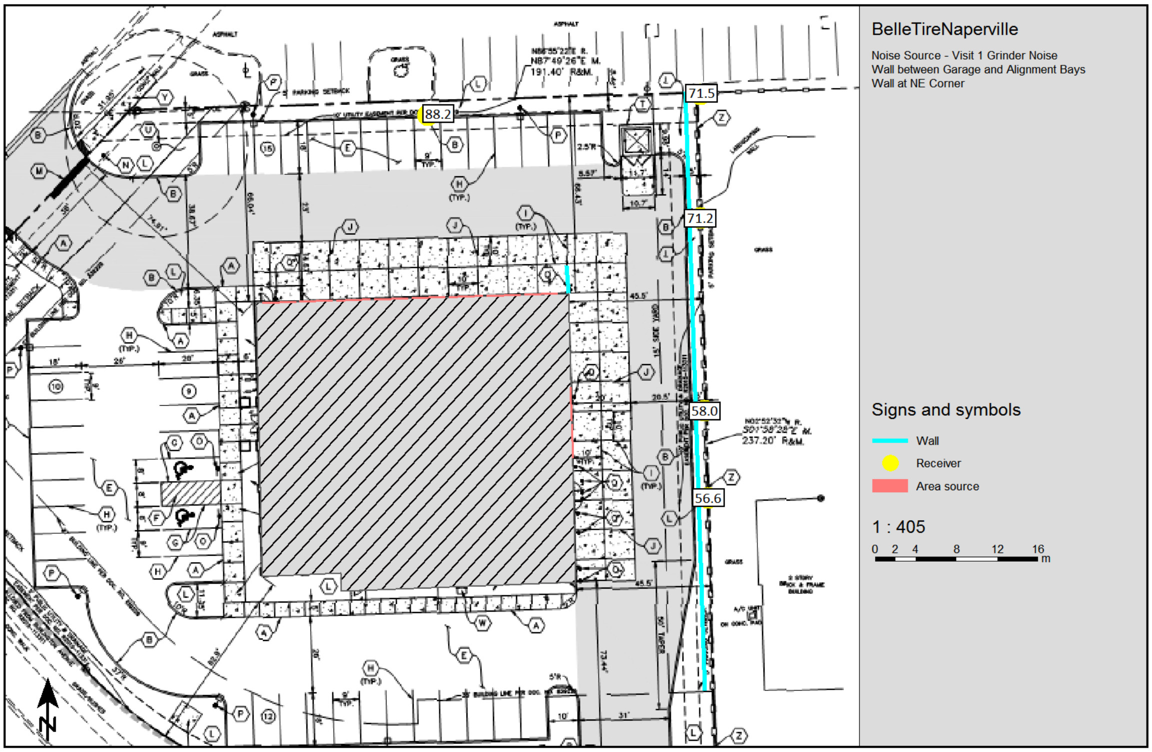

Figure 15: Sound Levels - Walls at Alignment Bay and Northeast Corner Plus Property Line Fence/Wall

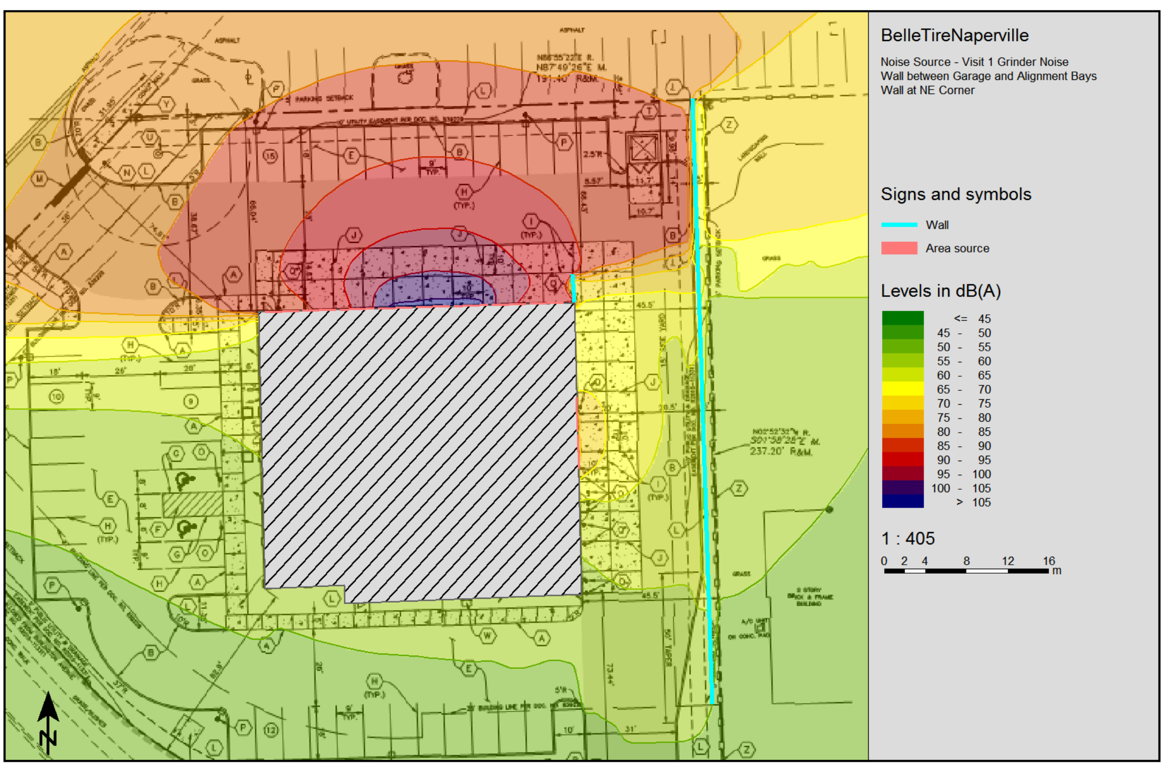

Figure 16: Sound Propagation - Wall at Alignment Bay and Northeast Corner Plus Property Line Fence/Wall

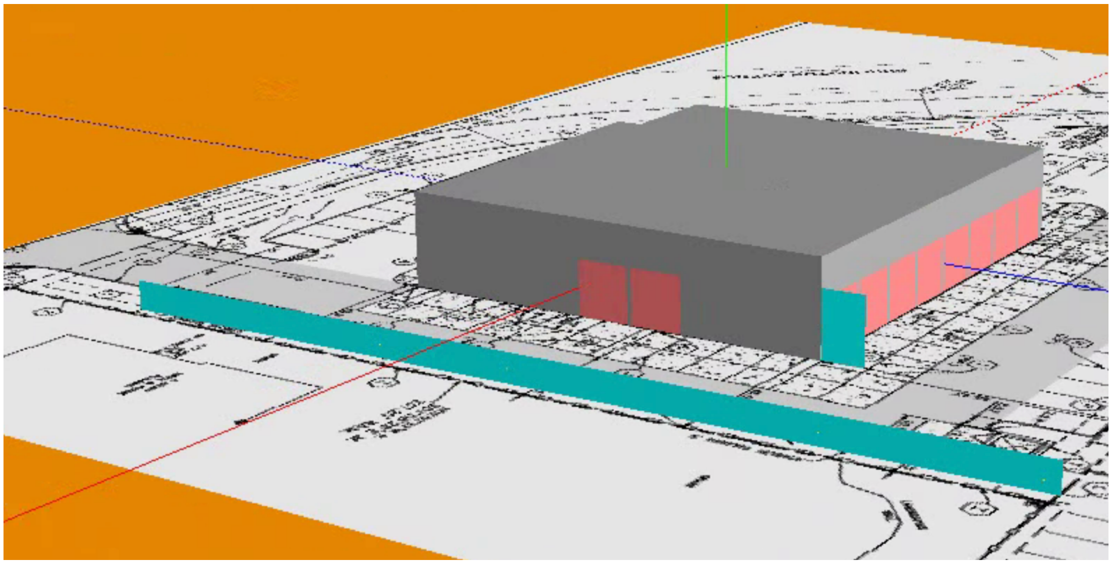

Figure 17: SoundPlan 3D View – External Wall and Property Line Fence/Wall

Average Sound Level Prediction

Figure 18 and Figure 19 present the model prediction of the measured average sound level (LAeq) of Location 1 during the first visit. Again, this is the average sound level recorded over a 10 minute period. A 3 dBA safety factor has been included in this prediction as well.

When examining this metric, the levels along much of the east property line are predicted to not exceed the nightime noise ordinance level of 55 dBA. The daytime limit of 62 dBA is predicted to be met along the entire property line.

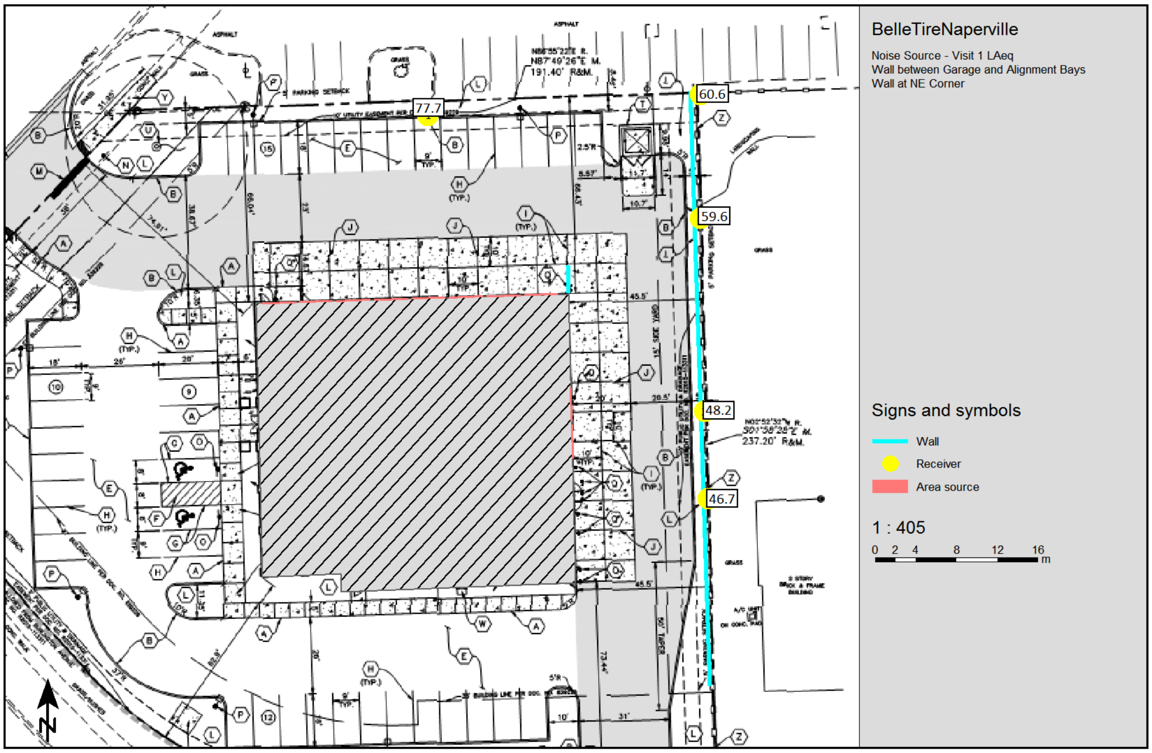

Figure 18: Average Sound Level - Walls at Alignment Bay and Northeast Corner Plus Fence/Wall

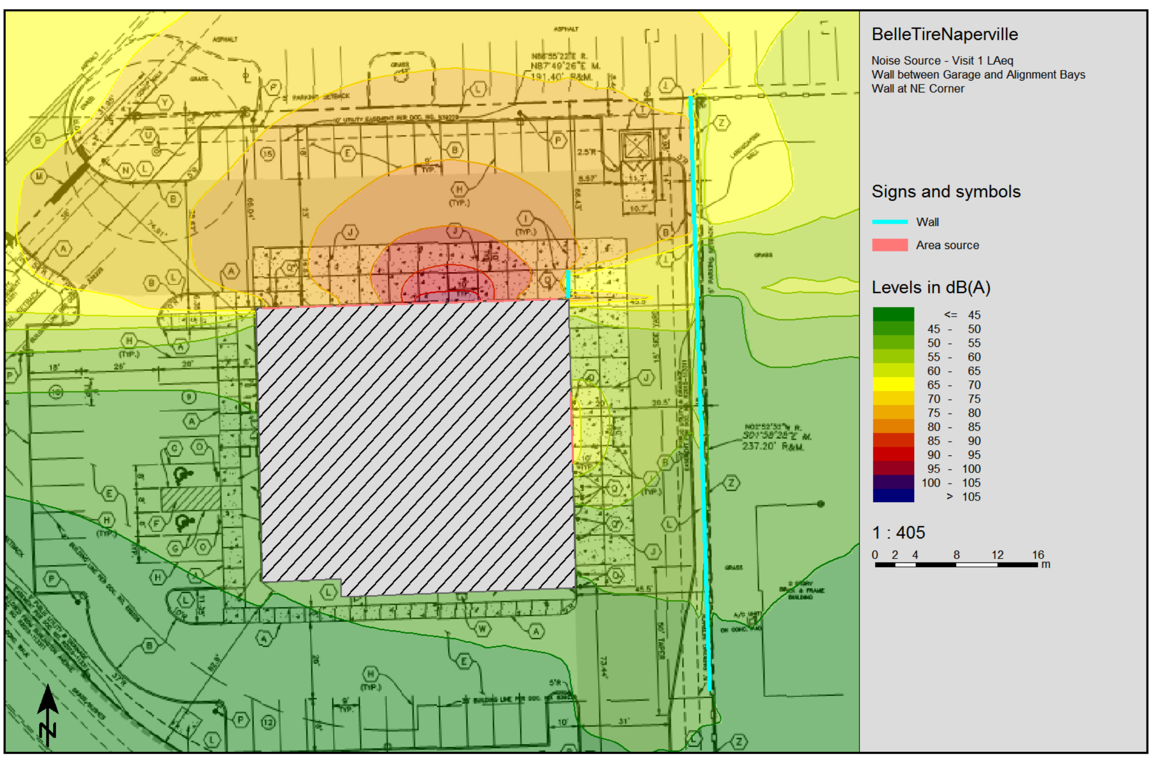

Figure 19: Average Sound Propagation – Walls at Alignment Bay and Northeast Corner Plus Fence/Wall

Final Note

Please note that our recommendations and comments are exclusive to acoustics. We cannot comment on such things as local codes, life-safety requirements, or any other non-acoustic issues.

This concludes our measurement report. We will be happy to elaborate on anything contained within this report.

Sincerely,

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Per:

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Appendix A: Acoustic Terminology
Appendix B: Gypsum Board Partition Details
Appendix C: Acoustical Barrier Screen Walls

Appendix A: Acoustics 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. Human 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.

Decibel addition is not on an arithmetic basis but on a logarithmic basis. This means that the level produced from two sound sources of 60 dBA is 63 dBA and not 120 dBA. While acoustics consultants use the mathematical formulas for this calculation, this table provides a shorthand method of calculation. To add up a spectrum of multiple bands, the logarithmic process has to be repeated multiple times.

When two dB values differ by…	…add the following dB to the higher value.
0 or 1	3
2 or 3	2
4 to 8	1
9 or more	0

Examples:

43 dB + 44 dB = 47 dB
43 dB + 48 dB = 49 dB
43 dB + 53 dB = 53 dB (sounds that are 10 dB or more less do not affect the final level)

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 sounds, such as fan noise, can be accurately measured for much shorter periods of time, such as 30 to 60 seconds.

Sound Transmission Class (STC) is a single number rating of the amount of sound blocked by a partition (a window glazing unit, door, wall, floor-ceiling assembly) 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 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.

Appendix B: Gypsum Board Partitions Details

Gypsum board partitions must adhere to the following conditions:

a. When the wall is parallel to metal deck flutes, sheet metal or treated plywood panels must be attached to the underside of metal deck to span a minimum one deck flute beyond the thickness of the wall. Stuff cavity with fiberglass batt insulation between metal deck and flute closure pane. See Figure 20 on the next page.

b. When the wall is perpendicular to the metal deck flutes, all layers of gypsum board called for in the detail must be coped to follow metal deck profile. Seal joint between metal deck and gypsum board with acoustical sealant to create an airtight seal. See Figure 21 on the next page.

c. Provide a continuous bead of acoustic caulk along the top and bottom of the wall between gypsum board and metal deck on each side of the partition. Use U.S. Gypsum Sheetrock Brand Acoustical Sealant or equivalent acoustical sealant. Non-acoustical sealants are not acceptable substitutes.

d. The gypsum board must be regular weight Type X or Type C with a density of 2.2 lb/ft^2 or greater. Do not use USG Ultralight panels or other brand of lightweight panels, because they do not have the necessary density for the acoustic partitions described in this report.

e. All gaps around wall or ceiling perimeters, and around wall/ceiling penetrations should be ¼" to ½" wide and sealed airtight with acoustical sealant.

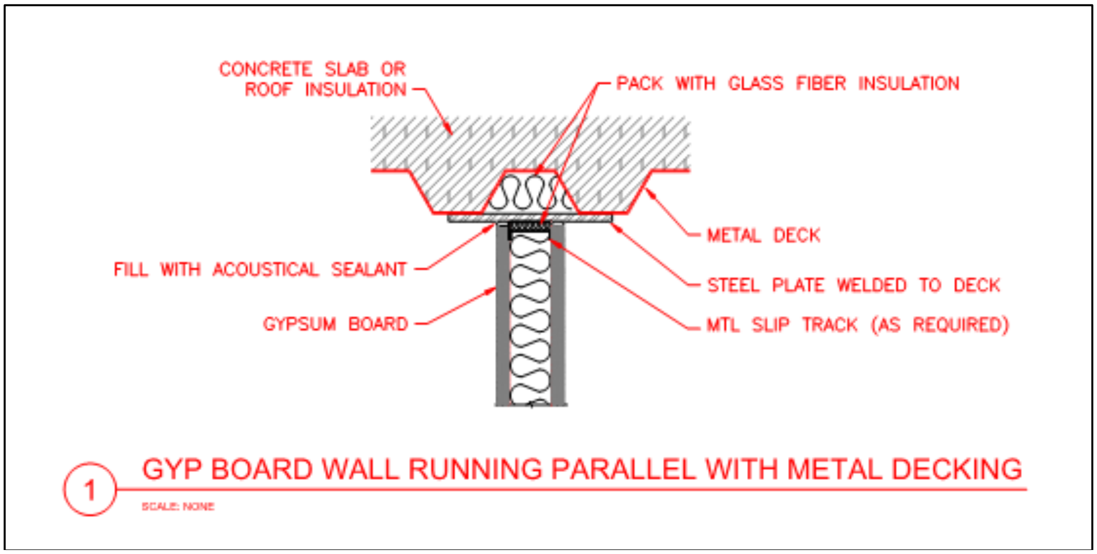

Figure 20: Wall Parallel to Deck

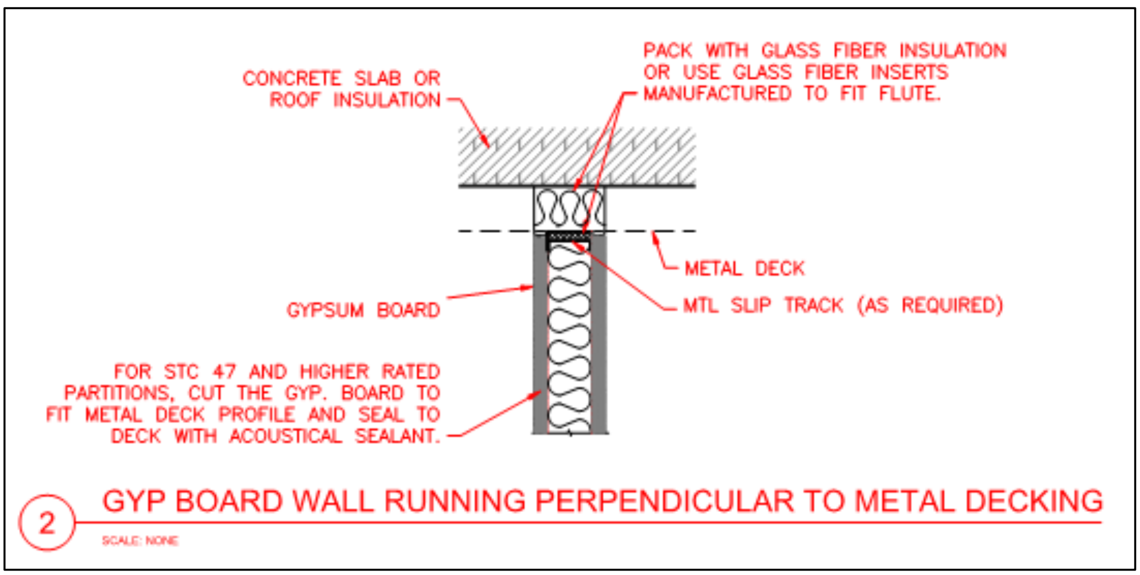

Figure 21: Wall Perpendicular to Deck

Appendix C: Acoustical Barrier Screen Walls

Acoustical barrier screen walls and berms are often used to reduce the sound level at a listener's location. The sound is referred to as the source and the listener as the receiver.

In order for a screen wall or berm to have acoustical value, it must break the line of sight between the source and receiver. Otherwise, the sound traveling along the direct path without the barrier (i.e., in the direct line of sight of the source) is not attenuated by the barrier, but by distance and atmospheric absorption only.

The taller the wall is with respect to the source and receiver, the more effective it is acoustically. The acoustical performance of a screen wall or berm is referred to as the insertion loss, measured in dB. This is the difference in sound level at a receiver location with and without the barrier in place. The barrier performance is frequency dependent, with higher frequency sounds being more easily blocked than low frequency sounds.

Figure 22 provides an illustration of an acoustical barrier and how it blocks sound. The sound source is shown as a person and the receiver can be assumed for our purposes to be halfway between the house and barrier.

An acoustical barrier blocks sound in an area called the shadow zone of the barrier. This is depicted in Figure 22 as the shaded area on the house side of the barrier wall. The sound level in this shaded area depends on the sound level of the source and the amount of sound diffracted (or bent downward) over the top of the wall. The amount of diffraction depends on the frequency of the sound (shown as "angle of diffraction"). This amount is calculated by an equation.

Acoustical barrier walls have a practical upper performance limit of approximately 24 dB of reduction in the higher frequencies. The performance is less in the lower frequencies because the diffraction phenomenon over the top and ends of the wall is more prevalent at lower frequencies. Also, the performance is dependent on how close the source and receiver are to the barrier and the distance that the barrier breaks the line of sight.

Different materials can be used for the acoustical barrier as long as the following conditions are met:

1. The amount of sound going through the barrier material is much less than the sound going (diffracting) over the barrier. For practical purposes, this means that the barrier material must be at least STC 33.

2. The material has no gaps or acoustically weak points that allow sound to pass through.

3. The selected material is appropriate for the amount of maintenance that it will receive.

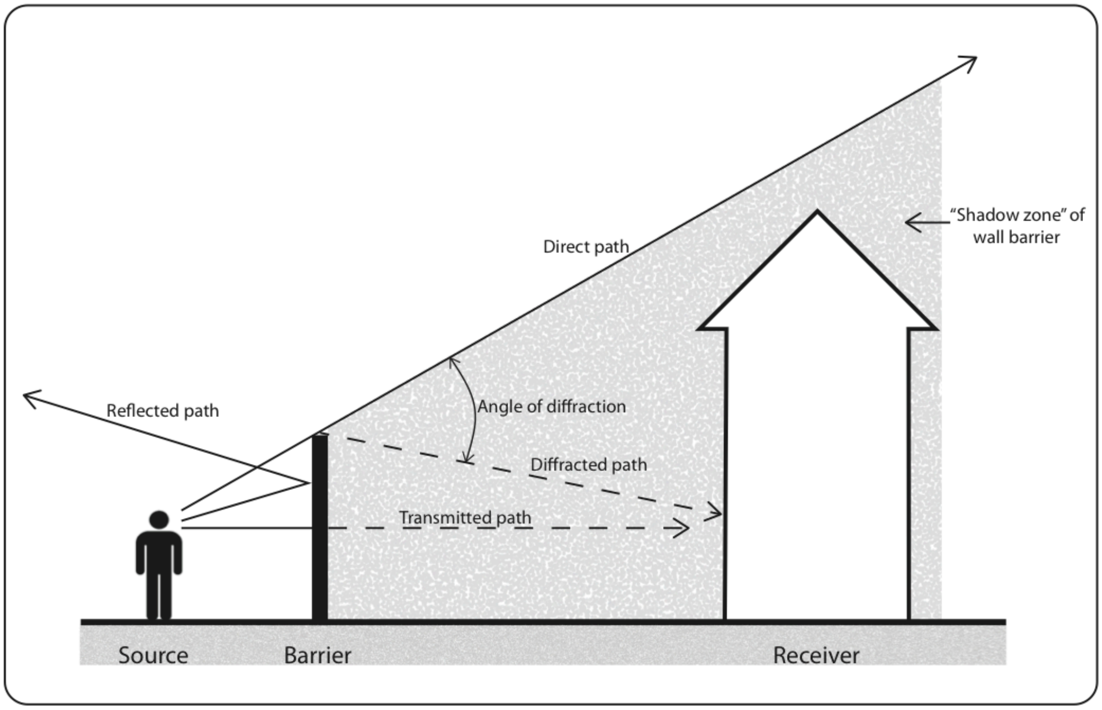

Figure 22: Acoustical barrier wall sound paths

A description of various acoustical barrier materials is provided for your consideration. Further details can be found in the Noise Barrier Design Handbook at the US Department of Transportation - Federal Highway Administration website at the link below.

https://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/design/design00.cfm

- ***Concrete:*** Cast-in-place or precast panels can form the barrier. Concrete is a durable material that easily meets the STC requirement of a barrier wall. Precast panels can be erected quickly.

- ***Brick and Masonry Block:*** Hand-laid or preassembled panels are options with this material. A continuous concrete foundation is required. Both materials meet the STC requirements for an acoustical barrier wall. This type of material may not be as durable as concrete should it come into contact with deicing salts.

- ***Metal:*** These panels are lighter than concrete or masonry. Typical materials are steel, aluminum or stainless steel. The STC of these panels may not meet the minimum requirement, but corrugations or ribs will improve the performance. The manufacturer should submit test data to demonstrate the STC performance. Also, the typical 18 to 22 gauge thickness may not be structurally strong enough to withstand impact or other types of damage.

- ***Wood:*** Pressure preservative treated lumber, plywoods and glue laminated products are common materials used for wood barrier walls. This material may be aesthetically more desirable near residential areas. The main issues with wood are warping and shrinkage, which can open up cracks and gaps. This can be partially solved by specifying deeper than standard tongue and groove construction or screwing multiple sheet layers together. The STC rating of the material should be verified so that it meets the required performance.

- ***Transparent Panels:*** These panels block sound while allowing scenic views and reducing the visual impact of the barrier. They can cost up to twenty times that of concrete or steel panels.

- ***Plastics:*** These engineered panels of polyethylene, PVC and fiberglass are lightweight and potentially recyclable. Some materials or products may not be dimensionally stable and over time and could deform, opening cracks in the wall.

- ***Recycled Rubber:*** This material should be tested for its STC rating prior to selection. Some products may be too porous to meet the required performance.

- ***Composites:*** Combinations of the above materials may be available. Again, the STC rating of the assembly should be verified prior to specification.