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Constructing SoundPLAN Models for Noise Studies That Are Consistent With the HUD Noise Guidebook

Joshua D Leasure
JEAcoustics
1705 W Koenig Lane
Austin, TX 78756

The HUD Noise Guidebook includes worksheets used to evaluate prospective project sites for noise exposure as part of the qualification process for HUD support. Although other environmental noise tools are available, the HUD Guidelines are required by officers of HUD or other housing authorities that adhere to HUD standards. Presented is a method for extracting the algorithms in the HUD Worksheets and applying them to SoundPLAN computer models. This allows more complicated and complete analysis to be performed on project sites that is still consistent with the HUD Worksheets.

1 INTRODUCTION

Residential developments with HUD support must meet HUD-established limits for noise exposure. If a proposed project site is within pre-established distances from traffic noise sources (roadways, rail, airports), a noise analysis must be performed¹, according to HUD guidelines. The HUD noise guidelines are presented in the HUD document entitled *The Noise Guidebook*². Included in *The Noise Guidebook* is a procedure and accompanying worksheets (referred to hereafter as “the Worksheets”) for predicting the Day-Night Average Sound Level (DNL) for a given Noise Assessment Location (NAL) on a project site, based on factors that include the proximity to traffic noise sources and the amount of use those noise sources are projected to experience in the future.

While the Worksheets provide a useful tool, their accuracy suffers for more complex scenarios that include multiple sources of shielding, terrain differences, and a high number of desired assessment locations. Evaluating building façades individually is also difficult. This paper describes a method that was developed to use SoundPLAN noise modeling software to perform environmental noise analysis that is consistent with the technical aspects of The Noise Guidebook.

2 ESTABLISHING MODEL TO MODEL RELATIONSHIP

For SoundPLAN to emulate the HUD Worksheets, a framework must be established that will translate inputs to the Worksheets that will cause SoundPLAN to arrive at equal results for simple scenarios while leveraging SoundPLAN’s ability to evaluate more complicated scenarios.

2.1 Noise Source Spectra

The Worksheets do not consider individual frequency bands, at least not explicitly. All calculations are done in terms of A-weighted DNL. To take advantage of SoundPLAN's ability to calculate propagation and diffraction across multiple frequencies, representative source spectra were drawn from measurements performed on previous environmental noise projects.

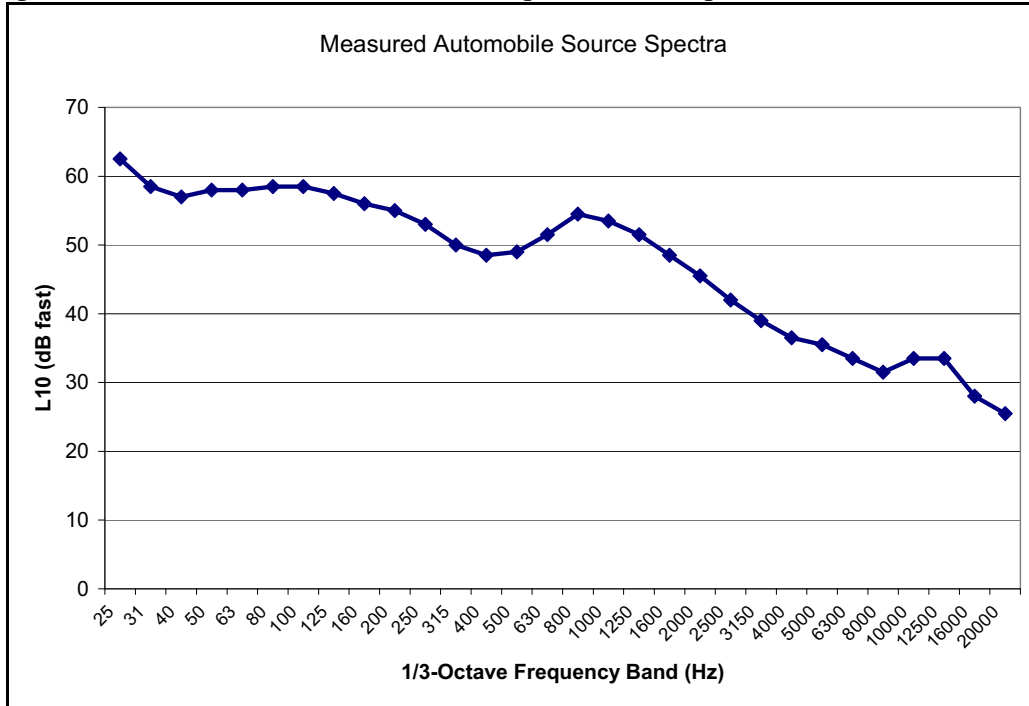


Figure 1- Source Spectrum for Automobiles/Medium Trucks

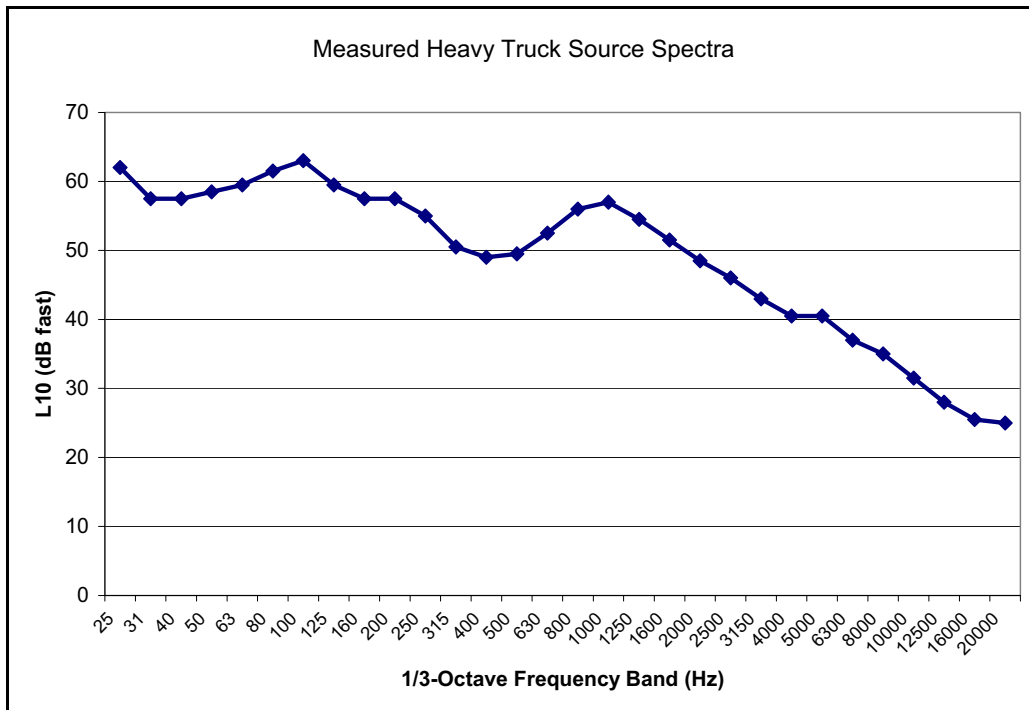


Figure 2- Source Spectrum for Heavy Trucks

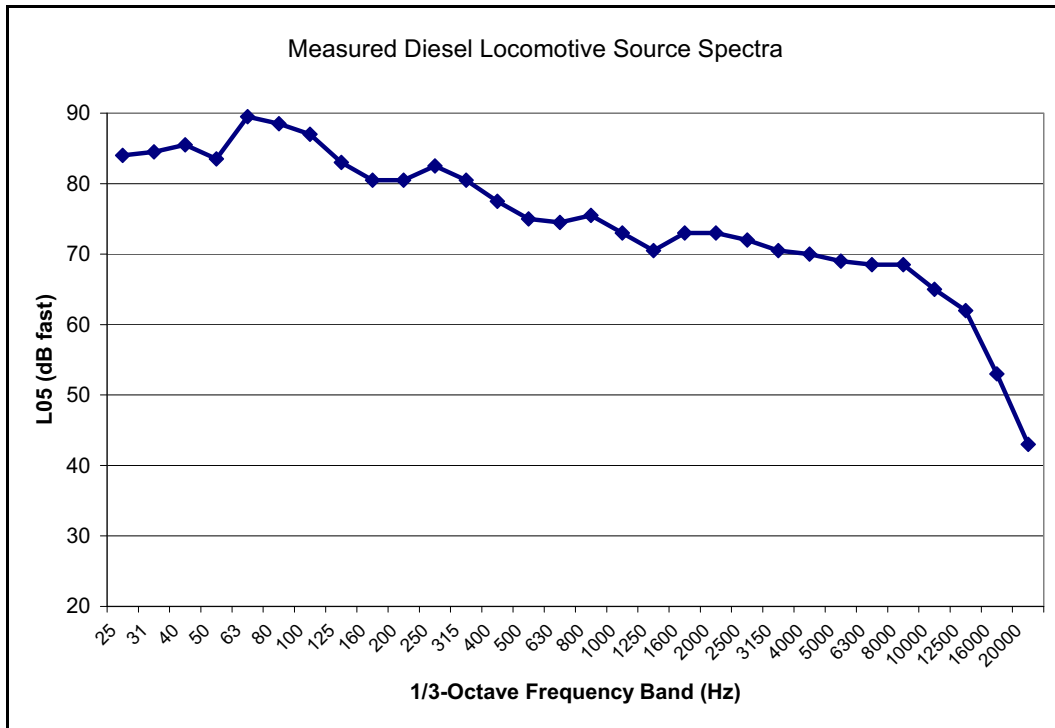


Figure 3- Source Spectrum for Diesel Locomotives

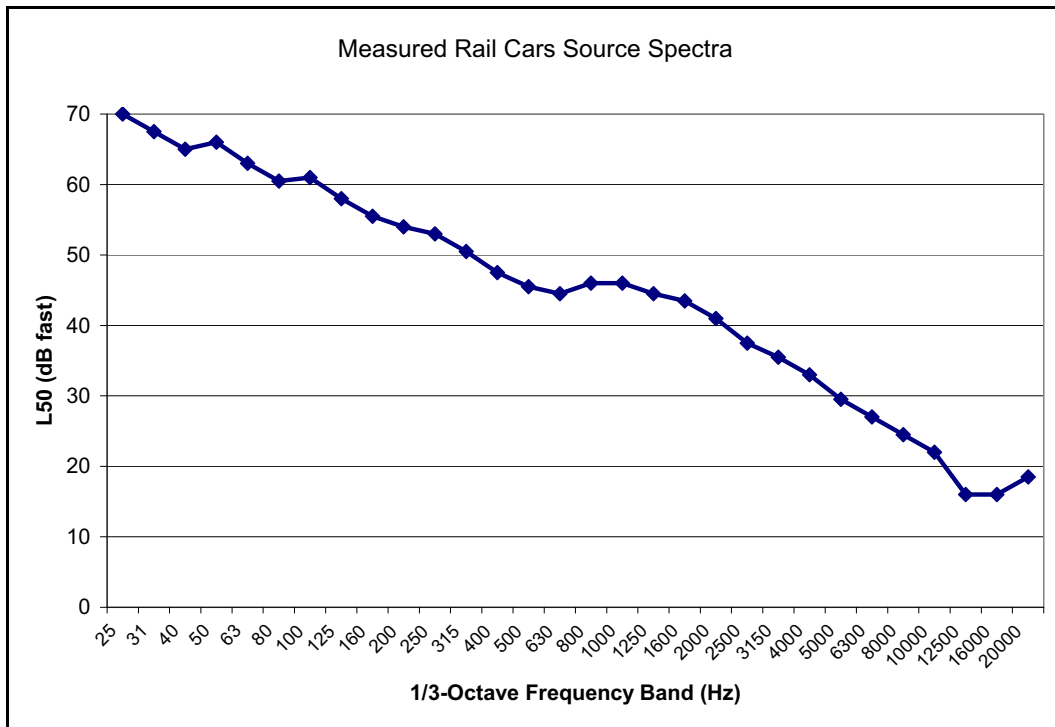


Figure 4- Source Spectrum for Rail Cars

The chosen spectra shown are from single measurements and of statistical values that best reflect the nature of the noise source for each measurement in particular. In the future, the method can be improved by developing spectra from multiple measurements of varying noise sources.

2.2 Propagation Modeling Standard

To find an appropriate combination of settings for noise propagation predictions, a simple SoundPLAN model was constructed with a single, long line source with receptors at 50, 100, 250, 500 and 1000 feet. The noise source was set to a height of 15 feet above ground level, consistent with The Guidebook. The diesel locomotive spectrum was loaded into the line source and the total power was adjusted until the 100-foot receptor registered approximately 74 dBA.

The model was run with various combinations of propagation standards, air absorption standards, and temperatures (when appropriate). The following figure shows a selection of standards that were tested when compared to the HUD results for 100 effective operations from the rail noise worksheet. The combination that showed the best agreement was the BS 5228³ standard at 25 degrees with no air absorption. At this setting SoundPLAN produced results that were equivalent to HUD at 100, 250, and 500 feet, while being -0.6 dBA at 50 feet and -0.3 dBA at 1000 feet.

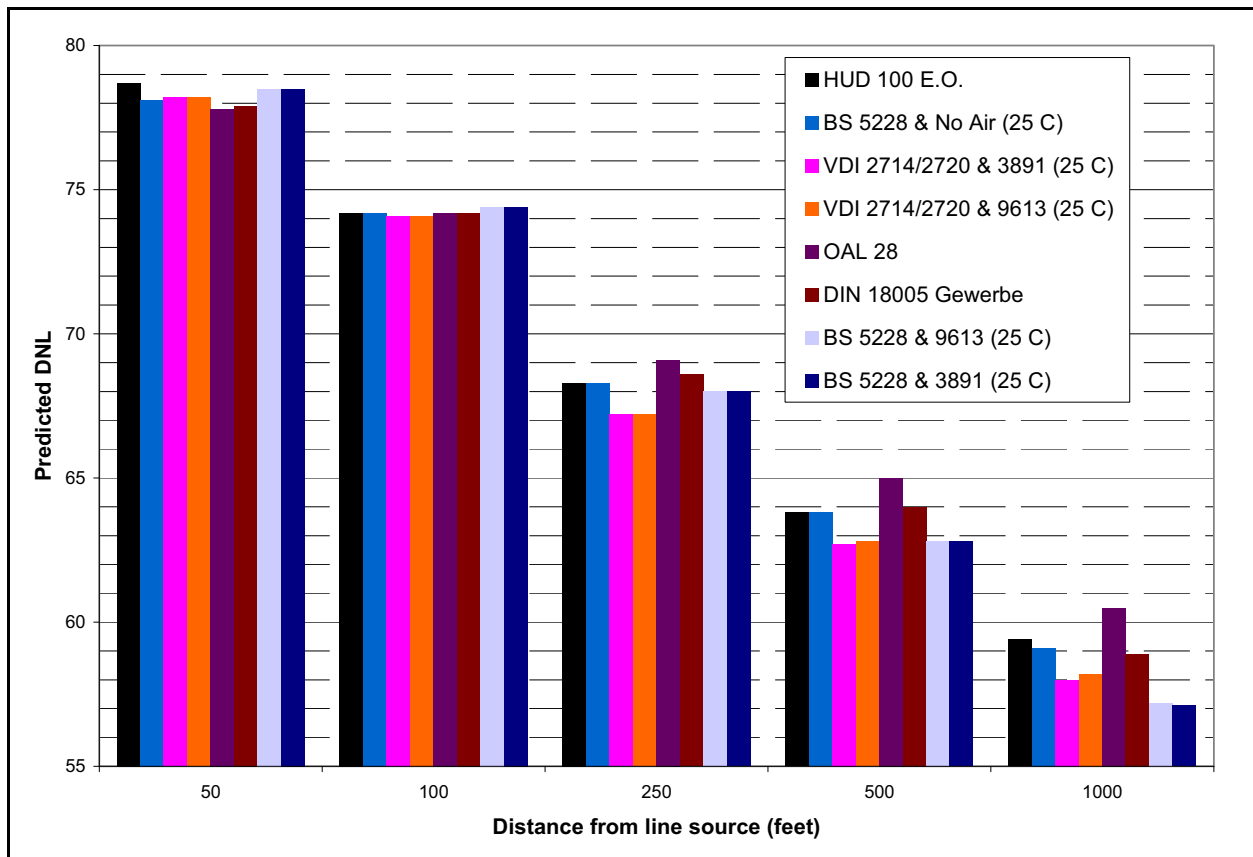


Figure 5- Comparison of Selected Propagation and Air Absorption Standards to HUD Guidelines

More complete information on tested standards is shown in Table 1.

2.3 Translating Effective Operations to Source Power Levels

The HUD Worksheets work in terms of “effective operations.” For each type of ground-level source (autos, heavy trucks, locomotives, rail cars), the effective number of operations is

determined based on factors that include but are not limited to speed, slope, and distribution of traffic between night and day. Effective operations can then be converted to resulting DNL for a given distance. In effect, the number of effective operations is a representation of sound power.

The conversion from effective operations to DNL in the HUD Worksheets is done graphically on a set of workcharts. The relationship between effective operations and DNL in decibels can be backed out by applying a curve-fitting algorithm to a set of data points plotted on the charts. The primary relationship between effective operations and DNL in decibels depends on a natural log relationship, specifically 4.34 times the natural log of effective operations.

To convert effective operations to sound power per meter of line source, the same $4.34 \ln(EO)$ relationship is adopted from the Worksheets. After constants are adjusted, the translations between effective operations and sound power per meter length are as follows (EO is effective operations):

Autos and Medium Trucks

$$L_w = 4.34 \cdot \ln(EO) + 52.0 \quad (1)$$

Heavy Trucks

$$L_w = 4.34 \cdot \ln(EO) + 67.1 \quad (2)$$

Diesel Locomotive

$$L_w = 4.34 \cdot \ln(EO) + 84.9 \quad (3)$$

Rail Cars

$$L_w = 4.34 \cdot \ln(EO) + 80.9 \quad (4)$$

These constant values are dependant on the source spectra above. With different or refined spectra, the constants would need to be adjusted to maintain the relationship between The Worksheets and SoundPLAN.

3 CONSTRUCTING AND EXECUTING THE MODEL

The SoundPLAN model can be constructed from elevation data, site plan CAD files, and overhead images, in a typical fashion for an environmental noise analysis. Each roadway or railway is modeled as a pair of line sources.

3.1 Roadways

Roadways are modeled as two line sources. The first represents automobiles and medium trucks and is located at ground level. Its source is set to the Autos and Medium Trucks spectrum with a sound power per meter set according to the relationship (1) above.

The second roadway line source represents Heavy Trucks and is located 8 feet above the ground. Its source is set to the Heavy Trucks spectrum and its sound power per meter is set according to the relationship (2) above.

Roadways can be split by direction if there is a significant difference between the geometries of the two directions. A reason to split directions might include analysis of a highway interchange, which the HUD Worksheets are not well-equipped to analyze.

3.2 Railways

Railways are also modeled as two line sources. The first represents noise from the wheels and chassis of rail cars and is located at ground level. Its source is set to the Rail Cars spectrum with a sound power per meter set according to the relationship (4) above.

The second railway line source represents locomotives and is modeled at a height of 15 feet. Its source spectrum is set to the Diesel Locomotives spectrum (assuming diesel locomotives are in use) and its sound power per meter is set according to the relationship (3) above.

3.3 Receptors

Any type of receptor can be used for analyses that are consistent with the HUD Guidelines. The most obvious application is the use of area receivers, so that entire housing developments can be analyzed simultaneously, instead of a single NAL at a time. HUD noise exposure classifications (“Acceptable,” “Normally Unacceptable,” and “Unacceptable”) are arranged in 5 dB brackets, so the graphical analysis tool in SoundPLAN can be adjusted to display colors based on the classification of each location. In this way individual building façades can be analyzed so that noise mitigation can be recommended where it is needed, and not unnecessarily applied to entire buildings.

SoundPLAN provides the ability to analyze in the vertical plane. This is useful for development of large residential buildings that might be found in downtown areas. This allows analysis to be performed and mitigation to be recommended on a floor-by-floor basis, rather than applying the same results and recommendations to entire building surfaces. The HUD Worksheets alone do not allow for this level of detail without a substantial amount of effort.

3.4 Calculation

The industrial noise calculation should be used and set to the BS 5228 standard, with no air absorption and an ambient temperature of 25 degrees. This provides the best known agreement with HUD’s noise propagation model. A simple Leq analysis will produce results that are equivalent to the DNL results of the HUD Worksheets.

4 EXAMPLES

Presented below are several projects where the method was used successfully. In every case HUD Worksheets verified that the results were consistent with the HUD Guidelines. In every case the SoundPLAN results were accepted by the reviewing HUD or other housing authority

representative, though in some cases an accompanying HUD Worksheet was required in addition to the SoundPLAN results.

4.1 Project No. 1 – Simple Project Site with Single Noise Source

Project No. 1 is a relatively simple development with a single roadway as a noise source. The entire project site was found to be “Acceptable” according to HUD Guidelines.



Figure 6- Project No. 1 SoundPLAN Model

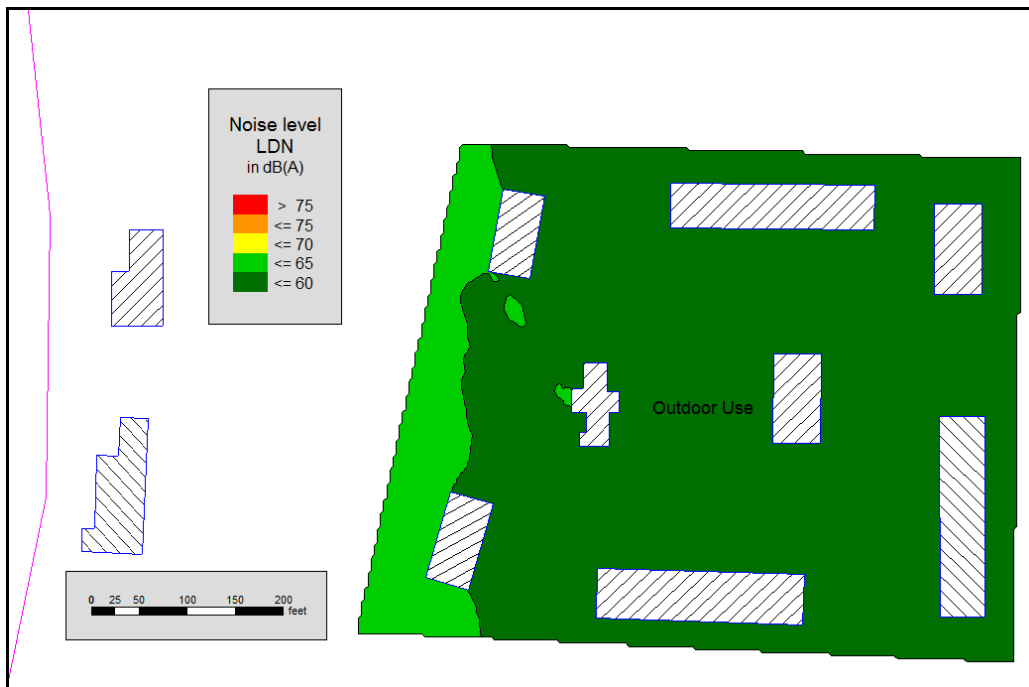


Figure 7- Project No. 1 SoundPLAN Results

4.2 Project No. 2 – Site Plan with Building Shielding

The project site of Project No. 2 features surrounding and project buildings that provide some degree of shielding from several noise sources. Three buildings were determined to have sides in the “Normally Unacceptable” HUD classification, although none of them had 4 sides with this exposure.

One outdoor use area, the Playscape, was determined to be in a normally unacceptable area that would have been difficult to shield with a noise barrier. The solution was to move the Playscape to an “Acceptable” area. Having a contour map that showed explicitly which areas of the site fall in the “Acceptable” classification allowed the developer to easily relocate the Playscape without the need for further analysis.

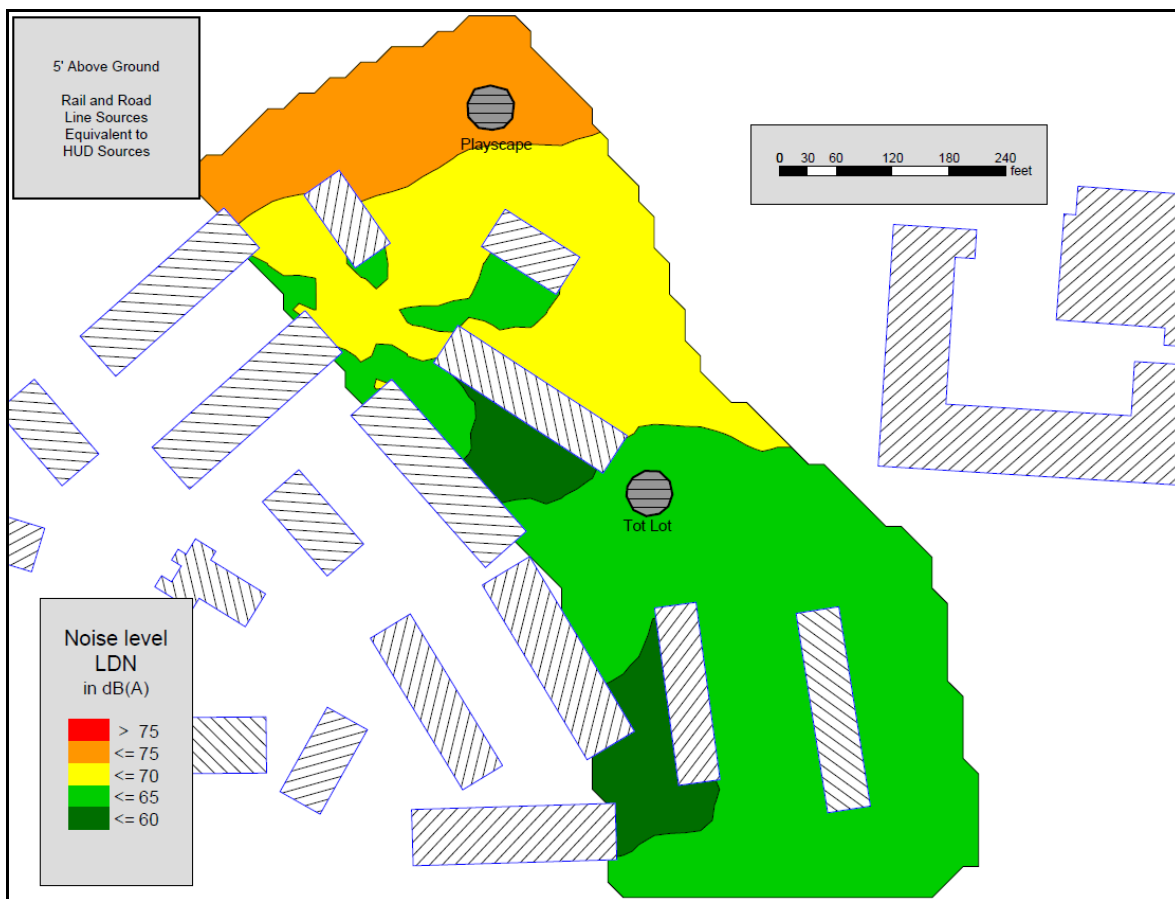


Figure 8- Project No. 2 SoundPLAN Results

4.3 Project No. 3 – Site Plan with Building Shielding and Rail Noise Source

The project site for Project No. 3 is located near both roadway and rail noise sources. It is arranged in a way that allows the front-most buildings to provide shielding for the rest of the project site. This shielding pattern would be difficult to recreate using the HUD Worksheets alone. Mitigation was only required on the shielding buildings, not the entire project.

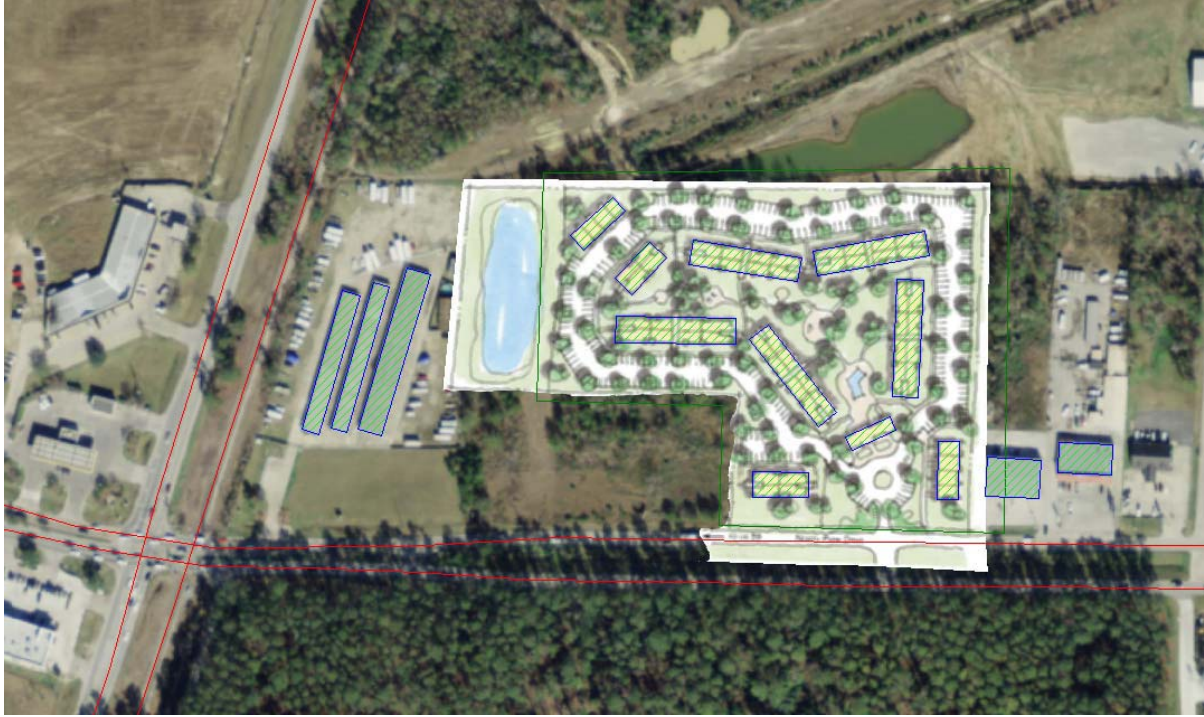


Figure 9- Project No. 3 SoundPLAN Model



Figure 10- Project No. 3 SoundPLAN Results



Figure 11- Project No. 3 Locations for Building Noise Mitigation Recommendations

4.4 Project No. 4 – Vertical Plane Analysis

The site of Project No. 4 is a downtown building with bus lines that run on 3 of the 4 streets that surround it. The remodeling of the building was supported by HUD and accordingly, required a HUD noise analysis. The HUD Guidelines do not provide techniques to analyze a building vertically. With SoundPLAN’s ability to analyze a vertical plane, the HUD Guidelines can be applied in situations the HUD Worksheets are unable to address.

The articulated building facades were analyzed as separate vertical planes. The exposure of each living unit could be analyzed individually but simultaneously. Mitigation can be recommended on a unit-by-unit basis, rather than for the entire building. This can save costs if the developer is able to utilize multiple types of windows, rather than installing catch-all high STC windows in every unit.



Figure 12- Project No. 4 Vertical SoundPLAN Results

5 CONCLUSIONS

By establishing a relationship between the HUD Guidelines Worksheets and SoundPLAN software, SoundPLAN (or other sound propagation modeling software packages) can be made to emulate a noise analysis based on the HUD Guidelines. This allows project sites with complicated features to be analyzed more easily and more accurately than relying on the HUD Worksheets alone. The benefits include lower analysis effort, better information presented to developers and HUD officials, and potentially lower development cost due to accurate targeting of locations requiring noise mitigation.

6 REFERENCES

1. U.S. Department of Housing and Urban Development. Title 24, Part 51 – *Environmental Criteria and Standards*. Washington, DC (24 CFR Subtitle A 4-1-04 Edition §51.101)
2. U.S. Department of Housing and Urban Development. *The Noise Guidebook*. Washington, DC: 1991. U.S. Government Printing Office.
3. British Standards Institution. *Code of Practice for Noise and Vibration Control on Construction and Open Sites*. London: BSI, 2008 (BS5228-1:2009)

Table 1- Tested Propagation Standards vs HUD @ 100 Effective Operations

| Propagation | Air Absorption | Temp. | 50' | 100' | 250' | 500' | 1000' |
|----------------|----------------|-------|------|------|------|------|-------|
| Gen Prediction | - | - | -0.8 | +0.2 | +1.1 | +1.6 | +1.7 |
| Method | | | | | | | |
| TNM | - | - | +0.9 | +1.9 | +3.2 | +3.3 | +1.1 |
| VDI 2714/2720 | - | - | -0.3 | +0.4 | -0.1 | +0.6 | +1.3 |
| VDI 2714/2720 | 3891 | 10C | -0.6 | -0.1 | -1.1 | -1.0 | -1.1 |
| VDI 2714/2720 | 3891 | 25C | -0.5 | -0.1 | -1.1 | -1.1 | -1.4 |
| VDI 2714/2720 | ANSI | 25C | -0.5 | 0.0 | -1.0 | -0.9 | -1.1 |
| VDI 2714/2720 | 9613 | 25C | -0.5 | -0.1 | -1.1 | -1.0 | -1.2 |
| VDI 2714/2720 | 9613 | 15C | -0.5 | -0.1 | -1.0 | -0.9 | -0.9 |
| Concawe | - | - | +2.9 | +4.0 | +4.9 | +3.8 | +1.4 |
| OAL 28 | - | - | -0.9 | 0.0 | +0.8 | +1.2 | +1.1 |
| DIN 18005 | - | - | -0.8 | 0.0 | +0.3 | +0.2 | -0.5 |
| Gewerbe | | | | | | | |
| BS 5228 | None | 10C | -1.5 | -0.9 | -0.9 | -0.9 | -1.2 |
| BS 5228 | None | 25C | -0.6 | 0.0 | 0.0 | 0.0 | -0.3 |
| BS 5228 | 9613 | 25C | -0.2 | +0.2 | -0.3 | -1.0 | -2.2 |
| BS 5228 | 3891 | 25C | -0.2 | +0.2 | -0.3 | -1.0 | -2.3 |
| BS 5228 | 9613 | 10C | -0.3 | +0.1 | -0.3 | -0.9 | -1.9 |