GEORGIA DOT RESEARCH PROJECT 14-15

FINAL REPORT

GDOT Noise Analysis Procedures

OFFICE OF PERFORMANCE-BASED MANAGEMENT AND RESEARCH
15 KENNEDY DRIVE
FOREST PARK, GA 30297-2534

GDOT Research Project No. 14-15

Final Report

GDOT NOISE ANALYSIS PROCEDURES

By
Dr. Robert Funk
Principal Research Engineer

Georgia Tech Research Institute
Aerospace, Transportation, and Advanced Systems Laboratory

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The primary objective of this project was the development of a Noise Analysis Procedures manual for Georgia Department of Transportation (GDOT) incorporating best practices from Federal Highway Administration (FHWA) and other states while addressing any GDOT specific procedures. The project consisted of three tasks – 1) Review of other state noise analysis guidance; 2) Development of GDOT Noise Analysis Procedures Manual; and 3) Development of a Frequently Asked Questions list addressing a number of repeating queries. The documents developed are described here and attached as appendices to the report.</td></tr>
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EXECUTIVE SUMMARY

Georgia Department of Transportation (GDOT) had identified the need for a definitive Noise Analysis Procedures Manual for GDOT projects to bring consistency to the analysis. The work under this project was conducted in a series of tasks leading up to a GDOT Noise Procedures Manual. The objectives of the program were to: (1) conduct a broad review of both national noise guidance/procedures and state procedures for those surrounding states with documented procedures manuals, (2) develop and document a modeling approach for Georgia, and (3) document the Georgia procedures and answers to frequently asked questions on noise analysis and abatement based on previous customer service inquiries.

Three tasks were done in support of these objectives. The first task was a review of other states noise guidance and/or procedures manuals to help establish best practices and guide the creation of a GDOT noise analysis procedures manual. The second task was to use the Federal Highway Administration (FHWA) guidance for operation of the Traffic Noise Model (TNM), test some examples in TNM, and document current GDOT procedures in a noise analysis procedures manual. The final task was to document a list of frequently asked questions gathered from GDOT and FHWA that can be used to answer many common questions on the topic for those going to the GDOT website. Task results are documented in this report, with the main results (the GDOT Noise Analysis Procedures Manual and Frequently Asked Questions list) included as appendices.

ACKNOWLEDGEMENTS

The author would like to gratefully acknowledge the work of Jonathan Gardner who was the student who did many of the TNM runs and research on other state policies.

INTRODUCTION

PROBLEM BACKGROUND

Georgia Department of Transportation (GDOT) had identified the need for a definitive Noise Analysis Procedures Manual for GDOT projects to bring consistency to the analysis. The GDOT Air/Noise Section recognized that although all Federal Highway Administration (FHWA) guidelines are followed in analyzing the traffic noise effects of transportation projects, the guidelines provide enough leeway to result in inconsistent project methodologies from one modeler to another. In some cases, these inconsistencies require analyses to be redone at the expense of project schedule and budget. FHWA had requested that GDOT develop a more uniform approach to alleviate this problem.

Presently there are different national approaches to establishing an acceptable noise model. Some states have developed modeling guidance to be used on all of their projects. GDOT would like to survey the best practices of other states as well as published validation of effects of modeling changes on TNM prediction accuracy to determine the "best fit" approach for Georgia. These "best fit" modeling standards would be defined in a GDOT Noise Procedures Manual to improve the consistency of analysis results and provide definitive guidance for the different modelers working on GDOT projects.

Additionally, GDOT staff has to respond to public inquiries about noise issues, many of which are similar questions. So GDOT would like to establish a webpage that includes not only the Noise Procedures Manual for consultants, but frequently asked questions (FAQs) and answers for the public. The webpage would have links to FHWA regulations and GDOT regulations, policies and noise evaluation process. It is envisioned that these webpages would give GDOT partners and customers ready access to answers to frequently asked questions regarding GDOT policies as well as the Noise Procedures Manual.

TRAFFIC NOISE MODEL (TNM)

The FHWA specifies use of their Traffic Noise Model (TNM) in all noise analysis for determining the effect of road projects on noise at receiver locations and determination of whether or not to implement noise abatement as part of the project. FHWA provides guidance on application of TNM (Ref 1), but there are some modeling choices allowed which may produce differing predictions.

In order to get more consistency in analysis, a number of states have developed more detailed guidance in the application of TNM for projects in their states. In each of these cases, the state provides more specific guidance than FHWA in some areas to ensure greater consistency in the project analyses they receive. Comparison of the recommendations in these guidance documents were used to form the basis for recommendations in the Georgia guidance developed under this project.

In making these recommendations, TNM validation studies were consulted to back up the various recommendations. FHWA has done some validation studies on TNM (Ref 2) comparing measured noise levels to those predicted by TNM. FHWA has also done comparisons on more specific variations. Ref 3 details the effect of pavement choice on the results computed with TNM. Additional studies have also been documented in the literature looking at various modeling assumptions in TNM and comparing measured results to TNM predictions. Ref 4 studies the traffic mix model used in TNM with measured traffic noise with a traffic blend skewed toward SUV's and pickup trucks. Ref 5 compares the noise height for heavy vehicles used in TNM modeling with measured noise heights from heavy vehicles and what effect that has on the prediction of noise wall effectiveness.

Task 1 of the project gathered more of the available documents in the open literature comparing TNM computed noise to measured noise and the effects of the modeling parameters in TNM.

OBJECTIVES

The objectives of the project were to:

1. Conduct a broad review of both national noise guidance/procedures and state procedures for those surrounding states with documented procedures manuals.
2. Develop a modeling approach for Georgia.
3. Document the approach in a Noise Analysis Procedures Manual.
4. Create a set of webpages documenting the Georgia procedures and answering frequently asked questions on noise analysis and abatement based on previous customer service inquiries.

RESULTS

SUMMARY

The work under this project was conducted in a series of tasks leading up to a GDOT Noise Procedures Manual.

The first task was an overview of procedures manuals from other states and recommendations published by FHWA. At the conclusion of this review a presentation was made to the GDOT Air and Noise Section detailing the findings and reviewing GDOT recommendations.

The second task involved conducting test runs with TNM and using the results to document procedures in the manual addressing things such as the number of lanes that can be combined in the modeling, the distances to which the model has to be run, the location of receivers and determination of benefited receivers. This modeling was combined with the GDOT noise policy and the GDOT Noise Assessment Template into a Noise Analysis procedures manual. The draft of the Noise Analysis Procedures Manual as of the date of the report is included in Appendix B. This manual represents a summary of the recommended analysis procedures and documentation of the noise study for Type I projects in Georgia.

A Type I project is a federally-funded roadway project that qualifies for a full noise impact assessment and the consideration of noise abatement to any noise impacts identified. The criteria to determine if a project is a Type I are as follows:

(1) The construction of a highway on new location; or,

(2) the physical alteration of an existing highway where there is either:

(i) Substantial Horizontal Alteration. A project that halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition; or,

(ii) Substantial Vertical Alteration. A project that removes shielding therefore exposing the line-of-sight between the receptor and the traffic noise source. This is done by either altering the vertical alignment of the highway or by altering the topography between the highway traffic noise source and the receptor; or,

(3) the addition of a through-traffic lane(s). This includes the addition of a through-traffic lane that functions as a (high occupancy vehicle (HOV) lane, High-Occupancy Toll (HOT) lane, bus lane, or truck climbing lane; or,

(4) the addition of an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

(5) the addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange; or,

(6) restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

(7) the addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot or toll plaza.

If any portion of a project is determined to be a Type I project under this definition then the entire project area as defined in the NEPA document is a Type I project.

The third task was to collect Frequently Asked Questions (FAQs) about noise analysis and noise walls to provide a resource for GDOT personnel, consultants and citizens. These questions are being organized into a webpage for reference. The questions collected from GDOT and other states are listed below as well as other possible questions that may be included in the future.

OVERVIEW OF OTHER STATES PRACTICES

The first task of the project was a review of policies and practices of other states in the analysis of traffic noise impacts of highway projects and the recommendations of FHWA in the application of TNM. At the kickoff meeting issues were raised as areas for TNM noise analysis procedures to address as shown in Table 1.

TABLE 1: ISSUES FOR NOISE ANALYSIS PROCEDURES TO ADDRESS

• Receiver locations
○ Locations for endpoints of walls
○ Location for outdoor spaces (parks, cemeteries, etc)
○ Selection of validation location
○ Inside vs outside receiver position for churches, etc.
• Outdoor space usage
• Guidance on using info about possible future projects in analysis (position of walls, etc.)
• Coordinating with policy on permits near project (ie how far back do you go)
• Peak traffic vs. level traffic for model

Initial guidance from GDOT was reviewed and publicly available noise analysis procedures and guidance manuals from other states were gathered and reviewed. References 8 – 17 list the state manuals that were used in this task. FHWA guidance on use of TNM was also used as a source to guide recommendations (References 6 and 7). A summary was prepared and presented to the Air and Noise Section at GDOT at a midterm meeting. A copy of the slides presented is included in Appendix A.

The initial guidance for Georgia was specified for certain issues shown in Table 2.

TABLE 2: INITIAL GEORGIA GUIDANCE

Issue	Guidance
How to handle noise in parks and public places (category C)?	Cemeteries, parks and other category C activities the number of receptors will be defined based on an equivalent number of residences of a lot size typical of the surrounding community will usually not extend beyond 500 feet from the project's proposed edge of pavement *(If needed, the area will be widened until to within 800 feet.)*
How to handle multilevel dwellings?	Each multi-level dwelling consisting of a single residential unit (e.g., two-story condo) is considered one receptor. For a multifamily dwelling, each floor is considered a receptor.
What is a feasible reduction?	Reduction in noise levels by 5 decibels (dB(A)) or more at one or more impacted sites.
How to handle interior noise?	Structures that are communal areas = one receptor Structures that are private areas (e.g. hospital patient rooms or) = 1 receptor per room Indoor analysis shall only be done after exhausting all outdoor analysis options.

The GDOT guidelines included the requirements of the FHWA and many of the key points documented by the other states guidance. However, the other states seem to go into more detail about a number of the topics discussed including handling of multilevel dwellings and interior noise. The significance of some of those details are arguable, but leaves no room for ambiguity. A number of states have feasibility measures based on percentage of receptors effected as opposed to a specific number of receptors effected. Virginia requires a 5dB reduction for 50% of affected receptors for a project to be considered feasible, while South Carolina requires a 5dB reduction for 75% of affected receptors for a project to be considered feasible. Oregon has a section named "Noise Standards" that summarizes Federal noise policy acts that are referenced throughout the document and included report guidelines for all three types of projects. South Carolina has an extensive section included in the introduction that defines traffic noise and its origins, as well as the difference between a preliminary is and detailed noise analysis. South Carolina also included a few TNM input parameters with examples. Florida has a detailed section on feasibility factors that include those in the Georgia document but also including right-of-way, drainage, and utility.

Suggestions for additions to the Georgia manual presented at the meeting included:

- For resident equivalence *consider* using the equation used by South Carolina and Kentucky (Equivalent # Residents = # Occupants/(# People/Residence) * Usage). This may provide a more accurate estimation.
- Add diagram(s) for interior noise/exterior noised standards
- Add images for clarification, examples, and references
- Include information about calibration periods/cycles of the instruments
- Include more details of standards for measuring periods
- Include more details of standards for traffic count (maybe a table for an example of one traffic count report)
- Include the FHWA "Table 7" for interior noise

After discussion, the equivalent number of residents calculation was rejected for use in the Georgia analysis.

DEVELOPMENT OF THE GDOT NOISE ANALYSIS PROCEDURES MANUAL

After reviewing other states documents and the FHWA recommended practice, a GDOT Noise Analysis Procedures Manual was constructed. Using FHWA guidance, test runs were done with

TNM and the results were used to document procedures in the manual addressing things such as the number of lanes that can be combined in the modeling, the distances to which the model has to be run, the location of receivers and determination of benefited receivers. This modeling was done with TNM 2.5 which was the current version at the time of the project. This modeling was combined with the GDOT noise policy and the GDOT Noise Assessment Template provided by the Air & Noise Section into a Noise Analysis procedures manual. The noise procedures manual was iterated with GDOT resulting in the draft manual included here as Appendix B.

FREQUENTLY ASKED QUESTIONS

The final task was to develop a list of frequently asked questions (FAQs) and answers to address many of the questions that are fielded by GDOT from the public regarding noise barriers. A set of questions was gathered using input from GDOT on the queries that have been answered in the past and also from FHWA and other states on noise barrier questions. The list of questions was provided in a document included here as Appendix C.

The initial program envisioned a web page constructed from the frequently asked questions. Surveying other sections on the GDOT website showed that several had links to download pdf documents including lists of FAQs. The GDOT website was being updated at the time of the project and it was suggested that the Air and Noise section add the developed FAQs to their GDOT website section page as it was updated to retain consistency with the layout and formatting of the site.

RECOMMENDATIONS

The Noise Analysis Procedures Manual was based on TNM Version 2.5 which was the current version at the time of preparation. Version 3 has been in preparation for a number of years and the procedures will have to be checked once it becomes the standard for analysis.

The Frequently Asked Questions list is also subject to update and additions. The Air and Noise section should be able to add and update the answers as needed.

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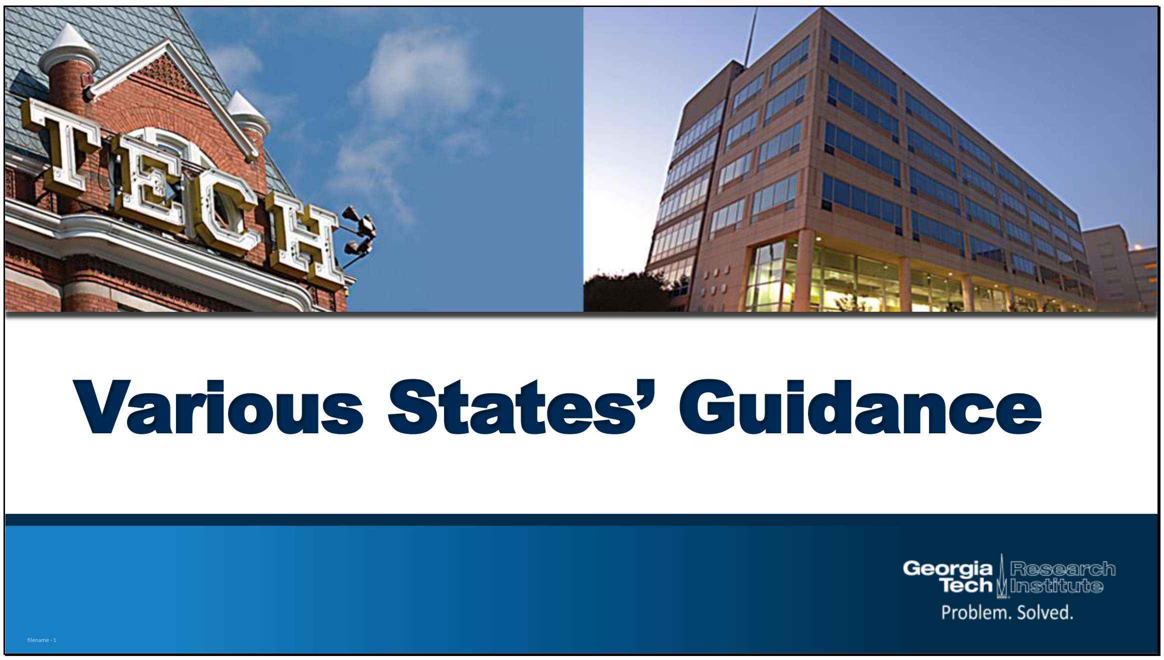
APPENDICES

APPENDIX A – GUIDANCE FROM OTHER STATES PRESENTATION

Slide 1



Slide 2

Georgia: General Overview

Georgia Tech Research Institute

How do they handle noise in parks and public places (category C)?
Cemeteries, parks and other category C activities the number of receptors will be defined based on an equivalent number of residences of a lot size typical of the surrounding community

will usually not extend beyond 500 feet from the project's proposed edge of pavement
(If needed, the area will be widened until to within 800 feet.)

How do they handle interior noise?
Structures that are communal areas = one receptor
Structures that are private areas (e.g. hospital patient rooms or) = 1 receptor per room
Indoor analysis shall only be done after exhausting all outdoor analysis options.

(The interior noise level will be determined by subtracting the exterior noise level from the appropriate building noise reduction factor provided in the Table 7 from the Highway Traffic Noise Analysis and Abatement policy (PDF 325KB))

How do they handle multilevel dwellings?
Each multi-level dwelling consisting of a single residential unit (e.g., two-story condo) is considered one receptor.
For a multifamily dwelling, each floor is considered a receptor.

How do they determine a feasible reduction?
Reduction in noise levels by 5 decibels (dB(A)) or more at one or more impacted sites.

Sampling Period
- Reading will be taken in a minimum of 15 minute increments.
- Traffic will be counted during the field noise reading and traffic speed will be estimated.
- Atmospheric conditions at the time of measurement will also be noted.

Slide 3

GDOT vs. Other States

Georgia Tech Research Institute

Overall, the **GDOT guidelines included the key points** as those for the other states and FHWA. However, the **other states seem to go into more detail** about a number of the topics discussed. The significance of some of those details **are arguable, but leaves no room for ambiguity**.

Oregon has a section "Noise Standards" that summarizes Federal noise policy acts that are referenced throughout the document.

South Carolina has an extensive section included in the introduction that defines traffic noise and its origins, as well as the difference between a preliminary is and detailed noise analysis.

Florida has a detailed section on feasibility factors that include those in the Georgia document but also including right-of-way, drainage, and utility.

A number of states have feasibility measures based on percentage of receptors effected as opposed to a specific number of receptors effected.

Oregon included report format guidelines for all three types of projects

South Carolina included a few TNM input parameters with examples

Slide 4

GDOT vs. Other States

Georgia Tech Research Institute

Suggestions for additions and alterations in addition to previous slide….

- For resident equivalence *consider* using the equation used by South Carolina and Kentucky (Equivalent # Residents = # Occupants/(# People/Residence) * Usage). This may provide a more accurate estimation.
- Add diagram(s) for interior noise/exterior noised standards
- Add images for clarification, examples, and references
- include information about calibration periods/cycles of the instruments
- Include more details of standards for measuring periods
- Include more details of standards for traffic count (maybe a table for an example of one traffic count report)
- Include the FHWA “Table 7” for interior noise

Slide 5

FHWA: Recommended Sampling Practice

Georgia Tech Research Institute

- minimum 30 minutes (3 repetitions of 10 minutes each)
- minimum 2 sets (1 in the morning, and 1 in the afternoon)
- recordings over 2 days period
- Identify unusual noise sources in the field documentation.
- A minimum of 10 seconds ambient levels should be sampled.

For different type of noise sources, follow the graph below.

Table 5. Sampling periods.

Temporal nature[16]	Greatest anticipated range		
	10dB	10 - 30dB	>30dB
Steady*	2 minutes	N/A	N/A
Nonsteady fluctuating	5 minutes	15 minutes	30 minutes
Nonsteady intermittent	For at least 10 events	For at least 10 events	For at least 10 events
Nonsteady, impulsive isolated bursts	For at least 10 events	For at least 10 events	For at least 10 events
Nonsteady, impulsive-quasisteady	3 cycles of on/off	3 cycles of on/off	3 cycles of on/off

* A minimum of three repetitions is recommended, with 6 repetitions being preferred.

Slide 6

FHWA: Recommended Sampling Practice

Georgia Tech Research Institute

Sound levels should be measured and/or recorded simultaneously with the collection of traffic data, including the logging of vehicle types, as defined below, vehicle-type volumes, and the average vehicle speed.

- Automobiles (A): All vehicles having two axles and four tires (gross vehicle weight < 4500 kg)
- Medium Trucks (MT): All cargo vehicles having six tires. (4500 kg < Gross vehicle weight <12,000 kg)
- Heavy Trucks (HT): All cargo vehicles having three or more axles. Gross vehicle weight > 12,000 kg
- Buses (B): All vehicles having two or three axles and designated for transportation of nine or more passengers.
- Motorcycles (MC): All vehicles having two or three tires with an open-air driver and/or passenger compartment.

Slide 7

FHWA: Receiver Positions

Georgia Tech Research Institute

Note: For receiver distances greater than 100 m (300 ft) from the source, atmospheric effects have a much greater influence on measured sound levels. In such instances, precise meteorological data will be needed to ensure BEFORE and AFTER equivalence of the meteorological conditions (See Section 3.2 of FHWA Measurement of Highway-Related Noise).

How do they handle interior noise?

- microphones are placed at 1.5 m (5 ft) above the floor of the interior location
- at least 1 m (3 ft) from any walls

(Measurements at several different heights and locations in the room are strongly recommended to achieve statistical precision.)

Building Type	Window Condition*	Noise Reduction Due to Exterior of the Structure
All	Open	10 dB
Light Frame	Ordinary Sash (closed)	20 dB
	Storm Windows	25 dB
Masonry	Single Glazed	25 dB
	Double Glazed	35 dB

*The windows shall be considered open unless there is firm knowledge that the windows are in fact kept closed almost every day of the year.

Source: FHWA Highway Traffic Noise: Analysis and Abatement Guidance. August 11, 2010.

Building Noise Reduction Factors

Slide 8

FHWA: Receiver Positions

How do they handle noise in parks and other Category C spaces?

Exterior measurement sites should have the following geometric characteristics:

- flat open space relatively free of large reflecting surfaces, within 30 m (100 ft) of the vehicle path or the microphones.
- The line-of-sight from microphone positions to the roadway unobscured within an arc of 150 degrees.
- The site to be located away from known noise sources, such as airports, construction sites, or rail yards.

Possible Exterior Receiver Position

Position 1:

- at least 3 m (10 ft) from the side of the building, at the same distance from the road as the front wall
- at a height of 1.5 m (5 ft) above ground level
- microphone is not shielded from the road by the building

Position 2:

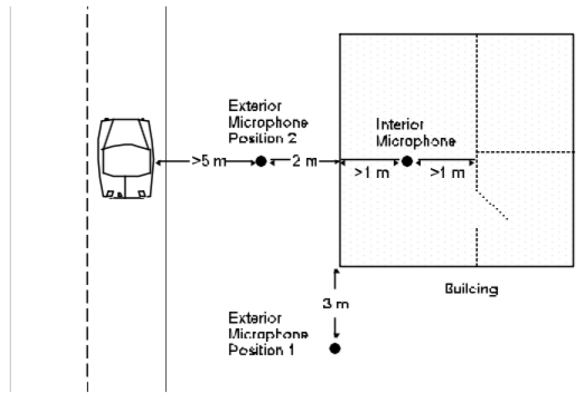
- no greater than 2 m (6.6 ft) from the facade, located on the roadway side of the building, at a point opposite the middle of the facade
- at a height of 1.5 m (5 ft) above ground level

(This setup is not recommended if the roadway facade of the building is within 7.5 m (25 ft) of the centerline of the near lane of traffic)

Slide 9

FHWA: Receiver Positions

Georgia Tech Research Institute



Interior and Exterior Positions diagram

Slide 10

Kentucky: Interior/Exterior Receptors

Georgia Tech Research Institute

How do they handle noise in parks and other Category C spaces?
Measurements are to be taken in exterior areas of frequent human use within 500 feet of the proposed edge of pavement.

(Structures lying totally beyond 500 feet shall not be counted as benefitted receptors
The number of persons shall be established through consultation with the school, church, day care, etc.)

How do they handle interior noise?
Interior readings are not required unless predicted exterior noise levels exceed the interior NAC by more than 10 dB(A).

For buildings with windows that are fixed closed, interior noise readings are not required unless the predicted exterior noise levels exceed the interior NAC by more than 20 dB(A).

(Interior readings are not required if exterior readings approach or exceed the NAC and thus abatement measures are already under consideration.
…additional measures follow the FHWA's "Measurement of Highway Related Noise")

Slide 11

Kentucky: Interior/Exterior Receptors

Georgia Tech Research Institute

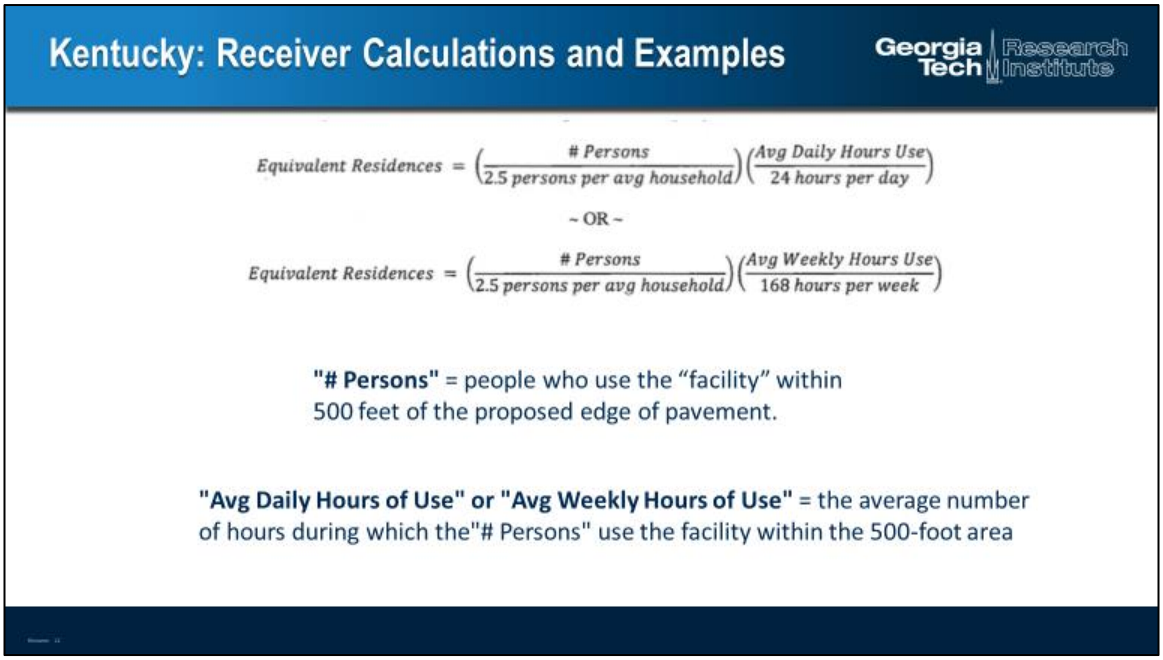
How do they determine a "feasible reduction"?
Feasible reduction: 5 dB or more for 50%
Noise reduction design goal: 7 dB(A) for a minimum of 40% of all benefitted receptors

How do they handle noise in residential spaces?
same for exterior spaces and interior noise criterion

How do they handle multilevel noise receptors?
confer with the KYTC Noise Specialist

Sampling Period
follow that of the FHWA

Slide 12


Kentucky: Receiver Calculations and Examples
Georgia Tech Research Institute
$Equivalent\ Residences = \left(\frac{\#\ Persons}{2.5\ persons\ per\ avg\ household}\right)\left(\frac{Avg\ Daily\ Hours\ Use}{24\ hours\ per\ day}\right)$
~ OR ~
$Equivalent\ Residences = \left(\frac{\#\ Persons}{2.5\ persons\ per\ avg\ household}\right)\left(\frac{Avg\ Weekly\ Hours\ Use}{168\ hours\ per\ week}\right)$
"# Persons" = people who use the "facility" within 500 feet of the proposed edge of pavement.
"Avg Daily Hours of Use" or "Avg Weekly Hours of Use" = the average number of hours during which the"# Persons" use the facility within the 500-foot area

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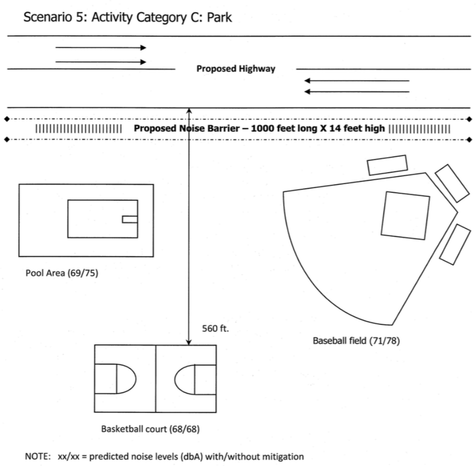
Kentucky: Receiver Calculations and Examples



The pool area Equivalent Residences could be calculated using the Average Daily Hours of Use equation.

The baseball area Equivalent Residences could be calculated using the Average Weekly Hours of Use equation

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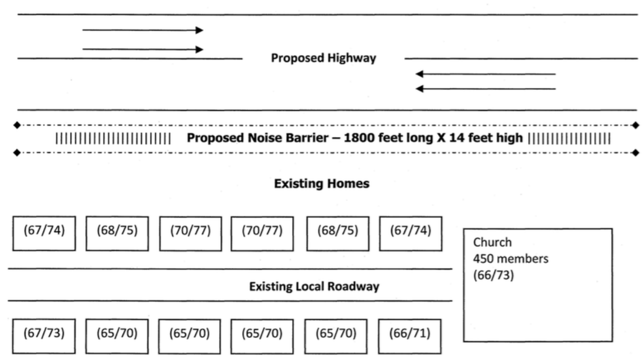
Kentucky: Receiver Calculations and Examples

Georgia Tech Research Institute

When evaluating **the church**, Equivalent Residences would be calculated using the Average Weekly Hours of Use equation.

For clarity, if the church offered a wide variety of services on various nights of the week, as well as multiple services on weekends to accommodate large congregations you may consider a use analysis similar to that of the park in Scenario #5.

Scenario 6: Activity Category C: Church in Residential Area



NOTE: xx/xx = predicted noise levels (dbA) with/without mitigation

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Florida: Receiver Positions

Georgia Tech Research Institute

How do they handle noise in parks and other Category C spaces?

- Primary placement of receptors are areas where frequent human use occurs.
- Secondary placement of the receptors in these cases will be dictated by the location of the noise source and the exterior activity that may be impacted, if any.

Sampling Period

Follows practices of the FHWA

NOISE ABATEMENT CRITERIA
[Hourly A-Weighted Sound Level-decibels (dB(A))]

Activity Category	Activity Leq(h)[1]		Evaluation location	Description of activity category
	FHWA	FDOT		
A	57	56	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B[2]	67	66	Exterior	Residential
C[2]	67	66	Exterior	Active sports areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreational areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	52	51	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E[2]	72	71	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F.
F	–	–	–	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing.
G	–	–	–	Undeveloped lands that are not permitted.

(Based on Table 1 of 23 CFR Part 772)

1 The Leq(h) Activity Criteria values are for impact determination only, and are not design standards for noise abatement measures.

2 Includes undeveloped lands permitted for this activity category.

Note: FDOT defines that a substantial noise increase occurs when the existing noise level is predicted to be exceeded by 15 decibels or more as a result of the transportation improvement project. When this occurs, the requirement for abatement consideration will be followed.

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Florida: Receiver Positions

How do they handle interior noise?

An interior analysis will only be performed after exhausting all outdoor analysis options, then consult the FHWA "Building Noise Reduction Factors"

How do they handle noise in residential spaces?

receptors are placed at the edge of the dwelling unit closest to the major traffic noise

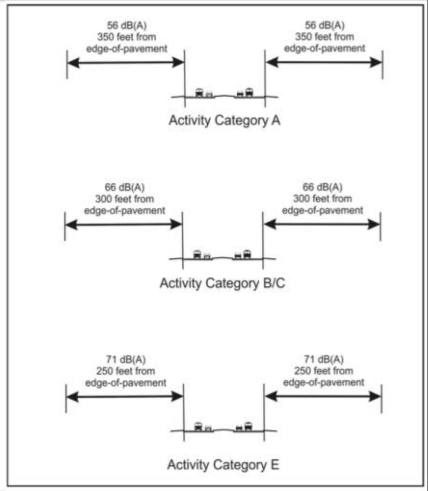
(When more than one unit is clustered together, a single receptor can be analyzed as representative of a group of noise sensitive sites.)

How do they handle multilevel noise receptors?

- First Floor: 5 feet above ground level
- Second Floor: 15 feet above ground level
- Third Floor and above: to be determined on a case by case basis

How do they determine a "feasible reduction"?

A "feasible reduction" is considered to be 5 dB or more



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Alabama: Overview

Georgia Tech Research Institute

How do they handle noise in parks and other Category C spaces?

Primary placement of receptors are areas where frequent human use occurs.

How do you handle interior noise?

Unspecified instructions aside from the fact that interior noise is neglected if the exterior NAC is met.

Noise Abatement Measures

1) Construction of noise barriers (excluding landscaping)
2) Traffic management measures (traffic control devices, prohibition of certain vehicle types, time-use restrictions, etc.)
3) Alteration of horizontal and vertical alignments
4) Noise insulation of Activity D land use facilities

How do they determine a "feasible reduction"?

Must be a 5dB reduction for 70% or more of the impacted receptors

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Alabama: Overview

Georgia Tech Research Institute

[Hourly A – Weighted Sound Level_decibels (dB(A))[1]]

Activity Category	Activity Leq(h)	Criteria[2] L10(h)	Evaluation Location	Activity Description
A	57	60	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B[3]	67	70	Exterior	Residential
C[3]	67	70	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, trails, and trail crossings.
D	52	55	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E[3]	72	75	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F.
F	....		....	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing.
G	....		....	Undeveloped lands that are not permitted.

[1] Either Leq(h) or L10(h) (but not both) may be used on a project.
[2] The Leq(h) and L19(h) Activity Criteria values are for impact determination only, and are not design standards for noise abatement measures.
[3] Includes undeveloped lands permitted for this activity category.

NOISE ABATEMENT CRITERIA

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South Carolina: Exterior/Impacted Receivers

How do they handle noise in parks and other Category C spaces?

Location of the receptor dependent on the noise source and mirrors practices of the FHWA

(Note: Active Sports Areas do not fall within the classification of non-residential uses. These areas are equivalent to one impacted residence.)

For non-residential uses and retirement homes, the following equation should be used to determine the equivalent number of impacted residents:

*Equivalent # Residents = # Occupants/(# People/Residence) * Usage*

# of Occupants = # of students in a school or the # of people in a congregation. For parks, an attempt should be made to contact the owner/operator of the park to estimate the average number of people that utilize the park.

# of People/Residence = Average number of people per residence as defined by the 2000 U.S. Census for the particular project area. For example the average number of people per occupied household for West Columbia, South Carolina is 2.13 according to the 2000 U.S Census. This should be rounded to 3 people per residence.

Usage = # of hours used per day/24 hours per day
If school is in session with children for 8 hours per day Usage = .33 (8 hours divided by 24 hours)

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South Carolina: Exterior

Georgia Tech Research Institute

How do they handle noise in residential spaces?

receptors are placed at the edge of the dwelling unit closest to the major traffic noise

(When more than one unit is clustered together, a single receptor can be analyzed as representative of a group of noise sensitive sites.)

How do they handle multilevel noise receptors?

- First Floor: 5 feet above ground level
- Second Floor: 15 feet above ground level
- Third Floor and above: to be determined on a case by case basis

Sampling Period

Follow practices of the FHWA

How do they determine a "feasible reduction"?

Must be a 5dB reduction for 75% or more of the impacted receptors

23 CFR, Part 772, Table 1 Noise Abatement Criteria (NAC)

Activity Category	Activity Criteria\2\		Evaluation Location	Activity Description
	Leq(h)	L10(h)		
A	57	60	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B\3\	67	70	Exterior	Residential
C\3\	67	70	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools , television studios, trails, and trail crossings
D	52	55	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios
E\3\	72	75	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F.
F	--	--	--	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing
G	--	--	--	Undeveloped lands that are not permitted

\1\ Either Leq(h) or L10(h) (but not both) may be used on a project.
\2\ The Leq(h) and L10(h) Activity Criteria values are for impact determination only, and are not design standards for noise abatement measures.
\3\ Includes undeveloped lands permitted for this activity category

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South Carolina: TNM Input Parameters

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Pavement: Use average pavement unless specified

Noise Contours: When using the Noise Contour function, users must ensure the grid spacing provides a sufficient resolution to provide good results and when using discrete receivers, the user must ensure the receivers are close enough together to enable relatively accurate extrapolation between receiver points. Noise Contours can only be used for project alternative screening or for land use planning purposes, NOT for determining highway traffic noise impacts.

Misc.: include elevation of the receivers, elevation of the roadways and shoulders

Traffic Conditions: when truck volumes and vehicle speeds are the greatest, and traffic is free flowing and at or near level of service. Also model at the highest traffic rates for a given season.

Speed limit: follow either the pavement's design speed or the road's speed limit according to which is higher.

Roadways: When a roadway consists of multiple lanes, each lane must be modeled as a separate roadway in TNM. A single TNM roadway that has an expanded width to account for the multiple lanes is not acceptable. The shoulders should be modeled in TNM 2.5 as a separate TNM roadway with no traffic.

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Virginia: General Overview

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How do they handle noise in parks and other Category C spaces?
exterior areas of frequent human use
500 feet of the proposed edge of pavement.
(assure that the instruments are calibrated once every two years)

How do they determine a "feasible reduction"?
Must be a 5dB reduction for 50% or more of the impacted receptors

Design goal: 7dB(A) of insertion loss for at least 1 impacted receptor

How do they handle interior noise?
Unspecified instructions aside from the fact that interior noise is neglected if the exterior NAC is met.

Indoor insulation of faculties are considered on a case-by-case basis, and follow the FHWA's Building Noise Reduction Factors table.

How do they handle noise in residential spaces?
In apartments, each unit is counted as one receptor and single family homes are counted as one receptor

(Future Dwellings: only noise abatement is only considered for the phases of construction in which builders has acquired a permit.)

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Missouri: General Overview

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Missouri's noise regulation guide:
http://epg.modot.mo.gov/index.php?title=127.13_Noise

MoDOT's program is designed to implement the FHWA Noise Standards

apply FHWA methods:
- How do they handle category c noise?
- How do they handle interior noise?
- How do they handle noise in residential spaces?
- How do they handle multilevel noise?

How do they determine a feasible reduction?

a minimum of 7 dBA for 67 percent of benefitted first-row receptors

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Oregon: Non-Residential Noise

Georgia Tech Research Institute

How do they handle noise in nonresidential places?
prediction sites are limited to frequently used outdoor areas

Examples:

commercial property: employee break area

parks, golf courses, schools, hospitals recreational areas: seating areas or congregating locations with at least one hour of activity

amphitheaters, auditoriums, public rooms, places of worship: similar to residential receivers the receptor
(outdoor use area that is between the structure and the ROW)

hotels and motels: outdoor swimming pool

Note: Sidewalks and parking lots are not considered frequently used.

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Oregon: Residential Noise

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How do they handle noise in residential spaces?
measurement sites are typically 15 feet from the face of the residence between the residence and the right-of-way.

(The prediction site is subject to change if the outside activity area is better represented by another location.)

Single family residences: the outdoor property immediately surrounding the residence
(When both front and back yards are present, the analyst should use the most conservative prediction location.)

Multi-level apartments: all levels should be modeled if they face the right-of-way

Generally sites should be located in the exterior frequently used area that is closest to the highway

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Oregon: General Information

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How do they determine a "feasible reduction"?

Must be at least a 5 dBA reduction

Sampling Period

Will be conducted according to FHWA procedures

Federal Highway Administration Noise Abatement Criteria—Oregon Department of Transportation Noise Abatement Approach Criteria Hourly A-Weighted Sound Level Decibels (dBA)

Activity Category	Activity Criteria[a] Leq (h)		Evaluation Location	Land Use Activity Description
	FHWA NAC[b]	ODOT NAAC[c]		
A	57	55	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where preserving those qualities is essential if the area is to continue to serve its intended purpose.
B[c]	67	65	Exterior	Residential
C[c]	67	65	Exterior	Active sports areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings
D	52	50	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios
E[c]	72	70	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties, or activities not included in A–D or F
F	—	—	—	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing
G	—	—	—	Undeveloped lands that are not permitted

[a] The Leq(h) Activity Criteria values are for impact determination only and are not design standards for noise abatement measures.

[b] Federal Highway Administration noise abatement criteria

[c] Oregon Department of Transportation noise abatement approach criteria

[c] Includes undeveloped lands permitted for this activity category

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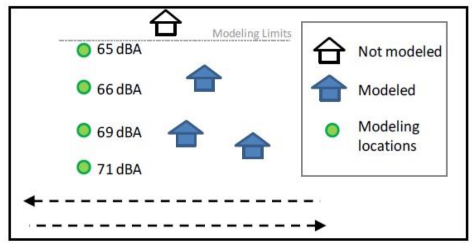
Washington State: Exterior Noise

How do they handle noise in parks and public places (category C)?

All outdoor frequent human use areas.

(The noise study area must be large enough to include all receptors between the project limits that may experience traffic noise impacts, including non-residential land uses described in the NAC Table.)



Exterior Modeling Example Layout

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Washington State: Interior Noise

How do they handle interior noise?

communal interior space nearest the traffic noise source

(An indoor analysis shall only be done after exhausting all outdoor analysis options, determined on a case-by-case basis.)

Exhibit 7: Noise Abatement Criteria (NAC) by Land Use Category

Activity Category	$L_{eq}(h)$* (dBA) at Evaluation Location	Description of Activity Category
A	57 (exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67 (exterior)	Residential (single and multi-family units)
C	67 (exterior)	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools , television studios, trails, and trail crossings
D	52 (interior)	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E	72 (exterior)	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F. Includes undeveloped land permitted for these activities.
F	-	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing
G	-	Undeveloped lands that are not permitted

**$L_{eq}(h)$ are A-weighted (dBA) hourly equivalent steady state sound levels used for impact determination and are not design standards for abatement.*

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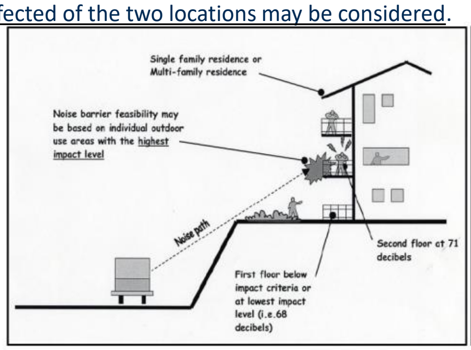
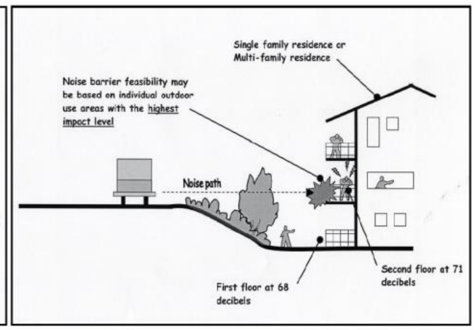
Washington State: Multilevel Dwellings

How do they handle multilevel dwellings?

If a balcony seems to be the only area of frequent use, and is also large enough to contain a chair, then the receptors will be placed slightly above that unit's ground floor.

If the unit has an individual outdoor use area and a shared/common outdoor use area, the more affected of the two locations may be considered.





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Washington State: First Row/ Second Row

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“First Row”/ “Second Row” Breakdown

Identify the first row of receivers from an aerial perspective. If traffic noise impacts are identified, additional modeled receivers may need to be added to the model to provide sufficient information for determining the feasibility of abatement. In most situations, first row receivers are the nearest receivers to the roadway along the entire length of the project. On some projects, first row receivers in one location may be further from the highway than 2nd/3rd row receivers in other locations in the same neighborhood. Identify the first row of receivers from the front and appropriate sides of the buildings. In most situations, the first row receiver should have a direct line of sight to traffic. At times, traffic noise from elevated roadways on fill or naturally elevated topography does not impact receivers within the descending noise shadow, but instead impacts second or third row receivers with a more direct line-of-sight to vehicles traveling along the roadway. For these situations, the first row of receivers with a direct line-of-site to the roadway shall be counted as the “first row” per the feasibility criteria. If receivers that are not closest to the roadway are being considered first row receivers, justification shall be documented.

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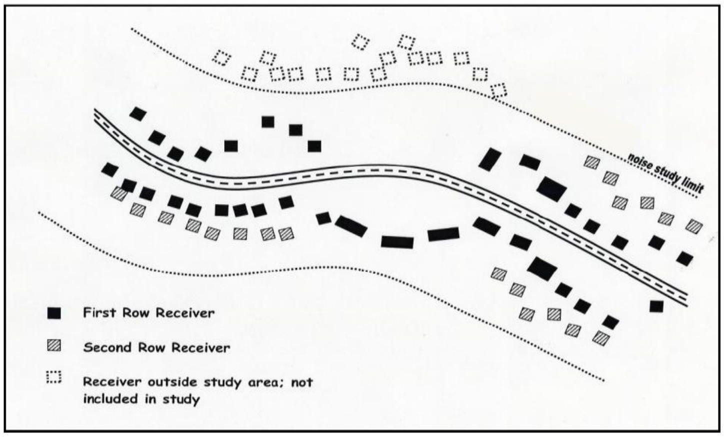
Washington State: First Row/ Second Row

Georgia Tech Research Institute



First Row/ Second Row Aerial View

How do they determine a feasible reduction?

Majority first row impacted receivers must obtain a minimum 5 dBA of noise reduction

The minimum design goal for abatement is at least 7 dBA of reduction for one receiver. *(Noise walls cannot be recommended if they do not achieve the design goal.)*

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APPENDIX B - GDOT NOISE PROCEDURES MANUAL

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Georgia Department of Transportation Traffic Noise Modeling Guidance Manual

(Georgia Tech Research Institute – 8/10/17)

Table of Contents

Introduction

The Georgia Department of Transportation (GDOT) uses the latest version of the Federal Highway Administration (FHWA) approved program, Traffic Noise Model (TNM) 2.5. This software is used to analyze sound levels due to traffic and the effects that various noise abatement projects would incur. TNM 2.5 operations are set in various embedded protocols. This document is intended to absolve common uncertainties that rise when using TNM 2.5, as well as cover common recommended practices that ought to be followed regarding noise analysis retrieval and related methods. Additionally, there are templates provided in the appendices of this document. Although every aspect of TNM 2.5 is not covered in this manual, the aspects that *are* covered facilitate the modeling process in providing common practices and methods to be observed across GDOT TNM modeling analyses.

This guide is based on the TNM modeling guidelines developed in the 2014 *Guidance for Noise Modeling Using FHWA's Traffic Noise Model (TNM) on Projects in Washington State*, the 2006 *Colorado Department of Transportation TNM Users Guide*, the 2011 *Federal Highway Administration's Traffic Noise Model (FHWA TNM®) User's Guide*, the FHWA's *23 CFR 772*, and the *FHWA Measurement of Highway-Related Noise (FHWA-PD-96-046).* The modifications within this manual were made in order to customize the modeling procedures for the Georgia traffic environment.

Definitions and Acronyms

The definitions below may vary from the definitions contained in 23 CFR 772.5 as they have been refined to disclose established criteria for use in Georgia.

CAD: Computer-aided drafting	dB(A): A-weighted decibels
DDHV: Directional Demand Hourly Volumes	DEM: Digital Elevation Model
DHV: Design Hourly Volumes	DTM: Digital Terrain Model
DXF: Drawing Exchange Format (a file CAD file format)	EROS: Earth Resources Observation and Science
FHWA: Federal Highway Administration	GDOT: Georgia Department of Transportation
HCM: Highway Capacity Manual	HDM: Highway Design Manual
HOT: High-Occupancy Toll	HOV: High Occupancy Vehicle
Ifsar: interferometric synthetic aperture radar	L_{Aeq}: A-weighted equivalent sound level
Leq(h): Hourly Equivalent Sound Level	LiDAR: light detection and ranging
LOS: Level-of-Service	NAC: Noise Abatement Criteria
NAVD 88: North American Vertical Datum of 1988	NBOT: Noise Barrier Optimization Tool
NEPA: National Environmental Policy Act	SHA: State Highway Association
SPCS: State Plane Coordinate System	TIN: Triangulated Irregular Network
TNM: Traffic Noise Model	

Benefited Receptor: The recipient of an abatement measure that receives a noise reduction at or above the minimum threshold of 5 dB(A).

Common Noise Environment: A group of receptors within the same Activity Category in Table 1 of 23 CFR 772 (page 7 of this document) that are exposed to similar noise sources, noise levels, traffic volumes, traffic mix, traffic speed, and topographic features.

Generally, common noise environments occur between two secondary noise sources, such as interchanges, intersections, or cross-roads.

Design Year: The future year used to estimate the probable traffic volume for which a highway is designed. Georgia highways are typically designed to function for 20 years beyond the year a project is opened to traffic.

Existing Noise Levels: The worst noise hour resulting from the combination of natural and mechanical sources and human activity usually present in a particular area.

Feasibility: The combination of acoustical and engineering factors considered in the evaluation of a noise abatement measure.

Impacted Receptor: The recipient that has a traffic noise impact.

L10: The sound level that is exceeded 10 percent of the time (the 90th percentile) for the period under consideration, with L10(h) being the hourly value of L10.

Leq: The equivalent steady-state sound level in which a stated period of time contains the same acoustic energy as the time-varying sound level during the same time period, with Leq(h) being the hourly value of Leq.

Multifamily Dwelling: A residential structure containing more than one residence. Each residence in a multifamily dwelling shall be counted as one receptor when determining impacted and benefited receptors.

NEPA Document: The CE, FONSI or ROD as defined in 23 CFR 771.

Noise Abatement Criteria: A numerical impact criteria issued by the FHWA, published in 23 CFR 772:

23 CFR, Part 772, Table 1 Noise Abatement Criteria (NAC)
[Hourly A-Weighted Sound Level decibels (dBA)\1\]

Activity Category	Activity Criteria\2\		Evaluation Location	Activity Description
	Leq(h)	L10(h)		
A	57	60	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B\3\	67	70	Exterior	Residential
C\3\	67	70	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools , television studios, trails, and trail crossings
D	52	55	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios
E\3\	72	75	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F.
F	--	--	--	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing
G	--	--	--	Undeveloped lands that are not permitted

\1\ Either Leq(h) or L10(h) (but not both) may be used on a project.

\2\ The Leq(h) and L10(h) Activity Criteria values are for impact determination only, and are not design standards for noise abatement measures.

\3\ Includes undeveloped lands permitted for this activity category

Noise Barrier: A structure that is constructed between the highway noise source and the noise sensitive receptor(s) that lowers the noise level, including stand-alone noise walls, noise berms (earth or other material), and combination berm/wall systems.

Noise Reduction Design Goal: The optimum desired dB(A) noise reduction determined from calculating the difference between future build noise levels with abatement, to future build noise levels without abatement. The noise reduction design goal shall be at least 7 dB(A), but not more than 10 dB(A). *[GDOT has selected a design goal of 7 dB(A)].*

Permitted: A definite commitment to develop land with an approved specific design of land use activities as evidenced by the issuance of a building permit.

Property Owner: An individual or group of individuals that holds a title, deed, or other legal documentation of ownership of a property or a residence.

Reasonableness: The combination of social, economic, and environmental factors considered in the evaluation of a noise abatement measure.

Receptor: A discrete or representative location of a noise sensitive area(s), for any of the land uses listed in Table 1 of 23 CFR 772 (page 7 of this document).

Residence: A dwelling unit. Either a single family residence or each dwelling unit in a multifamily dwelling.

Substantial Construction: In Georgia this is defined as the granting of a building permit, prior to approval of the NEPA document.

Substantial noise increase: One of two types of highway traffic noise impacts. For a Type I project, an increase in noise level of 15 dB(A) in the design year over the existing noise level is considered substantial.

Traffic Noise Impacts: Design year build condition noise levels that approach or exceed the Noise Abatement Criteria (NAC) listed in Table 1 of 23 CFR 772 (page 7 of this document) for the future build condition; or design year build condition noise levels that create a substantial noise increase over existing noise levels. A noise level which approaches the NAC is defined as 1 dB(A) less than the applicable NAC value.

Type I Project:

(1) The construction of a highway on new location; or,

(2) the physical alteration of an existing highway where there is either:

> (i) Substantial Horizontal Alteration. A project that halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition; or,
>
> (ii) Substantial Vertical Alteration. A project that removes shielding therefore exposing the line-of-sight between the receptor and the traffic noise source. This is done by either altering the vertical alignment of the highway or by altering the topography between the highway traffic noise source and the receptor; or,

(3) the addition of a through-traffic lane(s). This includes the addition of a through-traffic lane that functions as a (high occupancy vehicle (HOV) lane, High-Occupancy Toll (HOT) lane, bus lane, or truck climbing lane; or,

(4) the addition of an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

(5) the addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange; or,

(6) restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

(7) the addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot or toll plaza.

If a project is determined to be a Type I project under this definition then the entire project area as defined in the NEPA document is a Type I project.

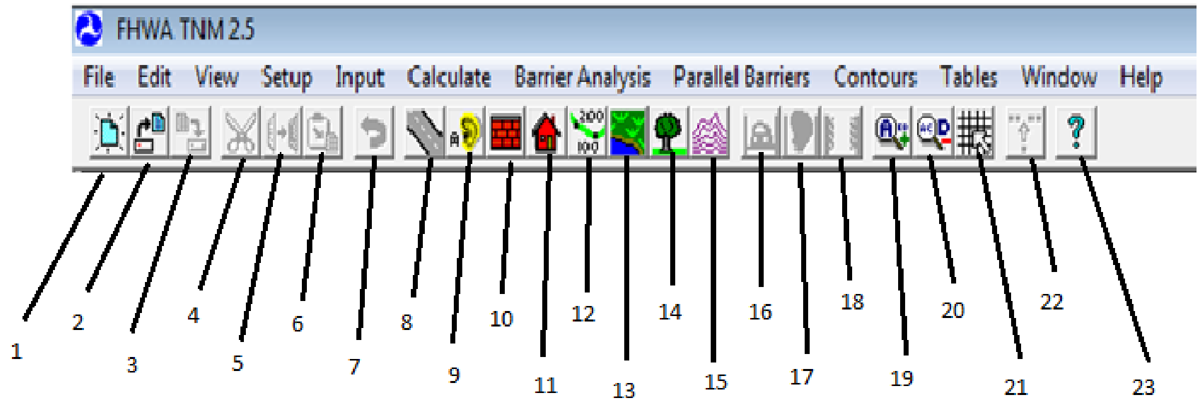
Type II Project: A federal or federal-aid highway project for noise abatement on an existing highway. GDOT does not have a noise abatement program for Type II projects.

Type III Project: A federal or federal-aid highway project that does not meet the classifications of a Type I or Type II project. Type III projects do not require the preparation of a noise study or abatement of highway noise impacts.

Validation: Process of verifying the accuracy of the traffic noise model inputs by measuring noise levels in the field and comparing the measured levels to the noise levels predicted in the model under the same traffic conditions. Having field-measured compared to computed levels within +/- 3 dBA will be considered to have a valid model.

TNM 2.5 Toolbar

The Toolbar near the top of the program window provides shortcuts for the user to operate more smoothly in TNM 2.5. The meanings of each icon can be seen below.



1. Create New Run

2. Open Previously Saved Run

3. Save Current Run

4. Cut Selection

5. Copy Selection

6. Insert Clipboard Contents

7. Undo (one time only)

8. Create new Roadway

9. Create new Receiver

10. Create new Barrier

11. Create new Building Row

12. Create new Terrain line

13. Create new Ground Zone

14. Create new Tree Zone

15. Create new Contour Zone

16. Create new Parallel Barrier Roadway

17. Create new Parallel Barrier Analysis Location

18. Create new Parallel Barrier Cross-Section

19. Zoom In on Current View

20. Zoom Out on Current View

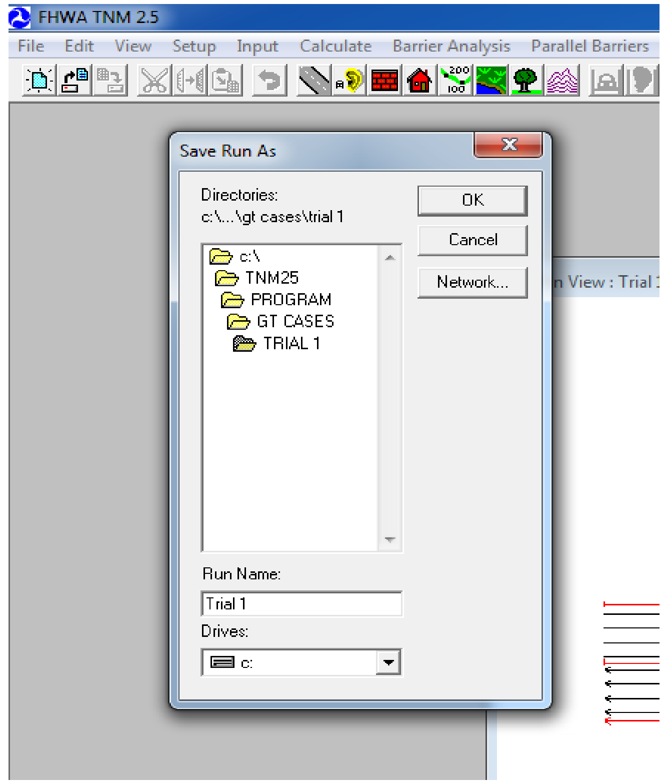
21. Snap to nearest Object in Current View

22. Interpolate Z coordinates in Roadway Profile View

23. Help Topic for Current Dialog or View

File

To open a file go to File > Open. Be sure that the path and run name do not exceed 87 characters. This is something to consider when saving a new document. To save a file go to File > Save As. When you save a file, TNM saves it to a folder that is the same as the project/file name. Within that folder TNM creates your project in two separate files. One file is a ".dat" file and the other is an ".idx" file. When transferring these files, it is imperative to move the entire folder.



Importing Stamina Files

If you have files you used in STAMINA and are now using TNM, then you can import those files at File > Import > STAMINA-2.0 Input Files. The import routine will create a terminal error when it tries to import certain formats, such as user entered emission factors. Also, the file name in the header of the Stamina file may need to be shortened to avoid causing an error in TNM. Also be sure to always check "Import Shielding Factors".

Importing DXF Files

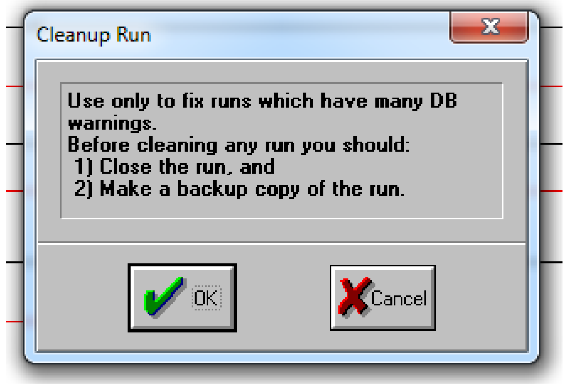
TNM software has an internal CAD model that is similar to AutoCAD 2000. Thus, CAD programs can be used to create your project's roads and barriers. After you have modeled your project parts in CAD, be sure to turn off all layers and information that is not going to be imported into TNM. Export the file to DFX format. Different layers should be divided into separate DXF files. It is easier for TNM to recognize only the pertinent information for that file. Note that there can be complications with this method. Arcs are often brought into TNM as straight lines, and sometimes with chords (line segments connecting the end of the arc) that are too long. TNM does not bring in DXF point objects, and TNM does not have any kind of raster display capability.

Printing

Printing in TNM can be adjusted by adjusting the margins and the scaling of the axis tick marks.

Cleanup Run

In the midst of computations, “DB error” messages may appear. These are common, due to internal third-party software complications. To bypass a great amount of errors that prevent TNM from computing,



the CLEANUP RUN feature can be used. To access this feature, go to File > Cleanup Run.

Edit

When you have a segment in your Plan view, this menu allows you to select a segment or segments and quickly alter them. This menu is self-explanatory for the most part. You can add points in more detailed fashion by opening your Roadway, Receiver, Barrier, Building Rows, Terrain Line, Ground Zone, or Tree Zone windows and selecting Insert Row or Append Row. You can also delete specific points by selecting Delete Row.

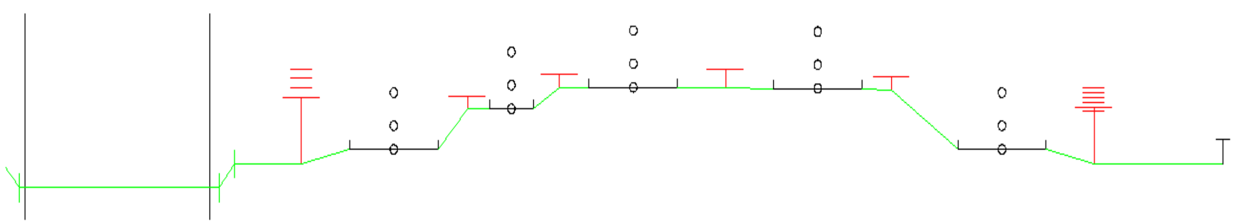
View

Show/Hide

Here you can enable or disable certain labels to appear in your Plan View, Perspective View and Barrier View (explained later in this document). This is useful when printing certain views and quickly identifying objects.

Skew Section

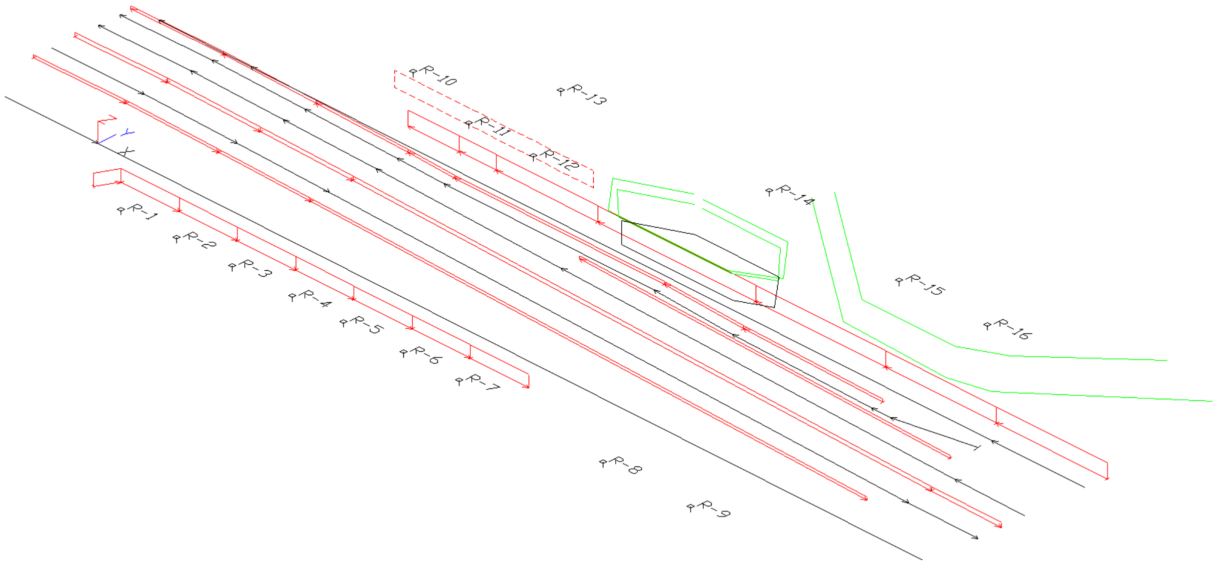
Skew Section is a good view to have for seeing the width, separation and elevations of roads and barriers and other TNM objects. In order for something to be viewed in the Skew Section window, the full section of the segment must be in the Plan View window. If you zoom out and then draw the cross section, then the Skew Section will be displayed. For quick panning, you can left-click and drag your mouse across the Skew Section view screen.



Perspective View

In this view, the TNM model can be seen in a 3-D plane. This is great way to see the relation between objects in space. To rotate, pan, and zoom the view you can select the action you desire in the Edit menu. Note that you can also use keyboard controls to rotate and pan. If you uncheck the DXF background then you can navigate across the screen faster. You can find this under the "Show Objects" tab in the View pull-down menu. You can re-check after you've found the view you desire. In fact, checking certain boxes under the "Show Text" column within the "Show/Hide" window can serve to be a more efficient way to troubleshoot different problems. It would be advised to use these various views to check your model before calculating results or conducting a barrier analyses.

rotate	Ctrl + up/down/left/right
pan	up/down/left/right



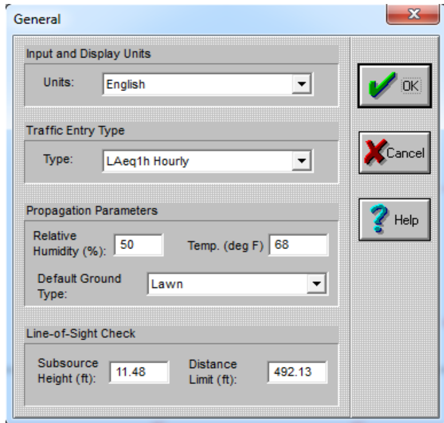
Setup Menu

In this section you can set default values and parameters for your project, along with general information for documentation and record keeping.

Run Identification

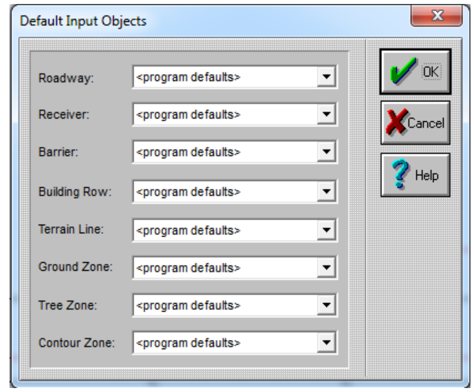
This window gives documentation to the title of the project, the sub name of the project, the company that is doing the analysis and the individual(s) within the company who conducted the analysis. If the “Popup Help” box is checked, Skew Section views would be stalled by way of popup windows.

General



This window is important in setting the standards for the units and other project specifics. GDOT will use English units when conducting any TNM analysis. For GDOT sound level will be found in the A weighted, one-hour equivalent sound level, L_{Aeq}(1h). Do not alter the Propagation Parameters without GDOT consent. Line-of-sight check is more focused on visibility effects rather than audible effects so do not worry about the Line-of-Sight parameters.

Default Input Objects



In this window you can set custom defaults for different input types. Although this is an option, it is not necessary because TNM has set defaults already for new runs. For example, **Receivers** have the following default criterion: 1 Dwelling Unit; 4.92 feet for Height Above Ground; 0 dB(A) for Existing Sound; 8 for noise reduction goal; 66 for noise impact criterion; 10 dB(A) for substantial impact criterion. For GDOT projects, set the Height Above Ground to 5 feet, and the Noise Reduction Goal to 7 dB(A) and substantial impact to 15 dB(A). 66 dbA for residential and 71 for non-residential NAC.

Input

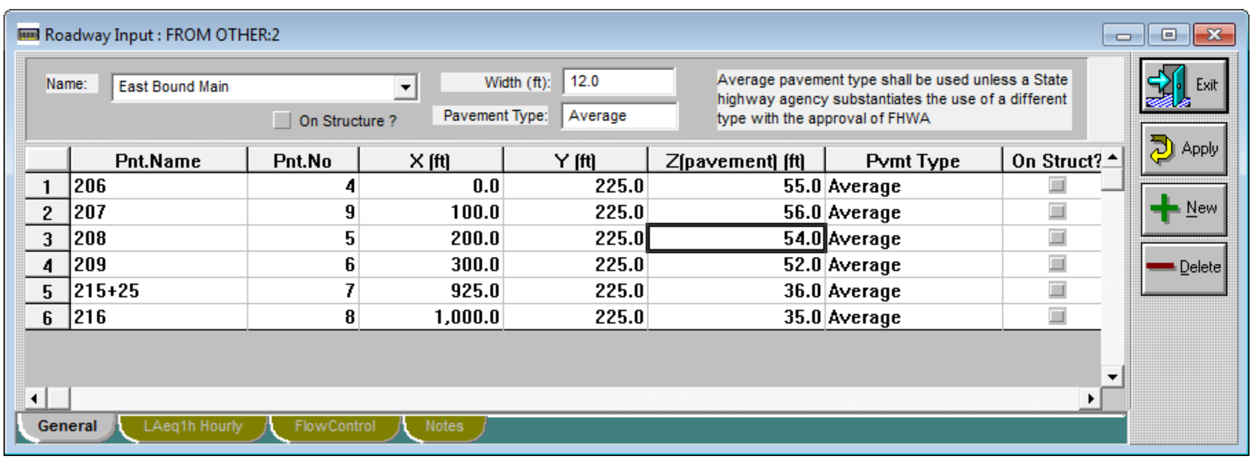
User Defined Vehicles

Noise levels are closely related to the emission levels of each vehicle at various speeds. TNM contains default emission factors for five vehicle types: *autos, medium trucks, heavy trucks, buses, and motorcycles.* Both FHWA require the use of the default TNM noise emission factors at this time. And so user-defined vehicles should not be modeled without consultation with and approval from GDOT and FHWA.

Roadways

To add a Roadway, go to Input > Roadways. This will open a grey window with subcategories “Name”, Width (ft)”, and “Pavement Type”. Roadways are added as points that are connected by a series of line segments. In order to have a roadway to model, you must create at least two points in the Roadway Input window. Points are added by “Inserting” and “Appending” rows. To create your first, have your Roadways Input window active. Then go to Edit > Insert Row. This will create only a point, but not a segment. From there to add a second point, and every point thereafter go to Edit > Append Row. To delete a point go to Edit > Delete Row. Every change in the roadway’s geometry will be shown in red. If you are happy with the changes, you can select the “Apply” button on the right side of the window. If you are unhappy with the changes, simply select the “Exit” button. If you are unhappy with the entire roadway, you can delete the entire roadway by selecting the “Delete” button. To add a new roadway, select the “New” button.

A shortcut to adding Roadways is the icon that is on the upper toolbar . Upon selecting this icon, a cursor will appear. The cursor will allow you to select the approximate location of where you desire the point of your road segments to be, along with their connecting lines. Meaning, left-clicking two points will create a one-segment road. Three points will create a two-segment road, and so on until you right-click. Right-click will exit this mode and return you to the normal idle status to begin your next command in the TNM program.



You can rename the roadway in the “Name” field. Ideally, you should choose a nomenclature that is specific and consistent throughout the entirety of the project. Specifics to include should be the actual name of the roadway and its direction (e.g. 1-75 N).

As far as **length** is concerned**,** roadways should extend beyond the last receivers located within the project’s study area by at least five times that from the roadway centerline to the receptors located at the edge of the study area. For example, if a roadway is 300 feet from the last receiver, the Roadway must extend 1,500 feet past the last receiver.

The **On Structure** box does not always have to be checked. A roadway can be elevated on piers, on fills, or partial fills. These fills can act as a barrier. If it is actually on a structure, sound can pass under the elevated roadway and it no longer acts as a barrier. This is only necessary when there is a roadway either under or behind it. If your road fits the On Structure criterion, then you can translate that in TNM by checking On Structure boxes for the corresponding end points of that road segment in TNM. Only check beginning points of segments on structure. Note that checking On Structure boxes for a line segment does by default not raise the entire roadway.

Be mindful of the **width** of the road that you are modeling. The default setting in TNM is 12 feet. However, if your road is not 12 feet, change the road width to that which is measured of that specific road. This includes **shoulders and paved medians**, which you should model as a roadway with no traffic. According to *FHWA-PD-96-009*, "*When you set roadway widths, do not try to avoid overlap or to exactly match up edges of parallel roadways. Instead, try to actually guarantee overlap, so that TNM does not insert an unwanted gap in the roadway pavement. In addition, (1) set the width of the right-most roadway to approximate the right edge of pavement, and (2) set the width of the left-most roadway to approximate the left edge of pavement. You do not have to be overly precise in locating these pavement edges. Plus or minus 3 m (10 ft.) is precise enough [within 10 ft. of the actual position of the edge of the pavement, to allow for coarseness of the TNM modeling software].*"

As far as **combining** roads is concerned, it is recommended that you do not combine any roadways when modeling TNM roadways. However, if occasion arises that you must combine any roads, GDOT recommends that you combine no more than 2 lanes. When combining roads be sure to apply the correct L_{Aeq1h} in the corresponding window that is attached as a tab in the Roadway Input window. (Meaning, if combining two roads into one, then be sure to combine the traffic volumes as well.) Yet again, do not neglect shoulders, which you model as a roadway with no traffic. Since they are a hard surface pavement type similar to that of the actual roadways, GDOT suggests that you model them as roads with no traffic. Be sure to model each travel lane separately when receptors are located below the elevation of the highway. Also model individual lanes when there are any intervening objects in the sound propagation path that block the line of sight between the roadway and receiver.

When modeling roads in TNM, **traffic distribution** across the lanes ought to be accurately represented. Sometimes the true traffic distribution is not uniform across lanes. And so, when doing preliminary TNM modeling it is not necessary to model non-uniform traffic if there are less than 12 lanes. However for the final stage design, the following guidelines can be followed (as suggested by the FHWA in their *Recommended Best Practices for the Use of the FHWA Traffic Noise Model* manual):

- The facility is 8 general-purpose lanes or more;
- Sound propagation occurs over soft ground;
- There is a high percentage of heavy trucks in the vehicle mix (20% or more)

- The freeway is either elevated or depressed, such that intervening terrain blocks the line of sight between any number of lanes and receivers of interest

Concerning the **Pavement Type**, it is imperative that you use “Average” Pavement Type for all TNM runs. FHWA recognizes the possibility for varied pavement types now and in the future. However, for uniformity in tests, FHWA policy requires that “Average” Pavement Type be used in modeling.

The **L_{Aeq} Hourly** tab takes you to the page that allows you to adjust the speed and traffic volume. You are allowed to input *automobiles, medium trucks, heavy trucks, buses, and motorcycles.* When inputting the values in this page, make sure to use the worst-case hour values. If you have no vehicles of a specific type, just put zero for its values. When inputting the speed, make sure to use the actual speed posted. If you use any different speed, make sure it is approved by GDOT and documented for future purposes.

When you are on the L_{Aeq} Hourly tab, each segment in that road is separately modifiable. To save on time, you can select the “Copy All” button and all of the values for that segment will be copied to every segment in the road.

Barriers

When modeling barriers in TNM 2.5, there are two ways that you can input barriers: fixed height and perturbable height. In the *General* tab you can decide if your barrier section will be perturbable or fixed. To make it perturbable, select non-zero value for your “Increment”, “#Up”, and “#Down” values. If you want it to be a fixed barrier, then set your “#Up” and “#Down” values to zero, and your “Increment” value to a non-zero value.

Privacy fences are not to be modeled as barriers since their noise abatement is so low. Also, if there is one standing large building that is not a part of a building row, then that building can be modeled as a fixed barrier. Note that TNM will produce an error if a barrier overlaps a road. Also, do not model berms with a flat top (i.e. the “Top Width” must be set to zero).

If you have a median, shoulder safety barrier, parapet wall, or crash barrier, these are to be set as fixed barriers with no perturbation values.

As far as barrier points are concerned make sure that they are at most 200 feet apart on level surfaces. This is so as to allow for more accuracy in possible changes in elevation. On surfaces with changing elevations, make sure that the barrier points are no more than 100 feet apart. This restriction is for the same reason stated in reference to the 200ft restriction above. There is no apparent restriction on the minimum distance between barrier points.

When inputting berms, make sure that the bottom of the berm does not interfere with a roadway. If it does then it will read back an error. The width to height ratio of berms needs to be a minimum of 3 to 1.

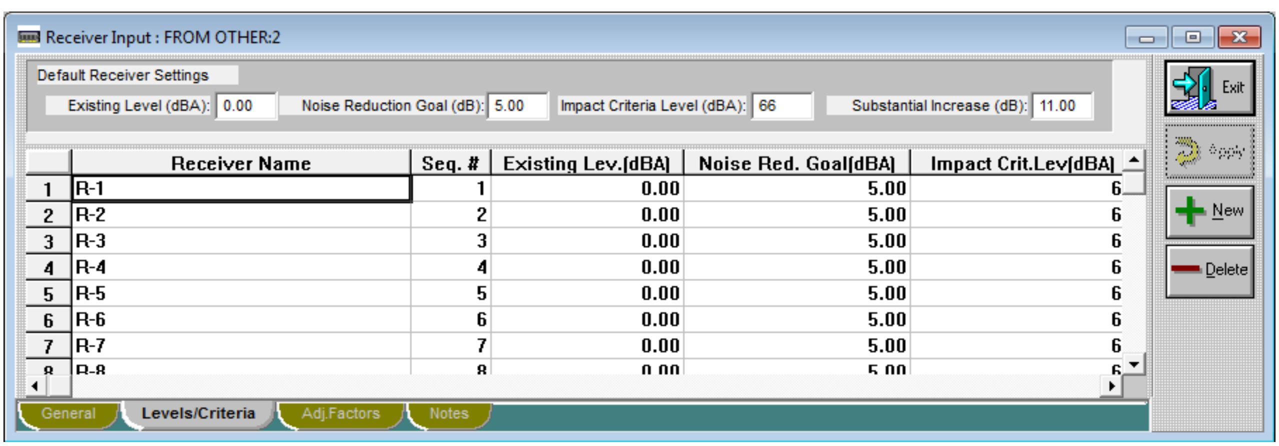
When putting a wall on a berm, keep in mind that the wall-on-berm feature in TNM does not work properly. If modeling an existing wall-on-berm combination, use the base of the wall to define the top of the berm and terrain lines to define the bottom of the berm. In this case, it is worth recognizing that the wall can be perturbed, but the berm must be fixed.

TNM allows you to measure sound reflections off of a single barrier unto the opposite side of the road. To do this, model the barrier as well as a receiver on the opposite side of the road. Then run the sound analysis and the results on that specific receiver will deliver the sound reflection experienced.

Receivers

All receivers should be modeled in accordance with the 2015 GDOT Highway Noise Abatement Policy. Be sure to set the Dwelling Units appropriately, and set the Height Above Ground to 5 feet if it is not already 5 feet. Do not change the adjustment factors unless it’s been approved by GDOT.

The Levels/Criteria page is where you can adjust specifics concerning the receivers. As stated in the “Setup Menu” section, receivers have the following default criterion: 1 Dwelling Unit; 4.92 feet for Height Above Ground; 0 dB(A) for Existing Sound; 8 dB(A) for noise reduction goal; 66 for noise impact criterion; 10 dB(A) for substantial impact criterion. For GDOT project, set the Height Above Ground to 5 feet, and the Noise Reduction Goal to 7 dB(A), and 15 dB(A) for substantial impact criterion, 66 for noise impact criterion for residential and 71 for noise impact criterion for non-residential.



23 CFR, Part 772, Table 1 Noise Abatement Criteria (NAC)
[Hourly A-Weighted Sound Level decibels (dBA)\1\]

Activity Category	Activity Criteria\2\		Evaluation Location	Activity Description
	Leq(h)	L10(h)		
A	57	60	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B\3\	67	70	Exterior	Residential
C\3\	67	70	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools , television studios, trails, and trail crossings
D	52	55	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios
E\3\	72	75	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F.
F	--	--	--	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing
G	--	--	--	Undeveloped lands that are not permitted

\1\ Either Leq(h) or L10(h) (but not both) may be used on a project.

\2\ The Leq(h) and L10(h) Activity Criteria values are for impact determination only, and are not design standards for noise abatement measures.

\3\ Includes undeveloped lands permitted for this activity category

Receiver Locations

Category A

The FHWA must approve a land use as Activity Category A before a noise analysis on an Activity Category A is initiated. Activity Category A land uses are analyzed at this stricter standard even if the land use is identified within an activity category with a higher NAC. For this reason, placement of Category A receivers are determined on a case-by-case basis. (e.g. Tomb of the Unknown Soldier) Category A receivers are very rare.

(Note: Appendix A provides example field-data log sheets, and Appendix B feasibility and reasonableness log.)

Category B

Receivers for these spaces should be placed at approximately 6.6 feet from the edge of the dwelling unit closest to the major traffic noise. It is also acceptable by FHWA standards to place a representative receiver at least 10 feet from the side of the building, at the same distance from the road as the front wall. Receivers are primarily to be placed at places of the most activity. Examples of these activity areas would include picnic areas, residential playgrounds, and pools. If there is an area of frequent activity that is further from the road than the front of the house, such as a pool in the backyard, then a receiver should be placed at the location closer to the roadway. If there is only a single structure unit, like a house, then that is considered one unit. If there is a multilevel residential development such as a two- story condo, then that is considered one unit. If there is a multifamily residential development such as an apartment, then each residential unit is considered as one receptor. For those units, the area of most frequent outdoor use is to be measured per floor. However, if there is more than one common use area for a floor of units, then the more active of the possible areas should be considered for receiver placement. In the case of a mixed building with business and residential areas sharing the same building, then the business is considered one receptor and each residential unit is considered to be one receptor.

The height of the receivers are as follows:

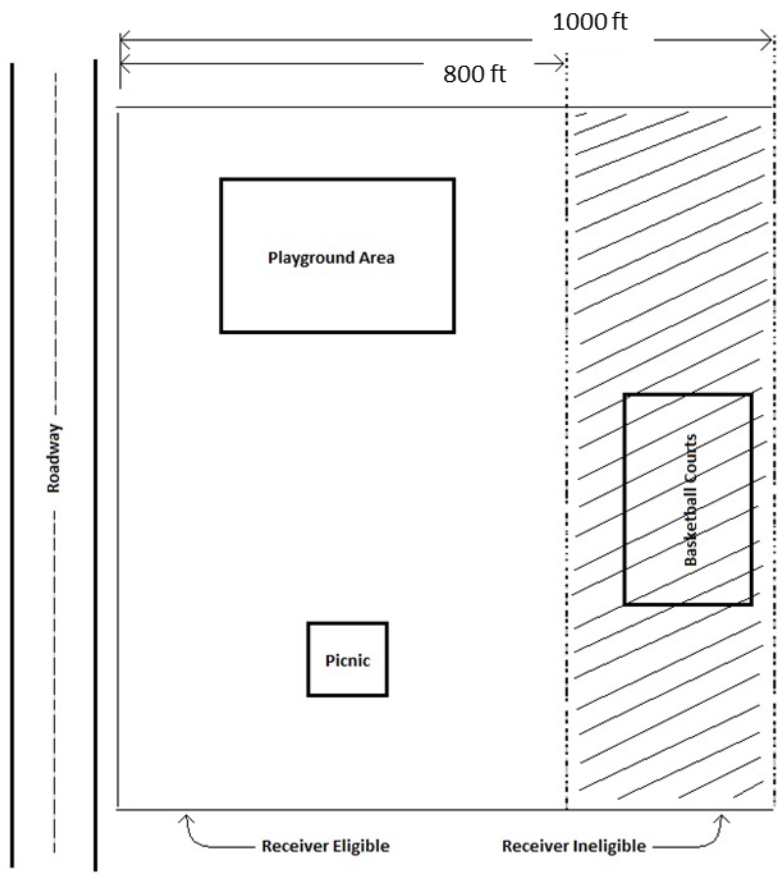
- First Floor: 5 feet above ground level
- Second Floor: 15 feet above ground level
- Third Floor and above: to be determined on a case by case basis

Analysis needs to include higher floors until there is no impact.

(Note: Appendix A provides example field-data log sheets, and Appendix B feasibility and reasonableness log.)

<u>Category C</u>

In the case of Category C applications, an outdoor analysis will be done regardless of the noise conditions of the interior properties. The receiver limits of Category C spaces is 800ft from the edge of pavement, or wherever impacts cease. Within this limit, the receivers are to be placed at the areas of frequent human use. Secondary placement of the receptors in these cases will be dictated by the location of the noise source and the exterior activity that may be impacted, if any. For example, consider a park that is 2,000ft X 1000ft with 2,000ft frontage. Within the park is a picnic area and a playground. At the edge furthest from the park are basketball courts. In this scenario, a receiver would be placed at the picnic area and the playground. However, no receiver would be placed at the basketball courts because they are outside of the 800ft boundary. Additionally, no other place in the park holds justification for measurement unless it is clear that another place in the park is an area of frequent human use. A diagram of this example can be seen below.



For cemeteries, parks, and other expansive Category C activities, the number of required receptors will be determined as follows: 1) determine the typical linear highway frontage of residences in the surrounding community; and 2) divide the proposed highway frontage length of the Category C site by the amount determined in step 1 above with any remainder counting as an additional receptor. For example, if the typical residential frontage in the surrounding community is 150 feet and the proposed frontage of a public park is 200 feet, the park would be counted as two receptor sites. (Note: Appendix A provides example field-data log sheets, and Appendix B feasibility and reasonableness log.)

Category D

In the case of Category D applications, an indoor analysis will be done regardless of the noise conditions of the exterior properties. Each structure generally will be considered one receptor site for discrete areas of frequent human use such as libraries, public meeting rooms, etc. Hospital patient rooms or classrooms that lack air conditioning and must open windows to cool will be considered one receptor per room. Put receivers at front door of building or closest edge of structure.

According to the FHWA *Highway Traffic Noise Analysis and Abatement Policy*, interior noise level predictions may be computed by subtracting from the predicted exterior levels the noise reduction factors for the building in question. If field measurements of these noise reduction factors are obtained or the factors are calculated from detailed acoustical analyses, the measured or calculated reduction factors should be used. In the absence of such calculations or field measurements, the noise reduction factors may be obtained from the following table:

**The windows shall be considered open unless there is firm knowledge that the windows are in fact kept closed almost every day of the year.*

Table 7: Building Noise Reduction Factors

Building Type	Window Condition	Noise Reduction Due to Exterior of the Structure
All	Open	10 dB
Light Frame	Ordinary Sash (closed)	20 dB
	Storm Windows	25 dB
Masonry	Single Glazed	25 dB
Masonry	Double Glazed	35 dB

(Note: Appendix A provides example field-data log sheets, and Appendix B feasibility and reasonableness log.)

Category E

This activity category includes the exterior impact criteria for developed lands that are less sensitive to highway noise. Each structure will generally be considered one receptor for the purpose of disclosure; however, in cases of single structures housing multiple commercial units, each commercial unit having an exterior area of frequent human use will be considered a separate receptor for abatement consideration (e.g., a strip mall with no exterior uses would be considered one receptor, and a strip mall of multiple commercial units only two of which have exterior uses would be considered two receptors.) In addition, for properties in this category that contain residential units (e.g. hotels), each room where sleep will occur (e.g. hotel room) with a balcony or ground level patio will be considered one receptor. Place receivers on edge of use (i.e. bench or table). (Note: Appendix A provides example field-data log sheets, and Appendix B feasibility and reasonableness log.)

Category F

According to FHWA-HEP-10-025, Activity Category F includes a number of land uses that are not sensitive to noise. No noise analysis is required for these locations, but may be included in noise modeling analyses for informational purposes only. (Note: Appendix A provides example field-data log sheets, and Appendix B feasibility and reasonableness log.)

Category G

TNM modeling would be completed for vacant parcels at 50 feet from the proposed edge of pavement or the right of way line (analyst must disclose which was used), at 100 feet, and at every additional 100 feet (not to exceed 800 feet) until a zone is established that would identify the impact zone for all land use types. Noise analyses performed for Category G properties will only be used to define distances for design year noise levels corresponding to each NAC.

If vacant land is not permitted by the date of public knowledge, the noise level information will be provided to appropriate local government office for planning purposes in accordance with 23 CFR 772.17(a). Permitted, undeveloped land will be assigned an activity category consistent with the permitted future land use and evaluated under that activity category. The date of public knowledge is the date the NEPA document is approved. Per 23 CFR 772.11(vii)(C)federal participation in noise abatement measures will not be considered for lands that are not permitted by the date of public knowledge. (Note: Appendix A provides example field-data log sheets, and Appendix B feasibility and reasonableness log.)

Building Rows

Building Rows contribute to the abatement of noise from receivers that are behind each building row. When modeling the building row, do not stress over the gaps between houses. TNM does not calculate the gaps. Focus more on the following factors: **Average Building Height** can be modeled as 10 feet for a single story building, and 10 feet per story for a multi-story building. Building elevation is also very important, as this can alter your values if there are elevated roads. Try to be within an accuracy of 4 feet for the initial studies, and 2 feet for the final design. **Building Percentage** refers to the amount of space that the building row blocks. So if you have a 300 ft. space with a row of buildings that collectively block 150 ft., then the Building Percentage is 50%. If a building row takes up more than 80% of the available space, after consultation with GDOT you may model the building row as a fixed barrier (in the Barrier window). If you try to input a Building Row with more than 80% Building Percentage, or less than 20% Building Percentage, then you will receive an error that will not allow you to continue until the value is within these constraints. If less than 20% don't model it. When finding the spacing for Building Rows, try to ensure that it is within ±10% accuracy.

Terrain Lines

Terrain Lines are used to show variations in elevation in terrain such as hills, valleys, etc. Typically, Terrain Lines are a curved portion of land elevations. However, since TNM does not draw curved lines, the Terrain Lines must be a series of line segments. For more precision, increase the number of segments you have added to depict the curved portion.

To **input** Terrain Lines, the same process as what is outlined in the *Roadways* section is followed here. A shortcut to adding Terrain Lines is the icon that is on the upper toolbar. This does not give a good amount of precision to the positioning of your Terrain Lines, but this can be adjusted in the *Terrain Line Input* window (Input > Terrain Line). A great way to check the varied elevation of your Terrain Line inputs is to open a Skew Perspective (View > New View > Skew Section).

Accuracy should be considered when modeling your Terrain Lines. Try to ensure that the elevation of the terrain is accurate to within 5 feet of accuracy.

Ground Zones

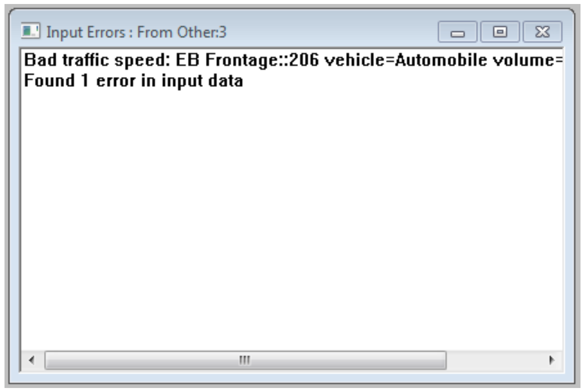
The Ground Zones change based on effective flow resistivity. The effective flow resistivity fluctuates with each ground type. The default setting for TNM is lawn grass. When changing the pavement, TNM gives you the options of water, hard soil, pavement, etc. DO NOT MODEL TREES AS A GROUND ZONE (there is a *Tree Zone* input section). Other than from noise model validation runs, the use of tree zones is not accepted for use on GDOT projects.

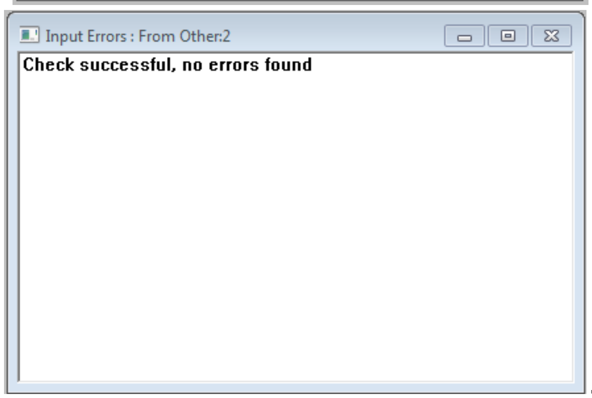
Contour Zones

TNM has difficulties modeling noise contours and FHWA policy states the following on contours: “TNM allows the user to model contour zones. However, calculating noise contours with TNM greatly increases run time. It is strongly recommended that this feature of TNM only be utilized for land-use planning activities and/or performing screening analyses to determine the number of impacted receivers in an area.” It is recommended that you do not make TNM contour lines unless it is approved by GDOT.

Calculations

Selecting “Input Check” will allow you to see if the model has any errors in the roadway elevations. However, TNM will not be able to check issues in receiver elevation, barriers, building rows, terrain lines, or tree zones. If there is an error, you we see a screen similar to that on the left. If there is not an error, a screen like the one on the right will be displayed.





As a tip, you can calculate the sound results and check for error at the same time by going to ***Calculate > Current Run > All Receivers.***

Barrier Analysis

Barrier Analysis allows you to breakdown the effects of specific barriers and alters their parameters. In order to start a new barrier analysis, you have to first select at least one barrier and at least one receiver. You can do this by holding *shift* and clicking on each object and then selecting New Barrier Analysis. “Remember” and “Remember As” work similar to the “Save” and “Save As” feature in other programs. Selecting “Remember As” creates a new Barrier Analysis file with a new name. To change the height of the barrier you can select a barrier section and hold *shift+Up/Down*. In order to select the entire barrier, you can double click any section of the barrier. To switch between barrier segments, click the *left* or *right arrows* while holding *shift*.

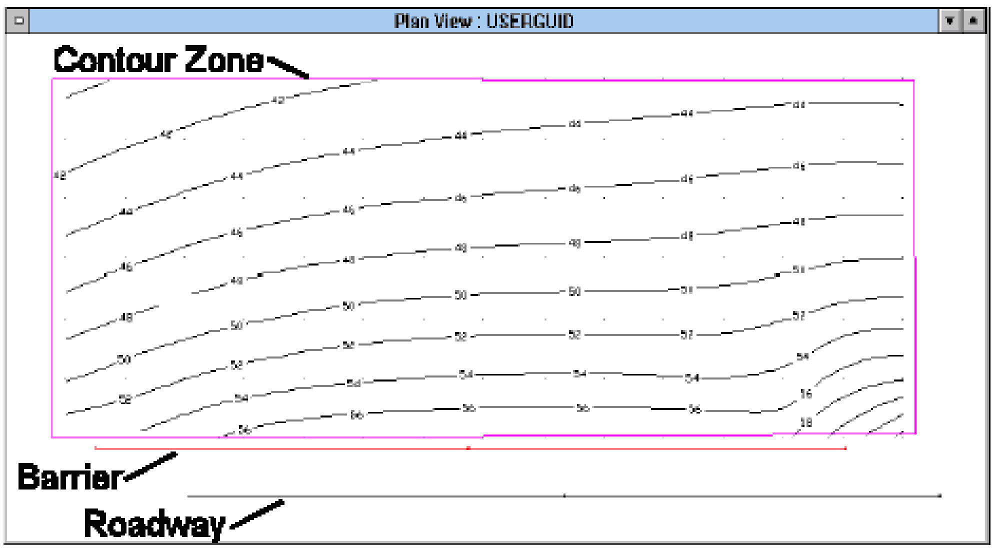
Parallel Barriers

When Barriers are built in close parallel to each other, noise can bounce between the walls, affecting the noise reduction efforts for the barrier setup. Studies have suggested that to avoid a reduction in the performance of parallel reflective noise barriers, the width-to-height ratio of the roadway section to the barriers should be at least 10:1. The width is the distance between the barriers, and the height is the average height of the barriers above the roadway. This means, that two parallel barriers 10 feet tall should be at least 100 feet apart. Accordingly, it is recommended that parallel plane surfaces not be modeled with TNM unless the width-to-height ratio of the surfaces is less that 10:1

(note that modeling parallel plane surfaces greatly increases TNM run time). A reference for further discussion on parallel barrier modeling may be found in National Academies of Sciences, Engineering, and Medicine. 2014. *Supplemental Guidance on the Application of FHWA's Traffic Noise Model (TNM)*. Washington, DC: The National Academies Press. https://doi.org/10.17226/22284, Chapter 12 – Parallel Barriers.

Contour

FHWA asserts the fact that the run time of the model increases when contour zones are included. For this reason, FHWA suggests, "this feature only be utilized for land-use planning activities and/or performing screening analyses to determine the number of impacted receivers in an area."



Tables

This pull-down menu is where you can see your result and inputs. The **Input** selection allows you to see what parameters you've set for that run (excluding ground type).

Test Analysis

Test 1: Varied Roadway Length

In modeling roadways in TMN V2.5, states such as Washington State and Oregon have adopted a policy stating that roadways should be modeled to extend at least four times the distance from the last receiver to the roadway centerline. In this case, the roadway centerline would be the middle red line marked “divider”.

To test the necessity of this modeling, we can place identical receivers on a path line parallel to the roadway and then vary the length of the modeled roadway. The constant or varied dB(A) results will be enough to recognize the effects of this modeling method.

The parameters of this test are as follows and are outlined in the images below:

- No barrier, but only three 1.5m dividers
- A 4-lane highway with shoulders
- No road elevations or receiver elevations

Each roadway now has the following type of flow traffic (shoulders are modeled as normal roadways with zero flow traffic).

	Vehicle Type	Veh/hr	Speed (mph)
1	Auto	1020	60.00
2	Medium Truck	150	60.00
3	Heavy Truck	50	60.00
4	Buses	10	60.00
5	Motorcycle	20	60.00

Default Receiver Settings

Dwelling Units: 1   Height Above Ground (ft): 5.00

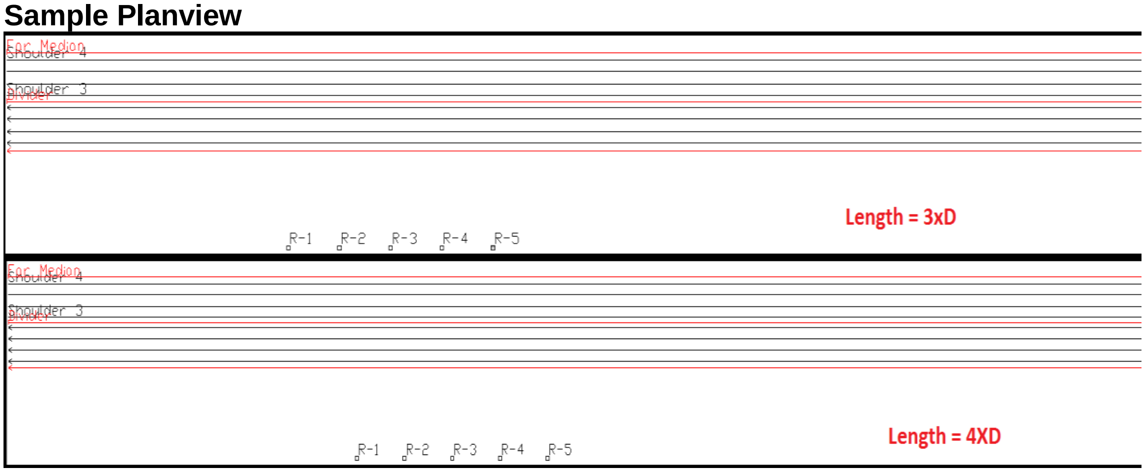
	Receiver Name	Seq. #	X (ft)	Y (ft)	Z(ground) (ft)	Dwelling Units	Height (ft)
1	R-1	1	200.00	110.00	0.00	1	5.00
2	R-2	2	260.00	110.00	0.00	1	5.00
3	R-3	3	320.00	110.00	0.00	1	5.00
4	R-4	4	380.00	110.00	0.00	1	5.00
5	R-5	5	440.00	110.00	0.00	1	5.00

Default Receiver Settings

Existing Level (dBA): 0.00 | Noise Reduction Goal (dB): 5.00 | Impact Criteria Level (dBA): 66 | Substantial Increase (dB): 11.00

	Receiver Name	Seq. #	Existing Lev.(dBA)	Noise Red. Goal(dBA)	Impact Crit.Lev(dBA)	Sub.Increase(dBA)
1	R-1	1	0.00	5.00	66	11.00
2	R-2	2	0.00	5.00	66	11.00
3	R-3	3	0.00	5.00	66	11.00
4	R-4	4	0.00	5.00	66	11.00
5	R-5	5	0.00	5.00	66	11.00

Sample Planview



The results are as follows where "D" is the distance from the road to the receiver (values given in dB(A)):

	Road End to Last Receiver				
	1xD	**2xD**	**3xD**	**4xD**	**5xD**
Receiver 1	68.5	69.1	69.3	**69.5**	69.5
Receiver 2	68.9	69.2	69.4	**69.5**	69.5
Receiver 3	69.1	69.3	69.4	**69.5**	69.5
Receiver 4	69.2	69.4	69.4	**69.5**	69.5
Receiver 5	69.3	69.4	69.4	**69.5**	69.5
Total Noise	345	346.4	346.9	**347.5**	347.5

According to this trial, extending the road four times the distance from the road to receivers give the most accurate results without leaving any noise from the road unaccounted for.

Test 2: Combining Roads

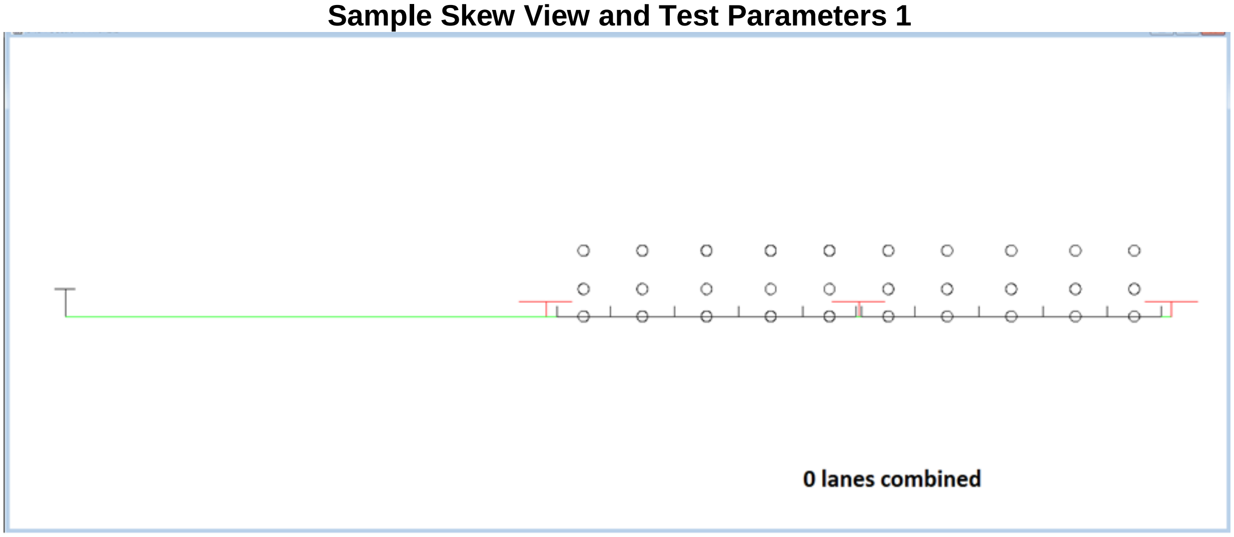
Combing roadways in TNM are a great way to save on time in modeling. However, there have been questions as to if this technique yields inaccurate noise values. Many states limit themselves to combining no more than two roads. This test will inspect the validity of results in combing even only two roads.

To test this, we set up five identical receivers at equal distances from the roadway. We calculated the noise produced from not combining any lanes. We then calculated the noise produced from combining two lanes in each direction, then again until there was only one massive lane for each direction. It is important to change the Flow Control parameters proportionally as lanes are combined. Meaning, the traffic volume of two lanes combined to one lane ought to modeled as twice as dense as one lane that was not a combined lane, and three lanes ought to be three times as dense as one lane that was not a combined lane.

The parameters of this test are as follows and are outlined in the images below:

- No perturbable barrier, three 5 ft. dividers
- A 6-lane highway with shoulders
- No road elevations or receiver elevations

Sample Skew View and Test Parameters 1



Name: Roadway13

Segment:

	Vehicle Type	Veh/hr	Speed (mph)
1	Auto	1020	60.00
2	Medium Truck	150	60.00
3	Heavy Truck	50	60.00
4	Buses	10	60.00
5	Motorcycle	20	60.00

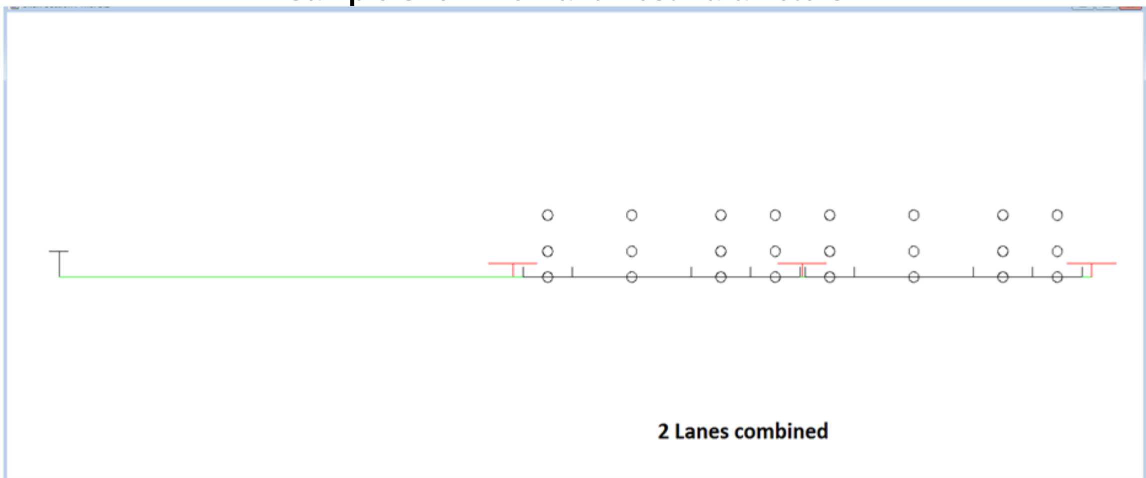
Name: Roadway14 Width (ft): 12.00

On Structure ? Pavement Type: Average

Average pavement type shall be used unless a State highway agency substantiates the use of a different type with the approval of FHWA

	Pnt.Name	Pnt.No	X (ft)	Y (ft)	Z(pavement) (ft)	Pvmt Type	On Stı
1		33	1,210.0	232.0	0.0	Average	
2	point34	34	-350.0	232.0	0.0	Average	

Sample Skew View and Test Parameters 2



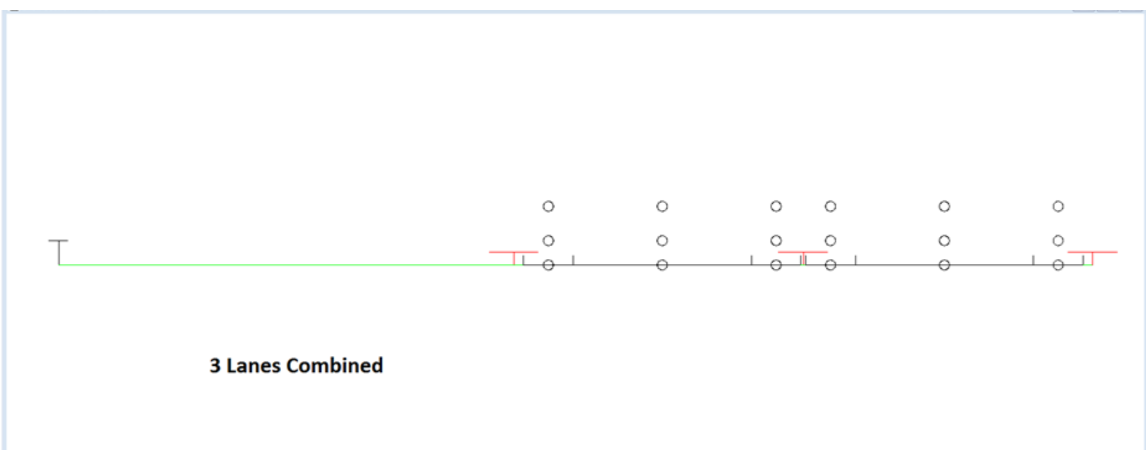
Name: Roadway28
Segment: point56

	Vehicle Type	Veh/hr	Speed (mph)
1	Auto	2040	60.00
2	Medium Truck	300	60.00
3	Heavy Truck	100	60.00
4	Buses	20	60.00
5	Motorcycle	40	60.00

Name: Roadway28 Width (ft): 24.00
On Structure ? Pavement Type: Average
Average pavement type shall be used unless a State highway agency substantiates the use of a different type with the approval of FHWA

	Pnt.Name	Pnt.No	X (ft)	Y (ft)	Z(pavement) (ft)	Pvmt Type	On Str
1	point56	56	-350.0	283.0	0.0	Average	
2	point57	57	1,210.0	283.0	0.0	Average	

Sample Skew View and Test Parameters 3



Name: Roadway26
Segment: point52

	Vehicle Type	Veh/hr	Speed (mph)
1	Auto	3060	60.00
2	Medium Truck	450	60.00
3	Heavy Truck	150	60.00
4	Buses	30	60.00
5	Motorcycle	60	60.00

Name: Roadway26 Width (ft): 36.00
On Structure ? Pavement Type: Average
Average pavement type shall be used unless a State highway agency substantiates the use of a different type with the approval of FHWA

	Pnt.Name	Pnt.No	X (ft)	Y (ft)	Z(pavement) (ft)	Pvmt Type	On Str
1	point52	52	-350.0	289.0	0.0	Average	
2	point53	53	1,210.0	289.0	0.0	Average	

The results are as follows (values given in hourly dB(A)):

Number of Lanes Combined (per direction)

	1 lane only	2 lanes	3 lanes
Receiver 1	71.2	71.2	71.3
Receiver 2	71.2	71.2	71.4
Receiver 3	71.2	71.2	71.4
Receiver 4	71.2	71.2	71.4
Receiver 5	71.2	71.2	71.3
Total Noise	356	**356**	356.8

The noise produced in a case of not combining any lanes is the more accurate value. This give us justification to compare all results to that case. As shown above, the results begin to show a margin of error when more than two roads are combined.

Test 3: Shoulder V. No Shoulder

It is advised by FHWA that the shoulders be modeled as lanes with no traffic. Shoulders are made of the same surfaces as the main roads, so this is a logical modeling practice. The effects of simply not modeling the shoulders at all will yield different results.

The parameters of this test are as follows:

- No perturbable barrier, only three 5 ft. dividers
- A 4-lane highway with shoulders
- No road elevations or receiver elevations

	Vehicle Type	Veh/hr	Speed [mph]
1	Auto	1020	60.00
2	Medium Truck	150	60.00
3	Heavy Truck	50	60.00
4	Buses	10	60.00
5	Motorcycle	20	60.00

The results are as follows (values given in dB(A)):

Default Receiver Settings

Dwelling Units: 1 Height Above Ground (ft): 5.00

	Receiver Name	Seq. #	X [ft]	Y [ft]	Z[ground] [ft]	Dwelling Units	Height [ft]
1	R-1	1	200.00	110.00	0.00	1	5.00
2	R-2	2	260.00	110.00	0.00	1	5.00
3	R-3	3	320.00	110.00	0.00	1	5.00
4	R-4	4	380.00	110.00	0.00	1	5.00
5	R-5	5	440.00	110.00	0.00	1	5.00

	Shoulder	No Shoulder
Receiver 1	69.5	69.1
Receiver 2	69.5	69.1
Receiver 3	69.5	69.2
Receiver 4	69.5	69.2
Receiver 5	69.5	69.2
Total Noise	**347.5**	345.8

The effect of removing the shoulder is evident by a slight decrease in the resulting noise reading. And so, all shoulders should be modeled as roads with zero traffic and "Average" pavement.

Appendix A

Sample Instrumentation Log

Site #: 1
Location: I-85 S
Date: 2-8-2016

Item #	Quantity	Instrument	ID Number (if Applicable)
1	1	Brüel & Kjaer 4155 Microphone	76245
2	1	Brüel & Kjaer 4155 Microphone	76246
3	10	9-Volt Batteries	N/A
4	1	Larson Davis 820 Sounds Level Meter	33768
5	1	Larson Davis 820 Sounds Level Meter	33769
6	2	Microphone Simulators	N/A
7	10	D-Cell Batteries	N/A
8	1	Cetec Ivie Random Noise General	501

Instrumentation Log

Site #:
Location:
Date:

Item #	Quantity	Instrument	ID Number (if Applicable)

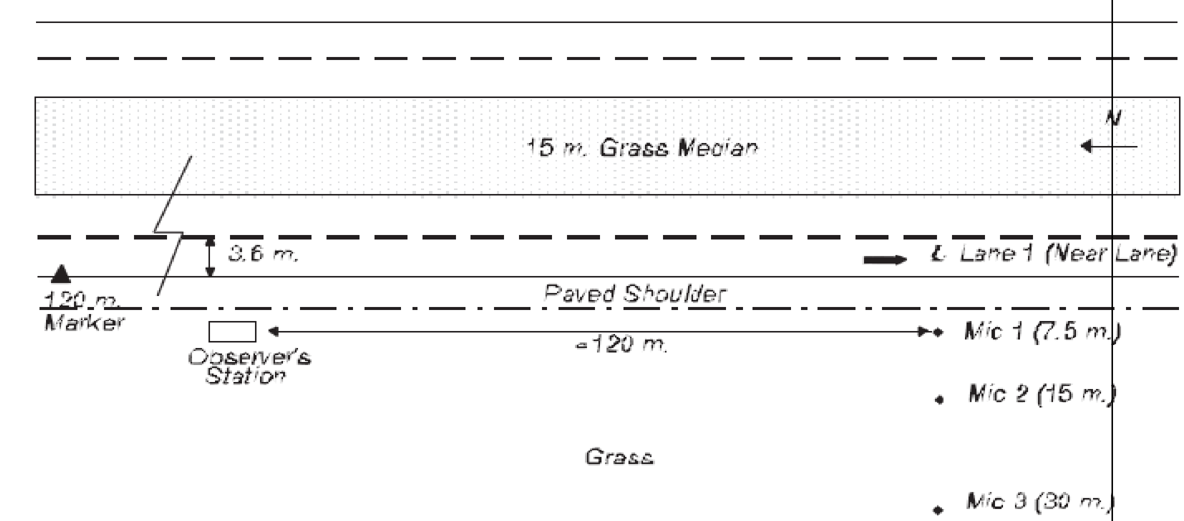
[Template]

Sample Site Data Log

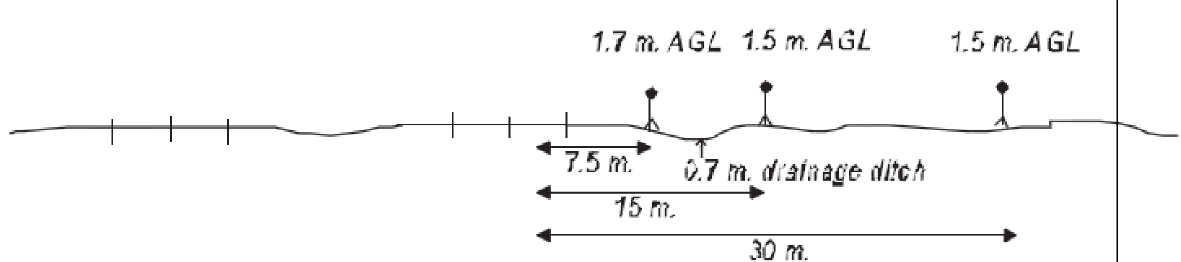
Site #: 1
Location: I-85 S
Date: 2-8-2016
Observer: John Smith

Direction: N / S / E / W NE / NW / SE / SW	**Site Surface:** soft / medium / hard	**Nearby Landmark:** I-85 / I-285 Junction **Distance to Landmark:** 0.25 km
Grade: 0%	**Pavement Type:** Concrete	

Plan View:



Elevation View:



Source: FHWA-PD-96-046

Site Data Log

Site #: **Location:** **Date:** **Observer:**		
Direction: N / S / E / W NE / NW / SE / SW	**Site Surface:** soft / medium / hard	**Nearby Landmark:** **Distance to Landmark:**
Grade %:	**Pavement Type:**	
Plan View:		
Elevation View:		

[Template]

Sample Meteorological Data Log

Site #: 1
Location: I-85 S
Date: 2-8-2016
Observer: John Smith

Time	Temp ˚C (dry bulb)	Temp ˚C (wet bulb)	Relative Humidity (%)	Wind Speed (mph)	Wind Direction	Cloud Cover Class
8:00	15	13	89.8	5	W-E	2
8:15	16	13	86.6	5	W-E	2
8:30	16	14	86.7	5-7	W-E	2
8:45	16	14	86.7	5-7	W-E	2
9:00	16	14	86.7	5	W-E	3
9:15	16	15	91.5	5	W-E	3
9:30	17	15	89.9	0	N/A	3
9:45	17	16	89.9	0	N/A	3
10:00	18	16	83.9	0-5	W-E	3
10:15	19	16	83.3	0-5	W-E	3
10:30	19	16	83.3	0-5	W-E	3
10:45	19	16	83.3	4	W-E	3
11:00	20	16	79.7	4	W-E	3
11:15	20	16	79.7	4	W-E	3

Meteorological Data Log

Site #:
Location:
Date:
Observer:

Time	Temp ˚C (dry bulb)	Temp ˚C (wet bulb)	Relative Humidity (%)	Wind Speed (mph)	Wind Direction	Cloud Cover Class

* See below to convert Dry-Wet bulb temperature readings to Relative Humidity.

[Template]

Relative Humidity Condition

This appendix presents the procedures for converting measured dry and wet bulb temperatures into relative humidity expressed in percent.

1. Convert Dry Bulb temperature from °F to °C:

$$\text{Dry, °C} = \frac{[(Dry, °F) - 32]}{1.8}$$

2. Convert Dry Bulb temperature from °C to °K:

$$\text{Dry, °K} = (\text{Dry, °C}) + 273.15$$

3. Repeat steps 1 and 2 to convert Wet Bulb temperature (Wet) to °K.

4. Compute the Saturation Pressure, assuming standard-day ambient atmosphere pressure, for the Dry Bulb temperature (DrySatPres):

$$\text{DrySatPres} = e^{\left[19.163 - \frac{\left(4063.2 + \frac{184089.0}{Dry}\right)}{Dry}\right]}$$

5. Repeat step 4 to compute the Saturation Pressure for the Wet Bulb temperature (WetSatPres).

6. Compute the Relative Humidity (RH) in percent:

$$\text{RH, \%} = 100 * \left[\frac{WetSatPres}{DrySatPres}\right]$$

Sample Existing – Noise Measurements Acoustic Data Log

Site #: 1
Location (Traffic Direction/Lane, etc.): I-85 (Southbound on Lane 1)
Date: 2-8-2016
Observer: John Smith

Event	Time	Main Speed (mph)	Auto	Medium Truck	Heavy Truck	Bus	Motorcycle	Other:	Comments
1	9:05	80	~~IIII~~ ~~IIII~~ ~~IIII~~ III	~~IIII IIII~~ ~~IIII~~	~~IIII~~ ~~IIII IIII~~ ~~IIII IIII~~ II	III			
2	9:10	85	~~IIII~~ ~~IIII~~ ~~IIII~~ II	~~IIII~~ II	~~IIII IIII~~ ~~IIII IIII~~	II	I		

Existing –Noise Measurements Acoustic Data Log

Site #:
Location (Traffic Direction/Lane, etc.):
Date:
Observer:

Event	Time	Main Speed (mph)	Auto	Medium Truck	Heavy Truck	Bus	Motorcycle	Other:	Comments

[Template]

Sample Vehicle Emission level Measurements Acoustic Data Log

Site #: 1
Location: I-85 S
Date: 2-8-2016
Observer: John Smith

Mic #: 1 | **Mic Location:** 7.5 m offset

Event	Time	Duration	L_{afmx} (dB(A))	Event Quality	Gain Setting	Comments
Pre Cal	8:00:31	25.0	N/A	N/A	0	
Cal	8:05:24	20.125	N/A	N/A	0	**Reset SLM**
Dummy	8:09:01	30.125	N/A	N/A	0	
Pink	8:15:00	31.625	N/A	N/A	0	
Precal	8:45:23	22.0	N/A	N/A	0	
Cal	8:55:15	20.25	N/A	N/A	0	
1	9:05:12	8.0	56.4	1	+20	
2	9:09:15	10.875	65.7	2		
3	9:15:09	18.9	79.0	2		
4	9:21:54	4.375	58.9	NG		No good – jet overhead
5	9:34:56	7.25	65.0	1		

Vehicle Emission Level Measurements Acoustic Data Log

Site #:
Location (Traffic Direction/Lane, etc.):
Date:
Observer:

Mic #:	**Mic Location:**					
Event	**Time**	**Duration**	**L_{afmx} (dB(A))**	**Event Quality**	**Gain Setting**	**Comments**

[Template]

Sample Vehicle Emission Level Measurements Data Log

Site #: 1
Location (Traffic Direction/Lane, etc.): I-85 (Southbound on Lane 1)
Date: 8-6-2016
Observer: John Smith

Event	Time	Vehicle Speed (mph)	Auto	Medium Truck	Heavy Truck	Bus	Motorcycle	Other:	Comments
1	9:05:12	80			•				5 axle
2	9:09:15	85		•					
3	9:15:09	75			•				3 axle
4	9:21:54	88	•						
5	9:34:56	90	•						

Vehicle Emission level Measurements Data Log

Site #: **Location (Traffic Direction/Lane, etc.):** **Date:** **Observer:**									
Event	**Time**	**Vehicle Speed (mph)**	**Auto**	**Medium Truck**	**Heavy Truck**	**Bus**	**Motorcycle**	**Other:**	**Comments**

[Template]

Sample Barrier Insertion Loss Measurements, Acoustic Data Log

Site #: 1
Location: I-85
Date: 8-6-2016
Observer: John Smith

Site Type (Check One):	Before	Equiv. BEFORE	AFTER	Mic Type (Check One)	Reference	Receiver	Mic #:	Mic Location:
	•					•	1	7.5m offset

Event	Time	Duration	Sound Level (dB(A))	Event Quality	Gain Setting	Comments
Pre Cal	8:00:31	25.0	N/A	N/A	0	
Cal	8:05:24	20.125	N/A	N/A	0	**Reset SLM**
Dummy	8:09:01	30.125	N/A	N/A	0	
Pink	8:15:00	31.625	N/A	N/A	0	
Precal	8:45:23	22.0	N/A	N/A	0	
Cal	8:55:15	20.25	N/A	N/A	0	
1	9:15:00	300.0	56.4	N/A	+20	
2	9:20:00	300.0	65.7	N/A		

Barrier Insertion Loss Measurements, Acoustic Data Log

Site #:
Location (Traffic Direction/Lane, etc.):
Date:
Observer:

Site Type (Check One):	Before	Equiv. BEFORE	After	Mic Type (Check One)	Reference	Receiver	Mic #:	Mic Location:

Event	Time	Duration	Sound Level (dB(A))	Event Quality	Gain Setting	Comments

[Template]

Sample Barrier Insertion Loss Measurements, Vehicle Data Log

Site #: 1
Location (Traffic Direction/Lane, etc.): I-85 (Southbound on Lane 1)
Date: 8-6-2016
Observer: John Smith

Event	Time	Main Speed (mph)	Auto	Medium Truck	Heavy Truck	Bus	Motorcycle	Other:	Comments
1	9:15	80	~~IIII~~ ~~IIII~~ ~~IIII~~ III	~~IIII~~—~~IIII~~ ~~IIII~~	~~IIII~~ ~~IIII~~—~~IIII~~ ~~IIII~~—~~IIII~~ II	III			
2	9:20	85	~~IIII~~ ~~IIII~~ ~~IIII~~ II	~~IIII~~ II	~~IIII~~—~~IIII~~ ~~IIII~~—~~IIII~~	II	I		

Barrier Insertion Loss Measurements, Vehicle Data Log

Site #:
Location (Traffic Direction/Lane, etc.):
Date:
Observer:

Event	Time	Main Speed (mph)	Auto	Medium Truck	Heavy Truck	Bus	Motorcycle	Other:	Comments

[Template]

Sample Construction equipment noise Measurements, Acoustic Data Log

Site #: 1
Location/Construction Phase: I-85/ Earthwork
Date: 8-6-2016
Observer: John Smith

Operating Mode (Check One):	**Stationary -Passive**	**Stationary-Active**	**Mobile-Passive**	**Mobile Active**	**Equipment Type:** Bulldozer	**Mic #:** 1	**Mic Location:** 15 m offset
			•				

Event	**Time**	**Duration (sec)**	**Sound Level (dB(A))**	**Event Quality**	**Gain Setting**	**Comments**
Pre Cal	8:00:31	25.0	N/A	N/A	0	
Cal	8:05:24	20.125	N/A	N/A	0	**Reset SLM**
Dummy	8:09:01	30.125	N/A	N/A	0	
Pink	8:15:00	31.625	N/A	N/A	0	
Pre Cal	8:45:23	22.0	N/A	N/A	0	
Cal	8:55:15	20.25	N/A	N/A	0	
1	9:15:00	300.0	56.4	N/A	+20	
2	9:20:00	300.0	65.7	N/A		

Construction Equipment Noise Measurements, Acoustic Data Log

Site #: **Location/Construction Phase:** **Date:** **Observer:**							
Operating Mode (Check One):	**Stationary -Passive**	**Stationary -Active**	**Mobile-Passive**	**Mobile Active**	**Equipment Type:**	**Mic #:**	**Mic Location:**
Event	**Time**	**Duration (sec)**	**Sound Level (dB(A))**	**Event Quality**	**Gain Setting**	**Comments**	

[Template]

Sample Building Noise Reduction Measurements, Acoustic Data Log

Site #: 1
Location: I-85
Date: 8-6-2016
Observer: John Smith

Site Type (Check One):	Interior	Exterior
		•

Event	Time	Duration (sec)	Sound Level (dB(A))	Event Quality	Gain Setting	Comments
Pre Cal	8:00:31	25.0	N/A	N/A	0	
Cal	8:05:24	20.125	N/A	N/A	0	**Reset SLM**
Dummy	8:09:01	30.125	N/A	N/A	0	
Pink	8:15:00	31.625	N/A	N/A	0	
Pre Cal	8:45:23	22.0	N/A	N/A	0	
Cal	8:55:15	20.25	N/A	N/A	0	
1	9:30:01	8.0	56.4	1	+20	
2	9:36:15	10.875	65.7	2		

Building Noise Reduction Measurements, Acoustic Data Log

Site #:
Location:
Date:
Observer:

Site Type (Check One):	Interior	Exterior				
Event	**Time**	**Duration (sec)**	**Sound Level (dB(A))**	**Event Quality**	**Gain Setting**	**Comments**

[Template]

Sample Building Noise Reduction Measurements, Vehicle Data Log

Site #: 1 **Location (Traffic Direction/Lane, etc.):** I-85 (Southbound on Lane 1) **Date:** 8-6-2016 **Observer:** John Smith									
Event	**Time**	**Main Speed (mph)**	**Auto**	**Medium Truck**	**Heavy Truck**	**Bus**	**Motorcycle**	**Other:**	**Comments**
1	9:15	80	~~IIII~~ ~~IIII~~ ~~IIII~~ III	~~IIII~~ ~~IIII~~ ~~IIII~~	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ II	III			
2	9:20	85	~~IIII~~ ~~IIII~~ ~~IIII~~ II	~~IIII~~ II	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	II	I		

Building Noise Reduction Measurements, Vehicle Data Log

Site #:
Location (Traffic Direction/Lane, etc.):
Date:
Observer:

Event	Time	Main Speed (mph)	Auto	Medium Truck	Heavy Truck	Bus	Motorcycle	Other:	Comments

[Template]

Sample Occupational Noise Exposure Data Log

Site #: 1
Task/Location: I-85/ toll booth at exit 19
Date: 8-6-2016
Employee/Observer: Chris Matthews/Matt Christian

Instrumentation:	**Noise Dosimeter**	**Sound Level**				**Mic Location:**
	•					
Event	**Time**	**Duration (hour)**	**L_{Aeq} (dB(A))**	**L_{AFmx} (db(A))**	**Gain Setting**	**Comments**
Pre Cal	7:00:31	25.0 sec	N/A		0	
Cal	7:05:24	20.125 sec	N/A		0	**Reset SLM**
Dummy	7:09:01	30.125 sec	N/A		0	
Pink	7:15:00	31.625 sec	N/A		0	
Pre Cal	7:45:23	22.0 sec	N/A		0	
Cal	7:55:15	20.25 sec	N/A		0	
1	8:30:01	0.33	88.0	90.1	+20	
2	8:36:15	0.33	73.0	77.9		
3	8:52:09	2.60	90.0	90.9		
4	11:15:12	3.50	105.0	105.1		
5	15:08:15	1.24	108.0	109.0		
6	16:25:09	2.00	95.0	96.9		

Occupational Noise Exposure Data Log

Site #:
Task/Location:
Date:
Employee/Observer:

Instrumentation:	**Noise Dosimeter**	**Sound Level**				**Mic Location:**
	•					
Event	**Time**	**Duration (hour)**	**L_{Aeq} (dB(A))**	**L_{AFmx} (dB(A))**	**Gain Setting**	**Comments**

[Template]

Sample Existing Noise Measurements, Acoustic Data Log

Site #: 1
Location: I-85
Date: 8-6-2016
Observer: John Smith

Site Type (Check One):	Overall Sound Level	Change in Sound Level		Mic Type (Check One):	Reference	Receiver	Mic #:	Mic Location:
		BEFORE	AFTER				1	7.5m offset
		•				•		

Event	Time	Duration	Sound Level (dB(A))	Gain Setting	Comments
Pre Cal	8:00:31	25.0	N/A	0	
Cal	8:05:24	20.125	N/A	0	**Reset SLM**
Dummy	8:09:01	30.125	N/A	0	
Pink	8:15:00	31.625	N/A	0	
Precal	8:45:23	22.0	N/A	0	
Cal	8:55:15	20.25	N/A	0	
1	9:15:00	300.0	56.4	+20	
2	9:20:00	300.0	65.7	0	

Existing Noise Measurements, Acoustic Data Log

Site #:
Location:
Date:
Observer:

Site Type (Check One):	Overall Sound Level	Change in Sound Level		Mic Type (Check One):	Reference	Receiver	Mic #:	Mic Location:
		BEFORE	AFTER					

Event	Time	Duration	Sound Level (dB(A))	Gain Setting	Comments

[Template]

Appendix B

GDOT Feasibility and Reasonableness Worksheet

Date: ____________________
Project Name: ________________________________
Highway Traffic Noise Abatement Measure:
____

Feasibility

Number of Impacted Receivers _______

Number of Non-Impacted Benefitted ______
Number of Impact Receivers Benefitted ______

Number of Impacted Receivers that would achieve a 5 dBA reduction from the proposed noise abatement measure __________

Is the proposed noise abatement measure acoustically feasible?
NOTE: GDOT Policy indicates that at least one receiver must achieve at least a 5 dBA reduction for it to be considered acoustically feasible. ☐ Yes ☐ No

Would any of the following limit the ability of the abatement to achieve noise reduction?

Topography	☐ Yes	☐ No
Safety	☐ Yes	☐ No
Drainage	☐ Yes	☐ No
Utilities	☐ Yes	☐ No
Maintenance	☐ Yes	☐ No
Access	☐ Yes	☐ No
Exposed Height of Wall	☐ Yes	☐ No

If "Yes" was marked for any of the question above, please explain below.

Reasonableness

#1. Noise Reduction Design Goal

Number of Impact Receivers Benefitted _______

Number of Impact Receivers Benefitted to achieve at least an 7 dBA reduction _______

Number of Non-Impacted Benefitted	________	Number of Non-Impacted Benefitted to achieve at least an 7 dBA reduction	________
Does the proposed noise abatement measure meet the noise reduction design goal?		☐Yes	☐ No

If marked "Yes", continue to #2. If "No" is marked, then abetment is determined NOT to be reasonable.

#2. Cost Effectiveness

Estimated cost per square foot for noise abatement measure	____________	Estimated construction cost for noise abatement measure	____________
Estimated cost per Benefited Receptor	____________		
Based on the GDOT policy of $55,000 per Benefitted Receptor, would the abatement measure be reasonable. NOTE: GDOT Policy states that the preliminary noise analysis is based on $25.000 per square foot and a more project-specific construction cost should be applied at a cost per square foot basis during the detailed noise abatement evaluation.		☐Yes	☐ No

If marked "Yes", continue to #3. If "No" is marked, then abetment is determined NOT to be reasonable.

#3. Viewpoints of the property owners and residents of the benefitted receivers

Number of Benefited Receptors (same as above)	________		
Number of Benefited Receptors in support of noise abatement measure	________	Percentage of Benefited Receptors in support of noise abatement measure	________
Number of Benefited Receptors opposed to noise abatement measure	________	Percentage of Benefited Receptors opposed to noise abatement measure	________

Number of Benefited Receptors that **did not respond** to solicitation on noise abatement measure	________	Percentage of Benefited Receptors that **did not respond** to solicitation on noise abatement measure	________

Based on the viewpoints of the owners and resident of the Benefitted Receptors, would the abatement measure be reasonable? NOTE: GDOT Policy states that a noise barrier will only be constructed if at a minimum, 50% plus one of the respondents vote in favor of noise abatement.	☐Yes	☐ No

Appendix C

Background Research

FHWA

FHWA has adopted sampling practices to create consistencies in accuracy of sam` v

pling results. Of them include the following:

- minimum 30 minutes sampling periods (3 repetitions of 10 minutes each)
- minimum 2 sets sampling periods (1 in the morning, and 1 in the afternoon)
- recordings over 2 days period
- Identify unusual noise sources in the field documentation.
- A minimum of 10 seconds ambient levels should be sampled.

Temporal nature[16]	Greatest anticipated range		
	10dB	10 - 30dB	>30dB
Steady*	2 minutes	N/A	N/A
Nonsteady fluctuating	5 minutes	15 minutes	30 minutes
Nonsteady intermittent	For at least 10 events	For at least 10 events	For at least 10 events
Nonsteady, impulsive isolated bursts	For at least 10 events	For at least 10 events	For at least 10 events
Nonsteady, impulsive-quasisteady	3 cycles of on/off	3 cycles of on/off	3 cycles of on/off

* A minimum of three repetitions is recommended, with 6 repetitions being preferred.

Sound levels should be measured and/or recorded simultaneously with the collection of traffic data, including the logging of vehicle types, as defined below, vehicle-type volumes, and the average vehicle speed.

- Automobiles (A): All vehicles having two axles and four tires (gross vehicle weight < 4500 kg)
- Medium Trucks (MT): All cargo vehicles having six tires. (4500 kg < Gross vehicle weight <12,000 kg)
- Heavy Trucks (HT): All cargo vehicles having three or more axles. Gross vehicle weight > 12,000 kg
- Buses (B): All vehicles having two or three axles and designated for transportation of nine or more passengers.
- Motorcycles (MC): All vehicles having two or three tires with an open-air driver and/or

The positioning of the microphones are important in that the exterior measuring sites for Category C spaces should be a flat open space relatively free of large reflecting surfaces, within 30 m (100 ft) of the vehicle path or the microphones. Also, the line-of-sight from microphone positions to the roadway should be unobscured and within a terrain arc of 150 degrees horizontally. Although there are special cases.

It should be noted that for receiver distances greater than 100 m (300 ft) from the source, atmospheric effects have a much greater influence on measured sound levels. In such instances, precise meteorological data will be needed to ensure BEFORE and AFTER equivalence of the meteorological conditions (See Section 3.2 of FHWA Measurement of Highway-Related Noise).

Possible Exterior receiver positions include those outlined below as “Position 1” and “Position 2”.

Position 1:

- at least 3 m (10 ft) from the side of the building, at the same distance from the road as the front wall
- at a height of 1.5 m (5 ft) above ground level
- microphone is not shielded from the road by the building

Position 2:

- no greater than 2 m (6.6 ft) from the facade, located on the roadway side of the building, at a point opposite the middle of the facade
- at a height of 1.5 m (5 ft) above ground level

As far as interior noise is concerned, microphones are to be placed at a height of 5 ft above the floor of the interior location. It’s important that the microphones are also 3 ft from any walls.

Individual state policies and practices can be seen below.

Kentucky

How do they handle noise in parks and other Category C spaces?	**How do they handle interior noise?**
Measurements are to be taken in exterior areas of frequent human use within 500 feet of the proposed edge of pavement. *(Structures lying totally beyond 500 feet shall not be counted as benefitted receptors The number of persons shall be established through consultation with the school, church, day care, etc.)*	Interior readings are <u>not required unless predicted exterior noise levels exceed the interior NAC by more than 10 dB(A).</u> For buildings with windows that are fixed closed, interior <u>noise readings are not required unless the predicted exterior noise levels exceed the interior NAC by more than 20 dB(A).</u> *(Interior readings are not required if exterior readings approach or exceed the NAC and thus abatement measures are already under consideration. …additional measures follow the FHWA's "Measurement of Highway Related Noise")*

How do they determine a "feasible reduction"?	How do they handle noise in residential spaces?
Feasible reduction: 5 dB or more for 50% Noise reduction design goal: 7 dB(A) for a minimum of 40% of all benefitted receptors	same for exterior spaces and interior noise criterion
How do they handle multilevel noise receptors? confer with the KYTC Noise Specialist	**Sampling Period** follow that of the FHWA

To calculate the equivalent residences for a specific facility or area, you can reference the equations outlined below.

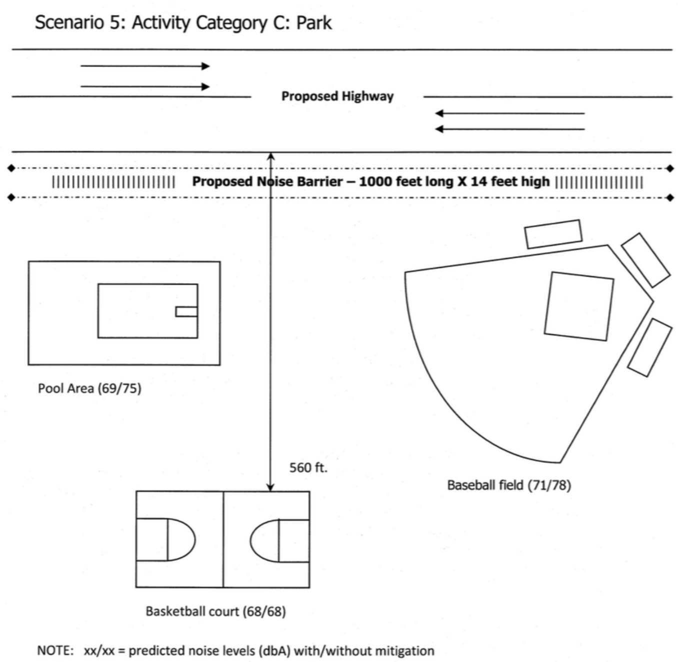
$$Equivalent\ Residences = \left(\frac{\#\ Persons}{2.5\ persons\ per\ avg\ household}\right)\left(\frac{Avg\ Daily\ Hours\ Use}{24\ hours\ per\ day}\right)$$

~ OR ~

$$Equivalent\ Residences = \left(\frac{\#\ Persons}{2.5\ persons\ per\ avg\ household}\right)\left(\frac{Avg\ Weekly\ Hours\ Use}{168\ hours\ per\ week}\right)$$

In these equations, "# Persons" is the number of people who use the "facility" within 500 feet of the proposed edge of pavement. "Avg Daily Hours of Use" or "Avg Weekly Hours of Use" is the average number of hours during which the "# Persons" use the facility within the 500-foot area. In the example like the one in the image below, the pool area Equivalent Residences could be calculated using the Average Daily Hours of Use equation. Whereas, the baseball area Equivalent Residences could be calculated using the Average Weekly Hours of Use equation. In Kentucky, if you were evaluating a church, Equivalent Residences would be calculated using the Average Weekly Hours of Use equation. For clarity, if a church offered a wide variety of services on various nights of the week, as well as multiple services on weekends to accommodate large congregations you may consider a use analysis similar to that of the park in "Scenario #5".

Florida



How do they handle noise in parks and other Category C spaces? • Primary placement of receptors are areas where frequent human use occurs. • Secondary placement of the receptors in these cases will be dictated by the location of the noise source and the exterior activity that may be impacted, if any.	**Sampling Period** Follows practices of the FHWA
How do they handle interior noise? An interior analysis will only be performed after exhausting all outdoor analysis options, then consult the FHWA "Building Noise Reduction Factors"	**How do they handle noise in residential spaces?** receptors are placed at the edge of the dwelling unit closest to the major traffic noise *(When more than one unit is clustered together, a single receptor can be analyzed as representative of a group of noise sensitive sites.)*

How do they handle multilevel noise receptors? • First Floor: 5 feet above ground level • Second Floor: 15 feet above ground level • Third Floor and above: to be determined on a case by case basis	**How do they determine a "feasible reduction"?** A "feasible reduction" is considered to be 5 dB or more

Alabama

How do they handle noise in parks and other Category C spaces? Primary placement of receptors are areas where frequent human use occurs.	**How do you handle interior noise?** Unspecified instructions aside from the fact that interior noise is neglected if the exterior NAC is met
Noise Abatement Measures 1) Construction of noise barriers (excluding landscaping) 2) Traffic management measures (traffic control devices, prohibition of certain vehicle types, time-use restrictions, etc.) 3) Alteration of horizontal and vertical alignments 4) Noise insulation of Activity D land use facilities	**How do they determine a "feasible reduction"?** Must be a 5dB reduction for 70% or more of the impacted receptors

South Carolina

How do they handle noise in parks and other Category C spaces? Location of the receptor dependent on the noise source and mirrors practices of the FHWA *(Note: Active Sports Areas do not fall within the classification of non-residential uses. These areas are equivalent to one impacted residence.)*	**How do they handle noise in residential spaces?** receptors are placed at the edge of the dwelling unit closest to the major traffic noise *(When more than one unit is clustered together, a single receptor can be analyzed as representative of a group of noise sensitive sites.)*

How do they handle multilevel noise receptors?	Sampling Period
• First Floor: 5 feet above ground level • Second Floor: 15 feet above ground level • Third Floor and above: to be determined on a case by case basis	Follow practices of the FHWA
How do they determine a "feasible reduction"? Must be a 5dB reduction for 75% or more of the impacted receptors	

Virginia

How do they handle noise in parks and other Category C spaces?	How do they determine a "feasible reduction"?
exterior areas of frequent human use 500 feet of the proposed edge of pavement. (assure that the instruments are calibrated once every two years)	Must be a 5dB reduction for 50% or more of the impacted receptors Design goal: 7dB(A) of insertion loss for at least 1 impacted receptor
How do they handle interior noise? Unspecified instructions aside from the fact that interior noise is neglected if the exterior NAC is met. Indoor insulation of faculties are considered on a case-by-case basis, and follow the FHWA's Building Noise Reduction Factors table.	**How do they handle noise in residential spaces?** In apartments, each unit is counted as one receptor and single family homes are counted as one receptor *(Future Dwellings: only noise abatement is only considered for the phases of construction in which builders has acquired a permit.)*

Appendix D

Geospatial Data

Adopted from Recommended Best Practices for the Use of the FHWA Traffic Noise Model (TNM)

Types of Topographic Data

"Source data" are the raw data for elevation models and other derivative products (e.g., contours, cross-sections, profiles, etc.). Examples of source data include:

- LiDAR (light detection and ranging) is a technology that uses a pulsing laser to produce a dataset comprised of millions of points and their x-, y-, and z-coordinates from the pulse's reflection off features on the earth's surface.
- Ifsar (interferometric synthetic aperture radar) is a technology based on pulsed radio waves that analyzes differences between emitted and reflected waveforms.

"Elevation models" depict the Earth's surface and its features. Elevation models may represent a bare-earth surface, which is a surface that excludes vegetation and structures, or a surface that includes such features. Examples of elevation models include:

- Digital Elevation Model (DEM), in its most basic form, is a raster dataset of bare-earth elevations without hydrologic features. Variations on a DEM include "hydro-flattened," "hydro-enforced," and "hydro-conditioned."
- Digital Terrain Model (DTM) is a bare-earth model that includes break lines, which are vector lines, and polygons used to define abrupt changes in topography or surface features.
- Digital Surface Model (DSM) is a raster grid of surface elevations, but includes the top of surfaces such as buildings and tree canopies.

The most familiar derivative product of the models list above is a set of topographic contours, or lines of equal elevation on the Earth's surface. Another type of derivative product is a triangulated irregular network (TIN). A TIN is a vector-based representation of a land surface, made up of irregularly distributed nodes and lines with 3D coordinates creating a network of triangles.

TNM users should be aware that there are many different types of elevation datasets; some much older than others. The datasets and types of data listed above represent some of the more recent/common types of elevation data in use today. TNM users can find standard definitions and more details about the types of elevation datasets available to the public by searching the internet for the type of dataset.

Sources for Geospatial data

The National Map

The National Map is a collaborative effort among the USGS and other Federal, state, and local partners to improve and deliver topographic information for the nation. *The National Map* contains a broad range of geospatial data and information including: orthographic images, elevation, geographic names, hydrography, boundaries, transportation, structures, and land cover. Research conducted in support of this study indicates that a number of SHAs and their consultants rely on *The National Map* for geospatial and elevation data for highway noise studies. To use this tool, go to http://nationalmap.gov.

State Agencies

A broad range of partners and stakeholders including various Federal, state, local, and tribal governments through their agencies, as well as academia and the private sector, provide geospatial and elevation data through a variety of clearinghouses, catalogs, and portals.

Environmental Systems Research Institute (ESRI)	http://www.esri.com/data/find-data (ESRI is an international supplier of GIS software and applications. ESRI products are available at different levels of licensing. Access to GIS content on the ESRI website requires an online subscription.)
Open Topography	OpenTopography is supported by the National Science Foundation under Award Numbers 1226353 & 1225810 http://www.opentopography.org/index.php
USDA Geospatial Data Gateway (GDG)	http://datagateway.nrcs.usda.gov/
US Census Bureau TIGER/Line® Shapefiles and TIGER/Line Files	https://www.census.gov/geo/maps-data/data/tiger-line.html
USGS Earth Resources Observation and Science (EROS) Center	https://eros.usgs.gov/find-data

Source: Table I-2 "Additional Sources for Geospatial Data", Recommended Best Practices for the use of FHWA Traffic Noise Model (TNM)

Tips for TNM Users When Conducting a Search for Geospatial Data

TNM users may be faced with the possibility of having to conduct an online search for geospatial data – especially if they are working on a highway project in a region unfamiliar to them. Below are tips for conducting such searches.

- Check with your project's technical lead at the SHA.
- Search for local agencies that provide geospatial data – start with agencies at the Town, District, and County level. Then, look for agencies at the State level. Some states, like Massachusetts, require towns to submit data to a central geographic data holding, which the state makes available to the public (e.g., through MassGIS).
- Search for information on websites hosted by state agencies that routinely use geospatial data, such as: SHAs, Conservation Commissions, Planning Commissions, Departments of Natural Resources, Redevelopment Authorities, etc.
- Search University Geographic Libraries – some universities provide geospatial data to the public – at times free of charge.
- Use GIS-specific key words and acronyms when searching.
- Know the coordinates for the geographic extent of your highway project, as well as the named geographic location.
- Know the coordinate system, as well as the horizontal and vertical datum for your project.

Geospatial data are available in a range of formats. If data are not available in the preferred format, be prepared to convert the data to other formats, as needed. Most GIS- and CAD-based applications can handle a range of data formats and can convert data from one format to another.

For more information on finding and using geospatial data in TNM 2.5, refer to https://www.fhwa.dot.gov/environment/noise/traffic_noise_model/documents_and_references/tnm_best_practices/page01.cfm .

Appendix E

Noise Barrier Optimization

Adopted from Recommended Best Practices for the Use of the FHWA Traffic Noise Model (TNM)

Current Best Practices for Barrier Design and Optimization

The study team surveyed many state and highway associations (SHAs) for current policies and practices for noise barrier design, and also asked whether and how states optimize noise barrier designs. Eleven SHAs responded to the information request. The respondents represented states with large noise barrier design and construction programs, as well as states with more modest programs. Based on the information received, the study team observed that some SHAs follow an approach whereby they try to minimize barrier height and cost, while still achieving the state's noise reduction design goal (NRDG). Other states attempt to maximize a barrier's height and acoustical benefit while staying within the cost-effectiveness limits. Some such states initially propose noise barrier designs that meet the reasonableness criteria at the SHA's maximum allowable height, and then reduce heights from a maximum based on the public involvement process. In its experience, the study team has observed that some communities are willing to give up some amount of acoustical benefit based on their desire to have a shorter wall height. In contrast, some other SHAs indicated that they start with a minimum-height design that meets the noise reduction goals, and then incrementally increase the barrier height, as long as the design accrues significant acoustical benefits relative to cost. More than one SHA indicated that it attempts to determine the point of diminishing return in a barrier design, where the acoustical benefits cease to accrue with increased barrier heights (and cost), and then selects that design as representing the best balance between cost and benefit.

Finally, other SHAs incorporate different elements into the noise barrier design process. For example, some SHAs indicated that they attempt to develop noise barrier profiles that are smooth and relatively uniform to achieve a more aesthetic design.

This Noise Barrier Optimization Tool can be found at the following: https://www.fhwa.dot.gov/environment/noise/traffic_noise_model/documents_and_references .

Overview

To utilize the Noise Barrier Optimization Tool (NBOT) most effectively, the study team recommends that TNM users create noise barriers with a reasonable number of barrier height perturbations, considering the trade-offs between run-time and the objectives of the analysis. Then, using TNM's Barrier Analysis Module, the analyst should step through the barrier design process, by creating one Barrier Analysis for a uniform-height noise barrier at each height perturbation. That is, with the Barrier View window open, the user would select the entire noise barrier and uniformly perturb the barrier heights up, from the minimum barrier height to the maximum height. With the Barrier View window open, the user arranges the Sound-level Results table, the Barrier Segment Descriptions table, and the Barrier Descriptions table in the FHWA TNM. The user would copy the information in these tables from the FHWA TNM, and then paste it into specific locations in worksheets of the Microsoft Excel® workbook, with one worksheet for each noise barrier design. Then, the NBOT computes the impacts, benefits, and all of the other metrics needed to evaluate each barrier design and places these results side-by-side in the "Summary" worksheet, or **[Summary]**, for easy comparison. Note that for the remainder of this report, the **[Worksheet Name]** notation will be used to designate individual worksheets within the Excel® workbook that is the NBOT. Likewise, the {TNM Table Name} notation will be used to designate one of the standard tables within the FHWATNM.

In addition to the customary metrics and criteria, the NBOT computes some additional metrics that factor into the computation of the E/C metric, which assists in barrier optimization, including:

1. "Benefit" – the total number of receptors (including non-impacted receptors) benefited by the barrier divided by the number of receptors exposed to impact behind the barrier with no barrier in place

2. "% meet NRDG" – the percentage of impacted receptors that meet or exceed the NRDG with the barrier in place

These two metrics are multiplied together to equal "Effectiveness" in the E/C metric. The "Cost" is simply the surface area of the barrier in square feet, divided by a constant of 10,000 to make the resultant E/C value in a reasonable range. In developing the E/C metric, the study team found that it was appropriate to use both the total Benefit normalized by total impact, as well as the percentage of impacts meeting the NRDG, to properly credit the barrier designs that largely achieve the NRDG. This was important, because many states attempt to achieve the NRDG at as many receptors as possible, within the allowable cost constraints.

To help identify the noise barrier design that represents the "point of diminishing returns" from among the uniform-height barrier designs, the user simply selects the design with the highest E/C ratio that also meets the SHA's NRDG and cost-effectiveness criterion. Each barrier design should be saved as a unique Barrier Analysis in the FHWA TNM, and the corresponding TNM tables should be copied to individual worksheets in the NBOT. The spreadsheet computes all of the metrics for the feasibility and reasonableness determination and compares calculated metrics across multiple noise barrier designs. Note, however, that at this point in the process the user has not yet identified the optimum noise barrier design. The user must take additional steps to refine the noise barrier design. Starting with the uniform-height barrier that achieved the highest E/C ratio, the analyst should consider dropping ineffective or unnecessary barrier segments, such as those at the ends of the noise barrier, or re-running the FHWA TNM for a noise barrier with smaller height increments. The following example illustrates the next steps that may be taken to identify the optimum design.

Yet again, this Noise Barrier Optimization Tool can be found at the following: https://www.fhwa.dot.gov/environment/noise/traffic_noise_model/documents_and_references/

Details and Functionality

The study team created two versions of the NBOT – one with basic metrics ("Basic NBOT") and one with more advanced metrics ("Advanced NBOT"). The latter version is intended for use in states that might require analysis of front row receivers, or other specialized analyses. This section provides details about the NBOT and its functionality.

The tool includes detailed instructions for user entry and use of the subsequent worksheets. First-time users of the NBOT should take the time to become familiar with this worksheet.

A condensed listing of SHA criteria and metrics for feasibility and reasonableness can be found on SHA Policies. This listing is provided for informational purposes only, and should not be used alone or as a reference for the noise study. The user should refer to the SHA's noise abatement policy and supporting guidance to fully understand the criteria for barrier analysis and as a source for up-to-date and current design metrics. The user should refer to the SHA's noise abatement policy when entering criteria on Global Variables. If desired, the user may choose to periodically check SHA websites of interest and update SHA Policies to maintain it as a useful reference. The workbook itself can be edited by the user at any time in order to stay up-to-date with each SHA noise policy. A password-protect feature has been added to the tool, however, to ensure that any edits made to spreadsheet equations are intended by the user.

The project name, project / contract number, FHWA TNM run name, barrier name, organization, analyst, and analysis date should be entered on Global Variables, where additional project-specific information also is entered. This includes the specific metrics, goals, and criteria for feasibility and reasonableness determinations that have been established by the SHA.

The layout of the workbook requires that the user enter the necessary SHA metrics and TNM tables for individual barrier designs into different worksheets. Summary then calculates the results of each barrier analysis and compares results across different designs. The NBOT is meant to be used in conjunction with TNM's Barrier Analysis Module. The user starts by selecting the barriers and receivers of interest and creating a new barrier analysis in the FHWA TNM. For each barrier design, the Sound-level Results table, the Barrier Segment Descriptions table, and the Barrier Descriptions table are copied from the FHWA TNM into specific locations on Receiver-Barr Input, No Barrier, and Analysis1 to Analysis15, as needed. The Receiver Input table, along with other receiver information such as existing sound level, ROW, and FHWA Noise Abatement Category, must be entered into Receiver-Barr Input. The Barrier Input table from the FHWA TNM also should be added to Receiver-Barr Input. If the study is being completed for a state that uses a sliding scale to determine substantial increase impact, the user can enter the required information into Global Variables and Receiver-Barr Input for the scale to be referenced. The user is instructed to enter "SS" on Global Variables into cell C14 if the substantial increase threshold is based on a sliding scale. After "SS" is entered, the user is instructed to enter more information on Receiver-Barr Input. On this worksheet, the user enters a "Y" in cell P14 and chooses the appropriate SHA.

On NoBarrier and Analysis1 to Analysis15, the Sound-level Results table, the Barrier Segment Descriptions table, and Barrier Descriptions table for each respective barrier analysis should be pasted. On NoBarrier, all barrier segments should be placed at a height of 0.0 feet before copying and pasting the applicable TNM tables. Summary pulls the sound levels and barrier parameters from each analysis worksheet so that impacts, benefits, and barrier costs can be calculated and displayed for each barrier analysis, all in one sheet. This allows the user to easily make comparisons across all of the barrier designs that have been considered on Summary so that the most appropriate barrier options can be recommended. Analysis1 to Analysis15 also include areas for a TNM image of the barrier design and the barrier's profile in graphical form to aid in the aesthetics of the design.

As discussed earlier, many SHAs desire to design and recommend noise barriers that provide the significant benefit for impacted receptors as well as non-impacted receptors while still being feasible and reasonable. Through the NBOT, the user can choose the most optimal barrier design by looking at the many various metrics that are computed. The E/C ratios, which reach a maximum value for the most cost-efficient barrier designs that also provide substantial benefit, are shown in Row 7 on Summary.

Generally, areas for user input are symbolized with light green shaded cells and/or red bold underlined column headers. In the Basic NBOT, there are no user input cells on Summary. In the Advanced NBOT, Summary requires the user to enter specific information. The Advanced NBOT also contains metrics that calculate the percent of front row impacts, or benefits, as required for some SHA's feasibility and reasonableness criteria. In the Advanced NBOT, Summary also contains a flag to switch the reasonableness metrics to include cost or surface area per decibel of average noise reduction per benefited receptor. Flags for front row feasibility and reasonableness metrics and per decibel reasonableness metrics are symbolized as light green shaded cells with red bold underlined headers directing the user to enter "Y" into the cell.

Summary includes a flag for each type of impact, such as approaching or exceeding the Noise Abatement Criteria (NAC), or causing a substantial increase (SI) over existing levels. Column E contains the No Barrier Build Sound level, which is bold and red if it is over the threshold for impact. Column F contains a bold red "Y" flag if there is a substantial increase impact. Column G is an "impact" flag that signifies whether the receiver is exposed to noise impact (without a noise barrier). The impact tally summary above this section shows the total number of impacts, the number of impacts for each type (NAC or SI), as well as the total number experiencing both types of impact. Each section under the barrier analysis headers (Analysis1, Analysis2, etc.) contains a tally of the total benefited receivers, the number of benefits that are impacted or not impacted, and the number of impacts and benefits achieving the NRDG.

Cost-reasonableness checks are given for each Analysis section below the number tallies. There are cells that show the percentage of impacts being benefited and the benefits achieving the NRDG, as well as a "Yes" or "No" Cost-Reasonable check, which signifies whether the cost or surface area per benefit meets the appropriate criterion. These cells are conditionally formatted to be green if the criterion is being met and red if it is not. The NBOT is currently set up to notify the user if more than one reasonableness criterion is entered, mainly to avoid user error and because most SHAs have only one. However, if the user is working for a SHA with both types of criteria, the cost reasonableness formula will return a "Yes" if either criterion meets the threshold.

If the SHA requires the number (rather than percentage) of impacted receivers being benefited, or the number of benefited receivers achieving the NRDG, such as one (1) impacted receptor, then the user should leave the percentage inputs on Global Variables blank and use the number tallies on Summary. Some analysts include measurement sites in TNM runs. In such cases, dwelling units may, or may not, be assigned to the receiver in the FHWA TNM. If measurement sites are included in the barrier analysis, the NBOT will calculate impacts properly if the sites are assigned an FHWA Activity Category. If the measurement sites are not intended to represent noise-sensitive land use for the purpose of the noise impact assessment, users should assign a value of zero (0) dwelling units to those receivers that represent measurement sites.
Barrier parameters such as surface area, height range, length, and total cost also are included in each analysis section on Summary. Barrier parameters are pulled from information on Analysis1 to Analysis15 in the Barrier Segment Descriptions section of the worksheet. On Analysis1 to Analysis15, the user can enter "Y" in Column AF for each barrier segment that should be included in that analysis.

For more help with using the NBOT, visit the following website:

https://www.fhwa.dot.gov/environment/noise/traffic_noise_model/documents_and_references/tnm_best_practices/page02.cfm.

Appendix F

Quality Assurance

Adopted from Recommended Best Practices for the Use of the FHWA Traffic Noise Model (TNM)

QA Processes for TNM Input

The recommended QA/QC processes in this section apply to the data used as input (coordinates, roadway details, topographic data, land use, traffic, etc.) to generate TNM objects.

Project Plans, Profiles, and Cross-sections

The GDOT's Highway Design Manual (HDM) provides current requirements and guidance on highway design methods to ensure uniformity of design practice throughout the highway system under its jurisdiction. It is the primary source of guidance for the design of highway facilities from scoping to preliminary design. The HDM not only contains design criteria for different classifications of highway facilities, as well as for interchanges and signalized intersections, but also typically contains standards and procedures for computer aided design (CAD). The CAD standards and procedures assure uniformity of practice and the creation of electronic data for projects designed by or for GDOT. The HDM may provide guidance and standards for the use of engineering software used for highway design, and specific configuration settings for the engineering software. While a thorough understanding of the HDM is not a prerequisite for highway noise analysis, the HDM can be a resource for the highway noise analyst. The highway noise analyst should coordinate with the highway designers.

At a minimum, the project plans and cross-sections provided to the highway noise analyst should contain the following design features for both the existing highway and the proposed highway. In general, if the project plans, profiles, and cross-sections were developed according to the SHA's HDM, these design features should be available to the highway noise analyst. The following design features are applicable to project and non-project roadways alike, to the extent that data are available for the latter:

- Project limits
- Locations of general purpose lanes, special use lanes (e.g., high occupancy vehicle lanes, special tolling lanes, etc.), acceleration and deceleration zones for ramps, shoulders
- Locations where the highway would be on structure and on fil,
- Limits of construction, including toe of slope and top of cut
- Edge of pavement
- Rights-of-way
- Civil station numbering baseline
- Rest areas and truck weigh stations
- Existing noise barriers
- Locations of jersey barriers
- Lane striping

As necessary, the project plans should contain information about other project features, including:

- Bodies of water (rivers, ponds, lakes, etc.) including wetland resources and buffer zones
- Storm water management basins

- Other transportation facilities (railroads, bike paths, shared use paths, etc.)
- Utilities (natural gas, telecommunications, water, electricity, etc.)
- Existing development along the highway corridor
- If available, future proposed development within the project corridor

The most commonly used coordinate system for highway projects is the State Plane Coordinate System (SPCS) based on the North American Datum of 1983 (NAD 83). Elevation data are commonly referenced to the North American Vertical Datum of 1988 (NAVD 88). Of course, the highway noise analyst should check with the project's designers or the SHA noise specialist to verify the preferred coordinate system for the project. When reviewing the project plans/profiles/cross-sections, the highway analyst should:

- Identify/verify the coordinate system
- Identify/verify the vertical datum
- Obtain the metadata for the project plans/profiles/cross-sections

Loudest-hour Traffic

In accordance with 23 CFR 772.9(d), "in predicting noise levels and assessing noise impacts, traffic characteristics that would yield the worst traffic noise impact for the design year shall be used." Research conducted in conjunction with this study revealed that SHAs have different views as to what constitutes the traffic characteristics that yield the "worst noise hour" or the "loudest hour of the day." For example:

- The majority of SHAs use Design Hourly Volumes (DHV) along with the corresponding speeds
- One SHA uses either Level-of-Service (LOS) C traffic volumes, or DHV, with posted speeds limits
- Another SHA calculates hourly vehicle volumes (over a 15- or 24-hour period) based on the equations contained in the latest version of the Highway Capacity Manual (HCM), combined with either posted speed limits or operational speeds, and then identifies the single hour that produces the highest traffic noise level along a particular stretch of the highway

Some SHAs have published detailed procedures for the development of traffic data (vehicle volumes, speeds, and classifications) for use in highway noise studies. Two examples are Florida DOT and Virginia DOT. Their procedures are summarized below:

- In May 2015, the Florida DOT (FDOT) published a new guidance document to assist highway noise analysts "in the prediction of existing and future traffic noise levels and the evaluation of the effectiveness of noise barriers while providing consistent, predictable, and repeatable noise studies." The FDOT Handbook provides references to more detailed guidance on the development of traffic conditions that are representative of the "worst case" noise condition. For FDOT noise studies, the "worst case" traffic noise condition is based either on LOS C volumes and posted speed limits or Directional Demand Hourly Volumes (DDHV). The FDOT Handbook provides guidance on the calculation of DDHV in the event that traffic volumes are provided in the form of Annual Average Daily Traffic (AADT).
- The Virginia DOT (VDOT) considers hourly traffic volume, speed, and vehicle mix for both peak hours and off-peak hours, to the extent that such data are available, to determine the worst noise hour of the day. The Virginia DOT experience is that while the *peak traffic hour* often coincides with the *worst noise*

hour, it is not always the case. For example, when peak-hour traffic volumes approach the capacity of a highway facility, operating speeds may be affected, causing the worst noise hour to differ from the peak traffic hour. In addition, off-peak truck percentages or atypical hourly traffic distributions may have the same effect.

As demonstrated by the different approaches used in the previous examples, the highway noise analyst should verify the established procedures for developing worst case traffic conditions, if any, with the noise specialist at the SHA in which the highway project is located. When developing the worst noise hour traffic for a highway project, the following Best Practices also should be considered:

- Traffic data should be developed for major non-project roadways within the study area; non-project roadways may dominate the noise environment at a receiver of interest and consequently limit the effectiveness of a noise barrier.
- If hourly traffic data are available, conduct a "loudest hour" analysis to determine the hourly traffic conditions (vehicle volume, speed, and mix) that combine to produce the worst noise hour of the day. Experience has shown that the loudest hour does not always coincide with either of the peak traffic hours. In some cases, off-peak hours may be the worst case for noise.
- If the traffic for the worst-case noise hour is based on a capacity-related approach, ensure that the vehicle speeds are not representative of a congested roadway. The traffic conditions for the worst noise hour should represent free-flow traffic conditions and not conditions for a congested facility.
- If the worst noise hour is based on DHV and speeds, evaluate the effect of directional splits for the peak traffic hours on computed noise levels adjacent to the highway. Directional splits can have non-negligible effects on computed noise levels, especially for commuter roadways. If the effect of directional split is more than 1 decibel, consider modeling different peak traffic hours for noise-sensitive land use on opposite sides of the highway.
- Long-term noise monitoring, for a minimum of 24 consecutive hours, often is used to identify the worst noise hour for existing conditions. The long-term noise measurement data along with 24-hour traffic data can inform the loudest hour determination for the future Design Year scenarios.

QA Processes for TNM Results

This section provides recommended QA processes for the review of TNM sound-level results and noise abatement designs. QA processes are described for three different scenarios: sound-level results from a single TNM run (without noise barriers for abatement); sound-level results where more than one TNM run is used to compute sound levels (i.e., for comparing sound-level results across multiple alternatives of a NEPA noise study); and sound-level results for noise barrier design.

This section presumes that the highway noise analyst has performed a noise model validation and has demonstrated that predicted traffic noise levels are within +/- 3 dBA of monitored traffic noise levels at each of the noise measurement sites.

Sound-Level Results from a Single TNM Run without Noise Barriers for Abatement

These QA processes apply to sound-level results from a single TNM run that does not contain noise barriers for abatement (but may contain noise barriers used to represent large buildings). The purpose of such a TNM run is to determine the extent of noise impacts within a common noise environment and whether noise barriers are warranted for further analysis.

- Review results graphically, preferably with GIS, with sound levels displayed adjacent to receiver locations on a base map showing buildings, terrain, existing roads, and any proposed roadways.
- Observe and make note of overall trends in sound levels with distance.
- Use symbol codes for the symbols that represent the receiver locations to convey information about noise impact and/or use labels to show sound levels at receiver locations to help determine the most important receivers.
- Look for outliers with unusually high or low sound levels, then investigate each one to see that the predicted sound level is justified (or not.). For such receivers with sound levels that do not follow the overall trends, look for the following elements in the TNM run that may be responsible for differences:
    - Shielding by nearby buildings will tend to reduce sound levels, whether the buildings are coded as building rows or as fixed-height barriers.
    - Elevation differences between the source roadways and the receiver often will affect sound levels. Higher elevation often means higher sound levels unless the roadway is in a cut and the top of cut provides noise shielding.
    - Ground type will affect sound levels such that significant areas of pavement or water between the roadways and receivers will tend to increase predicted sound levels.

Sound-Level Results where more than one TNM Run is used to Compute Sound Levels at the Same Receivers

These QA processes apply to TNM models and results that are prepared for an environmental document, where sound levels are computed for the existing conditions, along with the Design-year No-build and Build alternatives. These procedures do not consider noise barriers for abatement.

- A graphical review of the sound levels from each TNM run at each receiver is helpful. They should be color coded or ordered to make identification of the alternative that produced the results easy (round sound levels to whole decibels for ease of quick review and determining differences).
- Another very useful approach for finding trends and outliers is to compute differences in the sound levels between the different alternatives in a spreadsheet. Outliers can be spotted easily by scanning the different lists of sound levels.
- All trends and outliers in sound-level differences by receiver between alternatives should be investigated and should appear reasonable based on knowledge of differences between the alternatives being compared in the areas of:
    - Traffic (particularly important when comparing existing and future no-build alternatives, as the roadway geometry is usually the same).
    - Receiver distances to roadways – differences in build case alternatives should have logical differences in receiver sound levels.
    - Roadway geometry and elevation – differences in elevation or the introduction of new ramps will change sound levels; such differences should be logical based on the geometric differences.

Sound-Level Results where Noise Barriers are being Evaluated for Abatement

The highway noise analyst should consider using the Noise Barrier Optimization Tool (NBOT). Its use helps to ensure consistency in the presentation of results and barrier calculations, and serves to document the noise barrier design process that yields the most cost-effective noise barrier design that meets the SHA's acoustical feasibility and design goals. The NBOT also provides a quick and effective way to review the TNM-computed sound-level results across multiple barrier analyses. Use of the spreadsheet also helps to ensure that the physical dimensions of noise barriers are calculated accurately. The following QA processes are recommended for the review of sound-level results for noise barriers:

- A graphical review of the no-barrier and with-barrier sound levels along with insertion loss by receiver is a very fast and effective way to determine if trends are appropriate and to spot any outliers. Barrier-insertion loss values generally decrease with increasing distance from the barrier and toward the ends of the barrier. In concert with that trend, with-barrier sound levels may not change very much with increasing distance from the barrier for a fairly broad area behind the barrier.
- All else being equal, increases in receiver elevation behind a barrier will result in lower insertion loss values than at other nearby receivers with lower elevation. The converse is also often true, where lower elevation receivers will usually have higher insertion loss values than surrounding receivers. This trend can be reversed in cases with elevated roadways where edge-of-pavement shielding is significant for lower-elevation receivers, already reducing noise levels. Observing the trend in no-barrier sound levels will help identify these situations.
- When reviewing different barrier designs, higher and longer barriers should result in lower with-barrier sound levels and increased insertion loss, unless other roadway sources behind the barrier become the dominant sources of noise at those receivers.

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Noise Assessment Template

Executive Summary

GDOT Project #: [ ]
County: PI No.: [ ]
Project Name: [ ]
Date: [ ]

Project Description: [just a short three to four sentence description of project, i.e. "The proposed project would widen roadway x from x to y. Currently the road, x, consists of two 12 travel lanes. The proposed project would widen the existing roadway to four lane section divided by a x foot median. Required right-of-way ranges from x feet to y feet."]

Modeling Assumptions: Estimation of traffic-related sound levels associated with the existing [year], no-build [year] and build [year] alternatives was conducted using the Federal Highway Administration (FHWA) Traffic Noise Model (TNM), version 2.5. Inputs to the model include existing and future roadway alignments, [area terrain, and the shielding effects of structures within the corridor].
To provide a "worst case" analysis of the existing and future conditions, traffic volumes were based on a level of service (LOS) C [capacity for each travel lane operating at the posted speed limit or for peak hour traffic]. Existing truck percentages of % [% medium truck, % heavy truck] were used along [roadway name] while future condition truck percentages were modeled at [% medium truck, % heavy truck].

Summary of Findings:

Impacted Receiver #	# of Receptors Represented	Property Identification	Is Abatement Feasible & Reasonable	Approximate cost of abatement
[e.g., 1, 6, 8, 21]	[e.g., 4]	[e.g., Isolated areas along SR 5]	[e.g., Not Feasible due to driveway breaks]	[e.g., N/A]
[e.g., 30, 31, 32, 33, 35]	[e.g., 5]	[e.g., Lake Wood Subdivision]	[e.g., Yes]	[e.g., 150,000]

[Directions: group receivers by not feasible and the ones behind common barriers together. Keep summary table short, the goal is a one page summary. Under Feasible & Reasonable state reasons why if the answer is "Not Feasible".]

Prepared By: **[Type Name]** **QC/QA:** **[Type Name]**

Signature Date Signature Date

Signature Date
Approved By: GDOT

Contents

TABLES

[Add in a figures section for figures included in body of Document]

Attachments

Attachment 1	Noise Results Summary Table (…optional, if not provided in text)
Attachment 2	Figures (…any map not included in body of report)
Attachment 3	Traffic Volume Diagrams or Analysis and Approval Documentation
Attachment 4	Field Notes and Validation Input and Output TNM Runs
Attachment 5	TNM Files - Receiver Input
Attachment 6	TNM Files - Roadways
Attachment 7	TNM Files - Traffic
Attachment 8	TNM Files - Sound Level Results
Attachment 9	TNM Files - Vacant/Undeveloped Land Sound Levels
Attachment 10	TNM Files - Barrier Analysis (optional)
Attachment 11	Information for Local Officials for Vacant Land Use Development
Attachment 12	Summary Text for NEPA Documentation

[NOISE IMPACT ASSESSMENT or ADDENDUM]

[PROJECT'S 14-DIGIT PROJECT NUIMBER], [XXXXXX COUNTY]
[DESCRIPTIVE PROJECT TITLE]
[PI No. XXXXXX]
[DATE]

1. Introduction

In compliance with 23 USC Section 109(h) and (i), the Federal Highway Administration (FHWA) established a standard for the assessment of highway traffic-generated noise. The standard, published as Part 772 of Title 23 of the Code of Federal Regulations (23 C.F.R. § 772), provide procedures to be followed in conducting noise analyses that will protect the public health, welfare and livability. In accordance with the Noise Control Act of 1972, coordination of this regulation with the Environmental Protection Agency (EPA) has been completed. The following assessment has been prepared in accordance with 23 C.F.R. § 772.

This report focuses on the human environment and documents the results of a noise analysis completed for the proposed project, in order to:

a. Provide baseline noise levels that will be used in determining project impact.

b. Predict the effects that the proposed project would have on the noise environment.

c. Identify impacted locations where noise abatement is feasible and reasonable and likely to be included in the project, and locations where impacts will occur and abatement is not feasible and reasonable.

1.1 What is The Proposed Project?

[Brief description one to two sentences, reference location map]

[Details:

]

[Also add in a Location Map and reference again]

1.2 What is a Type I Project?

"Highway Traffic Noise Policy and Guidance," was issued in July 2010 (revised January 2011) by the FHWA. In compliance with this guidance, a Type I project is defined below:

(1) The construction of a highway on new location; or,

(2) The physical alteration of an existing highway where there is either:

(i) Substantial Horizontal Alteration. A project that halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition; or,

(ii) Substantial Vertical Alteration. A project that removes shielding therefore exposing the line-of-sight between the receptor and the traffic noise source. This is done by either altering the vertical alignment of the highway or by altering the topography between the highway traffic noise source and the receptor; or,

(3) The addition of a through-traffic lane(s). This includes the addition of a through-traffic lane that functions as a (high occupancy vehicle (HOV) lane, High-Occupancy Toll (HOT) lane, bus lane, or truck climbing lane; or,

(4) The addition of an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

(5) The addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange; or,

(6) restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

(7) The addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot or toll plaza.

1.3 How is this Project Classified as a Type I Project?

The proposed [project name] would include the [e.g., "addition of a through-traffic lane"] and, therefore, would be classified as a Type I project.

2. What is the Existing Noise Environment?

According to 23 C.F.R. § 772 existing noise levels are defined as "the worst noise hour resulting from the combination of natural and mechanical sources and human activity usually present in a particular area."

The study area is made up of [...describe the existing human environment list church names, school names, and known subdivision names, isolated residential and businesses etc.]

The principal source of noise in the study area [e.g. "is vehicular traffic, including automobiles and trucks. As an existing transportation corridor, most adjacent land uses are exposed to at least moderate noise levels."]

Details:
This chapter presents background information on the characteristics of sound and sound levels, the criteria used by the FHWA and GDOT to measure noise impacts, and the results of noise measurements conducted in the study area at noise-sensitive sites.

2.1 Background

2.1.1 How is Noise Defined?

Noise is typically defined as unwanted or undesirable sound. The basic parameters of noise that affect humans are:

(1) intensity or level,

(2) frequency content, and

(3) variation with time.

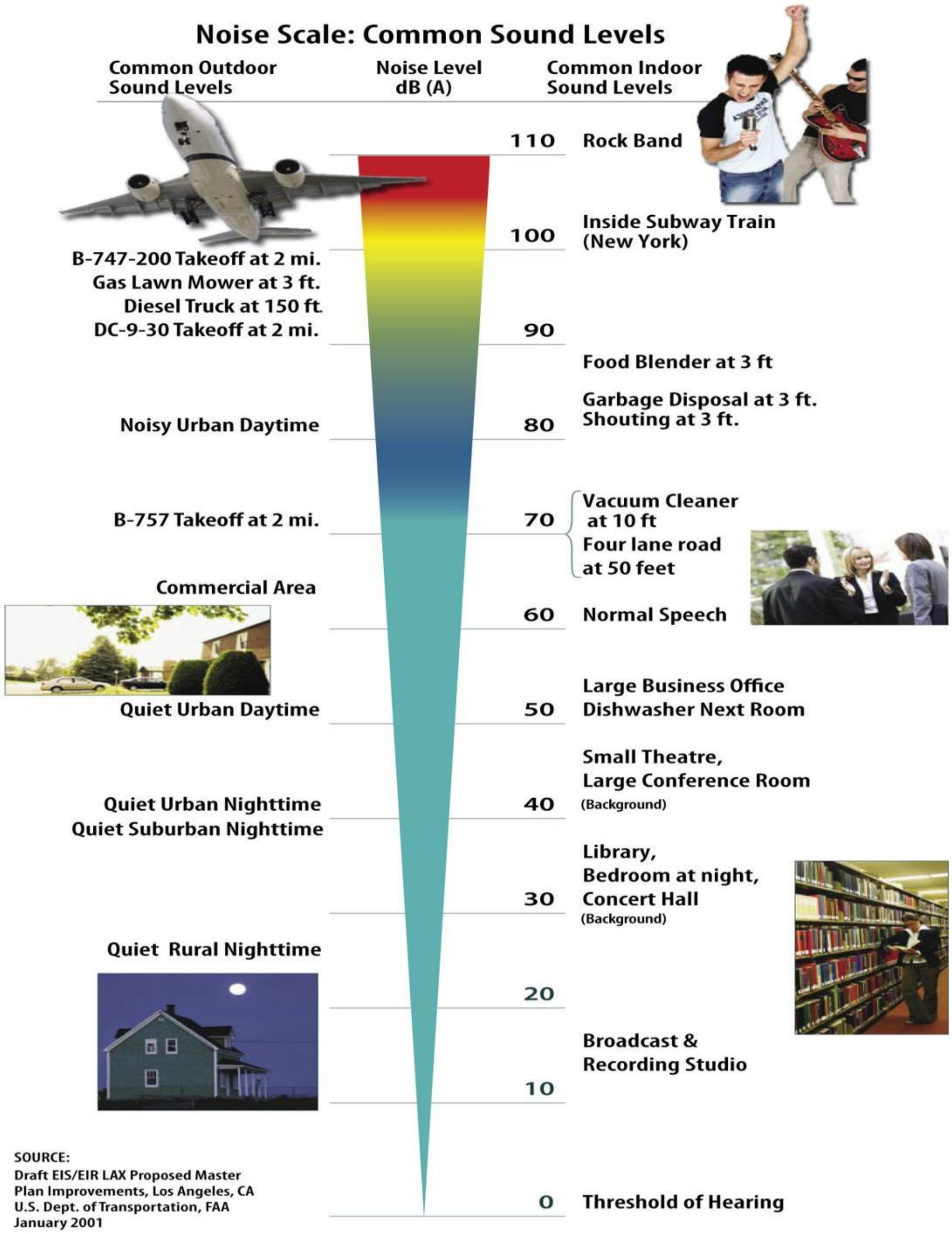
Details:
The first parameter is determined by the level of sound, which is expressed in units of decibels (dB(A)). By using this scale, the range of normally encountered sound can be expressed by values between 0 and 120 dB(A). On a relative basis, a 3-dB(A) change in sound level generally represents a barely perceptible

change in a common outdoor setting, to someone with average hearing. A 5-dB(A) positive change presents a “noticeable” change, and a 10-dB(A) positive change is typically perceived as a doubling in the loudness while a 10-dB(A) decrease in noise levels is perceived as a 50 percent reduction in loudness.

The frequency of noise is related to the tone or pitch of the sound and is expressed in terms of cycles per second called hertz (Hz). The human ear can detect a wide range of frequencies from about 20 Hz to 17,000 Hz. However, because the sensitivity of human hearing varies with frequency, the A-weighting system is commonly used. Sound levels measured using this weighting system are called “A-weighted” sound levels and are expressed in decibel notation as “dB(A).” The A-weighted sound level is widely accepted as a proper unit for describing environmental noise.

Because environmental noise fluctuates from moment to moment, it is common practice to condense all of this information into a single number called the “equivalent” sound level (Leq). The Leq is a measure of the average sound energy during a specified period of time (typically 1 hour or 24 hours). The Leq is defined as the constant level that, over a given period of time, transmits the same amount of acoustical energy to the receiver as the actual time-varying sound. Studies have shown that Leq is well correlated with human annoyance to sound, and therefore, this descriptor is widely used for environmental noise impact assessment. The Leq measured over a 1-hour period is the hourly Leq (1-hour), which is used to analyze highway noise impacts and abatement.

2.1.2 What are Typical Hourly Sound Levels?



2.1.3 What Factors Affect Traffic Noise Levels?

Many factors affect noise. Traffic noise level at a site depends on both site geometry (distance, land cover, topography, etc.) and traffic characteristics (volume, vehicle type, speed, truck numbers, etc.) of proposed roadways near a noise site.

Details:

As mentioned above, traffic noise level at a site depends on both site geometry and traffic characteristics of proposed roadways near the site. As an example, for a straight, at-grade roadway with a steady stream of vehicles, the Leq noise level decreases with distance from the roadway. Generally, in areas where the land between the roadway and the receptor site is primarily grass, lawn, or other sound absorptive material, the noise level decreases at a rate of 4.5 dBA per a doubling of the distance. Conversely, in more urban areas with concrete, the noise level drops off at a much slower rate—typically around 3 dBA per a doubling of the distance. These drop-off rates assume vehicle travel speeds remain constant and flat open terrain occurs between the receptor and the roadway. Higher drop off rates will typically occur in areas where there is excess shielding caused by building rows or variations in the terrain.

Assuming similar vehicle mix and travel speeds, a doubling in traffic volume over a given period of time produces a doubling in the sound energy. A doubling in sound energy corresponds to a barely perceptible 3-dBA increase in noise level. At locations where traffic volumes and noise levels are already high, a large change in traffic volume is required to cause a perceptible change in the noise level.

Noise levels from trucks are much greater than noise levels from automobiles. The noise generated by a single heavy truck is as loud as 10 automobiles. Consequently, at a given constant travel speed, noise level changes are more sensitive to the distance of nearby truck lanes and/or to changes in truck volumes than changes in overall traffic flow. However, travel speeds do play a factor, and on a roadway that is carrying a given volume of traffic, road-traffic noise levels increase by approximately 5 to 6 dBA as the speed increases from 30 to 45 mph, and by another 3 dBA as the speed increases to 55 mph.

2.2 What Methodology is used to Predict Noise?

The FHWA Traffic Noise Model (TNM) Version 2.5 was used to predict Leq (1-hour) traffic noise levels. The TNM model is used to obtain reasonable estimates of traffic noise at discrete locations by considering interactions between different noise sources and the effects of topographical features on altering predicted noise levels. A ***receiver*** is a discrete point modeled in the TNM program where as a ***receptor*** is defined as a representative location of a noise sensitive area for various land uses. In areas where there is a common noise environment, one modeled TNM receiver can be considered representative of many receptors. This occurs in places like multi-family buildings where noise level estimates at one modeled TNM receiver on a given floor may be representative of noise conditions for all the receptors on that floor. For this project, [x receivers], representing [x receptors], were modeled.

Details:

The TNM model estimates the total sound energy perceived at a modeling receiver by determining the logarithmic sum of the sound energy generated from each of the adjacent roadway segments. The total noise level estimated at a given receiver is a function of the number of automobiles, medium trucks, heavy trucks, and travel speed at which these vehicles are moving on each roadway segment. Moreover, roadway segments with a higher number of heavy trucks generate more noise than those with lower truck volumes. In the TNM model, these factors are combined in an empirical formula governing the relationship of the reference mean noise emission level of each vehicle type as a function of travel speed. In general, roadway segments located further away contribute less to the estimated total noise level than those roadway segments closer to the receiver. In addition, the TNM model also considers attenuating effects of distance, building rows, topography, and average pavement surface, ground surface conditions outside the roadway boundary, trees zones, atmospheric absorption, and any existing sound barriers. Noise generated from sources other than traffic is not included in the model.

Major roadways, […discuss model inputs], and sensitive receivers were modeled in TNM by importing Micro-station roadway design files into the TNM program. [Elevations for the TNM model runs were obtained from X]. Lastly, the number of automobiles, medium trucks, and heavy trucks and their associated travel speeds for each modeled roadway segment were input into the model. Traffic inputs in the model are always assumed as free flow, generally referred to as level of service (LOS) C, conditions which generates the loudest (worst case) traffic noise. Level of Service is defined as the maximum hourly rate at which a vehicles can reasonably be expected to traverse a point /section of a lane or roadway during a given time period. Traffic input in the model was based on […describe if peak hour traffic was used assuming free flow i.e. LOS C or if Level of Service C traffic was calculated for the project]. The TNM model preparation was completed and the program executed. Upon completion, noise level estimates at the receivers were provided in an output summary table.

2.3 What is Considered a Noise Impact?

The GDOT defines a noise impact as occurring when design-year build noise levels approach or exceed the NAC thresholds listed in [Table 1 below] or when predicted design-year build noise levels result in a substantial noise level increase over existing noise levels. The GDOT considers approach levels as 1 dBA less than the noise levels shown in [Table 1 below] and defines a substantial noise level increase as being 15 dBA or greater than existing noise levels.

Details:

The National Environmental Policy Act (NEPA) provides broad authority and responsibility for evaluating and mitigating adverse environmental effects, including highway traffic noise. Implementation of NEPA requires federal government agencies to use all practical means and measures to promote the general welfare and foster a healthy environment. The Federal-Aid Highway Act of 1970 required FHWA to develop standards for highway noise.

In response to the problems associated with highway traffic noise, 23 C.F.R. § 772 "Procedures for Abatement of Highway Traffic Noise and Construction Noise" establishes standards for impact determination and consideration of abatement. The regulation contains noise impact criteria for various land use activities as shown in [Table 1], FHWA Noise Abatement Criteria (NAC). The FHWA will not approve the plans and specifications for a federally aided highway project, unless the project includes an adequate evaluation of potential noise abatement measures to comply with the standards.

The FHWA regulations contain NAC, which if approached or exceeded on Type I roadway improvement projects require consideration for noise abatement. In addition to these absolute limits, noise impacts can occur if there is a substantial increase in future build noise levels over comparable existing noise levels. The GDOT defines a substantial noise level increase as 15 dBA or greater. The regulations emphasize that the NAC are not design goals. The NAC are simply impact criteria that when approached or exceeded require consideration of noise abatement. Also, the regulations require noise abatement where impacts occur and abatement is determined feasible and reasonable in accordance with 23 C.F.R. § 772.13 and the GDOT noise policy.

[Table 1] provides a summary of the FHWA traffic NAC for each type of land use activity category based on the noisiest hourly Leq value. The GDOT defines a noise impact as occurring when design-year build (a 20 year design horizon) noise levels approach or exceed the NAC thresholds listed in [Table 1] or when predicted design-year build noise levels result in a substantial noise level increase over existing (year of the traffic study) noise levels. The GDOT considers approach levels as 1 dBA less than the noise levels shown in [Table 1] and defines a substantial noise level increase as being 15 dBA or greater than existing noise levels. For example, the approach noise level for Category B land use activities is 66 dBA. The approach noise levels for all NAC categories represent absolute noise impact thresholds, when exceeded constitutes an impact. For example, for NAC land use Category B, a noise level of 65.9 dBA at residential property is not considered an impact, but a noise level of 66.0 dBA or greater is considered a noise impact.

Table 1: FHWA Noise Abatement Criteria (NAC)
Hourly A-Weighted Sound Level - decibels (dBA)

Activity Category	Leq(h)	Description of Activity Category
A	57 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67 (Exterior)	Residential
C	67 (Exterior)	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	52 (Interior)	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios
E	72 (Exterior)	Hotels, motels, offices, restaurants/bars, and other developed lands, properties, or activities not included in A-D or F
F	-	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing
G	-	Undeveloped lands that are not permitted

Source: FHWA, 23 C.F.R. § 772

Once the study area has been defined and land use categories determined, each property in the study area is assigned an Activity Category in accordance with [Table 1]. A detailed description of each type of land use included in each of the seven NAC Activity Categories is outlined in Section 2.4.

2.4 How Were Activity Categories Assigned?

Activity categories are assigned based on how land is being used. This means if the land is being used as a residence, business, church, etc, it is matched up to the corresponding activity as defined in [Table 1] above, section 2.3. Current land use in this project area consists of […describe].

Any area with a building permit prior to project disclosure, which is defined as approval of the NEPA document, is considered planned. Therefore, it is evaluated under the corresponding NAC category of the permit. For this project permits were reviewed though [xx-xx-xxxx]. During the NEPA reevaluation process the proposed project will be re-examined to determine if any new permits were issued between the date permits were reviewed and the date the NEPA document is approved. If building permits are issued between this time the permitted land use will be studied under the appropriate NAC category and mitigation measures would be studied as required.

[…if permit information was obtained, describe and discuss findings]

Details:

For purposes of noise analysis modeling, study area noise receptors were assigned one of seven different land use or activity categories—Activity Category A through G. These are described in the following paragraphs.

Activity Category A: This category includes exterior activities and relates to lands, as stated in 23 C.F.R. § 772, "on which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential for the area to continue to serve its intended purpose." Some examples of land uses designated as Activity Category A include the Tomb of the Unknown Soldier and a monastery.

There are [no] receptors of this activity category located within the study area.

Activity Category B: This category includes exterior activities for single-family and multi-family residences.

There are [X] **receivers**, representing [X] **receptors**, of this activity category located within the study area.

Activity Category C: This category includes exterior activities for Section 4(f) sites and nonresidential public and private facilities that tolerate less noise (e.g., recording studios, amphitheaters, libraries) than Activity Category E (see below).

For cemeteries, parks, and other expansive Category C activities, the number of required receptors shall be determined as follows: 1) determine the typical linear highway frontage of parcels in the surrounding community; and 2) divide the proposed highway frontage length of the Category C site by the amount determined in step 1 above with any remainder counting as an additional receptor.

There are [X] **receivers**, representing [X] **receptors**, of this activity category located within the study area.

Activity Category D: This category includes interior impacts for Activity Category C facilities that may have a noise-sensitive interior use. An indoor analysis is typically done only after exhausting all outdoor analysis options. In situations where no exterior activities would be affected by the traffic noise, or where the exterior activities are far from or physically shielded from the roadway in a manner that prevents an impact on exterior activities, Activity Category D is typically used as the basis of determining noise impacts. All activity Category D sound levels are estimated for informational purposes, as mentioned above a detailed analysis will only be done after exhausting all outdoor analysis options. Interior noise level estimates are determined by subtracting exterior levels (estimated at the nearest door/window to the noise source) by the noise reduction factor identified in [Table 2] below.

Table 2: Building Noise Reduction Factors

Building Type	Window Condition	Structure
All	Open	10dB(A)
Light Frame	Ordinary Sash (closed)	20dB(A)
	Storm Windows	25dB(A)

Masonry	Single Glazed	25dB(A)
Masonry	Double Glazed	35 dB(A)

Note: The windows shall be considered open unless there is firm knowledge that the windows are in fact kept closed almost every day of the year.

There are [X] **receivers**, representing [X] **receptors**, of this activity category located within the study area. The building types and windows consist of the following:

Table 3: Receiver Reduction Estimates

Receiver #	Building Type	Windows	Estimated Reduction
[e.g., 1A, 5A, 7A, 8A]	[e.g., Wood (light frame)]	[e.g., Ordinary]	[e.g., 20]
[e.g., 2A, 6A]	[e.g., Masonry]	[e.g., Single Glazed]	[e.g., 25]

Activity Category E: This category includes exterior activities for certain commercial and developed lands (e.g., restaurants, offices, hotels) that are less sensitive to highway noise.

[e.g., "Each structure generally was considered one receptor for the purpose of disclosure. For receptors in this category that contain lodging units (e.g., hotels), each room where sleep occurs that has a balcony or ground-level patio was considered one receptor. Multiple receivers for each floor were placed around the hotels to accurately assess noise levels as the receiver distance from the roadway varied. It was assumed each hotel room on each floor of the hotel shares a common noise environment. In the case of hotels or motels, exterior balconies of rented rooms were considered the primary noise sensitive area. There are **X receivers**, representing **X receptors**, of this activity category located within the study area."]

Activity Category F: This category includes land use activities that are generally not sensitive to highway noise. No noise analysis is required for this activity category. […if you included this category you must discuss that it is not a requirement of 23 CFR 772 and is included for informational purposes only]

Activity Category G: This category addresses future noise levels on undeveloped lands without a building permit.

For undeveloped lands without a building permit, noise contours were developed on vacant lands using the TNM. In accordance with 23 C.F.R. § 772 (772.17) and as outlined in the GDOT Noise Abatement Policy, information is to be provided to local officials "that can help them to be aware of incompatible land uses near state highways." Large undeveloped lands without permitted/anticipated future development along the project corridor were modeled at 50-feet and then 100-foot intervals from the nearest edge of pavement.

[X] large undeveloped sites, [Study Area X through Study Area X], where noise conditions are anticipated to change were identified along the corridor. The detailed results of this analysis are provided in Section 3.1 (*Projected Sound Levels for Undeveloped Land Without a Permit*) of this document.

2.5 When Were Field Measurements Taken?

Field measurements were collected on [date] from [#] locations within the study area between [e.g., "time of day 8:00am-12pm"]. These noise monitoring sites are depicted on [Figures X (located?)]. The sites were chosen […describe reason for choosing sites]. Noise measurement sites included [e.g., "residential dwellings, a church, and hotels"]. Copies of the field notes are provided in Attachment [X]. Field measurements indicate existing noise levels ranged, at the time measurements were taken, between [# and # dBA].

Details:
Noise measurements for each site were performed in accordance with procedures described in Measurement of Highway-Related Noise (FHWA, 1996). The measurements were recorded using a laboratory calibrated [e.g., "Bruel & Kjær Model 2238 sound level meter"]. All measurements were performed under acceptable weather and street surface conditions consistent with GDOT policy guidelines. These measurements were taken for [e.g., "15"] minutes at each location. The locations of field measurements and the observed sound levels are provided in [Table 4].

Table 4: Existing Field Measurements and TNM Results (dBA L_{eq})

Field Receiver #	Time Range	Figure Location	Field Measurement	TNM Calculation	Difference
[e.g, Receiver 1]					
[e.g, Receiver 2]					
[e.g, Receiver 3]					
[e.g, Receiver 4]					
[e.g, Receiver 5]					

2.5.1 Was the Model Validated?

The model was validated, all results were within 3dBA. Three Decibels is considered validated since it is the threshold, generally considered perceptible by the human ear.

Details:
Field measurements were compared with TNM-modeled noise levels to confirm the applicability of the model for this analysis. Traffic counts, by vehicle type (cars, medium trucks, and heavy trucks) were taken along the project corridor during each field measurement. In addition vehicle speeds of X were observed in the location of […give location for each receiver about speeds]. Total traffic counts were input into the TNM to determine if the model is accurately predicting sound levels along the corridor. The comparisons of field measurements to modeled levels are shown in [Table 4] above. The TNM modeled results for the field measurements indicated existing noise levels between [X and X dBA].

A difference of approximately three decibels is generally considered acceptable. Because each of the field measurements were within the accepted three-decibel range of the model, the model is considered applicable for use in analysis of noise levels within the study area. Therefore, existing noise levels for the receivers within the study area were calculated with TNM for comparison with the build and no build alternatives.

2.6 How Was the Project Modeled?

Noise levels were calculated using the *FHWA TNM 2.5.* Input to the model includes the existing and proposed roadway alignment, existing and projected traffic volumes, based on […describe LOS C conditions calculated or assumed based on peak hour traffic]. Vehicle speeds of [e.g., X mph were used on roadway X and a speed of X mph on all side roads].

Details:
Major roadways and sensitive receivers were modeled in TNM by importing Micro-station based roadway

design files into the TNM program. Receptor locations, [e.g., “terrain lines, building rows, and existing noise walls were also input into the TNM program using this same method”]. Figures provided, [name location of figures], show the locations of the receivers relative to the project study area. Elevations for the TNM model runs were obtained from […insert name source]. Lastly, [the number of automobiles, medium trucks, and heavy trucks and their associated travel speeds for each modeled roadway segment and year were put] into the model.

Table 5: Model Inputs Existing (year)/No-Build (year):

Road	Direction	Between Cross Streets	Lane Width Input	# of lanes Rep.	Truck Percent	Total DHV Existing/ No-Build	Cars Existing/ No-Build	Medium Trucks Existing/ No-Build	Heavy Trucks Existing/ No-Build
SR X	NB	M street and N street	12'	1	4% Medium & 1% Heavy	705/800	670/760	28/32	7/8
Road X	NB & SB	N/A Side Street	24'	2	4% Medium & 1% Heavy	1000/ 1105	950/ 1050	40/44	10/11
Shoulder	NB	M Street	6'	N/A	N/A	N/A	N/A	N/A	N/A

[...If easier this table can also be split into separate existing and no/build tables.]

Table 6: Model Inputs Build (year):

Road	Direction	Between Cross Streets	Lane Width Input	# of lanes Rep.	Truck Percent	Total DHV	Cars	Medium Trucks	Heavy Trucks
SR X	NB	M street and N street	12'	1	4% Medium & 1% Heavy	800	760	32	8
Road X	NB & SB	N/A Side Street	24'	2	4% Medium & 1% Heavy	1105	1050	44	11
Shoulder	NB	M Street	6'	N/A	N/A	N/A	N/A	N/A	N/A

3. What are the Results of the Noise Model?

Existing (the year of the traffic study) Noise levels range between: [X-Y]

No-Build (20 year horizon without project construction) Noise levels range between: [X-Y]

Build (20 year design horizon) Noise Levels range between: [X-Y]

There are [X] receivers, representing [X] receptors, along the project corridor predicted to be impacted in the build alternative based on approaching/exceeding the NAC and [X] based on a substantial increase. (See Table 5 below and figures X on pages?)

Details:
Upon completion, noise level estimates at the receivers were compiled in an output summary table in Attachment [X]. See [table 7 location if it's not in this section if provided here say below]. Copies of the input and output files from the TNM modeling associated with this analysis are provided in [Attachment X] of this document. Traffic used in the model is provided in Attachment [X]. See Figures [X on pages x, or in Attachment X] for receiver locations.

[Table 7]: TNM Noise Results Output Summary Table

Rec. #	# of Receptors	NAC Category	Property Identification	Outdoor area of frequent use yes or no*	Existing 2010	No Build 2033	Build 2033	Increase between build and existing	Impact
8/8A interior	3/1	C	Peachtree Church & Play ground	Yes or No	65 or NA	66 or NA	68 or NA	3 or N/A	Y or N/A
		D		N/A	(64**) 44	(65**) 45	(67**)47	3	N

*if no and the NAC category is not D this is for informational purposes only and there cannot be an impact.

** Receiver placed at window or door closest to noise source with results subtracted based on the look up table to estimate interior sound levels. A detailed analysis will only be conducted if exterior impacts cannot be abated and interior impacts exist based on the estimated interior sound levels.

[…directions under Property Identification reference resource name i.e. Resident (subdivision name if any), church and name, business name, etc.

[…be sure that the receiver locations on the figures clearly identify which receptors are represented by the receiver number]

[…Note that if there is no exterior use than only one receiver needs to be placed in the model, if there is an exterior area of use than a receptor needs to be placed at the door or window closest to the noise source in addition to the receiver used for the exterior area.]

Table [8] summarizes the number of receptors exceeding their corresponding NAC by activity category.

[Table 8]: Number of Receptors Approaching/Exceeding the NAC by Activity Category

NAC/Threshold	Existing	No Build	Build
A - 57			
B - 67			
C - 67			
D - 52			
E - 72			

No receptor sites along the project corridor would experience noise level increases of greater than 15 dBA. Therefore, **no receptors** are considered impacted based on the substantial increase criterion.

[…or]

[Table 9] summarizes the number of receptor sites along the project corridor predicted to experience noise level increases of greater than 15dBA.

[Table 9]: Number of Receptors Experiencing a Substantial Noise Increase

NAC/Threshold	Build
A - 57	
B - 67	
C - 67	
D - 52	
E - 72	

3.1 Projected Sound Levels for Undeveloped Land Without a Permit

In accordance with 23 C.F.R. § 772 (772.17) and as outlined in the GDOT Noise Abatement Policy (July 2011), information is to be provided to local officials "that can help them to be aware of incompatible land uses near state highways." At a minimum, this information is to include "an estimation of future design year noise levels at various distances from the edge of the nearest travel lane of the proposed project where future noise levels are within one decibel of the corresponding exterior values shown in [Table 1: NAC]", or until the parcel ends.

The data in [Table 10] below provides information to aid local officials with jurisdiction over properties in proximity to the project. Large undeveloped lands without permitted/anticipated future development along the project corridor were modeled at 50-feet (from the nearest edge of pavement), 100 feet, and then 100 foot intervals. Sites were selected for this analysis at each location along the corridor where noise conditions are anticipated to change.

As previously noted in section 2.4, for the purposes of this project, [seven locations (Study Area A through Study Area G)] were identified for this analysis. The locations of these study areas relative to the proposed project are provided in [Figures X through X (see Attachment X or pages X)]. The study areas depicted on the graphics represent large sample areas.

[Study Area A covers vacant parcels located]

[Study Area B covers vacant parcels located]

[Study Area C covers vacant parcels located]

[(Note this information can be put into a table or included in the below table)]

Local officials with jurisdiction over the development of parcels along the project corridor are encouraged to consider the information provided in [Table 10 below and] Table [1] when considering future land use and development changes. The information is provided by GDOT to discourage development that would be incompatible with the sound levels that are anticipated along the project corridor at these locations. TNM files for undeveloped land use are located in [Attachment X]. Documentation to aid local officials with future land use development on these parcels is included in Attachment [X].

[Table 10]: Projected Sound Levels to Aid Local Officials

Study Area	50 feet	100 feet	200 feet	300 feet	400 feet	500 feet	600 feet	700 feet	800 feet
A									
B									
C									
D									
E									
F									

*Distance shown is from roadway edge of pavement

4. What types of Noise Abatement were considered?

In accordance with 23 C.F.R. § 772, all impacts need to be studied to determine if abatement measures in the forms of, acquisition of rights-of-way, traffic management, alteration of horizontal and vertical alignments, and structural barriers are feasible and reasonable.

4.1 Acquisition of rights-of-way/Land Use and Zoning

Land use to create buffer zones or separation between noise sensitive receivers and traffic is considered during the design of a project. One noise abatement measure is the application of land use controls to minimize impacts to future development. In particular, land use controls can be used to create buffer zones. Although GDOT is typically not able to acquire land to create buffer zones, it is sometimes possible to relocate an impacted property outside of the potential noise impact zone. This approach is sometimes applied to mobile homes where relocation of the homes to a location outside the impact zone is possible. Typically, this approach would be made in consultation with the owner of the mobile home. [However, none of the receivers to be impacted are of the type that such relocation is practical. Therefore, such action is not appropriate for consideration for this project].

Constructive land use or zoning designations to create a "buffer" between developed areas and roads are most effective prior to development of areas adjacent to the road. The results of this noise study will be sent to local officials for use in future compatible land use planning.

4.2 Traffic Management

Traffic management techniques such as the restriction of truck traffic, use by only certain types of vehicles, restricting use to certain times of the day, traffic calming devices, and reduction in operating speeds were considered for noise abatement measures to the impacted receivers. [In many instances, such as this, construction is taking place on a designated state route/Interstate where prohibition of certain types of vehicles and reductions in speed would not be consistent with the roadway's intended purpose].

4.3 Alignment Alterations

A change in alignment [was or was not] considered to reduce noise impacts. Based on the level of development along [roadway X], an alignment shift to reduce impacts to these receivers would likely result in additional impacts to other receivers. In addition, a shift significant enough to achieve a required reduction level in noise impacts could result in displacements. [This project is on an established roadway therefore, a shift in alignment is not considered a reasonable noise abatement measure]. [Please change wording and discussion if project is on a new alignment, discuss how the alignment was chosen and why a shift would not be reasonable, or why one was already considered for noise from a different location if this was taken into consideration].

4.4 Structural Barriers

The use of structural barriers (earth berms and freestanding walls) must be considered for impacted receivers. The optimum situation for the use of freestanding noise barriers exists when a dense concentration of impacted sites are located directly adjacent to (and parallel with) the highway right-of-way. In these instances, one barrier can protect many people at a relatively low cost per impacted site.

Barriers are considered feasible when:

Feasible

Noise reduction: a calculated noise reduction of at least 5 dB(A) must be achievable for a minimum of one impacted receptor. Each noise receptor which receives a 5 dB(A) reduction (whether classified as impacted or not) is considered to be a benefited receptor.

Constructability: a noise abatement measure must be able to be constructed using reliable and common engineering practices.

Safety and Maintainability: an exterior noise abatement measure should conform to the AASHTO Green Book and Roadside Design Guide and should be accessible to maintenance personnel and not prevent access to other highway appurtenances (e.g., drainage structures). The maximum barrier height that can feasibly be maintained is 30 feet.

Access: an abatement measure must allow sufficient access to adjacent properties.

[Receivers X, Y, and Z all have direct driveway access to roadway x; therefore, a barrier is not feasible as it would prevent access to the properties]. […please note side street access cannot be automatically determined not feasible as a wall could be turned to wrap around the property, however, if other reasons automatically make it un-feasible such as sight distance, or clear zone issues this should be discussed separately, this information must be coordinated and obtained from the project design engineer].

[Table 11]: Noise Wall Feasibility Evaluations

Wall	Receiver # / # of Receptors Represented	Property Identification	Barrier Dimensions	Does Wall Achieve a 5dBA Reduction
1		[e.g., Happy Valley Subdivision]	[X] feet by 30feet	

2		[e.g., Residential structure/s west of SR X at intersection of Happy Valley Road]	[e.g., All Walls in this section should be 30 feet tall as that is the screening to determine feasibility]	

[…Note: “Property Identification” is the name of the structure, like a church name, school name, or area such as subdivision name, or if none street location approximation].

[e.g., “Receivers A, B, and C were studied; however, a 5dBA reduction could not be obtained utilizing a 30 foot barrier. Therefore, this barrier is not feasible to construct see table 11 and Attachment X (barrier analysis)”.]

[e.g., “Receivers J, K, and L appear to be feasible based on the above criteria. Therefore, they are being studied for reasonableness see table 11 and Attachment X (barrier analysis)”.]

[…the abatement discussion should thoroughly discuss why each barrier is or is not feasible. Include the feasibility noise abatement run in the attachment.]

[…ONLY DISCUSS REASONABLE FOR THOSE AREAS THAT ARE DETERMINED TO BE FEASIBLE TO DETERMINE FEASIBILITY ONE SHOULD SIMPLY DESIGN A BARRIER LONG ENOUGH TO PROVIDE ABATEMENT AT A HEIGHT OF 30 FEET, IF A 5 DECIBEL REDUCTION IS REACHED GO ON TO DISCUSS IF IT IS REASONABLE, IF THE MAXIMUM BARRIER COULD NOT REACH A 7 DECIBEL REDUCTION THEN DISCUSS THAT UNDER REASONABLE AND NO FURTHER WALL DESIGN IS REQUIRED.]

Reasonable

The below criteria are considered for each feasible noise abatement measure to evaluate reasonableness. The first two must be satisfied before contacting property owners and residents:

Noise Reduction: at least one benefited receptor must receive a minimum noise level reduction of 7 dBA – i.e., the noise reduction design goal. It is GDOTs goal to get a 7 dBA reduction to as many impacted properties as possible.

Cost Effectiveness: Using a $25 per square foot cost for the required noise barrier, the total cost must not exceed a $55,000 average allowance per benefited receptor.

Property Owners and Residents: The decision to provide abatement will be made in collaboration with property owners and tenants of a benefited receptor. A noise barrier will only be constructed if at a minimum 50% plus one of the respondents vote in favor of noise abatement.

[e.g., “A preliminary evaluation was conducted for # noise walls. The proposed noise wall evaluations are presented in Table 12 and their locations are shown on Figures X and Y”.]

[Table 12]: Noise Wall Reasonability Evaluations

Wall	Barrier Dimensions	Wall distance from center line	List of Feasible Receivers (# of Receptors Represented)	Decibel Reduction	Property Identification	Reasonable Cost	Estimated Cost	Reason able Yes/No
1	[e.g., 200x15]	[e.g., 50]	[e.g., R 1 (2)]	[e.g., 7.2]	[e.g., Happy Valley Subdivision]	[e.g., 165,000]	[e.g., 60,000]	[e.g., Yes]
			[e.g., R 2 (1)]	[e.g., 6.1]				
2					[e.g., Residential structure/s west of SR X at intersection of Happy Valley Road]			

[Proposed barrier wall #1 would begin and end …..Add in location. Barrier Wall # 1 would be located approximately X feet from the center line, would be approximately X feet in length, and heights would vary from X to Y discuss reasonable cost vs. actual.

Proposed barrier wall #2…..]

[…Note: Different heights/lengths, removing of end receivers to shorten walls to achieve reasonableness should be discussed in detail in this section to demonstrate different barrier designs were studied to try to design a reasonable wall. The wall shown in the table should be the closest to reasonable cost and decibel reduction that was achieved and place in attachment.]

5. How is Construction Noise Handled?

GDOT recognizes that minimizing construction noise is important; however, in the absence of standardized federal criteria for assessing construction noise impacts related to transportation projects (FHWA Construction Noise Handbook, 2006), it is necessary to primarily rely on the standards and requirements developed by local governments to determine the criteria to which contractors must adhere.

In Georgia, contractors on all highway construction projects are required to adhere to GDOT Standard Specification Section 107.01 – Laws to Be Observed, which states in part, “The Contractor shall at all times observe and comply with all such laws, ordinances, codes, regulations, orders and decrees…” unless the necessary variance is obtained. Additionally, night time construction is proposed for the proposed project. All construction activities would adhere to Special Provision 150.11.

In order to further minimize construction noise, GDOT’s Office of Environmental Services will give the Project Manager and the design team the noise sensitive receptor information as early as possible during project development. This information would be used for the incorporation of construction noise control strategies in the project layout and design. For example, haul roads could be relocated to areas that would minimize construction vehicle noise exposure to noise sensitive receivers. The sequencing of construction activities and techniques could also be developed to minimize construction noise impacts. For example, permanent noise barriers included in project design could be constructed as early as possible, and daytime (or specified) hours could be required for certain activities.

6. What are the Conclusions Reached Based on the Noise Analysis?

[The construction of this project will result in **x** impacts by approaching and/or exceeding the NAC and X by substantial increase. The proposed project in the design year (20xx) would result in a **x** decibel increase in traffic generated noise. Existing noise levels range from **x** to **y** *dBA*. The predicted no-build noise levels will range from **x** to **y** *dBA*. The predicted build noise levels will range from **x** to **y** *dBA*. Noise abatement for the impacted sites was considered. Discuss conclusion of abatement considerations. A summary of findings is provided in Table 13.]

[…Note: The number of impacts is total number of receptors impacted (receiver is only the points we put in TNM and are not a total of impacts and should not be used as such.)]

[Table 13]: Summary of Findings

Impacted Receiver #	# of Receptors Represented	Property Identification	Is Abatement Feasible & Reasonable	Approximate cost of abatement
[e.g., 1, 6, 8, 21]	[e.g., 4]	[e.g., Isolated areas along SR 5]	[e.g., Not Feasible due to driveway breaks]	[e.g., N/A]
[e.g., 30, 31, 32, 33, 35]	[e.g., 5]	[e.g., Lake Wood Subdivision]	[e.g., Yes]	[e.g., 150,000]

7. What is the Likelihood a Proposed Barrier will be Constructed?

[No impacts were identified for this project. Therefore, abatement measures were not considered. A reevaluation of the noise analysis will occur during final design, should changes warrant a reevaluation.]

[…or]

[No abatement measures were found to be feasible and/or reasonable. A reevaluation of the noise analysis will occur during final design, should changes warrant a reevaluation.]

[…or]

[Based on the studies and conclusions of this report it has been determined that noise abatement is likely, but not guaranteed, at (*number*) locations described as follows: (*brief general description of all anticipated noise abatement locations)*. Noise abatement at these locations is based upon preliminary noise analyses and design criteria.]

[A reevaluation of the noise analysis will occur during final design, should changes warrant a reevaluation. If during final design it has been determined that conditions have changed such that noise abatement is not feasible and reasonable, the abatement measures might not be provided. The final decision on the installation of any abatement measure(s) will be made upon the completion of the project's final design and the public involvement processes.]

APPENDIX C – FAQS

Georgia Department of Transportation | Office of Environmental Services Air & Noise Section

600 West Peachtree Street, N.W. | 16th Floor | Atlanta, Georgia 30308

404-631-1990

www.dot.ga.gov

Frequently Asked Questions:

WHY DOES GDOT BUILD NOISE BARRIERS?

It is part of a federal requirement. U.S. noise regulation (23 CFR 772). In 1972, the U.S. Congress passed legislation that requires state highway agencies to determine noise impacts and evaluate possible mitigation measures as part of a proposed Type I federally-funded roadway project.

HOW ARE SOUND LEVELS DETERMINED & DO YOU CONSIDER THE TRAFFIC VOLUME THAT WILL BE UTILIZING THE CORRIDOR IN THE FUTURE WHEN DETERMINING NOISE IMPACTS?

Sound levels are determined through a computer noise model. The existing and future noise levels are predicted by including the roadway, terrain/ground features, noise sensitive areas (such as homes, parks, etc.), and/or any other features that could influence traffic noise and inputting these features into a computer. To determine that the model is working, noise readings are taken at various locations along the project corridor. If the model and field readings are similar, the existing roadway is replaced in the model with the proposed future roadway and traffic volumes.

WHAT IS CONSIDERED A NOISE IMPACT?

Noise impacts occur when sound levels approach or exceed the federal Noise Abatement Criteria (NAC). In Georgia, "approach" is defined as one decibel lower than the NAC. The NAC for an outdoor area of frequent human use at a residential home is 67 decibels, meaning 66 decibels or higher is considered an impact. The NAC for an outdoor area of frequent human us at a business is 72 decibels, meaning 71 decibels or higher is considered an impact. Additionally an impact can also occur if the proposed project increases existing sound level by at least 15 decibels.

WHY IS MY PROPOSED NOISE BARRIER LIKELY BUT NOT GUARANTEED?

In some cases, as final design and utility information are obtained, it is discovered that there are design and/or utility conflicts which result in GDOT not being able to physically construct a noise barrier. In addition, once a barrier is determined during final design to be feasible to construct, a vote of those benefitting from the construction of the barrier occurs in order to determine if the barrier is ultimately desired. A barrier will not be constructed if a majority of those that would benefit from the barrier do not desire it.

WHEN WILL THE VOTING ON NOISE BARRIERS TAKE PLACE?

Voting may take place as soon as design confirms that a noise barrier can physically be constructed at the proposed location with the necessary specifications.

IF I RENT RATHER THAN OWN, DO I GET TO PARTICIPATE IN THE VOTING FOR NOISE ABATEMENT?

Yes. All individuals, owners and renters that would benefit from a proposed noise barrier get to participate in the voting.

WHY AM I IMPACTED BUT NOT BEHIND A PROPOSED NOISE BARRIER?

Every situation is different. Some common reasons why a barrier is not proposed are inability to physically construct or maintain a barrier, the barrier is not able to reduce sound levels for those impacted, or if a barrier does not meet GDOT's reasonability requirements for sound reduction and/or costs.

HOW FAR FROM THE ROAD DO YOU STUDY SOUND LEVELS (HOW WERE THE LIMITS OF THE NOISE STUDY DETERMINED)?

There is no set distance. Homes and other noise sensitive areas are studied until the noise model is no longer identifying noise impacts. Once all potential noise impacts (as a result of the proposed project) are identified, no further modeling or studies occur.

WILL THE NOISE STUDY COVER THE TRANSIT SYSTEM?

No. Sound levels are determined for traffic noise only. Any transit project would be studied by MARTA and the Federal Transit Administration (FTA).

WHAT IS A TYPE 1 PROJECT?

A Type I Project is a federally-funded roadway project that qualifies for a full noise impact assessment and the consideration of noise abatement to any noise impacts identified. This study involves computer noise modeling. The criteria to determine if a project is a Type I are as follows:

(1) The construction of a highway on new location; or,(2) the physical alteration of an existing highway where there is either:

(i) Substantial Horizontal Alteration. A project that halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition; or,

(ii) Substantial Vertical Alteration. A project that removes shielding therefore exposing the line-of-sight between the receptor and the traffic noise source. This is done by either altering the vertical alignment of the highway or by altering the topography between the highway traffic noise source and the receptor; or,

(3) the addition of a through-traffic lane(s). This includes the addition of a through-traffic lane that functions as a (high occupancy vehicle (HOV) lane, High-Occupancy Toll (HOT) lane, bus lane, or truck climbing lane; or,

(4) the addition of an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

(5) the addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange; or,

(6) restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane, except for when the auxiliary lane is a turn lane; or,

(7) the addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot or toll plaza.

If any portion of a project is determined to be a Type I project under this definition then the entire project area as defined in the NEPA document is a Type I project.

WHAT IS A TYPE 2 PROJECT?

Also called a retrofit project for noise abatement, it is a federal or federal-aid highway project for noise abatement on an existing highway. GDOT does not have a noise abatement program for Type II projects.

WHAT IS A TYPE 3 PROJECT?

A federal or federal-aid highway project that does not meet the classifications of a Type I or Type II project. Type III projects do not require the preparation of a noise study or abatement of highway noise impacts. Examples of this type of project include resurfacing or bridge replacement.

IS AN AUXILIARY LANE CONSIDERED A TYPE 1 PROJECT?

Yes. However, the addition of an auxiliary lane that serves as a turn lane would classify a project as Type III, rather than as a Type I project, unless other conditions classify the project as Type I.

WHO IS RESPONSIBLE FOR TRACKING THE NOISE BARRIER INVENTORY?

In accordance with 23 CFR 772.13(f), GDOT will maintain an inventory of all constructed abatement measures and will supply the same upon FHWA request.

HOW DOES GDOT DETERMINE WHERE TO PLACE NOISE BARRIERS?

The Traffic Noise Model (a computer program developed by the Federal Highway Administration) is used to predict future traffic sound levels. Impacted locations are then considered for noise abatement measures. Project staff evaluates potential design and traffic control modifications, such as prohibiting trucks or changing the horizontal or vertical alignment. Then, noise barriers are modeled for attenuating noise and are optimized to ensure that a beneficial and economical barrier is designed. After the evaluation, a determination is made as to whether each barrier is a feasible and reasonable mitigation measure.

WHAT IS AN IMPACTED RECEPTOR?

An impacted receptor is an individual noise sensitive structure that is projected to experience a traffic noise impact in which the projected sound level is expected to either exceed the Noise Abatement Criteria (NAC) or substantially increase by 15 decibels or more due to the construction of the roadway project.

WHAT DOES "FEASIBLE" AND "REASONABLE" MEAN?

A noise barrier is considered feasible if it would reduce noise levels by 5 decibels (dB(A)) or more at one or more impacted sites, would be no more than 30 feet in height, and would allow appropriate access to adjacent properties. A noise barrier is considered reasonable if at least one 7 dB(A) reduction is achieved, certain cost/benefit thresholds are met and a majority of the people receiving a benefit desire the noise barrier. If it is determined to be a feasible and reasonable expenditure of taxpayer money, then the noise barrier will be added to the project plans. In order to determine cost reasonableness, a noise barrier must cost $55,000 or less per benefited receptor. A $25 per square foot unit construction cost (post and panels) shall be used when determining cost reasonableness.

HOW IS THE BARRIER HEIGHT DETERMINED?

Noise barriers are generally designed to provide noise reductions of 7 dB(A) or more for as many receptors as reasonable (minimum of one). However, a minimum reduction of at least 5 dBA is required in order for the noise barrier to be considered minimally effective. The reasonableness criteria places a practical cost limitation on the height of any noise barrier. The maximum allowed average height for a noise barrier varies by foundation/anchoring method and ranges from 30ft on flat ground to 12ft along a bridge.

HOW EFFECTIVE ARE NOISE BARRIERS?

Generally, the effectiveness of a noise barrier depends on (1) the distance between the listener and the noise source, (2) the distance between the listener and the noise barrier and (3) the height of the noise barrier above the line-of-sight between the listener and the noise source. Typically, the benefit due to the noise reduction by a noise barrier will be greatest for the listeners nearest the noise barrier.

HOW MUCH DO NOISE BARRIERS COST?

Current barrier costs average $25 per square foot. The typical height required for an eight (8) dB reduction is 16 feet. With these figures, a barrier would cost $2.1 million per mile along just one side of the road. However, the total cost must not exceed a $55,000 average allowance per benefited receptor.

WHO PAYS FOR NOISE BARRIERS?

Federal and state highway money is used for the construction of noise barriers.

DOES THE PUBLIC HAVE ANY INPUT?

Yes. The decision to provide abatement will be made in collaboration with the property owners and residents, including tenants, of a benefited receptor(s). The outreach strategy will be customized for maximum effectiveness on each project. Outreach methods may consist of a first class mailed letter and survey provided to benefited property owners and tenants, public meetings, phone conversations, or any other method based on the project circumstances. A good faith effort to reach benefitted receptors will be made. If there are no or minimal responses (less than 25 percent), then the outreach method utilized will be reviewed to determine if another method would result in increased participation. A noise barrier will only be constructed if at a minimum 50% plus one of the respondents vote in favor of noise abatement. Both property owners and dwellers get a vote and their vote must be returned within 30 calendar days to receive consideration. Property owners will receive one vote per unit owned and an additional vote if they reside in the unit, and tenants will receive one vote for the benefited unit they occupy. For some projects, individual meetings, community meetings or other outreach efforts may also be utilized to determine a majority consensus.

HOW WAS THE SELECTION OF THE NOISE LEVELS IN THE NOISE ABATEMENT CRITERIA DETERMINED?

GDOT's selection of the noise abatement criteria levels was based on guidance from FHWA and is consistent with the criteria used by all state DOT's. FHWA considered numerous approaches in establishing the noise abatement criteria, to include concerns regarding hearing impairment, annoyance, sleep interference, and speech communication interference.

DOES GDOT HAVE A PROGRAM TO PROVIDE INSULATION OF PRIVATE RESIDENCES?

Unfortunately, GDOT does not have funds available for such a program. GDOT only considers interior noise reductions for certain types of structures defined as Category D in the GDOT noise policy. Category D structures include auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, schools, radio studios, recording studios, and television studios.

WHY NOT PLANT TREES INSTEAD OF PUTTING UP A BARRIER?

The planting of vegetation or landscaping is not an acceptable noise abatement measure since only dense stands of evergreen vegetation at least 100 feet deep will be able to reduce noise levels.

WHAT TYPES OF NOISE BARRIERS ARE CONSTRUCTED?

Noise barriers are typically made of pre-cast, composite, sound-absorptive panels that can have different texture looks and colors (e.g., stone, brick, smooth or grooved patterns).

IS A NOISE ANALYSIS REQUIRED IF MITIGATION IS CLEARLY NOT FEASIBLE?

Yes, the Federal noise standard, embodied in Title 23 CFR Part 772, requires an analysis of sufficient scope to determine if a traffic noise impact exists.

HOW DO I PUT IN A REQUEST FOR A NOISE BARRIER FOR MY COMMUNITY?

To turn in a request for a noise barrier, please visit us online at http://www.dot.ga.gov/BuildSmart/Pages/ContactUs.aspx, or call (404) 631-1990.

IS A NOISE ANALYSIS REQUIRED FOR UNDEVELOPED LANDS?

23 CFR 772 analysis requires identification of all land use activities for developed lands and for undeveloped lands for which development is "planned, designed and programmed", i.e. where development approval has been granted. Undeveloped land areas without development approval are only studied for information purposes and to assist in land-use planning.

Areas that have received development approval (i.e. granted a build permit) prior to the initial approval of the Environmental Document by FHWA are included in GDOT's noise assessment and are assessed for noise impacts. Areas receiving development approval after the approval of the Environmental Document are unable to be considered for noise impacts or noise abatement.

WHAT ARE THE FACTORS USED BY GDOT IN DETERMINING MY COMMUNITY'S ELIGIBILITY FOR A NOISE BARRIER?

GDOT will determine if the community is impacted by highway traffic noise on a federally-funded highway project and if the construction of a noise barrier is feasible and reasonable. Only barriers that are determined to be both feasible and reasonable will be approved.

WHAT DO I DO IF AN EXISTING BARRIER IS DAMAGED?

Noise barriers built by the state are maintained by the state. To file a complaint, please visit us online at http://www.dot.ga.gov/BuildSmart/Pages/ContactUs.aspx, or call (404) 631-1990.

HOW IS NOISE MEASURED?

Noise, usually defined as unwanted or unacceptable sound, is measured in terms of hourly equivalent, A-weighted decibels. A decibel is a unit of measurement that quantifies the sound pressure differences in the air that we perceive as sound (or noise). Zero decibels is the threshold of human hearing, 40 to 50 decibels is normal for a relatively quiet neighborhood, 70 to 80 decibels is the level adjacent to a busy urban street or 50 feet from a major freeway, and 120 to 140 decibels is a typical level at which sound is painful. For highway traffic noise studies, noise levels are quantified in terms of the equivalent sound level, or Leq. The Leq is essentially the average noise level over period of time, usually one hour. A-weighting is the processing of noise frequencies to reflect human hearing response typically referred to as dB(A).

WHAT IS A "SUBSTANTIAL NOISE REDUCTION"?

A noise barrier must provide at least a readily perceptible decrease in noise levels to adjacent receivers to be feasible. This is defined as a noise decrease of at least 5 decibels. As noise level changes of 3 decibels or less are not generally perceivable, it is not prudent to construct a noise barrier that gives only a 1 or 2 decibel benefit to adjacent properties.

ARE NOISE BARRIERS BUILT TO PROTECT LOCATIONS ON THE UPPER FLOORS OF HOMES?

Noise barriers may, under certain geographic conditions, be able to be designed to protect upper levels of multi-family structures, where each unit is a separate residence. For single-family homes, the primary consideration is the outdoor, ground-floor areas of human activity. Barriers built for the second floor would have to be tall enough to provide a substantial noise reduction for those areas, which in most cases would require very high barriers that would not be feasible or reasonable.

DOES GDOT CONSIDER 'QUIETER PAVEMENT' AS A NOISE ABATEMENT?

The use of quieter pavements is also not an acceptable noise abatement measure unless and until an approved Quiet Pavement Program is approved by FHWA for Georgia.