THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

TECHNICAL REPORT 0-6804-3
TxDOT PROJECT NUMBER 0-6804

Traffic Noise Barrier Analysis for SH 190 in Rowlett, Texas

Dr. Manuel Trevino

August 2019; Published September 2020

http://library.ctr.utexas.edu/ctr-publications/0-6804-3.pdf

Technical Report Documentation Page

1. Report No. FHWA/TX-19/0-6804-3	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Traffic Noise Barrier Analysis for SH 190 in Rowlett, Texas		5. Report Date August 2019; Published September 2020 6. Performing Organization Code
7. Author(s) Manuel Trevino		8. Performing Organization Report No. 0-6804-3
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3925 W. Braker Lane, 4th Floor Austin, TX 78759		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 0-6804
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Division P.O. Box 5080 Austin, TX 78763-5080		13. Type of Report and Period Covered Technical Report; June 2017–June 2019 14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

16. Abstract

The Texas Department of Transportation commissioned a study to analyze the feasibility and effectiveness of lightweight noise barriers on Interstate Highway (IH) 30, near downtown Dallas in 2013. The study led to the installation of two adjacent transparent highway noise barriers in 2013 and 2018, respectively. The success of that project led to the possibility of similar installations at other locations in the Dallas District. The President George Bush Turnpike (main lanes), and the State Highway (SH) 190 (frontage roads), in Rowlett, near Lake Ray Hubbard, represent a similar noise problem for the residential sites along the highway, with existing noise walls that were apparently insufficient to attenuate the traffic noise. Based on the experience obtained at the IH-30 site, it was decided to perform a similar study for the turnpike and SH 190. The first stages of this study are the subject of this preliminary report. The activities included the site selection for residential noise monitoring, investigating the pavement characteristics related to noise generation, and the computer modeling of the highway noise and the acoustic design of noise walls considering the geometry of the road, its profile, traffic and the existing noise walls. Residential sound pressure level tests were performed at various residential locations for several months. A portable weather station was used to monitor the conditions at the time of the tests. Measurements were conducted throughout the day—morning, afternoon, and evening—and test days occurred once a month. At the time this report is being prepared, the existing noise walls are being retrofitted with transparent panels to increase their height and provide noise reductions. Noise tests to monitor the post-installation wall's performance will ensue, following similar procedures as those of the first phase.

17. Key Words Highway traffic noise, Noise pollution, Noise barriers, Transparent noise barriers, Noise mitigation, Quieter pavements, CRCP, Traffic Noise Model.		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161; www.ntis.gov.	
19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 109	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

Traffic Noise Barrier Analysis for SH 190 in Rowlett, Texas

Manuel Trevino

CTR Technical Report:	0-6804-3
Report Date:	August 2019; Published September 2020
Project:	0-6804
Project Title:	Life Cycle Cost and Performance of Lightweight Noise Barrier Materials along Bridge Structures
Sponsoring Agency:	Texas Department of Transportation
Performing Agency:	Center for Transportation Research at The University of Texas at Austin

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Disclaimers

Author's Disclaimer: The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

Patent Disclaimer: There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

Engineering Disclaimer

NOT INTENDED FOR CONSTRUCTION, BIDDING, OR PERMIT PURPOSES.

Research Supervisor: Dr. Manuel Trevino

Acknowledgments

The author expresses gratitude to Mr. Bill Hale and Mr. George Reeves, formerly with TxDOT, Dallas District, and to Mr. Dan Perge, with the Dallas District, for their support and advice. The guidance of Mr. Wade Odell and Mr. Ray Umscheid, with TxDOT, are also appreciated.

The cooperation of the residents along SH 190 is acknowledged, especially those who kindly allowed and continue to allow the researcher to perform noise measurements in their property at all times of the day.

Table of Contents

List of Figures

List of Tables

Chapter 1. Introduction

This is the third report developed under research project 0-6804, *Life Cycle Cost and Performance of Lightweight Noise Barrier Materials along Bridge Structures*, a study funded by the Texas Department of Transportation (TxDOT). This study started as an investigation of the feasibility of lightweight noise barriers on Interstate Highway (IH) 30 in Dallas. The first two reports for this project presented the findings on the research on the two noise barrier segments on that highway. In 2017, the project scope was expanded to include a similar study on State Highway (SH) 190, in Rowlett, east of Dallas. This is an interim report produced to document the findings to date about the noise studies conducted on SH 190 as part of this project, including field data as well as analyses and conclusions derived from the data to date.

1.1. Background

Noise associated with transportation has progressively become a nuisance to communities along roads, especially in densely populated areas. As traffic volumes of people and freight continue to grow, roads expand and noise levels rise. Nowadays, transportation agencies have become more environmentally sensitive and make efforts to address pollution problems, including those related to noise. Multiple factors affect the level of traffic noise, such as vehicle speed, terrain, grade, surface absorption, and shielding provided by walls, fences, buildings, or even dense vegetation. The most frequently used noise abatement measure has been the construction of noise barriers on the side of the road. Such barriers are normally built along highways that carry heavy traffic in urban areas, where noise pollution is likely to be greater and affect more people.

Noise barriers are normally solid wall structures built between the highway and the impacted activity area to reduce noise levels. Barriers do not eliminate the noise; they only reduce the noise levels perceived by certain benefitted receivers, normally those in proximity to the road. Barriers are especially effective for those receivers situated directly behind it; they can experience a decrease in noise level of typically 5 to 10 dBA. Noise barriers are not effective for homes on a hillside overlooking a road, or for buildings that rise above the barrier; the barrier must be high enough and long enough to block the view of the road. Common materials for barrier construction are concrete and masonry; other materials are metal and acrylic.

The height, length, and material are key components to the effectiveness of the barrier. Openings in the barriers, such as those designed to allow access to side roads or driveways, decrease their effectiveness.

Noise barriers can reduce visibility and lighting for both the receivers behind the barrier and the drivers using the facility. Barriers can also present a problem for businesses along the road by restricting views and access by customers. Barriers constructed with transparent materials can address these problems by reducing the visual impact of opaque barriers, and providing aesthetic value by preserving scenic vistas.

1.2. Research Project Description

In 2013, staff at TxDOT's Dallas District asked CTR to develop a research project to investigate the use of lightweight noise barriers on the south side of IH 30 in an effort to mitigate the noise pollution generated at the highway that affects residences in the Kessler Park neighborhood, west of downtown Dallas. Two noise barriers were installed on top of the existing concrete walls, providing satisfactory results; the post-barrier phase of the data collection at the second site is currently in progress. The overall success of the noise barrier installations on IH 30 suggested that similar barriers to those installed there could be implemented at other locations in the Dallas District and elsewhere. Therefore, when a similar need arose at the District about investigating the possibility of adding noise barriers to a segment of SH 190, the 0-6804 research project was subsequently extended to include an analogous study on that road, located in Rowlett, east of Dallas.

1.2.1. Objective and Tasks

The main objective of this study is to assess the feasibility and effectiveness of lightweight noise barriers on SH 190 in Rowlett. The tasks are as follows:

- Select residential sites for noise monitoring
- Conduct a feasibility study for lightweight traffic noise walls.
- Perform noise modeling
- Make recommendations for noise mitigation measures
- Perform the acoustical design of the barriers
- Conduct periodic inspections of the barriers' condition
- Perform sound measurements before and after the barriers' installation
- Analyze measurements and evaluate performance

1.2.2. Report Organization

This report consists of seven chapters:

- Chapter 1 describes the project, the objectives, this report, and the highway in question.
- Chapter 2 presents the process for the selection of the sites where this project conducted noise monitoring.

- Chapter 3 presents a condition survey conducted on the pavements of SH 190, and the results of tire/pavement noise tests performed on such pavements within the section of study.

- The residential noise testing program is presented in Chapter 4, describing the equipment and test procedures.

- The results of such tests for the initial phase of this project, the pre-barrier condition stage (prior to any noise wall extension), are presented in Chapter 5, along with the analysis of those results and the weather variables and their influence on noise measurements.

- Chapter 6 presents the traffic noise modeling, which characterizes all aspects of the highway (geometry, traffic, receivers, profiles, elevations, existing walls, etc.) and predicts noise levels. The modeling also includes the design of additional noise mitigation measures.

- Finally, Chapter 7 includes a summary and preliminary conclusions, providing an update on the project activities.

1.3. Highway Description

The segment in question, referred in this report as SH 190, is located in Rowlett, east of Dallas, close to Lake Ray Hubbard. The section of interest includes the main lanes, which are part of the President George Bush Turnpike (PGBT), as well as the frontage roads, between south of Main St. and the north shore of the lake.

The PGBT is a 52-mile toll road running through the northern, northeastern, and western suburbs, forming a partial loop around Dallas (Figure 1.1). It is named for the late George H. W. Bush, the 41st President of the United States. At its west end near Belt Line Road in Irving, SH 161 continues southwest to IH 20 in Grand Prairie. The discontinuous toll-free frontage roads along the turnpike from IH 35E in Carrollton east to its end at IH 30 in Garland have the SH-190 designation. SH-190 signage appears only along the Garland, Richardson, Plano, and Carrollton sections of the frontage road with the undersign "frontage road only." At intersections with city streets, only the PGBT signs are displayed, not the SH-190 signage. Prior to the construction of the main lanes as a tollway, SH 190 was used as the name of the planned main lanes too. Similarly, the part west of IH 35E was planned as part of SH 161. PGBT is signed as a north–south road from IH 20 to IH 35E (the "Western Extension"), an east–west road from IH 35E to the Merritt Main Lane Gantry (the original sections) and as a north–south road from the Merritt Main Lane Gantry to IH 30 (the "Eastern Extension"), as the PGBT makes a nearly 90-degree curve in both places (*NTTA*).

Figure 1.1: Map of PGBT (Source: NTTA)

The turnpike segment from SH 78 to the interchange at IH 30 is known as the PGBT Eastern Extension (PGBT-EE); it consists of five sections (Sections 28 to 32, Figure 1.2), which opened to traffic in December 2011. The project was broken into five sections for purposes of managing and expediting the design and construction. There is a newer segment of the PGBT; this one is on the west side of Dallas, from south of SH 183 to IH 20. It opened to traffic in October 2012.

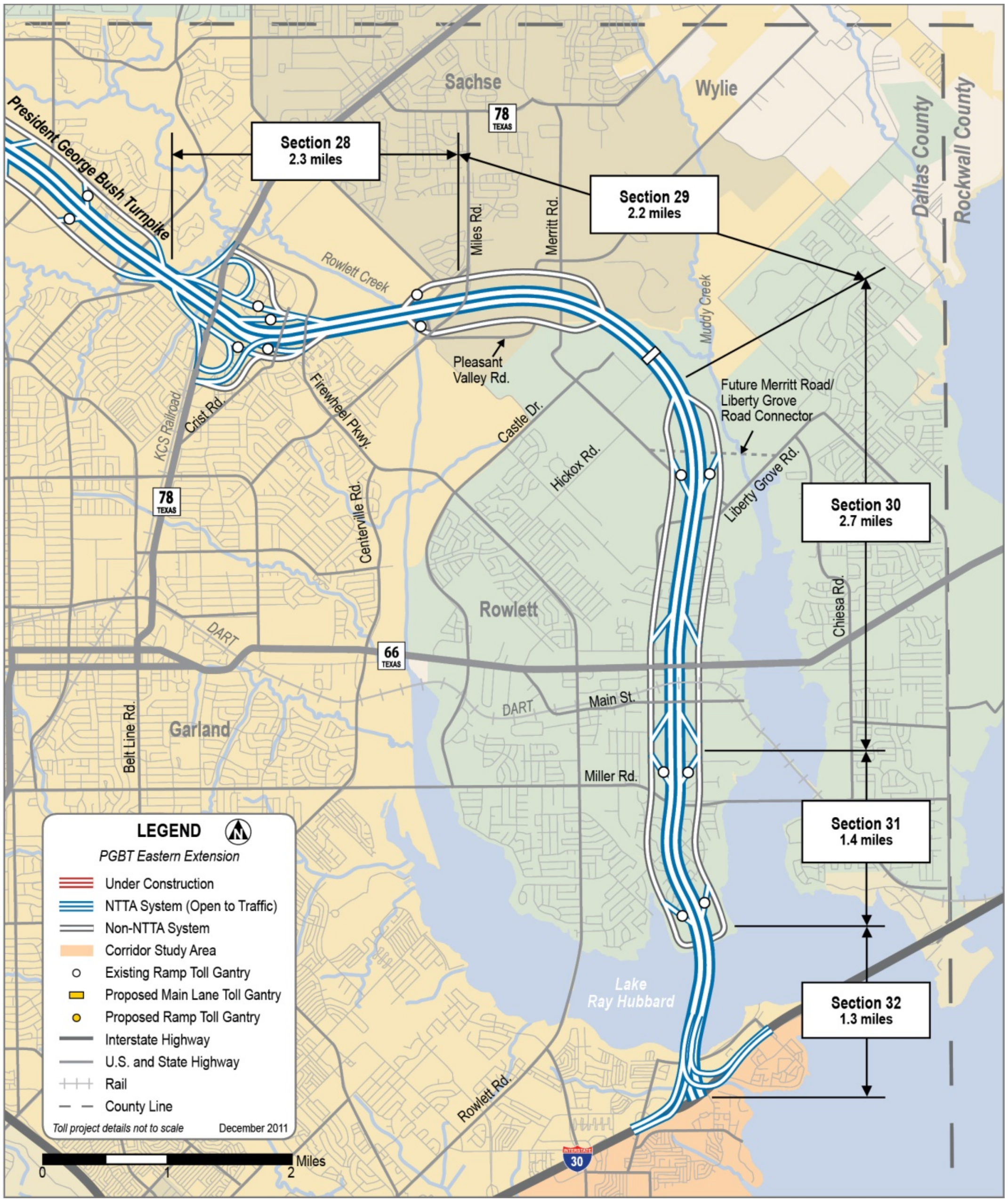

Figure 1.2: PGBT Eastern Extension (Source: NTTA 2013)

In particular, Section 31 is the section of interest in this study (Figure 1.3). The 1.4-mile section extends from south of Main St. to the north shore of Lake Ray Hubbard.

The PGBT is operated by the North Texas Tollway Authority (NTTA). The NTTA maintains the main lanes, while TxDOT maintains the frontage roads.

The NTTA was responsible for constructing main lane and ramp pavement, bridge and drainage structures, retaining walls, noise barriers, illumination, signing, pavement markings, traffic signals, landscaping, ITS infrastructure, and four ramp toll gantries for electronic toll collection.

Figure 1.3: Project location (Source: NTTA 2013)

1.3.1. Geometry

The highway section of interest is oriented north-south. It consists of three main lanes with inside and outside shoulders in each direction, separated with a 48-ft. wide median and a continuous concrete traffic barrier (CTB), as well as two and three lanes of frontage roads for the northbound direction, and two lanes for the southbound frontage road.

The PGBT main lanes are 12-ft. wide; the right (outside) shoulder is 10-ft. wide and the left (inside) shoulder is 12-ft. wide to allow a disabled vehicle to stop without interfering with the through traffic lanes. Both shoulders are paved with concrete and match the adjoining pavement section. The frontage road lanes are 12-ft. wide as well.

The vertical alignment of this section of highway corresponds to slightly rolling terrain. An important consideration is that the rolling terrain also varies in the east-west orientation, so with the highway segment oriented north-south, these variations are reflected in such way that the vertical profiles between main lanes, frontage roads and neighborhood are not even throughout the length of the road studied; this results in different elevations between them, making the noise walls not entirely effective for shielding the neighborhoods. (Please see section 1.3.5 for more information on this subject).

1.3.2. Pavements

The original pavement type for both the main lanes and the frontage roads is continuously reinforced concrete pavement (CRCP). The finishing for the CRCP is transverse tining. The pavement for main lanes and ramps consists of 13 in. of CRCP, supported by 1-1/2 in. thick asphalt bond breaker, 6 in. of cement stabilized base, and 12 in. of either lime stabilized subgrade or cement stabilized subgrade (CSS). Below these layers there is a 2 to 8 ft. layer of moisture-treated subgrade to reduce swelling of the expansive soils. The shoulders have the same thickness and materials as the main lanes. The frontage road pavement section consists of 11 in. of CRCP over 4 in. of asphaltic concrete pavement and 12 in. of CSS. Those original pavements constructed in 2011 are still in place and are in good condition up to the present. A thorough evaluation of the pavement conditions is presented in Chapter 3.

Images of the northbound main lanes are presented in Figures 1.4 and 1.5. Figures 1.6 and 1.7 show views of the southbound main lanes.

Pictures of the northbound frontage road are shown in Figures 1.8 to 1.10. Figure 1.9 shows the transition from three to two lanes. Figure 1.11 shows an image of the southbound frontage road.

Figure 1.4: View 1 of the northbound main lanes

Figure 1.5: View 2 of the northbound main lanes

Figure 1.6: View 1 of the southbound main lanes

Figure 1.7: View 2 of the southbound main lanes

Figure 1.8: View 1 of the northbound frontage road

Figure 1.9: View 2 of the northbound frontage road (transition from three to two lanes)

Figure 1.10: View 3 of the northbound frontage road

Figure 1.11: View of the southbound frontage road

1.3.3. Residential Communities

There are four main neighborhoods along the SH 190/PGBT-EE Section 31 (from south of Miller St. to the north shore of Lake Ray Hubbard) that are affected by the highway traffic noise, i.e., the noise generated by the traffic traversing the toll road and the frontage roads. These communities are called Ridgecove and Magnolia Springs on the west side of the highway, and Harborside and Lake Forest Estates on the east side of the road.

These neighborhoods were approved by the City of Rowlett prior to the construction of the PGBT-EE, with full knowledge of the upcoming highway and its location.

A timeline of the history pertaining to the highway and the surrounding neighborhoods is presented below (*NTTA 2012*):

- 1968: A loop around Dallas County (Loop 9) is identified
- February 1995: Rowlett adopted Resolution 2-21-95C, which created zoning to coincide with the approved SH 190 concept plan
- December 1995: Harborview 1 was re-platted to conform to the approved zoning plan
- February 1996: Harborview 2 was platted
- October 1997: Harborview 3 was platted, showing future SH 190
- July 1998: Ridgecove was platted, showing future SH 190
- December 2000: Magnolia Springs 3B was platted, showing future SH 190
- October 2004: Final Environmental Impact Statement (FEIS) approved by FHWA
- May 2005: Magnolia Springs 5 was platted, showing future SH 190
- July 2008: The FHWA approved the re-evaluation
- August 2008: Highway construction began
- December 2011: PGBT-EE opened to traffic

1.3.4. Existing Noise Walls

When the PGBT-EE project was initially designed, it was determined by the traffic noise analysis that the proposed project would result in a traffic noise impact. Therefore, NTTA constructed noise barriers to mitigate traffic noise impacts along the project. Through the environmental re-evaluation of 2008, it was determined that noise barriers were both feasible and reasonable to mitigate traffic noise. There are two existing noise walls, which are made of concrete and are 8-ft. tall. One is on the east side (northbound direction) and the other one is on the west side (southbound direction). They are placed between the frontage roads and the residences. They were constructed at the same time the highway was constructed. The east side wall is 2,858 ft. long, and the west side wall is 2,949 ft. long. The east side wall shields the Harborview community and the west side wall protects the Ridgecove community.

Figure 1.12 shows the residential communities along the highway as well as the location of the existing noise walls relative to the highway and the neighborhoods.

Figure 1.12: Residential communities and existing noise walls in the area of interest

As Figure 1.12 shows, the walls do not protect all the homes in the residential communities in question. On the east side, Lake Forest Estates is completely unprotected from the noise, and Magnolia Springs, on the west side, is in the same situation. Ridgecove and the majority of Harborview are protected by the existing walls. There are also some homes on Kirby Rd., on the west side, that are not part of any residential community that are also unprotected by the walls and exposed to the noise in close proximity to the frontage road.

Figures 1.13 to 1.15 show some views of the existing concrete walls from the neighborhood side and from the highway side.

Figure 1.13: View of the east noise wall from the neighborhood side

Figure 1.14: View of the west noise wall from the neighborhood side

Figure 1.15: View of the west noise wall from the westbound main lanes

As can be seen in Figure 1.15, most of the homes are two-story residences; thus, the 8-ft. walls only partially block the line of sight between the highway and the receivers. Therefore, some of the noise travels unobstructed from the source to the receivers. The problem is more complex when the differences in elevation between the main lanes and the frontage roads are considered, as the vertical profiles of frontage road, main lanes and the neighborhood first row residences do not match throughout the length of the section of interest. For instance, Figure 1.16 shows a view from the main lanes of PGBT towards the homes of the Ridgecove community on the west side of the highway, indicating a clear line of sight to the backyards, which signifies that the noise has a direct unobstructed path towards the receivers. In this photograph, the noise wall is not visible from the main lanes. The concrete wall in this image is the CTB. This is an example where the noise wall has no benefit in regard to the noise generated from the main lanes for this particular residence.

Figure 1.16: View from the main lanes towards the back of the residences on the west side of PGBT

1.4. Summary

This chapter describes the 0-6804 project, how the SH-190 study originated, and how it fits into the research. The objective and tasks for this part of the project were described, along with the organization of this report.

A description of the characteristics of the SH-190/PGBT section of highway of interest is presented, including geometry, pavements, the adjacent residential communities affected by the highway traffic noise, and the existing noise walls.

Chapter 2. Residential Locations

This chapter presents the work related to the selection of sites for noise monitoring along SH 190/PGBT. The residential locations were selected for measuring noise levels in subsequent stages of this project. The first-row residential sites selected are intended to be representative of the locations and conditions prevailing at the various neighborhood communities affected by the highway noise from SH 190/PGBT. The process for selecting the residential sites is presented in the next paragraphs, followed by a detailed description of each of the sites.

2.1. Site Selection

The site selection process started with a field trip around the neighborhoods along SH 190/PGBT, conducted in June 2017. Mr. George Reeves and Mr. Wade Odell, with TxDOT, showed the CTR researcher various accessible sites along the highway for possible noise test locations. The possible sites were documented with photographs, videos, and notes. The following month the researcher came back to the sites; this time, noise measurements were taken as well as GPS coordinates. This information was used to determine the best suited test sites. Among the key factors for site selection were accessibility, and proximity to the highway (first-row receivers). For accessibility, permission was obtained from a couple of owners to access their driveway and property so that the tests could be conducted regularly in the following months. Besides these homes, there were not very many options of receivers' sites that were easily accessible for routinely performing noise field tests. Another consideration for the site selection was having sites that were protected by existing noise walls, as well as sites not protected by walls, in order to have representative locations for both cases.

Four sites were chosen for the northbound direction, i.e., on the east side of the highway, and four were selected for the southbound direction, i.e., to the west of the highway. The eight sites are summarized in Table 2.1.

Table 2.1: SH 190 residential sites for noise monitoring

Site Number	Side	Community	Address	GPS Coordinates	
				Latitude	Longitude
1	East	Harborside	5010 Southport Dr.	N 32° 52.971'	W 96° 33.308'
2	East	Harborside	2205 Mermaid Cir.	N 32° 53.041'	W 96° 33.335'
3	East	Harborside	4901 Harborview Dr.	N 32° 53.399'	W 96° 33.343'
4a	East	Lake Forest Estates	3401 Francesca Ct.	N 32° 53.624'	W 96° 33.332'
6	West	Magnolia Springs	4317 Rose Leaf Ct.	N 32° 53.424'	W 96° 33.435'
7	West	Magnolia Springs	2629 Kirby Rd.	N 32° 53.235	W 96° 33.438'
8	West	Ridgecove	4509 Meadowcove Dr.	N 32° 52.945'	W 96° 33.378'
12	West	Ridgecove	2414 Brittany Dr.	N 32° 53.025'	W 96° 33.409'

The location of these residences are illustrated in Figure 2.1.

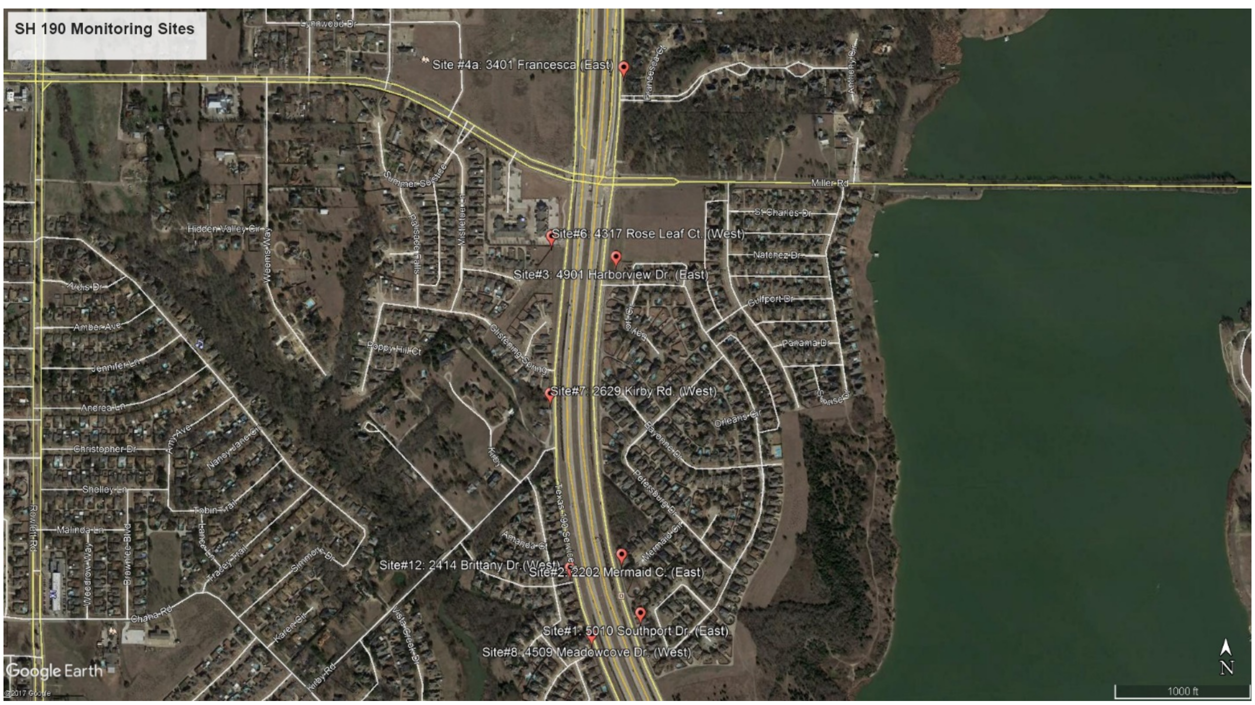

Figure 2.1: Residential sites along SH 190

2.2. Description of Residential Sites

2.2.1. Site #1: 5010 Southport Dr.

This residence is located on the east side of SH 190, within the Harborside community. Figure 2.2 shows a map of this site. This is one of the residences that are behind an existing 8-ft.-tall noise wall. Figure 2.3 shows the front of the house, as seen from Southport Dr. In the background of this picture, the existing noise wall can be seen. The back of this residence (Figure 2.4) faces the highway; therefore, the noise measurements are taken at the backyard. The location for measurements can be accessed from the service alley that runs approximately parallel to the existing noise wall protecting the majority of the Harborside community (Figure 2.5).

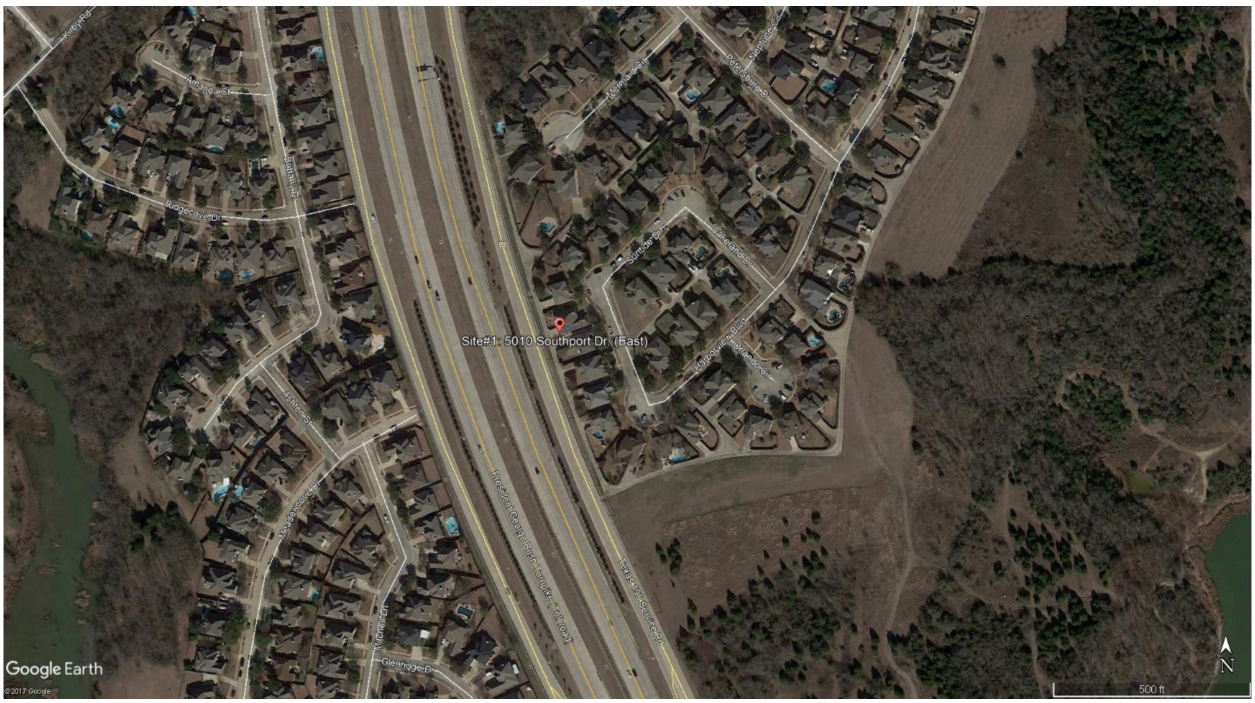

Figure 2.2: Map of Site #1: 5010 Southport Dr.

Figure 2.3: Front view of Site #1: 5010 Southport Dr.

Figure 2.4: View of Site #1: 5010 Southport Dr. from the back

Figure 2.5: Noise measurements at Site #1: 5010 Southport Dr.

2.2.2. Site #2: 2205 Mermaid Cir.

This residence is located on the east side of SH 190, within the Harborside community. Figure 2.6 shows a map of this site. This home is also behind the existing 8-ft.-tall noise wall. Figure 2.7 shows the front of the house, as seen from Mermaid Cir. In the background of this picture, the existing noise wall can be seen. The back of this residence (Figure 2.8) faces the highway; therefore, the noise measurements are taken at the backyard. The location for measurements can be accessed from the same service alley that runs behind most of the houses of the Harborside community (Figure 2.9).

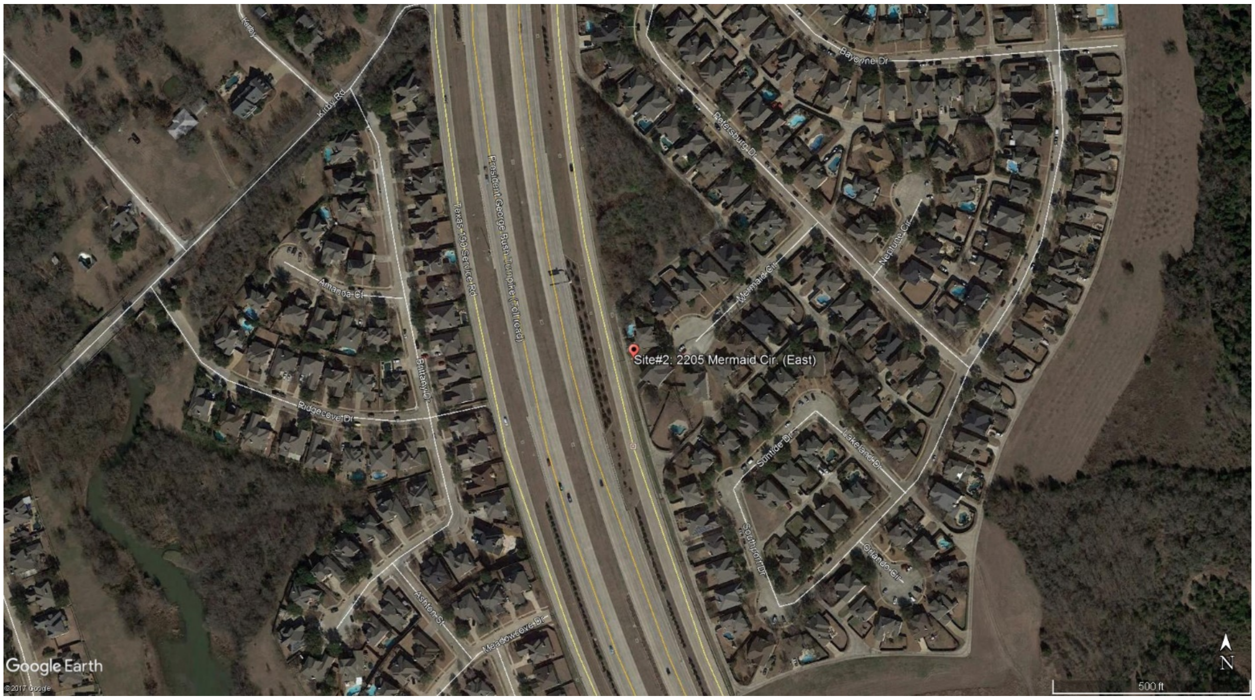

Figure 2.6: Map of Site #2: 2205 Mermaid Cir.

Figure 2.7: View of Site #2: 2205 Mermaid Cir. from the front of the house

Figure 2.8: Noise measurement at Site #2: 2205 Mermaid Cir. showing the back of the residence and existing noise wall

Figure 2.9: Noise measurement at Site #2: 2205 Mermaid Cir.

2.2.3. Site #3: 4901 Harborview Dr.

This residence is located on the east side of SH 190/PGBT, within the Harborside community. Figure 2.10 shows a map of this site. It is one of the northernmost houses in the Harborside community. Unlike the previous two sites, this home is not protected by noise walls. It sits next to an elevated section of PGBT, as shown in Figure 2.11. Furthermore, the yard is next to the frontage road, with no protection from the noise; however, a short stone fence exists in the lot, separating the home from the yard. Figure 2.12 shows the front of the house, as seen from Harborview Dr., which at this point is perpendicular to SH 190; therefore, the façade shown in Figure 2.12 is perpendicular to the toll road, as shown in Figure 2.13. In the background of this picture, the small stone wall within the property can be seen. The noise measurements are taken on the side of the house that faces the highway (Figure 2.14).

Figure 2.10: Map of Site #3: 4901 Harborview Dr.

Figure 2.11: Highway view from Site #3: 4901 Harborview Dr.

Figure 2.12: Front view of Site #3: 4901 Harborview Dr.

Figure 2.13: Front view of Site #3: 4901 Harborview Dr. and SH 190

Figure 2.14: Noise measurement at Site #3: 4901 Harborview Dr.

2.2.4. Site #4a: 3401 Francesca Ct.

This residence is located on the east side of SH 190/PGBT, within the Lake Forest Estates community. Figure 2.15 shows a map of this site. The front of the house faces Francesca Ct. (Figure 2.16). Noise walls do not protect this home; however, it sits next to an elevated section of

PGBT, just like Site #3, as shown in Figures 2.17 and 2.18. Furthermore, the yard is next to the frontage road, with no protection from the noise; however, a short privacy brick wall separates the home from the toll road, as illustrated in Figure 2.17. The noise measurements are taken next to the brick wall in the back of the house, which faces the highway (Figure 2.18).

Figure 2.15: Map of Site #4a: 3401 Francesca Ct.

Figure 2.16: Front view of Site #4a: 3401 Francesca Ct.

Figure 2.17: Noise measurement at Site #4a: 3401 Francesca Ct.

Figure 2.18: Noise measurement at Site #4a: 3401 Francesca Ct.

2.2.5. Site #6: 4317 Rose Leaf Ct.

This residence is located on the west side of SH 190/PGBT, within the Magnolia Springs community. This community is gated and access requires a code. However, the backside of this residence can be accessed from the frontage road of SH 190. Figure 2.19 shows a map of this site.

The front of the house faces Rose Leaf Ct. Noise walls do not protect this home; however, it sits next to an elevated section of PGBT, just like Site #3 and 4a, as shown in Figures 2.21 through 2.24. The backyard is next to the frontage road, but separated by a grassy area, a short metal gate and a short wooden fence (Figure 2.20). The location for the noise measurements is shown in Figures 2.20 through 2.24.

Figure 2.19: Map of Site #6: 4317 Rose Leaf Ct.

Figure 2.20: Noise measurement at Site #6: 4317 Rose Leaf Ct.

Figure 2.21: Noise measurement at Site #6: 4317 Rose Leaf Ct.

Figure 2.22: Noise measurement at Site #6: 4317 Rose Leaf Ct.

Figure 2.23: Noise measurement at Site #6: 4317 Rose Leaf Ct.

Figure 2.24: Noise measurement at Site #6: 4317 Rose Leaf Ct.

2.2.6. Site #7: 2629 Kirby Rd.

This residence is located on the west side of SH 190/PGBT, within the area of the Magnolia Springs community. However, the house appears not to pertain to the gated community. Figure 2.25 shows a map of this site. Access to the residence is through a private drive next to the frontage road of SH 190. Permission was obtained from the residents to access their property for the purposes of this research. There is no protection from the noise, and the house sits in close proximity to both the frontage road and main lanes with clear line of sight to both. This is the site that is more exposed to noise from all the sites considered in this study. The front of residence faces the frontage road of SH 190, as shown in Figures 2.26 and 2.27. The location for the noise measurements is the front yard, as shown in Figures 2.28 and 2.29. The proximity of the frontage road and main lanes can be seen in Figure 2.29. This photograph also shows that the main lanes and frontage road are only separated by a very short berm with scattered trees.

Figure 2.25: Map of Site #7: 2629 Kirby Rd.

Figure 2.26: Front view of Site #7: 2629 Kirby Rd., as seen from the frontage road of SH 190

Figure 2.27: Front view of Site #7: 2629 Kirby Rd., as seen from the main lanes of SH 190

Figure 2.28: Noise measurement at Site #7: 2629 Kirby Rd.

Figure 2.29: Noise measurement at Site #7: 2629 Kirby Rd.

2.2.7. Site #8: 4509 Meadowcove Dr.

This residence is located on the west side of SH 190/PGBT, within the area of the Ridgecove community. Figure 2.30 shows a map of this site. Access to the residence is through a dead-end street perpendicular to the frontage road of SH 190. The front of the residence can be seen from the street, and the left side of the home faces the highway, as seen in Figure 2.31. There is an 8-ft.-tall noise wall that protects the house from the noise, and the wall is between the frontage road and the side yard of the house. The location for the noise measurements is the front yard, as shown in Figures 2.31 and 2.33.

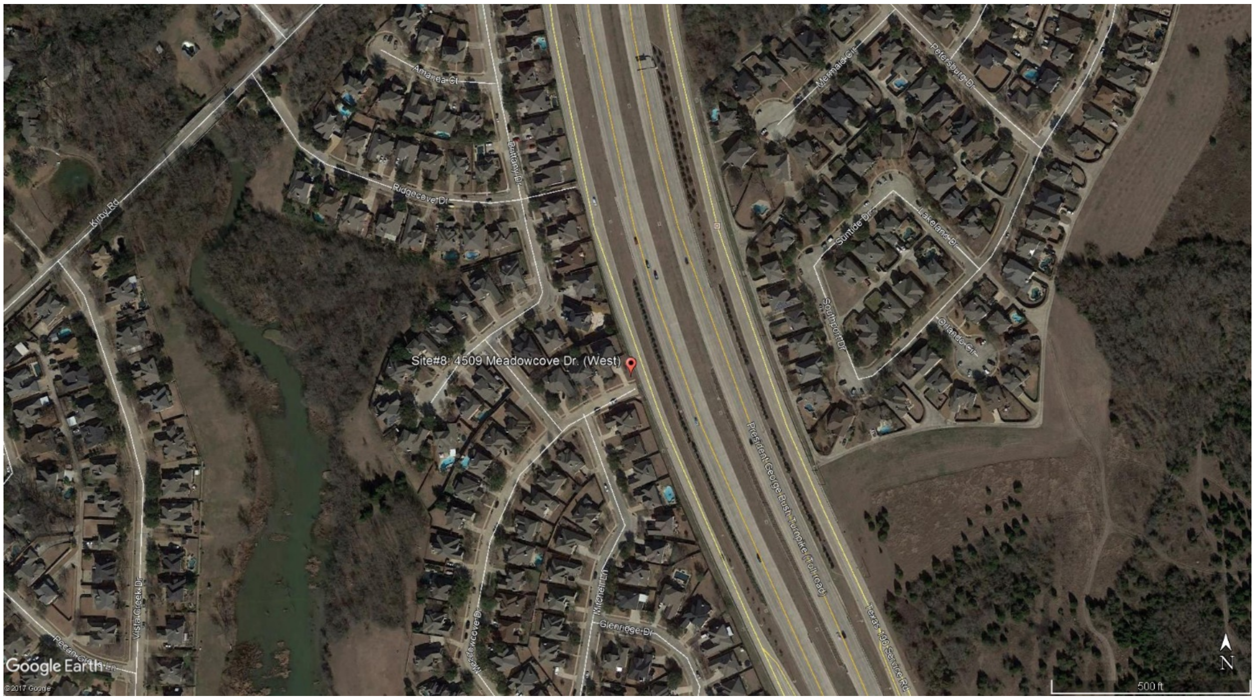

Figure 2.30: Map of Site #8: 4509 Meadowcove Dr.

Figure 2.31: Front view of Site #8: 4509 Meadowcove Dr.

Figure 2.32: View of SH 190 and noise wall from Site #8: 4509 Meadowcove Dr.

Figure 2.33: Night-time measurement at Site #8: 4509 Meadowcove Dr.

2.2.8. Site #12: 2414 Brittany Dr.

This residence is located on the west side of SH 190/PGBT, within the area of the Ridgecove community. Figure 2.34 shows a map of this site. The front of the residence can be seen from the street, and the back side of the home faces the highway, as seen in Figure 2.35. There is a small paved driveway on the south side of the residence that allows access to the back of the homes next to a retaining wall. This driveway functions as an easement and is used by the CTR researcher to conduct noise tests. At this site, the highway is at a higher elevation relative to the residences, and the aforementioned retaining wall is adjacent to the back of the first-row houses. The existing noise wall stands on top of the retaining wall. The retaining wall height varies, but at this location it is approximately 12 ft. tall. The driveway, the retaining wall, and the placement of the noise meter for the noise measurement can be seen in Figures 2.35 to 2.37.

Figure 2.34: Map of Site #12: 2414 Brittany Dr.

Figure 2.35: Front view of Site #12: 2414 Brittany Dr.

Figure 2.36: Noise measurement at Site #12: 2414 Brittany Dr.

Figure 2.37: Noise measurement at Site #12: 2414 Brittany Dr.

2.3. Summary

This chapter presents the sites in the various residential communities along SH 190/PGBT that were selected for noise monitoring. The selection process included accessibility and the residences location relative to the highway and the existing noise walls. The residential sites were chosen for noise monitoring during the noise-testing phase of this project. Eight sites were selected: four on the east side (northbound direction) and four on the west side (southbound direction) of the highway.

Chapter 3. Pavement Condition Survey and Tire/Pavement Noise Tests

This chapter presents the analysis and results of the pavement noise tests and the pavement condition survey for the highway traffic noise evaluation on SH 190 (PGBT) in Rowlett, Texas, between Lake Ray Hubbard and Miller Heights Dr. It was deemed that the information gathered from the pavement condition and the measurements of the noise generated at the tire/pavement interface is key in understanding the noise generation that occurs as traffic traverses the facility, both on the main lanes and the frontage roads. This information is important to determine the course of action to take in regards to noise mitigation for this segment of the turnpike.

3.1. Introduction

The approximately 1.4-mile highway segment that was surveyed and tested for noise extends from south of Miller Heights Dr. to the north shore of Lake Ray Hubbard (Figure 3.1).

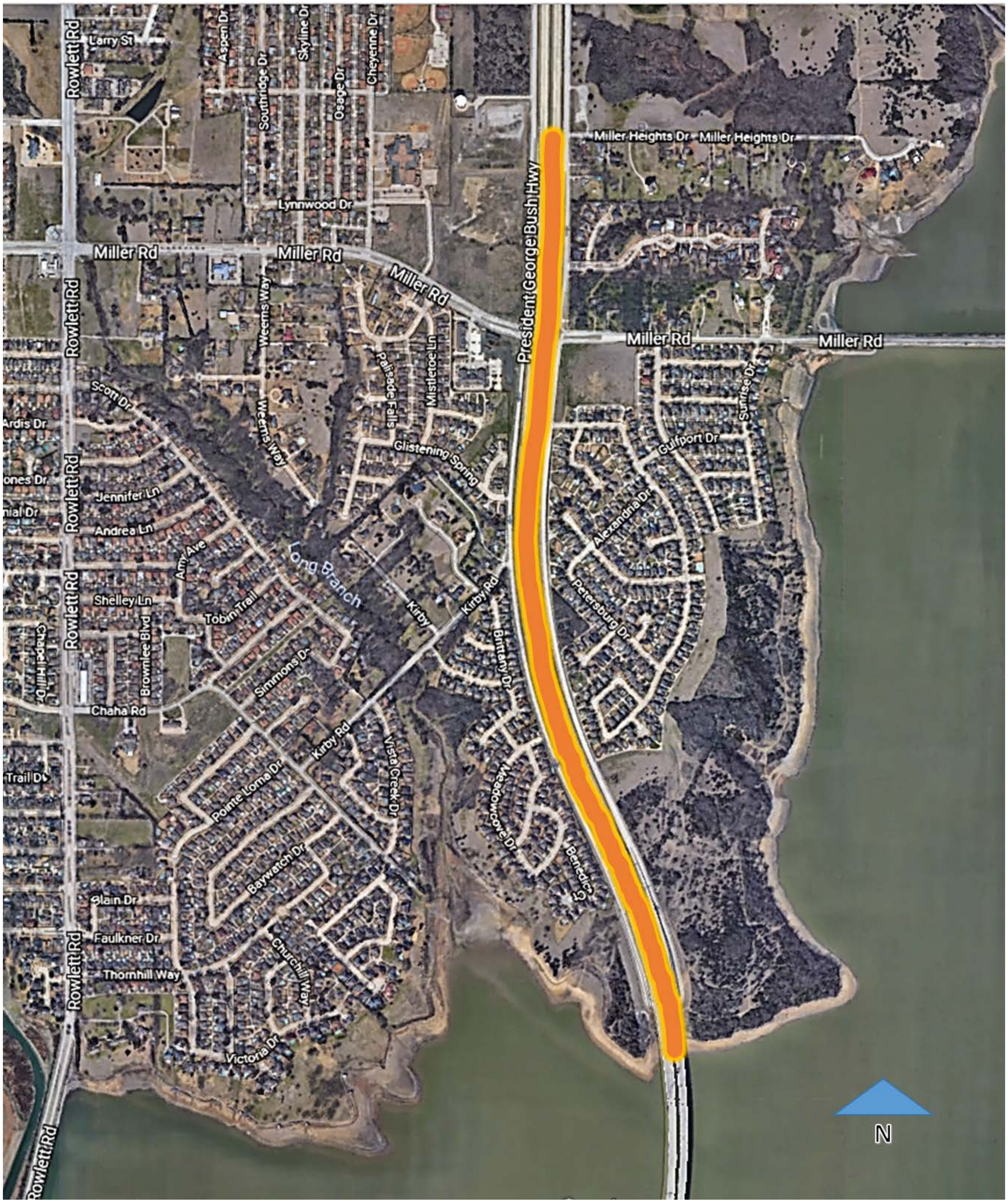

Figure 3.1: SH 190 location map with section of interest

Environmental noise measurements are a key component of this study. These measurements were conducted at various residences near the turnpike before any new sound wall installation to characterize the pre-barrier condition, and will be conducted after the placement of new walls to characterize the post-barrier condition. Tire/pavement noise is a major component of the noise recorded in those tests, especially at highway speeds. On-board sound intensity (OBSI) tests are the best method to evaluate solely the noise generated at the tire/pavement interface. Thus, in order to thoroughly investigate the noise generated from the highway, it was decided to run OBSI tests on the SH 190/PGBT pavements, including the main lanes and the frontage roads. The tests were conducted in November 2017. The condition of the pavement is important for the noise generation. In general, pavements in poor condition are also louder, as the distresses contribute to the roughness and unevenness of the surface. Therefore, a pavement condition survey was also conducted in October 2017 for both the main lanes and the frontage roads.

3.2. Pavement and Condition Survey

The PGBT main lanes and SH 190 frontage roads pavements throughout the 1.4 miles of interest in this study consist of transversely tined continuously reinforced concrete pavement (CRCP). The spacing between the transverse tines is 1 inch. The purpose of tining is to improve drainage and reduce hydroplaning of the vehicle tires on the pavement surface in the presence of water. However, tining is also related to higher tire/pavement noise levels and the occurrence of high noise at annoying frequencies to the human ear, especially in the 1-kHz frequency band.

Prior to the OBSI tests, a visual condition survey was conducted on the pavement; the survey was done partially by visual observations at various locations, mainly at sites accessible from the frontage roads, and some of it was conducted by means of videos taken from the vehicle, attaching a GoPro camera to a mount and driving at highway speeds (Figure 3.2). Subsequently, the videos were analyzed by playing them at very slow speeds in order to closely observe the surface condition. The relevance of the pavement condition in relationship to noise generation is that the presence of distresses makes a pavement louder, as the riding surface becomes uneven and rough on a distressed pavement. Both the severity and the amount of distresses correlate with higher noise levels produced at the tire/pavement interface.

Figure 3.2: GoPro camera mounted on research vehicle on SH 190 prior to recording survey videos

The CRCP on SH 190 was constructed in August and September of 2011. This information was found on the pavement itself: during the condition survey, two inscriptions were found on the main lanes pavement surface indicating the date the concrete was cast, one on the northbound direction, from August 31, 2011 (Figure 3.3) and one in the southbound direction, from September 10, 2011 (Figure 3.4). A CRCP that is 8 years old is still considered fairly new.

Figure 3.3: SH 190 Northbound main lane. Pavement cast on 8/31/2011 as indicated by inscription on the shoulder as recorded by video

Figure 3.4: SH 190 Southbound main lane. Pavement cast on 9/10/2011 as indicated by inscription on the shoulder as recorded by video

The pavement condition for the SH 190/PGBT is excellent, with minimal distresses; no punchouts, nor delaminations were observed. Punchouts and delaminations are normally considered as the major distresses occurring on CRCP. Figures 3.5 through 3.21 show various views of the SH 190/PGBT pavement, including main lanes and frontage roads.

Transverse cracks are a normal occurrence on CRCP. Transverse cracking is defined as cracks that are mainly perpendicular to the pavement centerline. Crack spacing and crack widths are two parameters of importance on CRCPs. From the visual survey conducted on the pavements, crack spacing is adequate and the crack openings do not seem wide, so the cracks appear in good condition. There is very little spalling in a few of the cracks. Few longitudinal cracks were observed, but they appear to be very minor.

Figure 3.5: Southbound main lanes

Figure 3.6: Northbound frontage road

Figure 3.7: Southbound main lanes

Figure 3.8: Southbound main lanes

Figure 3.9: Northbound frontage road

Figure 3.10: Northbound exit ramp

Figure 3.11: Northbound frontage road. Transverse cracks

Figure 3.12: Northbound frontage road. Longitudinal crack as recorded by video

Figure 3.13: Northbound frontage road. Minor spalling of the longitudinal joint as recorded by video

Figure 3.14: Northbound frontage road. Minor spalling of the transverse crack as recorded by video

Figure 3.15: Northbound frontage road. Transverse cracks as recorded by video

Figure 3.16: Southbound frontage road. Pavement in excellent condition as recorded by video

Figure 3.17: Northbound main lane. Pavement in excellent condition as recorded by video

Figure 3.18: Northbound frontage road. Pavement in excellent condition as recorded by video

Figure 3.19: Northbound main lane. Expansion joints in the elevated section as recorded by video

Figure 3.20: Southbound main lane. Pavement in excellent condition as recorded by video

Figure 3.21: Southbound main lane. Pavement in excellent condition as recorded by video

It is estimated that the condition of the SH 190 pavements is excellent and does not contribute to the generation of additional tire/pavement noise.

3.3. Speed Limits and Traffic Flow

Speed limits and traffic flow are important factors that have a decisive influence on noise levels generated by traffic on any given facility. Vehicles traveling at higher speeds generate more noise; free traffic flow allows for higher speeds as well, therefore, it is also associated with higher noise.

The posted speed limit on the main lanes for the segment in question is 70 mph (Figure 3.22), and the posted speed limit on the frontage roads is 50 mph (Figure 3.23). During all of CTR's visits to the site, which included trips once or twice per month since July 2017, with observations at several times of the day and night, as well as condition surveys, and OBSI tests, the flow of traffic has always been continuous and the turnpike has not reached the level of congestion, not even during rush hours. No lane closures, nor accidents have been observed. Therefore, the observed traffic has always been free-flowing.

Figure 3.22: Main lanes 70 mph speed limit sign

Figure 3.23: Frontage road 50-mph speed limit sign

The combination of free-flowing traffic condition with high speed limits and the limited number of exit and entrance ramps in this stretch of the turnpike results in high traffic flow at higher speeds, which translates into higher noise levels.

3.4. OBSI Test Description

Over the last few years, the OBSI method has become the most common technique for the evaluation of tire/pavement noise. The OBSI test method provides an objective measure of the acoustic power per unit area produced as a result of the operation of a vehicle; the close proximity of the OBSI device to the tire/pavement interface allows for the objective, repeatable and reliable acoustical evaluation of pavements. Dr. Paul Donavan and General Motors (*Donavan*) first developed this near-field measurement method for traffic noise. As the name indicates, the method measures sound intensity, which is defined as the average rate of sound energy transmitted in a specified direction at a point through a unit area normal to this direction at the point. The units are watt per square meter (W/m^2) (*Sandberg*). As such, it is a vector quantity with magnitude and direction, as opposed to sound pressure, which is a scalar quantity. The direction of sound intensity can be associated with the direction of sound propagation or the direction of the orientation of the probe used for measuring sound intensity.

A group of experts from all parts of the United States that had used the method over the last several years developed an AASHTO Standard (TP 76-13) in an effort to make the procedure a uniform test method that allows various pavements and textures to be directly compared (*AASHTO*). TxDOT, as well as CTR, as expert users of this test method, were involved in this effort. Once it was standardized, the test method has become widely accepted throughout the country and elsewhere, and this has enabled the use of a unified procedure for measuring tire/pavement noise.

The procedure utilizes a fixture positioned close to the tire to hold the sound intensity probe. The sound intensity probe consists of two pairs of half-inch microphones spaced 16 mm apart and preamplifiers in a side-by-side configuration. A foam windscreen is placed over the microphones to reduce the wind noise. The probe is positioned 4 in. away from the plane of the tire sidewall and 3 in. above the pavement surface, mounted to the rear tire on the passenger side of the test vehicle. Signals from the microphones are input into a real-time analyzer. Measurements are taken at 97 km/h (60 mph) at two intensity probe locations. One location corresponds to the leading edge and the other to the trailing edge of the tire/pavement contact patch. Figure 3.24 shows the intensity probe positions and distances in relation to the tire and pavement.

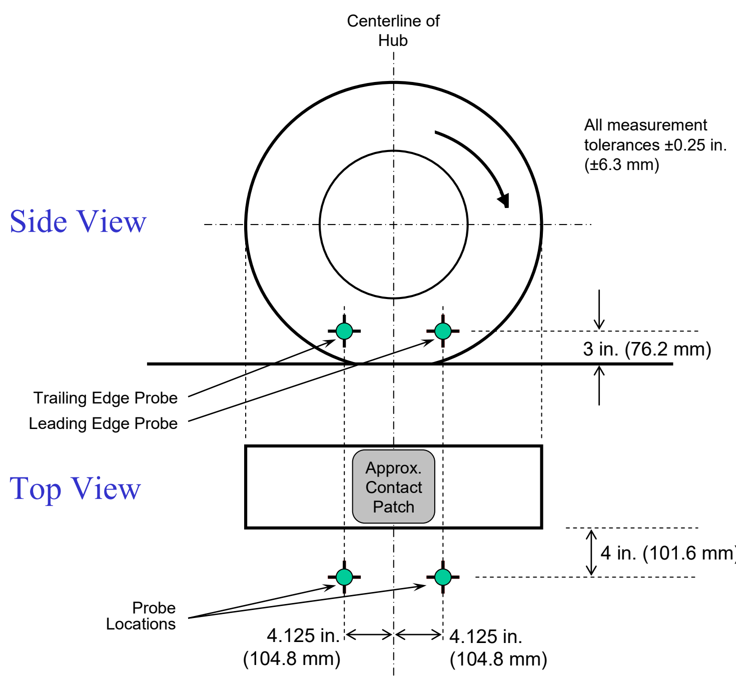

Figure 3.24: Sound intensity probe showing leading and trailing edges

At a minimum, two valid test runs shall be performed for a test section, according to the standard. In the majority of the cases, three replicate measurements are collected, and then averaged to obtain the overall noise levels. Each measurement is averaged over a 5-second period, yielding test sections that, given the traveling speed of 60 mph, are 440 ft. long. Therefore, a test section is defined as a 440 ± 10 ft. (134 ± 3 m) length of pavement over which a sound intensity measurement is made.

The results are reported as overall A-weighted sound intensity levels, and as A-weighted one-third octave band levels. The overall sound intensity level is the sound intensity level corresponding to the energy sum of the A-weighted sound intensity within the one-third octave bands ranging from 400 to 5000 Hz.

$$\textbf{Overall Sound Intensity Level} = 10 \times \textbf{Log}_{10}\left(\sum_{i=400}^{i=5000} 10^{(L_i/10)}\right)$$

Where L_i is the A-weighted intensity level in the one-third octave band with center frequency i.

The leading and trailing edge are energy-averaged to calculate a single result that is the average of test runs, commonly referred as the tire average.

The system used to measure the sound intensity using the on-board method comprises the following equipment: two matched microphone pairs, four preamplifiers, four cables, computer and data acquisition software, probe holders (fixture), and associated items mounted on the test vehicle, the vehicle itself, and the test tires. Some parts of such equipment are shown in Figure 3.25.

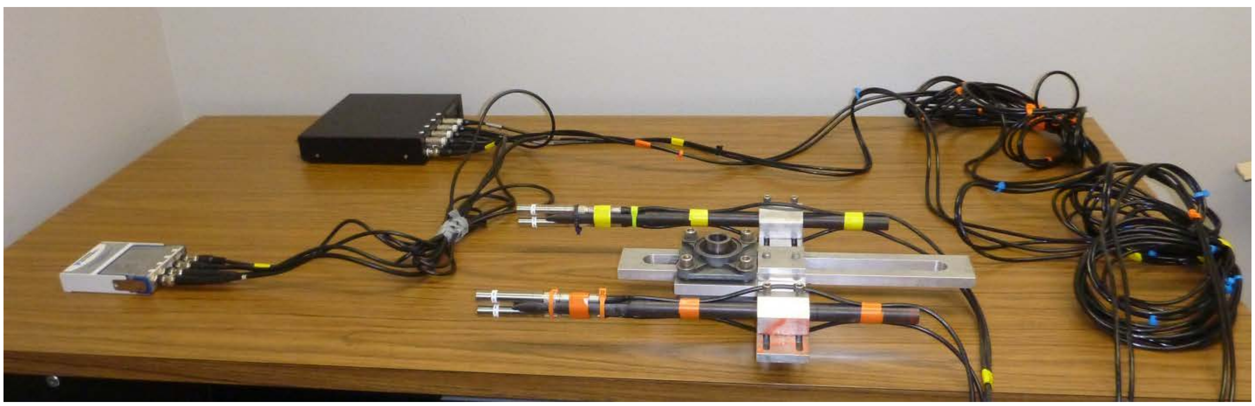

Figure 3.25: OBSI fixture and data acquisition equipment

The OBSI fixture is a custom-machined jig that bolts to the wheel rim and supports a sound intensity probe at very close proximity to the front and rear tire/pavement contact point. Because the device is bolted to the wheel, the vertical distance from the pavement does not vary as the suspension oscillates, and because there is a robust bearing connecting the bolted on assembly to the microphone holders, the device does not rotate with the wheels. A slender vertical bar affixes to the car body to steady the assembly and provide resistance to the small amount of rotational force generated by friction in the bearing. The fixture holds the microphone pairs in a vertical position (Figure 3.26).

The system utilizes two pairs of half-inch, phase-matched condenser free-field microphones (Figure 3.27). Preamplifiers are affixed to each individual microphone for signal amplification, and these, in turn, are attached to a plastic probe holder that keeps a space of 16-mm between microphones, in a side-by-side configuration. Each pair of microphones is fitted with a spherical windscreen.

The microphones and preamplifiers utilized for this project are manufactured by G.R.A.S., and comply with the requirements of the international standard IEC 1094 for Measurement Microphones, and as required by the AASHTO OBSI Standard, and also comply with the Class 1 requirements of ANSI S1.9. These devices are able to measure the real part of a complex sound intensity in sound fields with a high level of background noise, such as occurs on the highway.

Figure 3.26: OBSI fixture

Figure 3.27: Half-inch sound intensity microphone pair

The test tires and the test vehicle are other fundamental components of the system. The AASHTO standard only specifies that the test vehicle should be a passenger car, in which the test tire is not covered on the outboard side. The load on the test tire due to the weight of the vehicle including passengers, test hardware, fuel, and other contents shall be 800 ± 100 lb. (360 ± 45 kg) during the test, according to the standard. The test tires are also standardized. The “Standard Reference Test Tire” (SRTT) for OBSI must comply with Standard ASTM 2493 *(ASTM)*. Figure 3.28 shows the test vehicle and the OBSI fixture.

Figure 3.28: Test vehicle and OBSI fixture

3.5. SH 190/PGBT OBSI Tests

The tests were performed on November 28, 2017. Tests were conducted both on the main lanes and the frontage roads. For the main lanes, three subsections were identified in the northbound direction (labeled as NB1, NB2 and NB3, respectively) and three in the southbound direction (labeled as SB1, SB2 and SB3, respectively).

For the frontage roads, there were two northbound subsections (labeled as NB FR1 and NB FR2, respectively), and three southbound subsections (labeled as SB FR1, SB FR2, and SB FR3, respectively). As mentioned in the previous section, each subsection is 440 ft. long, tests are conducted at 60 mph and averaged over 5 s periods, per standard specifications.

Figure 3.29 shows the test vehicle with the OBSI equipment on the frontage road of SH 190.

Figure 3.29: OBSI Test vehicle on SH 190 frontage road

The overall results of the SH 190/PGBT tests are summarized in Figure 3.30. Each of the vertical bars in the graph corresponds to a subsection. There are also bars that correspond to the average of the main lanes and the average of the frontage roads, respectively. The vertical axis indicates the overall sound intensity level for each subsection, which is the average of at least three test runs in each case.

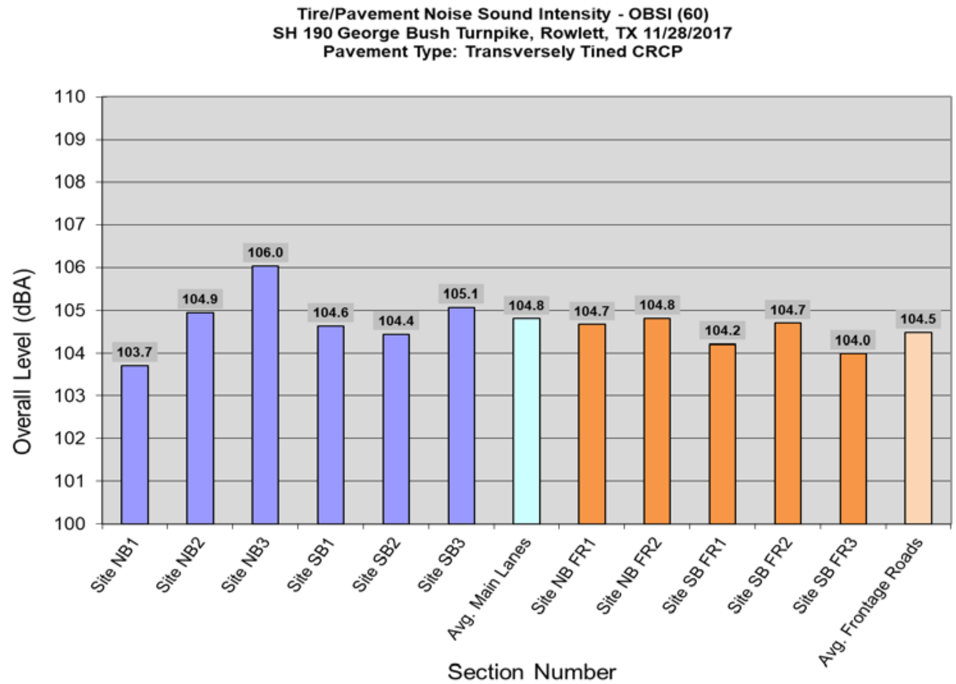

Figure 3.30: OBSI Test results for SH 190 main lanes and frontage roads

Overall noise levels are very similar for main lanes and frontage roads; this was expected, given the similar condition of the pavements. Noise levels range from 103.7 to 106.0 dBA for the main lanes, with an average of 104.8 dBA. For the frontage roads, the range is from 104.0 to 104.8 dBA and the average is 104.5 dBA. The northbound main lanes present the highest variability. The results appear to be very reasonable and consistent, and within the expectations for a transversely tined CRCP. As indicated in the previous section transverse tining in CRCP is normally correlated with higher tire/pavement noise levels and the occurrence of high noise at annoying frequencies to the human ear, especially in the 1-kHz frequency band. Figure 3.31 shows the frequency spectra for each subsection, graph which confirms this statement; all of the curves show the characteristic peak in the 1-kHz frequency band, typical of this pavement type.

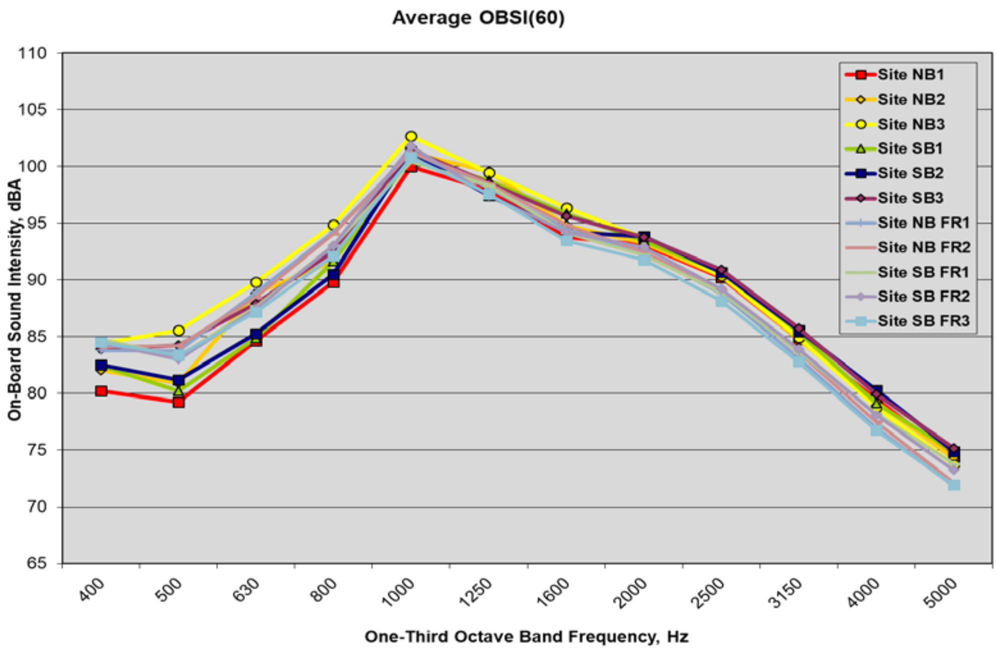

Figure 3.31: OBSI spectral analyses for SH 190 main lanes and frontage roads

The results of the spectral analyses indicate that all the subsections of main lanes and frontage roads are virtually identical in regards to their tire/pavement noise generation levels and frequencies.

3.5.1. Comparison with Other Pavement Sections

In order to provide an idea of how the pavements on SH 190/PGBT compare relative to other pavement surfaces, the chart in Figure 3.32 has been prepared, showing a variety of pavements, pavement types and their overall average noise levels, as obtained from various OBSI tests. These are all recent OBSI tests performed by CTR, from the Austin area. The pavements include thin overlay mixes (TOMs, represented by red bars), permeable friction courses (PFCs, in blue), dense graded asphalt concrete (DGAC, in orange), chip seals (green), and transversely tined CRCP (yellow). The chart is sorted from quieter to louder pavements.

At 104.8 dBA and 104.5 dBA for the main lanes and frontage roads, respectively, the SH 190/PGBT pavements are stacked toward the louder side of the graph, and are close to being the louder CRCP among those represented in the graph.

In conclusion, the SH 190/PGBT test results are very typical for transversely tined CRCP, the values can be considered very normal and expected, and nevertheless, they are slightly on the louder range for this type of pavement. There are other pavement surfaces and treatments that can provide lower noise levels as shown in the graph. As a recommendation for the future, the pavement surfaces of SH 190/PGBT—which are structurally sound, in excellent condition, and with many years of service life ahead—could be overlaid with a quieter overlay such as a PFC or a TOM. These quieter pavements have been proven to deliver good acoustical performance to alleviate the noise generated by vehicular traffic on highways. This would result in lower noise levels in the adjacent residential communities, as well as lower noise levels perceived by the driving public as users of the facility.

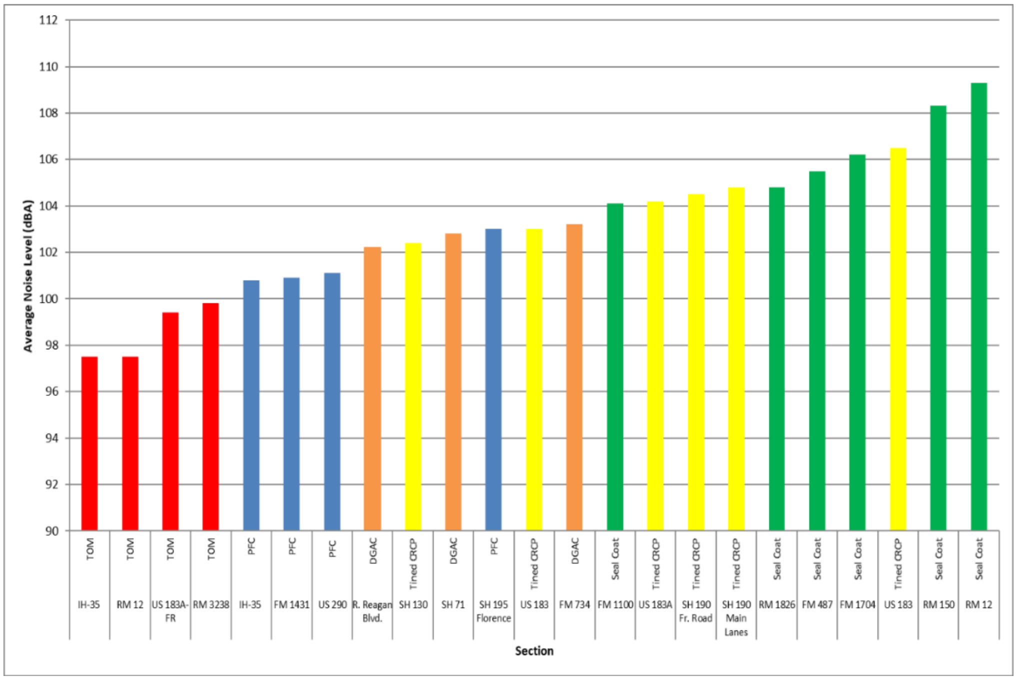

Figure 3.32: OBSI test results comparison of SH 190/PGBT with other pavements, sorted by noise level

3.6. Summary

This chapter presented the results of a condition survey and of tire/pavement noise tests conducted on both the main lanes and the frontage roads of the pavements of SH 190/PGBT. The pavement condition, especially for the case of a distressed pavement, can have a definitive influence on the generation of tire/pavement noise at highway speeds.

The condition survey revealed that the pavements are in excellent condition; therefore, it is considered that the pavement condition is not contributing to an increase in tire/pavement noise.

The noise generated at the tire/pavement interface was evaluated by means of the OBSI test, which is widely considered the best way of measuring the main component of traffic noise at the source: where the tire and the pavement are in contact.

The results of the tests, both for the main lanes and the frontage roads are very typical of the pavement type present in this facility, CRCP. However, a comparison with other pavements indicates that the SH 190/PGBT pavements are among the loudest compared to other CRCPs. And CRCPs are generally regarded as one of the loudest pavement types, mainly due to the typical transversely tined finishing applied to these surfaces for safety purposes.

It is recommended that, in order to reduce the noise at the source, a quieter pavement overlay should be considered, such as a TOM or a PFC, both of which are capable of providing substantial noise reductions over a typical transversely tined CRCP.

Chapter 4. Residential Noise Testing Program

This chapter presents the field testing procedure conducted as part of the research work at the residential sites along SH 190/ PGBT in Rowlett, east of Dallas. The field test program consists of noise measurements near the highway, between south of Main St. and the north shore of Lake Ray Hubbard, an area that is affected by the highway noise.

4.1. Introduction

Noise data was collected at the neighborhood sites before the noise wall installation, and collection will continue after the completion of the wall. Eight locations were selected. These are described in detail in Chapter 2. Measurements have been performed at these locations approximately once per month. During each test day, measurements are conducted at all locations at various times of the day, including morning, afternoon and evening, to cover a wide range of traffic and weather conditions. The purpose of the noise tests is to gather noise data before and after the new sound wall is installed, to assess the noise levels prevailing at the various locations and to evaluate the effectiveness of the walls. The pre-barrier condition data-collection period covered a 7-month period, from July 2017 through January 2018. The post-barrier testing period will start when the wall is finished and will continue through July 2020.

4.2. Test Equipment and Procedure

The noise measurements consist of sound pressure level (SPL) tests. For these, an SPL meter measures the noise level over a specified time period, and the average noise level over that time period is the result of the test. The SPL meter is illustrated in Figure 4.1. The time-averaged value of the SPL during the test interval, i.e., the "equivalent continuous sound level" [Leq(A)], is used. Leq(A) is defined as the equivalent steady-state sound level that, in a given time period, contains the same acoustic energy as a time-varying sound level during the same period (Figure 4.2). Leq(A) is used for all traffic noise analyses for TxDOT highway projects. The meter is placed on a tripod standing 1.50 meters above the ground. The test interval for this project consists of 10-minute periods.

Figure 4.1: Sound pressure level meter

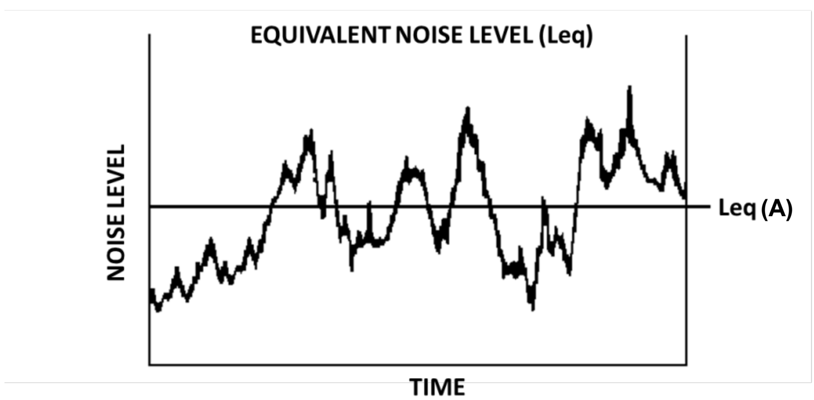

Figure 4.2: Leq(A): average noise level over a period of time

For this project, weather conditions at the time of each test are monitored by means of a portable weather station equipped with a data logger and software. The weather station utilized in this project is manufactured by Davis Instruments and the model is called Vantage Vue (shown in Figure 4.3). It consists of an Integrated Sensor Suite (ISS) and a wireless console. The ISS contains all the sensors and devices to measure weather variables—a rain collector, temperature and humidity sensors, an anemometer, and a wind vane. It is solar-powered, and a lithium battery provides backup. It communicates wirelessly to the console by means of low-power radio transmission. The console is battery-operated and has an LCD display (Figure 4.4). The ISS measures temperature, relative humidity, dew point, wind speed, wind direction, highest wind speed (gust), gust direction, wind chill, heat index, barometric pressure, total rain, and rain rate, and records the values for each of these variables at 1-minute intervals. Figure 4.5 shows the weather station mounted in the back of the research vehicle. The software, also created by Davis Instruments, is called WeatherLink, version 6.0.0.

Figure 4.3: Davis Instruments portable weather station, showing the ISS

Figure 4.4: Vantage Vue wireless console

Figure 4.5: Weather station mounted in the back of research vehicle

The sequence of operations for noise measurements is as follows:

- Mount weather station on its base.
- Verify communication between ISS and console.
- Calibrate the SPL meter.
- Mount the SPL meter on tripod approximately 1.5 m above the ground.
- Level the weather station.
- Position the weather station in such way that the solar panel faces south.
- Start recording period.

Leveling and correct orientation of the weather station must be done at each location in order to obtain accurate wind speed and wind direction readings. Leveling is done with the aid of a bubble level on top of the ISS. A mirror compass, shown in Figure 4.6, is used to orient the weather station. The sighting mirror in the compass allows for higher precision; its use with the weather station is shown in Figure 4.7.

Figure 4.6: Mirror compass utilized for orientation of the weather station


Figure 4.7: Use of the mirror compass for orientation of the weather station: the solar panel of the weather station, in the background, is positioned so that it faces south

Steps 1 through 3 are only necessary at the beginning of a series of measurements, i.e., the beginning of each recording period (morning, early afternoon, and evening).

At the end of the day, the weather station data is downloaded from the console to a computer by means of a USB connection. The WeatherLink software facilitates analyses and graphic interpretation of weather data. Some images from the screens generated by the software are presented in Figures 4.8 and 4.9.

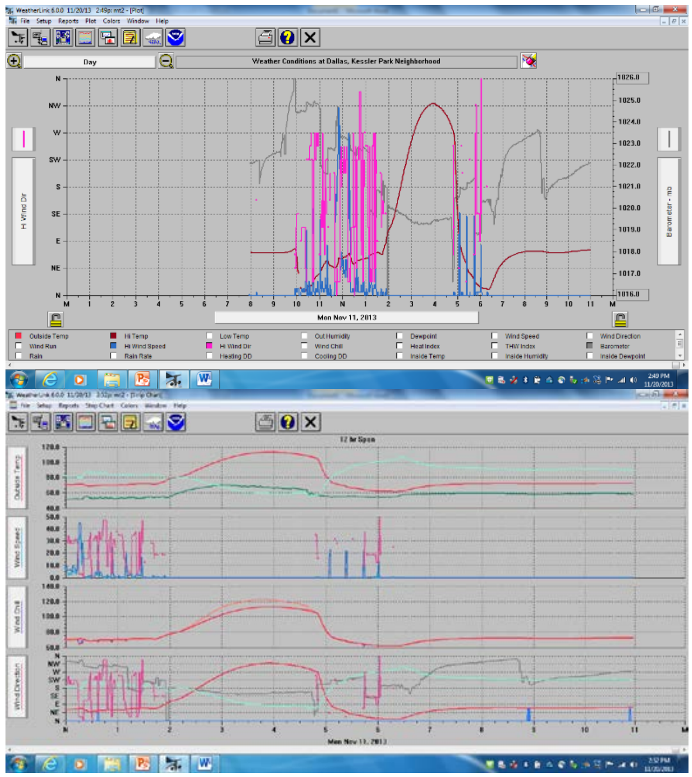

Figure 4.8: Weather plots of daily records generated by WeatherLink

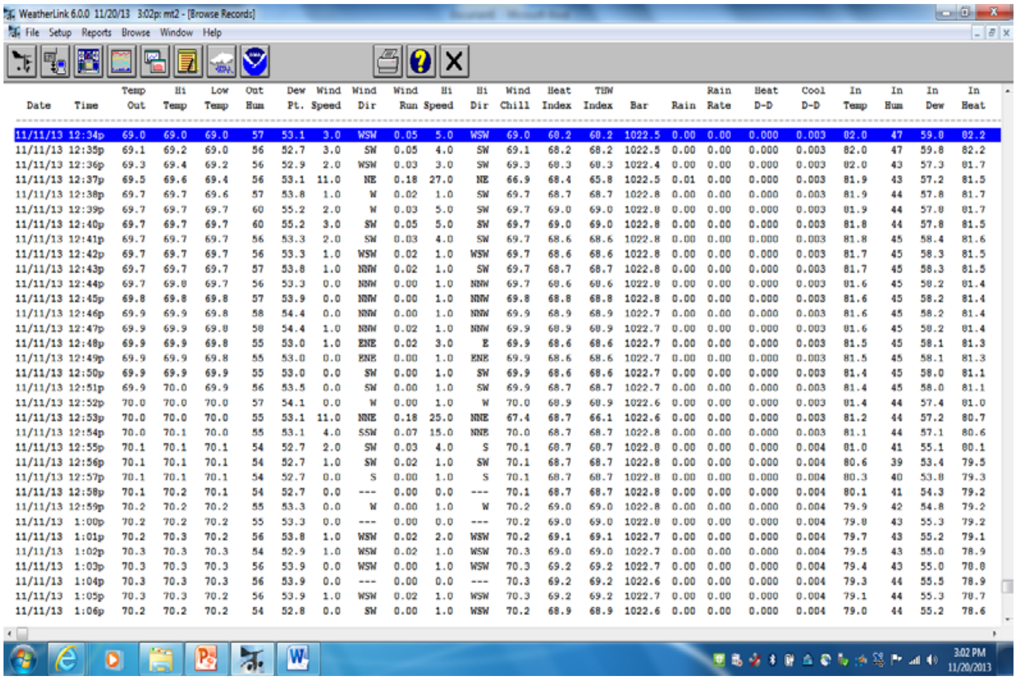

Figure 4.9: WeatherLink screen showing weather records for every minute

4.3. Summary

This chapter presents the noise testing program for the residential locations in the neighborhoods along SH 190/PGBT, before and after the lightweight transparent noise barriers are installed. Eight residential locations have been monitored. The noise measurements, performed with SPL meters, are collected for the purpose of evaluating the effectiveness of the new noise barriers. The tests are conducted at different times of the day to account for the variability in traffic and climatic conditions. At the same time the noise tests are performed, a weather station is used to monitor climatic variables. A detailed description of the equipment utilized for the measurements was presented, as well as the methodology for the field work.

Chapter 5. Pre-Barrier Noise Test Results

This chapter presents the results of the pre-barrier noise testing program. For the context of this report and this project, "pre-barrier" refers to the condition prior to any modification or extension of the existing noise walls. This highway section has two existing noise walls, on either side of the highway: one on the east side (northbound direction) and one on the west side (southbound direction). Each of these consists of an 8-ft.-tall pre-cast concrete wall, constructed at the time the PGBT was constructed in 2011.

This project encompasses the extension of the existing walls to improve their effectiveness by providing additional noise reductions. Once the new wall extensions are in place, the post-barrier phase of noise tests will start, to enable the evaluation of the effectiveness of the new walls.

5.1. Analysis of Results

The environmental noise tests for the pre-barrier condition started in July 2017 and ended in January 2018. A total of 106 noise tests were conducted in the vicinity of SH 190/PGBT, at the eight residential sites described in Chapter 2, and following the procedure described in Chapter 4.

The overall average noise level for these measurements, including all eight sites, was 67.4 dBA, the standard deviation was 4.6 dBA, and the coefficient of variance was 6.9%. The smallest noise level recorded was 53.3 dBA (Receiver R12, October 25, 2017, 14:00 hrs.), and the highest was 76.5 dBA, which occurred twice at the same location (Receiver R7, October 25, 2017, 18:15 hrs., and Receiver R7, November 7, 2017, 17:06 hrs.).

Table 5.1 presents the average noise level results by residential receiver.

Table 5.1: Pre-barrier condition test results

Receivers	Field Tests		
	Average Level	Std. Dev.	C. of Var.
	dBA	dBA	%
R1. 5010 Southport Dr.	67.5	3.4	5.1
R2. 2205 Mermaid Cir.	68.4	3.3	4.8
R3. 4901 Harborview Dr.	67.1	2.7	4.1
R4a. 3401 Francesca Ct.	67.5	3.1	4.6
R6. 4317 Rose Leaf Ct.	68.3	2.8	4.0
R7. 2629 Kirby Rd.	73.2	2.2	3.0
R8. 4509 Meadowcove Dr.	67.7	2.9	4.3
R12. 2414 Brittany Dr.	58.9	2.7	4.6

The results are also presented in Figure 5.1, showing the location of each receiver and the location of the existing noise walls.

Figure 5.1: Average noise level results by receiver

The frequency distribution of measured noise levels for the pre-barrier condition tests is shown in Figure 5.2, along with its histogram. The sample size is small, but it approximately follows a normal distribution.

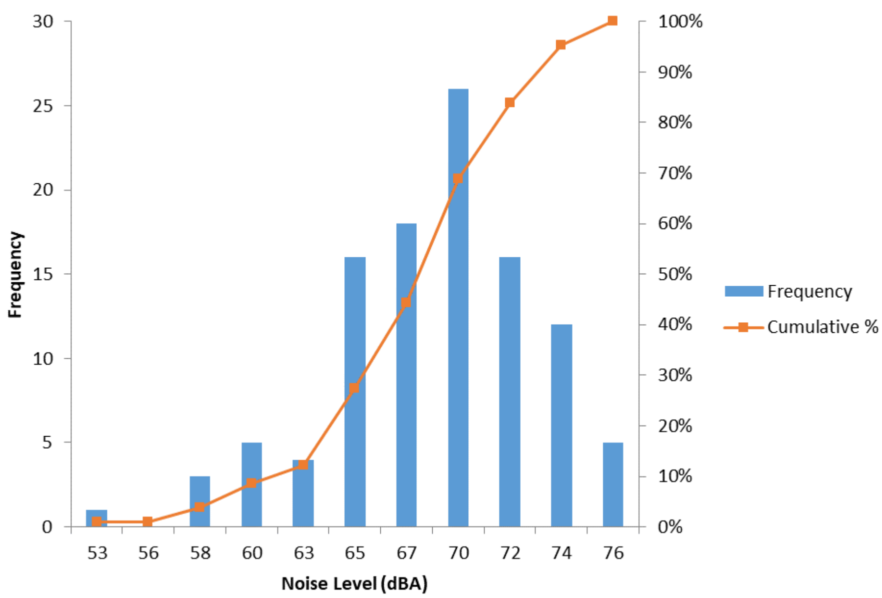

Figure 5.2: Frequency distribution for pre-barrier tests

5.1.1. Noise Impact

According to FHWA policies (*FHWA-HEP-10-025*), a traffic noise impact occurs when the existing or future noise levels approach or exceed the noise abatement criteria (NAC); TxDOT defines the level of approach as 1 dBA. The NAC are presented in Table 5.2 (*TxDOT 2011*). An impact can also occur when predicted future traffic noise levels substantially exceed the existing noise level, even though the predicted levels may not exceed the NAC.

Table 5.2: Noise abatement criteria

Activity Category	FHWA (dB(A) Leq)	TxDOT (dB(A) Leq)	Description of Land Use Activity Areas
A	57 (exterior)	56 (exterior)	Lands on which serenity and quiet are of extra-ordinary 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)	66 (exterior)	Residential
C	67 (exterior)	66 (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)	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	72 (exterior)	71 (exterior)	Hotels, motels, offices, restaurants/bars, and other developed lands, properties, or activities not included in A-D or F.
F	--	--	Agricultural, 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.

Thus, TxDOT policy indicates that an outdoor residential area, such as the subject of these analyses (Activity Category B, in Table 5.2) is considered to have an impact if the noise level is 66 dBA or above (*TxDOT 2011*).

For the pre-barrier condition, 68% of the total measurements (72 out of 106) correspond to an impact. For the average levels by residential location, all of the residences, except for one (R12), have an impact (Table 5.3).

Table 5.3: Average noise levels and impact, by receiver

Receivers	Field Tests	
	Actual Level dBA	Impact
R1. 5010 Southport Dr.	67.5	Yes
R2. 2205 Mermaid Cir.	68.4	Yes
R3. 4901 Harborview Dr.	67.1	Yes
R4a. 3401 Francesca Ct.	67.5	Yes
R6. 4317 Rose Leaf Ct.	68.3	Yes
R7. 2629 Kirby Rd.	73.2	Yes
R8. 4509 Meadowcove Dr.	67.7	Yes
R12. 2414 Brittany Dr.	58.9	No

The explanation for receiver R12 not having an impact is because this residence sits at a much lower elevation relative to the highway; the measurements at this site are conducted below the highway level, with a tall retaining wall and the existing noise wall sitting on top of the retaining wall. The retaining wall at this home is about 12 ft. tall, plus the 8-ft.-tall noise wall provides protection to the residence from the traffic noise. Thus, there is a 20-ft. elevation differential for the diffracted noise to reach the receiver, and there is no line of sight to the source. Please see Section 2.2.8 for more details about receiver R12 and photographs. This residence consistently had the lowest noise readings throughout the data collection period, numbers that are significantly lower than at any other residential location measured in this study.

On the other hand, receiver R7, on Kirby Rd., had the highest noise readings among the receivers studied. The reason is that this house is next to the frontage road, and also is in close proximity to the main lanes, and there is no noise wall to shield it from the noise. Moreover, the receiver is at the same level with the highway main lanes and frontage roads, so the noise has a direct path to the receiver. More information on this residence as well as photographs can be found in Section 2.2.6.

5.2. Noise By Test Date

Noise levels are analyzed by measurement date throughout the data-collection period. A chart showing total averages for measurements by date is shown in Figure 5.3. In general, higher noise levels are associated with lower temperatures; therefore, the common noise seasonal pattern results in the winter months having higher noise levels. This seasonal trend where noise levels are lower during the warmer months and increase during the colder season can be observed in the chart, even though the sample size is small.

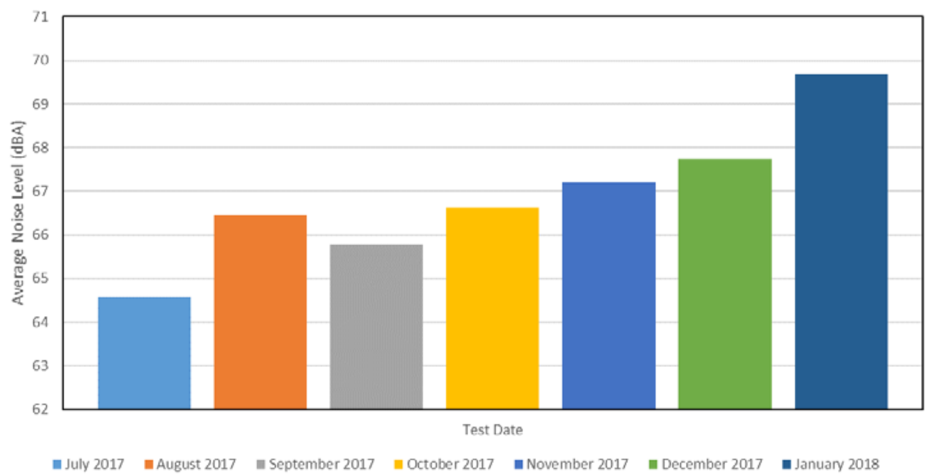

Figure 5.3: Average noise levels by test date

Another way to analyze the data is by receiver location. A plot illustrating this analysis is presented in Figure 5.4, where each line correspond to one of the eight receivers. The seasonal variation trend can be observed. This chart also clearly shows the loudest test site (R7) and the quietest test site (R12) easily distinguished from the other residences, as explained in the previous section.

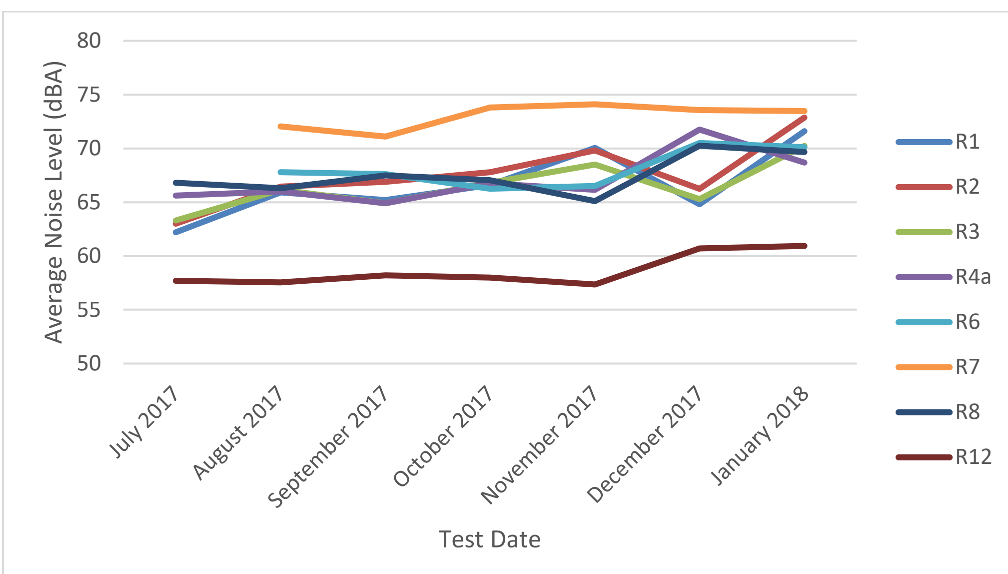

Figure 5.4: Average noise levels by receiver and test date

5.2.1. By Time of the Day

Noise measurements are taken at different times of the day and night, to account for different atmospheric conditions as well as for hourly variations in traffic patterns throughout the day. The measurements are grouped into three categories: morning, afternoon, and evening. The influence of the time of the day on the noise results is shown in Figure 5.5. The chart shows that the evening is generally the loudest time for traffic noise at the SH 190/PGBT.

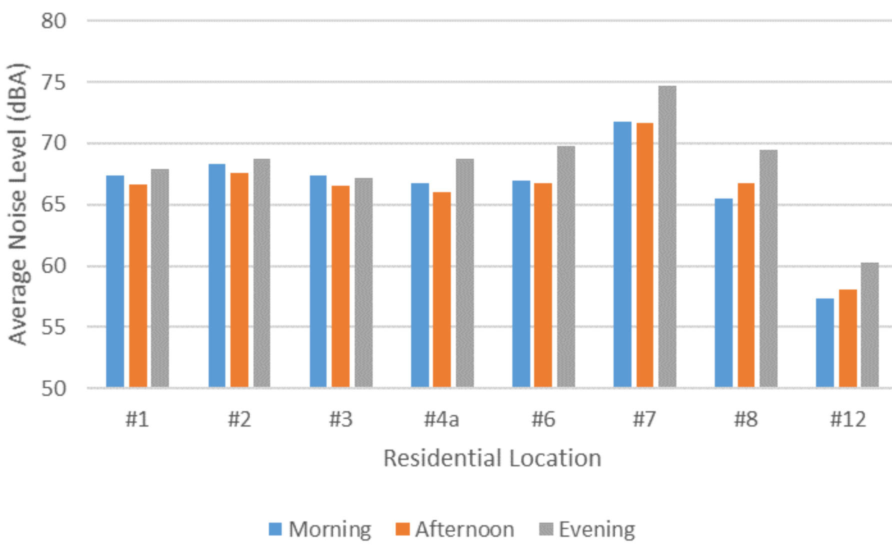

Figure 5.5: Noise measurements by time of the day and receiver

5.2.2. Weather Variables

5.2.2.1. Temperature

The weather variable that is known to have a greater influence on tire/pavement noise generation is temperature. In general, under colder conditions, the pavement materials as well as the rubber in the tires are stiffer and produce higher noise levels than under warmer conditions. Thus, cold temperatures are correlated to higher tire/pavement noise generation (1 dBA per 10°C) *(Sandberg)*. Therefore, for instance, a change from a temperature of 95°F, typical for the summer in Dallas, to a temperature of 40°F, which is very common in the winter, represents an increase of 3 dBA in tire/pavement noise generation alone, with all the other conditions staying constant. Such a difference in noise levels, attributable to temperature change only, represents a significant increase.

The relationship between noise measurements and air temperature was investigated in Figure 5.6; the chart shows the scattered temperature vs. noise level data points for each of the measurements collected during this stage of the project. The temperature range for all the measurements taken for the pre-barrier condition was between 45.7 and 97 °F, while the average temperature was 71.6 °F, the standard deviation was 13.3 °F, and the coefficient of variation was 18.6%. These and other statistics are shown in Table 5.4. There is a correlation showing that the lower temperatures are linked to higher noise levels, as explained in the previous paragraph, even though the R^2 value is small, but this is typical of other temperature vs. noise level data sets that have been collected during this and other similar projects.

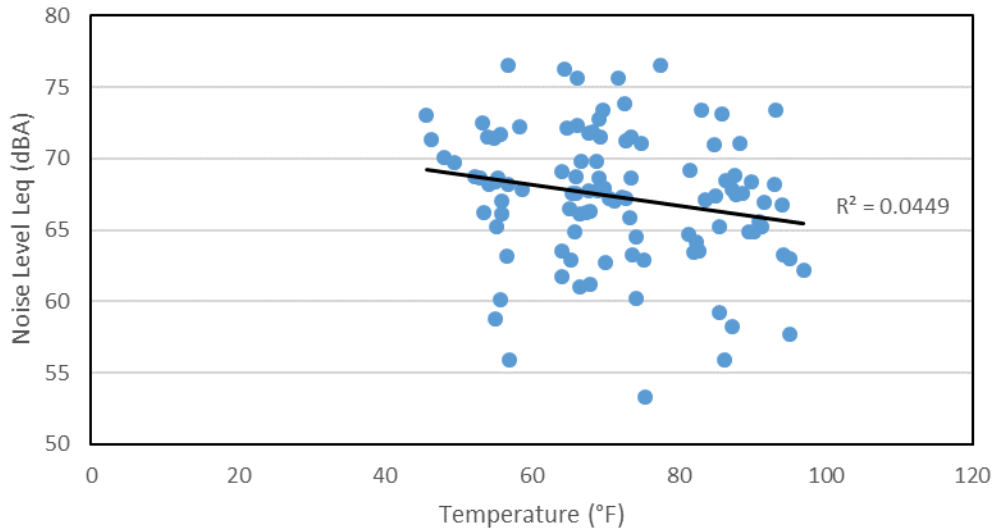

Figure 5.6: Noise level and temperature

Table 5.4: Statistics for temperature and noise level

	Temperature (°F)	L_{eq} (dBA)
Mean	71.6	67.4
Standard Deviation	13.3	4.6
Median	69.7	67.7
Mode	87.3	68.6
C.V. (%)	18.6	6.9
Minimum	45.7	53.3
Maximum	97.0	76.5
Range	51.3	23.2
Count	106	106

5.2.2.2. Wind

The wind and its direction could be important factors influencing the noise levels reached at the neighborhood residential locations. Strong winds blowing towards the residential areas can carry the noise generated by the traffic; for this to happen, it is required that both the wind speed is high enough, and that the wind is blowing in the direction of the receivers.

5.2.2.2.1. Wind Speed

Figure 5.7 shows a plot of noise levels and wind speed, in which each data point corresponds to a noise measurement and the average wind speed that was obtained by the weather station during the noise measurement. It shows that there is some correlation between wind speed and noise levels at the neighborhood (higher noise levels correlated with higher wind speeds). Similarly, Figure 5.8 presents the relationship between noise levels and high wind speeds (gusts), showing a similar correlation, indicating that there is an influence of the gusts on noise levels measured at the neighborhood, without considering the wind direction yet.

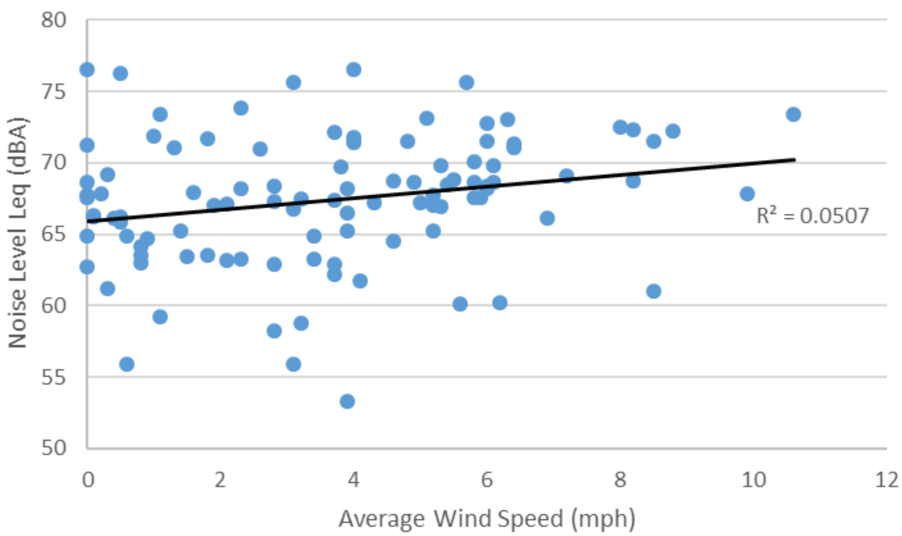

Figure 5.7: Noise level and average wind speed

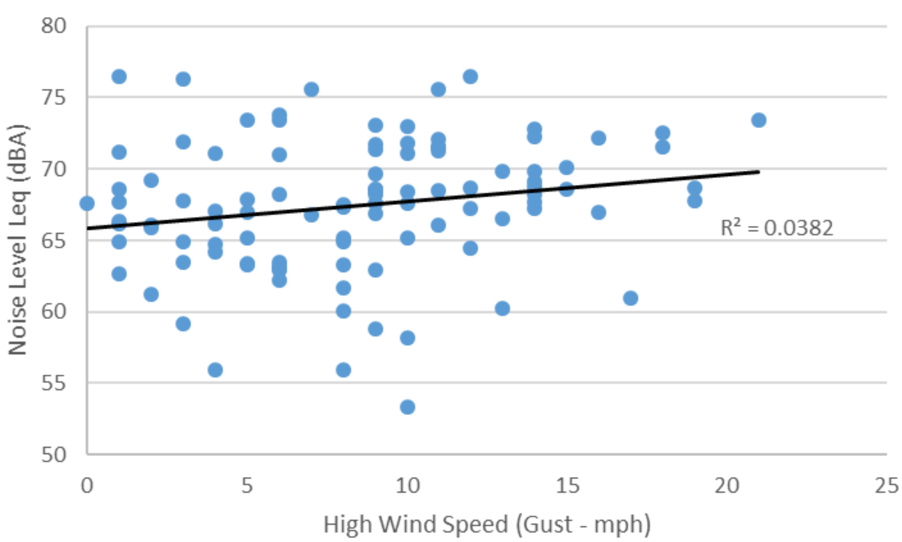

Figure 5.8: Noise level and high wind speed

5.2.2.2.2. Wind Direction

For the wind direction analysis, given that throughout each test period for an individual test (normally 10 minutes) the wind direction commonly fluctuates, the dominant wind direction for each test is considered to be that of the highest gust within that period. Therefore, for each test there is an average noise level, an average wind speed, a high wind speed (gust), and a high wind direction. The average wind speed is a scalar, whereas the gust is a vector.

The results of the wind direction analysis are shown in a group of four charts. The first chart (labeled as “a”) shows the percentage of the tests associated with each wind direction. In the second chart (b), the average noise levels were plotted with the wind direction of the gust as well as the gust speed. Finally, in the third (c) and fourth (d), the gust levels were plotted against the average noise levels, with (c) showing the values for each wind direction, and (d) showing the correlation. Therefore, the data points for (c) and (d) are identical. These charts are shown in Figure 5.9.

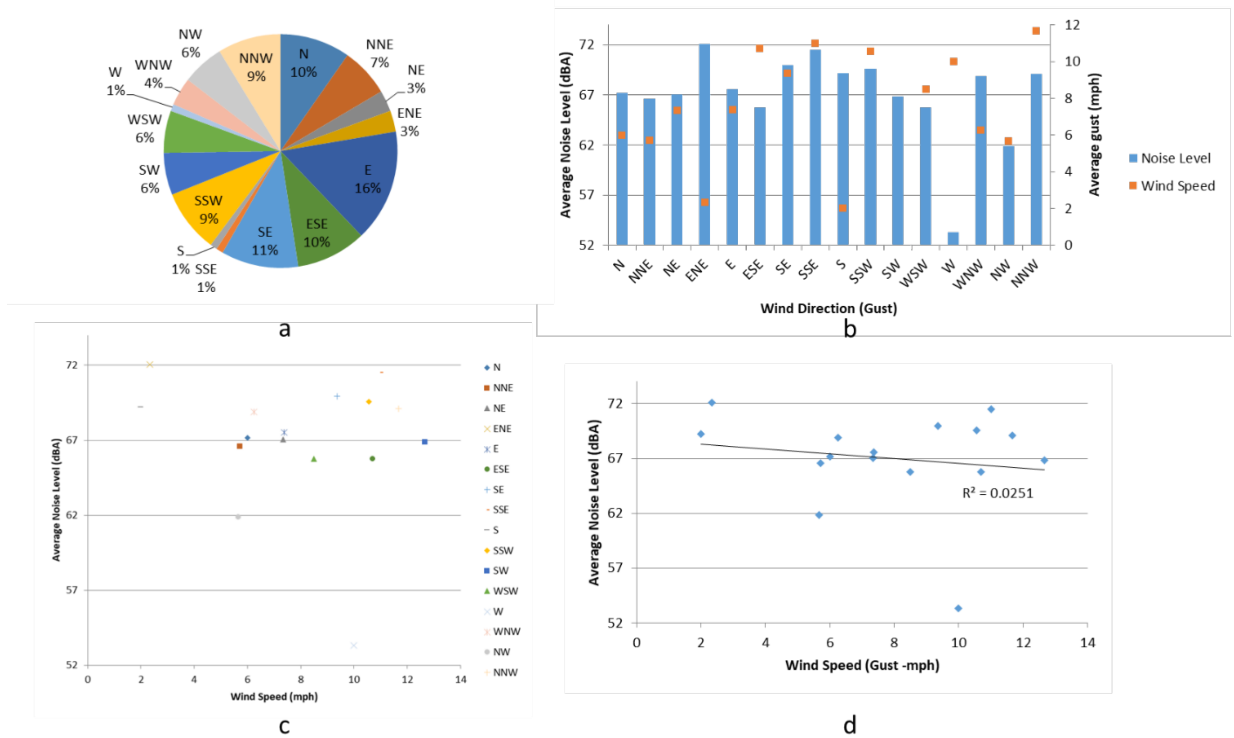

Figure 5.9: Wind, wind direction and noise: a) Dominant wind direction by percentage of time; b) Average noise levels and average gusts by direction; c) Average noise level vs. average gust by direction; and d) Average noise level and average gust correlation

These charts indicate that for the measurements conducted in the pre-barrier condition, the majority of the time (16%) the gusts blew from the E direction, with the SE being the second most dominant gust direction (11%), and N and ESE being close with 10% each (Figure 5.9 a). However, the highest average noise level (72.1 dBA) occurred when the gusts blew from the ENE direction (Figure 5.9 b and c). The lowest average noise level (52.5 dBA) occurred when the dominant wind came from the W, and the average wind speed for the gusts was 10 mph, which is relatively high (Figure 5.9 b and c). The correlation between gust speeds and average noise levels is poor and shows that louder noise levels happened with lower gusts, and vice versa (Figure 5.9 d).

5.2.2.3. Relative Humidity

The measurements for relative humidity for the pre-barrier data collection period are presented in Figure 5.10. The mean value was 55%. The correlation with noise levels is negligible, showing that higher relative humidity corresponded to slightly higher noise levels; this is consistent with other similar findings about relative humidity.

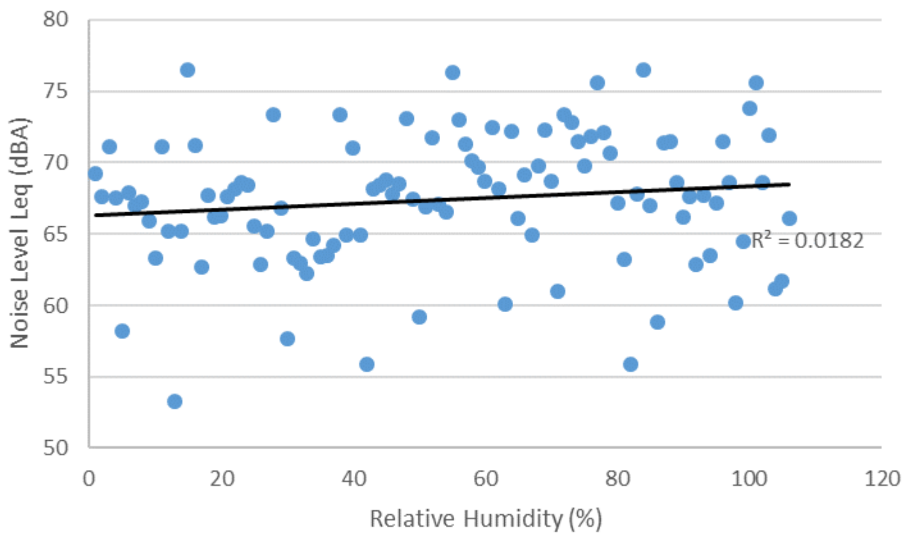

Figure 5.10: Noise level and relative humidity

Table 5.5 summarizes the analysis of weather variables along with noise levels, presenting the descriptive statistics.

Table 5.5: Statistics for weather variables and noise level

	Temperature (°F)	Relative Humidity (%)	Avg. Wind Speed (mph)	Max. Wind Speed (mph)	L_{eq} (dBA)
Mean	71.6	55.0	3.6	8.4	67.4
Standard Deviation	13.3	14.6	2.6	4.8	4.6
Median	69.7	58.0	3.7	9.0	67.7
Mode	87.3	69.0	0.0	9.0	68.6
C.V. (%)	18.6	26.5	70.9	57.4	6.9
Minimum	45.7	21.0	0.0	0.0	53.3
Maximum	97.0	84.0	10.6	21.0	76.5
Range	51.3	63.0	10.6	21.0	23.2
Count	105	105	102	103	106

5.3. Summary and Discussion of Results

This chapter presents the results of noise measurements and data analysis for the pre-barrier stage of SH 190. The measurements analyzed comprise tests conducted from July 2017 until January 2018.

The noise results indicate that noise levels are indeed high at most of the receivers' locations studied in this project. All the sites but one represent a noise impact, according to TxDOT policy; therefore, the neighbors' complaints are warranted and, in light of the noise levels measured, it is recommended to implement additional mitigation measures.

Weather variables—primarily temperature and wind speed—appear to have influenced the noise levels. The various times of the day during which the tests are performed—morning, afternoon, and evening—seem to have a slight impact on noise levels, especially considering that the evening tests consistently represented the times with higher noise levels. These are very likely associated with higher traffic volumes during those times of the day as well.

The seasonal variations also seemed to have an impact on the noise levels detected. Colder seasons were related to higher noise levels. The sample size is fairly small, however. It would have been desirable to have a longer data-collection period for the pre-barrier condition, considering that there was no data for the months of February to June. Having at least a complete year of data would have been ideal to represent all seasonal changes and their influence on noise.

Chapter 6. Traffic Noise Modeling

This chapter presents the noise analysis performed with a computer program, for the segment of SH 190/PGBT from just north of Miller Rd. to the north shore of Lake Ray Hubbard. The following sections explain the information contained in the model, including geometry, receivers, traffic, noise walls, and pavements. These are followed by the results and the barrier analyses.

6.1. Introduction

The design of the noise wall was performed by means of the FHWA Traffic Noise Model (TNM) program, Version 2.5 (Figure 6.1).

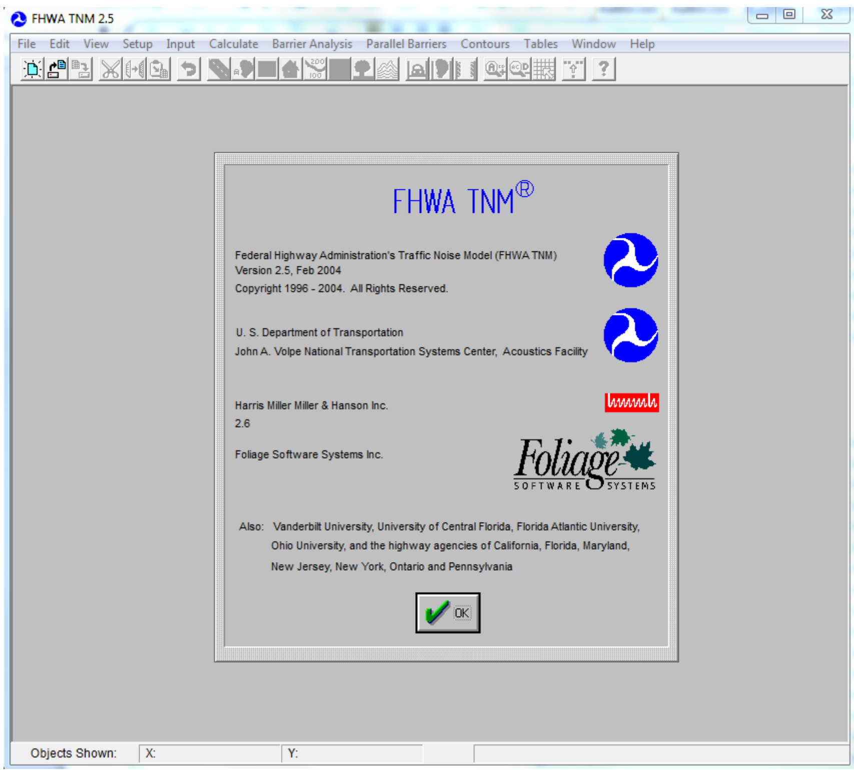

Figure 6.1: FHWA Traffic Noise Model (TNM) program, version 2.5

This program makes use of the geometry and topography of the highway and adjacent terrain, including number of lanes in each direction, presence of barriers or walls (e.g., noise walls, CTB or jersey barriers), curves, elevations, etc.; the location of the receivers, terrain lines, and the traffic; traffic composition (i.e., passenger cars, trucks, etc.), and the forecasted traffic levels.

6.2. TNM - Receivers

Eight receivers were included in the model. These receivers correspond to the residential monitoring locations that were used during the field-measuring stage of this study. The receivers are as follows:

- Site #1, R1. 5010 Southport Dr.
- Site #2, R2. 2205 Mermaid Cir.
- Site #3, R3. 4901 Harborview Dr.
- Site #4a, R4a. 3401 Francesca Ct.
- Site #6, R6. 4317 Rose Leaf Ct.
- Site #7, R7. 2629 Kirby Rd.
- Site #8, R8. 4509 Meadowcove Dr.
- Site #12, R12. 2414 Brittany Dr.

6.3. TNM - Traffic

The traffic figures included in the model correspond to future traffic projections. The predicted values for traffic volumes correspond to the year 2030. Traffic values were obtained from TxDOT.

6.4. TNM - Noise Walls

Two noise walls were considered in the model: the existing 8-ft.-tall walls along the east (northbound) and west (southbound) sides. Therefore, they were modeled as 8-ft.-tall walls. For the analysis, each wall had four up-increments and four down-increments in height; all the increments were 2 ft. Therefore, for the barrier analysis, each wall was analyzed for a maximum height of 16 ft. and a minimum height of zero, with the following increment heights (Table 6.1):

Table 6.1: Noise wall heights and increments

Increment	Barrier Height (ft.)
4 down	0
3 down	2
2 down	4
1 down	6
Reference	8
1 up	10
2 up	12
3 up	14
4 up	16

The noise wall descriptions are as follows (Table 6.2):

Table 6.2: Noise wall descriptions

Noise Wall	Status	Side	Community	Limits		Length (ft.)
				Northernmost	Southernmost	
1	Existing	West	Ridgecove	Kirby Rd.	Southern end of Ridgecove Community	2,949
2	Existing	East	Harborside	Harborview Dr.	Southern end of Harborside Community	2,858

The noise walls are illustrated in Figure 6.2, along with the receivers' locations.

Figure 6.2: Existing noise walls on SH 190

6.5. TNM - Pavements

The model was run first using "Average" pavement, as recommended by FHWA. However, in order to try to represent the existing road conditions, and to investigate variability due to pavement surface, it was run also using the "PCC" option of TNM. The pavement on SH 190 is transversely tined CRCP for both main lanes and frontage roads. However, for noise level prediction and the barrier analyses, the FHWA-recommended "Average" pavement setting was used.

6.6. TNM - Illustrations

A plan view of the TNM model is shown in Figure 6.3, which is a representation as seen on the computer screen, showing the geometry of the highway lanes, walls, and receivers.

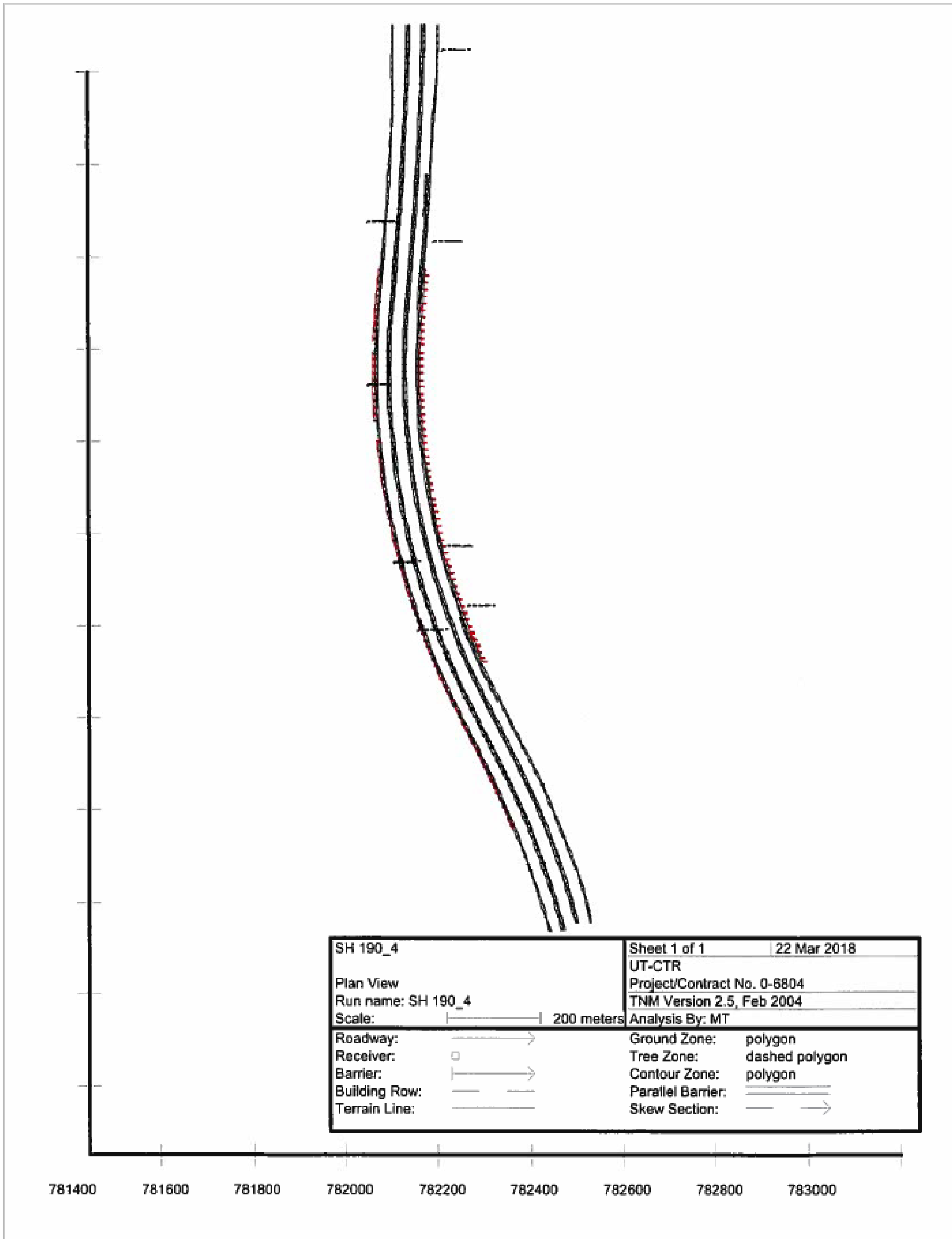

Figure 6.3: Plan view of the TNM model

An example of a skew view generated from TNM showing receiver R1, with Existing Noise Wall 1, on the left, and Existing Noise Wall 2, on the right, is shown in Figure 6.4.

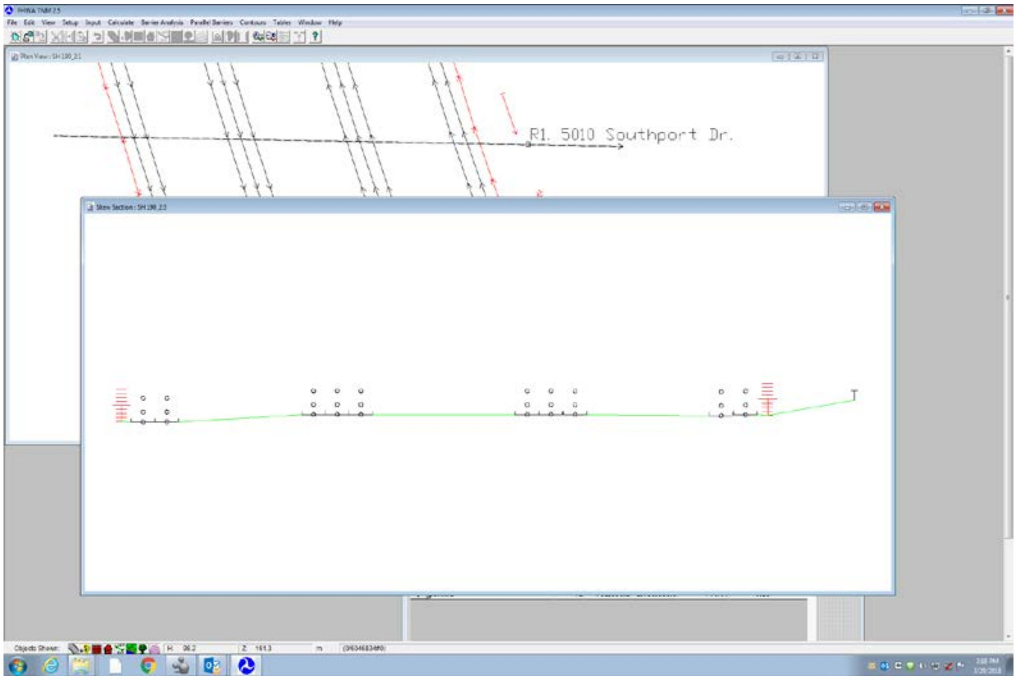

Figure 6.4: Skew view from TNM

Another example of a skew section from TNM is shown in Figure 6.5, which depicts the west side wall, named Existing Noise Wall 1 in the model, on the left, and the east wall, named Existing Noise Wall 2 in the model, on the right, as well as receivers R8 and R1.

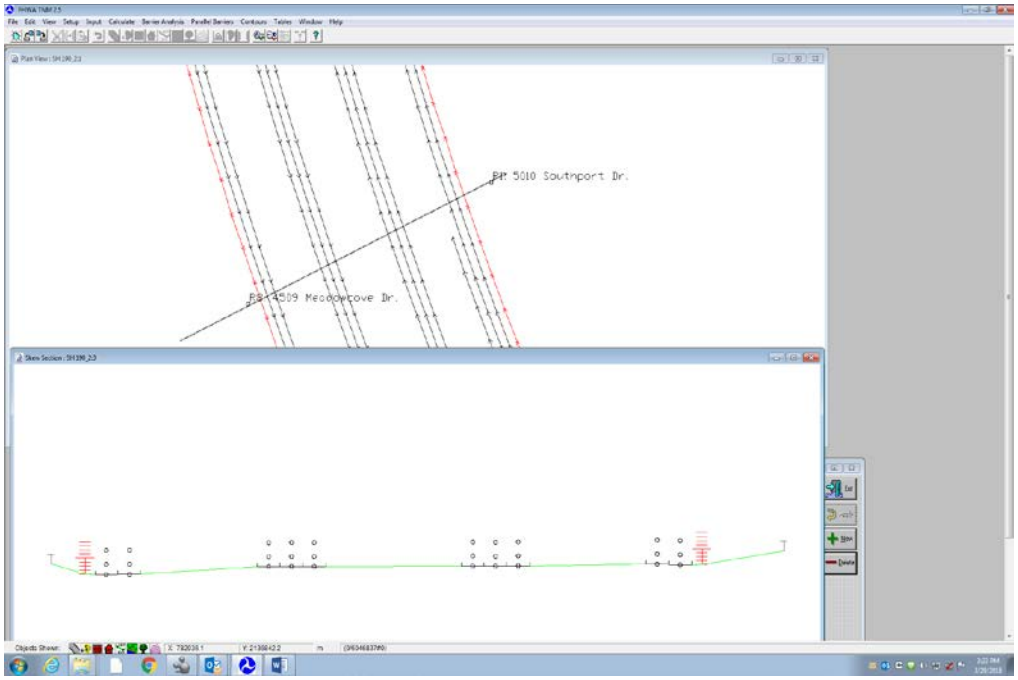

Figure 6.5: Skew view from TNM

6.7. TNM Results

The first set of results is shown in Table 6.3. This table shows TNM results for both "Average" and "PCC" pavements, compared to actual field noise measurements. The field tests include all the data collected in this project in the "Average Level" column, as well as the highest measurement at each particular location, in the "Highest Level" column. The table also indicates whether there is an impact, according to the previous chapter.

Table 6.3: Field results vs. TNM results with "Average" pavement and "PCC" pavement

Receivers	Field Tests				TNM (Average Pavement)				TNM (PCC Pavement)			
	Average Level (dBA)	Impact	Highest Level (dBA)	Impact	No Barriers (dBA)	Existing Barriers (dBA)	Impact (W/Barriers)	Noise Reduction (dBA)	No Barriers (dBA)	Existing Barriers (dBA)	Impact (W/Barriers)	Noise Reduction (dBA)
R1. 5010 Southport Dr.	67.5	Yes	72.8	Yes	69.6	68.9	Yes	0.7	71.9	71.2	Yes	0.7
R2. 2205 Mermaid Cir.	68.4	Yes	73.4	Yes	69.0	68.5	Yes	0.5	71.3	70.7	Yes	0.6
R3. 4901 Harborview Dr.	67.1	Yes	71.5	Yes	67.6	67.5	Yes	0.1	69.7	69.7	Yes	0.0
R4a. 3401 Francesca Ct.	67.5	Yes	76.3	Yes	67.5	67.5	Yes	0.0	69.5	69.5	Yes	0.0
R6. 4317 Rose Leaf Ct.	68.3	Yes	73.8	Yes	65.1	65.1	No	0.0	67.1	67.1	Yes	0.0
R7. 2629 Kirby Rd.	73.2	Yes	76.5	Yes	70.6	70.6	Yes	0.0	73.0	73.0	Yes	0.0
R8. 4509 Meadowcove Dr.	67.7	Yes	72.1	Yes	72.0	71.7	Yes	0.3	74.3	74.0	Yes	0.3
R12. 2414 Brittany Dr.	58.9	No	62.7	No	69.5	61.8	No	7.7	71.8	63.4	No	8.4

Actual field measurements indicate that all receivers but one (R12) have an impact, as described in the previous chapter. The same outcome was produced by TNM with PCC pavement, and a very similar result was obtained by using TNM with average pavement. Only R6 changed to no impact when using TNM with the average pavement option. In general, the TNM results are a fairly consistent representation of the actual field measurements. Even though it is an obvious and expected result, the receivers that are currently not shielded by any barriers (R4a, R6, and R7) show the same result for both the "No Barriers" and "Existing Barriers" runs, which indicates that the models are producing reasonable and consistent results. For all these numbers, the "Reference Height" of 8 ft. was used for all the existing walls.

The TNM PCC pavement option is assumed to be a more accurate representation of the actual noise levels for receivers R6 and R7 only, whereas the average pavement option seems like a fairly close representation of actual noise levels for all the other receivers. This can only be verified if the model is validated using actual traffic counts at the time the field measurements are taking place.

Actual noise levels were determined from field measurements conducted over several months (July 2017 through January 2018) at various times of the day and night, as described in Chapter 5.

6.7.1. TNM Barrier Analyses

A detailed barrier analysis for all the considered heights (the heights shown in Table 6.1), was performed for the existing walls in the model. These are shown in Tables 6.4 and 6.5. Additionally, two new noise walls were proposed, designed, and analyzed for the purpose of shielding the residential areas that are not currently protected by existing walls, particularly Magnolia Springs and the adjacent homes along Kirby Rd., on the west side of the highway. However, TxDOT decided at this time, since this is considered a pilot project, not to construct any new walls.

Table 6.4 shows the barrier analysis for Existing Noise Wall 1, on the west side of SH 190.

Table 6.4: Barrier analysis: Existing Noise Wall 1

Barrier Analysis: Existing Noise Wall 1						
Sample Receiver:	R8. 4509 Meadowcove Dr.			R12. 2414 Brittany Dr.		
Barrier Height (ft)	No Barrier LAeq1h Calculated dBA	With Barrier Calculated LAeq1h dBA	Noise Reduction Calculated dB	No Barrier LAeq1h Calculated dBA	With Barrier Calculated LAeq1h dBA	Noise Reduction Calculated dB
0	72	72	0	69.5	69.5	0
2	72	72	0	69.5	69.2	0.3
4	72	71.9	0.1	69.5	66.6	2.9
6	72	71.7	0.3	69.5	63.7	5.8
(Existing Height) 8	72	71.7	0.3	69.5	61.8	7.7
10	72	66.6	5.4	69.5	60.1	9.4
12	72	63	9	69.5	58.7	10.8
14	72	60.6	11.4	69.5	57.7	11.8
16	72	58.6	13.4	69.5	56.7	12.8

For the case of Existing Noise Wall 1, there are two representative receivers, R8 and R12. Receiver R12 represents a unique case—besides being behind the existing noise wall, it is also below a deep embankment and its corresponding tall retaining wall. This receiver consistently registered the lowest noise levels among the monitored residential locations, as its natural profile shields it well from the highway noise, as explained in Section 5.1.2. For receiver R8, the analysis shows that an additional height of 4 ft. on top of the existing wall would reduce noise by a substantial level (greater than 7 dBA). Therefore, for Existing Noise Wall 1, it is recommended to add 4 ft. to the existing height, for a total of 12 ft. of wall. Figure 6.6 shows the TNM screen of the Barrier Analysis for Existing Noise Wall 1.

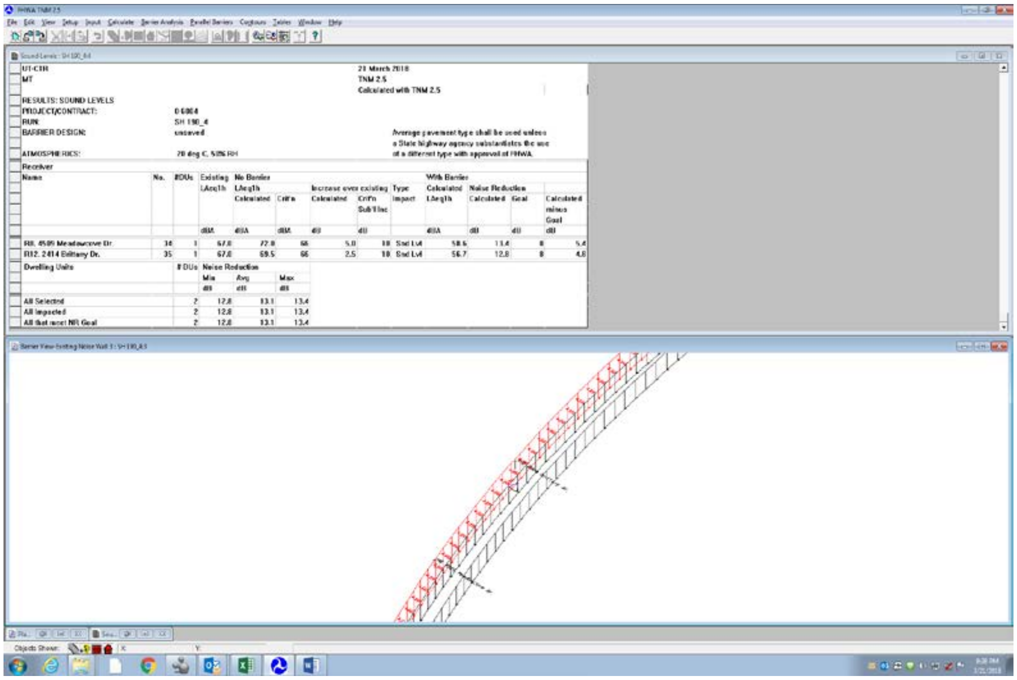

Figure 6.6: TNM Barrier Analysis for Existing Noise Wall 1

Table 6.5 shows the barrier analysis for Existing Noise Wall 2, which is on the east side of SH 190, protecting the Harborside Community.

Table 6.5: Barrier analysis: Existing Noise Wall 2

Barrier Analysis: Existing Noise Wall 2						
Sample Receiver:	R1. 5010 Southport Dr.			R2. 2205 Mermaid Cir.		
Barrier Height (ft)	No Barrier LAeq1h Calculated dBA	With Barrier Calculated LAeq1h dBA	Noise Reduction Calculated dB	No Barrier LAeq1h Calculated dBA	With Barrier Calculated LAeq1h dBA	Noise Reduction Calculated dB
0	69.6	69.6	0	69	69	0
2	69.6	69.6	0	69	69	0
4	69.6	69.6	0	69	68.8	0.2
6	69.6	69.4	0.2	69	68.6	0.4
(Existing Height) 8	69.6	68.9	0.7	69	68.5	0.5
10	69.6	67.1	2.5	69	68.4	0.6
12	69.6	64.6	5	69	66.9	2.1
14	69.6	62.7	6.9	69	63.4	5.6
16	69.6	61.3	8.3	69	61.2	7.8

For Existing Noise Wall 2, there are two representative receivers in the TNM model, R1, and R2. The analysis indicates that an additional height of 8 ft. on top of the existing 8-ft.-tall concrete wall would be necessary to drop the noise levels significantly (greater than 7 dBA). Therefore, a 16-ft.-tall wall would be recommended. Figure 6.7 shows the TNM screen during the Barrier Analysis of Existing Noise Wall 2.

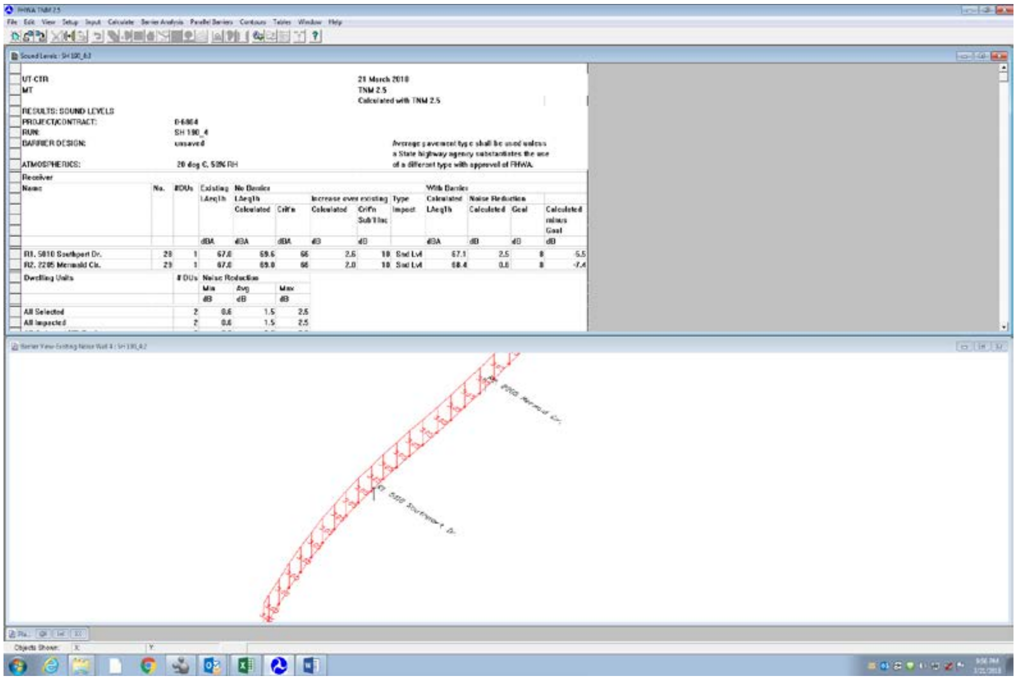

Figure 6.7: TNM Barrier Analysis for Existing Noise Wall 2

6.8. Summary and Discussion of Results

It is recommended to increase the height of Existing Noise Wall 1, on the west side of SH 190, next to the Ridgecove Community, by 4 ft., for a total of 12 ft. in order to provide a substantial noise level reduction. And for Existing Noise Wall 2, on the east side of SH 190, next to the Harborside Community, it is recommended to increase its height by 8 ft. for a total height of 16 ft.

Besides the existing noise walls, two new noise walls were proposed, designed, and analyzed for the purpose of shielding the residential areas that are not currently protected by existing walls, particularly Magnolia Springs and the adjacent homes along Kirby Rd., on the west side of the highway (e.g., R7). However, TxDOT decided at this time to not construct any new walls, since this is considered a pilot project.

As for the other impacted receivers, R3 (in the Harborside Community), R4a (in the Lake Forest Estates Community), and R6 (in the Magnolia Springs Community), because of the height of the highway relative to the residences, and the distance between the highway and the homes, a possible noise barrier would shield these residences only from the noise coming from the frontage roads, which are at the same level as the residences, but would not protect them from the noise coming from the main highway lanes, which are at a higher elevation. However, potential noise walls at these locations would not benefit a significant number of receivers.

Chapter 7. Summary and Conclusions

This report described the 0-6804 project and detailed the SH-190 study. This is an interim report, as the study is still in progress. The following aspects of the study were presented:

- A description of the characteristics of the SH-190/PGBT section of highway of interest, including geometry, pavements, the adjacent residential communities affected by the highway traffic noise, and the existing noise walls.

- The sites in the various residential communities along SH 190/PGBT that were selected for noise monitoring. The selection process included accessibility and the residences location relative to the highway and the existing noise walls. The residential sites were chosen for noise monitoring during the noise testing phase of this project. Eight sites were selected: four on the east side (northbound direction) and four on the west side (southbound direction) of SH 190.

- A pavement condition survey and tire/pavement noise tests conducted on both the main lanes and the frontage roads of the pavements of SH 190. The pavement condition, especially for the case of a distressed pavement, can have a definitive influence on the generation of tire/pavement noise at highway speeds.

- The noise generated at the tire/pavement interface was evaluated by means of the On-board Sound Intensity (OBSI) test, which is widely considered the best way of measuring the main component of traffic noise at the source: where the tire and the pavement are in contact.

- The noise testing program for the residential locations in the neighborhoods along SH 190 was described. The eight residential locations have been monitored following these procedures. The noise measurements, performed with sound pressure level meters, are collected for the purpose of evaluating the effectiveness of the future new noise barriers. The tests are conducted at different times of the day to account for the variability in traffic and climatic conditions. At the same time the noise tests are performed, a weather station is used to monitor climatic variables. A detailed description of the equipment utilized for the measurements was presented, as well as the methodology for the field work.

- The results of noise measurements and data analysis for the pre-barrier stage of SH 190. The measurements analyzed comprise tests conducted from July 2017 until January 2018.

The following preliminary conclusions are drawn from the data collected and analyzed:

- The results of the OBSI pavement tests, both for the main lanes and the frontage roads are very typical of the pavement type present in this facility, CRCP. A comparison with other pavements indicates that the SH 190 pavements are among the loudest compared to other CRCPs. This pavement type is generally regarded as one of the loudest pavement types, mainly due to the typical transversely tined finishing applied to these surfaces for safety purposes.

- The condition survey revealed that the pavements are in excellent condition; therefore, it is considered that the pavement condition is not contributing to an increase in tire/pavement noise.

- The environmental noise test results indicate that noise levels are indeed very high at most of the receivers' locations studied in this project. All the sites but one represent a noise impact, according to TxDOT policy; therefore, the neighbors' complaints are warranted and, in light of the noise levels measured, it is recommended to implement additional mitigation measures.

- Weather variables—primarily temperature and wind speed—appear to have influenced the noise levels. The various times of the day during which the tests are performed—morning, afternoon and evening—seem to have a slight impact on noise levels, especially considering that the evening tests consistently represented the times with higher noise levels. This is very likely associated with higher traffic volumes during those times of the day as well.

- The seasonal variations also seemed to have an impact on the noise levels detected. Colder seasons were related to higher noise levels. The sample size for the pre-barrier condition was small. There was no data for the months of February to June. Having at least a complete year worth of data would have been a better representation of all seasonal changes and their influence on noise.

The following are recommendations for the subsequent stages of the project and for the long-term future, in dealing with the traffic noise problem at SH 190:

- It is recommended that, in order to reduce the noise at the source, a quieter pavement overlay should be considered, such as a TOM or a PFC, both of which are capable of providing substantial noise reductions over a typical transversely tined CRCP. OBSI tests revealed that the existing pavement is loud.

- In order to provide substantial noise level reductions, it is recommended to increase the height of Existing Noise Wall 1, on the west side of SH 190, next to the Ridgecove Community, by 4 ft., for a total of 12 ft. And for Existing Noise Wall 2, on the east side of SH 190, next to the Harborside Community, it is recommended to increase its height by 8 ft. for a total height of 16 ft. These recommendations are based upon the TNM analysis performed.

- Besides the existing noise walls, two new noise walls were proposed, designed, and analyzed with the TNM program for the purpose of shielding the residential areas that are not currently protected by existing walls, particularly Magnolia Springs and the adjacent homes along Kirby Rd., on the west side of the highway (e.g., R7). However, TxDOT decided at this time not to construct any new walls, since this is considered a pilot project.

- The findings indicate that for the other impacted receivers—R3 (in the Harborside Community), R4a (in the Lake Forest Estates Community), and R6 (in the Magnolia Springs Community)—because of the height of the highway relative to the residences and the distance between the highway and the homes, a possible noise barrier would shield these residences mainly from the noise coming from the frontage roads, which are at the same level as the residences, but would not be effective for protecting them from the noise coming from the main highway lanes, which are at a higher elevation. Furthermore, potential noise walls at these locations would not benefit a significant number of receivers.

References

American Association of State Highway and Transportation Officials (AAHSTO), Standard Method of Test for Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method. AASHTO Designation: TP 76-13, Washington, DC.

ASTM Standard Designation: F 2493 – 08: Standard Specification for P225/60R16 97S Radial Standard Reference Test Tire. West Conshohocken, PA.

Donavan, P., and B. Rymer, Quantification of Tire/Pavement Noise: Application of the Sound Intensity Method, Presented at the 33rd International Congress and Exposition on Noise Control Engineering, Prague, Czech Republic, August 22-25, 2004.

FHWA Highway Traffic Noise: Analysis & Abatement Guidance, FHWA-HEP-10-025, 2011. http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/analysis_and_abatement_guidance/revguidance.pdf. Accessed Aug. 2019.

NTTA North Texas Tollway Authority. Presentation: PGBT-Eastern Extension Noise Analysis Presented to NTTA Board of Directors, by Elizabeth Mow. Unpublished, December 2013.

NTTA North Texas Tollway Authority. https://www.ntta.org/roadsprojects/existroad/Pages/President-George-Bush-Turnpike-(PGBT).aspx. Accessed Aug. 2019.

Sandberg, U. and J. A. Ejsmont, Tyre Road Noise Reference Book, Informex, Handelsbolag, Kisa Sweden, ISBN 91-631-2610-9, 2002.

TxDOT Guidelines for Analysis and Abatement of Roadway Traffic Noise, Texas Department of Transportation, April 2011.