Final Report

I-394 Pavement Noise Study

A statistical study of changes in tire-pavement noise.

Minneapolis, Minnesota
December 29, 2016

Executive Summary

This report presents the results of the I-394 Pavement Noise Study, a statistical study of possible changes in neighborhood noise levels due to possible changes in tire-pavement noise on I-394. This study was conducted by HDR, Inc., at the request of the Minnesota Department of Transportation (MnDOT).

In November 2015, MnDOT completed a pavement resurfacing project that made several improvements to a segment of Interstate Highway 394 (I-394) in Minneapolis. The study area for the I-394 Pavement Noise Study includes the segment of I-394 between Interstate Highway 94 (I-94) and Trunk Highway 100 (TH100).

The goal of the I-394 Pavement Noise Study was to determine whether the pavement resurfacing project caused statistically significant changes to noise levels in various neighborhoods adjacent to I-394. The new I-394 pavement surface was intended to reduce tire-pavement noise levels. HDR made their determinations by first measuring noise levels before and after the pavement resurfacing project. HDR also obtained monitoring data regarding the vehicle mixes in the study area and used traffic noise modeling to normalize measured results. A statistical analysis was then performed on the resulting data to determine whether the difference between the pre- and post-resurfacing neighborhood noise levels are statistically significant.

The statistical analysis indicated that some post-project neighborhood noise average levels are lower than pre-project levels by statistically significant amounts. However, the present study cannot demonstrate that the differences in noise levels can be attributed solely to the I-394 resurfacing project. In most locations it appears likely that the measurements are influenced to some degree by local sound sources rather than being dominated by the noise from I-394. The investigators noted that neighborhood B appeared to offer a fairly unobstructed view of a resurfaced section of I-394 for most residents and may represent an area dominated by I-394 traffic noise.

Assuming that neighborhood B is a good example of a neighborhood that might benefit from the I-394 resurfacing project, the level changes for this neighborhood were looked at in some detail. It was felt that the analysis of the L10 noise levels should be used as these levels are less affected by external noise sources than the L50 levels. Using the paired samples a statistically significant average decrease of 1.3 dBA in the L10 levels was found. While this decrease is statistically significant, it's quite small and doesn't qualify the I-394 resurfacing project to be considered as providing effective noise level mitigation.

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Glossary

confidence interval (CI) A region of numbers that has a certain probability of containing the true value of a population statistic—for instance, a region that has a 95 percent probability of containing the true mean of a population.

median The middle value of a set of data or the 50th percentile; half the data have higher values, and half the data have lower values.

normal distribution A common "bell-shaped" probability distribution.

normalization The process of adjusting values in a data set to remove or reduce known effects on the data.

p-value The probability that a statistical determination is due to random error.

quantile Percentiles of a data set or of a statistical distribution.

significance Describes a situation in which a p-value is less than a predetermined significance level.

standard deviation Square root of variance; a statistical description of the spread of data.

target hours The loudest daytime hour, loudest nighttime hour, and quietest overall hour for each measurement period.

test statistic A function of the sample data that is expected to follow a known distribution and is used for hypothesis testing and for making significance determinations.

1 Introduction

1.1 Study Description

In November 2015, MnDOT completed a pavement resurfacing project that made several improvements to a segment of Interstate Highway 394 (I-394) in Minneapolis. The new pavement surface is intended to reduce the tire-pavement noise levels. During the pavement resurfacing project, MnDOT:

- Removed the asphalt layer on the top of the pavement;
- Repaired the road joints in the concrete pavement beneath the asphalt;
- Diamond-ground the concrete pavement to make the tire-pavement interaction quieter;
- Redecked the Lyndale Avenue bridge over Dunwoody Boulevard;
- Repaired guardrails, approach panels, and storm sewers;
- Improved bicycle and pedestrian ramps;
- Resurfaced Wayzata Boulevard (north side of I-394) between Cedar Lake Road and Theodore Wirth Parkway; and
- Resurfaced Wayzata Boulevard (south side of I-394) between Penn Avenue and France Avenue.

The study area for this I-394 Pavement Noise Study is the segment of I-394 between Interstate Highway 94 (I-94) and Trunk Highway 100 (TH100). The study area extends about 500 feet perpendicular to the I-394 right-of-way.

For this study, HDR performed noise measurements over 24-hour periods using unattended environmental noise measuring equipment at five different residences in five different neighborhoods throughout the study area (for a total of 25 measurement locations). HDR identified the proposed measurement locations and sent a letter to residents at each location asking for permission (right of entry, or ROE) to perform the measurements on their property. None of the residents contacted MnDOT or HDR to complain about or disapprove the ROE request, so HDR staff set up the measuring equipment at each of the 25 locations during the pre-construction phase of the pavement resurfacing project.

During the post-construction phase of the pavement resurfacing project, HDR performed unattended 24-hour noise measurements at 17 measurement locations. During the post-construction phase, HDR-owned noise measuring equipment was vandalized at one location. In response to this vandalism, HDR implemented a more formal process to request ROE that included sending request letters via certified mail and providing a self-addressed stamped envelope with which residents could respond to the ROE request. A limited number of residents responded to the ROE requests, so there are fewer post-construction noise measurement locations than pre-construction measurement locations.

Using the measurement results, HDR identified the loudest daytime hour, the loudest nighttime hour, and the quietest overall hour for each measurement period. These hours are called the *target hours*.

To determine the mix of vehicles (cars, medium trucks, heavy trucks, buses, and motorcycles) on the road during the target hours, HDR used data from MnDOT's traffic monitoring systems. In addition, HDR modeled these traffic volumes using MnDOT's traffic noise model (MINNOISE31). The modeling results were used to normalize the monitored results. (For more information about data normalization, see Section 2.5.)

HDR then performed a statistical analysis on the measurement results to evaluate changes between the pre- and post-construction noise levels. The statistical analysis showed that the new pavement surface is quieter than the old surface and that this difference is statistically significant.

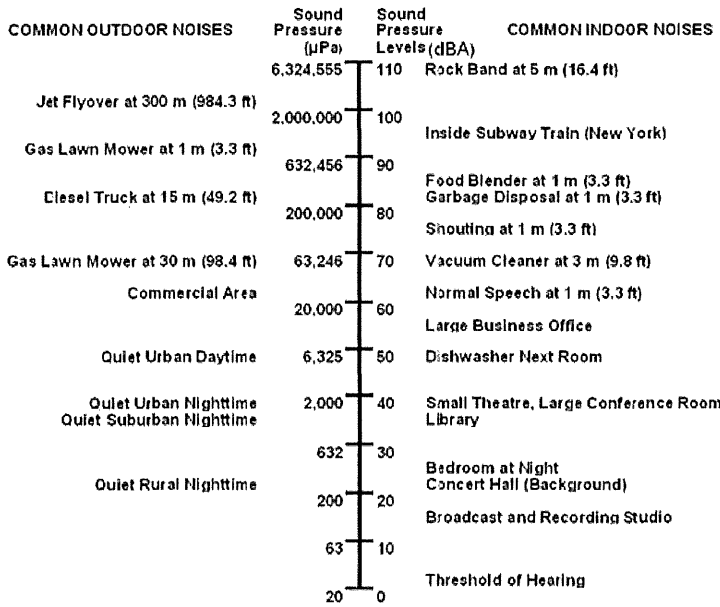
1.2 Fundamentals of Acoustics

Noise is defined as any unwanted sound. Sound travels in a wave motion and produces a sound pressure level. This sound pressure level is commonly measured in decibels. Decibels (dB) represent 10 times the logarithm of the ratio of a sound energy relative to a reference sound energy. For highway traffic noise, an adjustment, or weighting, of the high- and low-pitched sound is made to approximate the way that an average person hears sound. The adjusted sound levels are stated in units of "A-weighted decibels" (dBA). A sound increase of 3 dBA is barely noticeable by the human ear, a 5 dBA increase is clearly noticeable, and a 10 dBA increase is heard as twice as loud.

In Minnesota, traffic noise is evaluated by measuring and/or modeling the traffic noise levels that are expected to be exceeded 10 percent and 50 percent of the time during the hours of the day and/or night that have the loudest traffic noise levels. The noise level descriptors used to characterize traffic noise are the L_{10} and L_{50} levels, respectively. The L_{10} level is the noise level that is exceeded 10 percent, or 6 minutes, of an hour. The L_{50} level is the noise level that is exceeded 50 percent, or 30 minutes, of an hour. The I-394 Pavement Noise Study also looked at the noise level exceeded 90 percent of the time (the L_{90} level) and the equivalent-average sound level (the L_{eq}). The L_{eq} represents a constant sound that, over the specified period, has the same acoustic energy as the time-varying signal.

Figure 1-1 provides a rough comparison of the noise levels of some common noise sources.

Figure 1-1. Noise Levels of Common Noise Sources



Source: Minnesota Pollution Control Agency, http://www.pca.state.mn.us/index.php/air/air-monitoring-and-reporting/air-emissions-modeling-and-monitoring/noise-program.html

1.3 Study Area

The noise study area is the area within 500 feet of the segment of I-394 between I-94 and TH100. The noise study area includes residential and park land uses on both the north and south side of I-394. The residential land uses are the primary noise-sensitive receptors analyzed in this study. The segment of I-394 included in this analysis (between I-94 and TH100) has concrete retaining walls and wooden noise walls throughout much of the segment.

1.4 Pavement Characteristics

1.4.1 Pre-construction Pavement

The I-394 pavement in the study area was originally constructed with a transversely tined concrete surface. Transverse tines, which are perpendicular to the direction of travel, provide enhanced friction, and this is an appealing safety feature of the pavement. The unfortunate side effect of transverse tines is the loud tire-pavement noise.

In response to complaints about traffic noise from residents in the study area, MnDOT applied two asphalt overlays, covering up the transversely tined concrete surface and noticeably reducing tire-pavement noise. The harsh winter weather and freeze-thaw cycles in Minnesota took a toll on the asphalt overlays, and in 2014 MnDOT decided to repair the pavement surface again.

1.4.2 Post-construction Pavement

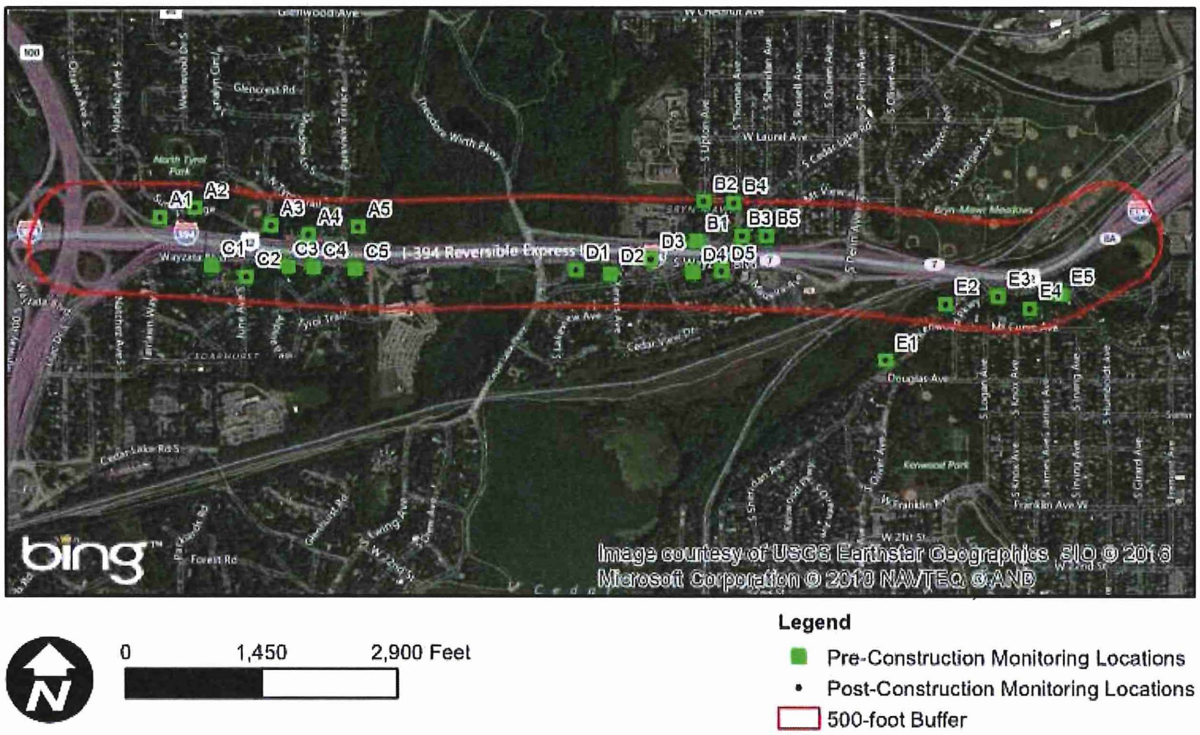
MnDOT decided to strip off the remaining asphalt overlays, repair the original concrete surface, and install a next-generation concrete surface (NGCS). NGCS was developed by Purdue University and MnDOT material engineers working at MnROAD. NGCS is characterized as a combination of diamond grinding and longitudinal grooving. Historically, diamond-ground pavements had a surface finish texture that was somewhat rough. This roughness contributed to additional tire-pavement noise. In contrast, NGCS surfaces are smooth and grooved, with most of the roughness removed. This makes NGCS pavement finishes much smoother than other pavements, and it is reputed to be one of the quietest non-porous concrete surfaces introduced in the last 30 years.

2 Methodology

2.1 Pre-construction Noise Measurements

Prior to the resurfacing project, HDR performed unattended 24-hour noise measurements using 15 sets of environmental noise measuring equipment. These measurements were performed between June 8 and June 11, 2015. HDR provided four HDR-owned sets of equipment, and MnDOT and HDR decided to rent an additional 11 sets. Three pairs of HDR staff, primarily HDR acousticians, set up the equipment at residential receivers near I-394. Measurements were performed at five individual residences in each of five neighborhoods for a total of 25 measurement locations. Figure 2-1 shows the noise measurement locations; 0 contains detailed maps of these locations.

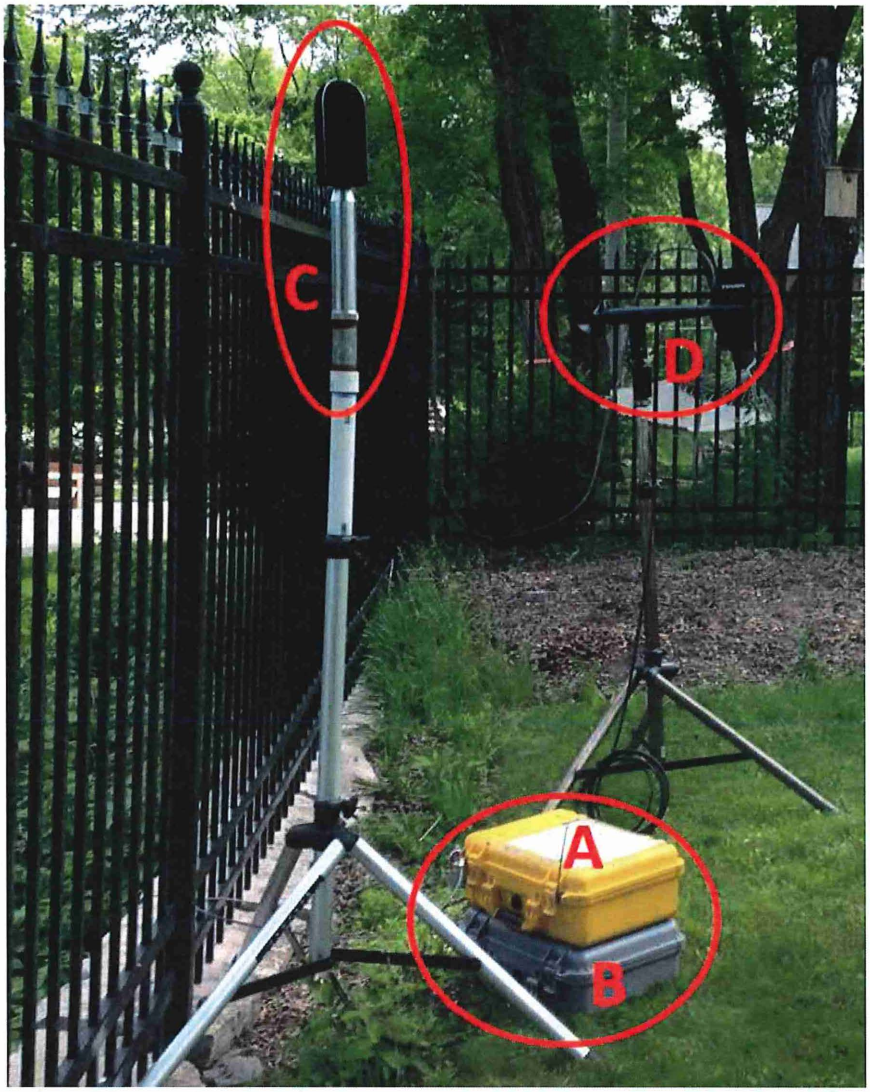
Figure 2-1. Noise Measurement Locations



Before obtaining the measurements, HDR sent a letter to residents at each of the measurement locations to explain the study and the purpose of the equipment and to request permission (ROE) to perform the measurement on the property.

Figure 2-2 shows the equipment used to perform a typical 24-hour noise measurement.

Figure 2-2. Equipment Setup for 24-Hour Noise Measurement



The following equipment is shown in Figure 2-2 above.

A. Larson-Davis sound level meter (and optional Edirol audio recording device) in a weatherproof Pelican case

B. External batteries in a weatherproof Pelican case

C. Environmental pre-amplifier, microphone, and windscreen mounted on a tripod (bird spikes are also visible above the wind screen)

D. Anemometer mounted on a tripod

All of the digital sound level meters and handheld calibrators used for this study meet the Class 1/Type 1 precision requirements in American National Standards Institute and International Electrotechnical Commission standards. All instrumentation used to measure noise levels for this study was calibrated on a regular basis by an independent accredited calibration laboratory using standards traceable to the National Institute of Standards and

Technology. Additionally, calibration checks of equipment were performed in the field before and after each measurement.

The sound level meters stored hourly noise levels and 1-second to 1-minute interval noise levels. The sound level meters stored the A-weighted L_{eq}, L_{10}, L_{50}, and L_{90} and unweighted 1/3-octave-band noise levels.

An anemometer was placed at one or two locations in each neighborhood to measure microphone-height wind speeds. An Edirol digital audio recording device was used at some of the measurement locations, and the audio signals received by the microphone on the sound level meter were also digitally recorded in order to better discern any unique trends in the noise data.

For this study, all noise levels were measured at a listener's location (that is, at a residence); noise was not measured using microphones attached to vehicle tires (referred to as on-board sound intensity, or OBSI, measurements).

2.2 Post-construction Noise Measurements

Post-construction noise measurements were performed between June 8 and July 26, 2016. During project planning, MnDOT and HDR decided to rent 11 sets of environmental noise measuring equipment and use four HDR-owned sets for performing the pre-construction noise measurements. Using 15 sets of equipment at the same time allowed HDR to perform the measurements much more quickly. This decision to collect the data simultaneously was driven by the pending start of the resurfacing.

The schedule for the post-construction noise measurements was not constrained in the same way, since the resurfacing was already completed. HDR could perform the post-construction measurements over a longer period, so renting additional measuring equipment was not necessary. As a result, the post-construction noise measurements were performed using five HDR-owned sets of measuring equipment. This also increased the number of target hours, because noise measurements were performed over a larger number of days.

HDR attempted to take noise measurements at 19 locations and completed noise measurements at 17 locations. One attempted location had a power issue, and the measurement stopped before the target hours for that measurement period. HDR's equipment was vandalized and damaged at a second location, so the target hours weren't measured at that location. In response to this vandalism, HDR implemented a more formal process to request ROE for the remaining locations than the process used for the pre-construction noise measurements. Only some of the residents responded and approved the ROE for post-construction noise measurements, so fewer post-construction measurement locations were used than pre-construction locations, as shown in Figure 2-1 above.

All other measurement methods were the same as the pre-resurfacing measurement methods.

2.3 Traffic Data Collection

After HDR processed the noise measurement results and identified the target hours (the loudest daytime hour, the loudest nighttime hour, and the quietest overall hour), the next step in the study was to identify the vehicle volume and mix during the noise measurements. MnDOT provided traffic data collected by two systems in the study area: video cameras and automatic traffic recorders.

HDR's traffic analysts began processing MnDOT's traffic data by observing videos from MnDOT's traffic cameras along I-394. The traffic camera at France Avenue had the clearest view of all interstate lanes. The camera on Theodore Wirth Parkway was used as a backup camera when the France Avenue camera's view was obstructed or otherwise unusable. By observing the video records stored by MnDOT traffic cameras, HDR was able to manually compile vehicle classification counts. These traffic counts were stored in 15-minute intervals for three distinct directions of travel: eastbound I-394, westbound I-394, and the reversible high-occupancy toll lanes (variable direction by time of day). This approach allowed HDR to count the number of medium trucks, heavy trucks, buses, and motorcycles for the target hours for both pre- and post-construction.

Under this methodology, recreational vehicles, trucks towing trailers, and service vans were considered to be passenger vehicles. HDR obtained total vehicle counts in each direction for each 15-minute interval using MnDOT's embedded traffic detectors, and the data were downloaded from MnDOT's server for the same periods where noise measurements were made. HDR subtracted the observed number of heavy trucks, medium trucks, buses, and motorcycles from these total vehicle counts to obtain a total number of passenger vehicles for each 15-minute interval.

HDR's traffic analysts performed a quality control check for one 15-minute interval out of every eight intervals (that is, one interval per 2 hours of observations). Each individual analyst performed at least one check for all others. There were some unique challenges during the process, such as sunlight obstructing the camera and nighttime observations being obstructed by headlights. For one 15-minute interval, HDR interpolated 1 minute of data from the previous period due to camera panning and rotation. The backup camera was also unusable during this 1-minute period; this period was the only period during which neither the primary nor backup camera had usable views.

This process was performed to identify the traffic volumes and mix that occurred while both the pre- and post-construction noise measurements were being performed. Appendix E and Appendix F contain all traffic data used in this study.

2.4 Traffic Noise Modeling

Using the collected traffic data (see Section 2.3), HDR used MnDOT's traffic noise model (MINNOISE31) to model traffic noise during all target hours. The target hours were the loudest daytime, loudest nighttime, and quietest overall hour from each measurement period. MnDOT provided a MINNOISE input file template, which HDR used to model traffic on eastbound I-394, westbound I-394, and the reversible high-occupancy toll lanes. Vehicle speeds used in the MINNOISE model were measured by MnDOT ATR's; mean vehicle speeds as shown in Appendix J were input into the traffic noise model.

Appendix G and Appendix H contain the modeled noise levels. The modeled noise levels were used to normalize the measured noise levels, because traffic volumes varied during the noise measurements.

2.5 Data Normalization

HDR normalized the measured L_{50} and L_{10} levels using the corresponding vehicle counts and mix from the MINNOISE traffic noise model (see Section 2.3). This approach provided a generalized correction for the amount of traffic on the road. Without this correction, it would not be possible to know whether a measured reduction in noise was due to quieter pavement or due to a coincidental reduction in traffic volume.

The normalization method that HDR used is similar to the American Association of State Highway and Transportation Officials (AASHTO) standard TP99-13, "Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)." This standard uses the L_{eq} level and 15-minute analysis time blocks; however, the normalization procedure can be easily adapted to the hourly L_{10} and L_{50} levels. Furthermore, this standard prescribes clear line-of-sight and a short distance to the roadway, but only because the effect of more complicated modeling on the accuracy has not been investigated.

HDR performed the statistical analyses for this study on the normalized traffic noise levels for each target hour. The normalization adjusts the sound levels so that they are representative of similar road traffic, even if the measurements did not have similar road traffic. The normalization also adjusts for the locations of measurement positions and the gross physical features in the sound path, even when the measurement locations are dissimilar. However the normalization does not account for other sources of measurement error, and perhaps the most influential aspect of measurement error is the external, non-highway environmental noise due to local roads, local human or animal activities, aircraft overflights, or other localized noise-making phenomena. These have potential to influence the measured noise levels and the normalization models do not account for these external noise sources, and these external noise sources are an unknowable quantity. The data were critically evaluated for potential error due to these types of effects.

2.6 Statistical Analysis

2.6.1 Exploratory Data Analysis

HDR began with a limited exploratory data analysis in order to determine whether there were any detectable patterns in the data. This exploratory data analysis included evaluating general descriptive statistics and various plots of the data in order to review the data from numerous perspectives. The results of the exploratory data analysis are presented in Section 4.1.

2.6.2 Confirmatory Data Analysis (Significance Tests)

After conducting the exploratory data analysis, HDR conducted confirmatory data analysis (Section 4.2). This step involved proposing a hypothesis—in this case, that the pre-and post-construction pavement treatments produced different noise levels —and then using statistical tools to determine whether the hypothesis was valid (hypothesis testing).

A number of statistical tools are available to provide that answer. One basic tool for determining whether there is a difference between two conditions is a *t-test*. For this study, we used this test to determine the statistical significance of the difference between the pavement treatments.

The statistical concept of *significance* indicates whether certain data support a hypothesis. In this case, the statistical significance output by the t-test answered the question of how likely it was that we had measured a real difference between the two conditions (pavement treatments) or had obtained two slightly different measurements of the same condition.

For this study, HDR used both a two-sample t-test and a paired-sample t-test. HDR provides the results of both tests because, in some instances, one test was better than the other at discerning a difference between the pre-construction and post-construction treatments.

- In the two-sample t-test, all the measurements from pre-construction are compared to all the measurements from post-construction. These two samples (pre- and post-construction) produced a test statistic to determine whether the two sample mean values were statistically different from each other.
- In the paired-sample t-test, measurements were taken at the same location for both the pre-construction and post-construction noise levels. The difference between each of those observations was used to produce a test statistic to determine whether the mean difference was statistically different from zero.

The *test statistic* follows an expected probability density function, in particular the Student's t-distribution (thus the name *t-test*). The test statistic produces a confidence interval and a p-value. Where the measured data produce a sample mean, the confidence interval shows the most likely range of the population mean. In other words, the measured data might not necessarily represent the real difference between pre-construction and post-construction noise levels, but rather they suggest that the actual difference in noise levels will fall somewhere in this confidence interval.

The p-value of the test statistic ranges in values from zero to one, and is the probability that the measurement data used to show a difference between two pavement treatments don't support an actual difference in the treatments. Conversely, as the p-value for the test statistic goes down, the evidence grows stronger that the observations captured a real difference between the treatments.

The p-value is compared to a predetermined criterion called the *significance level*. Researchers often use a 0.05 significance level for the p-value. If the p-value of the test statistic is less than 0.05, it means that the probability is less than 5 percent that there actually is no difference between the two conditions. In other words, the observed difference is statistically significant at the 5 percent significance level. Researchers can have confidence with such a low probability that the difference they've observed is real and not a result of random fluctuation. Consequently, for this study, the difference between the pre-construction and post-construction pavement treatment measurements is considered statistically significant if its p-value is less than 0.05.

One assumption that underlies this statistical testing is that the data are all independent normally distributed random variables. A few methods can be used to verify these assumptions. One method to determine the normality of the underlying data is by visually inspecting a normal quantile-quantile plot, or normal q-q plot. If the underlying data are exactly normally distributed, the plot shows all the points perfectly in line with each other.

3 Noise Measurement Results

3.1 Pre-construction Noise Measurements

Pre-construction noise measurements included 24-hour monitoring data taken at 25 locations. Appendix B contains the detailed hourly noise measurement results for each measurement location, which include the L_{eq}, L_{10}, L_{50}, and L_{90}.

The loudest daytime, loudest nighttime, and quietest overall hours were identified for each measurement period. Table 3-1 shows the identified target hours for each neighborhood.

Table 3-1. Pre-construction Loudest and Quietest Hours

Neighborhood	Loudest Daytime	Loudest Nighttime	Quietest Overall
A	8:00 AM	6:00 AM	3:00 AM
B	7:00 AM	6:00 AM	3:00 AM
C	8:00 AM	6:00 AM	3:00 AM
D	8:00 AM	6:00 AM	3:00 AM
E	12:00 PM	6:00 AM	3:00 AM

The loudest daytime hour was 8:00 AM for neighborhoods A, C, and D; 7:00 AM for neighborhood B; and 12:00 PM for neighborhood E for the pre-resurfacing measurements. The loudest nighttime hour was 6:00 AM and the quietest overall hour was 3:00 AM for all measurement locations for the pre-construction measurements. Measured pre-construction noise levels are summarized and compared with measured post-construction noise levels in Section 3.3.

3.2 Post-construction Noise Measurements

Post-construction noise measurements included 24-monitoring data at 17 locations. Table 3-2 shows the identified target hours for each neighborhood.

Table 3-2. Post-construction Loudest and Quietest Hours

Neighborhood	Loudest Daytime	Loudest Nighttime	Quietest Overall
A	7:00 AM	6:00 AM	3:00 AM
B	7:00 AM	6:00 AM	3:00 AM
C	6:00 PM	6:00 AM	2:00 AM
D	6:00 PM	6:00 AM	2:00 AM
E	11:00 AM	6:00 AM	2:00 AM

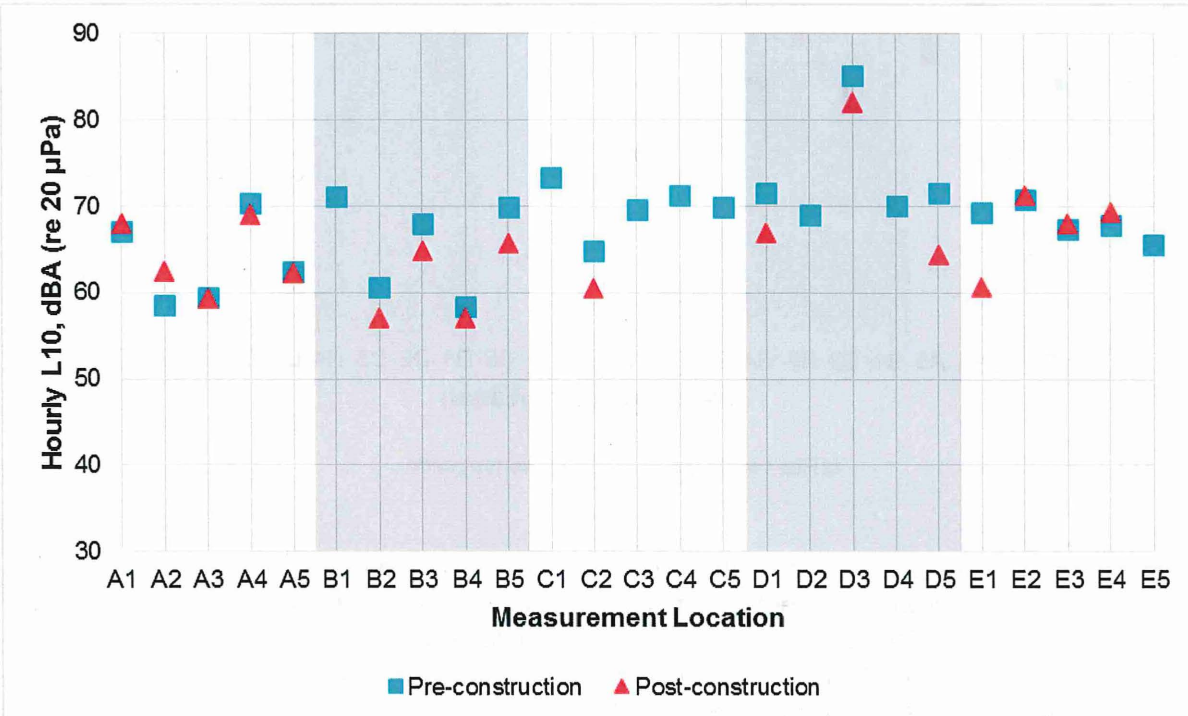
The loudest nighttime hour was consistently 6:00 AM, and the quietest overall hour varied between 2:00 AM and 3:00 AM. The loudest daytime hour varied among 7:00 AM, 11:00 AM, and 6:00 PM. Measured post-construction noise levels are summarized and compared with measured pre-construction noise levels in Section 3.3.

3.3 Post-construction vs. Pre-construction Measured Noise

3.3.1 L_{10} Noise Measurements

Figure 3-1 shows the loudest daytime hour L_{10} at each location for both the pre- and post-construction measurements. Neighborhoods are indicated by alternating gray and white blocks.

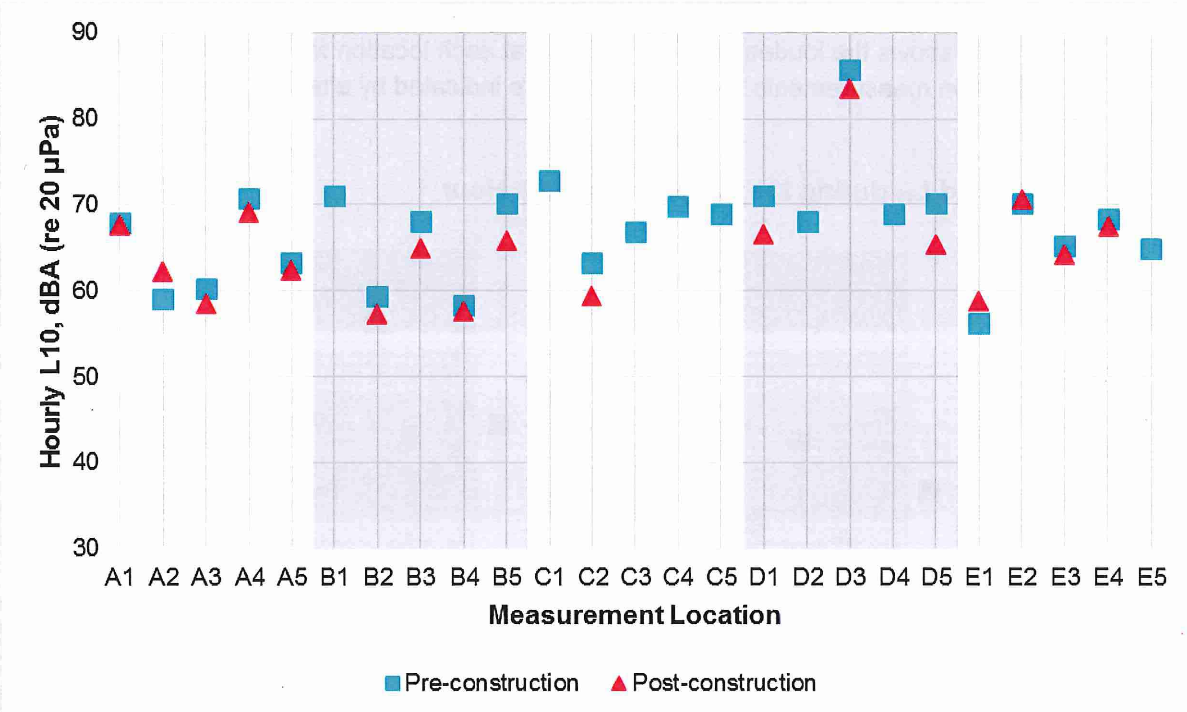
Figure 3-1. Measured L_{10} during the Loudest Daytime Hour



Although there is variation in the loudest daytime hour (expressed as an L_{10}), most of the pre-construction measurements are a few decibels above and below 70 dBA. The loudest post-construction daytime hourly L_{10} values are lower at most locations. However, at a few locations, the loudest post-construction hourly L_{10} is louder than the comparable pre-construction value.

Figure 3-2 shows the loudest nighttime hour L_{10} at each location for both the pre- and post-construction measurements.

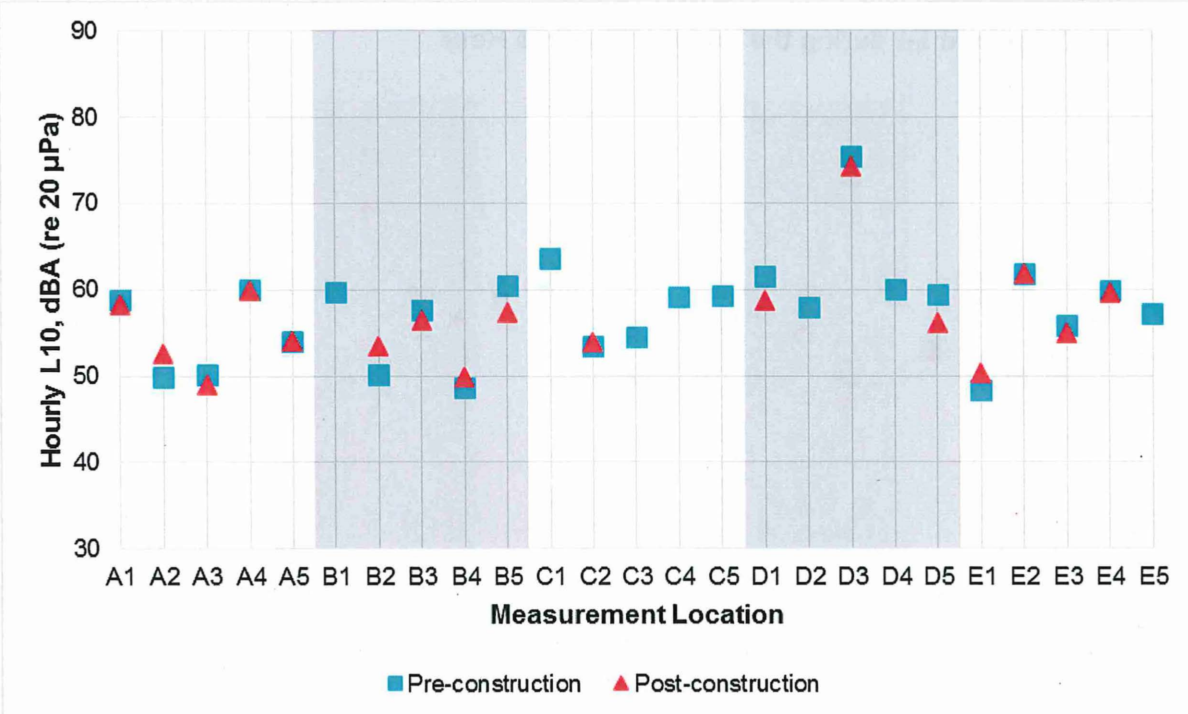
Figure 3-2. Measured L_{10} during the Loudest Nighttime Hour



Although there is variation in the loudest nighttime hour (expressed as an L_{10}), most of the pre-construction measurements are a few decibels above and below 70 dBA. The loudest post-construction hourly nighttime L_{10} values are lower at most locations. However, at a couple locations, the loudest post-construction nighttime hourly L_{10} is louder than the comparable pre-construction value.

Figure 3-3 shows the quietest overall hour L_{10} at each location for both the pre- and post-construction measurements.

Figure 3-3. Measured L_{10} during the Quietest Overall Hour

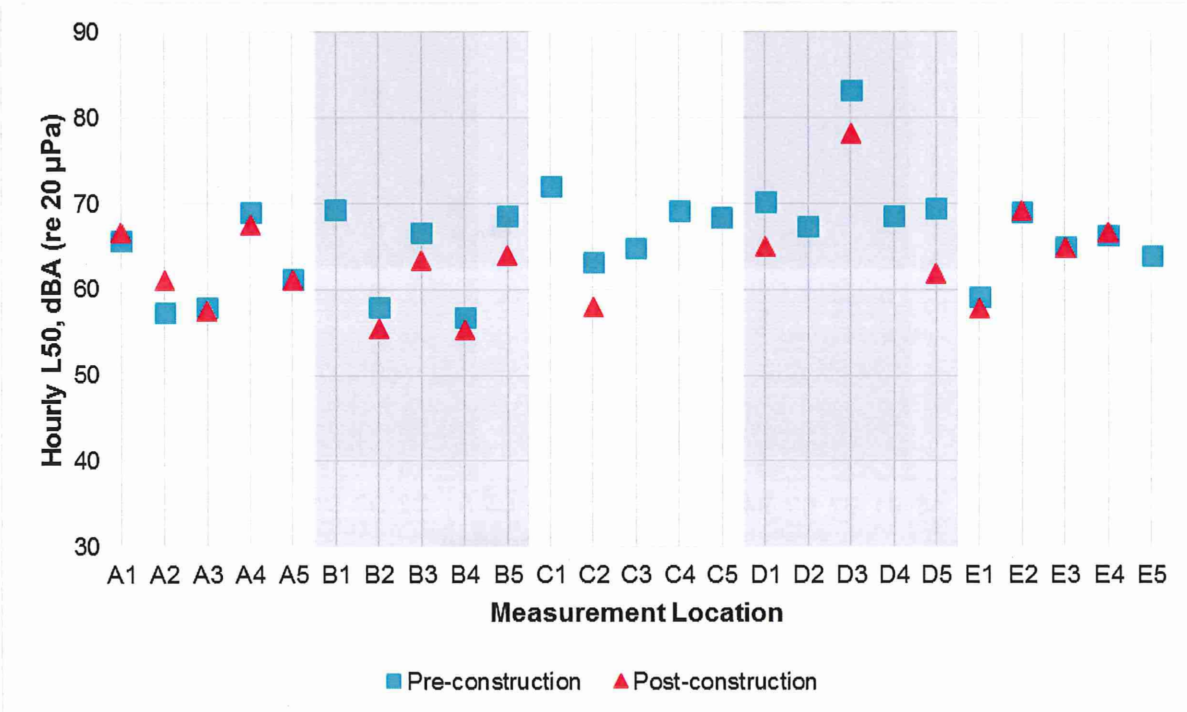


Although there is variation in the quietest overall hour (expressed as an L_{10}), most of the pre-construction measurements are a few decibels above and below 60 dBA. The quietest post-construction nighttime hourly L_{10} values are lower at some locations, but many show very little change. At a few locations, the loudest post-construction hourly L_{10} is louder than the comparable pre-construction value.

3.3.2 L_{50} Noise Measurements

Figure 3-4 shows the loudest daytime hour L_{50} at each location for both the pre- and post-construction measurements.

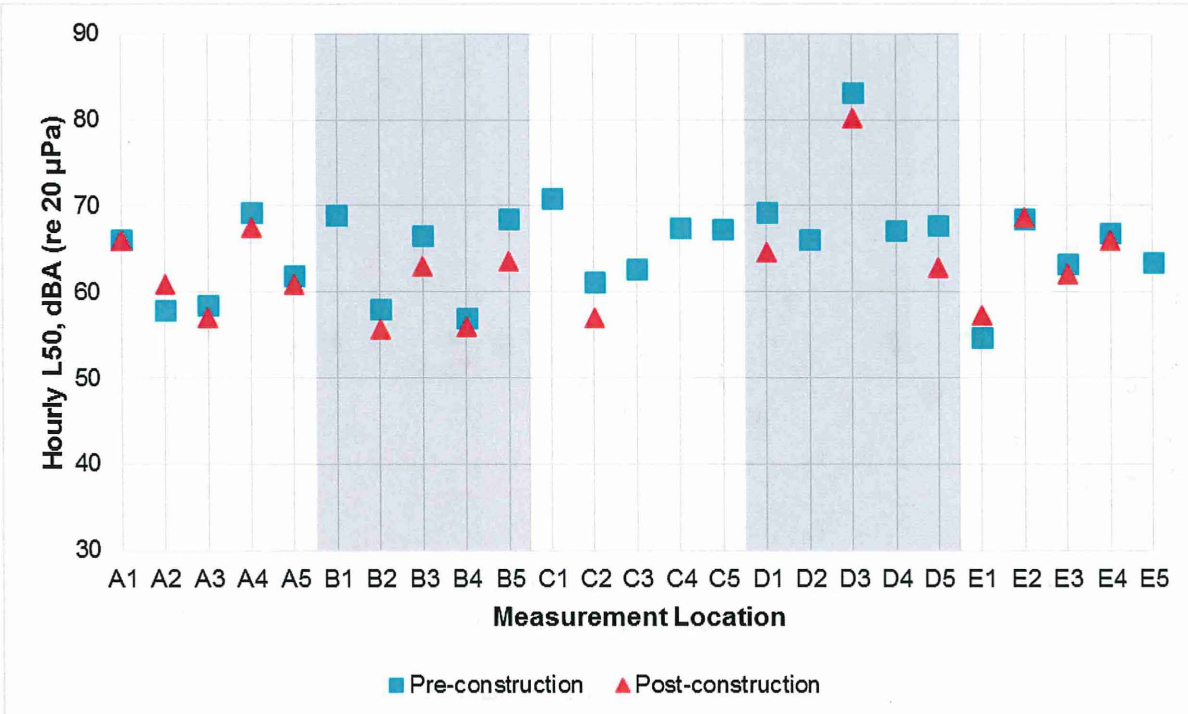
Figure 3-4. Measured L_{50} during the Loudest Daytime Hour



Although there is variation in the loudest daytime hour (expressed as an L_{50}), most of the pre-construction measurements are between 60 and 70 dBA. The loudest post-construction daytime hourly L_{50} values are lower at most locations. However, at a couple locations, the loudest post-construction daytime hourly L_{50} is louder than the comparable pre-construction value.

Figure 3-5 shows the loudest nighttime hour L_{50} at each location for both the pre- and post-construction measurements.

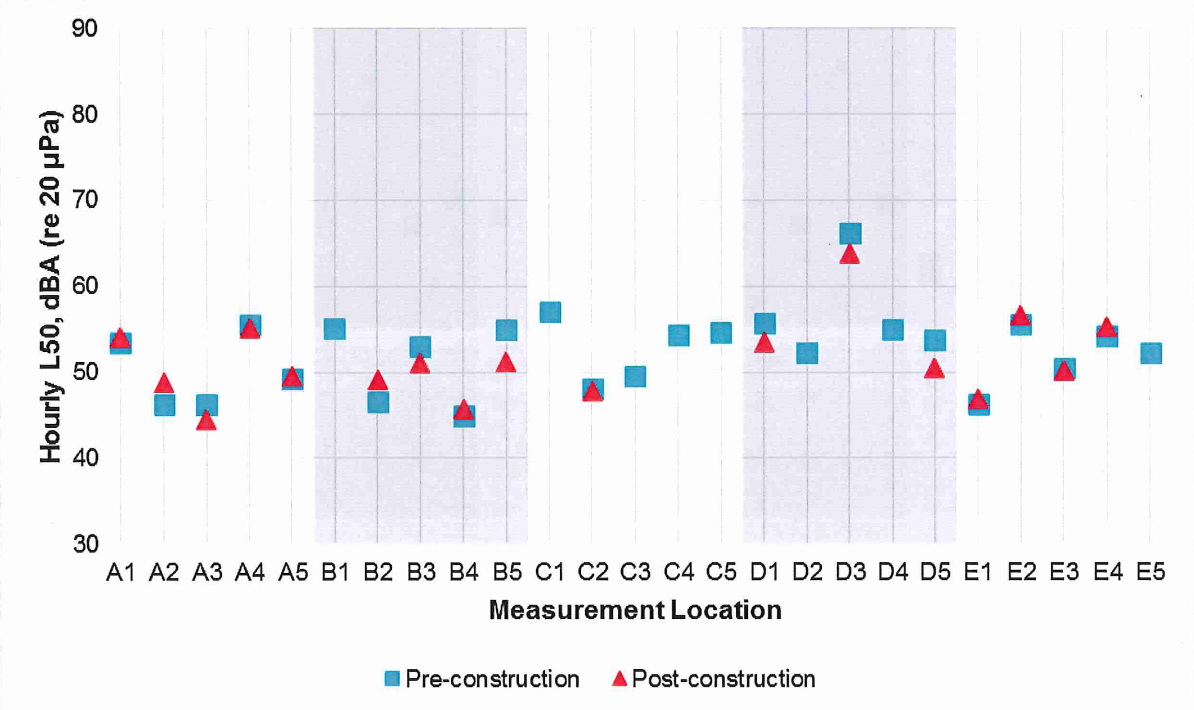
Figure 3-5. Measured L_{50} during the Loudest Nighttime Hour



Although there is also variation in the loudest nighttime hour (expressed as an L_{50}), most of the pre-construction measurements are between 60 and 70 dBA. The loudest post-construction hourly nighttime L_{50} values are lower at most locations. However, at a couple locations, the loudest post-construction nighttime hourly L_{50} is louder than the comparable pre-construction value.

Figure 3-6 shows the quietest overall hour L_{50} at each location for both the pre- and post-construction measurements.

Figure 3-6. Measured L_{50} during the Quietest Overall Hour

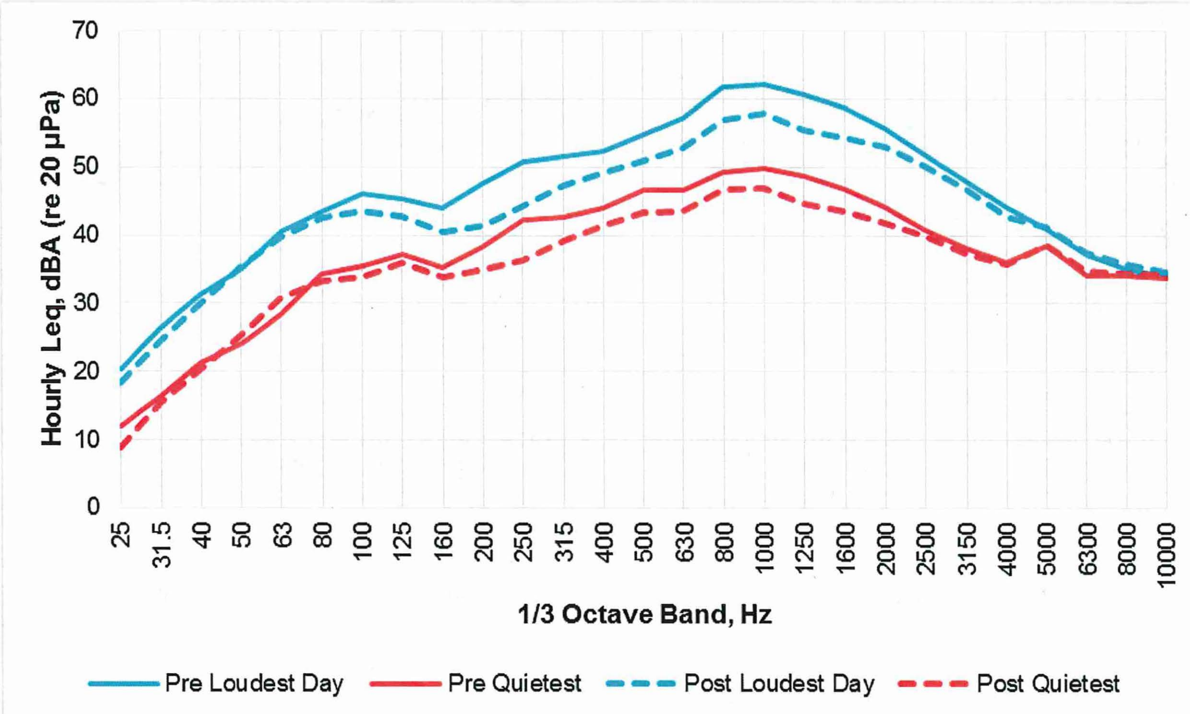


Although there is variation in the quietest overall hour (expressed as an L_{50}), most of the pre-construction measurements are between 50 and 60 dBA. The quietest post-construction nighttime hourly L_{50} values are lower at some locations, but many show very little change. At a few locations, the quietest post-construction hourly L_{50} is louder than the comparable pre-construction value.

3.3.3 Spectral Content

HDR reviewed the spectral content of selected measurement locations. Figure 3-7 shows the spectral noise levels from measurement location B5.

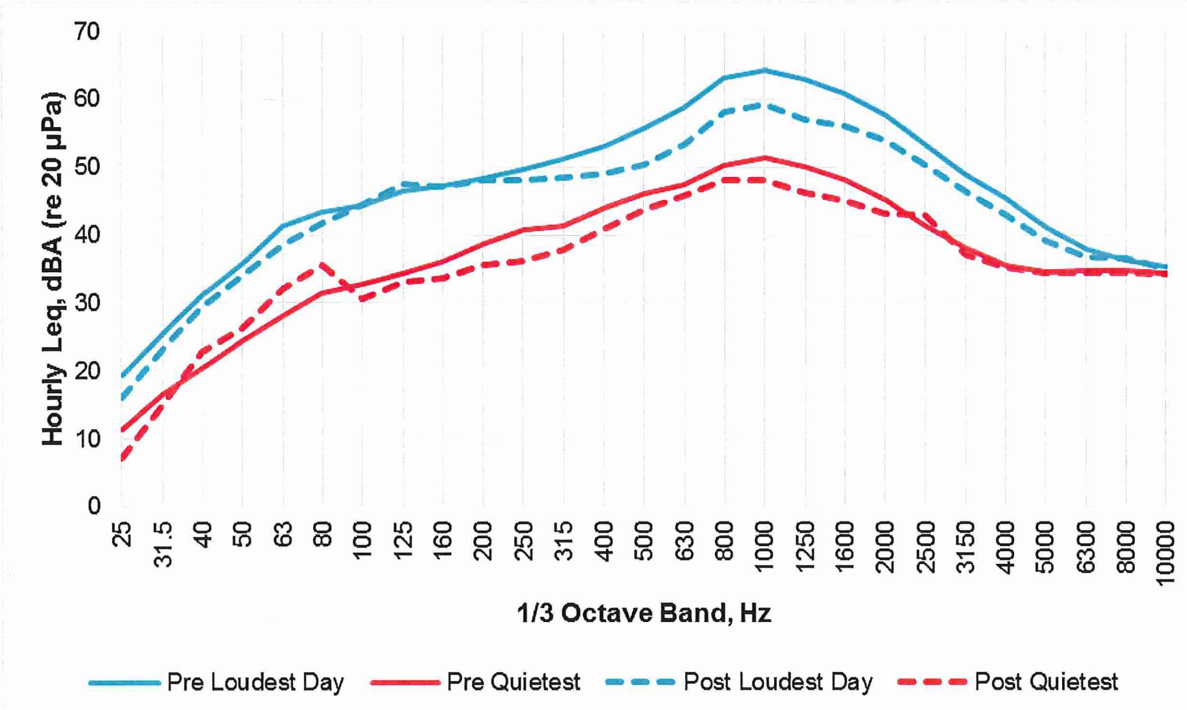
Figure 3-7. Measured Spectral Noise Levels at Location B5



The pre-construction noise levels are shown using solid lines, and the post-construction noise levels are shown using dashed lines. The loudest daytime hour is shown in blue, and the quietest overall hour is shown in red. The peak centered at 1,000 Hertz (Hz) is characteristic of tire-pavement noise. The 1,000 Hz peak was lower for the post-construction measurements for both the loudest daytime hour and the quietest overall hour. However, the difference was smaller for the quietest overall hour.

Figure 3-8 shows the spectral noise levels from measurement location D1.

Figure 3-8. Measured Spectral Noise Levels at Location D1



As at measurement location B5, the 1,000 Hz peak at location D1 was lower for the post-construction measurements for both the loudest daytime hour and the quietest night hour. The post-construction quietest overall hour had a secondary low-frequency peak, which was quieter than the tire-pavement noise.

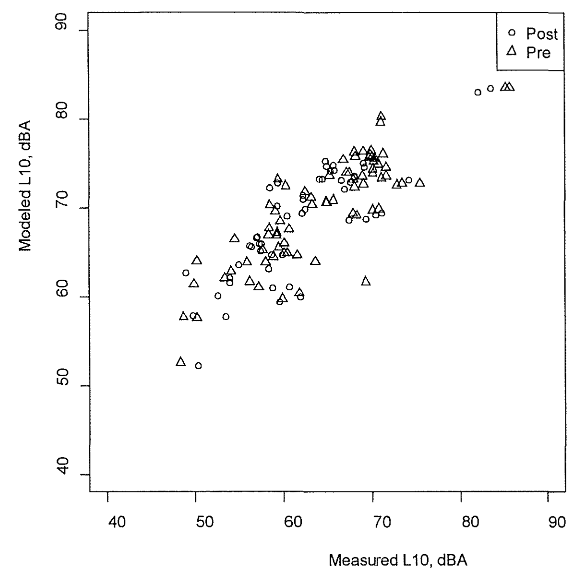
Appendix D contains measured spectral noise levels from neighborhoods A, C, and E.

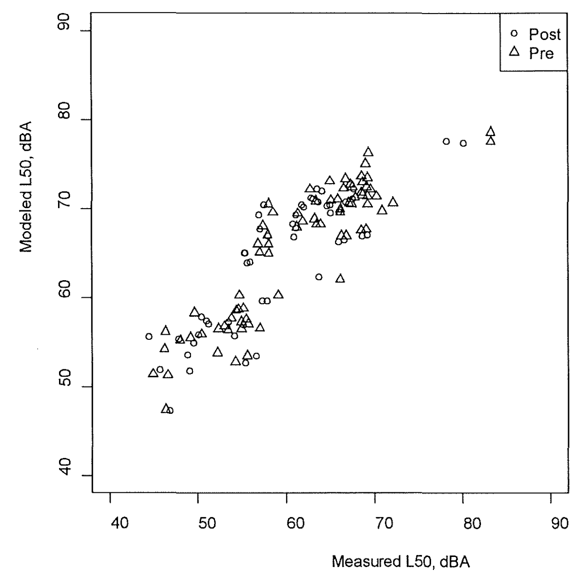
4 Statistical Analysis

4.1 Exploratory Data Analysis

HDR performed a limited exploratory analysis of the data to gain some insight into the nature of the noise measurements, noise modeling, and the normalized noise data. First, HDR plotted the modeled and measured noise levels, as shown in Figure 4-1.

Figure 4-1. Comparison of Modeled vs. Measured Noise Levels



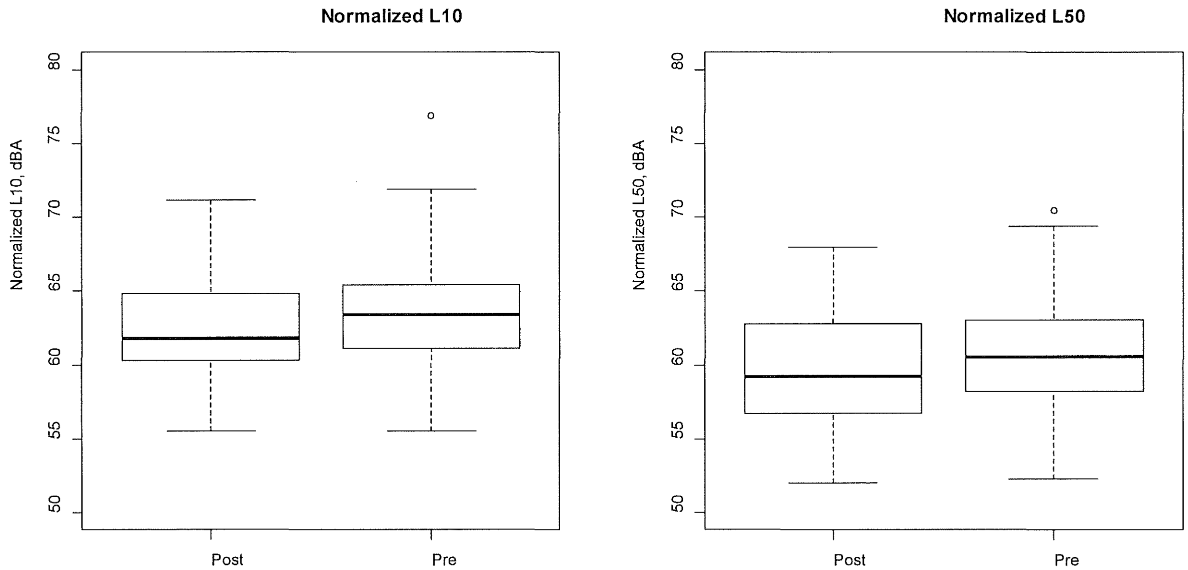


The scatterplots in Figure 4-1 above show a clear linear correlation between the measured and the modeled noise levels (though HDR did not examine correlation statistics). The linear correlation is indicated by the data points clustering along an imaginary diagonal line from the lower left to the top right of each plot. This linear correlation indicates that the modeling is likely providing a suitable normalization factor.

Normalization is intended to remove or reduce the variance in noise measurement data due to traffic volumes, mixes and speeds. If the modeling accurately predicts the change in traffic noise based on the increase or decrease of traffic volumes, mixes, or speeds, then the normalization will correct for those changes, and the remaining variation will be attributable to the changes in pavement and other random error. Naturally the model is only representative of typical traffic noise, not necessarily the unique characteristics of each vehicle in the actual traffic which occurred during the measurement periods, so there is still some variability attributable to changes in traffic characteristics. Furthermore other random error will include interfering noise such as local road traffic, local mechanical equipment such as air-conditioning units, human activities in the area, and other natural noise sources. Regardless, it is safe to say that variability is generally reduced as a result of the normalization. The smaller variance was helpful to HDR for determining statistical significance where the differences weren't as great; the test for significance shows more significance with smaller variances.

The box plots in Figure 4-2 compare the range of the pre-construction and post-construction noise levels between the normalized L_{10} measurements and the normalized L_{50} measurements.

Figure 4-2. Box Plots of Normalized Noise Levels



The vertical "whiskers" in the plots illustrate the range of values—generally the minimum and maximum values, though potential outliers are shown as points beyond the ends of the whiskers. The rectangular boxes illustrate the interquartile range—the bottom of the box is at the first quartile (the 25th percentile of the distribution), and the top of the box is at the third quartile (the 75th percentile of the distribution). The heavier horizontal line in the middle of the box shows the median value. This type of plot is a visual tool for quickly assessing the distribution of the values.

For the box plots in Figure 4-2 above, it's clear that the post-construction noise is lower than the pre-construction noise in all cases. However, for each comparison of pre- and post-construction noise, most of the interquartile ranges (the boxes) overlap each other. This suggests that the distributions might have more similarity than differences. The results of the t-tests (Section 4.2) provide more insight into whether there is a statistically significant difference between the pavements despite the overlapping distributions.

4.1.1 Exploring Data by Neighborhood

Figure 4-3 and Figure 4-4 on page 26 show the same data as shown in the normalized levels in Figure 4-2 above but broken out by neighborhood. Figure 4-3 shows the normalized L_{50} comparing pre-construction noise levels in each neighborhood to the post-construction levels. Figure 4-4 shows the normalized L_{10} comparing pre-construction noise levels in each neighborhood to the post-construction levels.

Figure 4-3 and Figure 4-4 below show that the normalized L_{50} measurements and the normalized L_{10} measurements have similar distributions relative to each other—the L_{10} boxes are simply higher than the L_{50} boxes by approximately equal amounts in all cases. Furthermore, in three of the five neighborhoods, the median noise level drops. In two of the neighborhoods, the median noise level increases.

Figure 4-3. Box Plots of Normalized L_{50} by Neighborhood

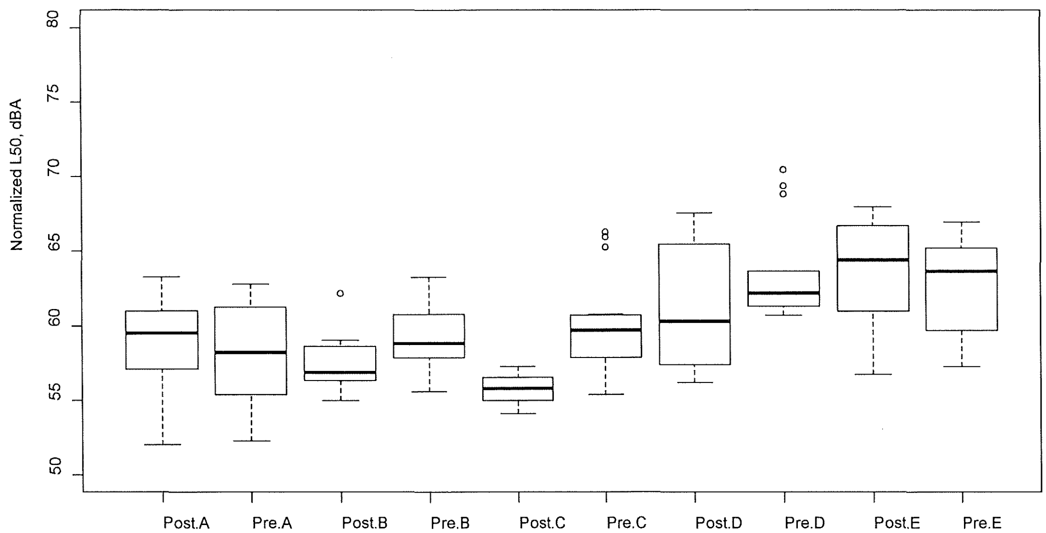
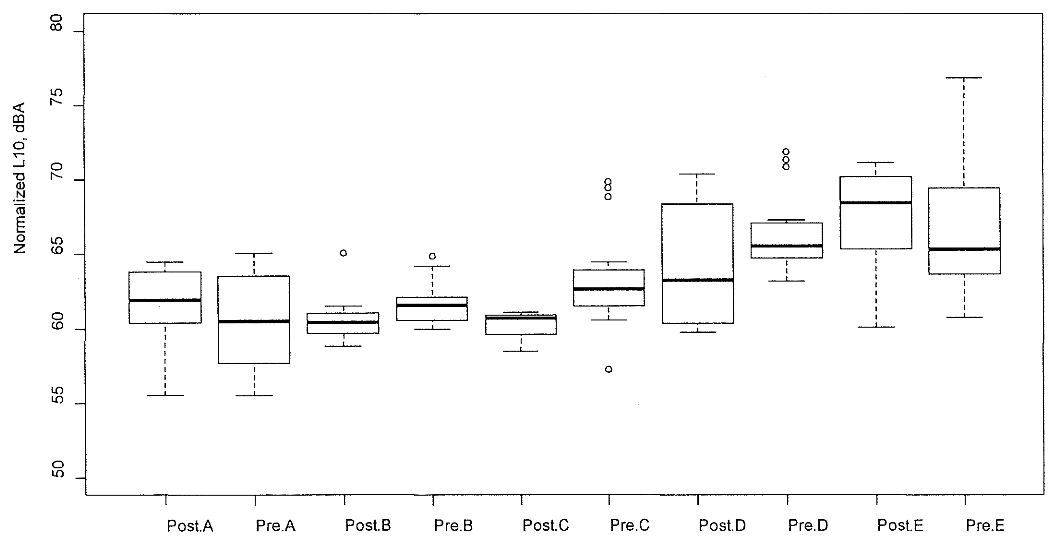


Figure 4-4. Box Plots of Normalized L_{10} by Neighborhood



The following sections consider each neighborhood based upon the box plots shown in Figure 4-3 and Figure 4-4, as well as drilling down into the underlying sound level measurements and normalized sound levels, evaluating the influence of the measurement locations, and critical assessment in the context of the measurement and analysis methods.

Neighborhood A

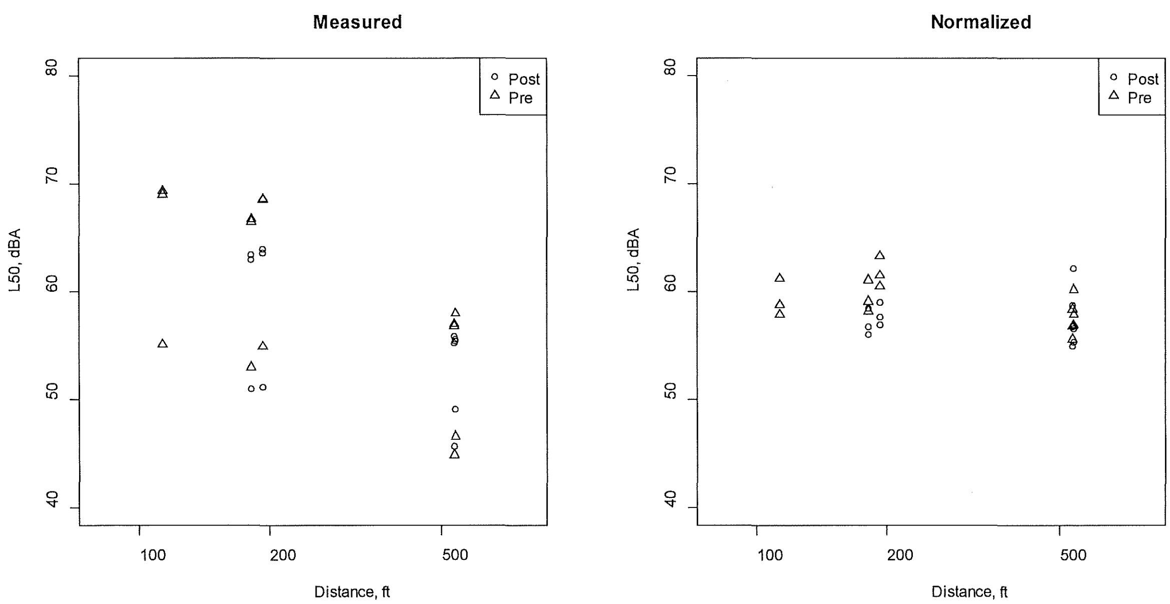
Figure 4-3 and Figure 4-4 show that in neighborhood A, the first quartile and median noise levels increase after the pavement rehabilitation project, but the third quartile and maximum noise levels don't increase. The increase is mainly attributable to measurements at three locations. Two of the locations were heavily shielded from the I-394 traffic noise. It is reasonable to suppose that local noise sources at these locations would interfere with the measurement of traffic noise on I-394. The normalization cannot account for this effect, and the influence of local noise sources is an unknowable quantity so it cannot be accounted for in any other way. This would mask effects of the pavement treatments, making the difference difficult or impossible to discern.

The location furthest west might have been influenced by the TH-100 interchange. This traffic was not included in the normalization modeling, so it too is an unknowable quantity. However due simply to the relative distances to I-394 and TH-100, it is reasonable to expect that the closer traffic noise on I-394 would dominate over the traffic noise from TH-100 except in extreme circumstances. It is impossible to know without additional data whether the measurements reflect unexpected conditions.

Neighborhood B

Figure 4-3 and Figure 4-4 show that in neighborhood B, the median noise levels decrease after the pavement rehabilitation project, and the interquartile ranges don't overlap. This condition is promising for the t-tests (Section 4.2) to show that the two distributions are distinctly different. In general, the underlying data for neighborhood B provides a clear illustration of how this approach is intended to demonstrate a difference in sound levels between the two pavement treatments, and merits much more explicit discussion. For illustration, Figure 4-5 shows both the measured L_{50} and normalized L_{50} for neighborhood B.

Figure 4-5. Neighborhood B L_{50} by Distance



The left hand plot in Neighborhood A

Figure 4-3 and Figure 4-4 show that in neighborhood A, the first quartile and median noise levels increase after the pavement rehabilitation project, but the third quartile and maximum noise levels don't increase. The increase is mainly attributable to measurements at three locations. Two of the locations were heavily shielded from the I-394 traffic noise. It is reasonable to suppose that local noise sources at these locations would interfere with the measurement of traffic noise on I-394. The normalization cannot account for this effect, and the influence of local noise sources is an unknowable quantity so it cannot be accounted for in any other way. This would mask effects of the pavement treatments, making the difference difficult or impossible to discern.

The location furthest west might have been influenced by the TH-100 interchange. This traffic was not included in the normalization modeling, so it too is an unknowable quantity. However due simply to the relative distances to I-394 and TH-100, it is reasonable to expect that the closer traffic noise on I-394 would dominate over the traffic noise from TH-100 except in extreme circumstances. It is impossible to know without additional data whether the measurements reflect unexpected conditions.

Neighborhood B

Figure 4-3 and Figure 4-4 show that in neighborhood B, the median noise levels decrease after the pavement rehabilitation project, and the interquartile ranges don't overlap. This condition is promising for the t-tests (Section 4.2) to show that the two distributions are distinctly different. In general, the underlying data for neighborhood B provides a clear illustration of how this approach is intended to demonstrate a difference in sound levels between the two pavement treatments, and merits much more explicit discussion. For illustration, Figure 4-5 shows both the measured L_{50} and normalized L_{50} for neighborhood B.

Figure 4-5 presents the measured sound levels by distance from the interstate in Neighborhood B. The sound levels exhibit a logarithmic decay with distance, but with the logarithmic abscissa (x-axis) it appears as a straight line sloped downwards. There are in fact two straight-line decays shown: the top set of points represents the loudest daytime and the loudest nighttime hours, and the bottom set of points represents the quietest nighttime hours. This is exactly as would be expected, since sound spreads out from a highway in a logarithmic decay, and the quietest hour will have much less traffic than the loudest hours.

The right hand plot in Neighborhood A

Figure 4-3 and Figure 4-4 show that in neighborhood A, the first quartile and median noise levels increase after the pavement rehabilitation project, but the third quartile and maximum noise levels don't increase. The increase is mainly attributable to measurements at three locations. Two of the locations were heavily shielded from the I-394 traffic noise. It is reasonable to suppose that local noise sources at these locations would interfere with the measurement of traffic noise on I-394. The normalization cannot account for this effect, and the influence of local noise sources is an unknowable quantity so it cannot be accounted for in any other way. This would mask effects of the pavement treatments, making the difference difficult or impossible to discern.

The location furthest west might have been influenced by the TH-100 interchange. This traffic was not included in the normalization modeling, so it too is an unknowable quantity. However due simply to the relative distances to I-394 and TH-100, it is reasonable to expect that the closer traffic noise on I-394 would dominate over the traffic noise from TH-100 except in extreme circumstances. It is impossible to know without additional data whether the measurements reflect unexpected conditions.

Neighborhood B

Figure 4-3 and Figure 4-4 show that in neighborhood B, the median noise levels decrease after the pavement rehabilitation project, and the interquartile ranges don't overlap. This

condition is promising for the t-tests (Section 4.2) to show that the two distributions are distinctly different. In general, the underlying data for neighborhood B provides a clear illustration of how this approach is intended to demonstrate a difference in sound levels between the two pavement treatments, and merits much more explicit discussion. For illustration, Figure 4-5 shows both the measured L_{50} and normalized L_{50} for neighborhood B.

Figure 4-5 shows the same levels in Neighborhood B after normalization. This might be thought of the effect of uniform sound levels over the entire neighborhood, irrespective of distance to interstate, combined with uniform traffic levels irrespective of the hour in which they were measured. Note that the triangles and the squares within the right-hand plot are the source of the box-plots in Figure 4-3, in particular the two boxes for Neighborhood B, and there is one outlier shown on the box plot for post-construction normalized levels which appears in this plot at one of the 500 ft. distance locations.

The post-construction normalized levels are generally a little lower than the pre-construction normalized levels, although less of a difference than the measured levels. This suggests that the preconstruction measurements had higher traffic volumes than post-construction and the normalization corrected for this discrepancy. However there is one post-construction measurement in the quietest hour at one of the 500 ft. locations which is higher than any of the others. This may be an effect of local non-interstate sound levels influencing the measurement. If this is the case, and since the normalization modeling cannot account for it, the normalization would have over-corrected the sound level. This may account for the outlier shown in Figure 4-3 for postconstruction levels in neighborhood B.

Neighborhood C

Figure 4-3 and Figure 4-4 show that in neighborhood C, the median noise levels increase, and the interquartile ranges don't overlap. This condition is promising for the t-tests (Section 4.2) to show that the two distributions are distinctly different. However there is only one location with a postconstruction measurement, compared to preconstruction measurements at all five locations. Field staff received right of entry to only one of the properties in neighborhood C for the postconstruction measurements.

The one location with a postconstruction measurement exhibited very little change to either measured or normalized sound levels. This may be due to either very little change due to the pavement rehabilitation effects, or very little change to local noise sources which might have interfered with detecting a change due to the pavement rehabilitation. However one location that was only included in the preconstruction measurements exhibited extraordinarily high sound levels, inconsistent with sound levels that would have been attributable to I-394 traffic noise. It is reasonable to suppose at this location that local noise sources interfered with the measurement of traffic noise on I-394 and therefore artificially elevated the preconstruction sound level average. This would result in overstating the magnitude of improvement due to the pavement rehabilitation project's effect on I-394 traffic noise.

Neighborhood D

Figure 4-3 and Figure 4-4 show that in neighborhood D, the median noise level decreases, but the interquartile range for post-construction noise is greater than for pre-construction noise. This suggests a large variance in the post-construction normalized sound levels.

Neighborhood E

Figure 4-3 and Figure 4-4 show that in neighborhood E, the median noise level and the interquartile range both increase. The increase is mainly attributable to measurements at three locations, the locations furthest from I-394. Due to the distance from the interstate and the shielding conditions between the locations and the interstate, it is reasonable to suppose that local noise sources at these locations would interfere with the measurement of traffic noise on I-394. The normalization cannot account for this effect, and the influence of local noise sources is an unknowable quantity so it cannot be accounted for in any other way. This would mask effects of the pavement treatments, making the difference difficult or impossible to discern.

4.1.2 Data Normality

One goal of the exploratory data analysis was to assess the assumption of normality for the data used in the subsequent t-tests. Normal q-q plots are provided in Appendix I. The q-q plots show that many of the distributions resemble a normal distribution, but some distributions have a tenuous resemblance to normality, especially with small sample sizes. This is a fairly common limitation of small sample sizes, and it is correspondingly more difficult to achieve significance with a t-test using small sample sizes.

4.2 Confirmatory Data Analysis (Significance Tests)

The statistical concept of *significance* is a tool to evaluate whether certain data support a hypothesis. For this study, HDR used two tests to determine the significance of the measured data, specifically whether the data support the hypothesis that post-construction noise is lower than the pre-construction noise.

- The first test is a two-sample t-test, in which all the normalized measurements from pre-construction are compared to all the normalized measurements from post-construction to evaluate whether two conditions (pre-and post-construction pavement treatments) produced different results.
- The other type of test is a paired-sample t-test, in which measurements were taken at the same location for both the pre-construction and post-construction noise levels to evaluate whether the difference between each of those normalized measurements can demonstrate a change between the two conditions (pre-and post-construction pavement treatments).

Each of these two types of tests produces a confidence interval (CI) and a p-value. The p-value is compared to a 0.05 significance level. The difference between the pre-construction and post-construction pavement treatments is considered statistically significant if its p-value is less than 0.05, and consequently the probability is less than 5 percent that there is actually no difference between the two treatments.

4.2.1 Two-sample t-test

For the two-sample t-test, each of the normalized pre-construction and post-construction measurements has a number of observations (N), an average ($\overline{L_{50}}$ or $\overline{L_{10}}$) using an arithmetic mean, and a standard deviation ($s_{L_{50}}$ or $s_{L_{10}}$). The normalized L_{50} and L_{10} measurements are shown in separate tables, though the same field measurements and models produced both metrics simultaneously. Table 4-1 shows the outcome of the two-sample t-test for the normalized L_{50} measurements.

Table 4-1. Two-sample t-test for Normalized L_{50} Measurements

Neighborhood	Post-construction Measurements			Pre-construction Measurements			Two-sample t-test	
	N	$\overline{L_{50}}$	$s_{L_{50}}$	N	$\overline{L_{50}}$	$s_{L_{50}}$	95% CI	p-value
A	15	58.6	3.54	15	58.1	3.45	[−2.1 3.1]	0.6905
B	12	57.5	1.96	15	59.2	2.10	[−3.3 −0.1]	0.0397
C	3	55.8	1.60	15	60.2	3.40	[−7.5 1.3]	0.0121
D	9	61.1	4.34	15	63.6	3.27	[−6.1 1.1]	0.1628
E	12	63.7	3.63	15	62.7	3.17	[−1.8 3.7]	0.4862
Overall	51	59.8	4.12	75	60.8	3.69	[−2.4 0.5]	0.1923

The descriptive statistics and the two-sample t-test shown in Table 4-1 above reveal the following about the L_{50} measurements:

- A 1.0 dBA *decrease* in overall noise levels averaged across all neighborhoods, but not a statistically significant decrease
- An *increase* in noise levels for neighborhoods A and E, but the increases are 0.5 dBA and 1.0 dBA, respectively, and are not statistically significant; the p-values are high enough to suggest there might be no difference between the pre- and post-construction treatments
- A *statistically significant decrease* in noise levels of 1.7 dBA for neighborhood B and 4.4 dBA for neighborhood C
- A *decrease* in noise levels of 2.5 dBA for neighborhood D, but not a statistically significant decrease

Table 4-2 shows the outcome of the two-sample t-test for the normalized L_{10} measurements.

Table 4-2. Two-sample t-test for Normalized L_{10} Measurements

Neighborhood	Post-construction Measurements			Pre-construction Measurements			Two-sample t-test	
	N	$\overline{L_{10}}$	$s_{L_{10}}$	N	$\overline{L_{10}}$	$s_{L_{10}}$	95% CI	p-value
A	15	61.2	3.20	15	60.4	3.28	[−1.6 0.2]	0.4939
B	12	60.7	1.60	15	61.6	1.51	[−2.2 0.3]	0.1171
C	3	60.1	1.40	15	63.4	3.54	[−6.1 0.5]	0.0258
D	9	64.3	4.08	15	66.5	2.78	[−5.5 1.1]	0.1768
E	12	67.3	3.86	15	66.6	4.33	[−2.5 4.0]	0.6536
Overall	51	63.0	4.12	75	63.7	4.03	[−2.2 0.8]	0.3458

The descriptive statistics and the two-sample t-test shown in Table 4-2 above reveal the following about the L_{10} measurements:

- A 0.7 dBA *decrease* in overall noise levels averaged across all neighborhoods, but not a statistically significant decrease
- An *increase* in noise levels for neighborhoods A and E, but the increases are 0.8 dBA and 0.7 dBA, respectively, and are not statistically significant; the p-values suggest that there might be no difference between the pre- and post-construction treatments
- A *statistically significant decrease* in noise levels of 3.3 dBA for neighborhood C
- A *decrease* in noise levels of 0.9 dBA for neighborhood B and 2.2 dBA for neighborhood D, but not a statistically significant decrease

4.2.2 Paired-sample t-test

For the paired-sample t-test, the pre-construction measurements are matched to the post-construction measurements at the same location. The corresponding normalized measurements have a number of observations (N), an average ($\overline{L_{50}}$ or $\overline{L_{10}}$) using an arithmetic mean, and a standard deviation ($s_{L_{50}}$ or $s_{L_{10}}$). The normalized L_{50} and L_{10} measurements are shown in separate tables, though the same field measurements and models produced both metrics simultaneously. Table 4-3 shows the outcome of the paired-sample t-test for the normalized L_{50} measurements.

Table 4-3. Paired-sample t-test for Normalized L_{50} Measurements

Neighborhood	Difference of Paired Observations			Paired-sample t-test	
	N	$\overline{L_{50}}$	$s_{L_{50}}$	95% CI	p-value
A	15	0.5	1.77	[−0.5 1.5]	0.2797
B	12	−1.7	1.86	[−2.8 −0.5]	0.0101
C	3	−2.6	1.93	[−7.4 2.2]	0.1447
D	9	−3.8	1.14	[−4.7 2.9]	<0.0001
E	12	0.6	1.06	[−0.1 1.3]	0.0825
Overall	51	−0.9	2.28	[−1.6 −0.3]	0.0053

The descriptive statistics and the paired-sample t-test shown in Table 4-3 above reveal the following about the L_{50} measurements:

- A *statistically significant decrease* in overall noise levels of 0.9 dBA averaged across all neighborhoods
- A *small increase* in noise levels for neighborhoods A and E, but the increases are 0.5 dBA and 0.6 dBA, respectively, and are not statistically significant; the p-values suggests that there might be no difference between the pre- and post-construction treatments for neighborhood A, but the increase might be considered marginally significant for neighborhood E (simply meaning that the p-value is approaching the significance threshold but has not crossed the significance threshold)
- A *statistically significant decrease* in noise levels of 1.7 dBA for neighborhood B and 3.8 dBA for neighborhood D

- A *decrease* in noise levels of 2.6 dBA for neighborhood C, but not a statistically significant decrease; the difference is greater than for neighborhood B, but the decrease doesn't achieve significance because of the small sample size

Table 4-4 shows the outcome of the paired-sample t-test for the normalized L_{10} measurements.

Table 4-4. Paired-sample t-test for Normalized L_{10} Measurements

Neighborhood	Difference of Paired Observations			Paired-sample t-test	
	N	$\overline{L_{10}}$	$s_{L_{10}}$	95% CI	p-value
A	15	0.8	1.83	[−0.2 1.8]	0.1053
B	12	−1.3	2.03	[−2.6 0.0]	0.0482
C	3	−2.0	2.19	[−7.4 3.5]	0.2607
D	9	−3.4	1.36	[−4.4 2.3]	<0.0001
E	12	0.1	2.84	[−1.7 1.9]	0.8739
Overall	51	−0.7	2.54	[−1.5 0.0]	0.0411

The descriptive statistics and the paired-sample t-test shown in Table 4-4 above reveal the following about the L_{10} measurements:

- A *statistically significant decrease* in overall noise levels of 0.7 dBA averaged across all neighborhoods
- A *small increase* in noise levels for neighborhoods A and E of 0.8 dBA and 0.1 dBA, respectively, but not statistically significant increases; the p-values suggests that there might be no difference between the pre- and post-construction treatments
- A *statistically significant decrease* in noise levels of 1.3 dBA for neighborhood B and 3.4 dBA for neighborhood D
- A *decrease* in noise levels of 2.0 dBA for neighborhood C, but not a statistically significant decrease; the decrease is greater than in neighborhood B but doesn't achieve significance because of the small sample size

4.2.3 Neighborhood D

Neighborhood D is on the south side of I-394 between the Theodore Wirth Parkway overpass and the Penn Avenue overpass. This study finds that the noise levels in neighborhood D show the following as a result of the new pavement treatment:

- A *statistically significant decrease* of 3.8 dBA for the L_{50} measurements from the paired-sample t-test
- A *statistically significant decrease* of 3.4 dBA for the L_{10} measurements from the paired-sample t-test

The two-sample t-tests don't show a statistically significant decrease in noise levels for neighborhood D. This is not surprising, since paired-sample t-tests are generally better at discerning whether there is a difference between two experimental treatments.

The magnitude of decrease to noise measurements after the pavement rehabilitation project in this neighborhood is somewhat larger than in other neighborhoods. Closer examination of the data offers some suggestions that this may not offer an accurate picture of the pavement rehabilitation benefits due to uncontrollable external influence on the sound level measurements.

4.2.4 Neighborhood E

Neighborhood E is on the south side of I-394 between the Penn Avenue overpass and the Dunwoody Boulevard exit. This study finds that the noise levels in neighborhood E show the following as a result of the new pavement treatment:

- A *small increase* in noise levels as low as 0.6 dBA for the L_{50} measurements, which is not statistically significant by either the two-sample or paired-sample t-test.
- A *small increase* in noise levels as low as 0.1 dBA for the L_{10} measurements, which is not statistically significant by either the two-sample or paired-sample t-test.

The p-value for increases to the L_{50} or the L_{10} measurements in neighborhood E aren't statistically significant. This suggests that there might be no difference between the measurements of pre- and post-construction treatments.

Closer examination of the data offers some suggestions that the effect of the pavement rehabilitation project in neighborhood E may be masked by external sounds, in particular there appears to be potential for local noise sources to interfere with the measurement of traffic noise on I-394. Consequently, the data for neighborhood E are not able to demonstrate a change due to the different pavement treatment.

5 Conclusions

This section summarizes the overall conclusions of the I-394 Pavement Noise Study. This study included pre-construction and post-construction sound level measurements, in the neighborhoods, that were normalized to account for the variation in traffic volumes and speeds in each neighborhood. Also, normalized measured levels were evaluated for statistically significant differences between level means.

5.1 Findings

This study finds that the noise levels averaged across all neighborhoods show the following as changes to overall neighborhood levels:

- A *statistically significant decrease* of 0.9 dBA for the L_{50} measurements from the paired-sample t-test.
- A *statistically significant decrease* of 0.7 dBA for the L_{10} measurements from the paired-sample t-test.

While the means show a statistically significant decrease, the magnitude of the decreases are quite small. Such small decreases, where many measurement locations had obstructed views of I-394, aren't very useful in making a judgement about the effectiveness of the I-394 resurfacing project on noise levels in distant neighborhoods. Results, broken out by neighborhood, follow.

5.1.1 Neighborhood A

Neighborhood A is on the north side of I-394 between the TH-100 interchange and the Theodore Wirth Parkway overpass. The study found the following results based on normalized noise levels in neighborhood A:

- A *small increase* in noise levels of 0.5 dBA for the L_{50} measurements, which is not statistically significant by either the two-sample or paired-sample t-test.
- A *small increase* in noise levels of 0.8 dBA for the L_{10} measurements, which is not statistically significant by either the two-sample or paired-sample t-test.

The average level increases in neighborhood A are not found to be statistically significant. This would suggest a lack of confidence that the average differences aren't just the result of random variations in the collected data. In the determination of the significance of statistical results it's important for the investigators to make sure that all possible confounding, environmental and measurement effects, are controlled and fully understood.

A closer examination of the neighborhood A data suggests that the effect of the pavement rehabilitation project may be masked by external sounds. In particular, it appears that local noise sources influenced the noise measurements thereby confounding the role of the traffic noise from I-394. Consequently, the data for neighborhood A will not allow for any meaningful results specifically concerning the noise from I-394.

5.1.2 Neighborhood B

Neighborhood B is on the north side of I-394 between the Theodore Wirth Parkway overpass and the Penn Avenue overpass. This study found the following results based on the noise levels measured in neighborhood A:

- A *statistically significant decrease* of 1.7 dBA for the L_{50} measurements from both the two-sample and paired-sample t-tests.
- A *statistically significant decrease* of 1.3 dBA for the L_{10} measurements from the paired-sample t-tests.

This neighborhood has many locations with a clear view of I-394. The investigators feel that the measurements throughout this neighborhood are mainly influenced by I-394 traffic. The level decreases in this neighborhood may be considered indicative of changes due to the I-394 resurfacing project.

5.1.3 Neighborhood C

Neighborhood C is on the south side of I-394 between the TH-100 interchange and the Theodore Wirth Parkway overpass. This study finds that the noise levels in neighborhood C show the following as a result of the new pavement treatment:

- A *statistically significant decrease* of 4.4 dBA for the L_{50} measurements from the two- sample t-test.
- A *statistically significant decrease* of 3.3 dBA for the L_{10} measurements from the two- sample t-test.

The paired-sample t-tests don't show a statistically significant decrease in noise levels for neighborhood C. This neighborhood shows the largest magnitude of decrease in noise measurements. HDR suggests that the large differences seen in the post-construction levels in this neighborhood are due to uncontrolled external influences on the measured sound levels collected.

5.1.4 Neighborhood D

Neighborhood D is on the south side of I-394 between the Theodore Wirth Parkway overpass and the Penn Avenue overpass. This study finds that the noise levels in neighborhood D show the following as a result of the new pavement treatment:

- A *statistically significant decrease* of 3.8 dBA for the L_{50} measurements from the paired-sample t-test
- A *statistically significant decrease* of 3.4 dBA for the L_{10} measurements from the paired-sample t-test

The two-sample t-tests don't show a statistically significant decrease in noise levels for neighborhood D.

The magnitude of decrease to noise measurements after the pavement rehabilitation project in this neighborhood is larger than in other neighborhoods. A closer examination of the data suggests that this may not portray an accurate picture of the pavement rehabilitation benefits because of uncontrollable external influences on the measured sound levels.

5.1.5 Neighborhood E

Neighborhood E is on the south side of I-394 between the Penn Avenue overpass and the Dunwoody Boulevard exit. This study finds that the noise levels in neighborhood E show the following as a result of the new pavement treatment:

- A *small increase* in noise levels as low as 0.6 dBA for the L_{50} measurements, which is not statistically significant by either the two-sample or paired-sample t-test.
- A *small increase* in noise levels as low as 0.1 dBA for the L_{10} measurements, which is not statistically significant by either the two-sample or paired-sample t-test.

The p-value for increases to the L_{50} or the L_{10} measurements in neighborhood E aren't statistically significant. This suggests that there might be no difference between the measurements of pre- and post-construction treatments.

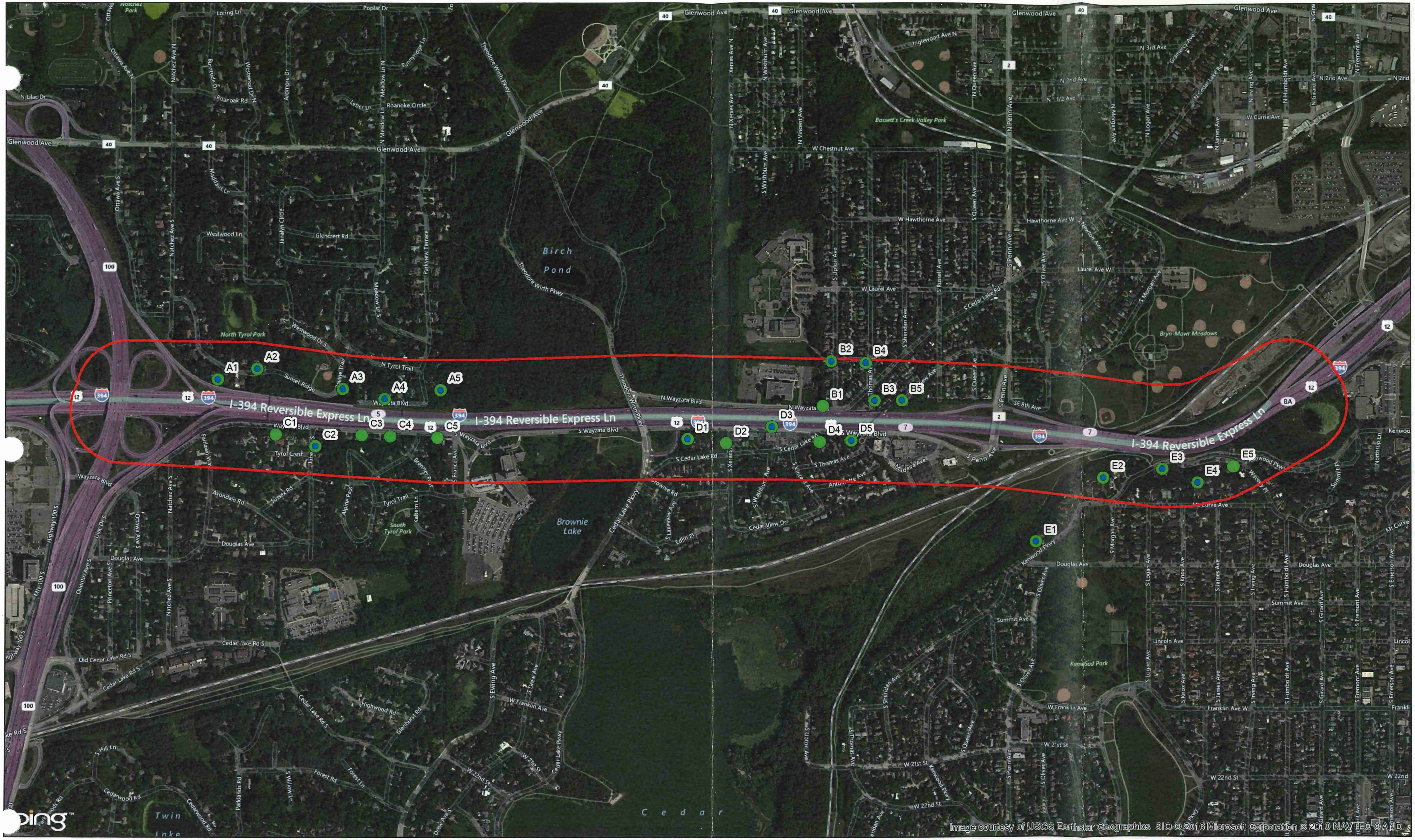
Closer examination of the data offers some suggestions that the effect of the pavement rehabilitation project in neighborhood E may be masked by external sounds, in particular there appears to be potential for local noise sources to interfere with the measurement of the traffic noise on I-394. Consequently, the data for neighborhood E are not able to demonstrate a change due to the different pavement treatment.

5.2 Overall Discussion

The present work can only demonstrate whether differences between averaged, normalized measurements, collected during the pre-construction and post-construction periods, are statistically significant. The present work cannot demonstrate that the differences between averaged normalized measured differences can be attributed exclusively to the effects of the I-394 resurfacing project. Based upon a critical evaluation of the data, decreases in neighborhood noise levels cannot be definitively proven to be based upon the evidence gathered in the present study. In some studied locations it appears that the measurements were influenced by local sound sources rather than representing the sound solely attributable to I-394 traffic. Nonetheless, the measurements show a statistically significant decrease in sound levels at some locations. These decreases are not conclusive evidence that the pavement rehabilitation produced noticeable noise level benefits in the neighborhoods. On the other hand, there's no conclusive evidence that the reductions weren't due, to some extent, to the pavement rehabilitation.

The investigators noted that neighborhood B appeared to offer a fairly clean view of a resurfaced section of I-394 to most residents and may represent an area dominated by I-394 traffic noise. Assuming that neighborhood B is a good example of a neighborhood that might benefit from the I-394 resurfacing project, the level changes for this neighborhood were looked at in some detail. It was felt that the analysis of the L10 noise levels should be used as these levels are less likely affected by external noise sources than the L50 levels. Using the paired samples a statistically significant average decrease of 1.3 dBA in the L10 levels was found. While this decrease is statistically significant, it's quite small and doesn't qualify the I-394 resurfacing project to be considered as providing effective noise level mitigation.

Appendix A. Project Area Maps

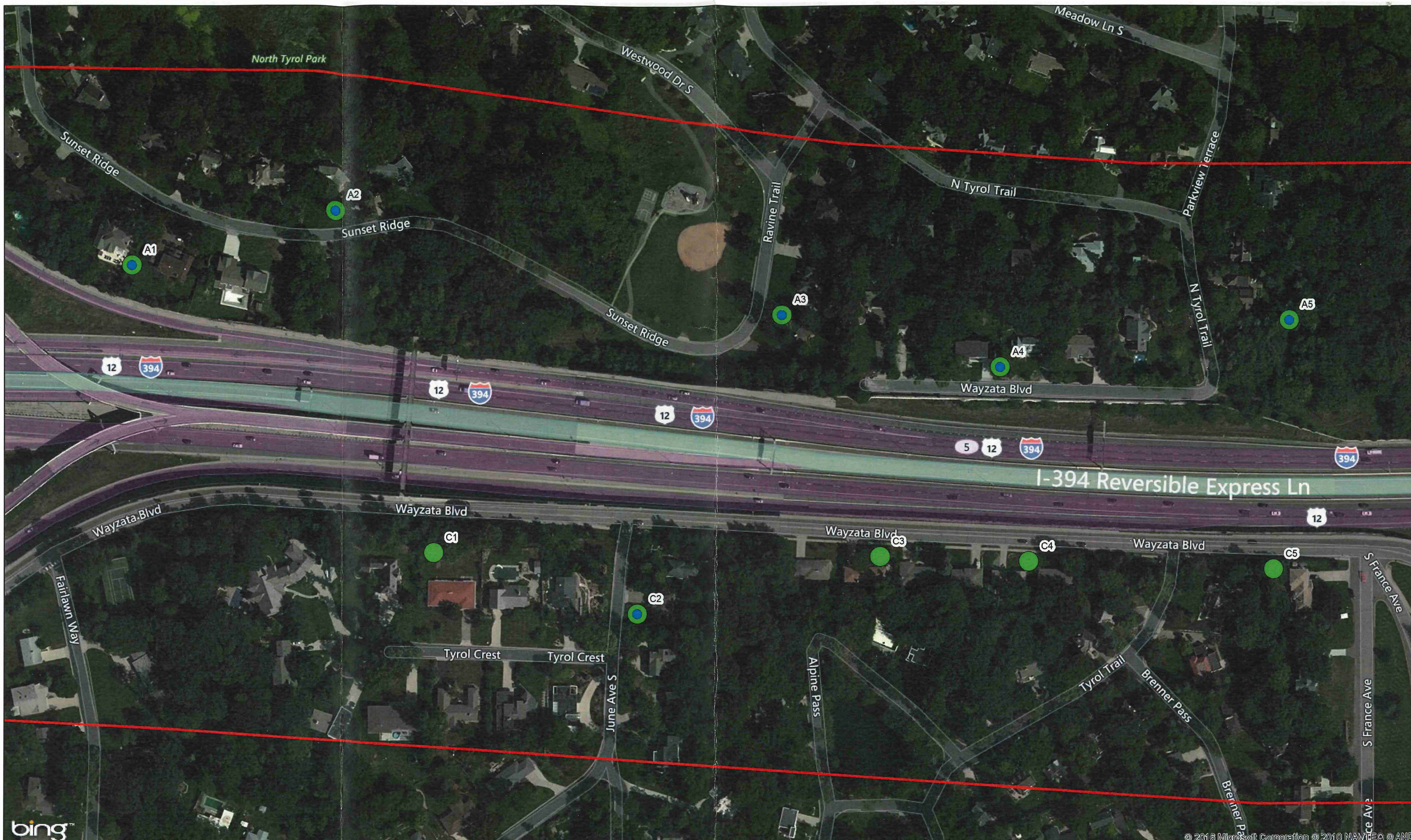


0 500 1,000 Feet

Legend

- Pre-Construction Monitoring Locations
- Post-Construction Monitoring Locations
- 500-foot Buffer

MnDOT I-394 Noise Measurements
Noise Monitoring Locations

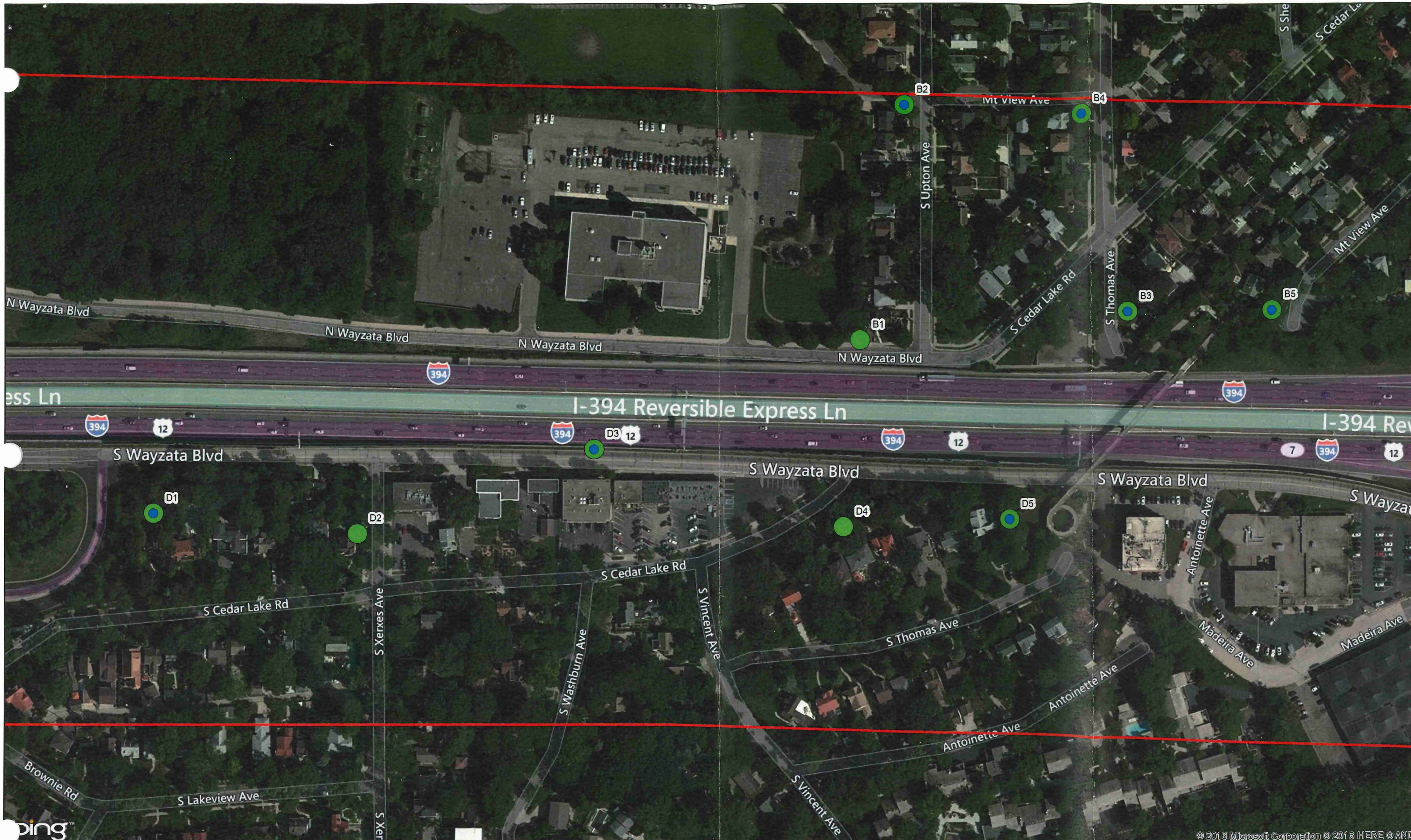


0 100 200 Feet

Legend

- Pre-Construction Noise Monitoring Locations
- Post-Construction Noise Monitoring Locations
- 500-foot Buffer

MnDOT I-394 Noise Measurements
Noise Monitoring Locations



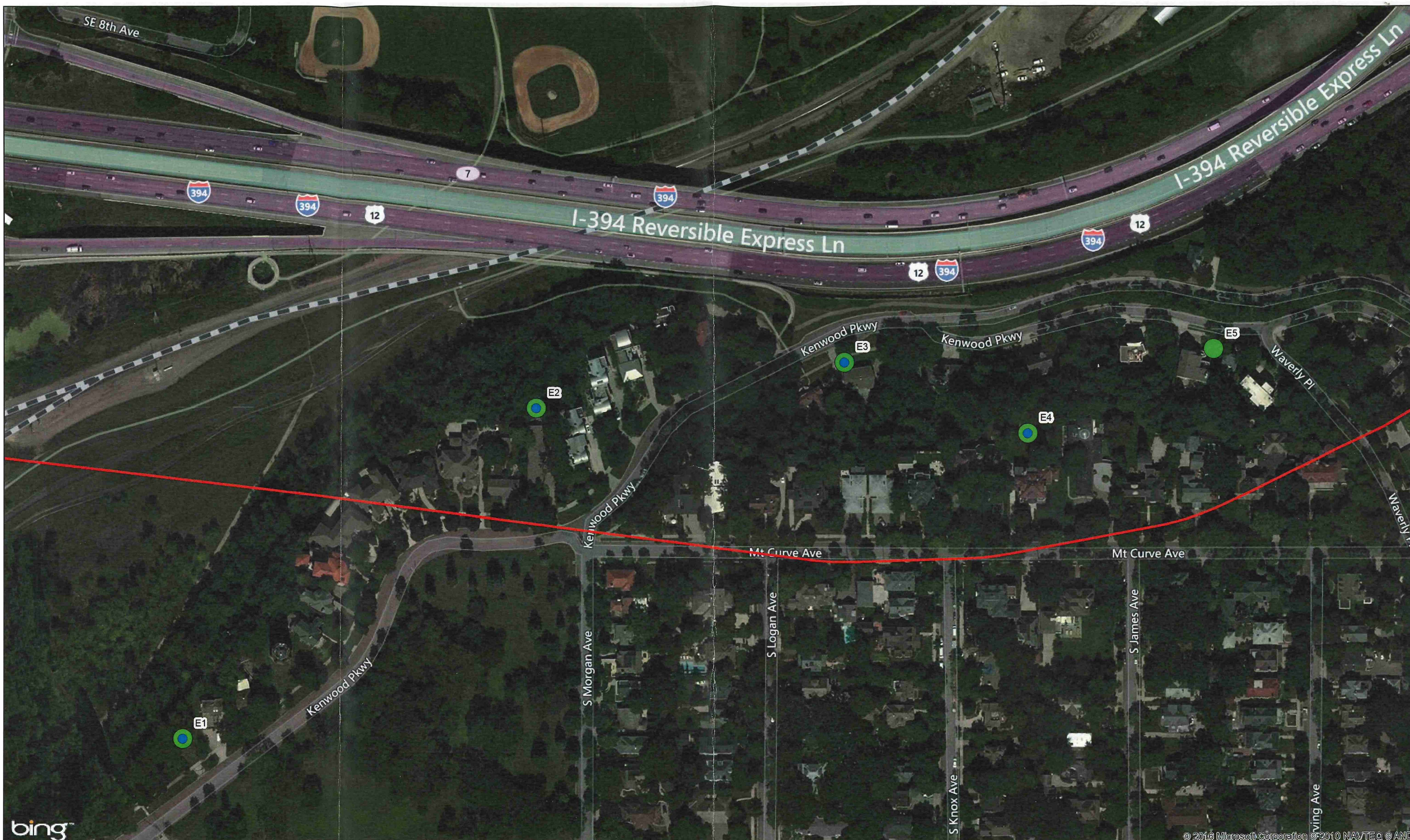
N

0 100 200 Feet

Legend

- Pre-Construction Noise Monitoring Locations
- Post-Construction Monitoring Locations
- 500-foot Buffer

MnDOT I-394 Noise Measurements
Noise Monitoring Locations



0 100 200 Feet

Legend

Pre-Construction Noise Monitoring Locations

Post-Construction Noise Monitoring Locations

500-foot Buffer

MnDOT I-394 Noise Measurements
Noise Monitoring Locations

Appendix B. Detailed Pre-construction Noise Measurement Data

Figure B-1 illustrates measured pre-construction hourly noise levels at A1.

Figure B-1. Pre-construction Measured Hourly Noise Levels at A1

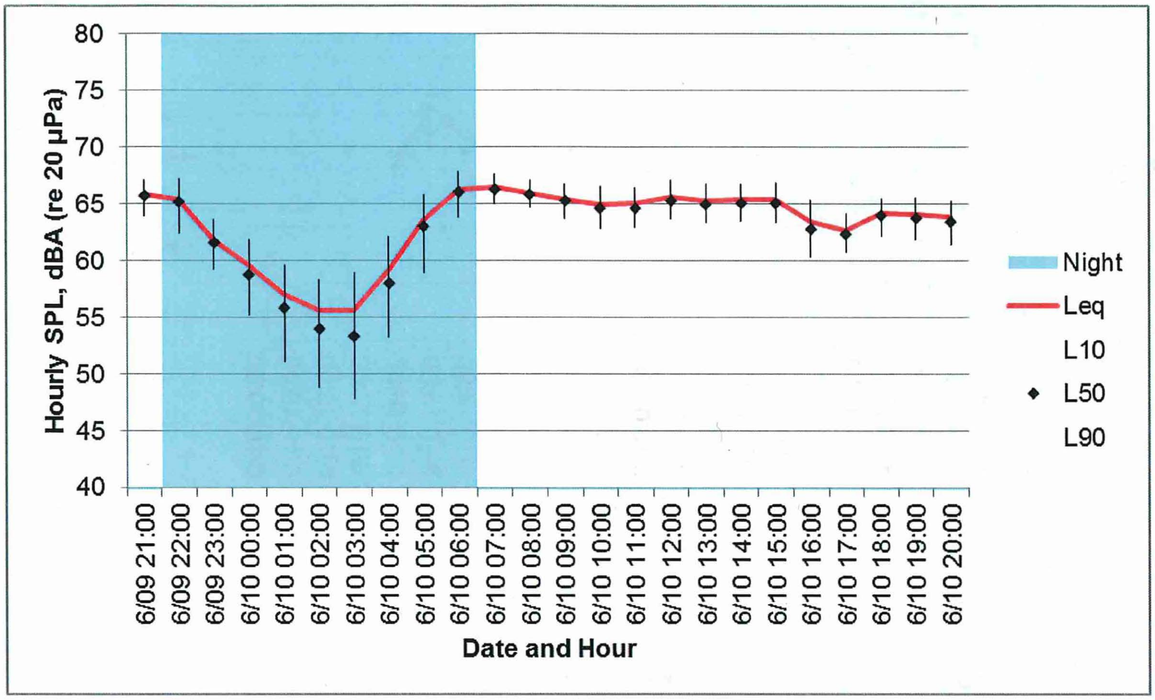


Figure B-2 illustrates measured pre-construction hourly noise levels at A2.

Figure B-2. Pre-construction Measured Hourly Noise Levels at A2

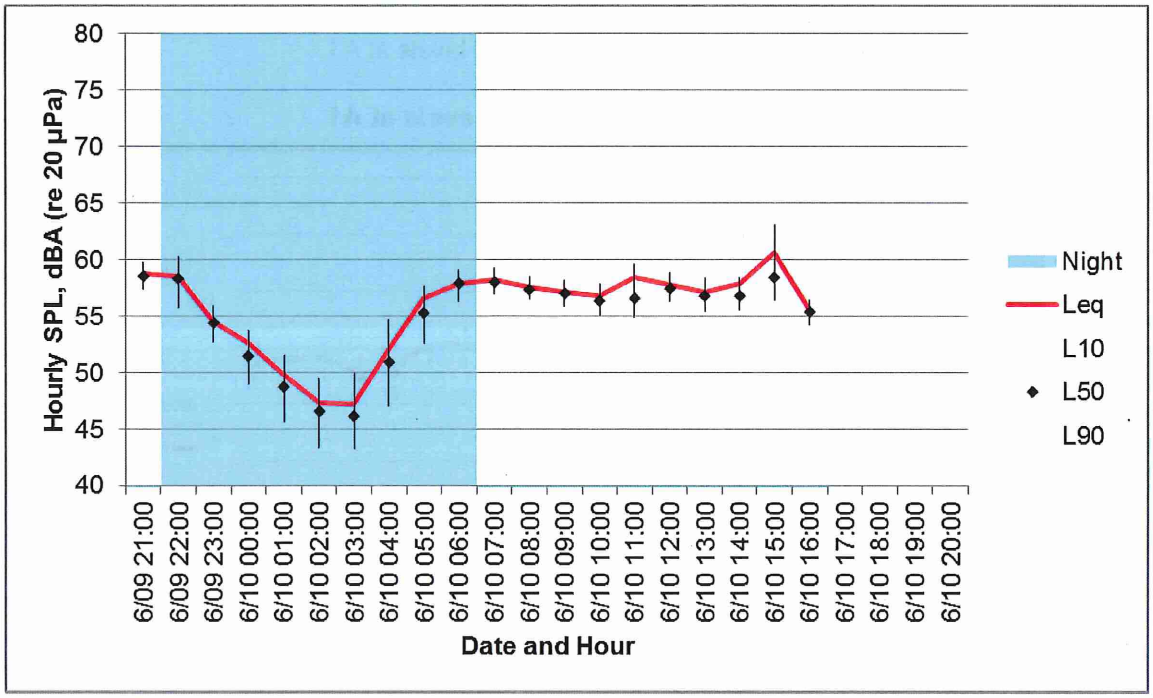


Figure B-3 illustrates measured pre-construction hourly noise levels at A3.

Figure B-3. Pre-construction Measured Hourly Noise Levels at A3

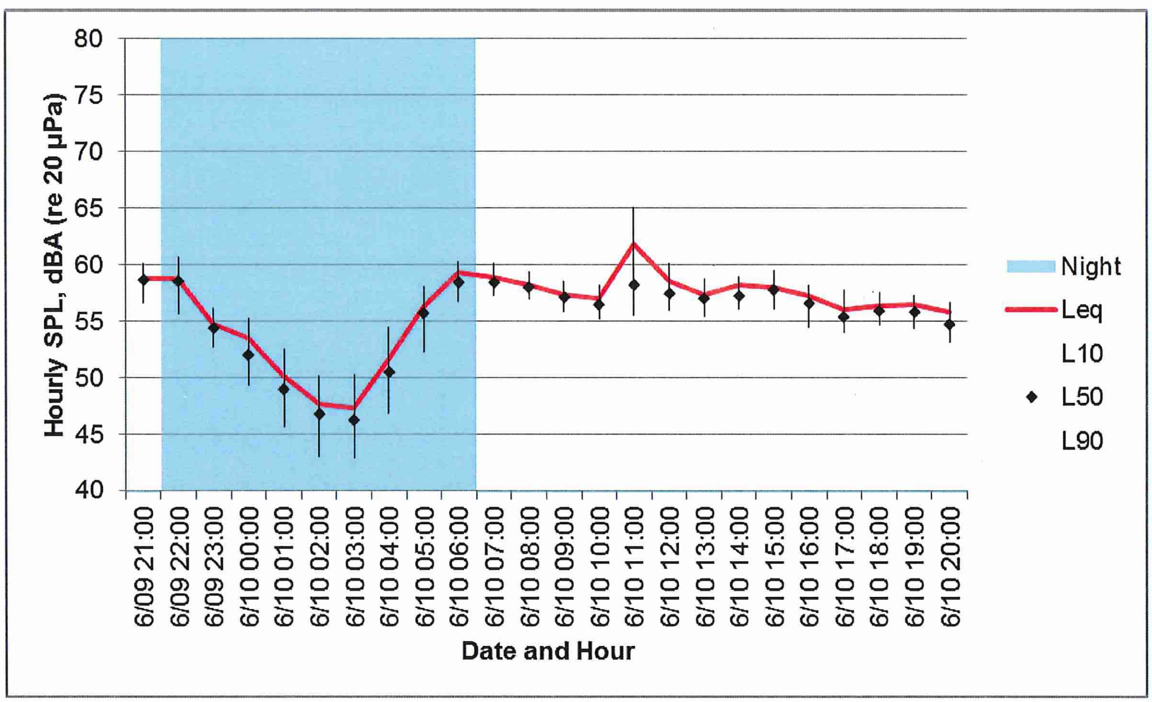


Figure B-4 illustrates measured pre-construction hourly noise levels at A4.

Figure B-4. Pre-construction Measured Hourly Noise Levels at A4

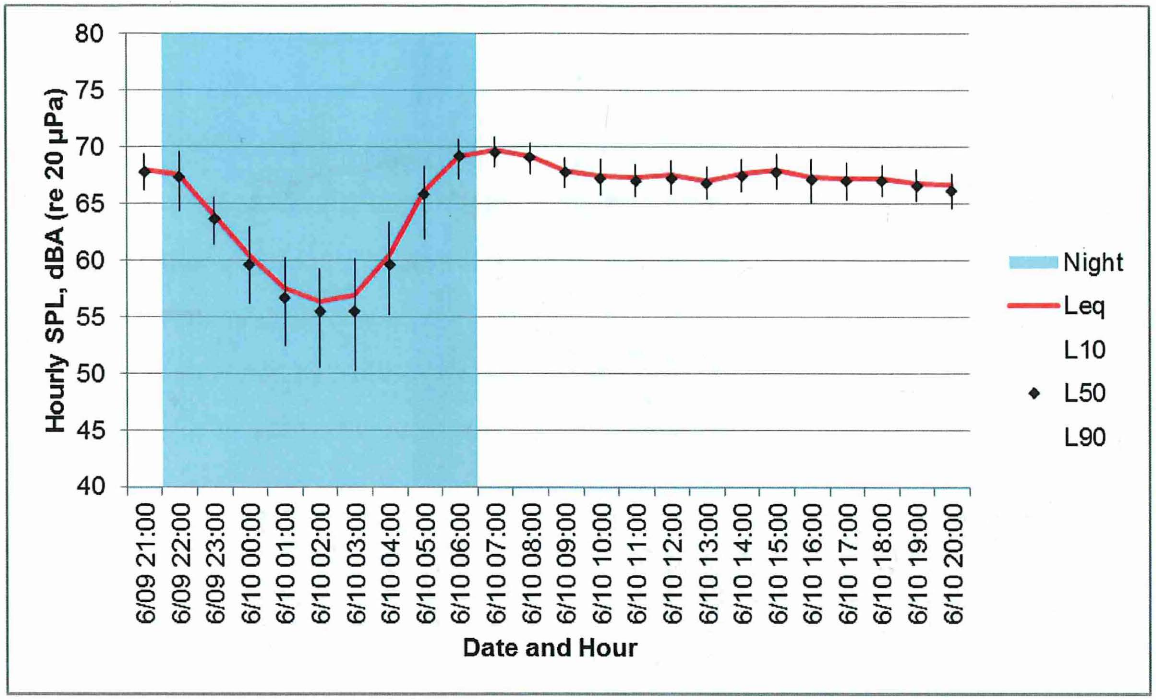


Figure B-5 illustrates measured pre-construction hourly noise levels at A5.

Figure B-5. Pre-construction Measured Hourly Noise Levels at A5

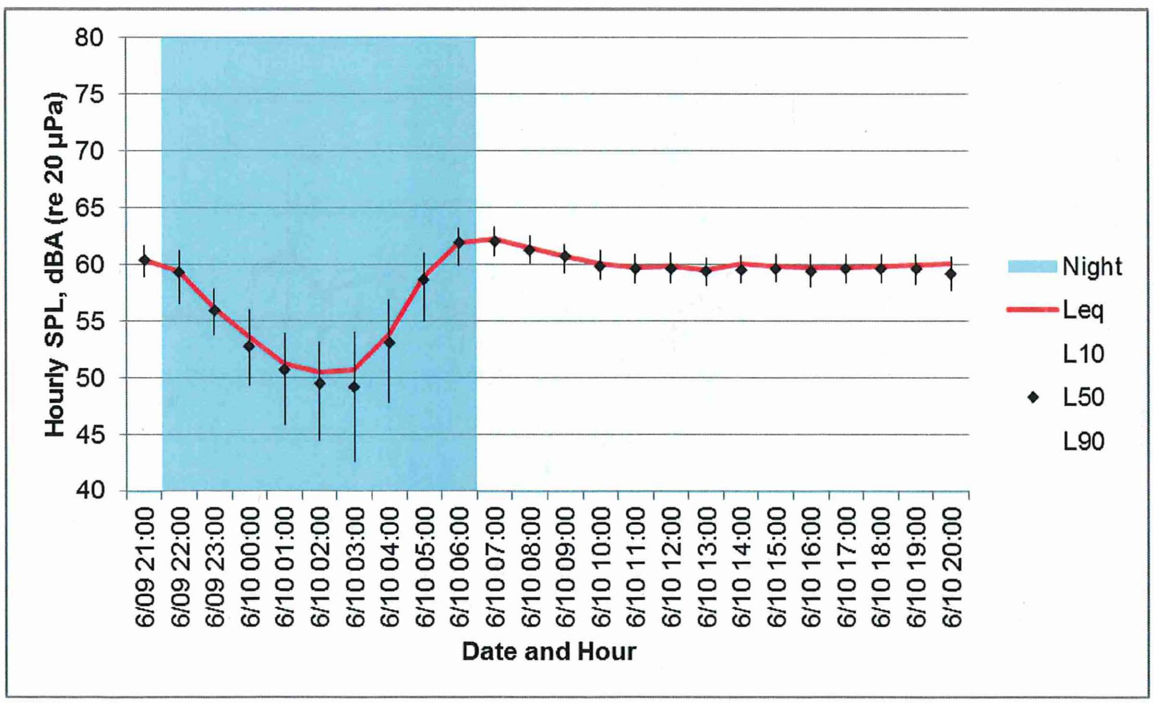


Figure B-6 illustrates measured pre-construction hourly noise levels at B1.

Figure B-6. Pre-construction Measured Hourly Noise Levels at B1

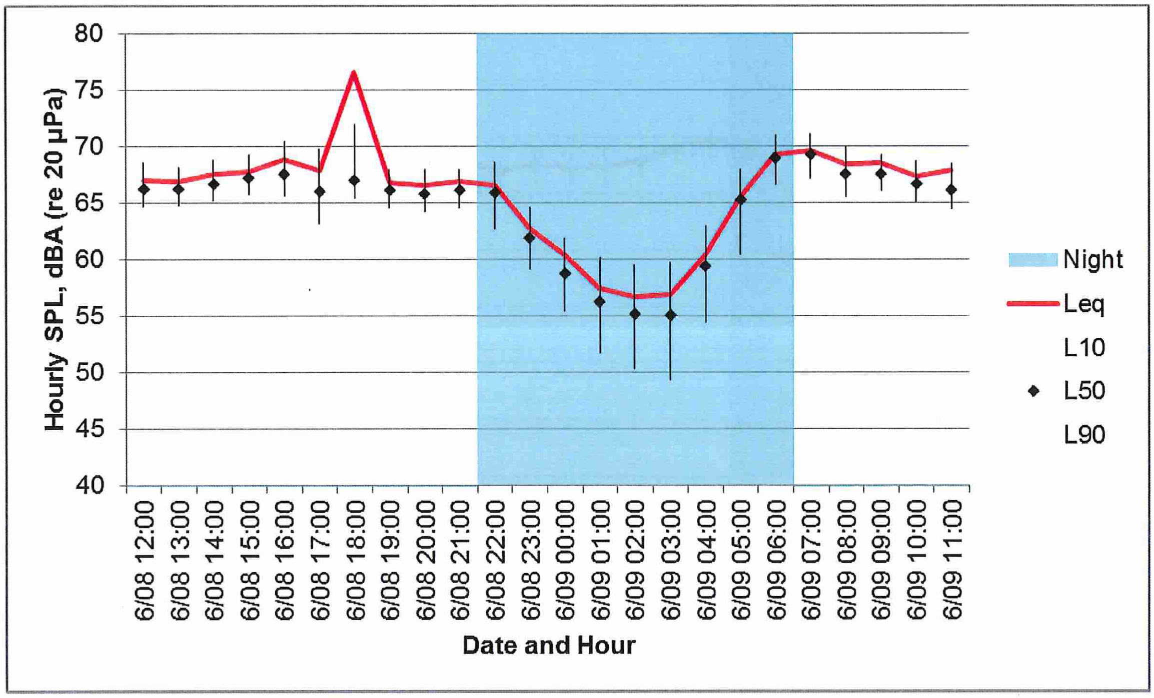


Figure B-7 illustrates measured pre-construction hourly noise levels at B2.

Figure B-7. Pre-construction Measured Hourly Noise Levels at B2

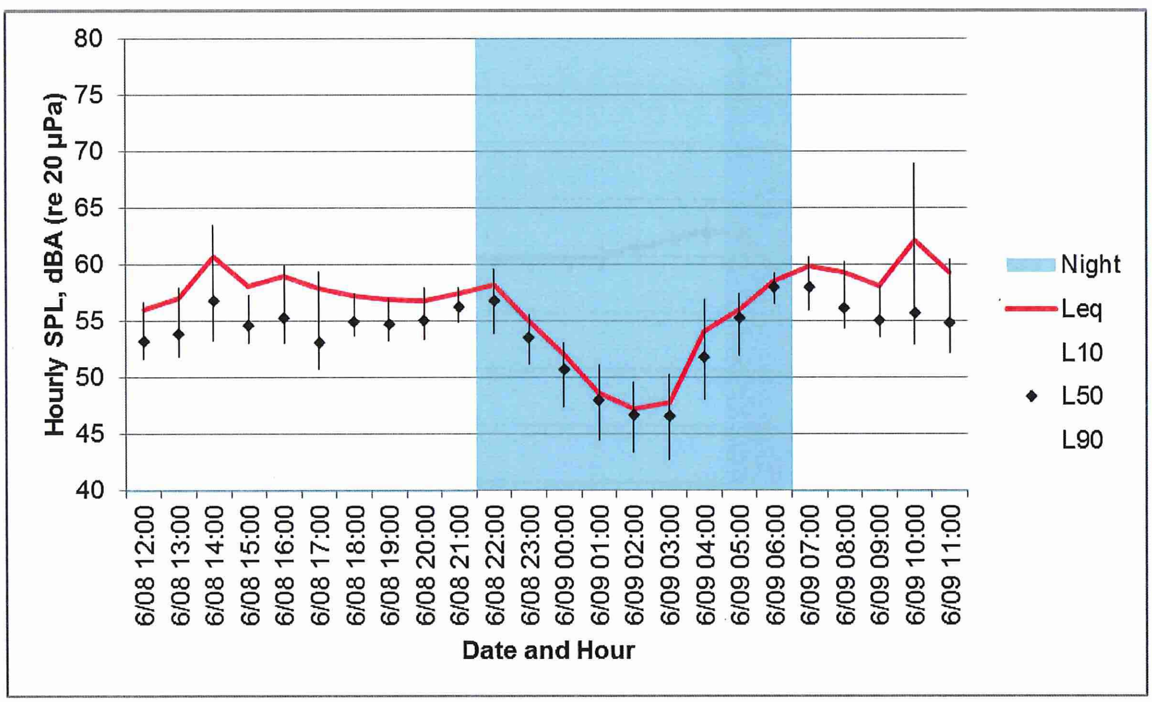


Figure B-8 illustrates measured pre-construction hourly noise levels at B3.

Figure B-8. Pre-construction Measured Hourly Noise Levels at B3

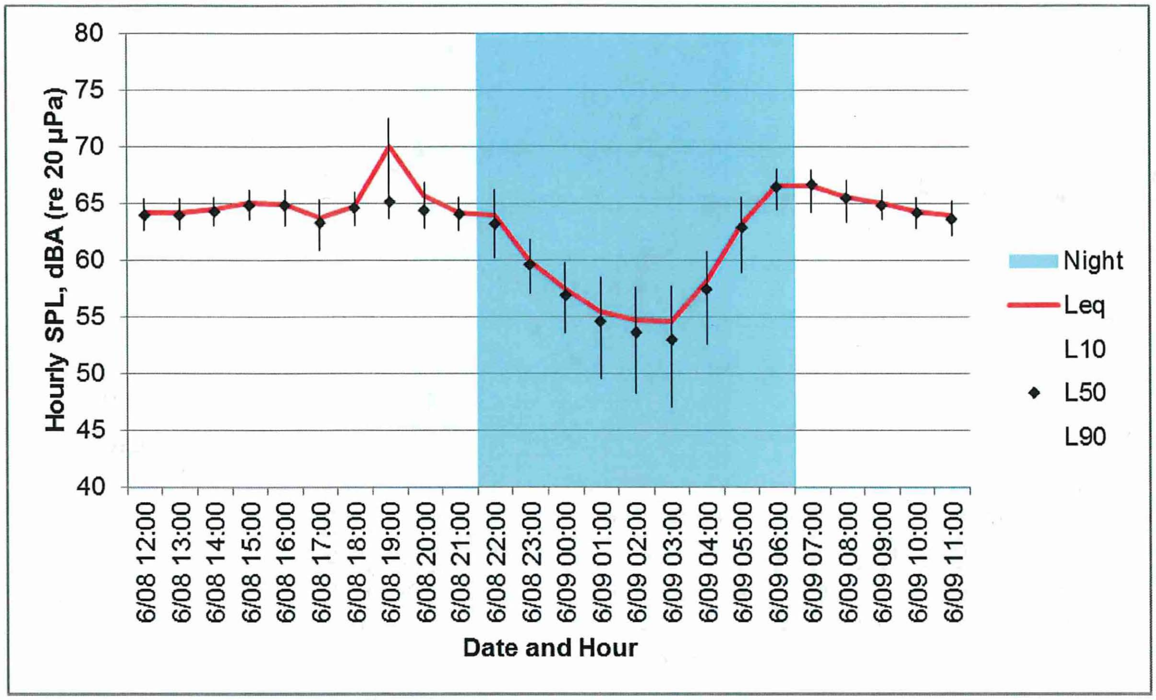


Figure B-9 illustrates measured pre-construction hourly noise levels at B4.

Figure B-9. Pre-construction Measured Hourly Noise Levels at B4

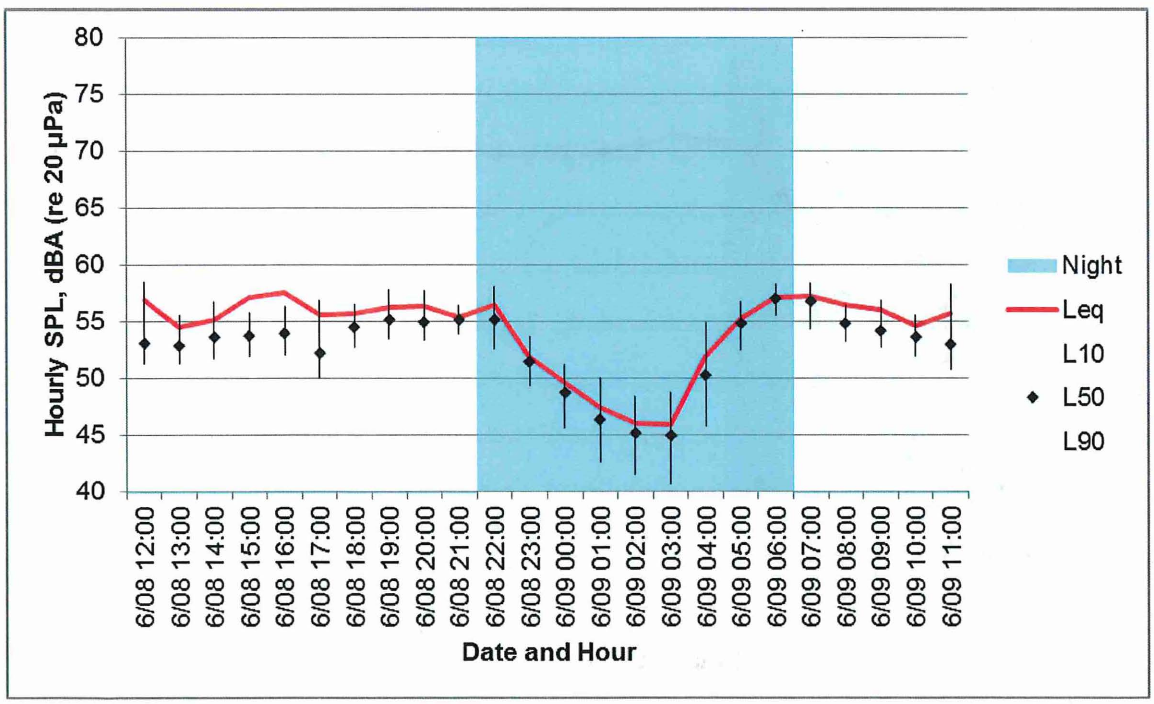


Figure B-10 illustrates measured pre-construction hourly noise levels at B5.

Figure B-10. Pre-construction Measured Hourly Noise Levels at B5

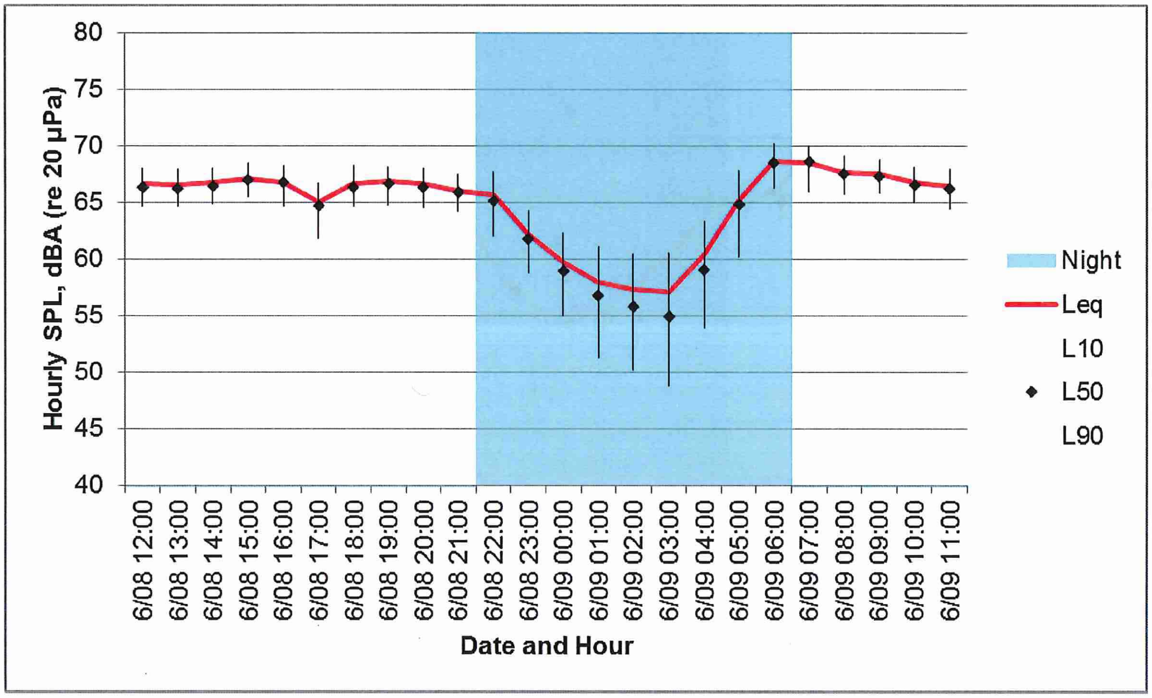


Figure B-11 illustrates measured pre-construction hourly noise levels at C1.

Figure B-11. Pre-construction Measured Hourly Noise Levels at C1

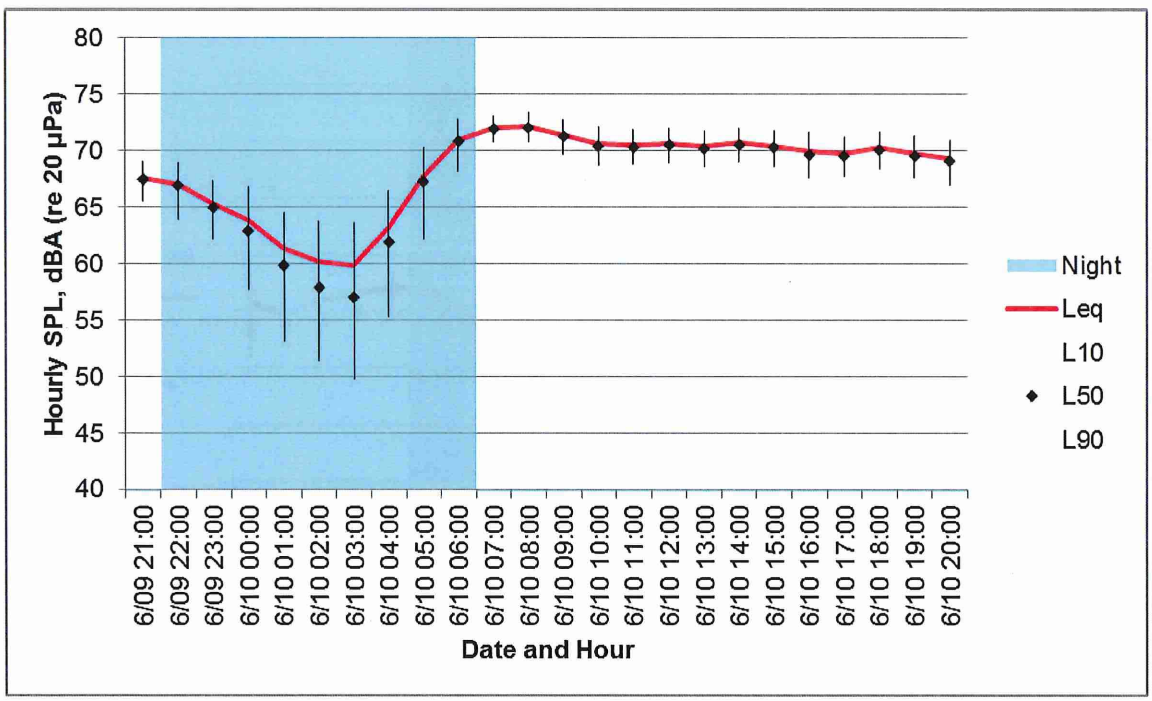


Figure B-12 illustrates measured pre-construction hourly noise levels at C2.

Figure B-12. Pre-construction Measured Hourly Noise Levels at C2

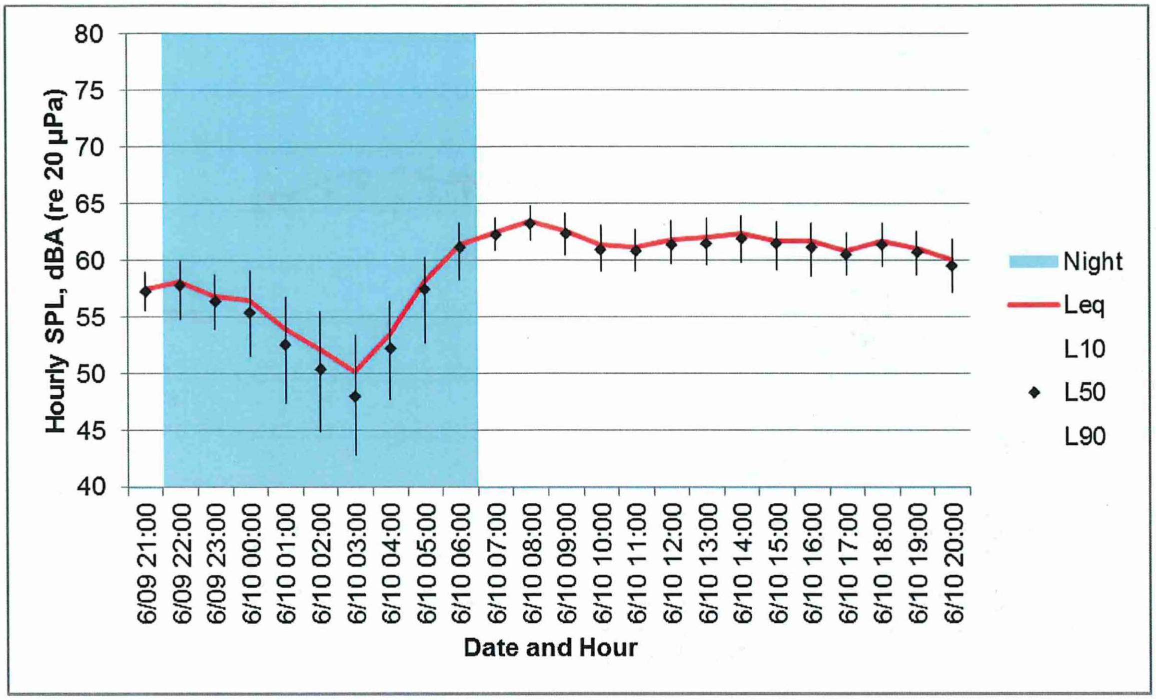


Figure B-13 illustrates measured pre-construction hourly noise levels at C3.

Figure B-13. Pre-construction Measured Hourly Noise Levels at C3

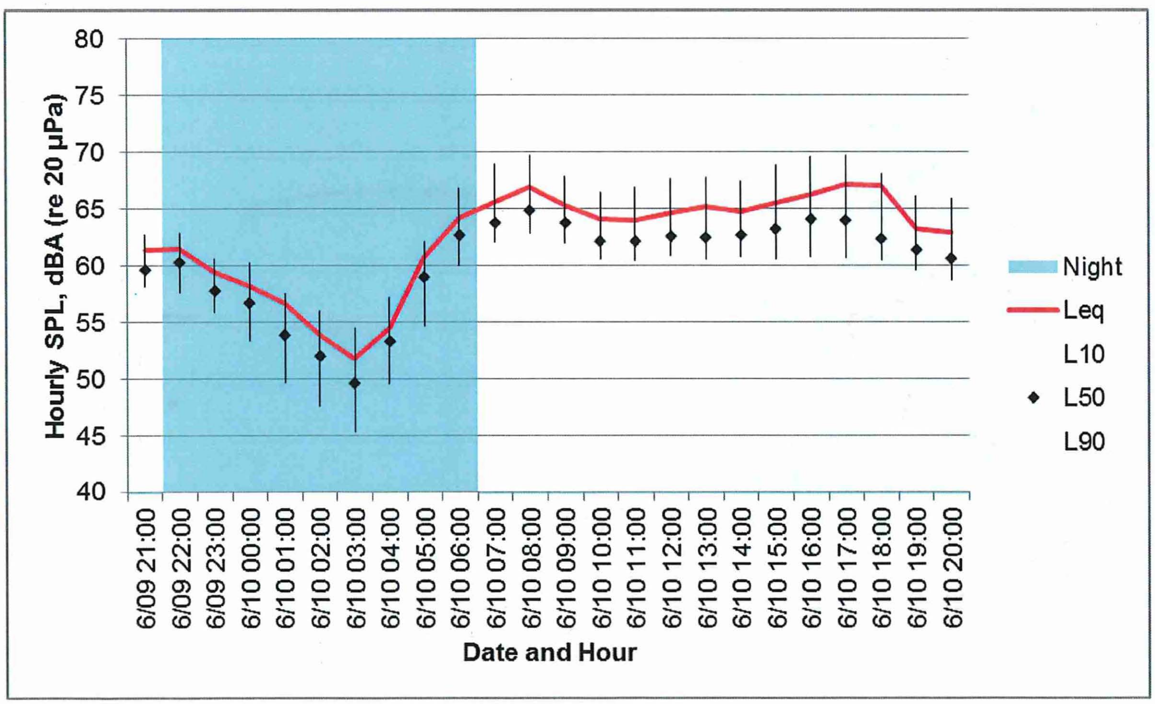


Figure B-14 illustrates measured pre-construction hourly noise levels at C4.

Figure B-14. Pre-construction Measured Hourly Noise Levels at C4

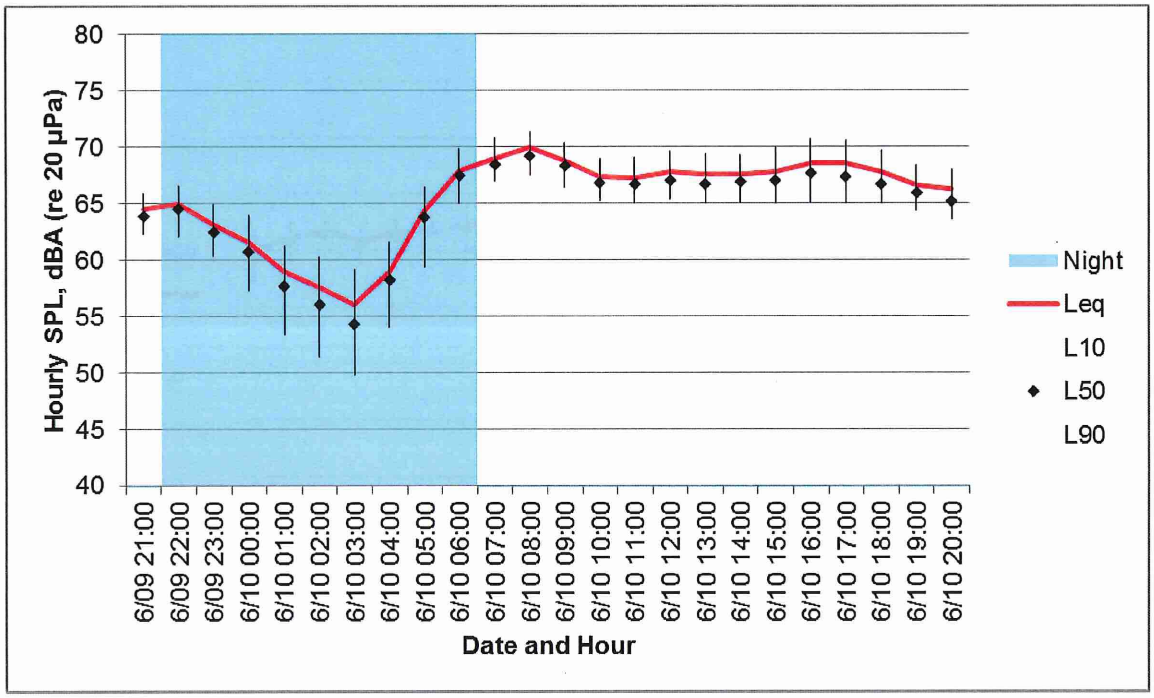


Figure B-15 illustrates measured pre-construction hourly noise levels at C5.

Figure B-15. Pre-construction Measured Hourly Noise Levels at C5

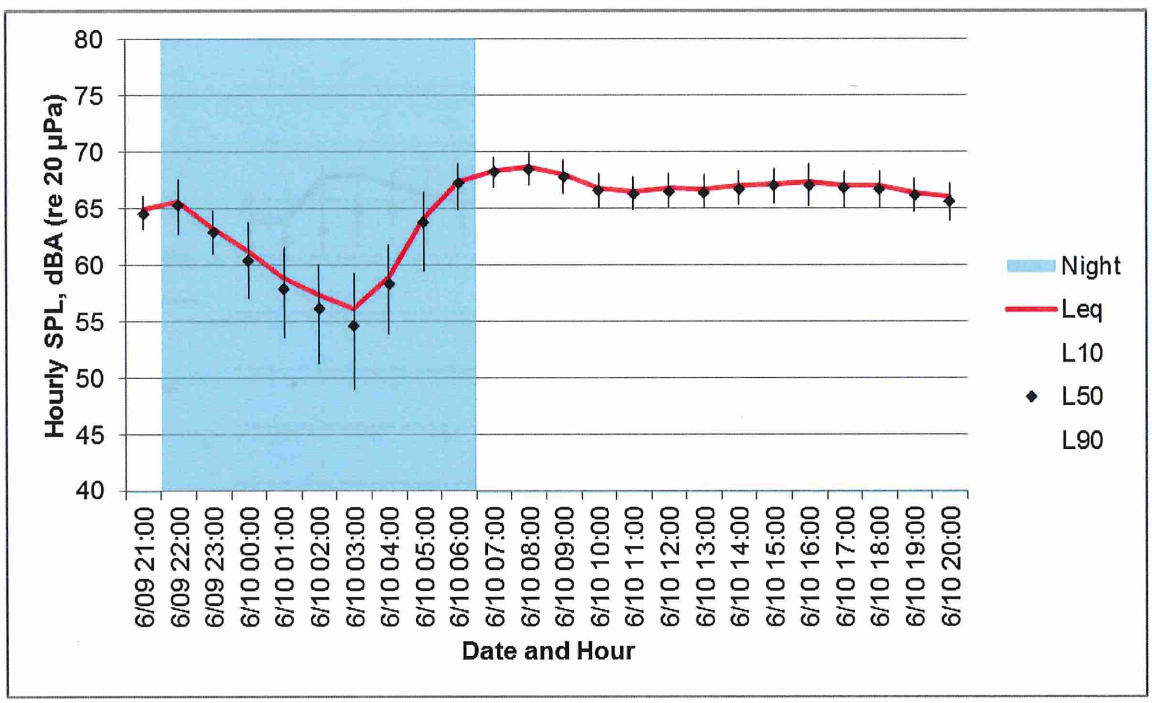


Figure B-16 illustrates measured pre-construction hourly noise levels at D1.

Figure B-16. Pre-construction Measured Hourly Noise Levels at D1

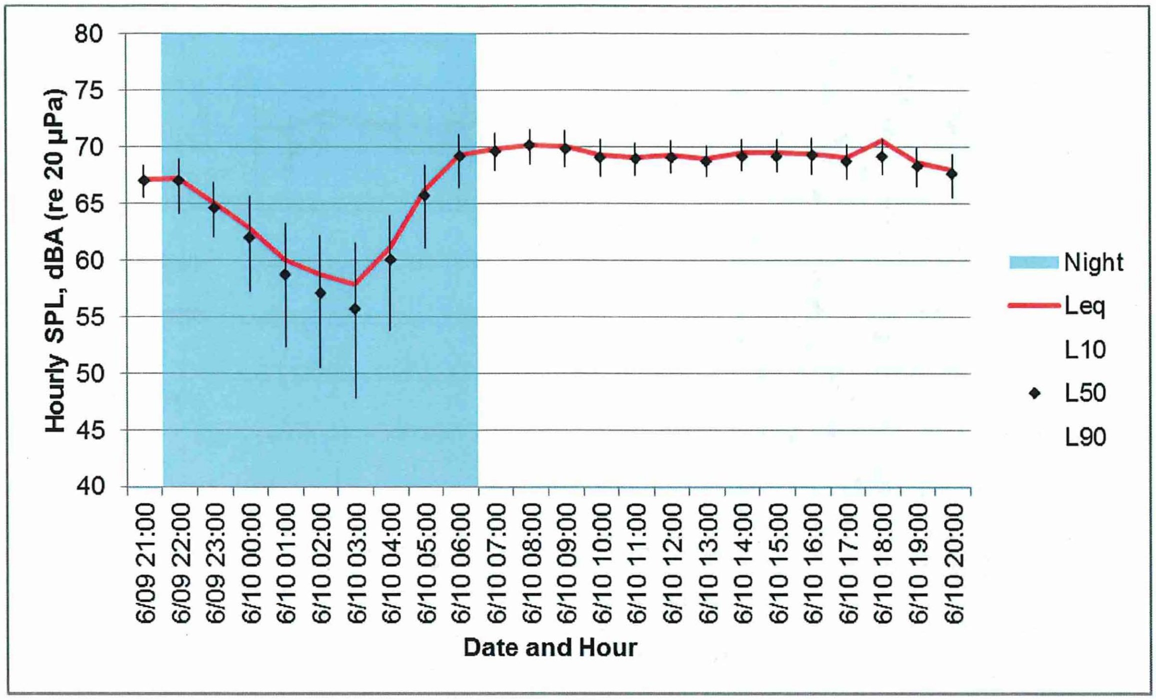


Figure B-17 illustrates measured pre-construction hourly noise levels at D2.

Figure B-17. Pre-construction Measured Hourly Noise Levels at D2

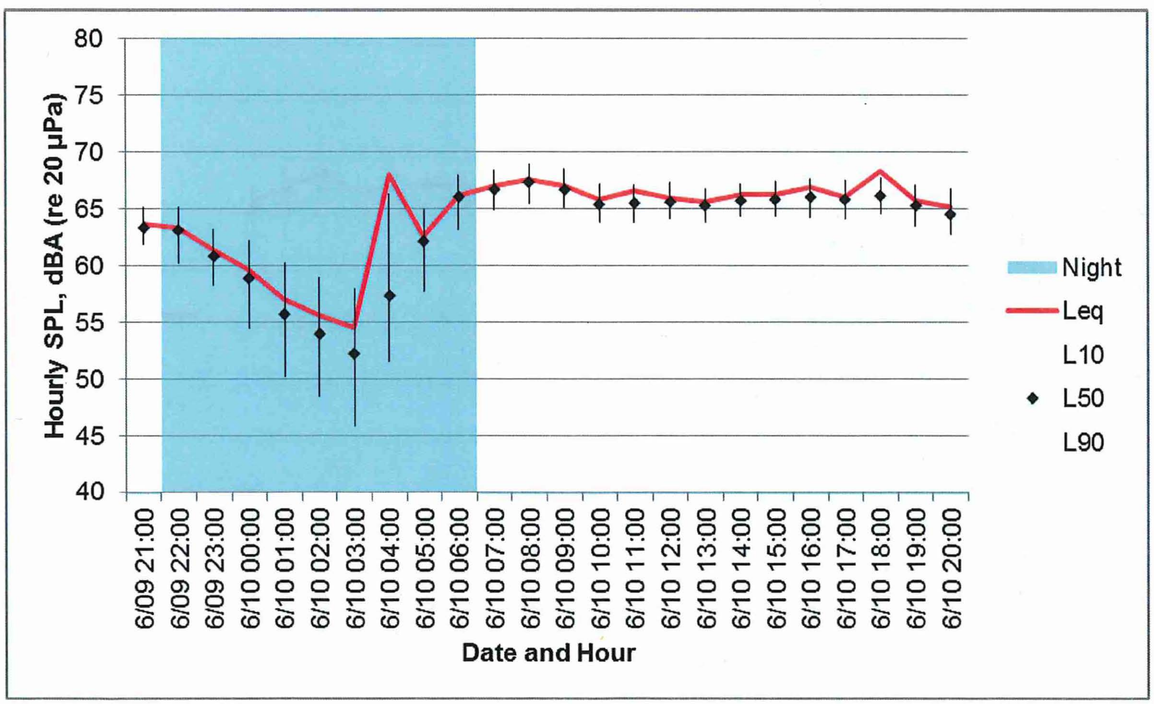


Figure B-18 illustrates measured pre-construction hourly noise levels at D3.

Figure B-18. Pre-construction Measured Hourly Noise Levels at D3

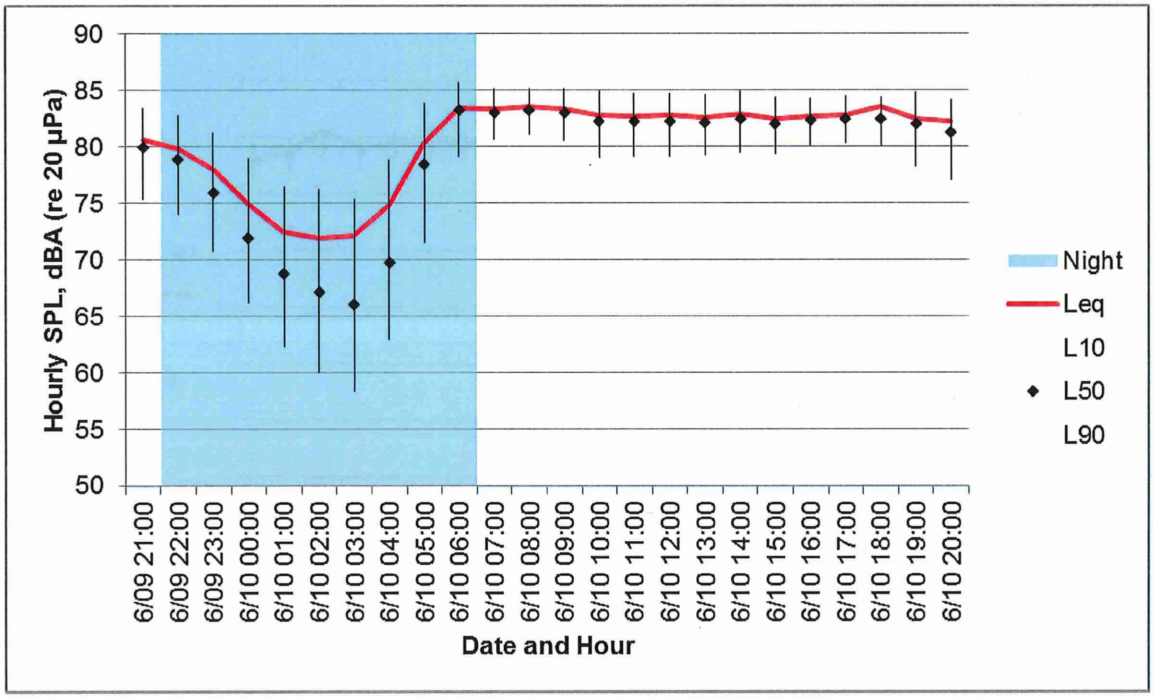


Figure B-19 illustrates measured pre-construction hourly noise levels at D4.

Figure B-19. Pre-construction Measured Hourly Noise Levels at D4

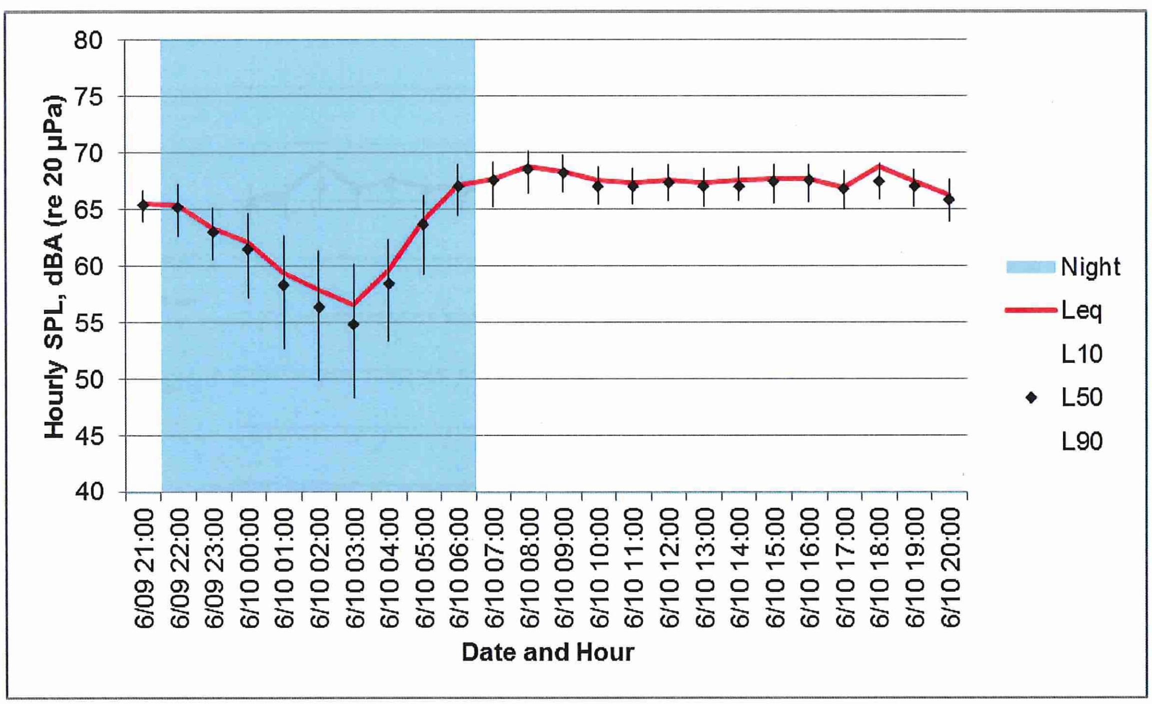


Figure B-20 illustrates measured pre-construction hourly noise levels at D5.

Figure B-20. Pre-construction Measured Hourly Noise Levels at D5

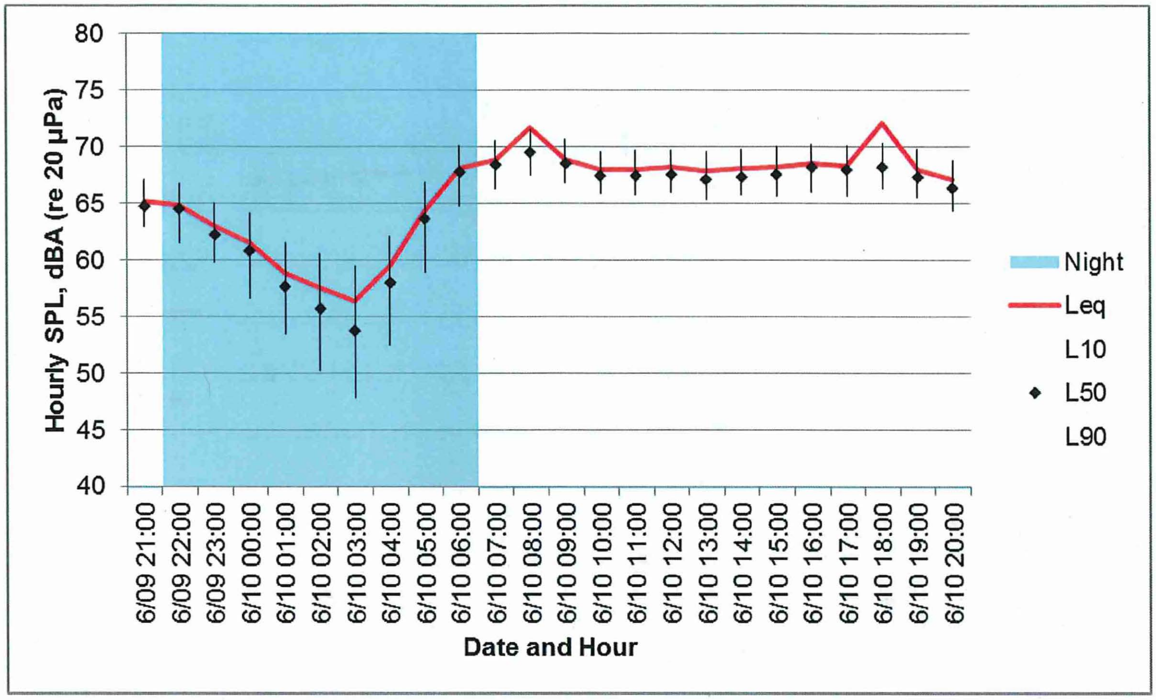


Figure B-21 illustrates measured pre-construction hourly noise levels at E1.

Figure B-21. Pre-construction Measured Hourly Noise Levels at E1

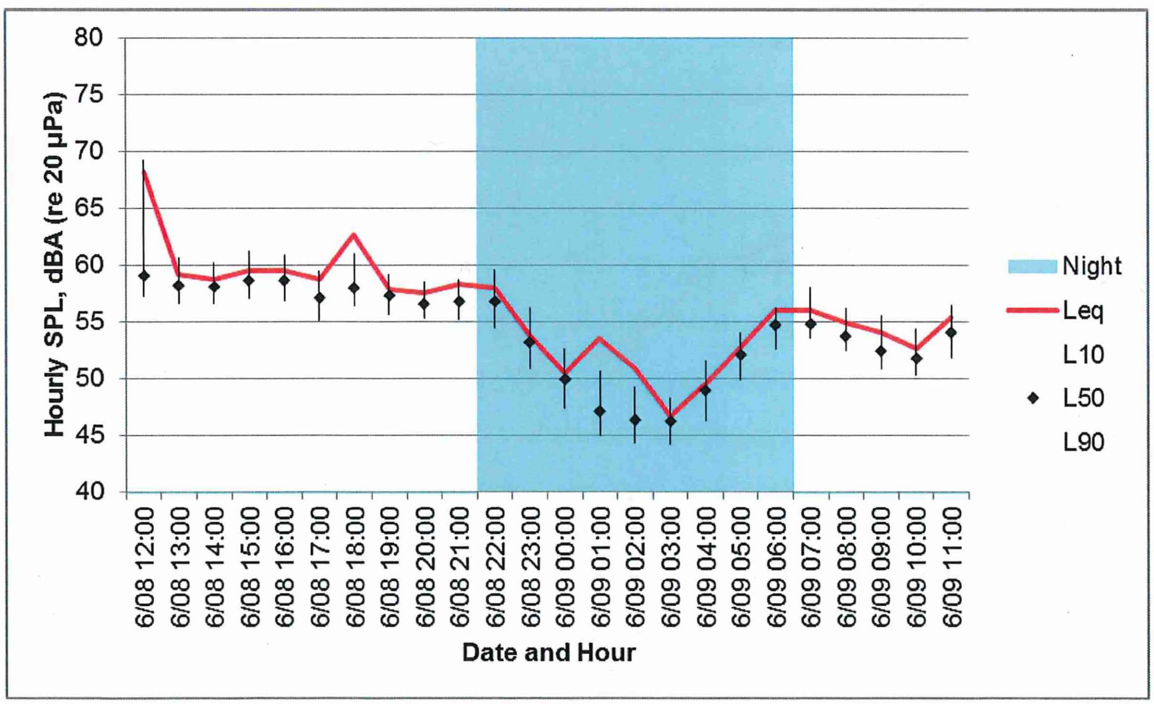


Figure B-22 illustrates measured pre-construction hourly noise levels at E2.

Figure B-22. Pre-construction Measured Hourly Noise Levels at E2

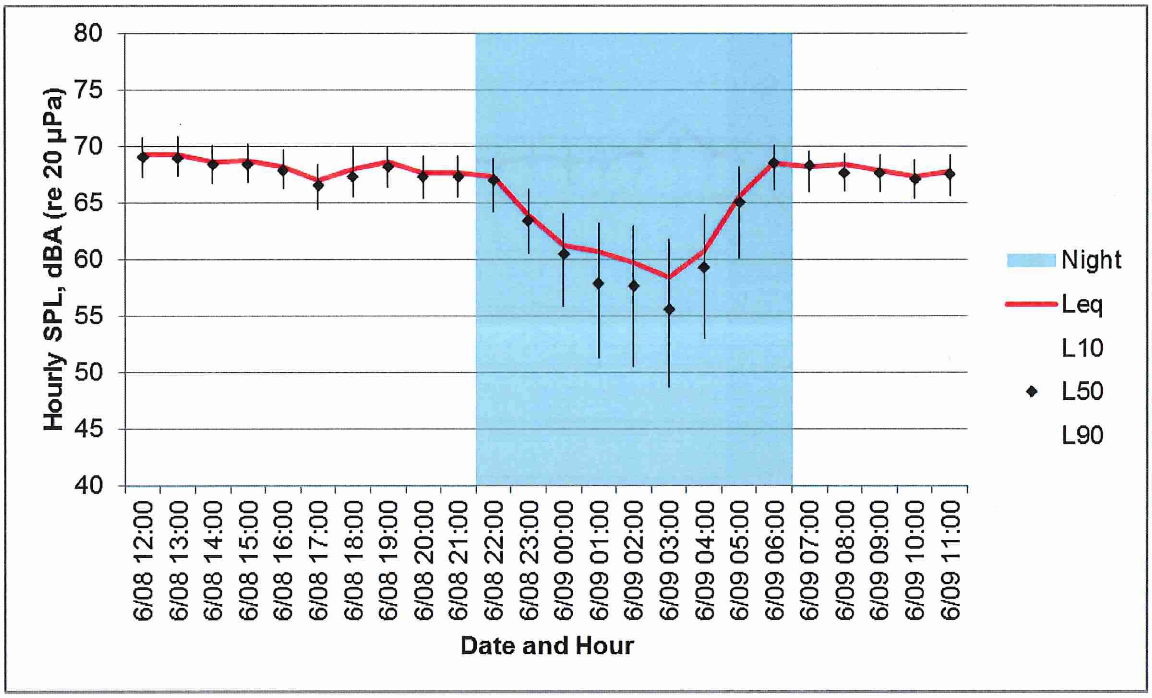


Figure B-23 illustrates measured pre-construction hourly noise levels at E3.

Figure B-23. Pre-construction Measured Hourly Noise Levels at E3

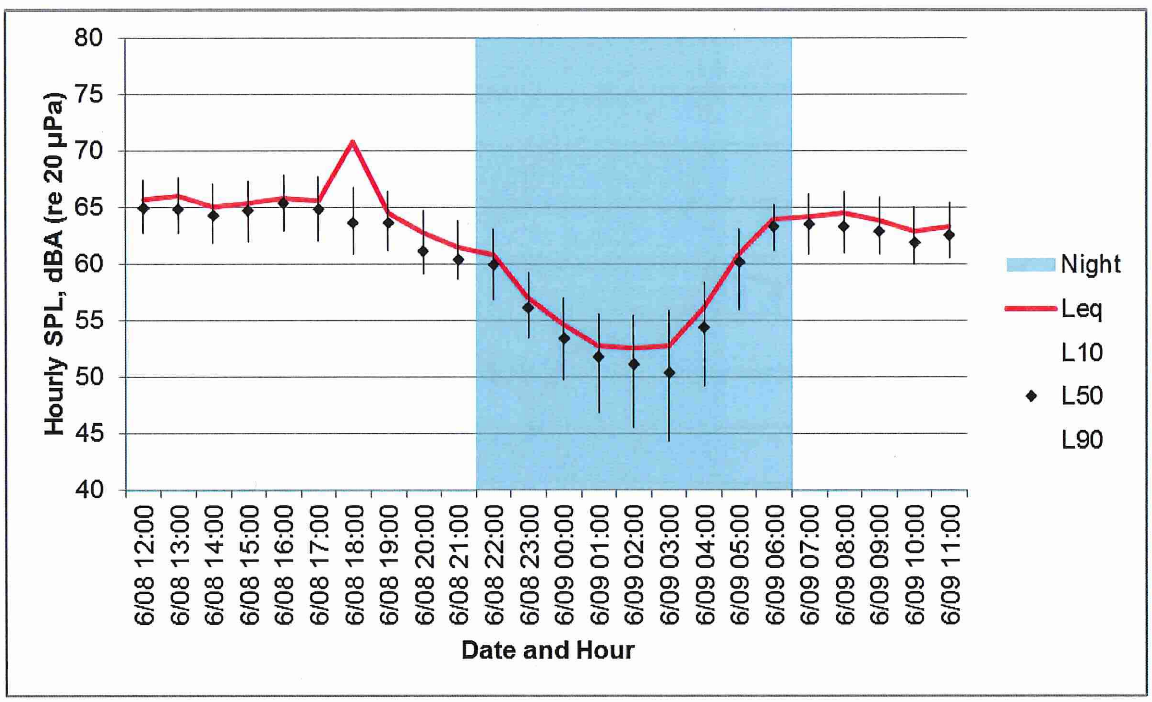


Figure B-24 illustrates measured pre-construction hourly noise levels at E4.

Figure B-24. Pre-construction Measured Hourly Noise Levels at E4

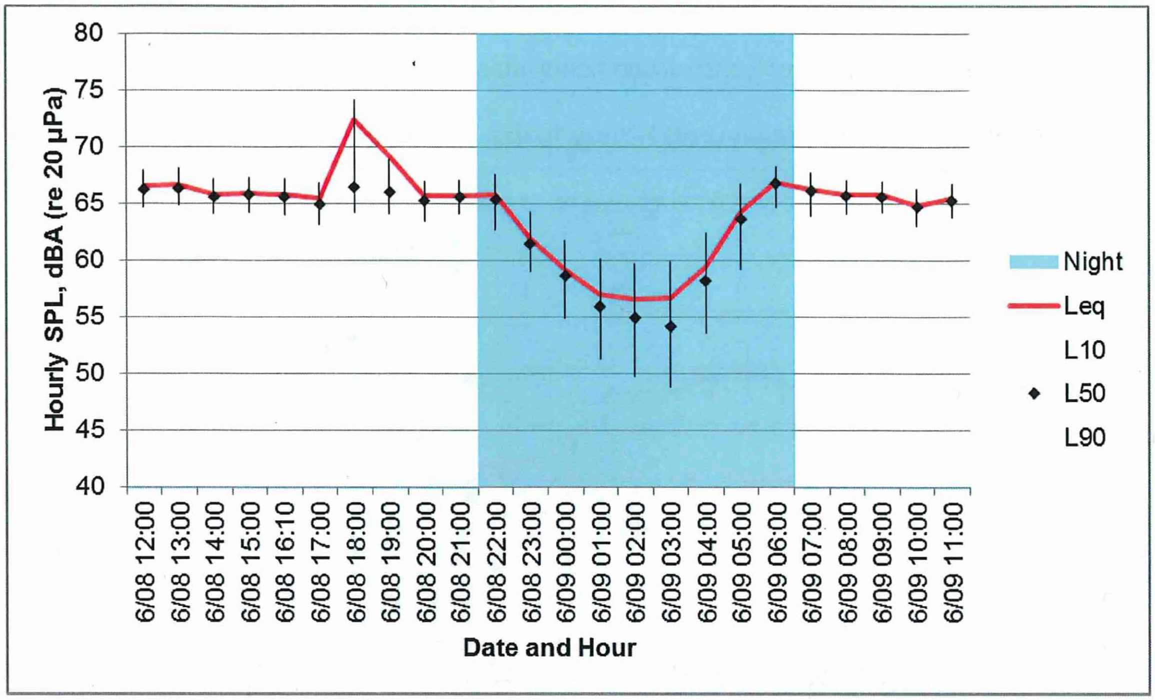
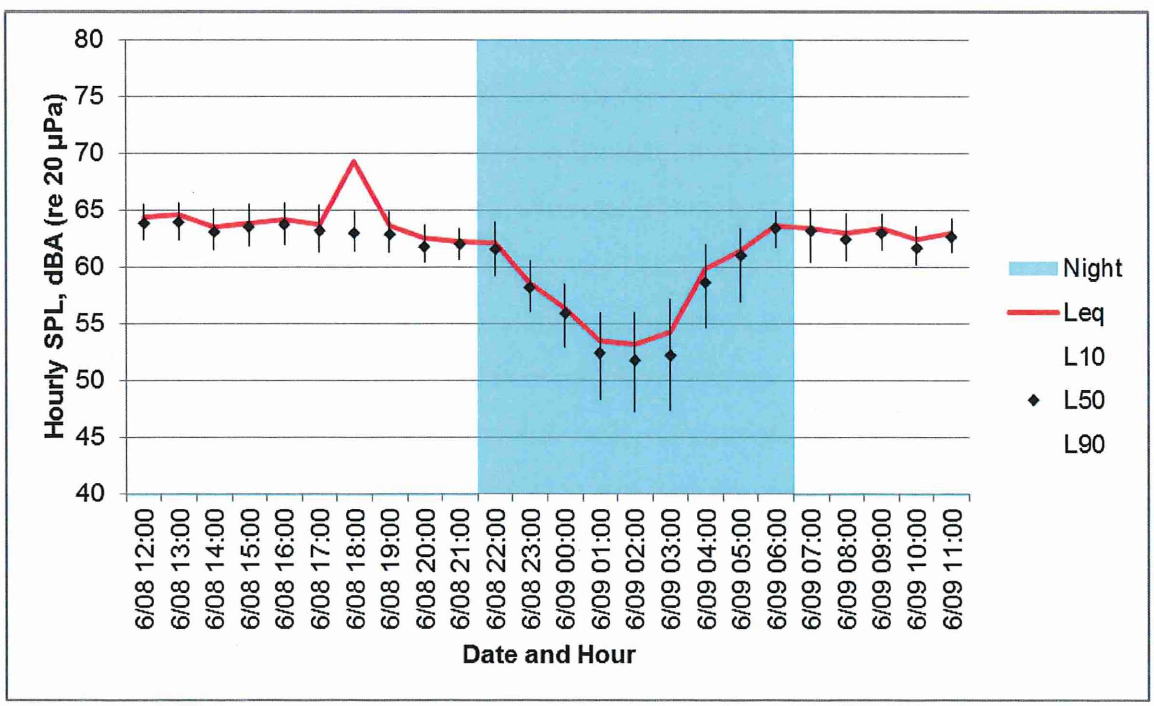


Figure B-25 illustrates measured pre-construction hourly noise levels at E5.

Figure B-25. Pre-construction Measured Hourly Noise Levels at E5



Appendix C. Detailed Post-construction Noise Measurement Data

Figure C-1 illustrates measured post-construction hourly noise levels at A1.

Figure C-1. Post-construction Measured Hourly Noise Levels at A1

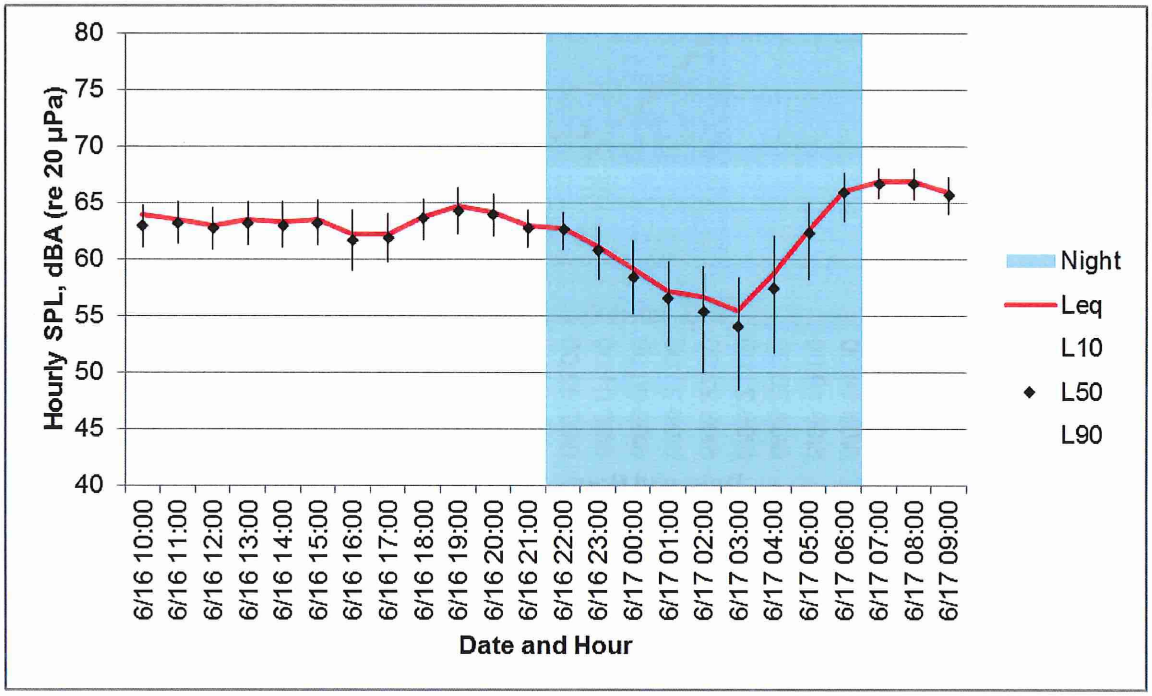


Figure C-2 illustrates measured post-construction hourly noise levels at A2.

Figure C-2. Post-construction Measured Hourly Noise Levels at A2

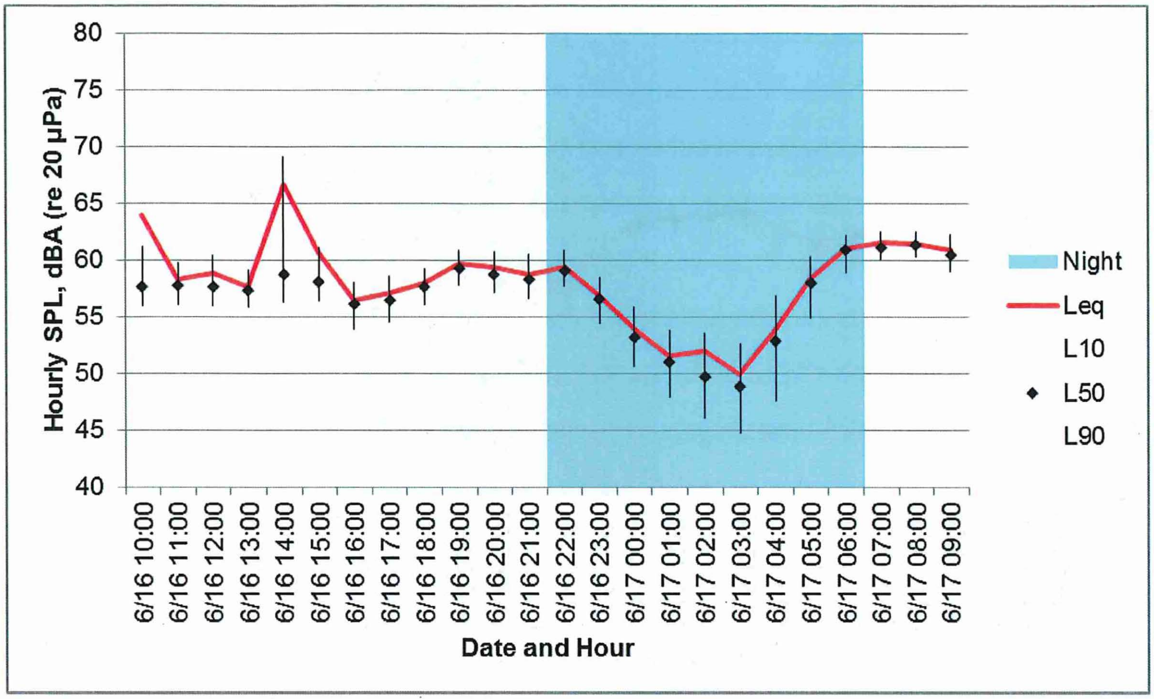


Figure C-3 illustrates measured post-construction hourly noise levels at A3.

Figure C-3. Post-construction Measured Hourly Noise Levels at A3

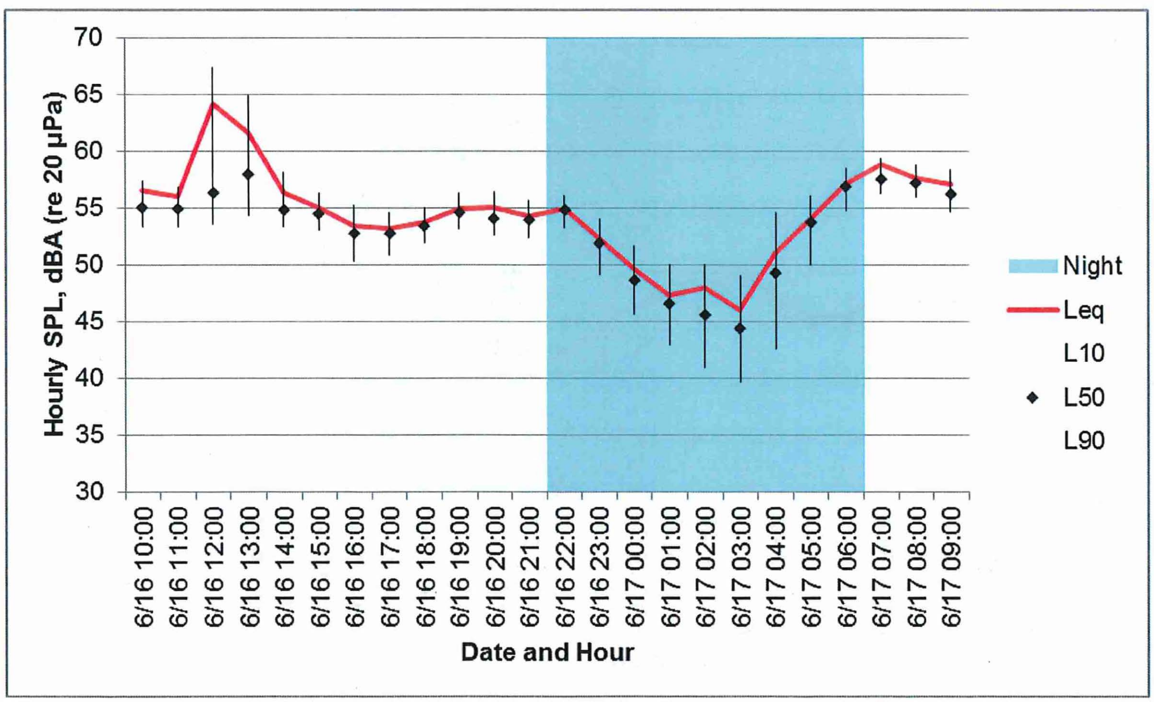


Figure C-4 illustrates measured post-construction hourly noise levels at A4.

Figure C-4. Post-construction Measured Hourly Noise Levels at A4

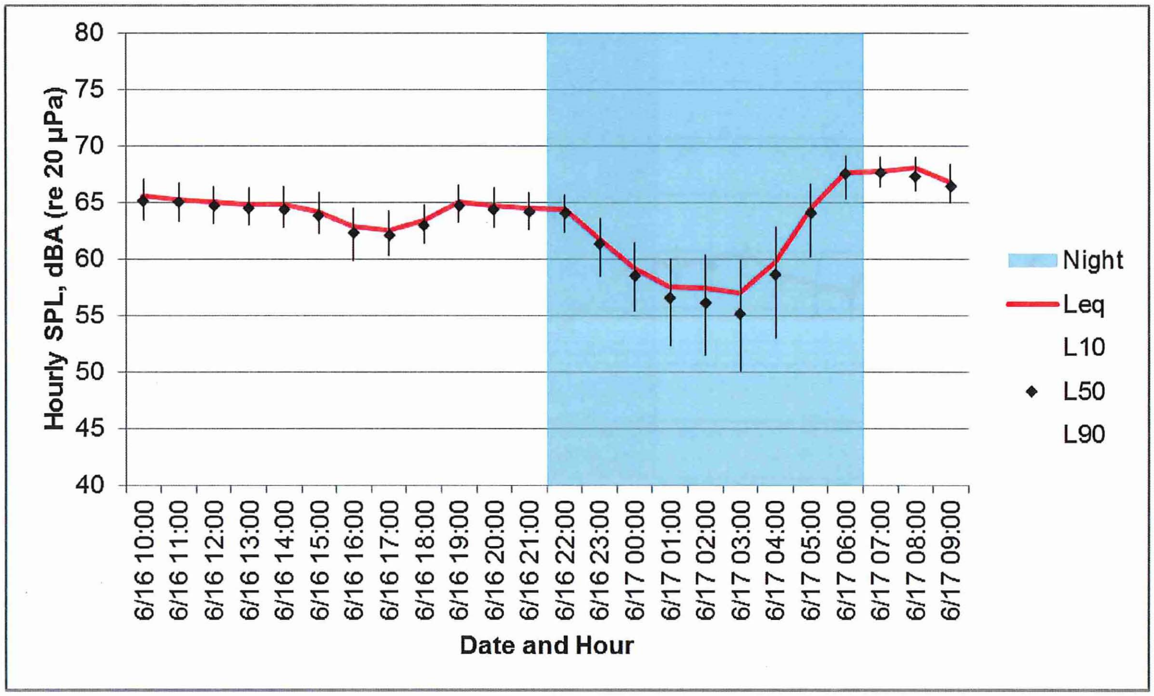


Figure C-5 illustrates measured post-construction hourly noise levels at A5.

Figure C-5. Post-construction Measured Hourly Noise Levels at A5

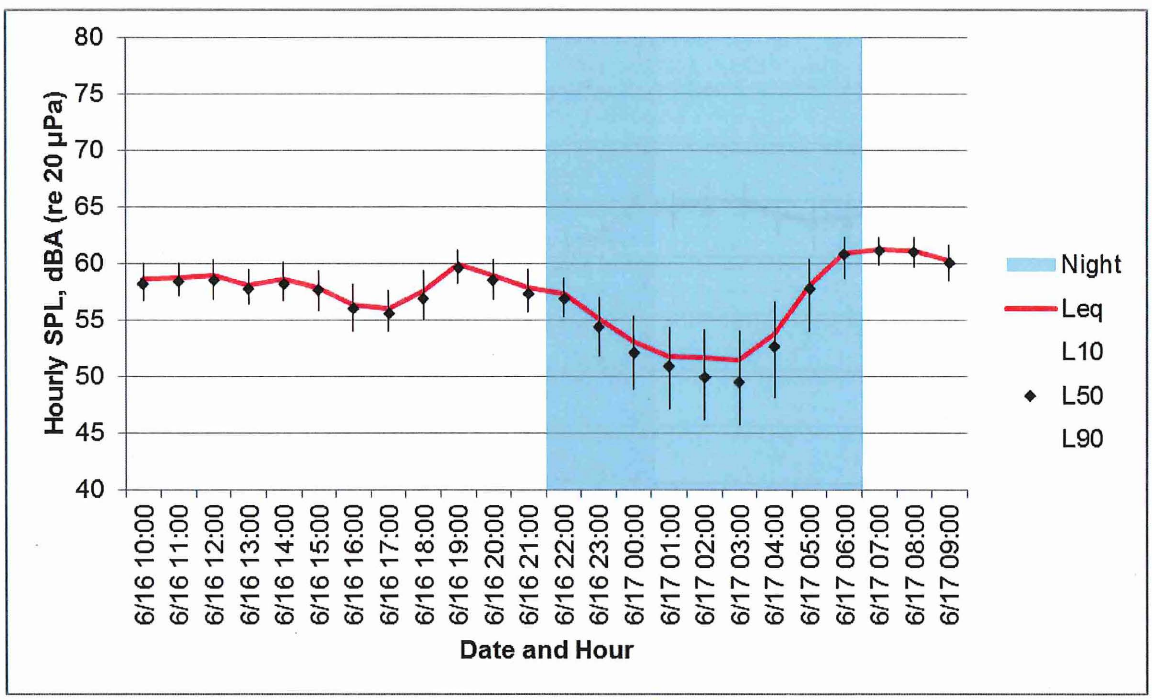


Figure C-6 illustrates measured post-construction hourly noise levels at B2.

Figure C-6. Post-construction Measured Hourly Noise Levels at B2

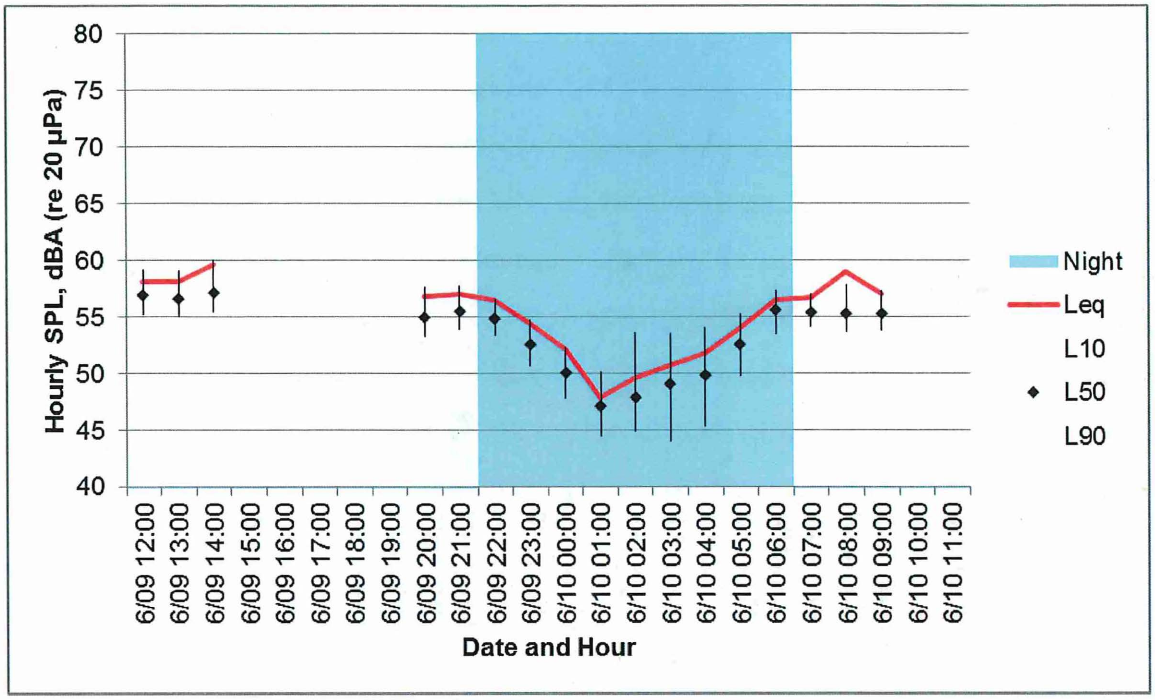


Figure C-7 illustrates measured post-construction hourly noise levels at B3.

Figure C-7. Post-construction Measured Hourly Noise Levels at B3

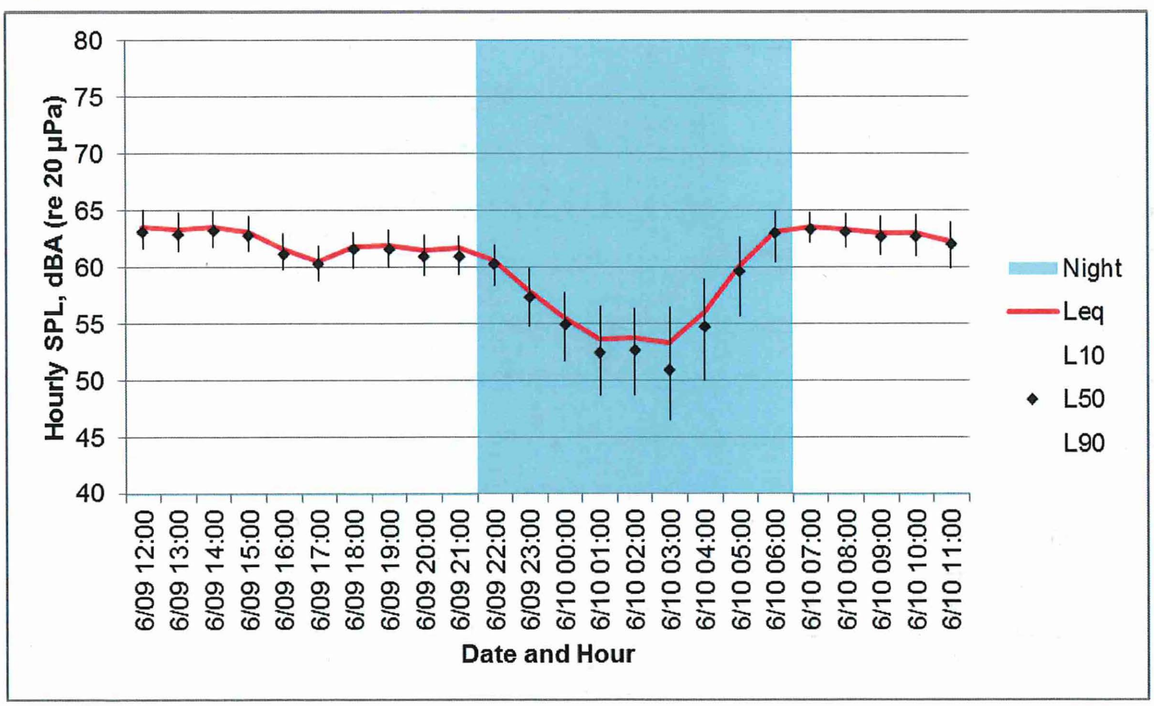


Figure C-8 illustrates measured post-construction hourly noise levels at B4.

Figure C-8. Post-construction Measured Hourly Noise Levels at B4

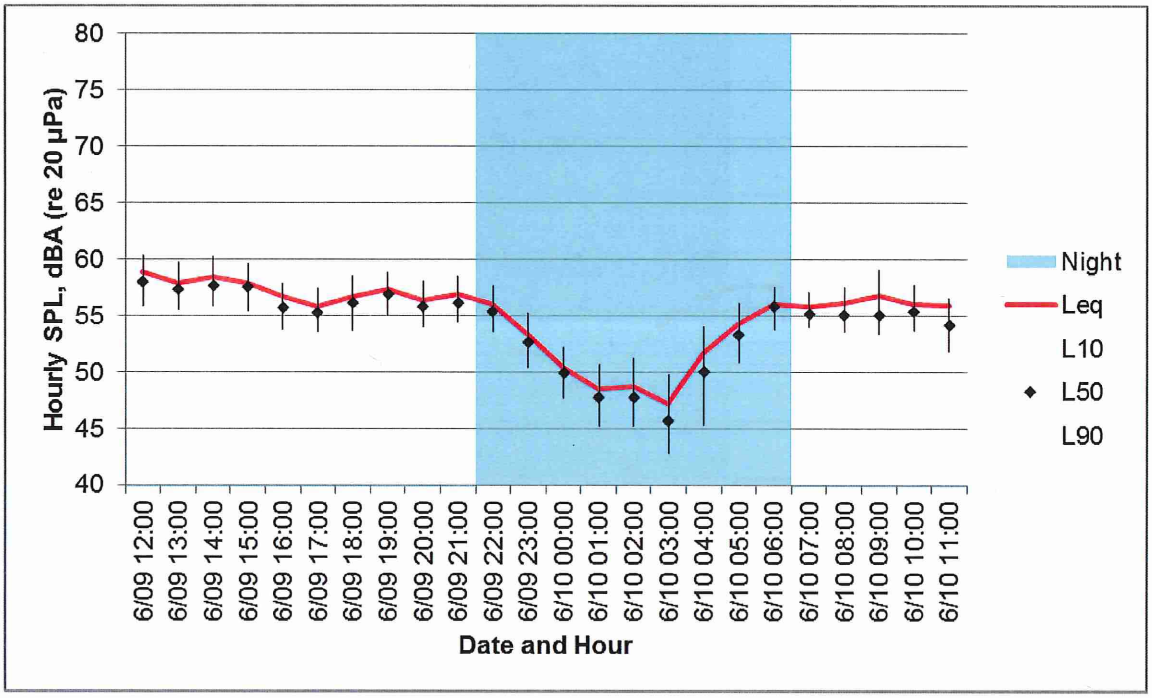


Figure C-9 illustrates measured post-construction hourly noise levels at B5.

Figure C-9. Post-construction Measured Hourly Noise Levels at B5

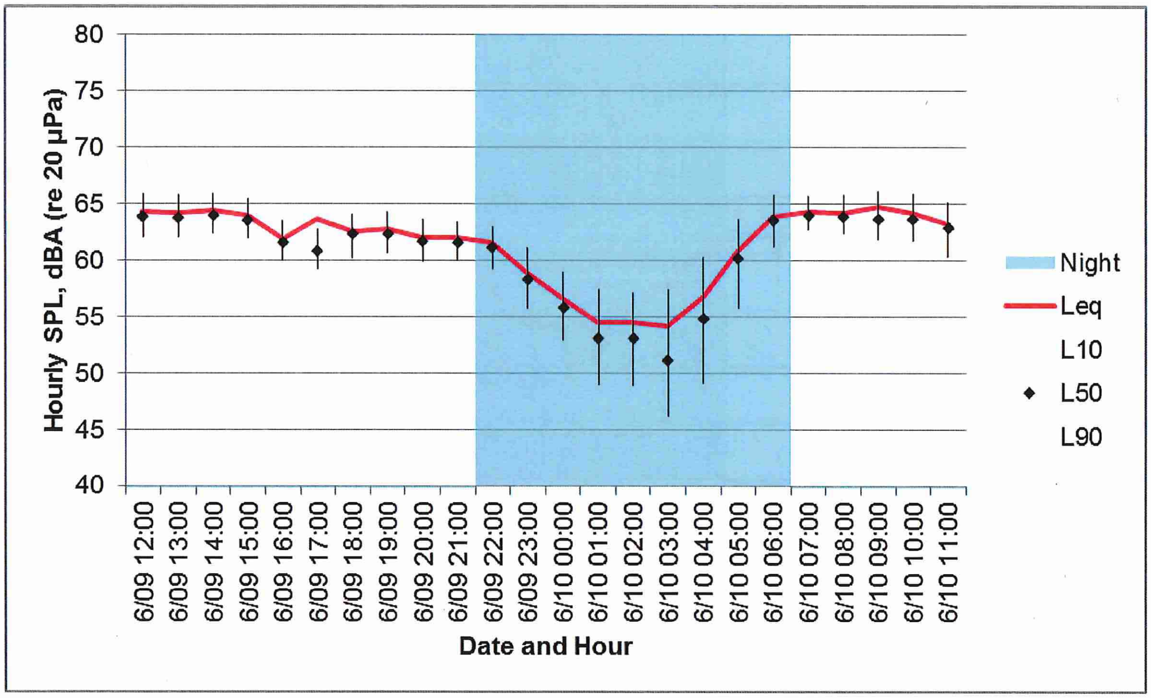


Figure C-10 illustrates measured post-construction hourly noise levels at C2.

Figure C-10. Post-construction Measured Hourly Noise Levels at C2

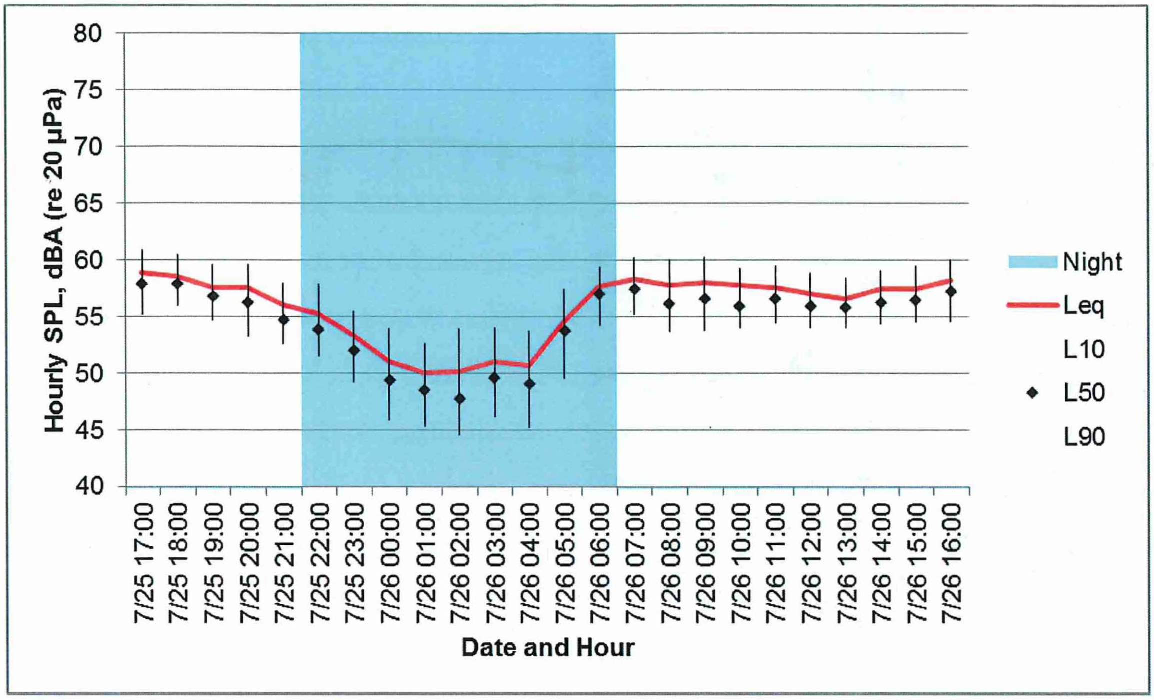


Figure C-11 illustrates measured post-construction hourly noise levels at D1.

Figure C-11. Post-construction Measured Hourly Noise Levels at D1

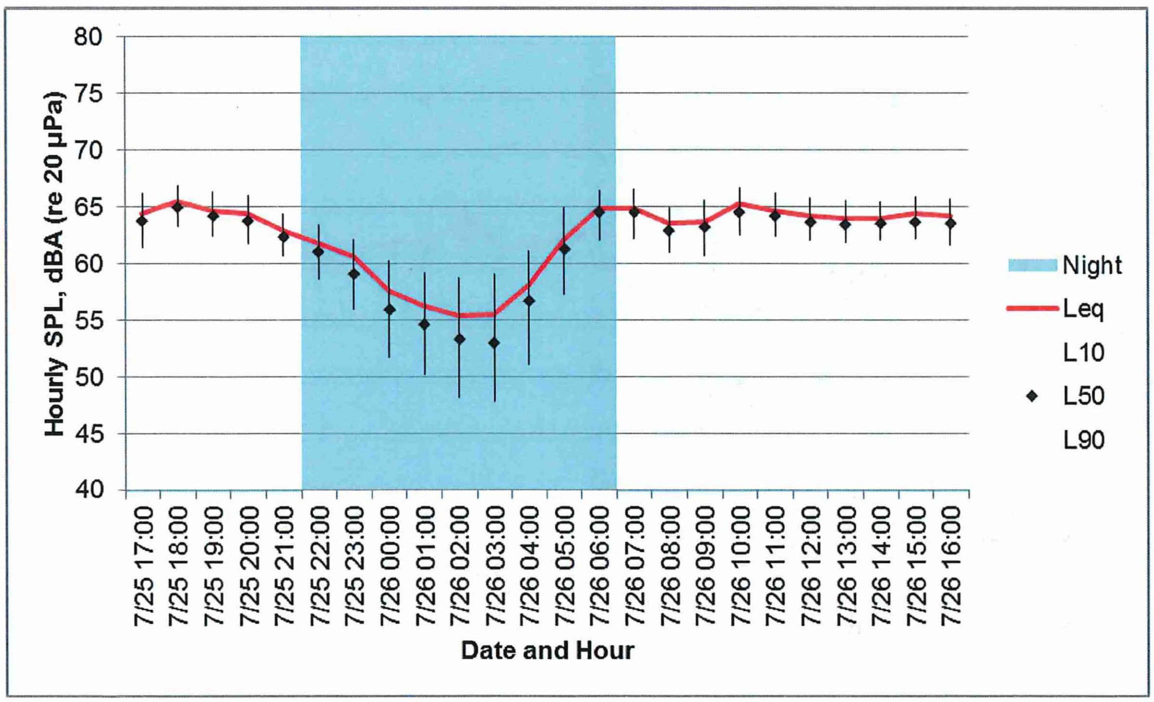


Figure C-12 illustrates measured post-construction hourly noise levels at D3.

Figure C-12. Post-construction Measured Hourly Noise Levels at D3

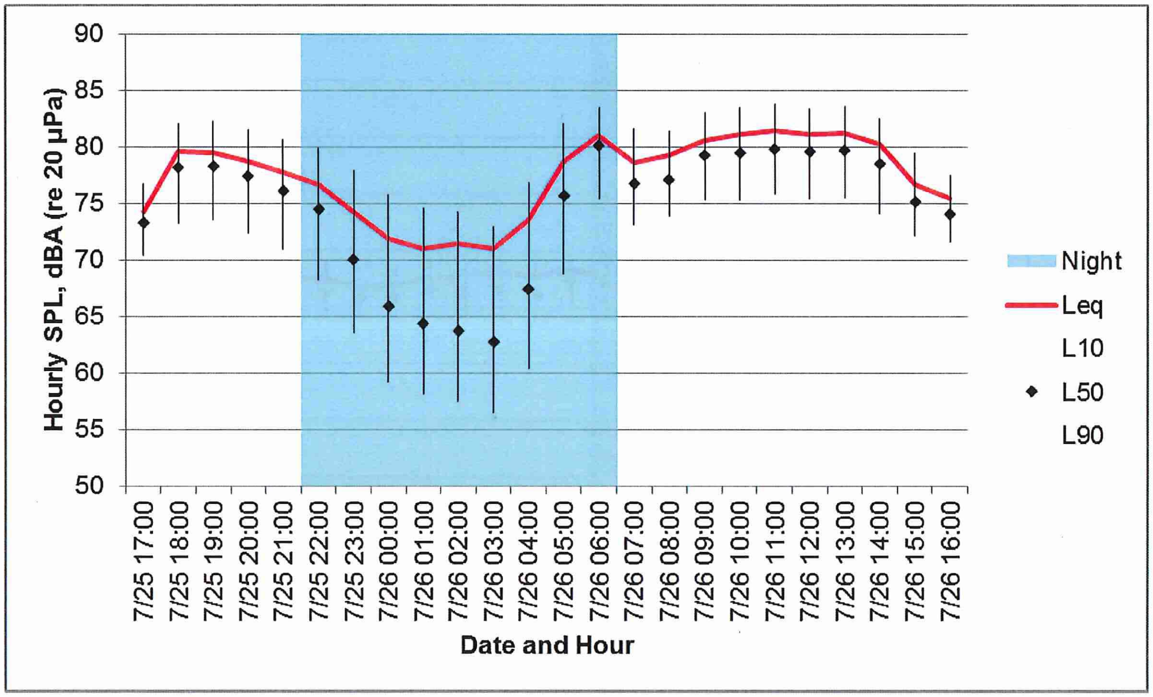


Figure C-13 illustrates measured post-construction hourly noise levels at D5.

Figure C-13. Post-construction Measured Hourly Noise Levels at D5

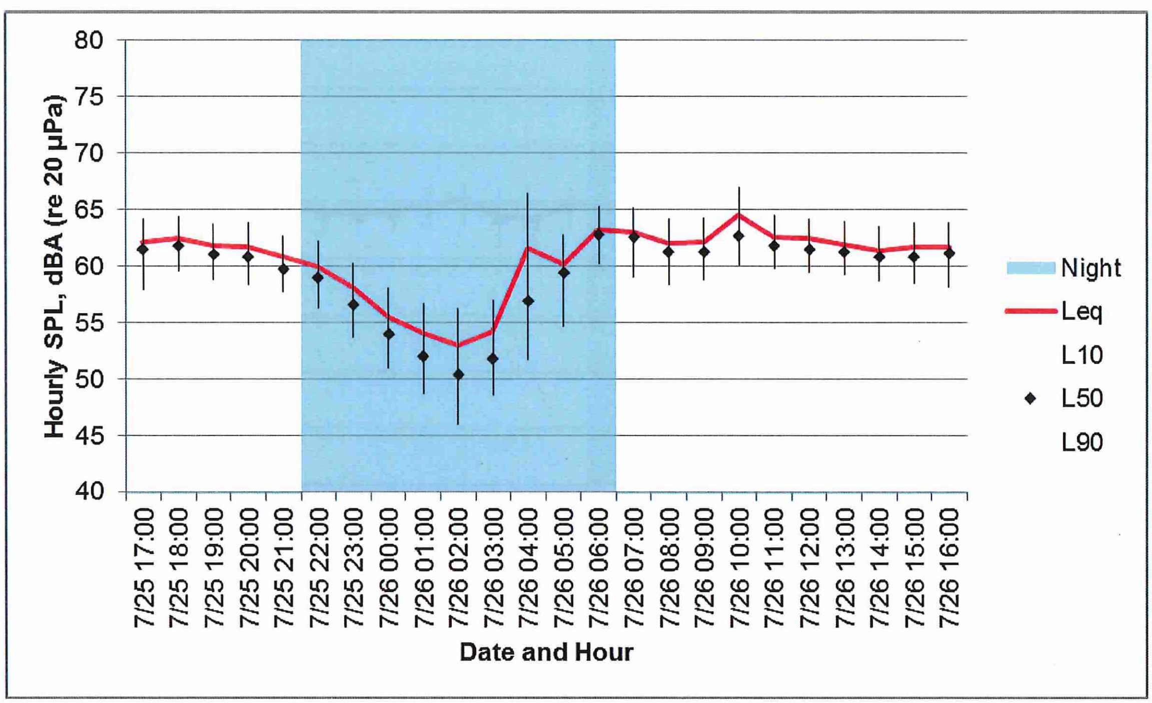


Figure C-14 illustrates measured post-construction hourly noise levels at E1.

Figure C-14. Post-construction Measured Hourly Noise Levels at E1

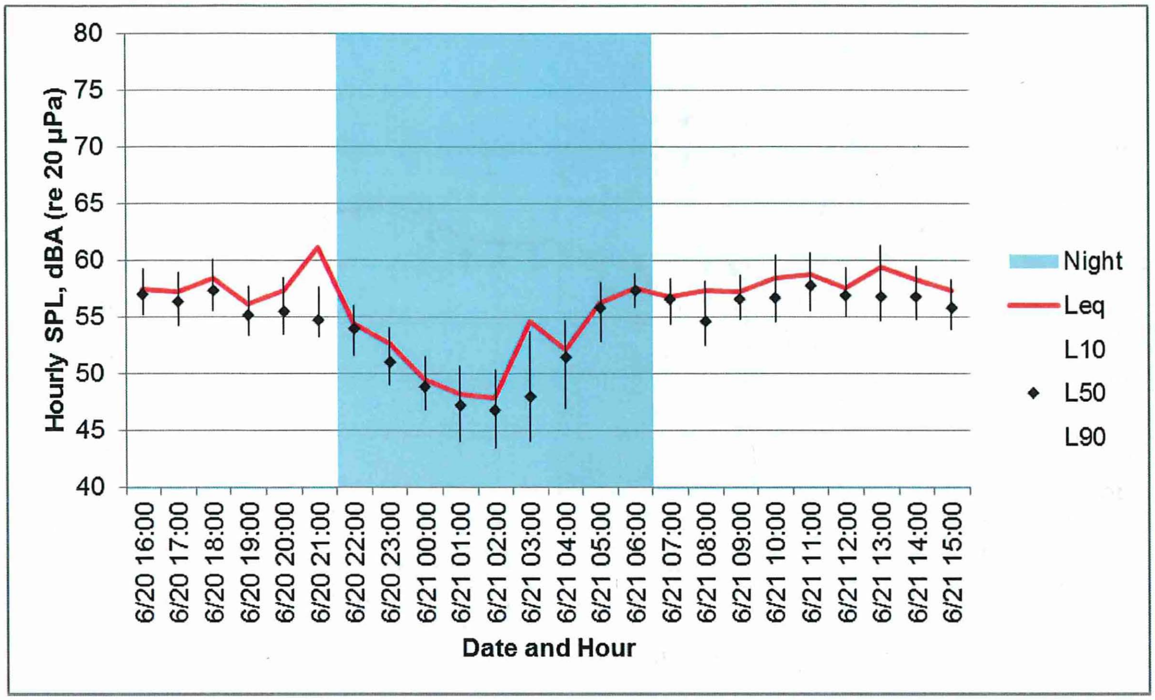


Figure C-15 illustrates measured post-construction hourly noise levels at E2.

Figure C-15. Post-construction Measured Hourly Noise Levels at E2

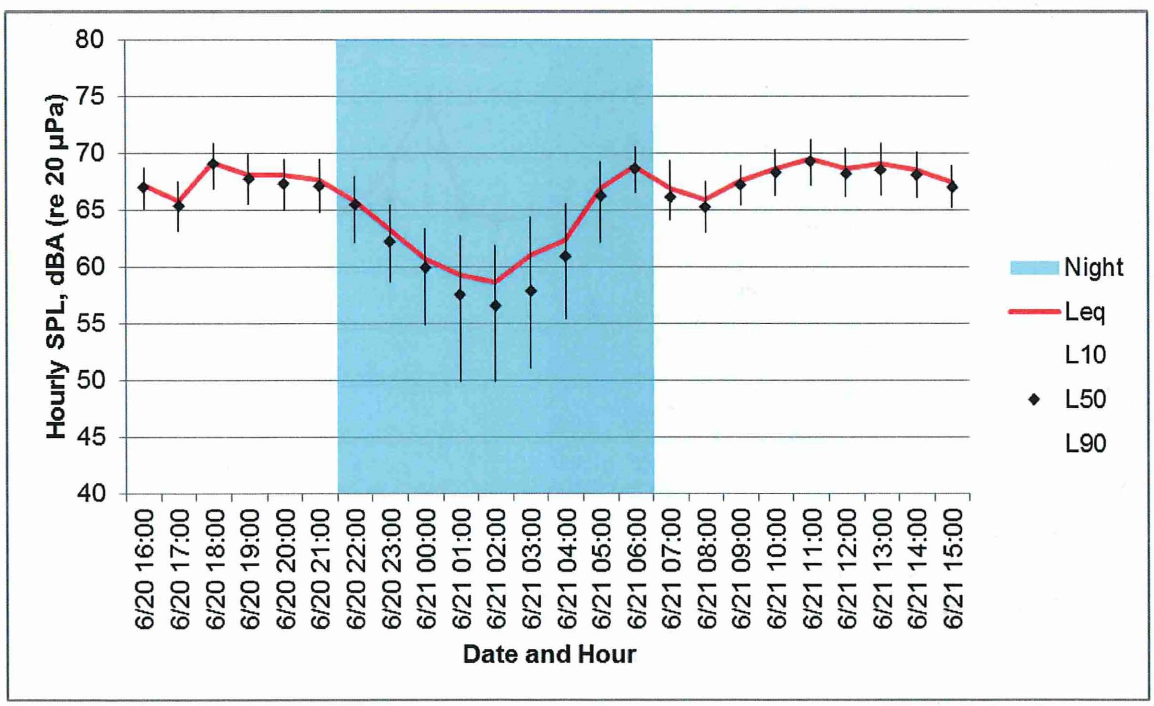


Figure C-16 illustrates measured post-construction hourly noise levels at E3.

Figure C-16. Post-construction Measured Hourly Noise Levels at E3

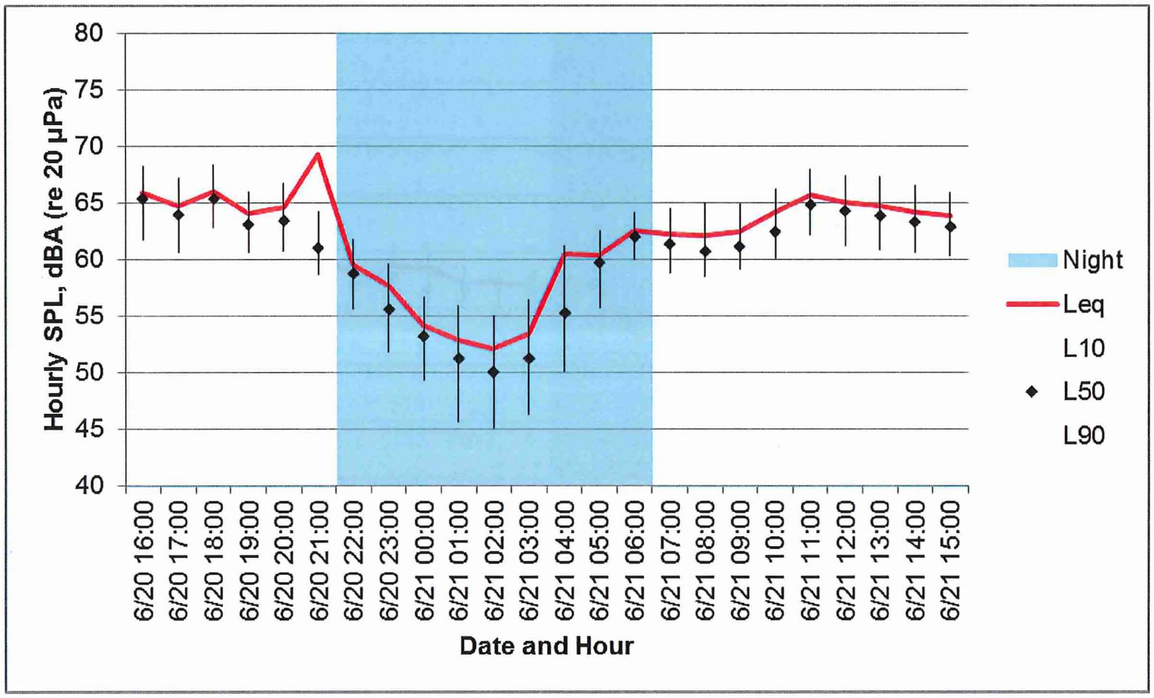
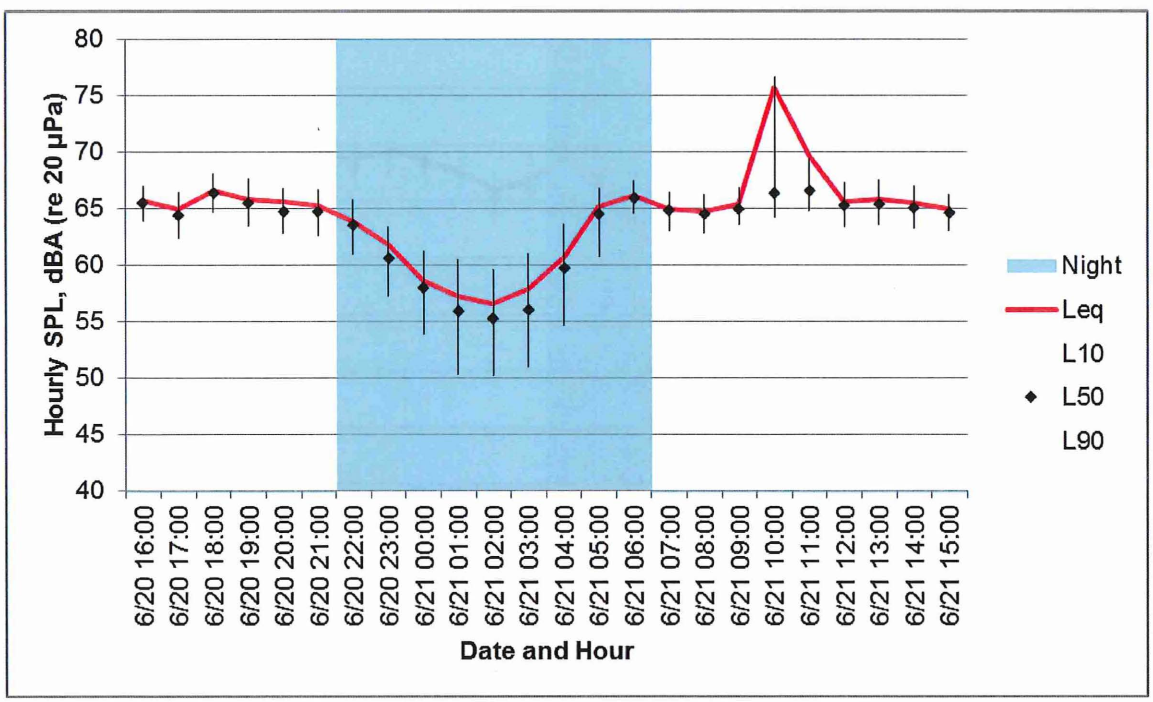


Figure C-17 illustrates measured post-construction hourly noise levels at E4.

Figure C-17. Post-construction Measured Hourly Noise Levels at E4



Appendix D. Noise Measurement Spectral Data

Figure D-1 shows measured pre-construction and post-construction spectral noise levels at A4.

Figure D-1. Measured Spectral Noise Levels at A4

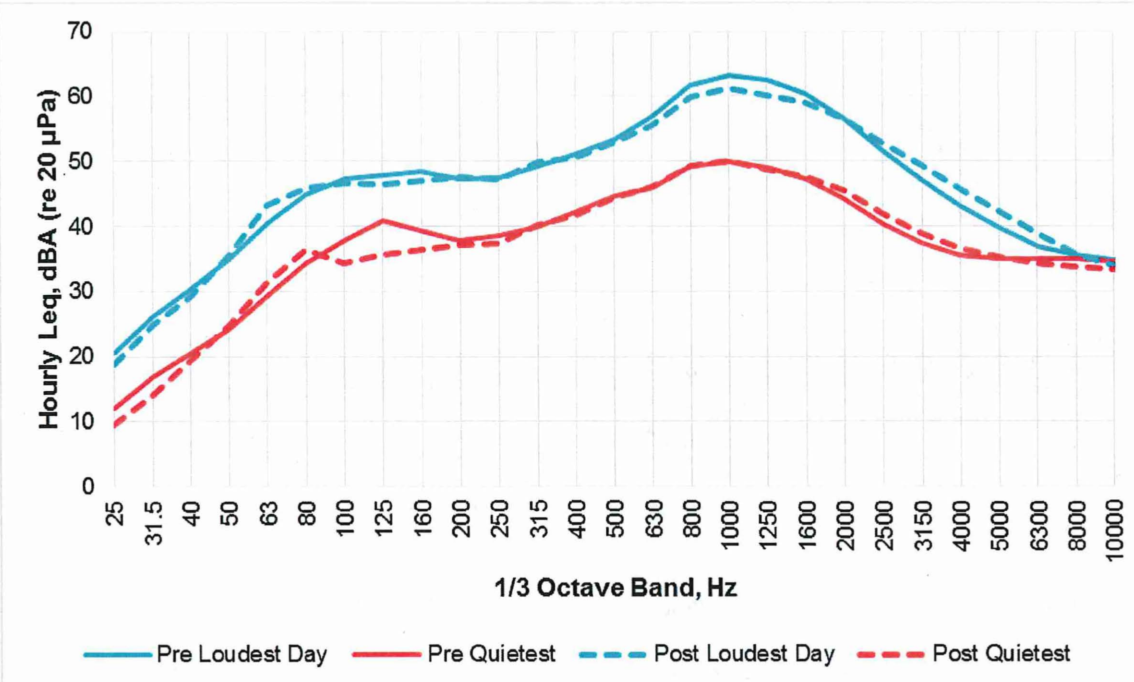


Figure D-2 shows measured pre-construction and post-construction spectral noise levels at C2.

Figure D-2. Measured Spectral Noise Levels at C2

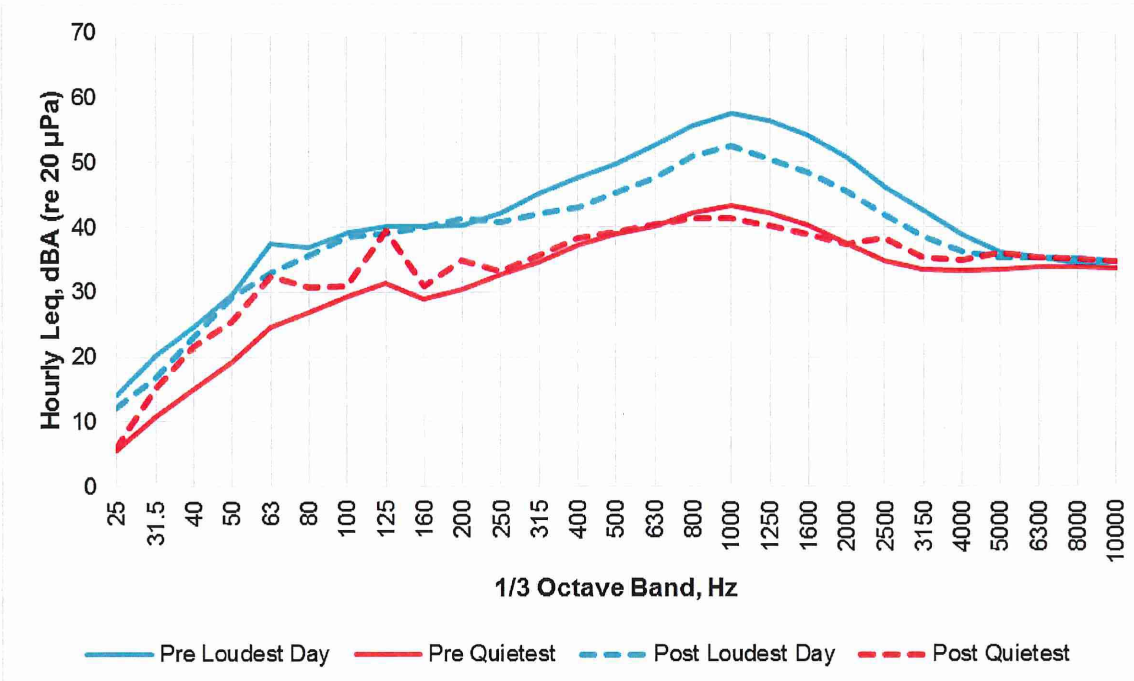
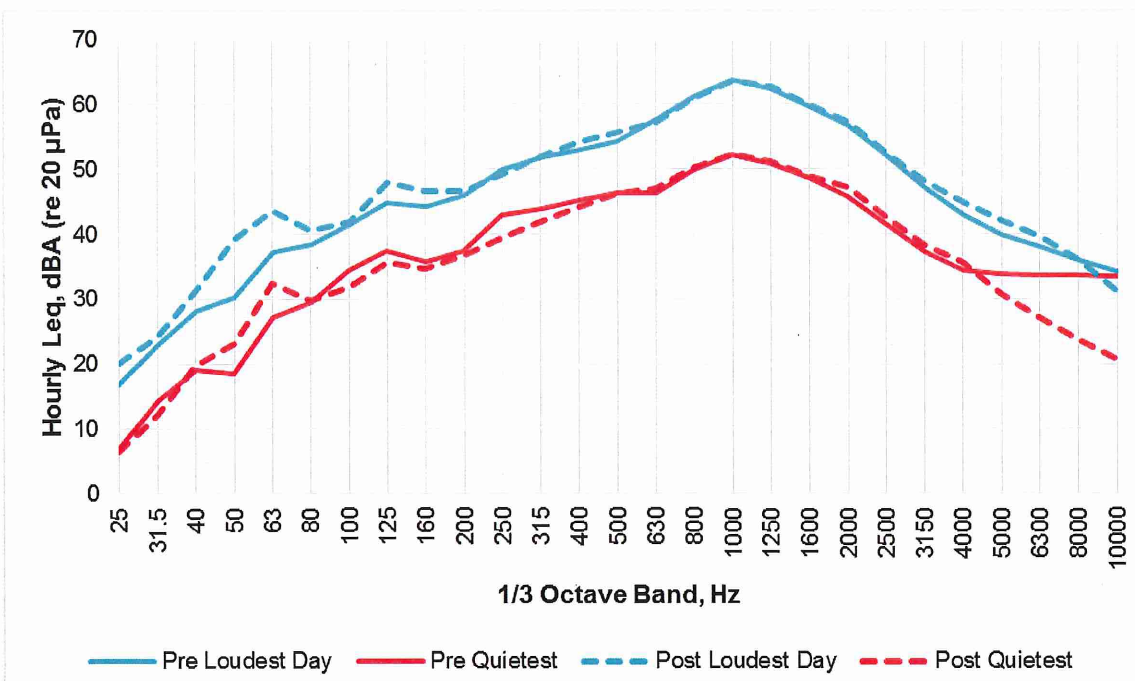


Figure D-3 shows measured pre-construction and post-construction spectral noise levels at E2.

Figure D-3. Measured Spectral Noise Levels at E2



Appendix E. Pre-construction Traffic Data

The following tables use color shading to differentiate between eastbound lanes (EB), westbound lanes (WB), and the high-occupancy toll lanes (HOT). The colors designate each set of lanes as follows.

EB
WB
HOT

The following tables represent traffic during target hours measured during the pre-construction phase of the resurfacing project.

6/8/15 - 12 PM to 1 PM

	788 Volume 6/8/15	789 Volume 6/8/15	790 Volume 6/8/15	791 Volume 6/8/15	792 Volume 6/8/15	793 Volume 6/8/15	794 Volume 6/8/15	795 Volume 6/8/15
12:15 PM	353	381	251	33	23	316	346	298
Medium Truck		21		1			17	
Heavy Truck		31		0			21	
Bus		3		1			4	
Motorcycle		0		3			5	
Pass. Veh.		930		51			913	
12:30 PM	356	409	245	56	29	303	354	307
Medium Truck		17		4			23	
Heavy Truck		23		0			27	
Bus		2		2			4	
Motorcycle		0		2			2	
Pass. Veh.		968		77			908	
12:45 PM	381	421	290	50	33	296	348	313
Medium Truck		25		2			27	
Heavy Truck		33		0			34	
Bus		0		2			2	
Motorcycle		1		1			3	
Pass. Veh.		1033		78			891	
1:00 PM	386	454	294	37	21	315	358	298
Medium Truck		23		1			26	
Heavy Truck		26		0			35	
Bus		0		1			4	
Motorcycle		1		3			5	
Pass. Veh.		1084		53			901	

6/9/15 - 3 AM to 4 AM

	788 Volume 6/9/15	789 Volume 6/9/15	790 Volume 6/9/15	791 Volume 6/9/15	792 Volume 6/9/15	793 Volume 6/9/15	794 Volume 6/9/15	795 Volume 6/9/15
3:15 AM	15	20	3	0	3	16	19	2
Medium Truck		4		0			5	
Heavy Truck		1		0			4	
Bus		0		0			0	
Motorcycle		0		1			0	
Pass. Veh.		33		2			28	
3:30 AM	18	31	3	0	1	15	24	4
Medium Truck		1		0			2	
Heavy Truck		2		0			8	
Bus		0		0			0	
Motorcycle		0		0			0	
Pass. Veh.		49		1			33	
3:45 AM	22	18	2	0	0	21	32	9
Medium Truck		2		0			3	
Heavy Truck		3		0			3	
Bus		0		0			0	
Motorcycle		1		0			0	
Pass. Veh.		36		0			56	
4:00 AM	29	29	7	0	2	18	26	8
Medium Truck		6		0			4	
Heavy Truck		7		0			1	
Bus		0		0			0	
Motorcycle		1		1			0	
Pass. Veh.		51		1			47	

6/9/15 - 6 AM to 7 AM

	788 Volume 6/9/15	789 Volume 6/9/15	790 Volume 6/9/15	791 Volume 6/9/15	792 Volume 6/9/15	793 Volume 6/9/15	794 Volume 6/9/15	795 Volume 6/9/15
6:15 AM	178	225	127	30	32	242	276	236
Medium Truck		12		0			19	
Heavy Truck		15		0			18	
Bus		2		6			14	
Motorcycle		1		12			5	
Pass. Veh.		500		44			698	
6:30 AM	250	334	217	65	49	339	295	356
Medium Truck		15		3			17	
Heavy Truck		11		0			10	
Bus		0		11			22	
Motorcycle		1		7			3	
Pass. Veh.		774		93			938	
6:45 AM	359	393	391	107	100	389	375	429
Medium Truck		17		3			26	
Heavy Truck		22		0			31	
Bus		1		16			15	
Motorcycle		1		9			1	
Pass. Veh.		1102		179			1120	
7:00 AM	411	457	454	134	151	378	366	468
Medium Truck		12		7			28	
Heavy Truck		18		0			36	
Bus		0		22			27	
Motorcycle		3		5			4	
Pass. Veh.		1289		251			1117	

6/9/15 - 7 AM to 8 AM

	788 Volume 6/9/15	789 Volume 6/9/15	790 Volume 6/9/15	791 Volume 6/9/15	792 Volume 6/9/15	793 Volume 6/9/15	794 Volume 6/9/15	795 Volume 6/9/15
7:15 AM	445	460	440	170	199	365	363	484
Medium Truck		13		3			30	
Heavy Truck		11		0			15	
Bus		1		21			17	
Motorcycle		2		9			6	
Pass. Veh.		1318		336			1144	
7:30 AM	508	523	548	195	220	386	387	506
Medium Truck		11		6			28	
Heavy Truck		10		0			15	
Bus		0		25			22	
Motorcycle		1		5			7	
Pass. Veh.		1557		379			1207	
7:45 AM	508	511	593	203	265	358	407	527
Medium Truck		8		3			29	
Heavy Truck		8		0			17	
Bus		1		24			12	
Motorcycle		0		9			9	
Pass. Veh.		1595		432			1225	
8:00 AM	460	485	569	205	274	354	392	481
Medium Truck		10		2			33	
Heavy Truck		15		0			19	
Bus		0		20			3	
Motorcycle		1		8			9	
Pass. Veh.		1488		449			1163	

6/10/15 - 3 AM to 4 AM

	788 Volume 6/10/15	789 Volume 6/10/15	790 Volume 6/10/25	791 Volume 6/10/15	792 Volume 6/10/15	793 Volume 6/10/15	794 Volume 6/10/15	795 Volume 6/10/15
3:15 AM	26	25	8	2	2	24	23	4
Medium Truck		7		0			6	
Heavy Truck		2		0			11	
Bus		1		0			0	
Motorcycle		3		2			0	
Pass. Veh.		46		2			34	
3:30 AM	12	23	3	0	0	19	28	6
Medium Truck		4		0			1	
Heavy Truck		4		0			2	
Bus		0		0			0	
Motorcycle		0		0			0	
Pass. Veh.		30		0			50	
3:45 AM	22	26	4	1	1	20	23	6
Medium Truck		5		0			0	
Heavy Truck		4		0			7	
Bus		0		0			0	
Motorcycle		2		0			0	
Pass. Veh.		41		2			42	
4:00 AM	26	28	4	0	1	24	27	6
Medium Truck		6		0			4	
Heavy Truck		2		0			5	
Bus		0		0			0	
Motorcycle		1		0			1	
Pass. Veh.		49		1			47	

6/10/15 - 6 AM to 7 AM

	788 Volume 6/10/15	789 Volume 6/10/15	790 Volume 6/10/15	791 Volume 6/10/15	792 Volume 6/10/15	793 Volume 6/10/15	794 Volume 6/10/15	795 Volume 6/10/15
6:15 AM	182	207	125	38	27	239	258	223
Medium Truck		7		0			15	
Heavy Truck		13		0			25	
Bus		2		5			15	
Motorcycle		2		6			5	
Pass. Veh.		490		54			660	
6:30 AM	292	302	216	54	59	332	318	335
Medium Truck		13		1			20	
Heavy Truck		11		0			27	
Bus		0		8			16	
Motorcycle		3		11			4	
Pass. Veh.		783		93			918	
6:45 AM	354	405	363	98	104	392	362	401
Medium Truck		19		0			20	
Heavy Truck		23		0			36	
Bus		1		17			15	
Motorcycle		2		9			9	
Pass. Veh.		1077		176			1075	
7:00 AM	399	470	421	140	135	344	366	445
Medium Truck		12		4			16	
Heavy Truck		18		0			32	
Bus		0		20			23	
Motorcycle		2		5			5	
Pass. Veh.		1258		246			1079	

6/10/15 - 8 AM to 9 AM

	788 Volume 6/10/15	789 Volume 6/10/15	790 Volume 6/10/15	791 Volume 6/10/15	792 Volume 6/10/15	793 Volume 6/10/15	794 Volume 6/10/15	795 Volume 6/10/15
8:15 AM	474	475	538	178	259	369	392	498
Medium Truck		12		4			30	
Heavy Truck		15		1			37	
Bus		1		28			9	
Motorcycle		3		4			4	
Pass. Veh.		1456		400			1179	
8:30 AM	466	443	530	169	256	363	411	525
Medium Truck		10		6			24	
Heavy Truck		27		1			27	
Bus		1		19			8	
Motorcycle		0		8			12	
Pass. Veh.		1401		391			1228	
8:45 AM	466	450	528	189	238	299	414	493
Medium Truck		15		6			42	
Heavy Truck		17		0			29	
Bus		5		19			5	
Motorcycle		1		4			4	
Pass. Veh.		1406		398			1126	
9:00 AM	451	450	482	167	212	307	381	484
Medium Truck		15		8			35	
Heavy Truck		22		0			36	
Bus		8		7			12	
Motorcycle		0		6			9	
Pass. Veh..		1338		358			1080	

Appendix F. Post-construction Traffic Data

The following tables use color shading to differentiate between eastbound lanes (EB), westbound lanes (WB), and the high-occupancy toll lanes (HOT). The colors designate each set of lanes as follows.

EB
WB
HOT

The following tables represent traffic during target hours measured during the post-construction phase of the resurfacing project.

6/10/16 - 3 AM to 4 AM

	788 Volume 6/10/16	789 Volume 6/10/16	790 Volume 6/10/16	791 Volume 6/10/16	792 Volume 6/10/16	793 Volume 6/10/16	794 Volume 6/10/16	795 Volume 6/10/16
3:15 AM	32	22	6	0	1	18	25	4
Medium Truck		4		0			5	
Heavy Truck		4		0			7	
Bus		0		0			0	
Motorcycle		0		0			0	
Pass. Veh.		52		1			35	
3:30 AM	35	20	6	0	0	15	29	5
Medium Truck		2		0			4	
Heavy Truck		4		0			4	
Bus		0		0			0	
Motorcycle		0		0			1	
Pass. Veh.		55		0			40	
3:45 AM	39	23	10	1	3	22	28	8
Medium Truck		5		0			3	
Heavy Truck		1		0			2	
Bus		0		0			0	
Motorcycle		0		0			1	
Pass. Veh.		66		4			52	
4:00 AM	35	29	7	2	0	25	28	13
Medium Truck		2		0			1	
Heavy Truck		2		0			11	
Bus		0		0			0	
Motorcycle		1		0			0	
Pass. Veh.		66		2			54	

6/10/16 - 6 AM to 7 AM

	788 Volume 6/10/16	789 Volume 6/10/16	790 Volume 6/10/16	791 Volume 6/10/16	792 Volume 6/10/16	793 Volume 6/10/16	794 Volume 6/10/16	795 Volume 6/10/16
6:15 AM	231	172	113	24	26	208	239	191
Medium Truck		12		0			12	
Heavy Truck		13		0			18	
Bus		3		6			14	
Motorcycle		1		2			0	
Pass. Veh.		487		42			594	
6:30 AM	316	262	225	68	50	314	310	293
Medium Truck		12		1			26	
Heavy Truck		23		0			25	
Bus		6		13			18	
Motorcycle		1		6			1	
Pass. Veh.		761		98			847	
6:45 AM	389	312	322	86	97	350	333	371
Medium Truck		8		4			23	
Heavy Truck		16		1			25	
Bus		1		16			13	
Motorcycle		0		8			2	
Pass. Veh.		998		154			991	
7:00 AM	433	424	367	121	120	299	315	397
Medium Truck		9		1			22	
Heavy Truck		12		0			36	
Bus		0		25			19	
Motorcycle		2		3			6	
Pass. Veh.		1201		212			928	

6/10/16 - 7 AM to 8 AM

	788 Volume 6/10/16	789 Volume 6/10/16	790 Volume 6/10/16	791 Volume 6/10/16	792 Volume 6/10/16	793 Volume 6/10/16	794 Volume 6/10/16	795 Volume 6/10/16
7:15 AM	454	411	448	155	154	308	376	418
Medium Truck		16		5			26	
Heavy Truck		11		0			25	
Bus		1		22			19	
Motorcycle		2		7			3	
Pass. Veh.		1283		275			1029	
7:30 AM	506	446	465	149	196	333	386	502
Medium Truck		12		7			40	
Heavy Truck		14		0			24	
Bus		1		21			19	
Motorcycle		0		3			2	
Pass. Veh.		1390		314			1136	
7:45 AM	542	474	553	192	216	289	386	468
Medium Truck		12		6			27	
Heavy Truck		11		1			25	
Bus		1		28			15	
Motorcycle		0		6			3	
Pass. Veh.		1545		367			1073	
8:00 AM	481	454	478	214	242	320	387	491
Medium Truck		8		8			19	
Heavy Truck		23		1			24	
Bus		0		19			12	
Motorcycle		0		4			4	
Pass. Veh.		1382		424			1139	

6/17/16 - 3 AM to 4 AM

	788 Volume 6/17/16	789 Volume 6/17/16	790 Volume 6/17/16	791 Volume 6/17/16	792 Volume 6/17/16	793 Volume 6/17/16	794 Volume 6/17/16	795 Volume 6/17/16
3:15 AM	32	20	11	0	2	15	26	5
Medium Truck		4		0			1	
Heavy Truck		3		0			2	
Bus		0		0			0	
Motorcycle		0		0			0	
Pass. Veh.		56		2			43	
3:30 AM	28	25	14	0	3	17	29	10
Medium Truck		1		0			0	
Heavy Truck		5		0			2	
Bus		0		0			0	
Motorcycle		0		0			1	
Pass. Veh.		61		3			53	
3:45 AM	47	19	12	0	1	6	48	10
Medium Truck		4		0			2	
Heavy Truck		2		0			5	
Bus		0		0			0	
Motorcycle		0		0			0	
Pass. Veh.		72		1			57	
4:00 AM	35	35	10	0	1	24	41	15
Medium Truck		6		0			3	
Heavy Truck		6		0			3	
Bus		0		0			0	
Motorcycle		1		1			0	
Pass. Veh.		67		0			74	

6/17/16 - 6 AM to 7 AM

	788 Volume 6/17/16	789 Volume 6/17/16	790 Volume 6/17/16	791 Volume 6/17/16	792 Volume 6/17/16	793 Volume 6/17/16	794 Volume 6/17/16	795 Volume 6/17/16
6:15 AM	237	155	105	19	29	223	230	197
Medium Truck		8		0			14	
Heavy Truck		20		0			24	
Bus		0		6			12	
Motorcycle		1		4			0	
Pass. Veh.		468		38			600	
6:30 AM	311	250	198	55	45	290	294	292
Medium Truck		10		0			19	
Heavy Truck		29		0			22	
Bus		0		10			17	
Motorcycle		2		10			2	
Pass. Veh.		718		80			816	
6:45 AM	354	321	325	101	88	333	362	386
Medium Truck		9		7			14	
Heavy Truck		26		0			37	
Bus		0		15			19	
Motorcycle		2		11			8	
Pass. Veh.		963		156			1003	
7:00 AM	442	408	403	125	116	336	378	457
Medium Truck		10		1			23	
Heavy Truck		20		1			31	
Bus		1		21			19	
Motorcycle		3		5			6	
Pass. Veh.		1219		213			1092	

6/17/16 - 7 AM to 8 AM

	788 Volume 6/17/16	789 Volume 6/17/16	790 Volume 6/17/16	791 Volume 6/17/16	792 Volume 6/17/16	793 Volume 6/17/16	794 Volume 6/17/16	795 Volume 6/17/16
7:15 AM	407	378	394	164	169	354	358	469
Medium Truck	23			6		26		
Heavy Truck	20			0		28		
Bus	0			18		10		
Motorcycle	0			10		8		
Pass. Veh.	1136			299		1109		
7:30 AM	491	441	489	145	210	348	399	495
Medium Truck	11			3		26		
Heavy Truck	18			0		37		
Bus	1			25		19		
Motorcycle	1			3		6		
Pass. Veh.	1390			324		1154		
7:45 AM	485	415	502	203	254	350	427	522
Medium Truck	10			13		28		
Heavy Truck	11			0		29		
Bus	0			24		19		
Motorcycle	0			7		5		
Pass. Veh.	1381			413		1218		
8:00 AM	476	413	477	211	253	309	405	472
Medium Truck	13			8		20		
Heavy Truck	19			0		26		
Bus	0			24		7		
Motorcycle	1			4		8		
Pass. Veh.	1333			428		1125		

6/21/16 - 2 AM to 3 AM

	788 Volume 6/21/16	789 Volume 6/21/16	790 Volume 6/21/16	791 Volume 6/21/16	792 Volume 6/21/16	793 Volume 6/21/16	794 Volume 6/21/16	795 Volume 6/21/16
2:15 AM	41	19	12	1	1	23	30	6
Medium Truck		1		0			2	
Heavy Truck		2		0			5	
Bus		0		0			0	
Motorcycle		0		0			0	
Pass. Veh.		69		2			52	
2:30 AM	26	27	6	2	1	22	38	4
Medium Truck		2		0			1	
Heavy Truck		1		0			3	
Bus		0		0			0	
Motorcycle		0		0			0	
Pass. Veh.		56		3			60	
2:45 AM	34	23	4	1	3	18	37	3
Medium Truck		5		0			2	
Heavy Truck		4		0			7	
Bus		0		0			0	
Motorcycle		0		1			0	
Pass. Veh.		52		3			49	
3:00 AM	15	22	4	1	0	30	27	6
Medium Truck		2		0			2	
Heavy Truck		7		0			4	
Bus		0		0			0	
Motorcycle		0		0			0	
Pass. Veh.		32		1			57	

6/21/16 - 6 AM to 7 AM

	788 Volume 6/21/16	789 Volume 6/21/16	790 Volume 6/21/16	791 Volume 6/21/16	792 Volume 6/21/16	793 Volume 6/21/16	794 Volume 6/21/16	795 Volume 6/21/16
6:15 AM	241	174	131	48	30	152	324	284
Medium Truck		12		1			15	
Heavy Truck		20		0			16	
Bus		0		6			9	
Motorcycle		1		6			2	
Pass. Veh.		513		65			718	
6:30 AM	324	262	204	43	42	299	311	303
Medium Truck		7		2			17	
Heavy Truck		25		0			22	
Bus		1		10			21	
Motorcycle		6		5			0	
Pass. Veh.		751		68			853	
6:45 AM	397	334	335	111	100	359	391	440
Medium Truck		19		5			27	
Heavy Truck		26		0			24	
Bus		1		16			15	
Motorcycle		3		9			7	
Pass. Veh.		1017		181			1117	
7:00 AM	426	402	420	148	148	340	374	519
Medium Truck		15		4			26	
Heavy Truck		18		0			28	
Bus		1		18			14	
Motorcycle		1		6			7	
Pass. Veh.		1213		268			1158	

6/21/15 - 11 AM to 12 PM

	788 Volume 6/21/16	789 Volume 6/21/16	790 Volume 6/21/16	791 Volume 6/21/16	792 Volume 6/21/16	793 Volume 6/21/16	794 Volume 6/21/16	795 Volume 6/21/16
11:15 AM	371	364	232	42	39	279	353	313
Medium Truck		23		4			27	
Heavy Truck		26		0			24	
Bus		0		1			1	
Motorcycle		0		3			7	
Pass. Veh.		918		73			886	
11:30 AM	403	420	221	43	33	311	357	321
Medium Truck		17		4			14	
Heavy Truck		25		0			23	
Bus		2		0			3	
Motorcycle		2		1			2	
Pass. Veh.		998		71			947	
11:45 AM	409	438	279	53	56	342	375	318
Medium Truck		25		4			26	
Heavy Truck		22		1			24	
Bus		0		2			2	
Motorcycle		2		2			4	
Pass. Veh.		1077		100			979	
Noon	420	434	236	44	42	325	350	294
Medium Truck		16		3			32	
Heavy Truck		31		0			17	
Bus		3		0			3	
Motorcycle		2		2			4	
Pass. Veh.		1038		81			913	

7/25/16 - 6 PM to 7 PM

	788 Volume 7/25/16	789 Volume 7/25/16	790 Volume 7/25/16	791 Volume 7/25/16	792 Volume 7/25/16	793 Volume 7/25/16	794 Volume 7/25/16	795 Volume 7/25/16
6:15 PM	404	385	387	87	155	275	314	340
Medium Truck		7		2			9	
Heavy Truck		2		0			3	
Bus		8		12			0	
Motorcycle		2		3			1	
Pass. Veh.		1157		225			916	
6:30 PM	415	391	321	79	129	254	329	318
Medium Truck		10		1			10	
Heavy Truck		6		1			5	
Bus		11		8			1	
Motorcycle		8		7			4	
Pass. Veh.		1092		191			881	
6:45 PM	346	375	251	57	101	299	327	289
Medium Truck		7		1			4	
Heavy Truck		6		0			10	
Bus		10		3			0	
Motorcycle		4		5			2	
Pass. Veh.		945		149			899	
7:00 PM	327	333	229	31	78	270	317	284
Medium Truck		5		1			5	
Heavy Truck		9		0			3	
Bus		4		1			0	
Motorcycle		5		2			2	
Pass. Veh.		866		105			861	

7/26/16 - 2 AM to 3 AM

	788 Volume 7/26/16	789 Volume 7/26/16	790 Volume 7/26/16	791 Volume 7/26/16	792 Volume 7/26/16	793 Volume 7/26/16	794 Volume 7/26/16	795 Volume 7/26/16
2:15 AM	32	28	8	1	3	30	33	12
Medium Truck		1		1			4	
Heavy Truck		7		0			7	
Bus		0		0			0	
Motorcycle		0		1			0	
Pass. Veh.		60		2			64	
2:30 AM	30	25	5	1	0	18	34	8
Medium Truck		2		0			4	
Heavy Truck		3		0			5	
Bus		0		0			1	
Motorcycle		0		0			0	
Pass. Veh.		55		1			50	
2:45 AM	24	29	4	0	1	28	33	10
Medium Truck		2		0			1	
Heavy Truck		8		0			4	
Bus		0		0			0	
Motorcycle		0		0			1	
Pass. Veh.		47		1			65	
3:00 AM	24	24	11	0	0	25	35	9
Medium Truck		3		0			2	
Heavy Truck		6		0			7	
Bus		0		0			0	
Motorcycle		0		0			0	
Pass. Veh.		50		0			60	

7/26/16 - 6 AM to 7 AM

	788 Volume 7/26/16	789 Volume 7/26/16	790 Volume 7/26/16	791 Volume 7/26/16	792 Volume 7/26/16	793 Volume 7/26/16	794 Volume 7/26/16	795 Volume 7/26/16
6:15 AM	243	181	123	37	48	223	271	213
Medium Truck		7		0			16	
Heavy Truck		14		0			19	
Bus		0		6			12	
Motorcycle		0		5			2	
Pass. Veh.		526		74			658	
6:30 AM	319	275	234	63	51	308	313	319
Medium Truck		5		1			20	
Heavy Truck		20		0			12	
Bus		0		11			17	
Motorcycle		1		7			1	
Pass. Veh.		802		95			890	
6:45 AM	380	315	350	98	91	379	364	398
Medium Truck		9		1			26	
Heavy Truck		21		0			19	
Bus		2		17			12	
Motorcycle		2		10			2	
Pass. Veh.		1011		161			1082	
7:00 AM	448	402	432	131	132	364	384	473
Medium Truck		14		1			26	
Heavy Truck		11		0			29	
Bus		1		17			19	
Motorcycle		0		2			5	
Pass. Veh.		1256		243			1142	

Appendix G. Detailed Pre-construction Traffic Noise Modeling Results

The following tables contain modeled noise levels for each pre-construction target hour. Because the measurements occurred over several days, only certain target hours apply to each receiver. These modeled noise levels were used to normalize the measured noise levels.

	6/8/15 – 12 PM to 1 PM				
RECEIVER	$L_{eq(h)}$, dBA	SIG, dBA	L_{10}, dBA	L_{50}, dBA	L_{90}, dBA
B1	74.2	3.5	77.3	72.8	68.3
B2	63.2	1.5	64.9	63.0	61.1
B3	70.9	2.6	73.5	70.1	66.7
B4	63.3	1.5	65.0	63.1	61.2
B5	70.5	2.5	73.0	69.8	66.5
E1	58.6	1.1	59.9	58.5	57.1
E2	66.3	1.8	68.2	65.9	63.6
E3	69.9	2.5	72.4	69.2	66.1
E4	65.7	1.9	67.7	65.3	62.9
E5	67.1	2.1	69.2	66.6	63.9

	6/9/15 – 3 AM to 4 AM				
RECEIVER	$L_{eq(h)}$, dBA	SIG, dBA	L_{10}, dBA	L_{50}, dBA	L_{90}, dBA
B1	63.6	7.4	66.8	57.4	47.9
B2	52.4	4.7	55.9	49.9	43.9
B3	60.2	6.5	63.7	55.4	47.1
B4	52.5	4.7	56.0	50.0	43.9
B5	59.8	6.4	63.3	55.1	47.0
E1	47.8	3.9	51.0	46.0	41.0
E2	55.4	5.3	58.9	52.1	45.3
E3	59.0	6.3	62.5	54.5	46.4
E4	54.8	5.4	58.3	51.4	44.4
E5	56.1	5.7	59.7	52.4	45.1

	6/9/15 – 6 AM to 7 AM				
RECEIVER	**$L_{eq(h)}$, dBA**	**SIG, dBA**	**L_{10}, dBA**	**L_{50}, dBA**	**L_{90}, dBA**
B1	74.0	3.4	77.0	72.6	68.2
B2	62.9	1.4	64.5	62.6	60.8
B3	70.6	2.6	73.2	69.8	66.5
B4	63.0	1.4	64.6	62.7	60.9
B5	70.2	2.5	72.7	69.5	66.3
E1	58.2	1.1	59.4	58.0	56.7
E2	65.7	1.7	67.6	65.4	63.2
E3	69.3	2.3	71.7	68.7	65.7
E4	65.1	1.8	67.0	64.8	62.5
E5	66.5	1.9	68.6	66.1	63.6

	6/9/15 – 7 AM to 8 AM				
RECEIVER	**$L_{eq(h)}$, dBA**	**SIG, dBA**	**L_{10}, dBA**	**L_{50}, dBA**	**L_{90}, dBA**
B1	74.8	2.9	77.5	73.8	70.1
B2	63.8	1.1	65.1	63.7	62.3
B3	71.5	2.1	73.7	71.0	68.3
B4	63.9	1.1	65.2	63.8	62.4
B5	71.1	2.0	73.2	70.6	68.1
E1	59.2	0.8	60.2	59.2	58.2
E2	66.8	1.2	68.3	66.7	65.1
E3	70.5	1.7	72.3	70.2	68.0
E4	66.2	1.3	67.7	66.0	64.4
E5	67.6	1.4	69.2	67.4	65.6

	6/10/15 – 3 AM to 4 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
A1	59.3	6.0	62.9	55.1	47.4
A2	56.2	5.3	59.7	53.0	46.2
A3	58.9	5.8	62.4	55.0	47.6
A4	60.9	6.3	64.4	56.4	48.3
A5	57.7	5.5	61.3	54.2	47.2
C1	59.2	5.9	62.8	55.2	47.7
C2	57.3	5.4	60.8	53.9	47.0
C3	61.8	6.5	65.3	57.0	48.7
C4	62.2	6.6	65.7	57.2	48.8
C5	62.6	6.8	66.0	57.4	48.7
D1	59.9	6.0	63.5	55.8	48.2
D2	59.0	5.8	62.6	55.2	47.8
D3	69.2	8.4	71.8	61.1	50.3
D4	60.2	6.1	63.7	55.9	48.2
D5	60.9	6.2	64.4	56.4	48.4

	6/10/15 – 6 AM to 7 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
A1	69.0	2.4	71.4	68.3	65.2
A2	65.8	1.9	67.9	65.4	63.0
A3	68.5	2.2	70.8	67.9	65.0
A4	70.5	2.6	73.1	69.7	66.4
A5	67.3	2.0	69.4	66.9	64.3
C1	68.8	2.2	71.1	68.2	65.4
C2	66.8	1.9	68.8	66.4	64.0
C3	71.3	2.7	73.9	70.5	67.1
C4	71.8	2.8	74.4	70.9	67.4
C5	72.1	2.9	74.9	71.2	67.4
D1	69.5	2.3	71.8	68.9	66.0
D2	68.6	2.1	70.8	68.1	65.4
D3	78.6	4.8	82.1	76.0	69.9
D4	69.7	2.3	72.1	69.1	66.1
D5	70.4	2.5	72.9	69.7	66.6

	6/10/15 – 8 AM to 9 AM				
RECEIVER	**$L_{eq(h)}$, dBA**	**SIG, dBA**	**L_{10}, dBA**	**L_{50}, dBA**	**L_{90}, dBA**
A1	70.4	2.0	72.5	69.9	67.3
A2	67.3	1.6	69.0	67.0	65.0
A3	69.9	1.9	71.9	69.5	67.1
A4	71.9	2.2	74.2	71.3	68.5
A5	68.8	1.7	70.6	68.4	66.3
C1	70.3	1.8	72.2	70.0	67.7
C2	68.4	1.5	70.0	68.1	66.2
C3	72.9	2.1	75.1	72.4	69.7
C4	73.4	2.2	75.7	72.8	70.0
C5	73.7	2.3	76.1	73.1	70.1
D1	71.0	1.8	73.0	70.7	68.3
D2	70.2	1.7	72.0	69.8	67.7
D3	80.2	4.0	83.5	78.3	73.1
D4	71.3	1.9	73.3	70.9	68.5
D5	72.0	2.0	74.1	71.5	69.0

Appendix H. Detailed Post-construction Traffic Noise Modeling Results

The following tables contain modeled noise levels for each post-construction target hour. Because the measurements occurred over several days, only certain target hours apply to each receiver. These modeled noise levels were used to normalize the measured noise levels.

	6/10/16 – 3 AM to 4 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
B2	53.1	4.5	56.6	50.8	45.0
B3	60.9	6.3	64.4	56.3	48.2
B4	53.2	4.5	56.7	50.8	45.0
B5	60.5	6.2	64.0	56.1	48.1

	6/10/16 – 6 AM to 7 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
B2	62.5	1.5	64.2	62.2	60.3
B3	70.3	2.8	72.9	69.4	65.9
B4	62.6	1.5	64.3	62.3	60.4
B5	69.9	2.7	72.5	69.0	65.6

	6/10/16 – 7 AM to 8 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
B2	63.9	1.2	65.2	63.7	62.2
B3	71.5	2.3	73.8	70.9	68.1
B4	64.0	1.2	65.3	63.8	62.2
B5	71.1	2.2	73.4	70.6	67.8

	6/17/16 – 3 AM to 4 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
A1	58.4	5.8	62.0	54.5	47.1
A2	55.4	5.1	58.9	52.5	46.0
A3	58.0	5.6	61.6	54.5	47.3
A4	60.0	6.0	63.5	55.8	48.1
A5	56.9	5.3	60.5	53.7	47.0

	6/17/16 – 6 AM to 7 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
A1	68.9	2.5	71.3	68.1	65.0
A2	65.7	1.9	67.8	65.3	62.8
A3	68.4	2.3	70.7	67.8	64.8
A4	70.4	2.7	73.0	69.6	66.1
A5	67.2	2.1	69.4	66.7	64.0

	6/17/16 – 7 AM to 8 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
A1	70.1	2.0	72.3	69.7	67.0
A2	67.0	1.6	68.7	66.7	64.7
A3	69.6	1.9	71.6	69.2	66.8
A4	71.6	2.2	73.9	71.1	68.2
A5	68.5	1.7	70.3	68.1	66.0

	6/21/16 – 2 AM to 3 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
E1	48.0	3.8	51.2	46.3	41.5
E2	55.6	5.2	59.1	52.5	45.9
E3	59.2	6.1	62.7	54.9	47.0
E4	55.0	5.3	58.5	51.8	45.0

	6/21/16 – 6 AM to 7 AM				
RECEIVER	$L_{eq(h)}$, **dBA**	**SIG, dBA**	L_{10}, **dBA**	L_{50}, **dBA**	L_{90}, **dBA**
E1	58.2	1.1	59.5	58.1	56.6
E2	65.8	1.8	67.7	65.4	63.1
E3	69.4	2.5	71.8	68.7	65.6
E4	65.2	1.9	67.1	64.8	62.4

RECEIVER	6/21/16 – 11 AM to 12 AM				
	$L_{eq(h)}$, dBA	SIG, dBA	L_{10}, dBA	L_{50}, dBA	L_{90}, dBA
E1	58.5	1.1	59.8	58.4	57.0
E2	66.2	1.8	68.1	65.8	63.5
E3	69.8	2.4	72.3	69.2	66.0
E4	65.6	1.8	67.5	65.2	62.8

RECEIVER	7/25/16 – 6 PM to 7 PM				
	$L_{eq(h)}$, dBA	SIG, dBA	L_{10}, dBA	L_{50}, dBA	L_{90}, dBA
C2	65.9	1.6	67.6	65.6	63.6
D1	68.6	1.9	70.6	68.2	65.7
D3	78.0	4.2	81.3	76.0	70.7
D5	69.6	2.1	71.7	69.1	66.4

RECEIVER	7/26/16 – 2 AM to 3 AM				
	$L_{eq(h)}$, dBA	SIG, dBA	L_{10}, dBA	L_{50}, dBA	L_{90}, dBA
C2	57.7	5.3	61.3	54.5	47.8
D1	60.4	5.9	64.0	56.4	48.9
D3	69.8	8.3	72.5	61.8	51.1
D5	61.4	6.2	64.9	57.0	49.1

RECEIVER	7/26/16 – 6 AM to 7 AM				
	$L_{eq(h)}$, dBA	SIG, dBA	L_{10}, dBA	L_{50}, dBA	L_{90}, dBA
C2	66.6	1.9	68.6	66.2	63.8
D1	69.3	2.3	71.6	68.7	65.8
D3	78.4	4.8	81.9	75.8	69.7
D5	70.2	2.5	72.7	69.5	66.3

Appendix I. Normal Quantile-Quantile Plots for Statistical Analysis

Figure I-1. Normal q-q plots for Post-construction Normalized L_{50} Measurements

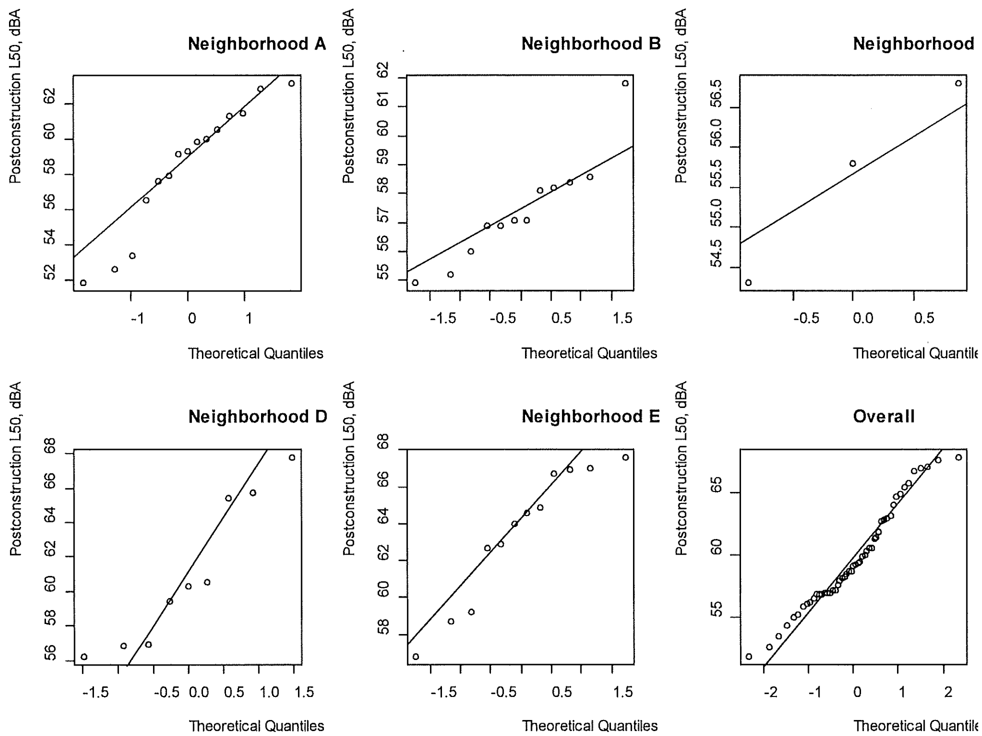


Figure I-2. Normal q-q plots for Pre-construction Normalized L_{50} Measurements

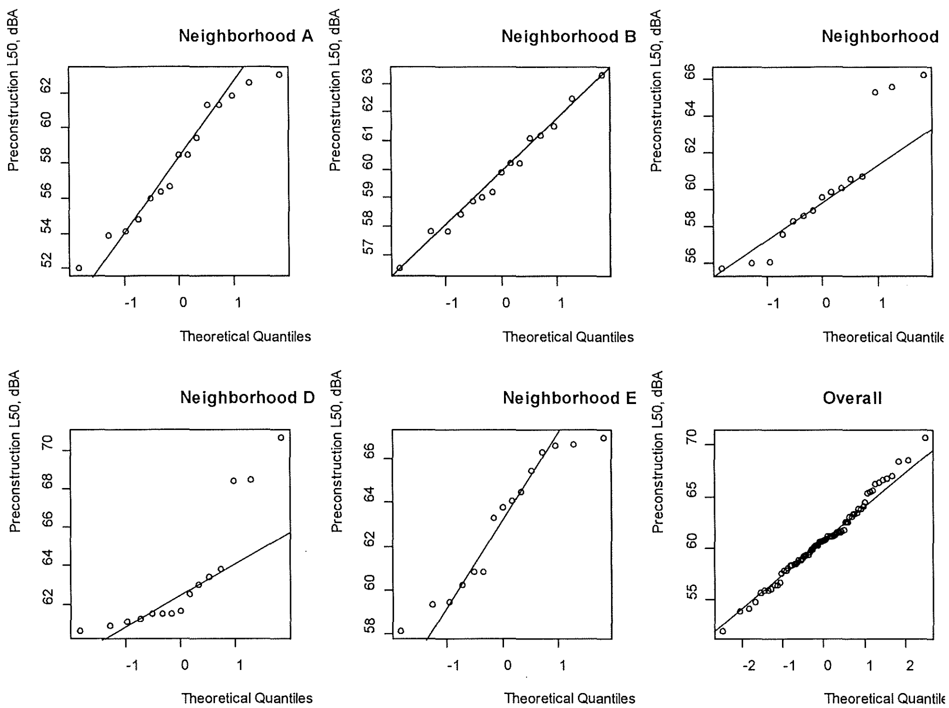


Figure I-3. Normal q-q plots for Post-construction Normalized L_{10} Measurements

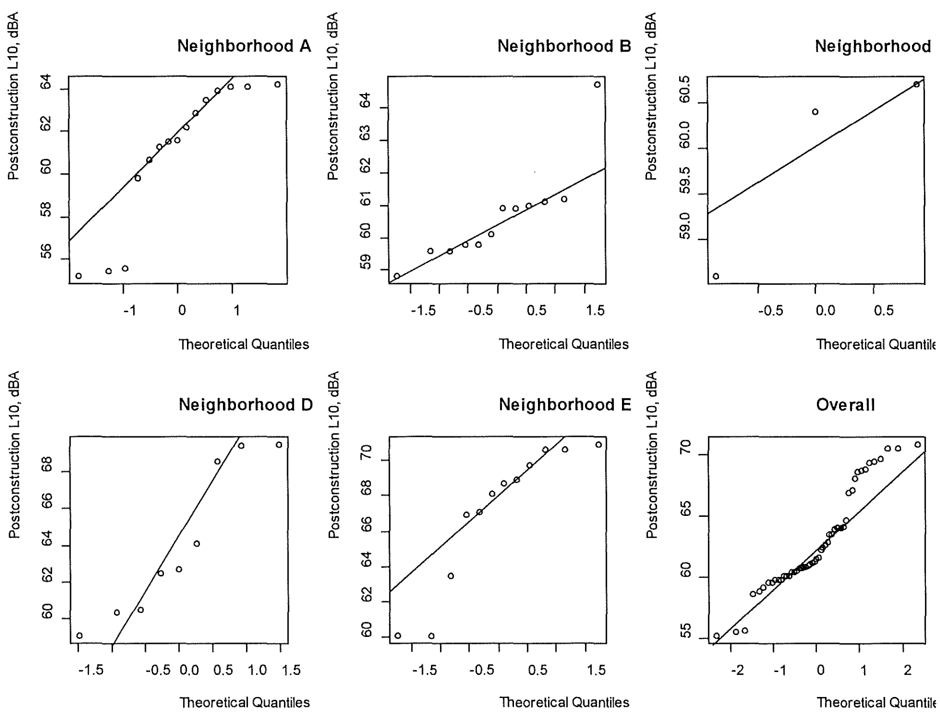


Figure I-4. Normal q-q plots for Pre-construction Normalized L_{10} Measurements

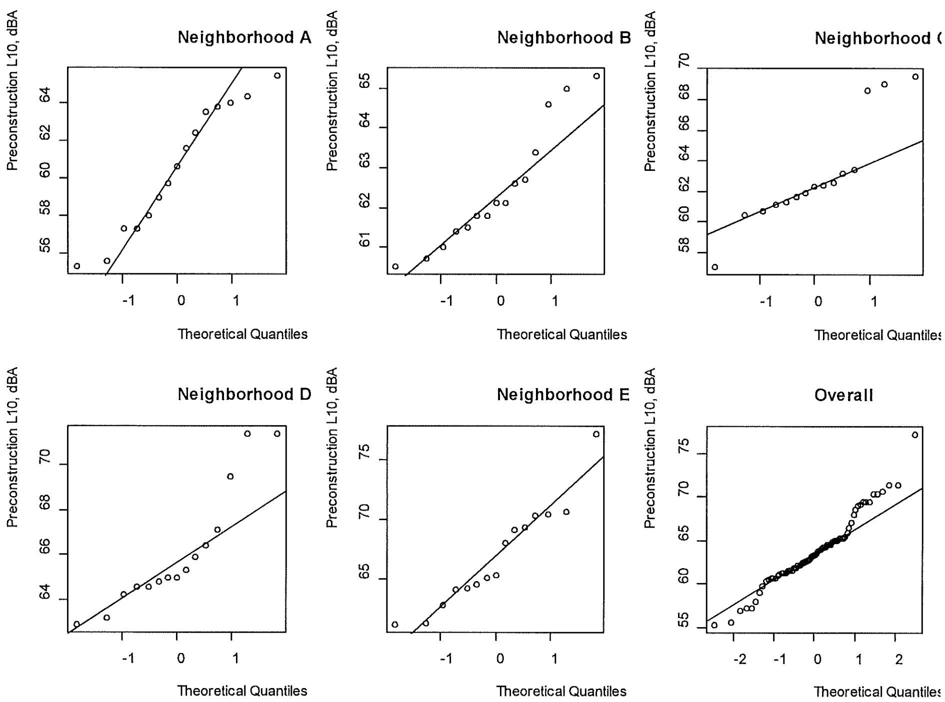


Figure I-5. Normal q-q plots for Paired-sample Normalized L_{50} Measurements

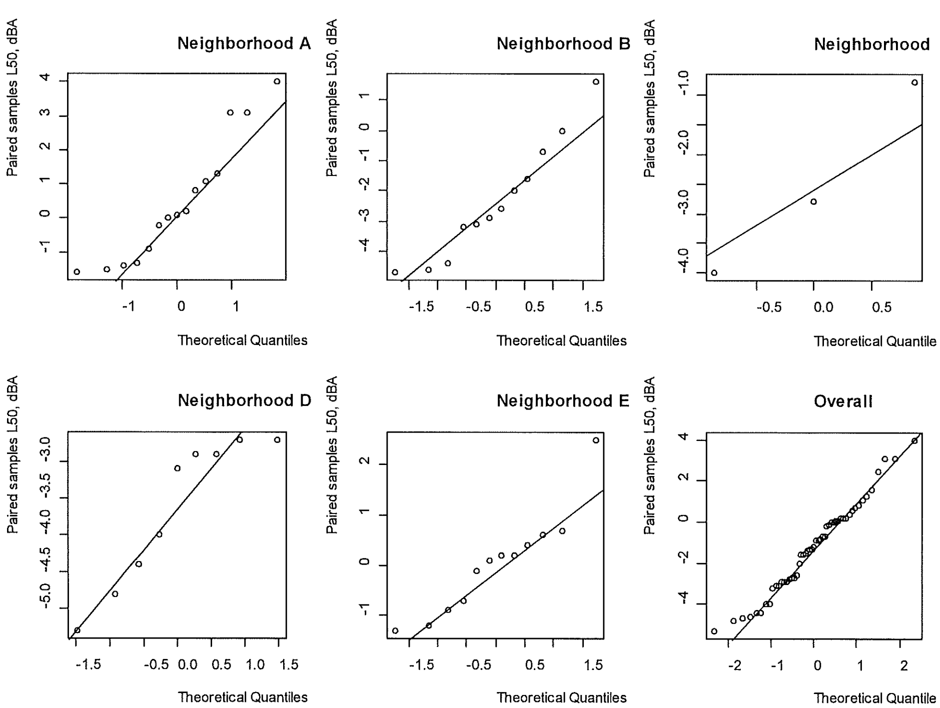
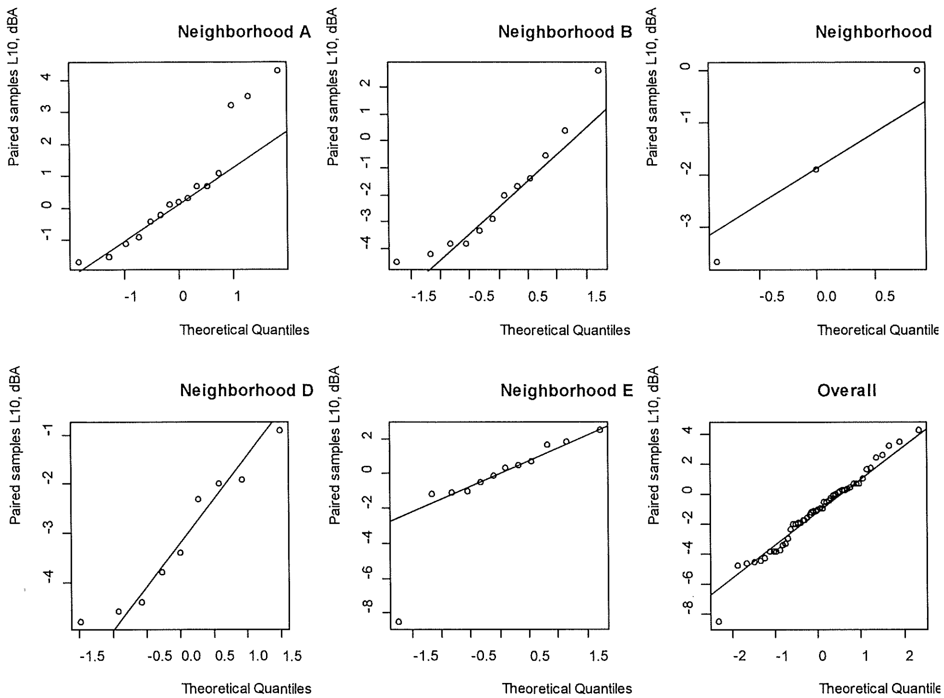


Figure I-6. Normal q-q plots for Paired-sample Normalized L_{10} Measurements



Appendix J. Traffic Speeds for MINNOISE Model

HDR

Memo

Date:	Thursday, September 15, 2016
Project:	I-394 Pavement Noise Study
To:	Minnesota Department of Transportation
From:	Tim Casey and Kate Grady, HDR
Subject:	Traffic Speeds for MINNOISE Model

In response comments from MNDOT on HDR's MINNOISE modeling for the I-394 Pavement Noise Study, HDR has evaluated traffic speeds and is seeking further guidance regarding what speeds to input into the model for each hour.

Included in this memo are three summary graphs—one each for eastbound, high-occupancy toll (HOT), and westbound lanes—as well as graphs for each hour that includes all lanes. The graphs display data extracted from eight automated traffic recorder (ATR) sensors on I-394 from MNDOT's DataExtract Tool. The eight ATR data sets were combined for each section of the highway being evaluated: the eastbound lanes, the HOT lanes, and the westbound lanes. The eastbound lanes include sensors 788 394/EWirthW1, 789 394/EWirthW2, and 790 394/EWirthW3. The HOT lanes include sensors 791 394R/EWirthEHT1 and 792 94R/EWirthEHT2. The westbound lanes include sensors 793 394/EWirthE1, 794 394/EWirthE2, and 795 394/EWirthE3.

For each hour being evaluated, the graphs display the mean, quartiles 1 and 3 (the middle 50th percentile of the speed data), the median (the line between the first and third quartiles, within the boxes), and the minimum and maximum recorded speeds. These data are also represented in corresponding tables that include the mean, median, mode, and data sample size.

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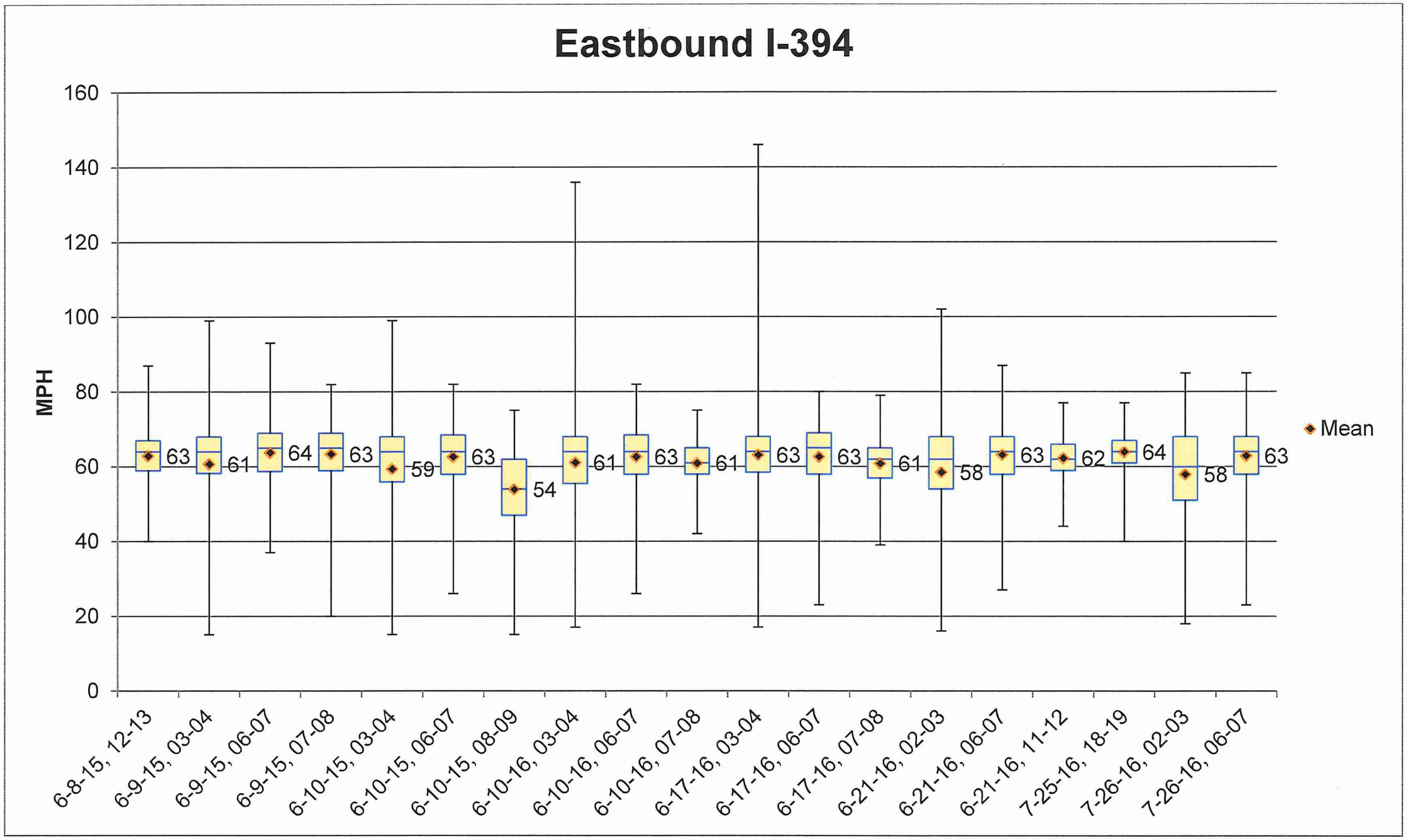
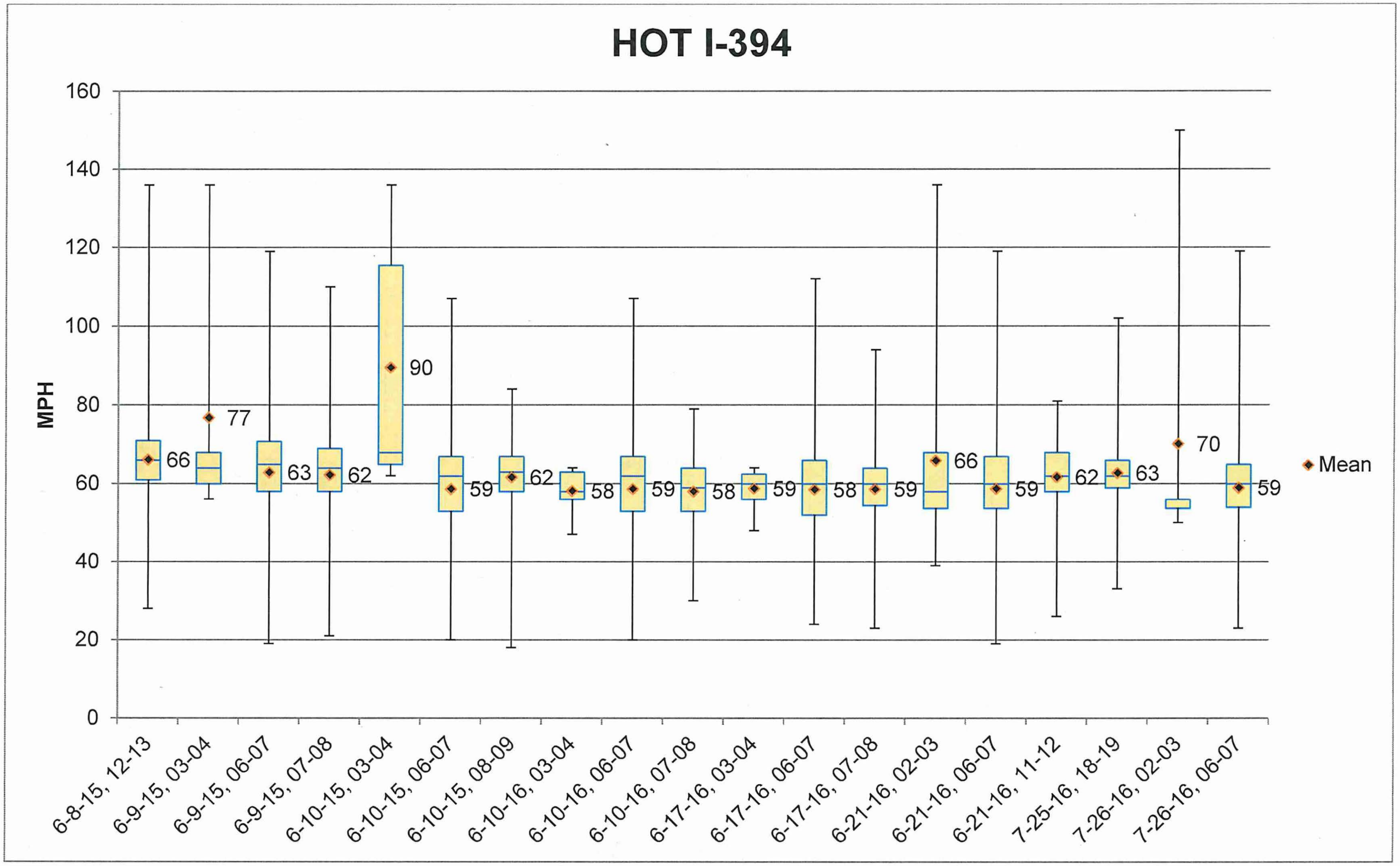
Eastbound I-394



HOT I-394



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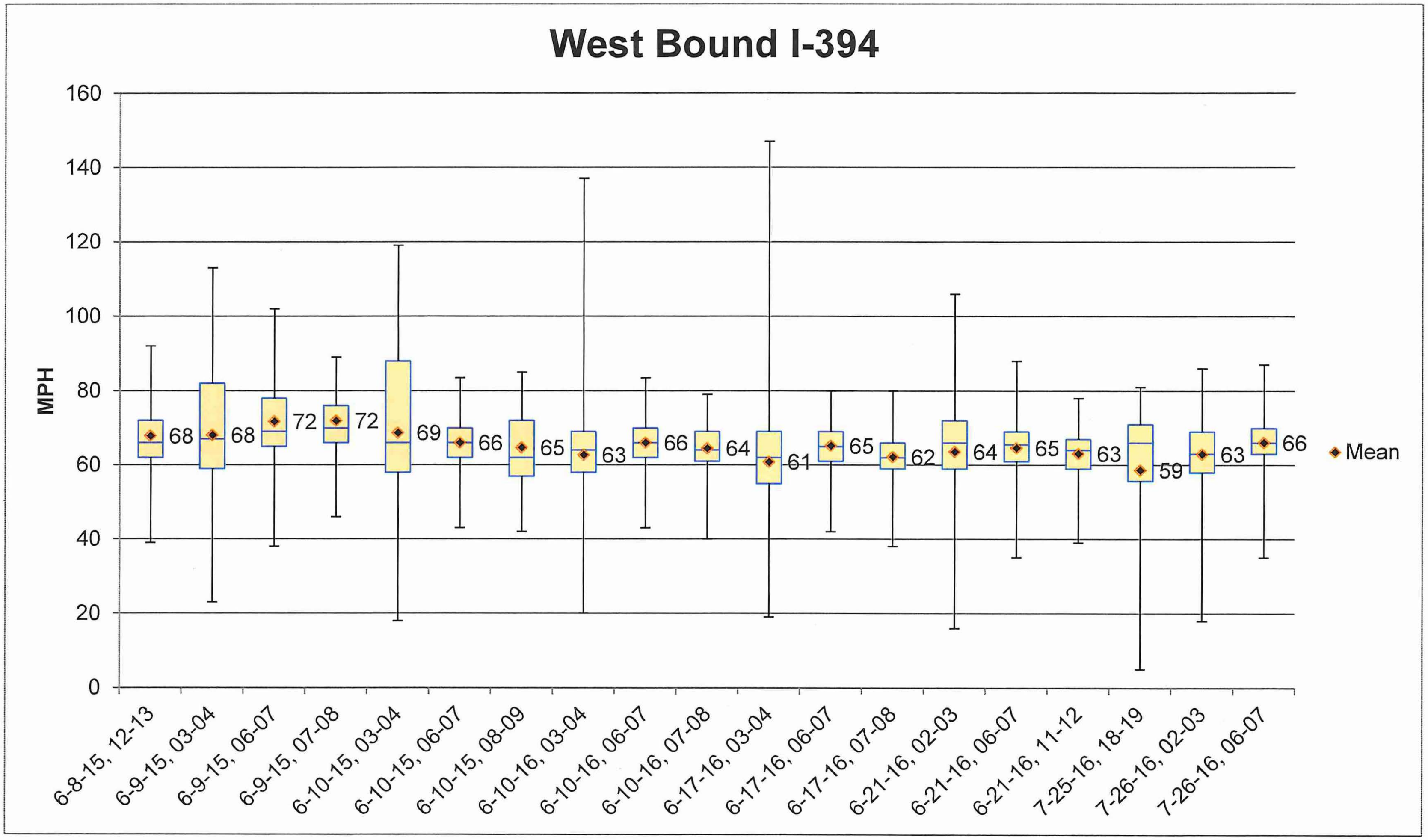
Westbound I-394



Eastbound I-394

Date and Time	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
6-8-15, 12-13	63	64	67	360
6-9-15, 03-04	61	64	64	146
6-9-15, 06-07	64	65	67	360
6-9-15, 07-08	63	65	68	358
6-10-15, 03-04	59	64	64	151
6-10-15, 06-07	63	64	65	355
6-10-15, 08-09	54	54	63	360
6-10-16, 03-04	61	64	68	183
6-10-16, 06-07	63	64	65	355
6-10-16, 07-08	61	61	62	360
6-17-16, 03-04	63	64	68	203
6-17-16, 06-07	63	65	67	358
6-17-16, 07-08	61	62	63	360
6-21-16, 02-03	58	62	68	151
6-21-16, 06-07	63	64	66	357
6-21-16, 11-12	62	62	64	360
7-25-16, 18-19	64	64	66	360
7-26-16, 02-03	58	60	68	157
7-26-16, 06-07	63	64	64	360

HOT I-394

Date and Time	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
6-8-15, 12-13	66	66	68	157
6-9-15, 03-04	77	64	N/A	5
6-9-15, 06-07	63	65	68	202
6-9-15, 07-08	62	64	68	201
6-10-15, 03-04	90	68	136	7
6-10-15, 06-07	59	62	62	201
6-10-15, 08-09	62	63	62	240
6-10-16, 03-04	58	58	56	7
6-10-16, 06-07	59	62	62	201
6-10-16, 07-08	58	59	64	238
6-17-16, 03-04	59	60	60	8
6-17-16, 06-07	58	60	68	189
6-17-16, 07-08	59	60	61	239
6-21-16, 02-03	66	58	58	10
6-21-16, 06-07	59	60	68	204
6-21-16, 11-12	62	62	68	179
7-25-16, 18-19	63	62	62	209
7-26-16, 02-03	70	56	56	6
7-26-16, 06-07	59	60	60	209

Westbound I-394

Date and Time	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
6-8-15, 12-13	68	66	64	360
6-9-15, 03-04	68	67	88	136
6-9-15, 06-07	72	69	69	360
6-9-15, 07-08	72	70	67	360
6-10-15, 03-04	69	66	88	151
6-10-15, 06-07	66	66	68	359
6-10-15, 08-09	65	62	60	360
6-10-16, 03-04	63	64	62	165
6-10-16, 06-07	66	66	68	359
6-10-16, 07-08	64	64	64	360
6-17-16, 03-04	61	62	62	174
6-17-16, 06-07	65	65	64	360
6-17-16, 07-08	62	62	62	360
6-21-16, 02-03	64	66	72	161
6-21-16, 06-07	65	65.5	65	350
6-21-16, 11-12	63	64	65	360
7-25-16, 18-19	59	66	66	360
7-26-16, 02-03	63	63	62	169
7-26-16, 06-07	66	66	64	360

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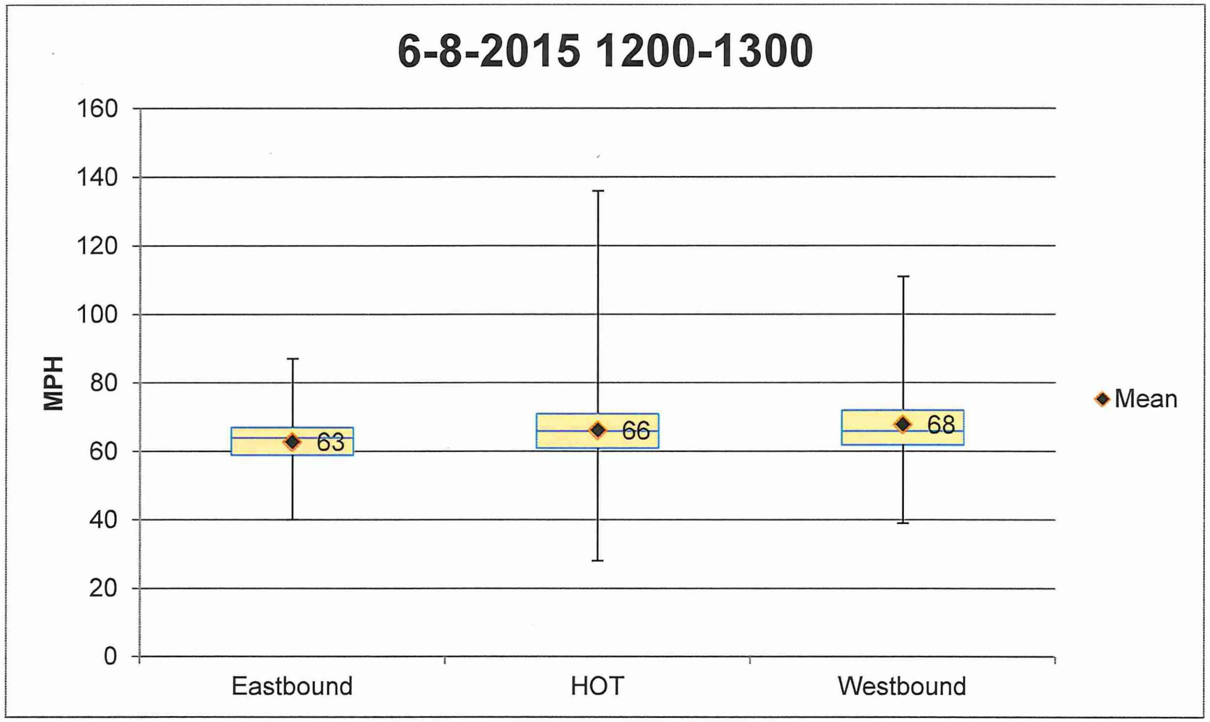
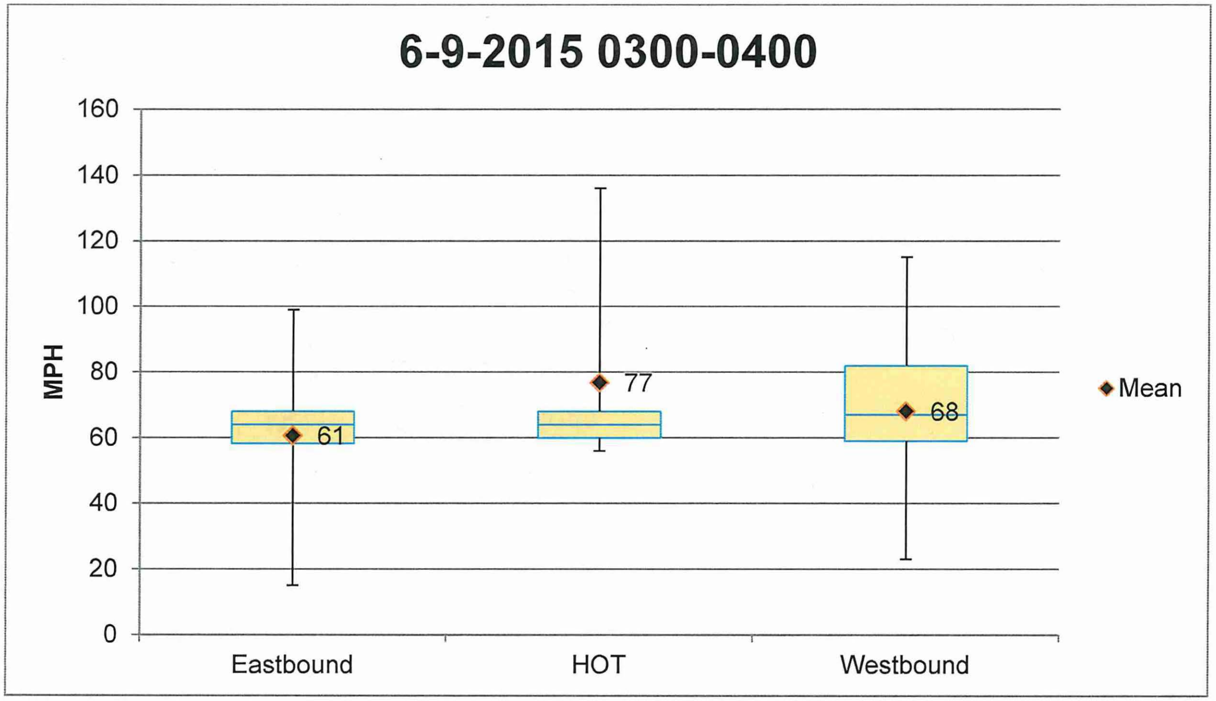


6-8-15, 12-13	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	63	64	67	360
HOT	66	66	68	157
Westbound	68	66	64	360



6-9-15, 03-04	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	61	64	64	146
HOT	77	64	N/A	5
Westbound	68	67	88	136

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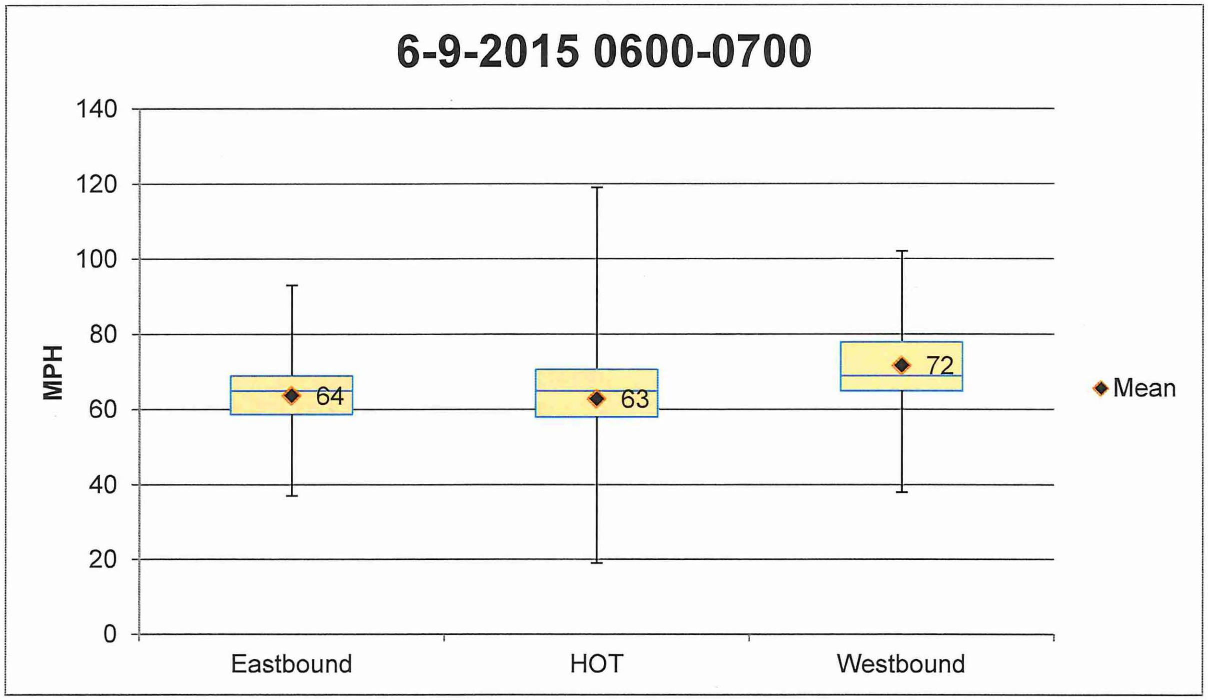
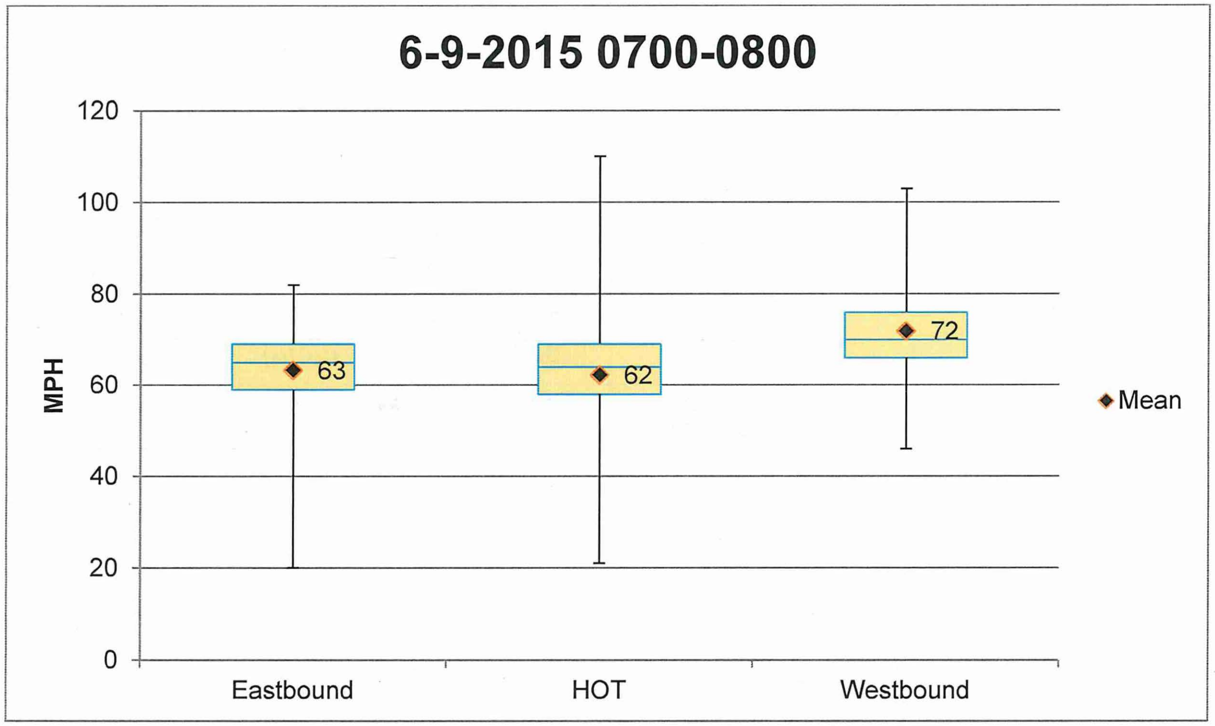


6-9-15, 06-07	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	64	65	67	360
HOT	63	65	68	202
Westbound	72	69	69	360



6-9-15, 07-08	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	63	65	68	358
HOT	62	64	68	201
Westbound	72	70	67	360

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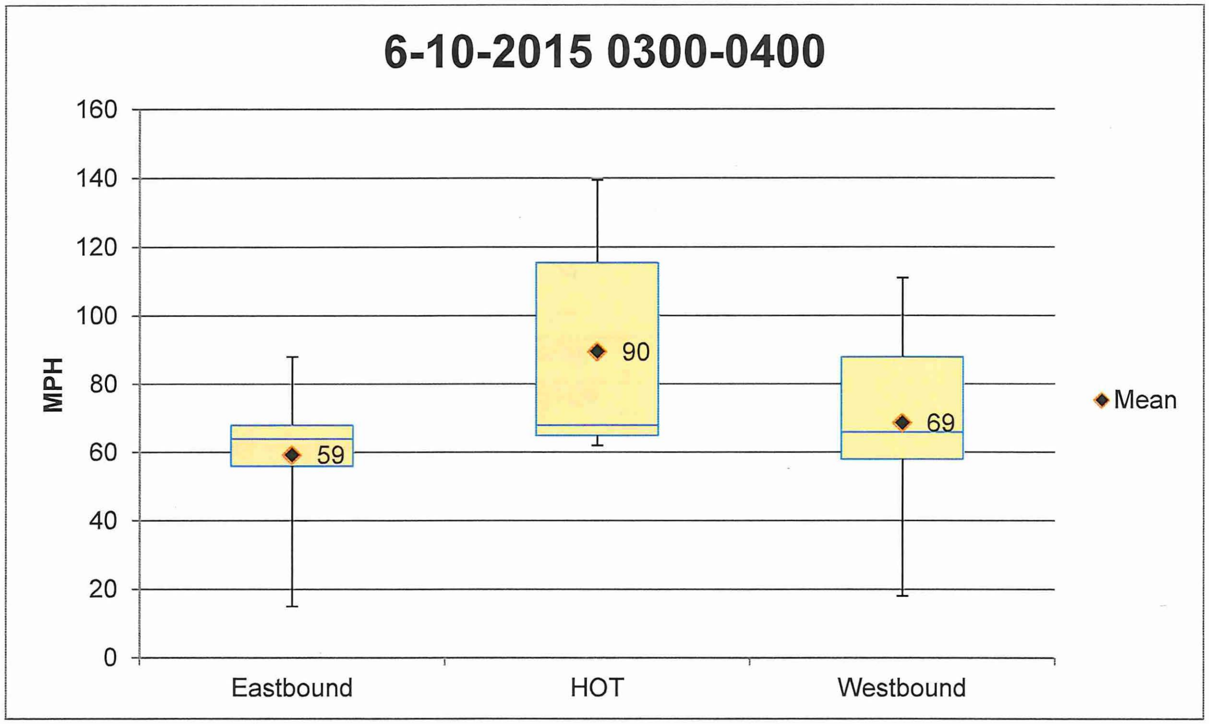
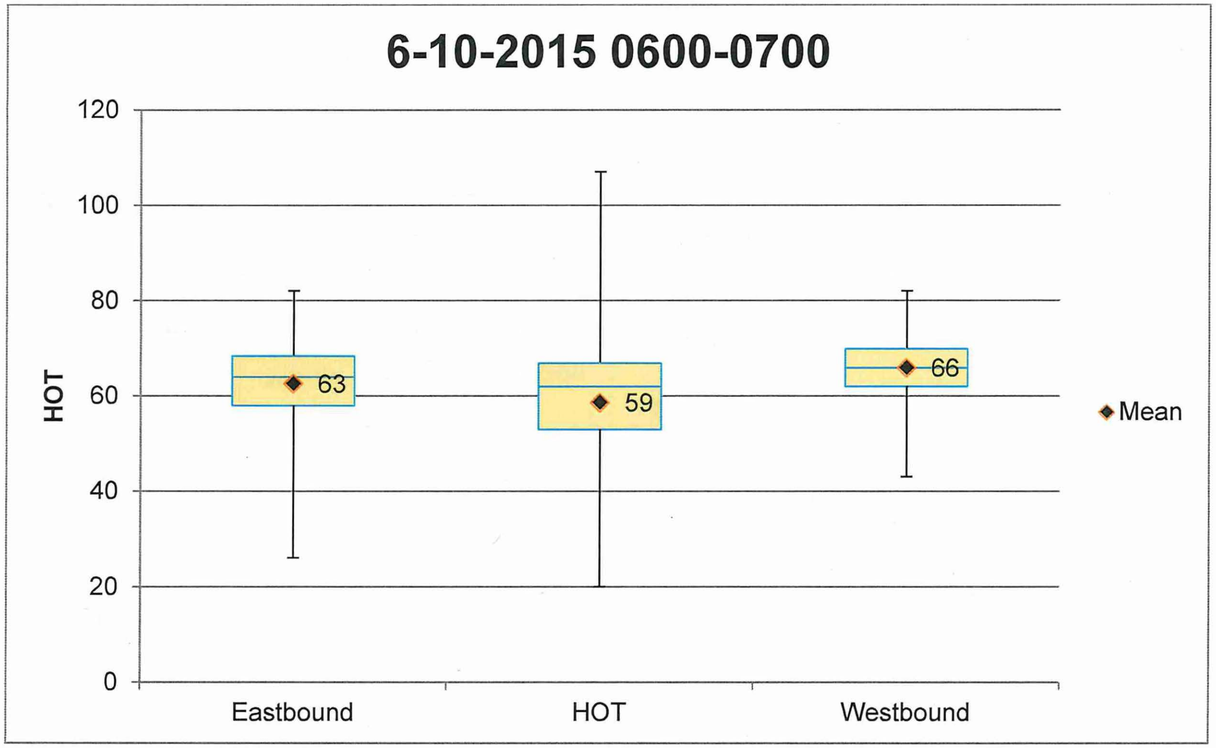


6-10-15, 03-04	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	59	64	64	151
HOT	90	68	136	7
Westbound	69	66	88	151



6-10-15, 06-07	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	63	64	65	355
HOT	59	62	62	201
Westbound	66	66	68	359

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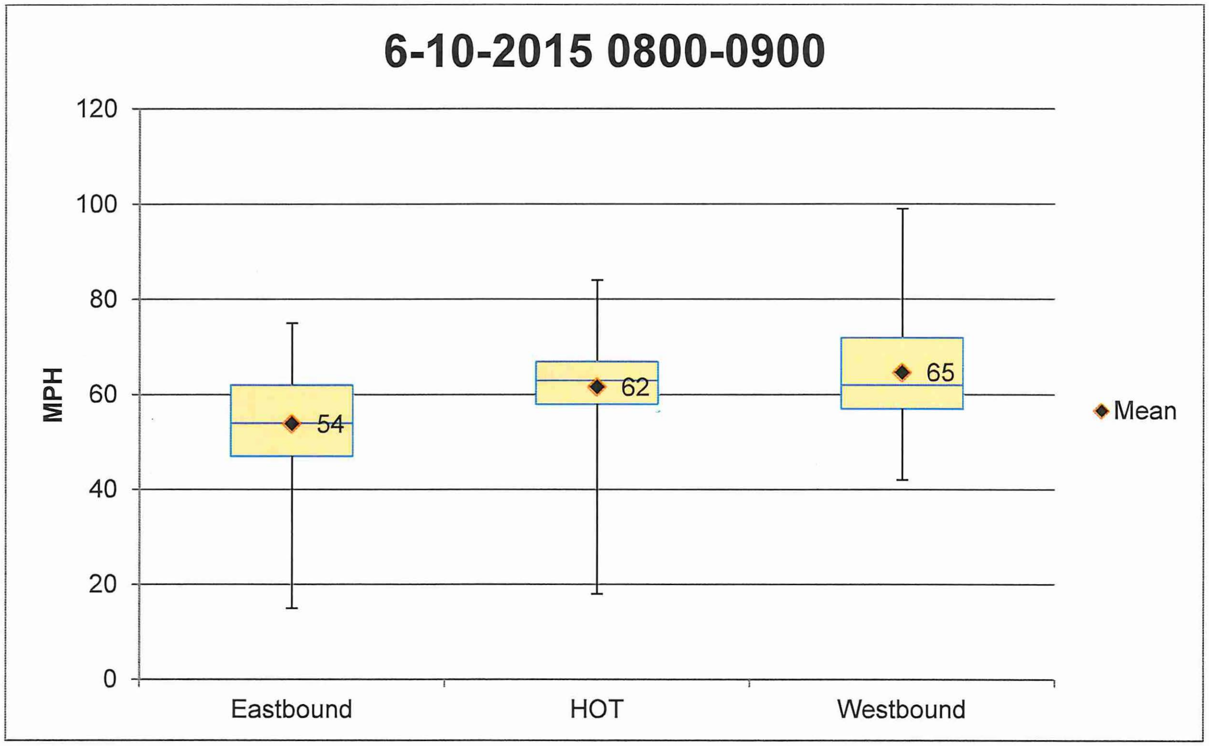
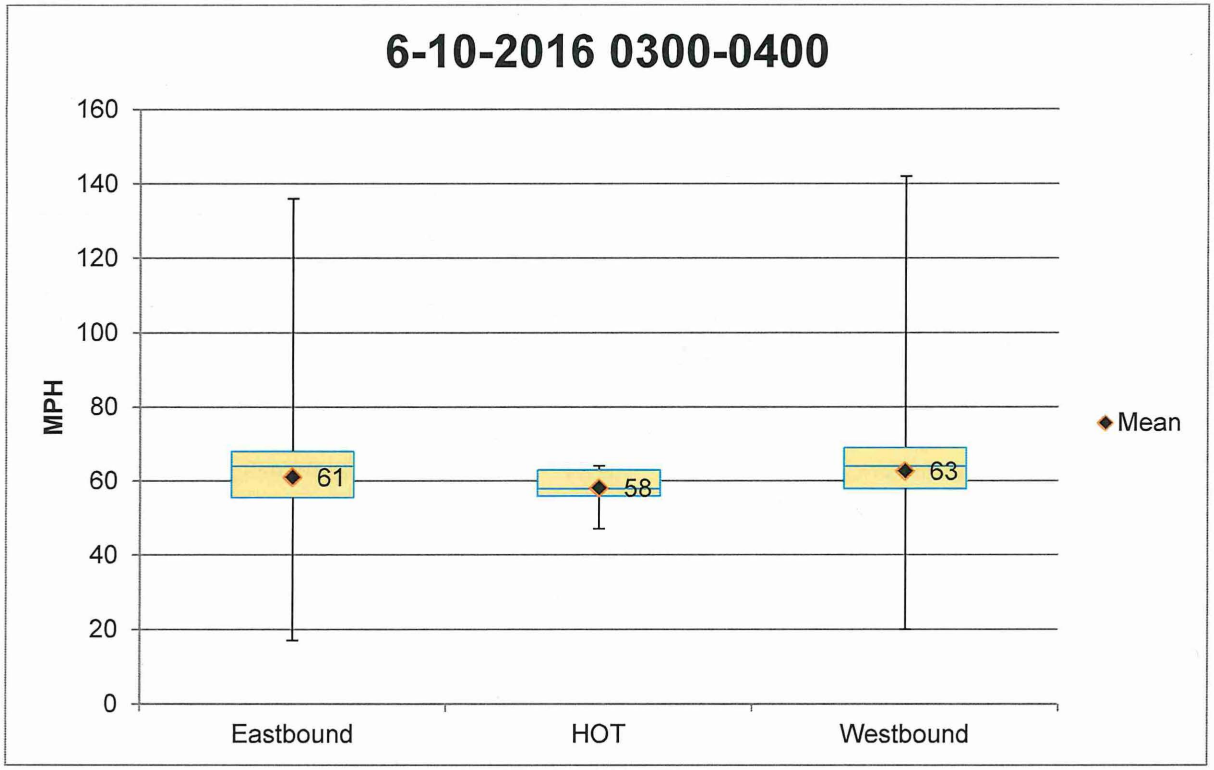
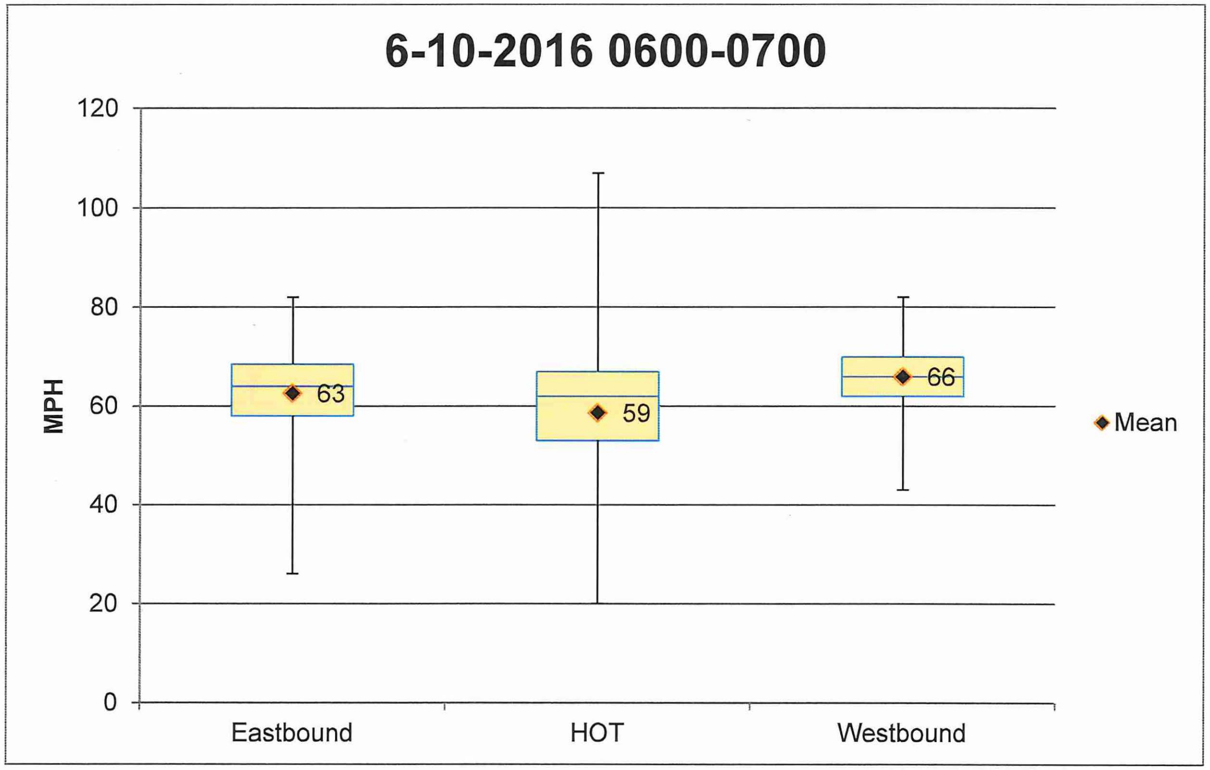


6-10-15, 08-09	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	54	54	63	360
HOT	62	63	62	240
Westbound	65	62	60	360



6-10-16, 03-04	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	61	64	68	183
HOT	58	58	56	7
Westbound	63	64	62	165



6-10-16, 06-07	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	63	64	65	355
HOT	59	62	62	201
Westbound	66	66	68	359

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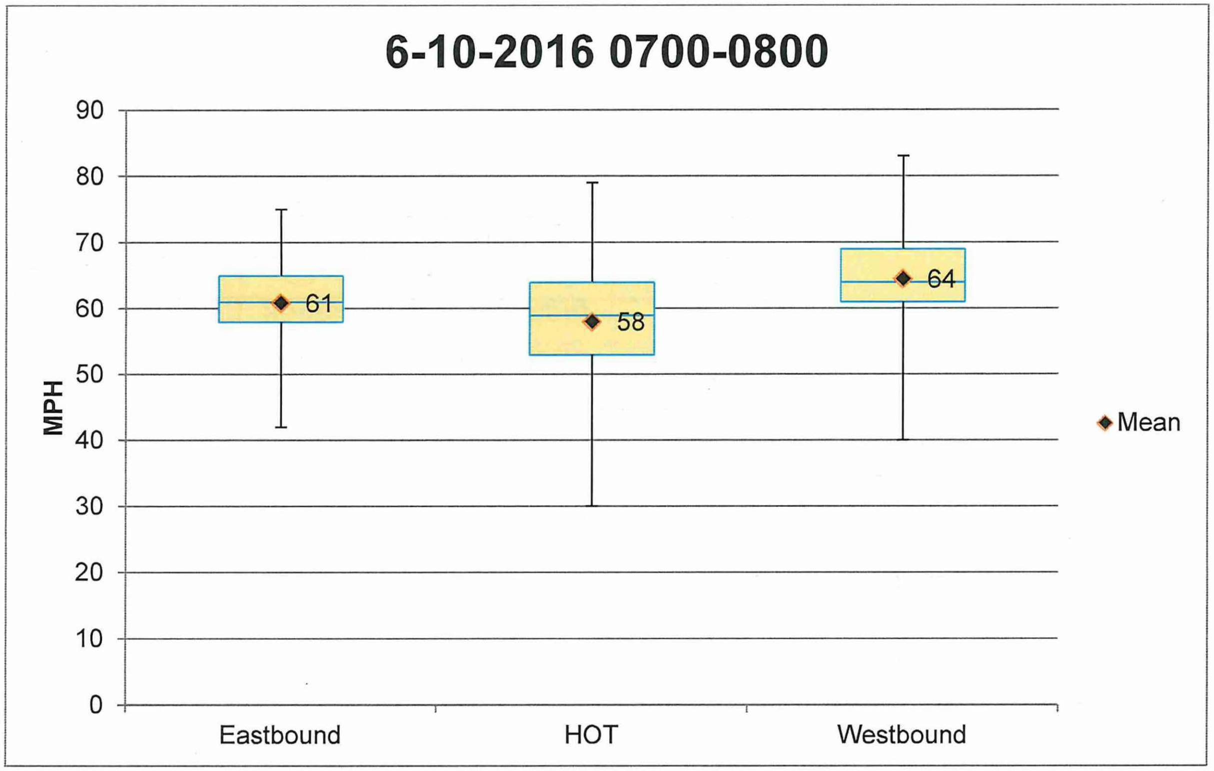
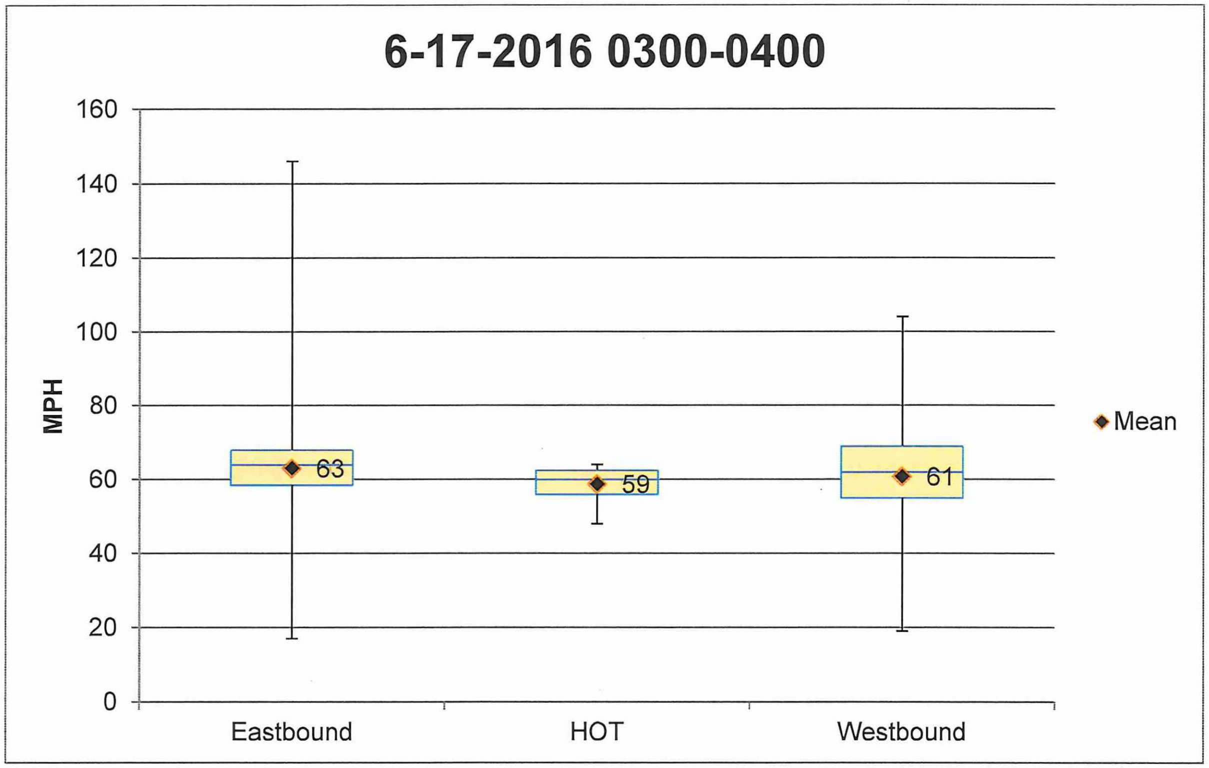


6-10-16, 07-08	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	61	61	62	360
HOT	58	59	64	238
Westbound	64	64	64	360



6-17-16, 03-04	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	63	64	68	203
HOT	59	60	60	8
Westbound	61	62	62	174

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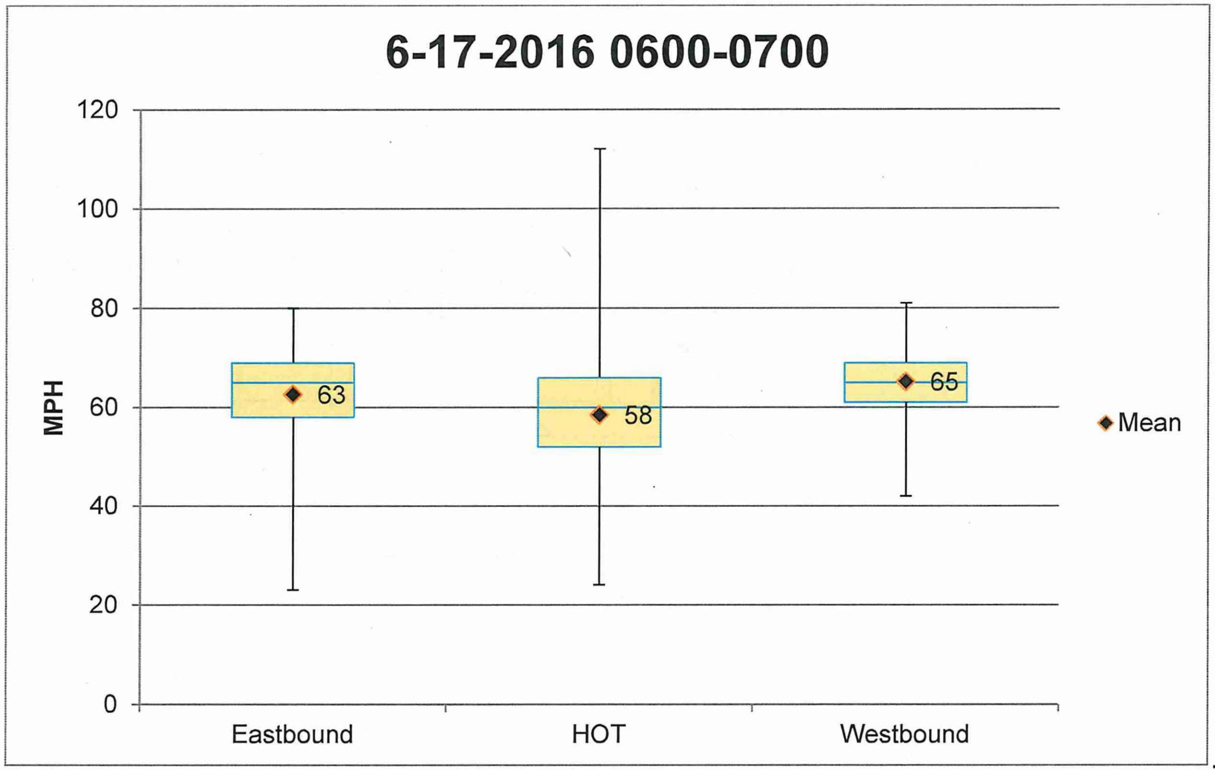
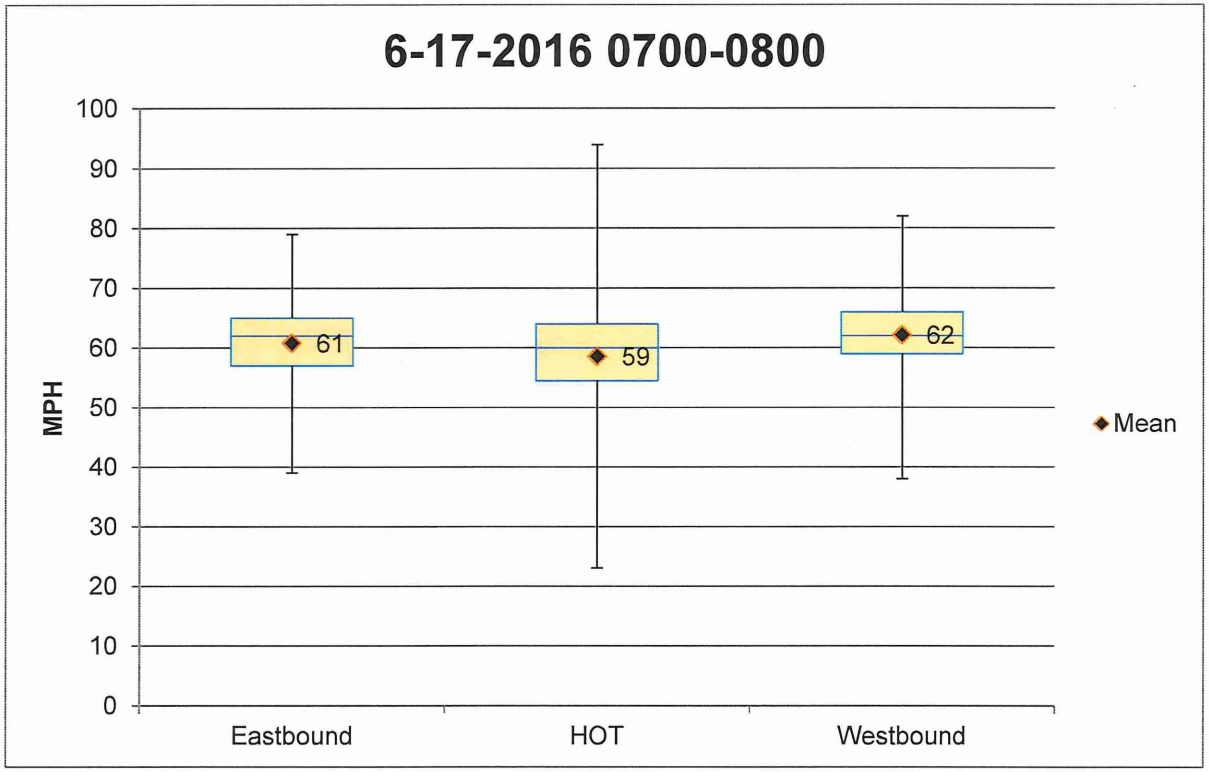
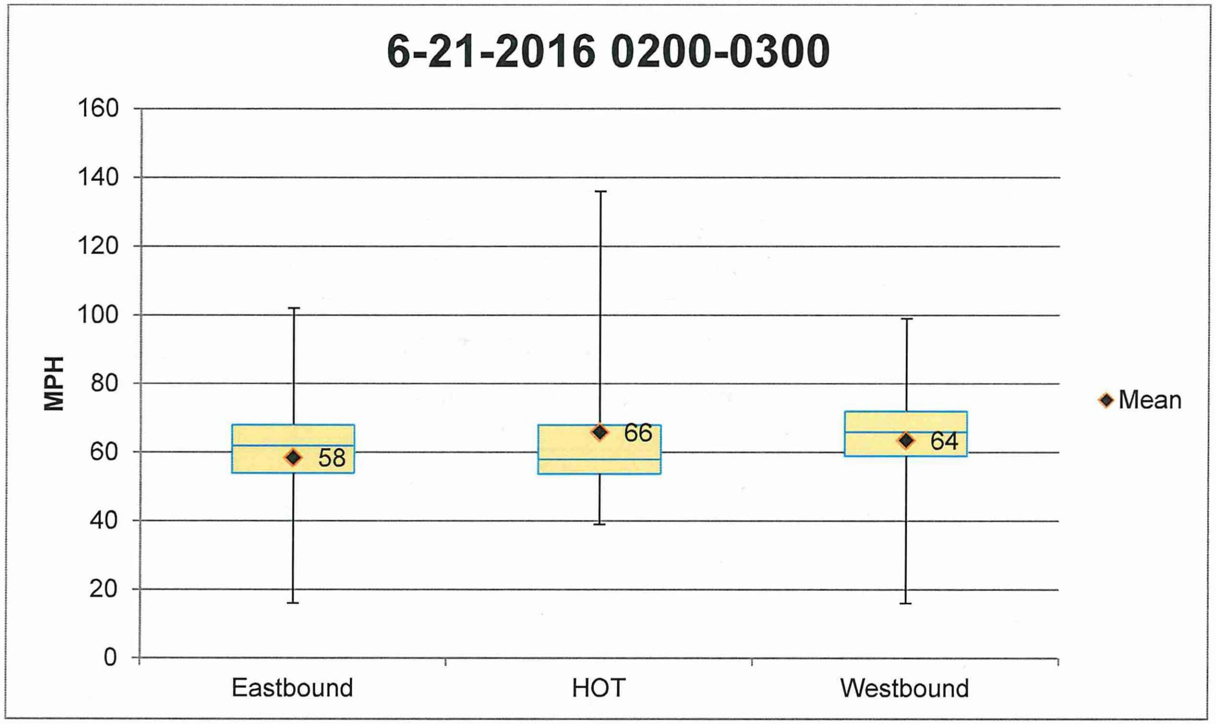


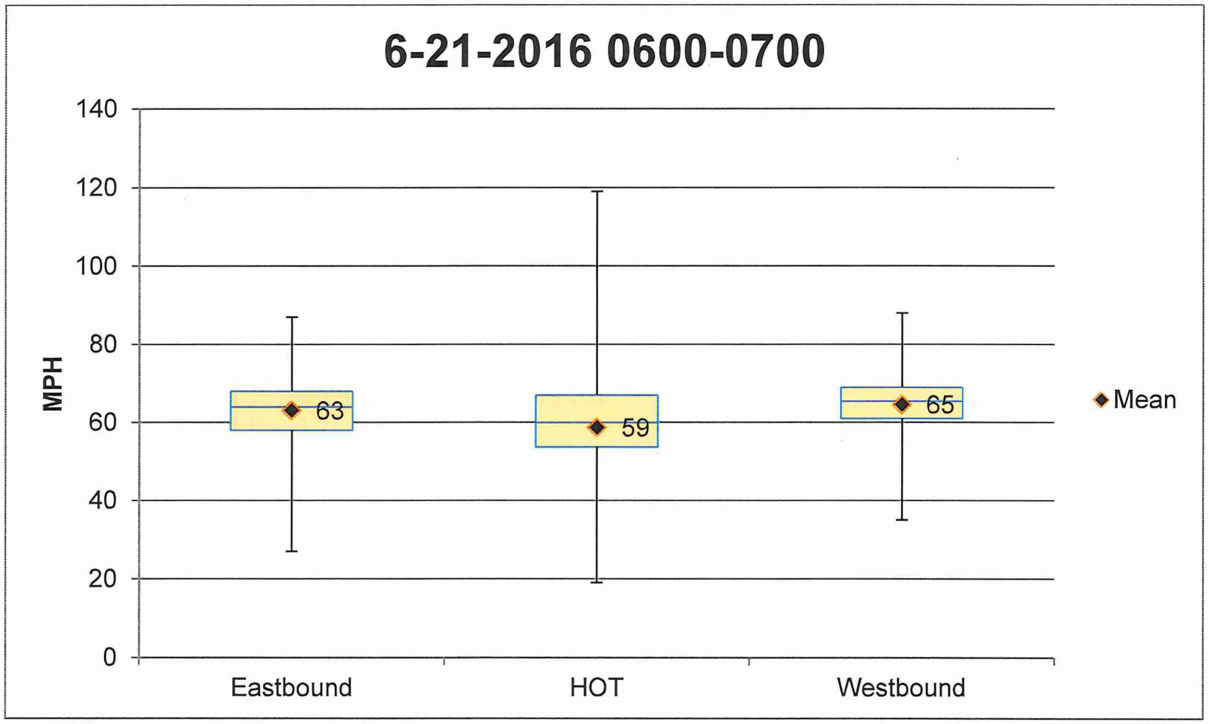
6-17-16, 06-07	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	63	65	67	358
HOT	58	60	68	189
Westbound	65	65	64	360



6-17-16, 07-08	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	61	62	63	360
HOT	59	60	61	239
Westbound	62	62	62	360



6-21-16, 02-03	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	58	62	68	151
HOT	66	58	58	10
Westbound	64	66	72	161



6-21-16, 06-07	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	63	64	66	357
HOT	59	60	68	204
Westbound	65	65.5	65	350

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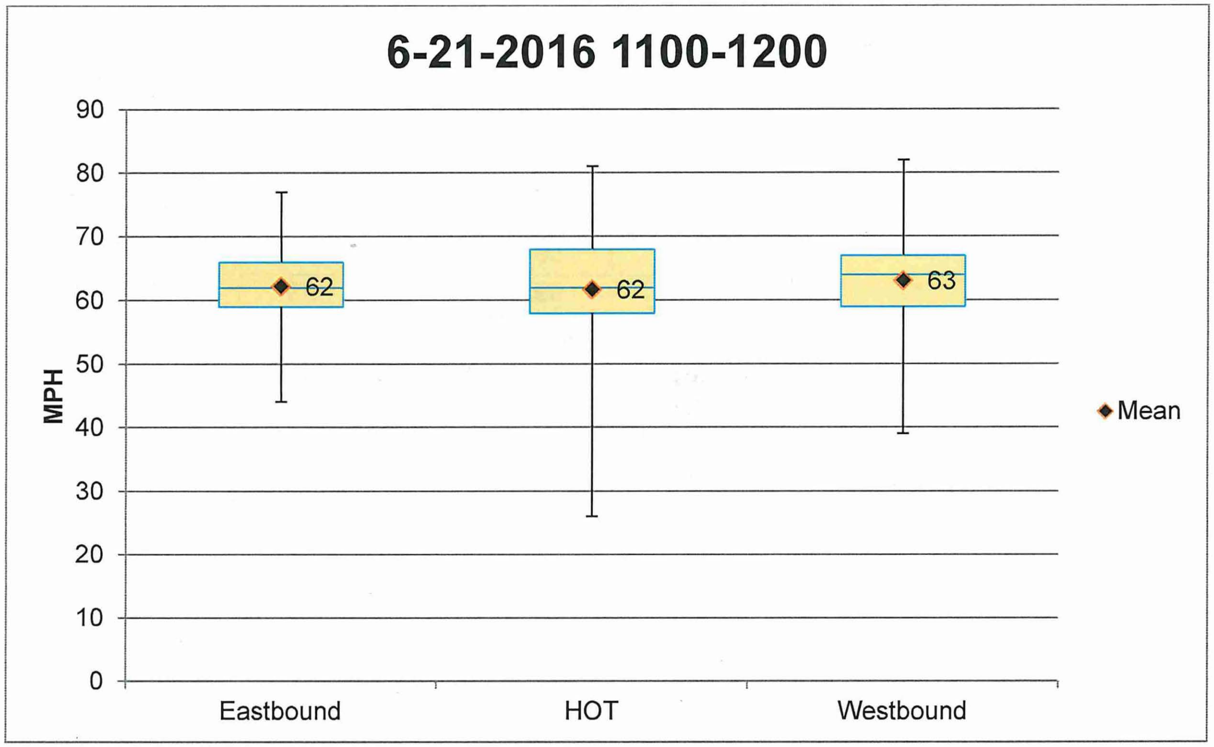
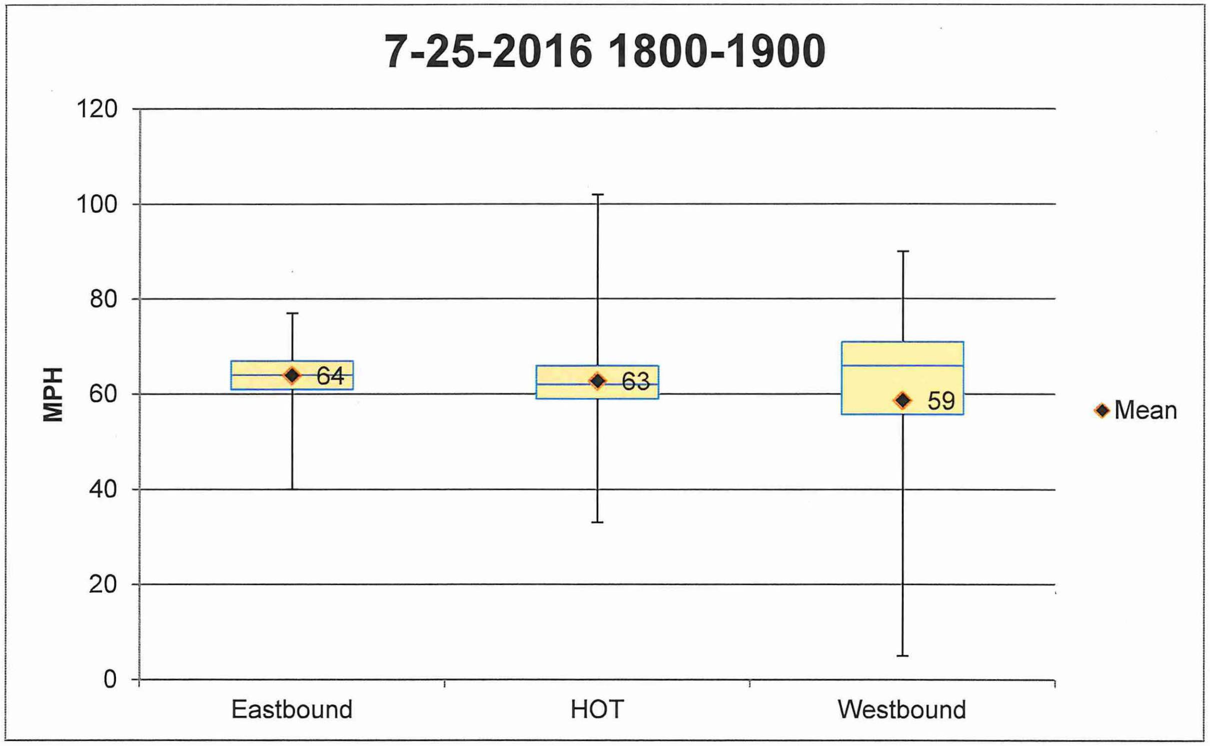


6-21-16, 11-12	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	62	62	64	360
HOT	62	62	68	179
Westbound	63	64	65	360



7-25-16, 18-19	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	64	64	66	360
HOT	63	62	62	209
Westbound	59	66	66	360

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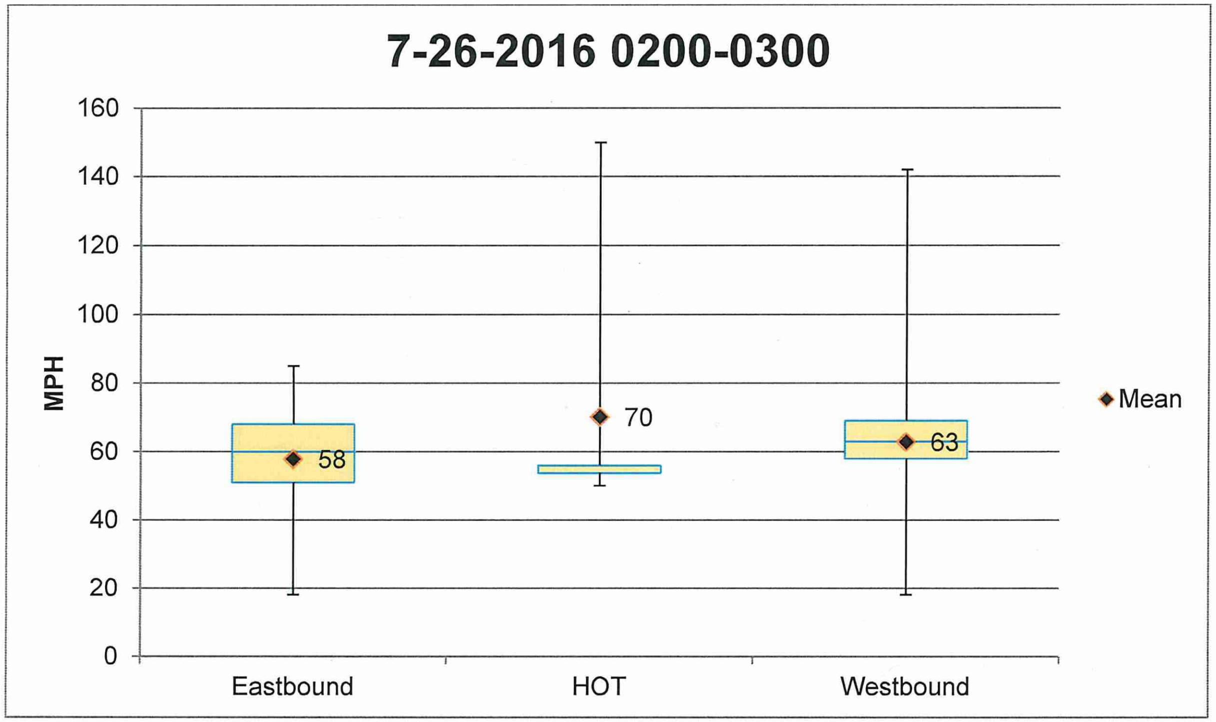
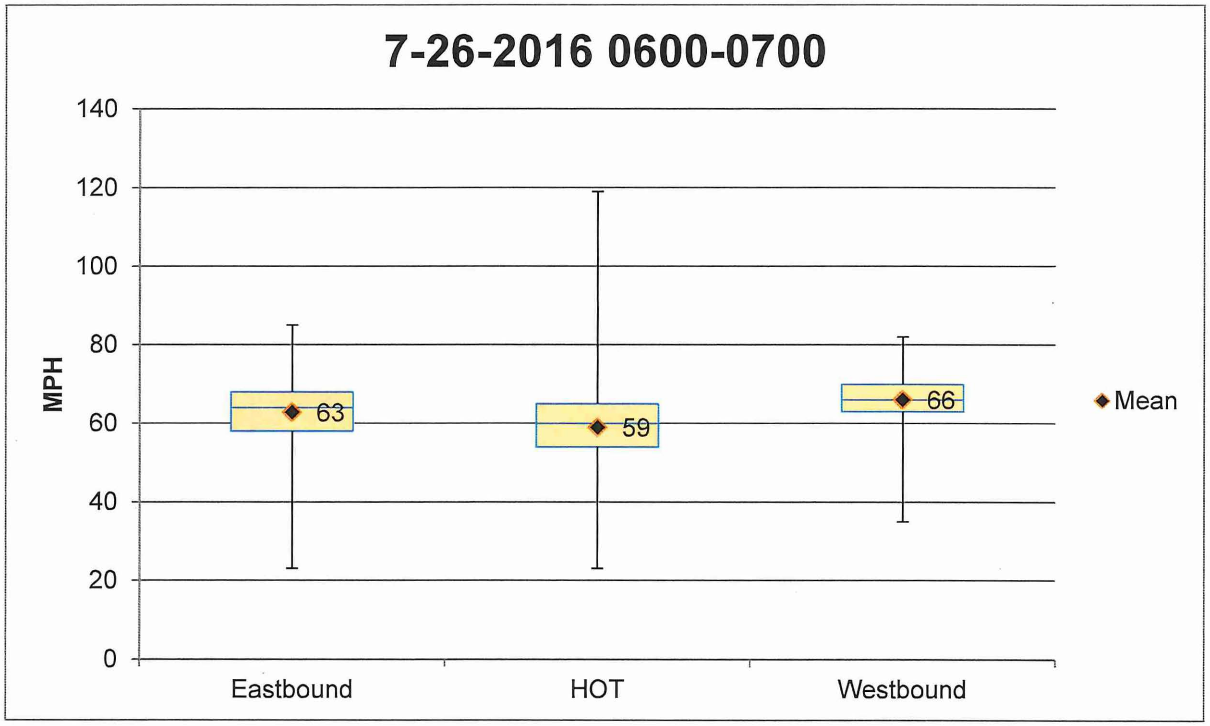


7-26-16, 02-03	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	58	60	68	157
HOT	70	56	56	6
Westbound	63	63	62	169



7-26-16, 06-07	Mean (mph)	Median (mph)	Mode (mph)	Sample Size (n)
Eastbound	63	64	64	360
HOT	59	60	60	209
Westbound	66	66	64	360

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