STUDY SESSION

City Council
November 11, 2014

TO: Mayor and City Council

FROM: Jeff Boynton, City Manager

ORIGINATED BY: Mark Stowell, P.E., Public Works Director/City Engineer
Gary Sanui, Public Works Manager
Tony Moreno, Administrative Analyst I

SUBJECT: RAILROAD NOISE MITIGATION STUDY FINDINGS

BACKGROUND

The BNSF Railway runs 1.8-miles parallel to Stage Road in La Mirada. The original railroad was built prior to the City's incorporation in 1960, and over time additional tracks have been added within the rail corridor. The Triple Track Project will add a third main line track. Additionally, there are up to nine ancillary tracks along the rail corridor in La Mirada which are used for train operations.

Area residents have periodically expressed concerns with the railroad noise. While the completed grade separation project has significantly reduced train horns in the area, some residents remain concerned with noise associated with rail operations.

In October of 2012 a petition with more than 700 signatures was submitted to the City Council by a group of residents expressing concerns with noise from the BNSF Railway tracks located near their homes. The petition requested the City to initiate an environmental noise pollution study to determine whether current, and potential future, railroad noise levels are in excess of federal and/or state regulations.

In December of 2012, a Request for Proposals for a Noise Mitigation Study (RFP) was issued inviting proposals from qualified firms to conduct a noise and vibration study. Bollard Acoustical Consultants, Inc. was selected as the best qualified and suited to conduct the study.

Staff pursued funding for the study through the Los Angeles County Metropolitan Transportation Authority (Metro), and funding was approved in March of 2014.

FINDINGS

In May of 2014 Bollard Acoustical Consultants, Inc. performed the railroad noise and vibration studies. The attached Railroad Noise & Vibration Assessment report presents the findings. The study analyzed existing noise and vibration levels and reviewed vibration findings. The study also evaluated potential noise mitigation alternatives and each alternative's noise reduction performance and feasibility.

Mr. Paul Bollard with Bollard Acoustical Consultants, Inc. will present the report and findings.

RECOMMENDED ACTION

It is recommended the City Council review and discuss the railroad noise mitigation study.

STRATEGIC PLAN 2015	
Strategy 5:	Provide Quality Planning and Infrastructure
Goal 4:	Identify Alternatives for Upgrading Block Walls
Action 4.4:	Explore alternatives (through a Sound Study) and potential funding sources for a sound wall on Stage Road adjacent to the BNSF Railway Tracks.

Railroad Noise & Vibration Assessment

La Mirada BNSF Railway Study

La Mirada, California

BAC Job # 2013-030

Prepared For:

City of La Mirada

Attn: Mr. Tony Moreno
Public Works
15515 Phoebe Avenue
La Mirada, California 90638

Prepared By:

Bollard Acoustical Consultants, Inc.

Paul Bollard, President

November 4, 2014

BOLLARD
Acoustical Consultants

Introduction

The City of La Mirada has retained Bollard Acoustical Consultants, Inc. (BAC) to conduct an evaluation of Burlington, Northern, Santa Fe Railroad (BNSF) noise and vibration levels along Stage Road between McComber Road and Valley View Avenue. The purposes of the evaluation are to quantify existing railroad noise and vibration levels at residences located along the project study corridor, and identify the feasibility and effectiveness of potential noise mitigation measures on nearby homes.

BAC completed a series of railroad noise and vibration measurements along the project study corridor during the weeks of May 19th and June 2nd, 2014. The purpose of this report is to present the data collection methodology and results of those measurements.

Fundamentals and Terminology

Noise

Noise is often described as unwanted sound. Sound is defined as any pressure variation in air that the human ear can detect. Measuring sound directly in terms of pressure would require a very large and awkward range of numbers. The decibel scale was devised to compress the million-fold increase in sound pressure into a more practical 120 dB range. Another useful aspect of the decibel scale is that changes in levels (dB) correspond closely to human perception of relative loudness. Appendix A contains definitions of Acoustical Terminology. Table 1 shows common noise levels associated with various sources.

The perceived loudness of sounds is dependent upon many factors, including sound pressure level and frequency content. However, within the usual range of environmental noise levels, perception of loudness is relatively predictable, and can be approximated by weighing the frequency response of a sound level meter by means of the standardized A-weighing network. There is a strong correlation between A-weighted sound levels and community response to noise. For this reason, the A-weighted sound level has become the most-common metric for environmental noise assessment. All noise levels presented in this report are in terms of A-weighted decibels. Even though all decibel values in this report are expressed simply as dB, rather than dBA, all values are A-weighted.

Community noise is commonly described in terms of the "ambient" noise level, which is defined as the all-encompassing noise level associated with a given noise environment. A common statistical tool to measure the ambient noise level is the average, or equivalent, sound level (L_{eq}) over a given time period (usually one hour). The L_{eq} is the foundation of the Day-Night Average Level noise descriptor, L_{dn}, which is one metric commonly used to evaluate community response to transportation noise sources such as railroad.

The Day-Night Average Level (L_{dn}) is based upon the average noise level over a 24-hour day, with a +10 decibel weighing applied to noise occurring during nighttime (10:00 p.m. to 7:00 a.m.) hours. The nighttime penalty is based upon the assumption that people react to nighttime noise exposures as though they were twice as loud as daytime exposures. Because L_{dn} represents a 24-hour average, it tends to disguise short-term variations in the noise environment. L_{dn}-based noise standards are commonly used to assess noise impacts associated with traffic, railroad and aircraft noise sources.

Table 1
Typical A-Weighted Sound Levels of Common Noise Sources

Loudness Ratio	dBA	Description
128	130	Threshold of pain
64	120	Jet aircraft take-off at 100 feet
32	110	Riveting machine at operators position
16	100	Shotgun at 200 feet
8	90	Bulldozer at 50 feet
4	80	Diesel locomotive at 300 feet
2	70	Commercial jet aircraft interior during flight
1	60	Normal conversation speech at 5-10 feet
1/2	50	Open office background level
1/4	40	Background level within a residence
1/8	30	Soft whisper at 2 feet
1/16	20	Interior of recording studio

A single noise event is an individual distinct loud activity, such as a train passage, or any other brief and discrete noise-generating activity. Because most noise policies applicable to transportation noise sources are typically specified in terms of 24-hour-averaged descriptors, such as Ldn or CNEL, the potential for annoyance or sleep disturbance associated with individual loud events can be masked by the averaging process.

Extensive studies have been conducted regarding the effects of single-event noise on sleep disturbance, with the Sound Exposure Level (SEL) metric being a common metric used for such assessments. SEL represents the entire sound energy of a given single-event normalized into a one-second period regardless of event duration. As a result, the single-number SEL metric contains information pertaining to both event duration and intensity. Another descriptor utilized to assess single-event noise is the maximum, or Lmax, noise level associated with the event. A problem with utilizing Lmax to assess singe events is that the duration of the event is not considered.

There is currently no national consensus regarding the appropriateness of SEL criteria as a supplement or replacement for cumulative noise level metrics such as Ldn and CNEL. Nonetheless, because SEL describes a receiver's total noise exposure from a single impulsive event, SEL is often used to characterize noise from individual brief loud events.

Due to the wide variation in test subjects' reactions to noises of various levels (some test subjects were awakened by indoor SEL values of 50 dB, whereas others slept through indoor SEL values exceeding 80 dB), no universal criterion has been developed for environmental noise assessments.

Vibration

According to the Federal Transit Administration Noise and Vibration Impact Assessment Guidelines (FTA-VA-90-06), ground-borne vibration can be a serious concern for nearby neighbors of a transit system route or maintenance facility, causing buildings to shake and rumbling sounds to be heard. In contrast to airborne noise, ground-borne vibration is not a common environmental problem. It is unusual for vibration from sources such as buses and trucks to be perceptible, even in locations close to major roads. Some common sources of ground-borne vibration are trains, buses on rough roads, and construction activities such as blasting, pile-driving and operating heavy earth-moving equipment.

The effects of ground-borne vibration include perceptible movement of building floors, rattling of windows, shaking of items on shelves, movement of pictures hanging on walls, and rumbling sounds. In extreme cases, the vibration can cause damage to buildings. Building damage is not a factor for normal transportation projects, with the occasional exception of blasting and pile-driving during construction. Annoyance from vibration often occurs when the vibration exceeds the threshold of perception by only a small margin. A vibration level that causes annoyance will be well below the damage threshold for normal buildings.

Train wheels rolling on rails create vibration energy that is transmitted through the track support system into the ground, creating vibration waves that propagate through the various soil and rock strata to the foundations of nearby buildings. The vibration propagates from the foundation throughout the remainder of the building structure. The maximum vibration amplitudes of the floors and walls of a building often will be at the resonance frequencies of various components of the building.

Ground-borne vibration is seldom annoying to people who are outdoors. Although the motion of the ground may be perceived, without the effects associated with the shaking of a building, the motion does not provoke the same adverse human reaction. In addition, the rumble noise that usually accompanies the building vibration is frequently perceptible only inside buildings.

Vibration can be described in terms of acceleration, velocity, or displacement. A common practice is to monitor vibration measures in terms of peak particle velocities (inches/second). All vibration levels reported in this study are in terms of velocity in inches per second.

Criteria for Acceptable Noise and Vibration Exposure

City of La Mirada

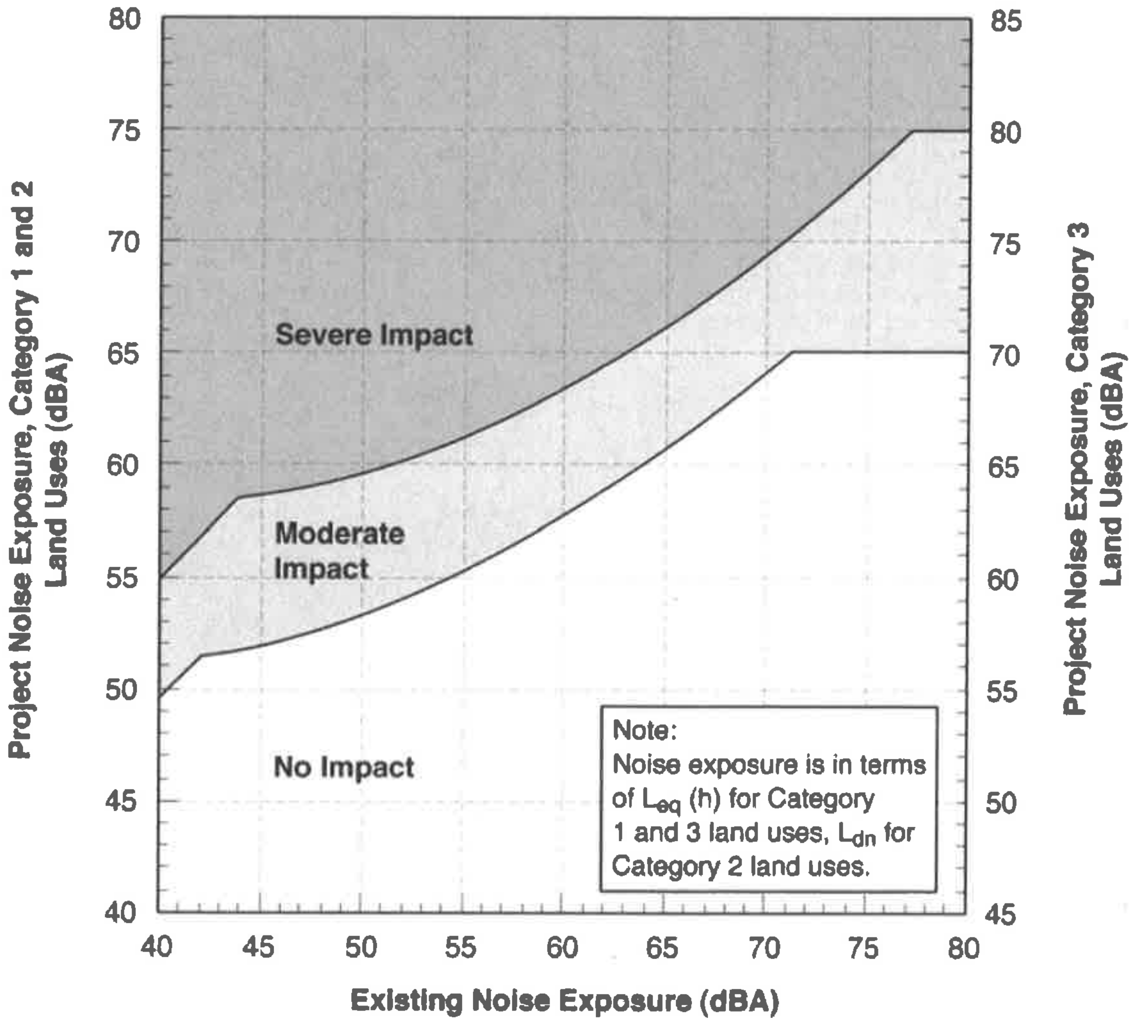
The City of La Mirada General Plan Noise Element establishes 60 dB L_{dn} as a normally acceptable exterior noise environment for outdoor activity areas of residential land uses affected by transportation noise sources, such as railroad. The intent of this standard is to provide an acceptable exterior noise environment for outdoor activities. The City of La Mirada also utilizes an interior noise level standard of 45 dB L_{dn} or less within residential land uses affected by transportation noise source. The intent of this interior noise limit is to provide a suitable environment for indoor communication and sleep. The City's exterior and interior noise level standards are based on extensive research into human reaction to noise and are very commonly used by most cities and counties in the state of California. The City of La Mirada General Plan does not contain vibration thresholds.

Federal Transit Administration Noise Impact Assessment Criteria

The Federal Transit Administration Transit Noise and Vibration Impact Assessment report (FTA-VA-90-1003-06) presents procedures for assessing noise and vibration impacts of rail transit systems, including noise and vibration impact criteria.

The FTA noise impact criteria depend on the type of land use, and existing noise exposure. Residences are considered Category 2 land uses in the FTA guidelines, and the noise metric used to assess impacts for this category is Outdoor L_{dn}. The graph illustrating the FTA noise impact criteria is reproduced on the next page as Figure 1.

Figure 1
FTA Noise Impact Criteria



The FTA noise impact criteria shown in Figure 1 indicate that severe railroad noise impacts could occur at levels as low as 55 dB Ldn if the ambient conditions in the absence of railroad noise are very low (40 dB Ldn). While the FTA criteria are commonly applied to new transit projects, they can provide valuable context for noise impact assessment relative to existing transit corridors provided the background noise levels in the absence of the transit noise in question can be quantified. For this assessment, overall daily Ldn values were computed from measured hourly Leq data and the railroad noise exposure was isolated and subtracted from the daily Ldn values through a detailed analysis of individual railroad single event data collected at each monitoring location. This process is described in greater detail later in this report.

Criteria for Assessing Railroad Single Event Sleep Disturbance

The Federal Interagency Committee on Aviation Noise (FICAN) has provided estimates of the percentage of people expected to be awakened when exposed to specific SELs inside a home (FICAN 1997). However, FICAN did not recommend a threshold of significance based on the percent of people awakened. According to the FICAN study, 10% of the population is estimated to be awakened when the SEL interior noise level reaches 81 dBA. An estimated 5 to 10 percent of the population is affected when the SEL interior noise level is between 65 and 81 dBA, and few sleep awakenings (less than 5 percent) are predicted if the interior SEL is less than 65 dBA. The FICAN results focused on individual single-event sound levels but did not take into consideration how exposure to multiple single events affected sleep disturbance.

American National Standards Institute (ANSI) and the Acoustical Society of America (ASA) released a voluntary methodology to predict sleep disturbance in terms of the probability of awakening. ANSI's *Quantities and Procedures for Description and Measurement of Environmental Sound -Part 6: Methods for Estimation of Awakenings Associated with Outdoor Noise Events Heard in Homes*, July 2008, provides a method to predict sleep disturbance associated with noise levels in terms of indoor A-weighted sound exposure level (ASEL). The methodology was developed from about 10,000 subject-nights of observations primarily in homes near areas of routine jet aircraft takeoff and landings, railroads, roads, and highways. The methodology assumes that the individuals have no sleep disorders, normal hearing, and only applies to individuals over 18 years of age. The methodology also defines "disturbance" as being restricted to a behaviorally confirmed awakening.

While the Federal Interagency Committee on Aviation Noise has a recommended means of predicting awakenings from a single aircraft event, the new ANSI standard further refines this approach by taking into account the time since the person fell asleep and the ability to identify the probability of being awakened from multiple aircraft events over the course of the entire night. Although the FICAN and ANSI methodologies provide a means by which the potential for awakenings due to single events can be predicted, neither methodology provides a recommended target level for acceptable single-event noise or percentage of awakening.

Because the FICAN test results on aviation noise indicate that less than 5% of the population experiences sleep disturbance from individual events provided interior noise levels associated with those events is less than 65 dB SEL, it could be concluded that an interior SEL threshold of 65 dB SEL would be a reasonable target to minimize the potential for sleep disturbance. However, using the ANSI methodology with the same 65 dB SEL interior threshold and an assumed 27 nighttime railroad passbys (this is the approximate number of current nighttime passbys), the potential for awakening increases to 38%.

Regardless of which methodology is utilized to predict the likeliness of awakening due to single events, the threshold for sleep disturbance is not absolute because there is a high degree of variability from one person to another, as well as a high degree of variation between the FICAN and ANSI prediction methodologies. The City of La Mirada General Plan Noise Element policies do not provide an interior noise standard specific to railroad single-events.

Vibration Impact Assessment Criteria

For vibration impact assessment, the FTA guidelines express acceptable ground-borne vibration in terms of root-mean-square (RMS) velocity levels depending on the sensitivity of various land use categories. Residential land uses are defined as Vibration Category 2 land uses. The recommended vibration criteria for Category 2 land uses are as follows:

- 80 VdB for Infrequent Vibration Events (fewer than 30 per day)
- 75 VdB for Occasional Events (between 30 and 70 per day)
- 72 VdB for Frequent Events (more than 70 per day)

The impact thresholds shown above are based on experience with vibration from rail transit systems. They have been used to assess vibration from freight trains since no specific impact criteria exist for freight railroads. However, the significantly greater length, weight and axle loads of freight trains make it problematic to use these impact criteria for freight rail.

Because the current rail activity along the project study corridor consists of a combination of passenger, switching operations, and heavy freight trains, and because the train speeds vary considerably, the vibration generation of the passing trains is not uniform. Although approximately 90 daily railroad operations were identified during the monitoring program, the vibration generated by many of these operations were imperceptible. As a result, it is unclear whether the slower and lighter trains which generated imperceptible vibration levels should be included in the count of daily events used to establish the impact criteria shown above.

As an alternative to the FTA vibration impact assessment methodology, criteria contained in the Transportation and Construction Induced Vibration Guidance Manual are considered (Jones & Stokes, June 2004). Table 6 of that publication indicates that peak particle velocities for transient events of 0.035 inches/second are barely perceptible whereas a PPV of 0.24 inches/second is distinctly perceptible.

There are a variety of vibration criteria used to assess potential damage to structures. These criteria vary depending on the type of vibration (continuous vs. transient), the frequency content of the vibration source, and the type and age of the building construction. While there is no universal consensus as to what vibration levels would result in damage to residential structures such as those in the City of La Mirada near the railroad tracks, several studies report a peak particle velocity of 0.5 to 1.0 inches per second as being the threshold at which damage to residential structures could occur.

Evaluation of Railroad Noise Levels in Residential Backyards

Methodology

Nine (9) locations along the project study corridor were selected for noise monitoring. Eight of the sites represented outdoor activity areas (backyards) of existing residences located between McComber Road and Valley View Avenue. The ninth location represented a control site located within the City of La Mirada maintenance yard immediately adjacent to the railroad tracks. The control site was used to definitively identify every railroad passby during each of the 48-hours during the monitoring period through the creation of audio recordings (.wav files) for each single event occurrence. Figure 2 shows the project study limits and locations of noise monitoring sites. Appendix B shows an aerial overview and photographs of each noise monitoring site.

The railroad noise surveys were conducted at Sites 1-3, 5 and 7 on May 21-22, 2014, and at Sites 4, 6 and 8 on June 4-5, 2014. Equipment used for the railroad noise surveys consisted of Larson Davis Laboratories (LDL) Model 820 precision integrating sound level meters at Sites 1-8 and an LDL Model 831 precision integrating sound level meter at the control site. The systems were calibrated using LDL Model CAL200 acoustical calibrators to ensure the accuracy of the measurements. The measurement systems measurement systems meet all of the pertinent requirements of the ANSI for Type 1 (precision) sound measurement systems.

The purpose of the noise level measurements was to quantify overall day/night average noise levels as well as individual railroad single events at each location. As a result, the meters were programmed to record multiple noise metrics at hourly intervals, and to log separate exceedance records for any noise event which exceeded programmed thresholds for event duration and sound level.

Due to the presence of traffic on Stage Road, which was between the backyard noise monitoring locations and BNSF railroad tracks, several single events were logged at each location which were traffic-related and not associated with railroad operations. To filter non-railroad events from the single-event records collected at Sites 1-8, BAC staff observations and audio recordings of each single-event records logged at the control site were reviewed. Because the sound level meters were time-synchronized, it was possible to predict what time a railroad event should have been logged at each backyard location based on the time the train event was registered at the control site. This analysis tool was invaluable in analyzing nighttime train operations when BAC staff were not present at the control site conducting observations of each train passby.

During the daytime hours of the surveys, a BAC staff member remained at the control site and kept detailed records of every train operation. Data collected by the BAC observer included the date and precise time of the operation, the train type (freight passby, freight switching, or passenger train passby), train direction (northbound or southbound), the number of locomotives and cars per train, and the train speed. Train speeds were captured using a Bushnell Velocity radar gun.

Figure 2
Project Study Limits and Noise & Vibration Survey Locations
BNSF Railroad Project - La Mirada, California

Noise Monitoring Results

The results of the railroad noise monitoring surveys were used to compute the number of daily trains during the survey period, the computed day/night average noise level (Ldn) at each measurement site, the mean single-event sound exposure level at each location, and the computed railroad Ldn.

In order to calculate the day/night average (L_{dn}) railroad noise exposure at the noise monitoring sites, the following equation was used:

$$L_{dn} = SEL + 10 \log N_{eq} - 49.4 \text{ dB, where:}$$

SEL is the mean SEL of the train events at each site, N_{eq} is the sum of the number of daytime events (7 a.m. to 10 p.m.) per day plus ten times the number of nighttime events (10 p.m. to 7 a.m.) per day, and 49.4 is ten times the logarithm of the number of seconds per day. A summary of the railroad noise monitoring results and computed railroad Ldn at each location is provided in Table 2. A graphical illustration of the continuous noise measurement data is provided in Appendix C.

Table 2
Noise Measurement Results
BNSF Railroad Noise Survey – La Mirada, California

Site	Distance to Near Track (ft.)	Date	# of Trains	Mean SEL	Railroad Ldn	Non-Railroad Ldn	Total Ldn
1	185	May 21	83	88	**62**	**64**	**66**
		May 22	87	88	**63**	**63**	**66**
2	115	May 21	85	89	**64**	**65**	**68**
		May 22	90	89	**64**	**64**	**67**
3	115	May 21	82	85	60	**63**	**64**
		May 22	82	86	**61**	**61**	**64**
4	150	June 4	55	80	53	**60**	**61**
		June 5	73	80	55	58	60
5	135	May 21	48	81	54	57	59
		May 22	51	84	57	58	**61**
6	195	June 4	76	88	**63**	**62**	**65**
		June 5	86	90	**65**	59	**66**
7	240	May 21	86	92	**66**	58	**67**
		May 22	93	90	**66**	**62**	**67**
8	140	June 4	85	94	**69 A**	**66**	**71**
		June 5	99	93	**69 A**	**65**	**70**

Source: Bollard Acoustical Consultants, Inc. (BAC)
Note: Noise Levels in Bold font exceed the City of La Mirada 60 dB Ldn exterior noise standard.
A – Site 8, which was located closest to the Valley View Drive construction area, was periodically influenced by noise from railroad warning horn usage. Without warning horns, Site 8 railroad noise levels are expected to be approximately 1-2 dB Lower.

The Table 2 data indicate that both railroad and non-railroad noise levels varied by location. At every measurement site, the distance to Stage Road was fairly similar whereas the distance to the railroad tracks varied considerably. In addition, the elevation of the railroad tracks relative to both Stage Road and the noise monitoring sites also varied considerably. Not surprisingly, the measurement sites with the greatest elevation difference relative to the railroad tracks (Sites 3-5) exhibited the lowest measured railroad noise levels. Both railroad and non-railroad noise levels exceeded the City of La Mirada's 60 dB Ldn exterior noise level criteria at 6 of the 8 sites monitored.

As noted previously, audio recordings were captured of each train passage by the control location during the entire span of the noise measurement surveys. In addition, observations of rail activity were conducted during daytime hours during the survey. Those recordings and observations were analyzed and correlated, with the results presented in Table 3.

Table 3
Summary of Analysis of Railroad Audio Recordings and Observations
May 19-23, 2014 - BNSF Railroad Noise Survey – La Mirada, California

	Passenger	Freight	Total
Number of Survey Hours	91	91	91
Total Number of Train Passbys During Survey	197	136	333
Average Number of Passbys per Day	52	36	88
Total Number of Passbys with Horn Usage	26	19	45
Percentage of Passbys with Horn Usage	13%	14%	14%
Direction (Northbound / Southbound)	50% /50%	50% /50%	50% /50%
Average Number of Engines per Passby	2	4	3
Average Number of Rail Cars per Passby	6	105	43
Daytime / Nighttime[3] Distribution of Passbys	77% / 23%	63% / 37%	71% / 31%

Source: Bollard Acoustical Consultants, Inc.
1. PPV = Peak Particle Velocity
2. Vibration measurement sites are illustrate on Figure 1 and in Appendix B.
3. Daytime = 7 a.m. – 10 p.m. Nighttime = 10 p.m. – 7 a.m.

Evaluation of Railroad Noise Levels within Residential Interior Spaces

Compliance with 45 dB Ldn City of La Mirada Interior Noise Standard

According to the City of La Mirada noise standards, railroad noise impacts are identified at interior spaces of new residential developments if interior railroad noise levels exceed 45 dB Ldn. As indicated in Table 2, existing exterior railroad noise levels at the nearest residences to the railroad tracks within the project study corridor ranged from 53-69 dB Ldn. Now that the Valley View Avenue undercrossing has been completed, railroad warning horn noise has been significantly reduced, which is expected to diminish existing railroad noise levels at Site 8 to approximately 67 dB Ldn.

Based on exterior railroad noise levels ranging from 53-67 dB Ldn at the building facades of the nearest residences to the BNSF tracks, building façade railroad noise reductions ranging from 8 to 22 dB Ldn would be required to achieve interior noise levels of 45 dB Ldn or less.

The degree of exterior to interior noise level reduction provided by the various building facades is a function of their construction. Standard residential construction in conformance with common industry practices and local building code requirements normally consists of 2x4-inch wood stud exterior walls, exterior wood or stucco siding, dual pane windows (two 1/8-inch panes separated by 1/4-inch airspace – STC 27), perimeter weather-stripping, and composition roofs.

A visual survey of the residences located nearest to the railroad tracks indicates that the vast majority of residences are constructed with stucco exterior siding and in very good condition. BAC test data for residential construction similar to that located along the project study corridor indicates this type of construction typically provides at least 25 dB of exterior to interior building façade railroad noise reduction. For a conservative assessment of project noise impacts, this analysis assumes 25 dB exterior to interior railroad noise reduction at existing residences within with windows in the closed position.

When windows are in the open position, much of the noise reducing benefits of the façade are lost as sound will enter the sensitive rooms through the path of least resistance (the open window). With windows in the open configuration, the degree of noise reduction provided by the building façade depends on the window size, wall size, room volume, proximity to open window, and sound absorption present within the room. Although this number is highly variable, building façade noise reduction with windows open is often considered to be at least 10 dB. Although it is recognized that interior noise levels are considerably higher with windows open, the City of La Mirada, as with most jurisdictions, applies the interior noise level standards assuming windows in the closed position.

Because existing railroad noise levels do not exceed 67 dB Ldn, and because the degree of exterior to interior railroad noise reduction provided by the residences along the project study corridor is estimated to be at least 25 dB, the predicted interior railroad noise level within residences is approximately 42 dB Ldn or less. This range of existing interior railroad noise levels is considered satisfactory relative to the City's 45 dB Ldn interior noise level standard.

Sleep Disturbance Assessment

Nearly all of the residents of the homes at which railroad noise monitoring was conducted reported having been awakened by railroad noise at some point, sometimes frequently. As indicated in Table 2, the measured average railroad Sound Exposure Levels (SEL) at the exterior building facades of the representative noise measurement locations ranged from 80 to 94 dB SEL. After applying the estimated 25 dB building façade noise reduction to these values, interior sound exposure levels during train passbys are estimated to be approximately 55 to 69 dB SEL with windows closed.

As discussed previously, there is no single noise threshold above which sleep disturbance will occur or below which sleep disturbance will not. This is because sensitivity to railroad noise and the effect it has on a person's sleep can vary widely from one individual to the next. Based on a single nighttime railroad passage of 69 dB SEL within a bedroom, past studies have shown that approximately 5-10% of the population would be awakened. When multiple nighttime train passages occur, the potential for sleep disturbance or awakening logically increases.

There is ample anecdotal evidence indicating that a percentage of the population living near the railroad tracks in the City of La Mirada currently experience some form of sleep disturbance during nighttime railroad passages. The railroad noise level data collected as part of this survey supports that anecdotal evidence. Specifically, that measured noise levels during several nighttime train passages (particularly freight trains and especially those using horns), were of sufficient magnitude to result in awakening or sleep disturbance for a percentage of the population.

Evaluation of Exterior Railroad Vibration Levels

Methodology

The same eight (8) locations along the project study corridor that were selected for noise monitoring were also used for vibration monitoring. Figure 2 shows the vibration measurement site locations and Appendix B shows an aerial overview and photographs of each vibration monitoring site.

The railroad vibration surveys were conducted at Sites 1-8 on May 21-22, 2014. The vibration measurements consisted of rms vibration velocity sampling using a Larson Davis Laboratories Model HVM100 Vibration Analyzer with a PCB Electronics Model 353B51 ICP Vibration Transducer. The test system is a Type I instrument designed for use in assessing vibration as perceived by human beings, and meets the full requirements of ISO 8041:1990(E).

Vibration Measurement Results

The results of the vibration measurements are shown in Table 4.

Table 4
Vibration Measurement Results (PPV, Inches/Second[1])
BNSF Railroad Noise Survey – La Mirada, California

		Passenger			Freight		
Site[2]	Ambient	Low	High	Average	Low	High	Average
1	0.0834	0.1960	0.1960	0.1081	0.1960	0.1960	0.1960
2	0.0393	0.0786	0.2160	0.1545	0.1330	0.2210	0.1770
3	0.0245	0.0638	0.1380	0.1116	0.0885	0.1820	0.1353
4	0.0638	0.0981	0.3240	0.1750	0.0541	0.4770	0.1621
5	0.0393	0.1080	0.1080	0.1080	0.0443	0.3590	0.1714
6	0.0245	0.0590	0.1820	0.1223	0.0541	0.2850	0.1277
7	0.0393	0.0344	0.0834	0.0663	0.0443	0.1330	0.0968
8	0.0393	0.0885	0.2110	0.1424	0.1080	0.3040	0.1947

Source: Bollard Acoustical Consultants, Inc.
4. PPV = Peak Particle Velocity
5. Vibration measurement sites are illustrate on Figure 1 and in Appendix B.

The Table 4 data indicate that peak particle velocities measured during train passages varied by location and train type. Nearly all of the passenger train passbys were below the 0.24 inches/second threshold considered "distinctly perceptible" at or above the threshold of perception commonly considered to be 0.1 inch/second. Conversely, several of the freight train passbys were at or above the threshold considered distinctly perceptible. However, even the highest measured vibration levels for both passenger and freight trains were well below the commonly accepted threshold of 0.5-1.0 inch/second for damage to structures.

Railroad Noise Mitigation Alternatives

Noise Mitigation Fundamentals

Any noise problem may be considered as being composed of three basic elements: the noise source, a transmission path, and a receiver. The appropriate acoustical treatment for a given noise source should consider several factors, including the type of noise source and the sensitivity of the receiver. The problem should be defined in terms of appropriate noise criteria (Ldn or SEL), the location of the sensitive receiver (inside or outside), and when the problem occurs (daytime, nighttime, or 24-hour average). Noise control techniques should then be selected to provide the most effective use of resources to obtain the desired degree of noise attenuation while remaining consistent with local aesthetic standards and practical structural and economic limits. Fundamental noise control techniques include the following:

Use of Setbacks

Noise exposure may be reduced by increasing the distance between the noise source and receiving use. The available noise attenuation from this technique is limited by the characteristics of the noise source, but is generally about 4 to 6 dB per doubling of distance from the source. Because the locations of the railroad tracks and existing residences are fixed, this would not be a viable mitigation option for reducing railroad noise levels in the City of La Mirada.

Use of Noise Barriers

Shielding by barriers can be obtained by placing walls, berms or other structures, such as buildings, between the noise source and the receiver. The noise reduction provided by noise barriers can affect both interior and exterior areas of the sensitive receiver (residences in this case), provided the barrier intercepts line of sight between the railroad noise source and backyard areas or residential building facades.

The effectiveness of a barrier depends upon blocking line-of-sight between the source and receiver, and is improved with increasing the distance the sound must travel to pass over the barrier as compared to a straight line distance from source to receiver. The difference between the distance over a barrier and a straight line between source and receiver is called the "path length difference," and is the basis for calculating barrier noise reduction.

Barrier effectiveness depends upon the relative heights of the source, barrier and receiver. In general, barriers are most effective when placed close to either the receiver or the source. An intermediate barrier location yields a smaller path-length-difference for a given increase in barrier height than does a location closer to either source or receiver.

For maximum effectiveness, barriers should be continuous and relatively airtight along their length and height. To ensure that sound transmission through the barrier is insignificant, barrier mass should be about 3-4 pounds per square foot, although a lesser mass may be acceptable if the barrier material provides sufficient transmission loss. Satisfaction of the above criteria requires substantial and well-fitted barrier materials, placed to intercept line of sight to all significant noise sources.

There are practical limits to the noise reduction provided by barriers. For railroad noise, a 5-10 dB noise reduction may often be attained. Due to the height of the railroad noise source above the tracks, noise reductions exceeding 10 dB are usually difficult to attain, with noise reductions in excess of 15 dB extremely difficult to achieve.

Because the majority of the residences located along Stage Road (Nearest residences to the railroad tracks) are single-story, the construction of noise barriers along either the east or west side of Stage Road could provide shielding of the majority of the residential building facades as well as outdoor activity areas (backyards).

Noise Reduction by Building Facades

When interior noise levels are of concern in a noisy environment, noise reduction may be obtained through improvements to residential building façade construction. As noted previously, standard residential construction practices provide approximately 25 dB noise reduction when windows are closed. Thus a 25 dB exterior-to-interior noise reduction can be obtained by the requirement that building design include adequate ventilation systems, allowing windows on a noise-impacted facade to remain closed under any weather condition.

Where greater noise reduction is required, acoustical treatment of the building facade may be feasible. The greatest improvement in building façade noise reduction can typically be realized through specification of upgraded windows with higher Sound Transmission Class (STC) ratings, as windows tend to be the path of least resistance for noise. For example, replacing single-pane windows with dual-pane assemblies can result in a 3-5 dB reduction in interior noise levels. Even greater noise reductions can be achieved through the use of laminated glazing or larger airspaces.

Use of Vegetation

Trees and other vegetation are often thought to provide significant noise attenuation. However, approximately 100 feet of dense foliage (so that no visual path extends through the foliage) is required to achieve a 5 dB attenuation of traffic noise. Thus the use of vegetation as a noise barrier would not be a viable means of reducing railroad noise levels within the City of La Mirada.

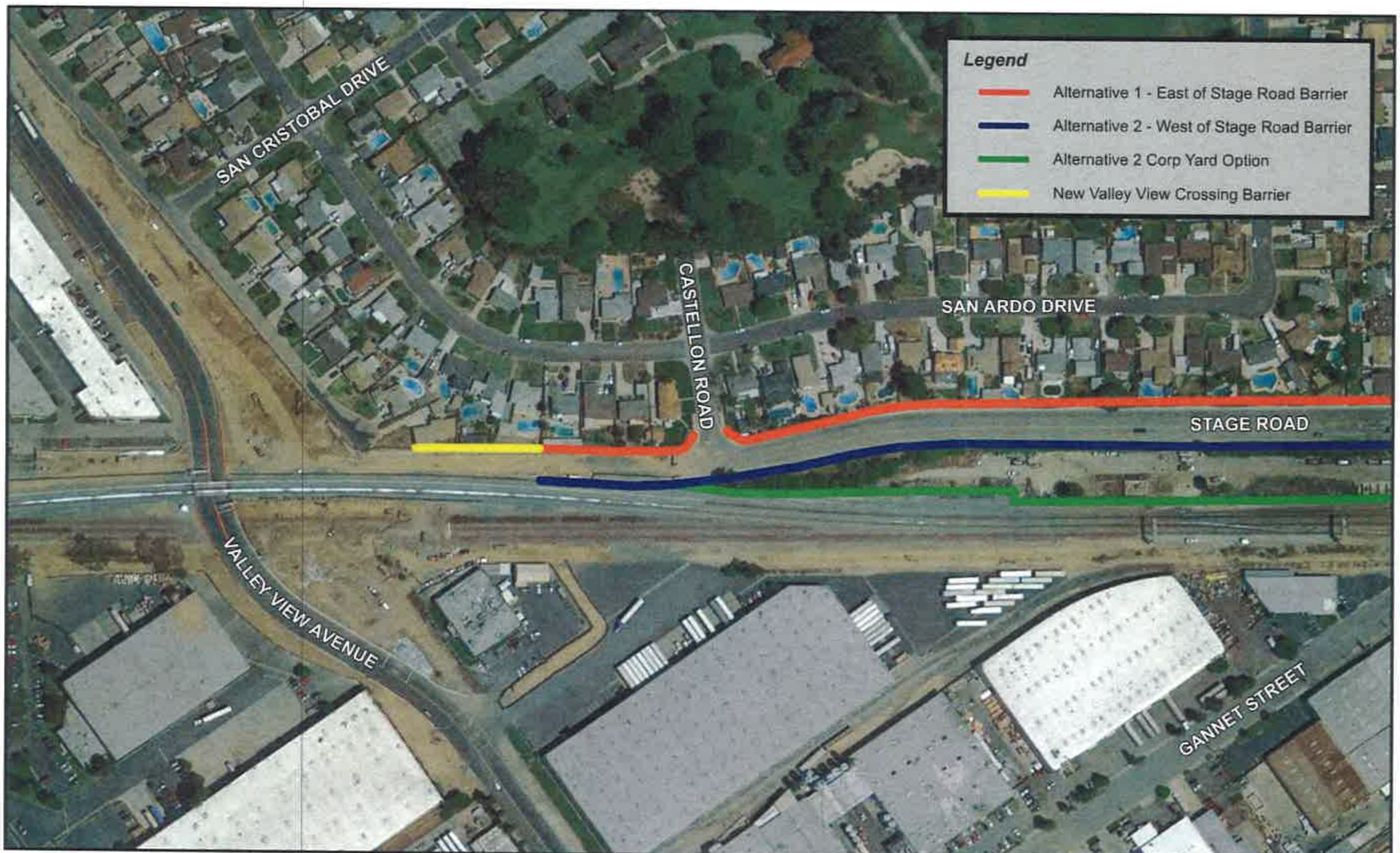
Noise Barrier Analysis

Because the construction of solid noise walls may be a feasible means of reducing railroad noise exposure at both interior and exterior areas of the nearest residences to the railroad tracks, a detailed noise barrier analysis was performed as part of this study. Two primary noise barrier alignments were considered for this study. The first alignment (Alignment 1), would be located along the east side of Stage Road, between the residences and Stage Road. The second alignment (Alignment 2), would be located on the east side of Stage Road, between Stage Road and the Railroad Tracks. A sub-alignment was also considered to Alignment 2, which would route the noise barrier behind the City's corporation yard located at the northern portion of the project study limits. Figures 3-7 show the noise barrier alignments considered for this analysis.

The railroad noise barrier analysis was conducted at eight (8) discrete locations representing the eight noise monitoring locations. Inputs to the railroad noise barrier analysis included distances from the railroad tracks to the barrier alignments, distances from each barrier alignment to the residential back yard, the measured railroad noise exposure shown in Table 2, and the elevations of the railroad tracks, base of noise barrier, and backyards. Noise barrier heights ranging from 6-16 feet were evaluated with the railroad noise source assumed to be 10 feet above the railroad tracks and the receiver assumed to be 5 feet above backyard elevation. The barrier material was assumed to be sufficiently massive such that the only railroad noise which would be heard at the receiver following barrier construction would be that refracting over the top of the barrier, with no audible railroad noise passing through the barrier.

The detailed results of the noise barrier analysis are provided in Appendices D and E for barrier alignment Alternatives 1 and 2, respectively. The noise barrier results are summarized in Tables 5 and 6 for Alignments 1 and 2, respectively.

Figure 3
Noise Barrier Alternatives
BNSF Railroad Project - La Mirada, California



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Scale (feet)
0 200 400

Figure 4
Noise Barrier Alternatives
BNSF Railroad Project - La Mirada, California

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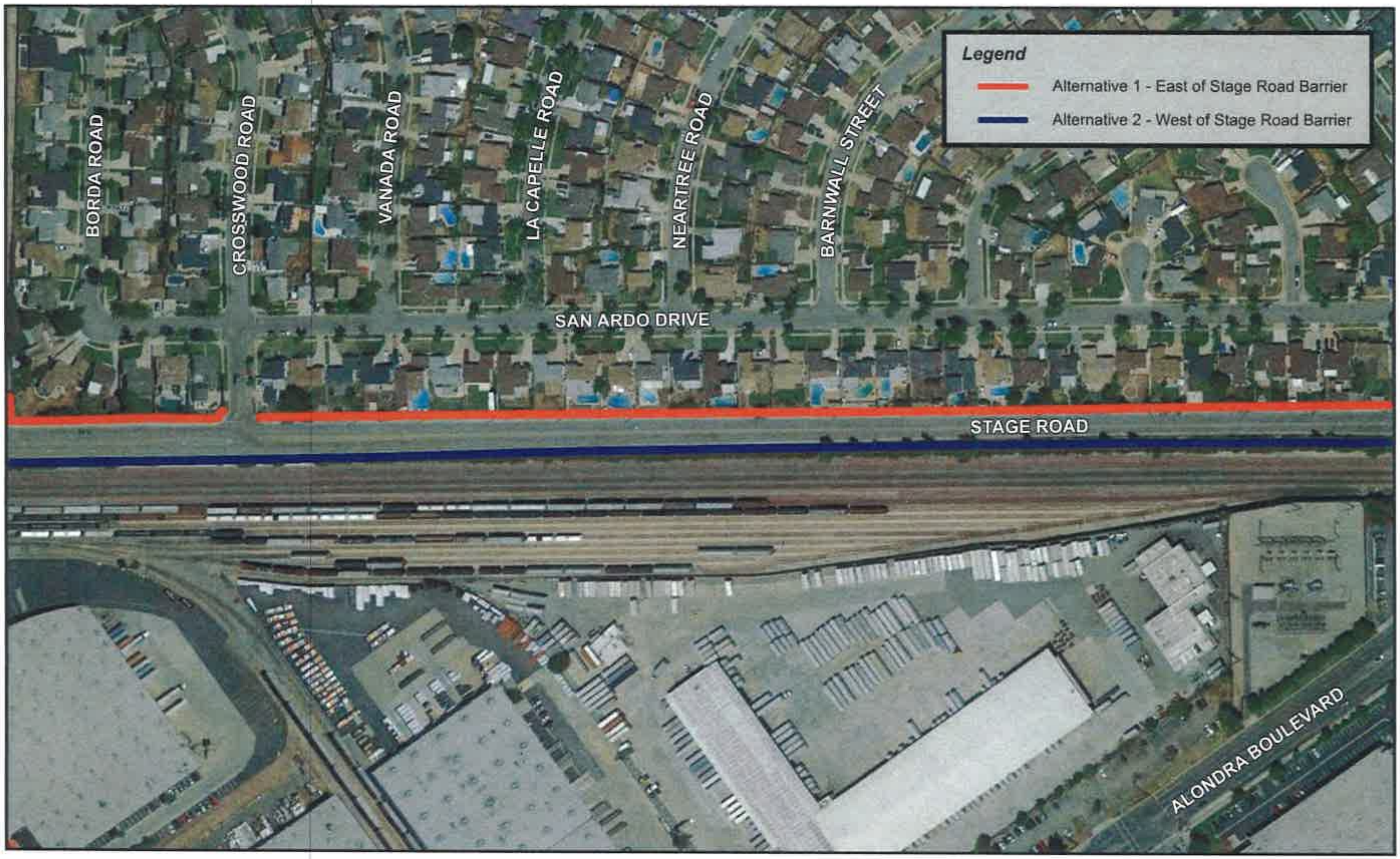
Scale (feet)
0 200 400

Figure 5
Noise Barrier Alternatives
BNSF Railroad Project - La Mirada, California



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Scale (feet)
0 200 400

Figure 6
Noise Barrier Alternatives
BNSF Railroad Project - La Mirada, California

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Figure 7

Noise Barrier Alternatives

BNSF Railroad Project - La Mirada, California

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Scale (feet)

0 200 400

Table 5
Predicted Noise Barrier Effectiveness and Resulting Noise Levels
BNSF Railroad Noise Study - Alignment 1 (Barrier on East Side of Stage Road)

Barrier	Site 1[A]		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8	
Height[B]	I.L.[C]	Ldn[D]	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn
6	-5	58	-5	59	-5	56	-10	45	-8	49	-5	60	-5	61	-3	65
7	-5	58	-5	59	-6	56	-11	45	-9	48	-5	60	-5	61	-4	63
8	-5	58	-6	58	-6	55	-11	44	-10	47	-5	60	-5	61	-5	62
9	-6	58	-7	57	-8	54	-12	44	-10	47	-6	59	-5	61	-5	62
10	-6	57	-8	56	-9	52	-12	43	-11	46	-7	58	-6	60	-5	62
11	-7	56	-9	55	-10	51	-13	42	-12	45	-8	57	-7	59	-6	61
12	-8	55	-10	54	-10	51	-13	42	-13	45	-9	56	-7	59	-7	60
13	-9	54	-11	53	-11	50	-14	42	-13	44	-9	56	-8	58	-8	59
14	-9	54	-12	53	-12	49	-14	41	-14	43	-10	55	-9	58	-9	58
15	-10	53	-12	52	-13	48	-14	41	-14	43	-11	54	-9	57	-10	57
16	-11	52	-13	51	-13	48	-15	40	-15	42	-11	54	-10	56	-11	57

Notes:

A. The barrier evaluation sites are the same as the noise measurement locations. Those locations are identified on Figure 2.
B. Noise barrier heights are specified relative to Stage Road edge of pavement elevations.
C. I.L. = Insertion Loss. Insertion loss is the level of predicted railroad noise reduction provided by each barrier height at each location.
D. Ldn is the resulting Ldn within the backyard areas of each Site following noise barrier construction.

Table 6
Predicted Noise Barrier Effectiveness and Resulting Noise Levels
BNSF Railroad Noise Study - Alignment 2 (Barrier on West Side of Stage Road)

Barrier	Site 1[A]		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8	
Height[B]	I.L.[C]	Ldn[D]	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn	I.L.	Ldn
6	-5	58	-9	55	-10	51	-11	45	-9	48	-2	63	-4	62	-1	66
7	-5	58	-10	54	-11	50	-11	44	-10	47	-4	61	-5	61	-1	66
8	-5	58	-10	54	-12	50	-12	44	-10	47	-5	60	-5	61	-3	64
9	-6	57	-11	53	-12	49	-12	43	-11	46	-5	60	-5	61	-4	63
10	-7	56	-12	53	-13	48	-13	42	-11	46	-5	60	-6	60	-5	62
11	-7	56	-12	52	-13	48	-13	42	-12	45	-6	59	-6	60	-5	62
12	-8	55	-13	51	-14	47	-14	42	-13	45	-7	58	-7	59	-5	62
13	-8	55	-13	51	-14	47	-14	41	-13	44	-8	57	-8	58	-6	61
14	-9	54	-14	50	-15	46	-14	41	-13	44	-9	56	-9	58	-6	61
15	-10	53	-14	50	-15	46	-15	40	-14	43	-10	55	-9	57	-7	60
16	-10	53	-15	49	-15	46	-15	40	-14	43	-11	54	-10	56	-8	59

Notes:

A. The barrier evaluation sites are the same as the noise measurement locations. Those locations are identified on Figure 2.
B. Noise barrier heights are specified relative to Stage Road edge of pavement elevations.
C. I.L. = Insertion Loss. Insertion loss is the level of predicted railroad noise reduction provided by each barrier height at each location.
D. Ldn is the resulting Ldn within the backyard areas of each Site following noise barrier construction.

The Table 5 and 6 data indicate that a noise barrier on the west side of Stage Road would be more effective at reducing railroad noise levels at locations where the railroad tracks are below the grade of Stage Road, and slightly less effective at the far northern end of the study area where the tracks are elevated relative to Stage Road. At receptors 1 and 7 the barrier performance would be effectively identical for barriers on the east or west side of Stage Road.

Not surprisingly, the greatest degree of noise barrier effectiveness would result at locations where the railroad tracks are substantially depressed in elevation relative to Stage Road (Sites 4 & 5), where barrier noise reductions ranging from 8 to 15 dB would result from barrier heights of 6-16 feet.

To achieve a clearly noticeable railroad noise reduction of at least 5 dB at the nearest residences, a minimum barrier height of 10 feet would be required if the barrier were constructed on the west side of Stage Road, or 8-feet if it were constructed on the east side. Because the elevation of the railroad tracks varies throughout the study area, an 8-foot tall barrier at one location will produce a different degree of noise reduction than the same height barrier at another.

It should be noted that a barrier located on the east side of Stage Road would require openings at each cross street, thereby diminishing the performance of the noise barrier at locations deeper into the residential neighborhoods. A barrier constructed on the west side of Stage Road would, theoretically, only require openings at the corporation yard and perhaps one access near the south end of the study area.

From a barrier performance standpoint, a barrier constructed on the west side of Stage Road would provide the greater degree of overall railroad noise reduction to the residences of La Mirada. However, such a barrier would need to be constructed of sound-absorbing properties to prevent noise generated by Stage Road traffic being reflected off of the new barrier and back into the community.

It is important to note that the noise level reductions shown in Tables 5 and 6 would apply not only to the backyard areas of the residences along the study corridor, but also to the first-floor interior spaces of the residences. With a barrier constructed on the west side of Stage Road, some benefit may also be achieved within second-floor rooms, but that would depend on the ultimate barrier height and the elevation of the railroad tracks. Second-floor rooms would overlook a barrier constructed on the east side of Stage Road. As noted previously, however, the vast majority of residences located adjacent to Stage Road are single-story construction.

Ultimately, if construction of a solid noise barrier is considered along the project study corridor, several factors would need to be considered in order to determine the feasibility, costs, heights, materials and locations of such a barrier.

Vibration Mitigation

The vibration monitoring results indicate that vibration levels for the majority of passenger train passbys were below the threshold of perception and well below the threshold for damage to structures. For freight train passbys, several vibration levels were measured to be in the clearly perceptible range but still below the threshold that would be expected to cause damage to structures. Some of the vibration experienced by residences along the study corridor is undoubtedly due to airborne sound impacting the residential façade and causing it to vibrate, rather than groundborne vibration. In such cases, the reduction of airborne sound through the construction of a solid noise barrier would also result in reduced airborne vibration of the structure, as there would be less sound energy impacting the residence and causing it to vibrate.

For new railway construction, vibration can be mitigated through the use of resilient substructures beneath the tracks which absorb vibration energy. For existing railways, however, the tracks would have to be removed and reconstructed to allow the installation of such resilient material. This would be a monumental undertaking, requiring disruption of rail service through the corridor, cooperation of the railroad companies, considerable cost, and considerable additional noise generation during the construction period. Such hurdles may render mitigation to reduce the perceptibility of vibration generated during train passages infeasible.

Summary

The noise and vibration monitoring data collected at existing residential backyards along the project study corridor indicate a wide range of variation. In general, noise levels were determined to be in excess of the City of La Mirada noise standards at six of the eight noise monitoring sites, and vibration levels during train passbys were measured to range from imperceptible to clearly perceptible, but below the threshold for damage to structures.

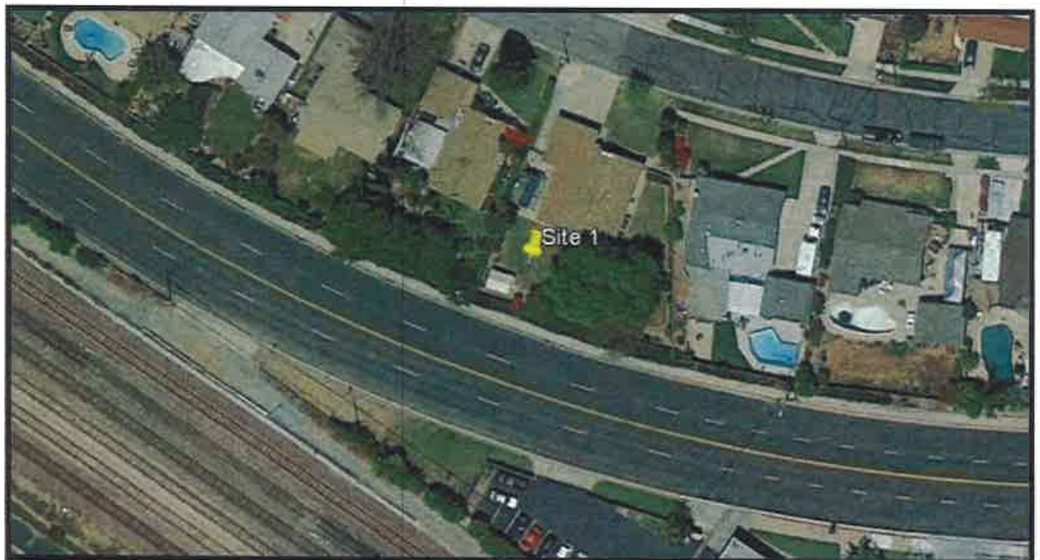
If consideration is to be given to noise mitigation, this analysis concludes that a solid noise barrier constructed along the west side of Stage Road, if feasible, would yield a greater reduction in railroad noise exposure in the community than would a barrier constructed on the east side of Stage Road. Such a barrier would also reduce airborne vibration levels within residences. It may not be feasible to implement measures to further reduce groundborne vibration within the nearest residences, but groundborne vibration levels were measured to be below the threshold for damage to structures.

Appendix A

Acoustical Terminology

Acoustics	The science of sound.
Ambient Noise	The distinctive acoustical characteristics of a given space consisting of all noise sources audible at that location. In many cases, the term ambient is used to describe an existing or pre-project condition such as the setting in an environmental noise study.
Attenuation	The reduction of an acoustic signal.
A-Weighting	A frequency-response adjustment of a sound level meter that conditions the output signal to approximate human response.
Decibel or dB	Fundamental unit of sound, A Bell is defined as the logarithm of the ratio of the sound pressure squared over the reference pressure squared. A Decibel is one-tenth of a Bell.
CNEL	Community Noise Equivalent Level. Defined as the 24-hour average noise level with noise occurring during evening hours (7 - 10 p.m.) weighted by a factor of three and nighttime hours weighted by a factor of 10 prior to averaging.
Frequency	The measure of the rapidity of alterations of a periodic signal, expressed in cycles per second or hertz.
Ldn	Day/Night Average Sound Level. Similar to CNEL but with no evening weighting.
Leq	Equivalent or energy-averaged sound level.
Lmax	The highest root-mean-square (RMS) sound level measured over a given period of time.
Loudness	A subjective term for the sensation of the magnitude of sound.
Masking	The amount (or the process) by which the threshold of audibility is for one sound is raised by the presence of another (masking) sound.
Noise	Unwanted sound.
Peak Noise	The level corresponding to the highest (not RMS) sound pressure measured over a given period of time. This term is often confused with the "Maximum" level, which is the highest RMS level.
RT_{60}	The time it takes reverberant sound to decay by 60 dB once the source has been removed.
Sabin	The unit of sound absorption. One square foot of material absorbing 100% of incident sound has an absorption of 1 sabin.
SEL	A rating, in decibels, of a discrete event, such as an aircraft flyover or train passby, that compresses the total sound energy of the event into a 1-s time period.
Threshold of Hearing	The lowest sound that can be perceived by the human auditory system, generally considered to be 0 dB for persons with perfect hearing.
Threshold of Pain	Approximately 120 dB above the threshold of hearing.

Appendix B-1: Site 1 - 15392 San Ardo Drive
BNSF Railroad Noise and Vibration Study – City of La Mirada



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Appendix B-2: Site 2 - 15314 San Ardo Drive
BNSF Railroad Noise and Vibration Study – City of La Mirada

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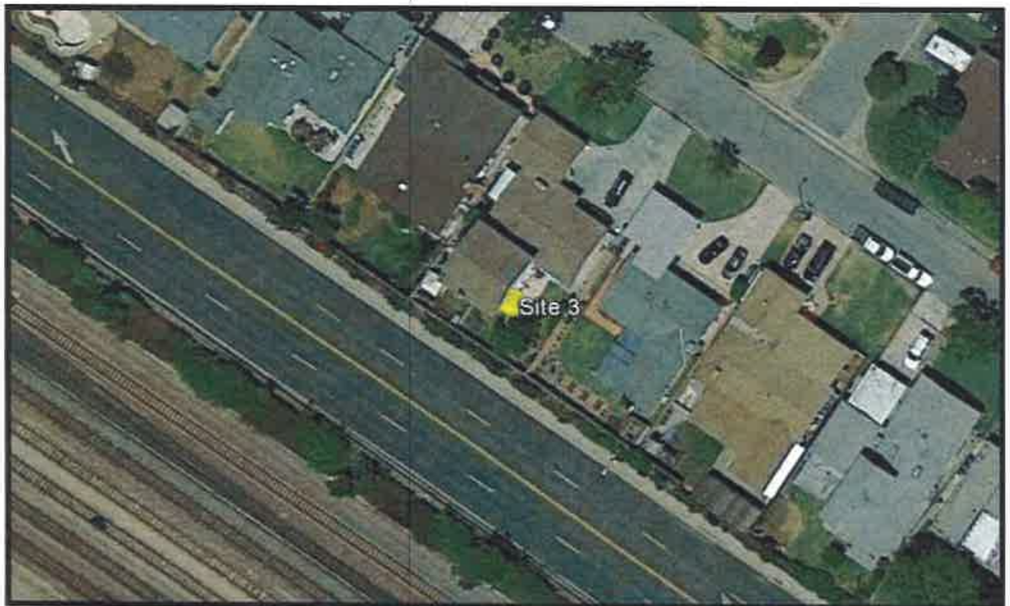
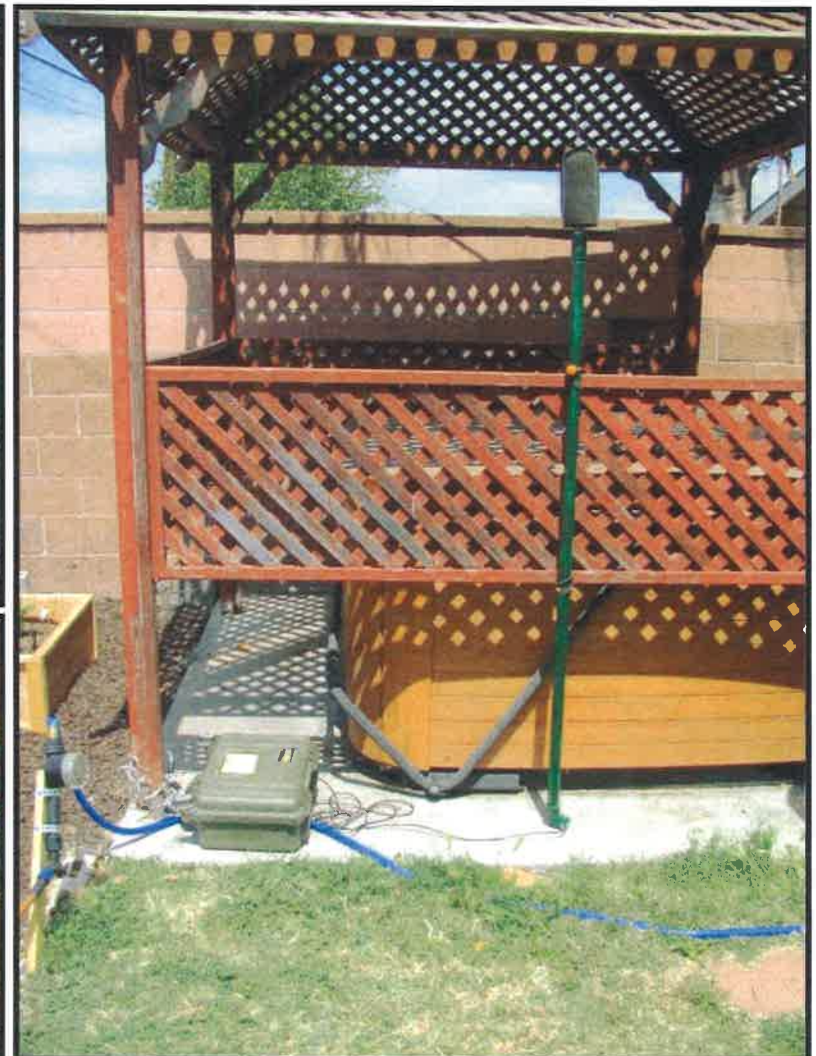
Appendix B-3: Site 3 - 15224 San Ardo Drive
BNSF Railroad Noise and Vibration Study – City of La Mirada





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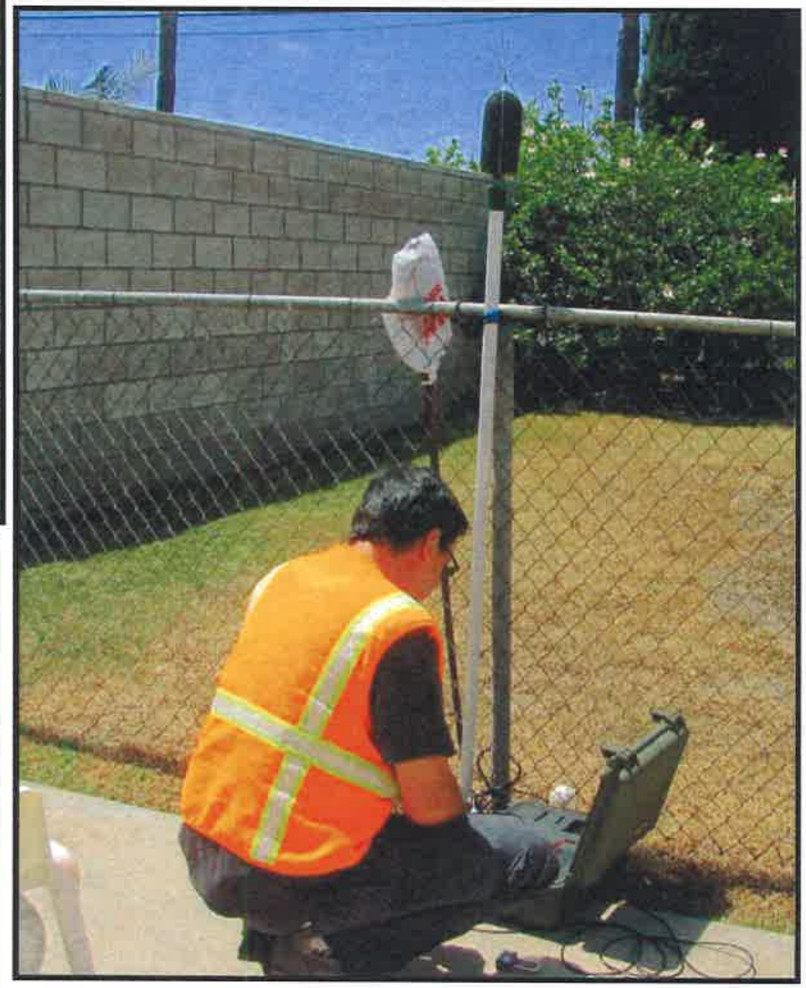
Appendix B-4: Site 4 - 14850 San Ardo Drive
BNSF Railroad Noise and Vibration Study – City of La Mirada



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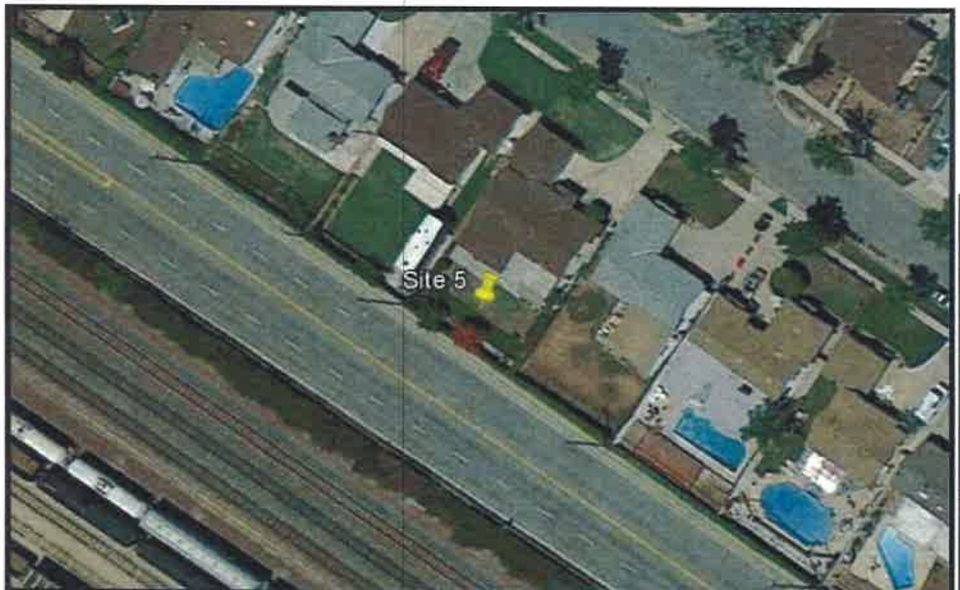
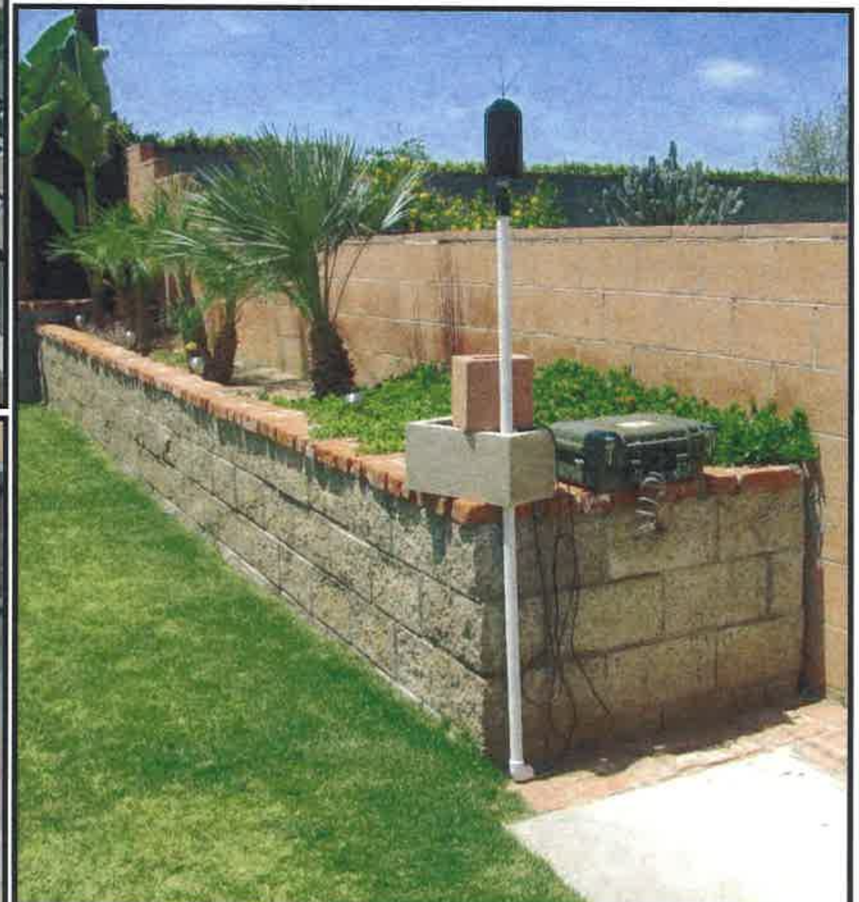
Appendix B-5: Site 5 - 14714 San Ardo Drive
BNSF Railroad Noise and Vibration Study – City of La Mirada





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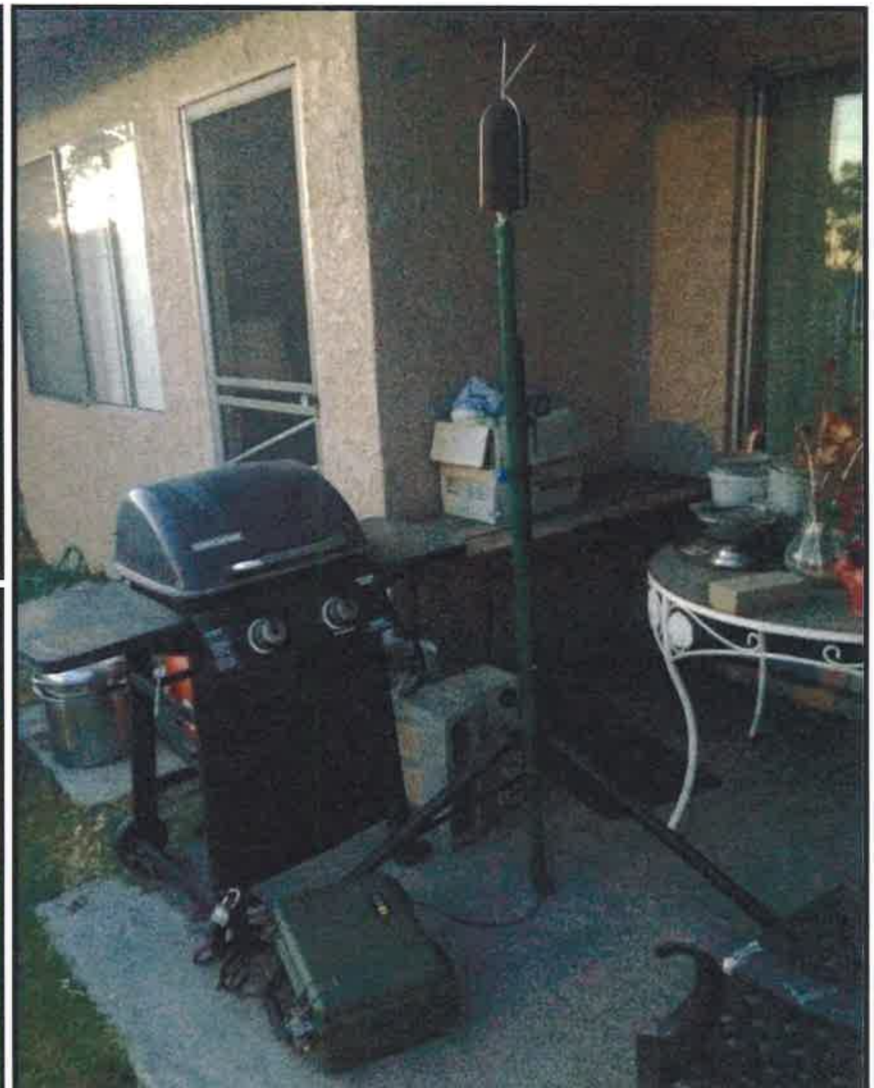
Appendix B-6: Site 6 - 14521 Stage Road #2
BNSF Railroad Noise and Vibration Study – City of La Mirada



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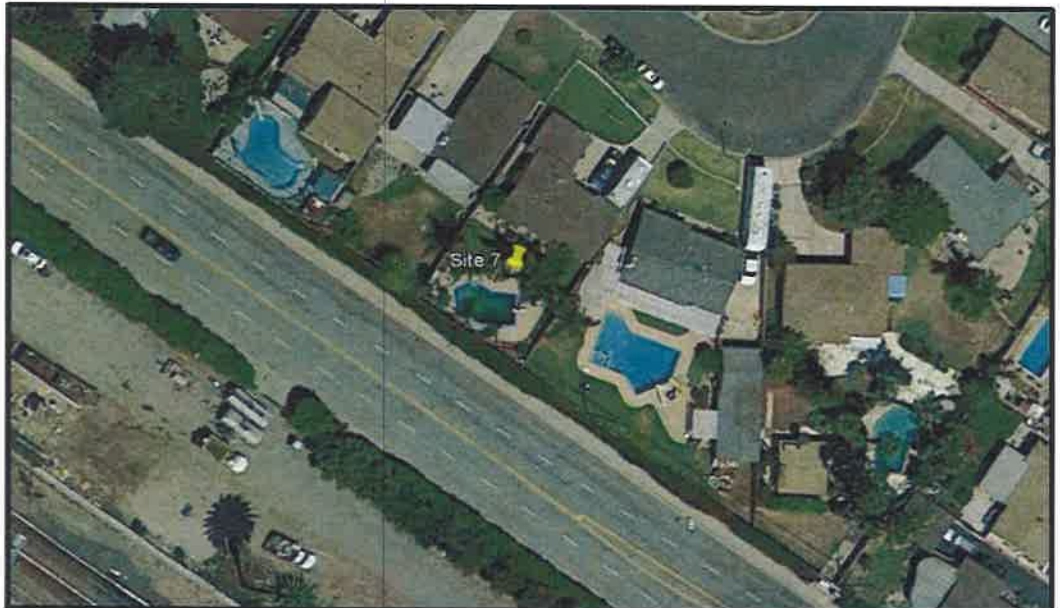
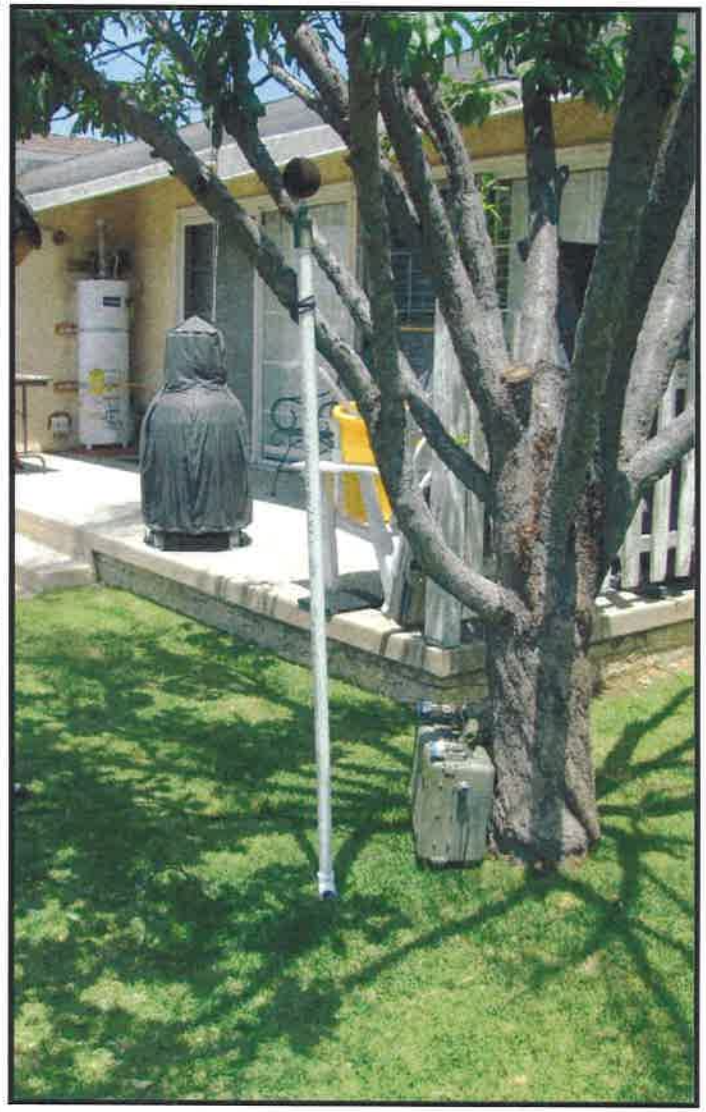
Appendix B-7: Site 7 - 14488 San Ardo Drive
BNSF Railroad Noise and Vibration Study – City of La Mirada





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Appendix B-8: Site 8 - 14342 San Ardo Drive
BNSF Railroad Noise and Vibration Study – City of La Mirada

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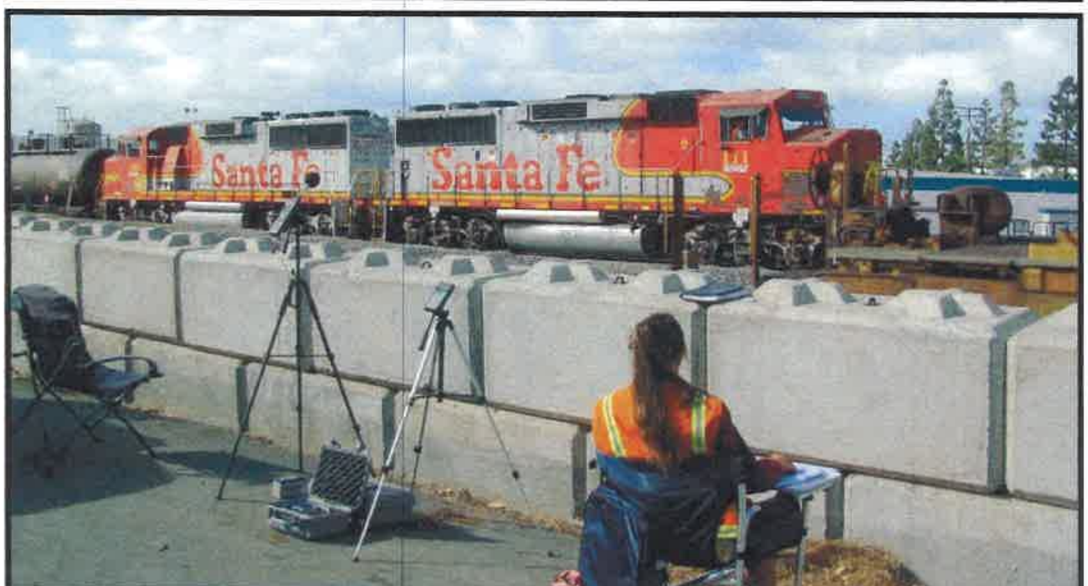
Appendix B-9: Control Site
BNSF Railroad Noise and Vibration Study – City of La Mirada



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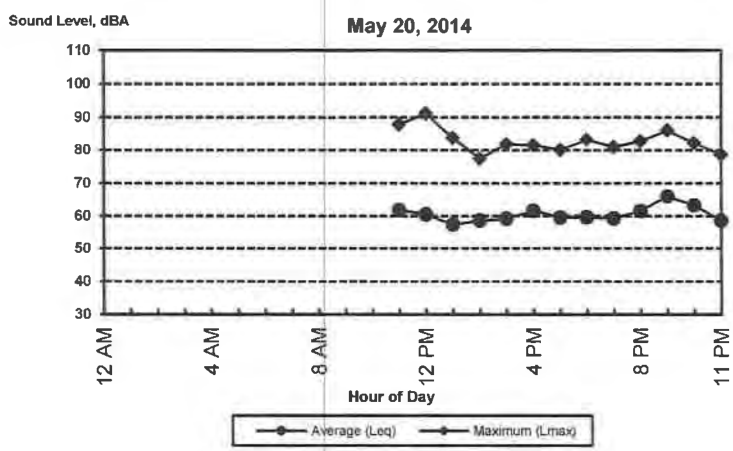
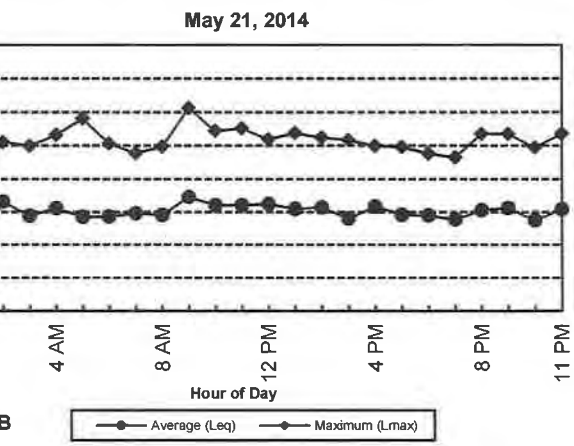
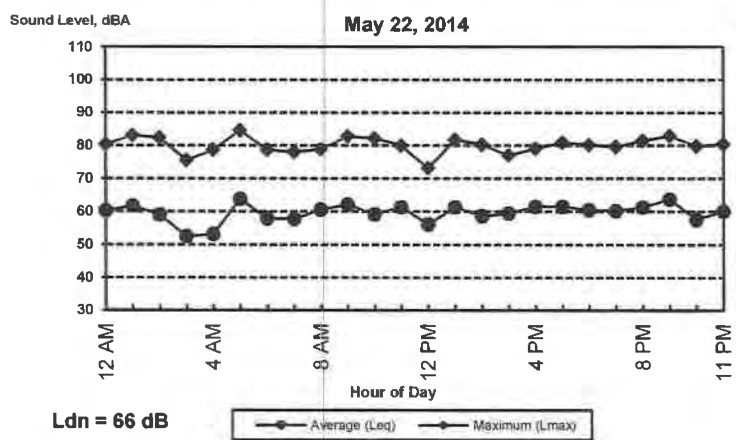
Appendix C-1
La Mirada BNSF Railway Study
Site 1 - May 20 - May 23





Ldn = 66 dB



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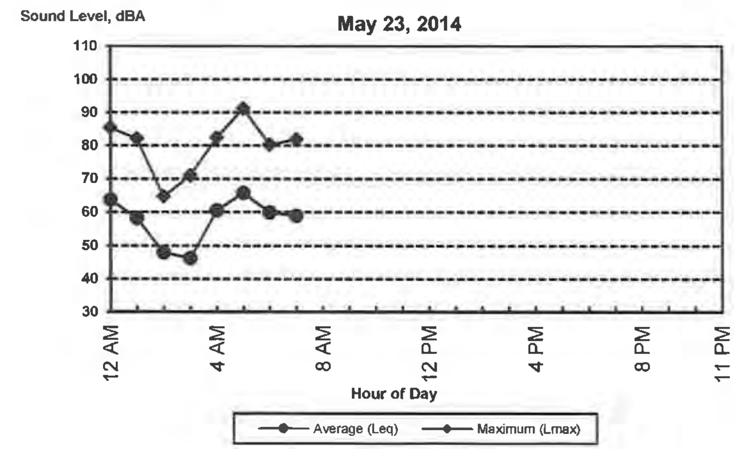

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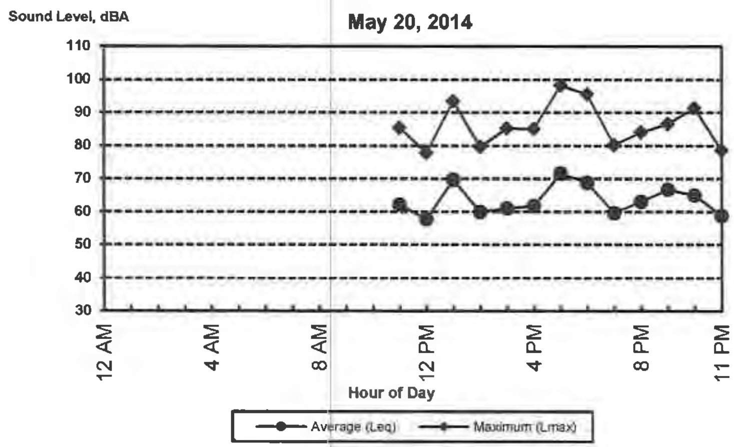
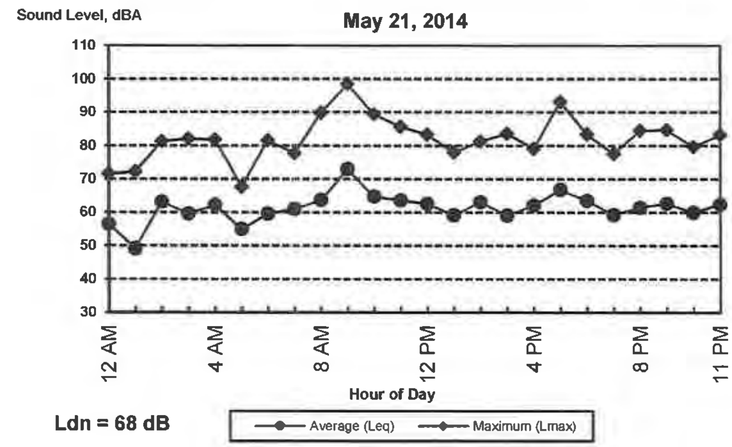
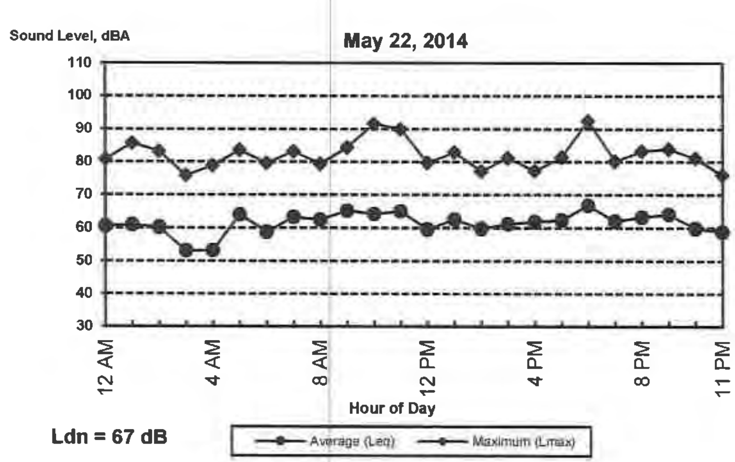
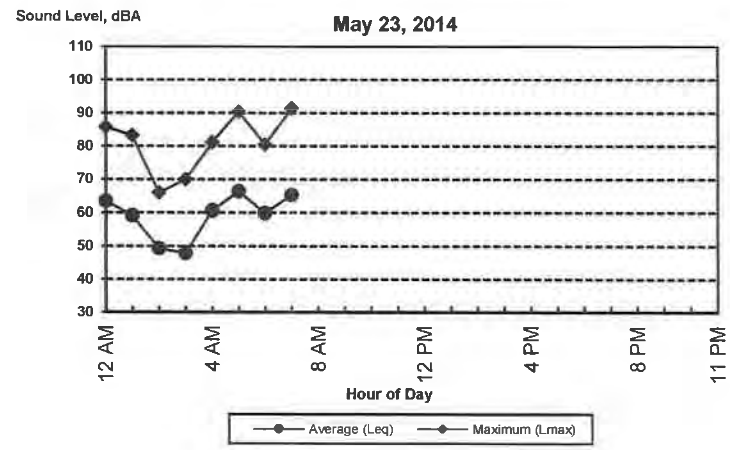
Appendix C-2
La Mirada BNSF Railway Study
Site 2 - May 20 - May 23









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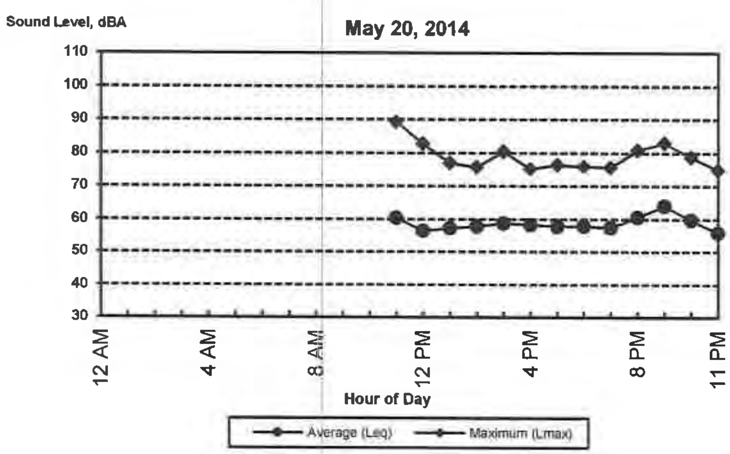
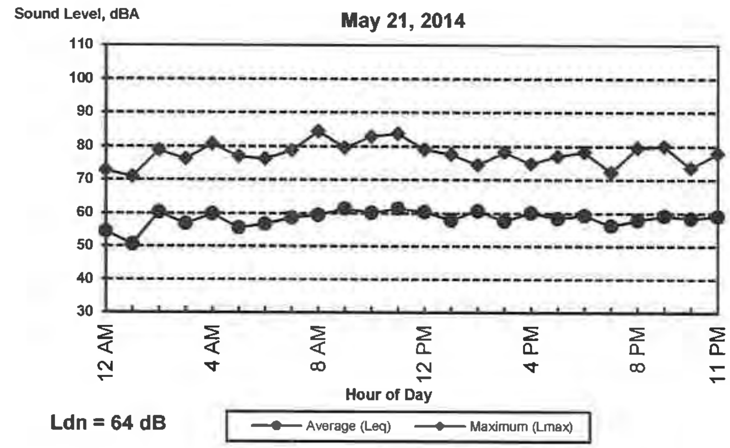
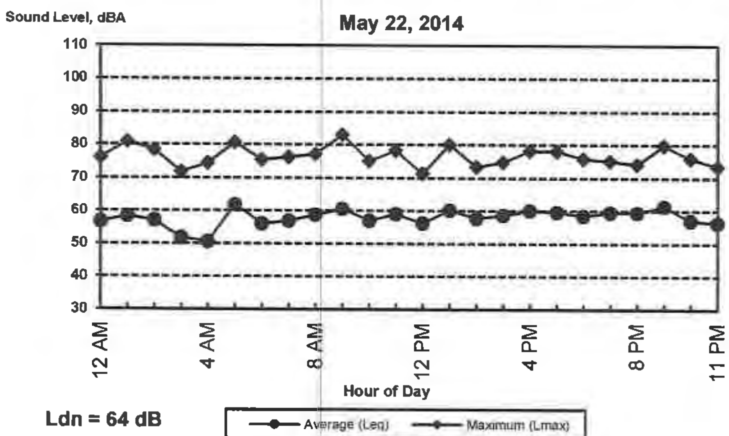
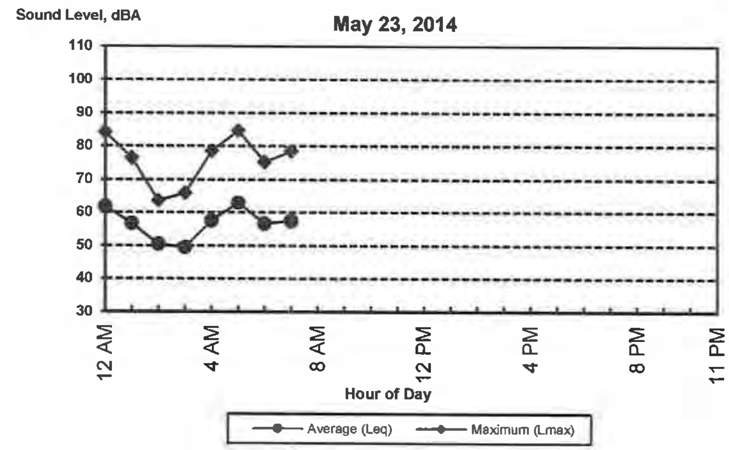
Appendix C-3
La Mirada BNSF Railway Study
Site 3 - May 20 - May 23









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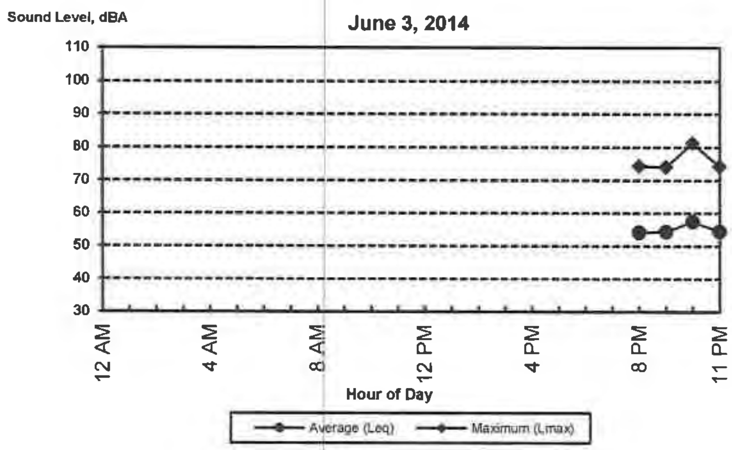
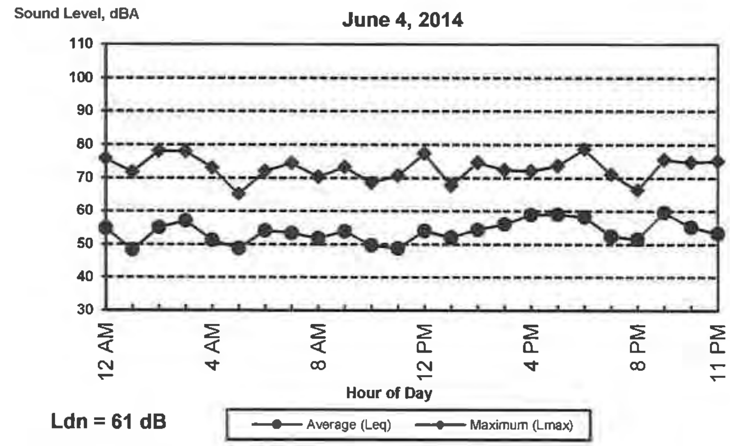
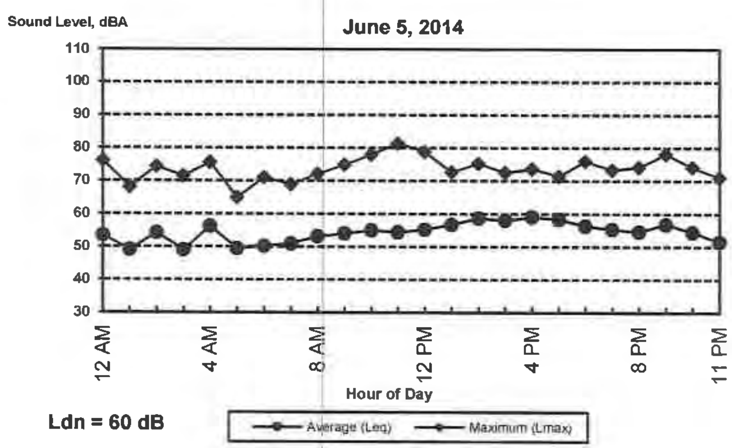
Appendix C-4
La Mirada BNSF Railway Study
Site 4 - June 3 - June 6

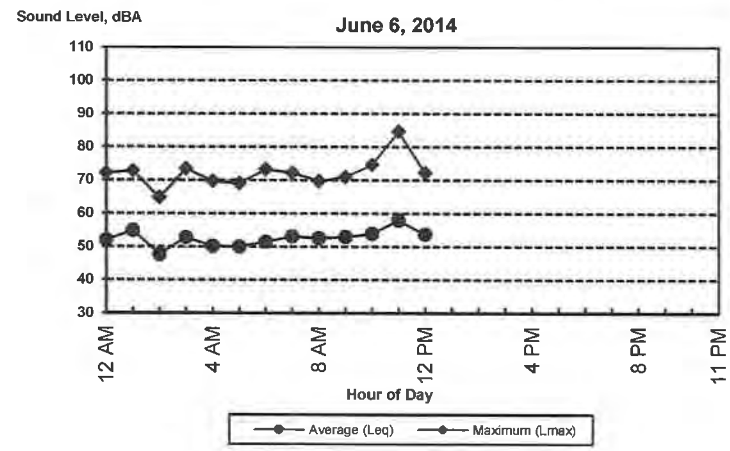




Ldn = 61 dB



Ldn = 60 dB



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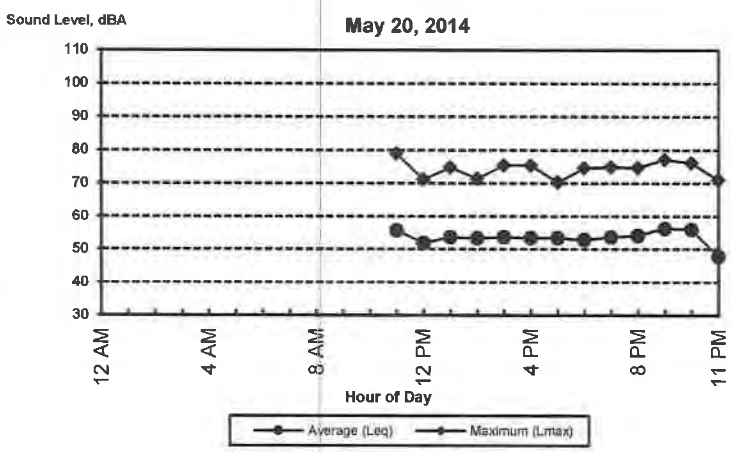
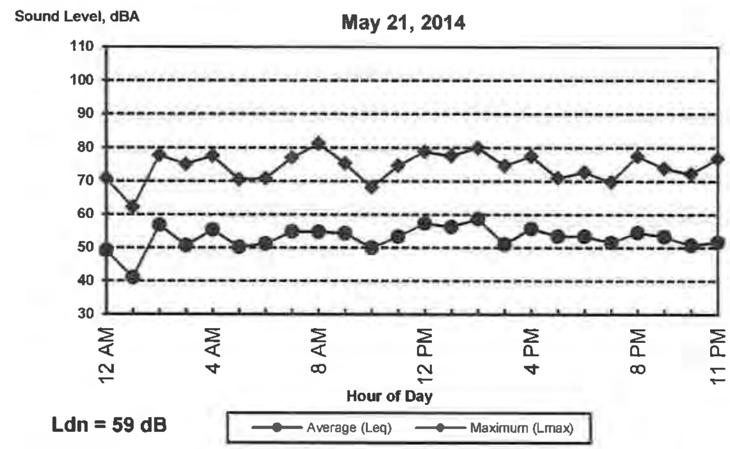
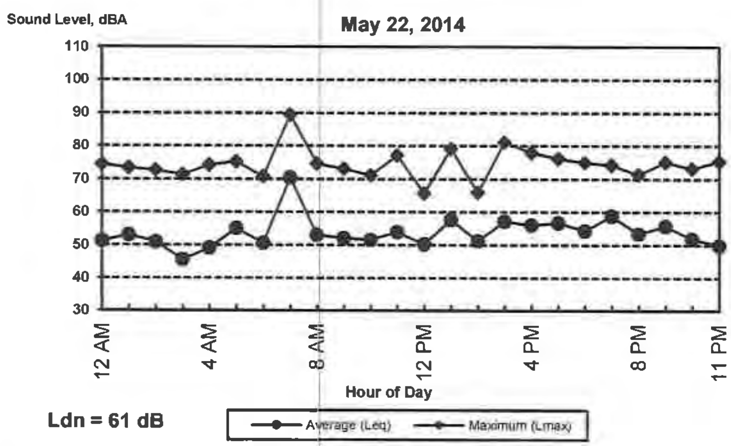
Appendix C-5
La Mirada BNSF Railway Study
Site 5 - May 20 - May 23





Ldn = 59 dB



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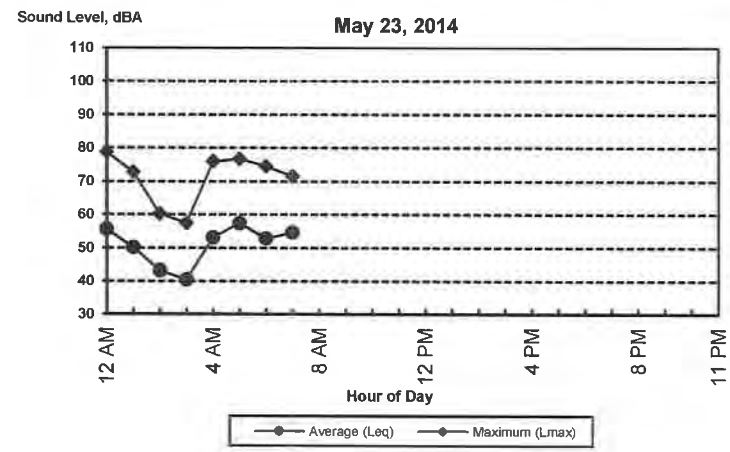

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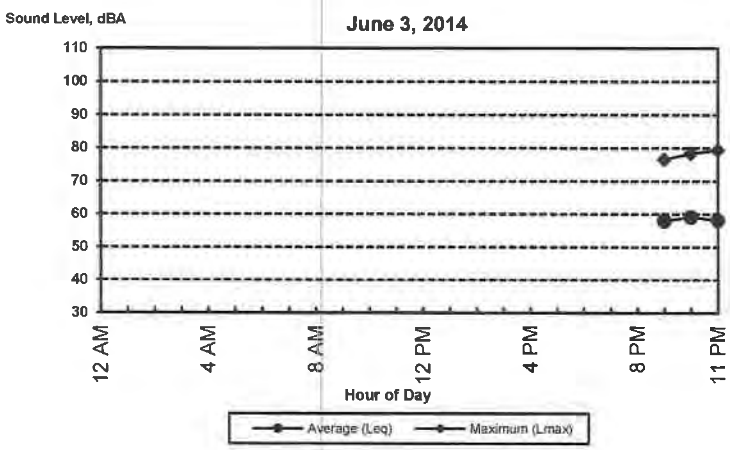
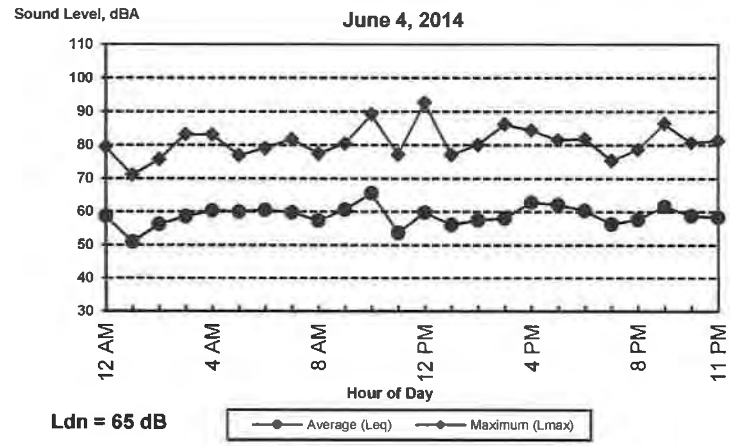
Appendix C-6
La Mirada BNSF Railway Study
Site 6 - June 3 - June 6





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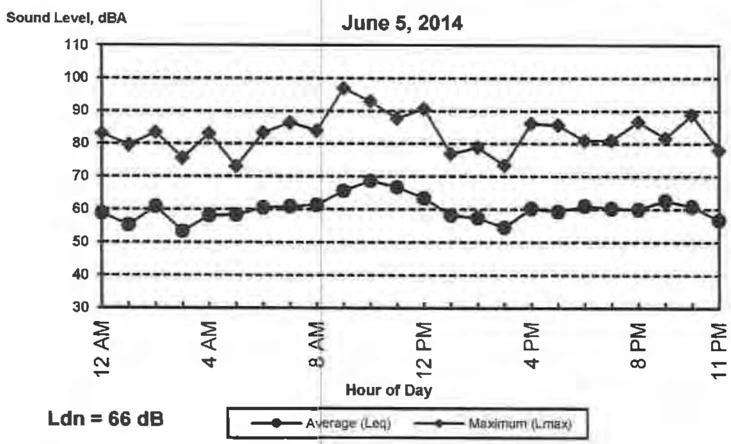
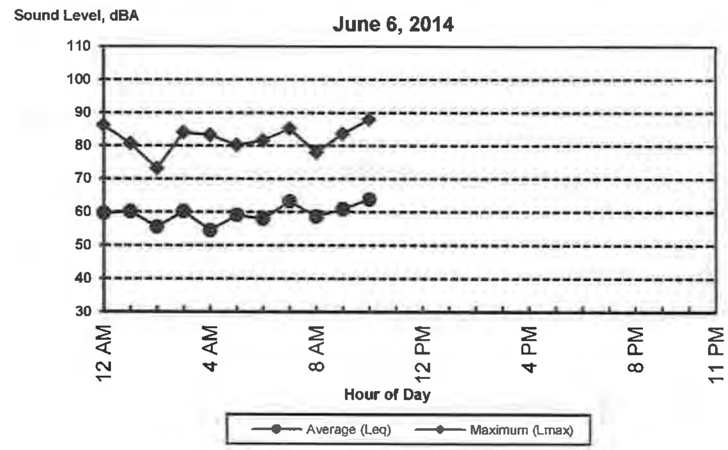


Ldn = 66 dB



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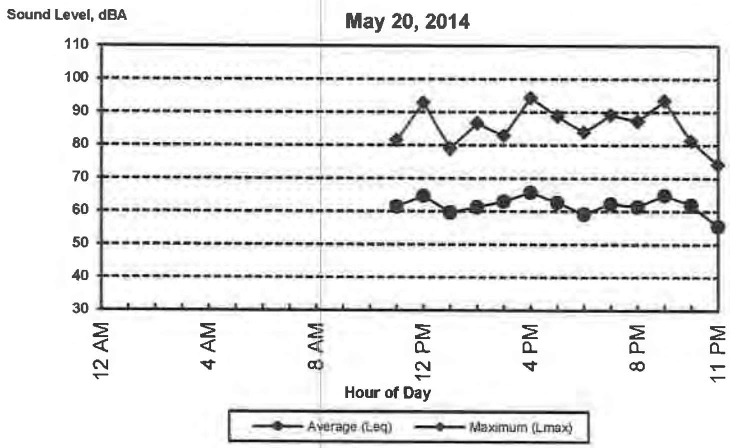
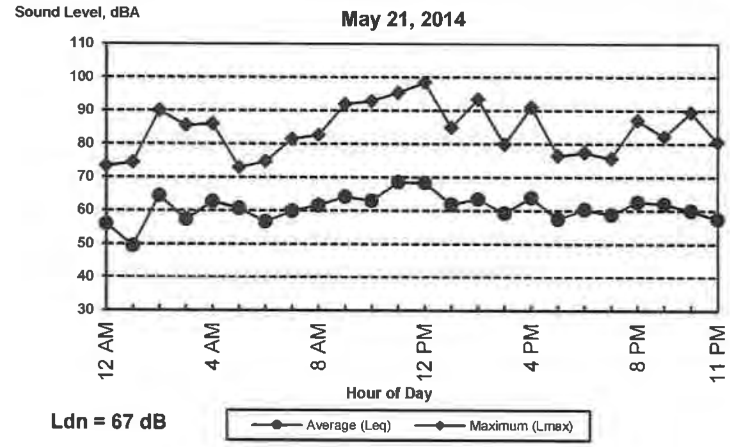
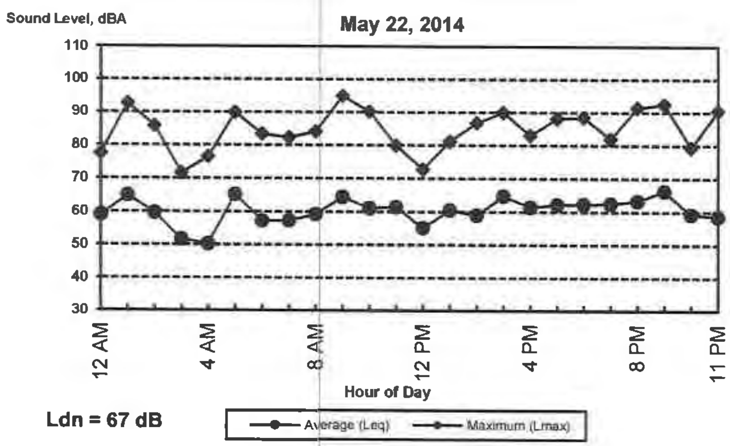
Appendix C-7
La Mirada BNSF Railway Study
Site 7 - May 20 - May 23

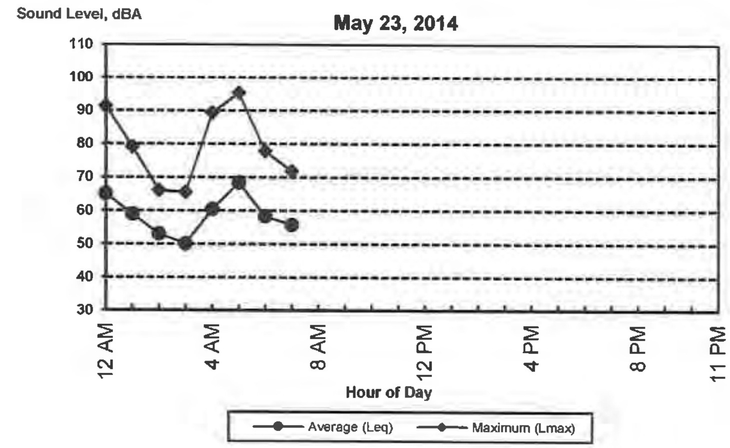




Ldn = 67 dB



Ldn = 67 dB



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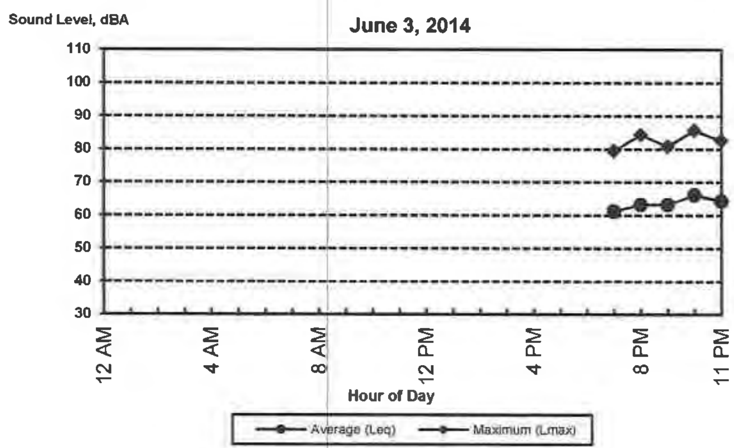
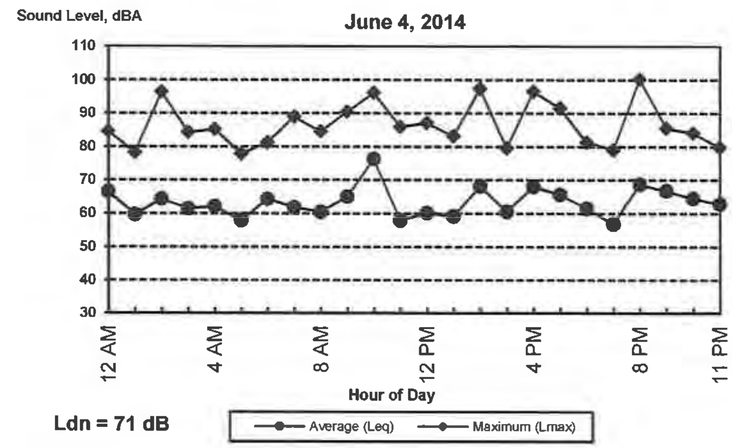
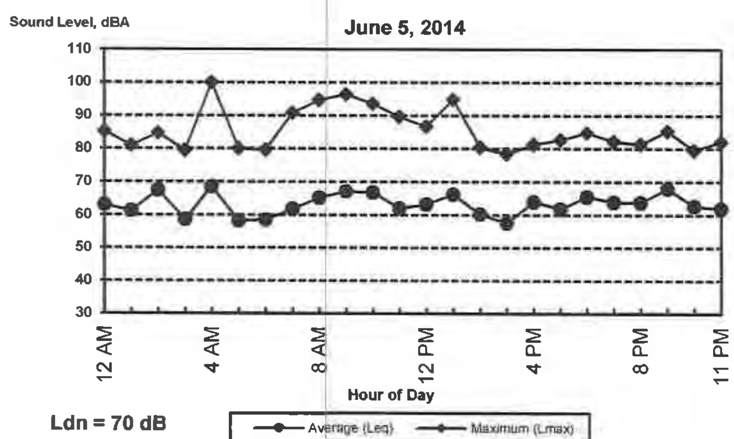
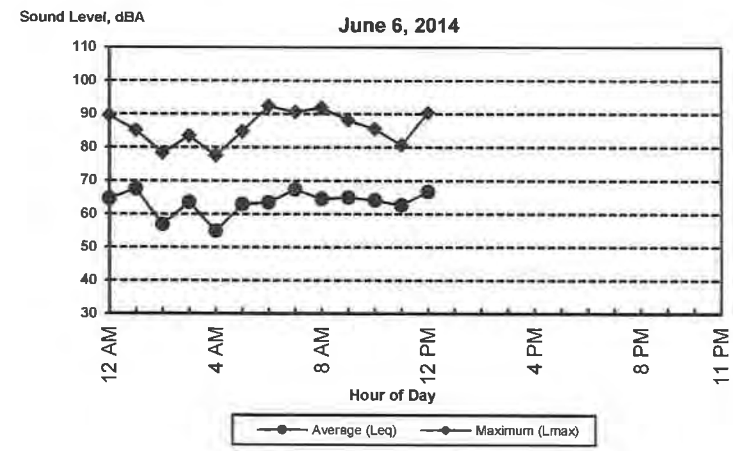
Appendix C-8
La Mirada BNSF Railway Study
Site 8 - June 3 - June 6









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Appendix D-1

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 1

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 63
Source Frequency (Hz): 500
Source Height (ft): 108

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 135
Barrier to Receiver Distance (C_2): 35

Pad/Ground Elevation at Receiver: 107
Receiver Elevation[1]: 112
Base of Barrier Elevation: 104
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
110	6	-4.6	58	No
111	7	-4.9	58	No
112	8	-5.1	58	Yes
113	9	-5.5	58	Yes
114	10	-6.2	57	Yes
115	11	-6.9	56	Yes
116	12	-7.8	55	Yes
117	13	-8.7	54	Yes
118	14	-9.4	54	Yes
119	15	-10.2	53	Yes
120	16	-10.7	52	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix D-2

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 2

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 64
Source Frequency (Hz): 500
Source Height (ft): 103

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 93
Barrier to Receiver Distance (C_2): 22

Pad/Ground Elevation at Receiver: 109
Receiver Elevation[1]: 114
Base of Barrier Elevation: 106
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
112	6	-5.0	59.0	Yes
113	7	-5.3	58.7	Yes
114	8	-6.0	58.0	Yes
115	9	-6.9	57.1	Yes
116	10	-8.0	56.0	Yes
117	11	-9.1	54.9	Yes
118	12	-10.0	54.0	Yes
119	13	-10.7	53.3	Yes
120	14	-11.5	52.5	Yes
121	15	-12.3	51.7	Yes
122	16	-12.9	51.1	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix D-3

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 3

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 61
Source Frequency (Hz): 500
Source Height (ft): 102

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 95
Barrier to Receiver Distance (C_2): 20

Pad/Ground Elevation at Receiver: 111
Receiver Elevation[1]: 116
Base of Barrier Elevation: 108
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
114	6	-5.0	56	Yes
115	7	-5.5	56	Yes
116	8	-6.4	55	Yes
117	9	-7.5	54	Yes
118	10	-8.6	52	Yes
119	11	-9.6	51	Yes
120	12	-10.3	51	Yes
121	13	-11.1	50	Yes
122	14	-11.9	49	Yes
123	15	-12.8	48	Yes
124	16	-13.4	48	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix D-4

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 4

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 55
Source Frequency (Hz): 500
Source Height (ft): 94

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 80
Barrier to Receiver Distance (C_2): 70

Pad/Ground Elevation at Receiver: 108
Receiver Elevation[1]: 113
Base of Barrier Elevation: 107
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
113	6	-10.0	45	Yes
114	7	-10.5	45	Yes
115	8	-10.9	44	Yes
116	9	-11.5	44	Yes
117	10	-12.1	43	Yes
118	11	-12.6	42	Yes
119	12	-13.0	42	Yes
120	13	-13.5	42	Yes
121	14	-13.8	41	Yes
122	15	-14.2	41	Yes
123	16	-14.6	40	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix D-5

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 5

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 57
Source Frequency (Hz): 500
Source Height (ft): 101

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 110
Barrier to Receiver Distance (C_2): 25

Pad/Ground Elevation at Receiver: 102
Receiver Elevation[1]: 107
Base of Barrier Elevation: 104
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
110	6	-7.8	49	Yes
111	7	-8.8	48	Yes
112	8	-9.7	47	Yes
113	9	-10.3	47	Yes
114	10	-11.1	46	Yes
115	11	-11.7	45	Yes
116	12	-12.5	45	Yes
117	13	-13.2	44	Yes
118	14	-13.6	43	Yes
119	15	-14.2	43	Yes
120	16	-14.6	42	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix D-6

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 6

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 65
Source Frequency (Hz): 500
Source Height (ft): 109

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 165
Barrier to Receiver Distance (C_2): 30

Pad/Ground Elevation at Receiver: 101
Receiver Elevation[1]: 106
Base of Barrier Elevation: 100
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
106	6	-4.9	60	No
107	7	-5.0	60	Yes
108	8	-5.4	60	Yes
109	9	-6.0	59	Yes
110	10	-6.8	58	Yes
111	11	-7.7	57	Yes
112	12	-8.6	56	Yes
113	13	-9.4	56	Yes
114	14	-10.2	55	Yes
115	15	-10.7	54	Yes
116	16	-11.3	54	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix D-7

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 7

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 66
Source Frequency (Hz): 500
Source Height (ft): 109

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 190
Barrier to Receiver Distance (C_2): 50

Pad/Ground Elevation at Receiver: 103
Receiver Elevation[1]: 108
Base of Barrier Elevation: 101
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
107	6	-4.8	61	No
108	7	-4.9	61	No
109	8	-5.0	61	Yes
110	9	-5.3	61	Yes
111	10	-5.8	60	Yes
112	11	-6.6	59	Yes
113	12	-7.1	59	Yes
114	13	-7.8	58	Yes
115	14	-8.5	58	Yes
116	15	-9.2	57	Yes
117	16	-9.8	56	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix D-8

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 8

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 67
Source Frequency (Hz): 500
Source Height (ft): 108

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 115
Barrier to Receiver Distance (C_2): 25

Pad/Ground Elevation at Receiver: 99
Receiver Elevation[1]: 104
Base of Barrier Elevation: 96
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
102	6	-2.5	65	No
103	7	-4.1	63	No
104	8	-4.8	62	No
105	9	-5.0	62	Yes
106	10	-5.3	62	Yes
107	11	-6.0	61	Yes
108	12	-6.9	60	Yes
109	13	-7.9	59	Yes
110	14	-8.9	58	Yes
111	15	-9.8	57	Yes
112	16	-10.5	56.5	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix E-1

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 1

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 63
Source Frequency (Hz): 500
Source Height (ft): 108

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 85
Barrier to Receiver Distance (C_2): 100

Pad/Ground Elevation at Receiver: 107
Receiver Elevation[1]: 112
Base of Barrier Elevation: 104
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
110	6	-5.0	58	Yes
111	7	-5.1	58	Yes
112	8	-5.4	58	Yes
113	9	-5.9	57	Yes
114	10	-6.6	56	Yes
115	11	-7.1	56	Yes
116	12	-7.8	55	Yes
117	13	-8.4	55	Yes
118	14	-9.1	54	Yes
119	15	-9.7	53	Yes
120	16	-10.2	53	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix E-2

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 2

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 64
Source Frequency (Hz): 500
Source Height (ft): 103

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 35
Barrier to Receiver Distance (C_2): 80

Pad/Ground Elevation at Receiver: 109
Receiver Elevation[1]: 114
Base of Barrier Elevation: 106
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
112	6	-8.8	55.2	Yes
113	7	-9.6	54.4	Yes
114	8	-10.3	53.7	Yes
115	9	-10.9	53.1	Yes
116	10	-11.5	52.5	Yes
117	11	-12.1	51.9	Yes
118	12	-12.8	51.2	Yes
119	13	-13.3	50.7	Yes
120	14	-13.8	50.2	Yes
121	15	-14.2	49.8	Yes
122	16	-14.6	49.4	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix E-3
Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 3

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 61
Source Frequency (Hz): 500
Source Height (ft): 102

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 35
Barrier to Receiver Distance (C_2): 80

Pad/Ground Elevation at Receiver: 111
Receiver Elevation[1]: 116
Base of Barrier Elevation: 108
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
114	6	-10.3	51	Yes
115	7	-10.9	50	Yes
116	8	-11.5	50	Yes
117	9	-12.1	49	Yes
118	10	-12.8	48	Yes
119	11	-13.3	48	Yes
120	12	-13.8	47	Yes
121	13	-14.2	47	Yes
122	14	-14.6	46	Yes
123	15	-14.6	46	Yes
124	16	-15.3	46	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix E-4

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 4

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 55
Source Frequency (Hz): 500
Source Height (ft): 94

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 70
Barrier to Receiver Distance (C_2): 80

Pad/Ground Elevation at Receiver: 108
Receiver Elevation[1]: 113
Base of Barrier Elevation: 107
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
113	6	-10.5	45	Yes
114	7	-11.1	44	Yes
115	8	-11.5	44	Yes
116	9	-12.1	43	Yes
117	10	-12.6	42	Yes
118	11	-13.2	42	Yes
119	12	-13.5	42	Yes
120	13	-13.9	41	Yes
121	14	-14.3	41	Yes
122	15	-14.6	40	Yes
123	16	-14.6	40	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix E-5

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 5

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 57
Source Frequency (Hz): 500
Source Height (ft): 101

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 55
Barrier to Receiver Distance (C_2): 80

Pad/Ground Elevation at Receiver: 102
Receiver Elevation[1]: 107
Base of Barrier Elevation: 104
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
110	6	-8.9	48	Yes
111	7	-9.6	47	Yes
112	8	-10.2	47	Yes
113	9	-10.7	46	Yes
114	10	-11.3	46	Yes
115	11	-11.7	45	Yes
116	12	-12.5	45	Yes
117	13	-12.9	44	Yes
118	14	-13.4	44	Yes
119	15	-13.8	43	Yes
120	16	-14.2	43	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix E-6
Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 6

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 65
Source Frequency (Hz): 500
Source Height (ft): 109

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 20
Barrier to Receiver Distance (C_2): 175

Pad/Ground Elevation at Receiver: 101
Receiver Elevation[1]: 106
Base of Barrier Elevation: 100
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
106	6	-2.1	63	No
107	7	-3.9	61	No
108	8	-4.8	60	No
109	9	-5.0	60	Yes
110	10	-5.4	60	Yes
111	11	-6.2	59	Yes
112	12	-7.3	58	Yes
113	13	-8.2	57	Yes
114	14	-9.2	56	Yes
115	15	-10.1	55	Yes
116	16	-10.7	54	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix E-7

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 7

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 66
Source Frequency (Hz): 500
Source Height (ft): 109

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 40
Barrier to Receiver Distance (C_2): 200

Pad/Ground Elevation at Receiver: 103
Receiver Elevation[1]: 108
Base of Barrier Elevation: 101
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
107	6	-4.4	62	No
108	7	-4.9	61	No
109	8	-5.0	61	Yes
110	9	-5.1	61	Yes
111	10	-5.6	60	Yes
112	11	-6.2	60	Yes
113	12	-6.9	59	Yes
114	13	-7.7	58	Yes
115	14	-8.5	58	Yes
116	15	-9.2	57	Yes
117	16	-9.9	56	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix E-8

Barrier Insertion Loss Calculation

Project Information:

Job Number: 2013-030
Project Name: La Mirada RR Study
Location(s): Site 8

Noise Level Data:

Source Description: Railroad
Source Noise Level, dBA: 67
Source Frequency (Hz): 500
Source Height (ft): 108

Site Geometry:

Receiver Description: Backyard Area
Source to Barrier Distance (C_1): 40
Barrier to Receiver Distance (C_2): 100

Pad/Ground Elevation at Receiver: 99
Receiver Elevation[1]: 104
Base of Barrier Elevation: 96
Starting Barrier Height 6

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height (ft)	Insertion Loss, dB	Noise Level, dB	Barrier Breaks Line of Site to Source?
102	6	-0.7	66	No
103	7	-0.9	66	No
104	8	-2.9	64	No
105	9	-4.2	63	No
106	10	-4.8	62	No
107	11	-5.0	62	Yes
108	12	-5.2	62	Yes
109	13	-5.7	61	Yes
110	14	-6.4	61	Yes
111	15	-7.3	60	Yes
112	16	-8.0	59.0	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

BOLLARD
Acoustical Consultants