April 2015

Federal Way Link Extension

Draft Environmental Impact Statement

NOISE AND VIBRATION TECHNICAL REPORT

Appendix G3

SOUNDTRANSIT
Central Puget Sound
Regional Transit Authority

U.S. Department of Transportation
Federal Transit Administration

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Federal Way Link Extension

Noise and Vibration Technical Report

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Acronyms and Abbreviations

ANSI	American National Standards Institute
B&T	ballast and tie
CFR	Code of Federal Regulations
dB	Decibel
dBA	decibel with A-weighting
DF	direct-fixation
DNL	day-night equivalent sound level (see also Ldn)
EDNA	Environmental Designation for Noise Abatement
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FDL	force density level
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FWLE	Federal Way Link Extension
GBN	groundborne noise
HC	Highline College
HCDF	high-compliance direct-fixation
HCT	high-capacity transit
HUD	U.S. Department of Housing and Urban Development
Hz	Hertz
I-5	Interstate 5
in./sec	inches per second
lb./in.	pounds per inch
Ldn	24-hour, time-averaged, A-weighted sound level (day-night) with +10 dB weighting added to nighttime noise (10 p.m. to 7 a.m.)
Leq	equivalent continuous sound level

Leq(h)	maximum one hour Leq
LIF	“low-impact” frog
Lmax or Lm	maximum noise level
LSTM	line source transfer mobility
Lv	train vibration velocity level
mph	miles per hour
NAC	Noise Abatement Criteria
OWL	one-way low-speed frog
PPV	peak particle velocity
PSTM	point source transfer mobility
RBM	rail-bound manganese frog
RMS	root mean square
Sound Transit	Central Puget Sound Regional Transit Authority
SR	State Route
ST2	Sound Transit 2
STC	Sound Transmission Class
TCRP	Transit Cooperative Research Program
TDA	tire-derived aggregate
VdB	vibration velocity decibels using a decibel reference of 1 micro-inch per second
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation

1.0 Introduction and Summary

This technical report presents a noise and vibration impact study for the Federal Way Link Extension (FWLE) being proposed by the Central Puget Sound Regional Transit Authority (Sound Transit). The objective of the study is to assess the potential noise and vibration impacts of the planned light rail transit project.

Section 1 of this report describes the background and results of this noise and vibration assessment. Section 2 discusses environmental noise and vibration basics, and Section 3 describes the existing noise conditions and noise and vibration measurement results. The criteria and methods used to assess noise and vibration impacts are presented in Sections 4 and 5, respectively. Section 6 summarizes the noise and vibration impact assessment results, and Section 7 outlines potential mitigation measures for the projected impacts. Appendix A includes detailed photos of the noise monitoring locations, Appendix B provides detailed noise impact assessment data, and Appendix C presents noise and vibration impact maps by affected alternative. The vibration propagation test sites are described in Appendix D, and more details of the vibration test results are presented in Appendix E. The detailed vibration predictions for each sensitive receiver are provided in Appendix F.

1.1 Summary of Noise Impacts and Potential Mitigation

The noise analysis was performed for over 5,000 noise-sensitive properties along the SR 99 corridor and approximately 3,100 properties along the I-5 corridor. There would be greater impacts for alternatives along SR 99 due to the close proximity of the light rail improvements to multi-family residences and motels with large numbers of units. Table 1-1 summarizes the number of moderate and severe noise impacts by alternative before and after mitigation. Note that for the noise impacts before mitigation, the number in parentheses represents the range of impacts for the design options for each alternative.

TABLE 1-1
Summary of Noise Impacts

Alternative	Moderate Noise Impacts (Range with Options)		Severe Noise Impacts (Range with Options)	
	Before Mitigation	After Mitigation	Before Mitigation	After Mitigation
SR 99	2,211 (1,225 – 2,277)	0	1,515 (766-1,669)	0
I-5	982 (867 – 1,120)	0	468 (460 – 561)	0
SR 99 to I-5	1,452 (1,264 – 1,472)	0	738 (529 – 738)	0
I-5 to SR 99	1,629 (1,428-1,660)	0	1,313 (881-1,381)	0

For noise, the SR 99 alternatives and options have the highest number of noise impacts because there are noise-sensitive properties along both sides of the alignment. The I-5 Alternative has fewer impacts because noise-sensitive properties are generally only found on one side of the alignment. All noise impacts could be mitigated. Potential mitigation measures could include constructing sound walls (sound barriers on the light rail guideway and/or freestanding walls), installing special track work to reduce crossover noise levels, and insulating residential buildings where required.

1.2 Summary of Vibration Impacts and Potential Mitigation

The vibration and groundborne noise impact assessment was based on vibration propagation tests performed at 12 test sites in the study area and the characteristics of the existing Sound Transit trains operating in the Central Link corridor. Groundborne noise is the rumbling noise caused by the vibration of the walls in enclosed spaces and is different from the airborne noise discussed in the previous section.

Table 1-2 shows the predicted impacts for each alternative and a range of impacts when options are considered. Unlike noise, vibration impacts only occur at structures located within approximately 50 feet of the alignment. Therefore, the I-5 Alternative would have the greatest number of potential vibration impacts due to the proximity of the alignment to residences, while the SR 99 Alternative would have the fewest potential impacts due to its location in the median of SR 99, which would be farther from sensitive receptors, thereby resulting in lower vibration levels.

Because airborne noise is louder for transit systems that are above grade, the Federal Transit Administration (FTA) groundborne noise impact criteria are not applied for the three FTA category receivers. However, groundborne noise impact criteria are applied to special buildings as defined in the FTA Guidance Manual (FTA, 2006). Groundborne noise impact is predicted at the future Performing Arts Center within the Federal Way High School property (under construction) for the SR 99 and I-5 to SR 99 Alternatives. This impact is a result of proximity of the alignment to the future Performing Arts Center at the high school. Mitigation for vibration/ groundborne noise impacts could include resilient fasteners, ballast mats, and special track work.

TABLE 1-2
Summary of Vibration and Groundborne Noise Impacts

Alternative	Vibration Impacts (Range with Options)		Groundborne Noise	
	Before Mitigation	After Mitigation	Before Mitigation	After Mitigation
SR 99	50 (0 – 271)	0	1	0
I-5	222 (202 – 225)	0	0	0
SR 99 to I-5	209 (209 – 227)	0	0	0
I-5 to SR 99	845 (45-238)	0	1	0

2.0 Environmental Noise and Vibration Basics

2.1 Noise Fundamentals and Descriptors

What humans perceive as sound is a series of continuous air pressure fluctuations superimposed on the atmospheric pressure that surrounds us. The amplitude of fluctuation is related to the energy carried in a sound wave; the greater the amplitude, the greater the energy, and the louder the sound. The full range of sound pressures encountered in the world is so great that it is more convenient to compress the range by using a logarithmic scale, resulting in the fundamental descriptor used in acoustics—the sound pressure level, which is measured in decibels (dB). When sounds are unpleasant, unwanted, or disturbingly loud, we tend to classify them as noise.

Another aspect of sound is the quality described as its pitch. Pitch of a sound is established by the frequency, which is a measure of how rapidly a sound wave fluctuates. The unit of measurement is cycles per second, called hertz (Hz). When a sound is analyzed, its energy content at individual frequencies is displayed over the frequency range of interest, usually the range of human audibility from 20 Hz to 20,000 Hz. This display is called a frequency spectrum.

Sound is measured using a sound-level meter with a microphone designed to respond accurately to all audible frequencies. However, the human hearing system does not respond equally to all frequencies. Low-frequency sounds below about 400 Hz are progressively and severely attenuated, as are high frequencies above 10,000 Hz. To approximate the way humans interpret sound, a filter circuit with frequency characteristics similar to the human hearing mechanism is built into sound-level meters. Measurements with this filter enacted are called A-weighted sound levels, expressed in A-weighted decibels (dBA). Community noise is usually characterized in terms of the A-weighted sound level.

The range of human hearing extends from about 0 dBA for young healthy ears (that have not been exposed to loud noise sources) to about 140 dBA. When sounds exceed 110 dBA, there is a potential for hearing damage, even with relatively short exposures. In quiet suburban areas far from major freeways, the noise levels during the late night hours will drop to about 30 dBA. Outdoor noise levels lower than this only occur in isolated areas where there is a minimum amount of natural noises, such as leaves blowing in the wind, crickets, or flowing water. Exhibit 2-1 shows a comparison of various noise levels expressed as the maximum sound level (Lmax) in dBA.

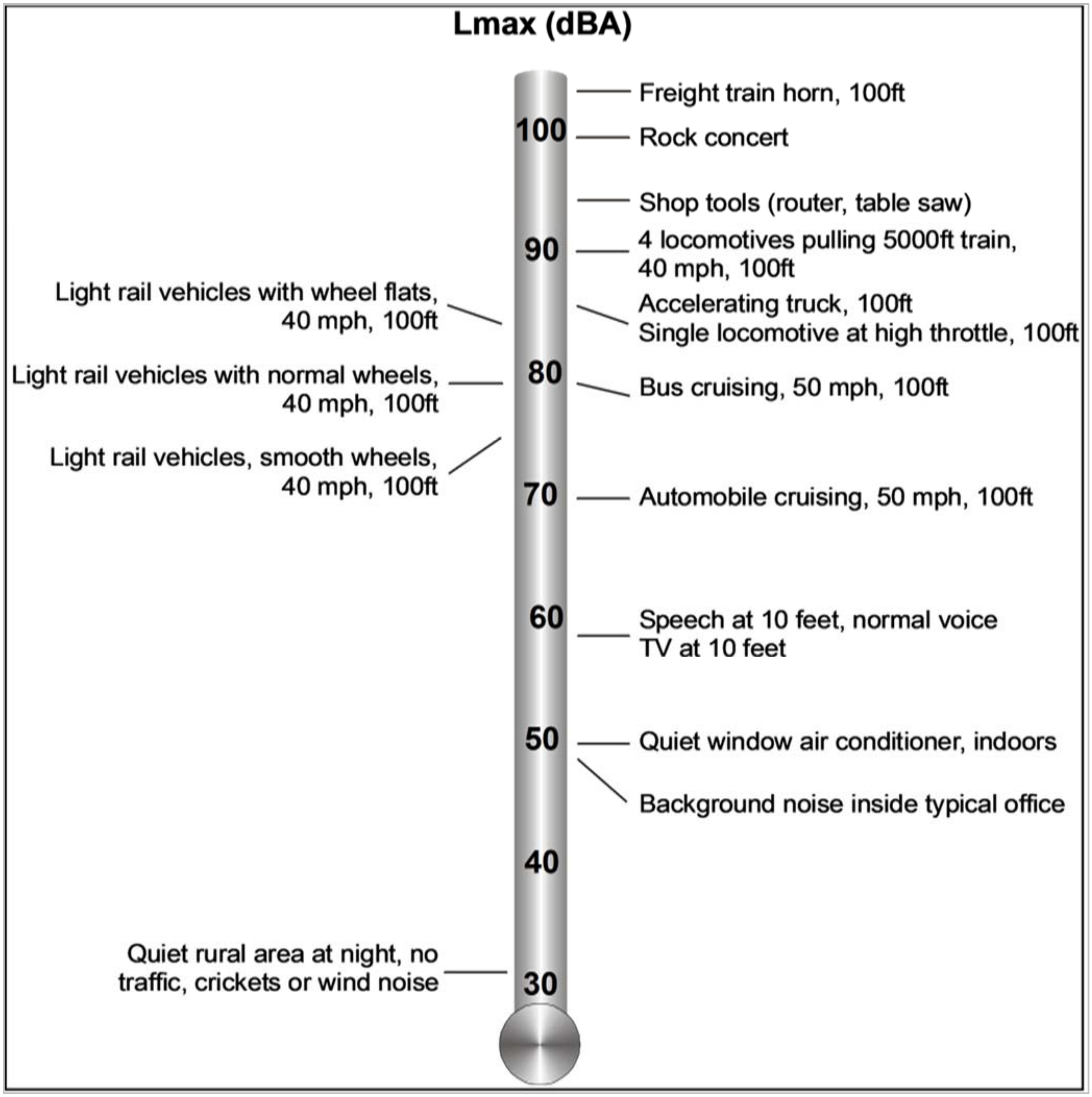
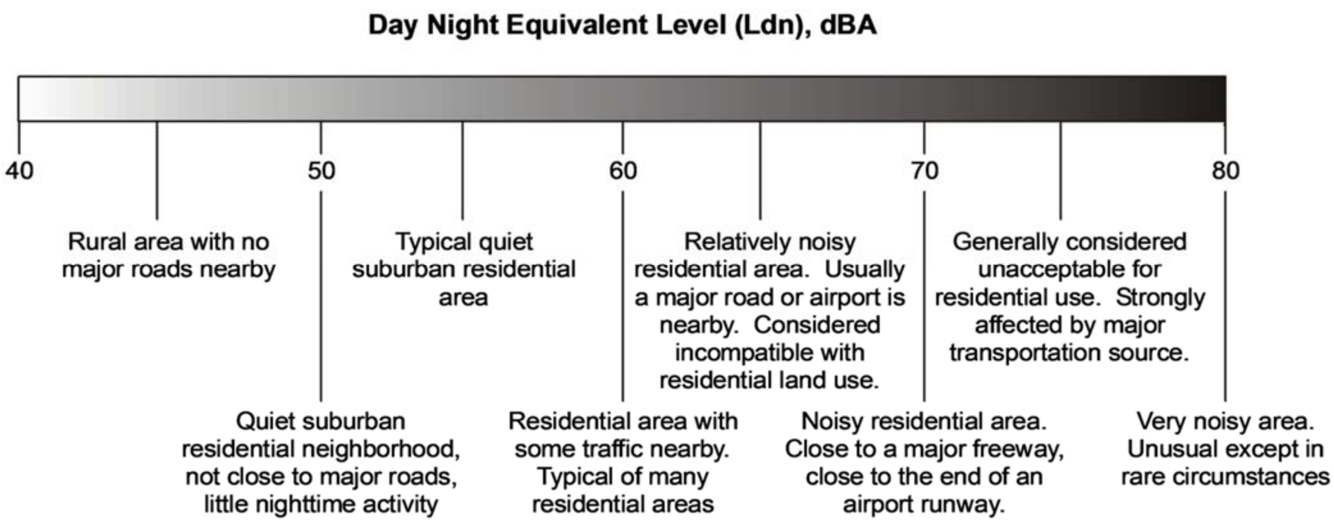


EXHIBIT 2-1
Comparison of Various Noise Levels

Another characteristic of environmental noise is that it is constantly changing. The noise level increase when a train passes is an example of a short-term change. The lower average noise levels occur during nighttime hours, when activities are at a minimum, and higher noise levels during daytime hours are caused by daily patterns of noise-level fluctuation. The instantaneous A-weighted sound level is insufficient to describe the overall acoustic “environment.” Thus, it is common practice to condense the fluctuating noise levels into a single number, called the “equivalent” sound level (Leq). Leq can be thought of as the steady sound level that represents the same sound energy as the varying sound levels over a specified time period (typically 1 hour or 24 hours). Often the Leq values over a 24-hour period are used to calculate cumulative noise exposure in terms of the day-night equivalent sound level (Ldn, also abbreviated DNL), which is defined as the 24-hour Leq but with a 10-dB penalty added to each nighttime hourly Leq (with "nighttime" defined as the period from 10 p.m. to 7 a.m.). The effect of this penalty is that any event during the nighttime is equivalent to 10 events during the daytime. This strongly weights Ldn toward nighttime noise to reflect most people being more easily annoyed by noise at night, when background noise is lower and most people are resting.

Environmental impact assessments for mass transit projects in the United States typically use Ldn to describe the community noise environment at residential locations. Studies of community response to a wide variety of noises indicate that Ldn is a good measure of the noise environment. Exhibit 2-2 defines typical community noise levels in terms of Ldn. Most urban and suburban neighborhoods are usually in the range of Ldn 50 dBA to 70 dBA. An Ldn of 70 dBA is a relatively noisy environment that might be found at buildings on a busy surface street, close to a freeway, or near a busy airport, and would usually be considered unacceptable for residential land use without special measures taken to enhance outdoor-indoor sound insulation. Residential neighborhoods that are not near major sound sources are usually in the range of Ldn 55 dBA to 60 dBA. If there is a freeway or moderately busy arterial nearby, or any nighttime noise, Ldn is usually in the range of 60 to 65 dBA.



Source: FTA, 2006.

EXHIBIT 2-2
Examples of Typical Outdoor Noise Exposure

Ldn is the designated noise metric of choice for many federal agencies, including the Department of Housing and Urban Development (HUD), Federal Aviation Administration (FAA), FTA, and U.S. Environmental Protection Agency (EPA). Most federal and state agency criteria for noise impacts are based on some measurement of noise energy. For example, the FAA and HUD use Ldn, and the Federal Highway Administration (FHWA) uses peak-hour Leq. The noise impact criteria applicable to residential areas, and included in the 2006 *FTA Transit Noise and Vibration Impact Assessment* (FTA Guidance Manual) (FTA, 2006), use both Leq and Ldn to characterize community noise.

2.2 Vibration Fundamentals and Descriptors

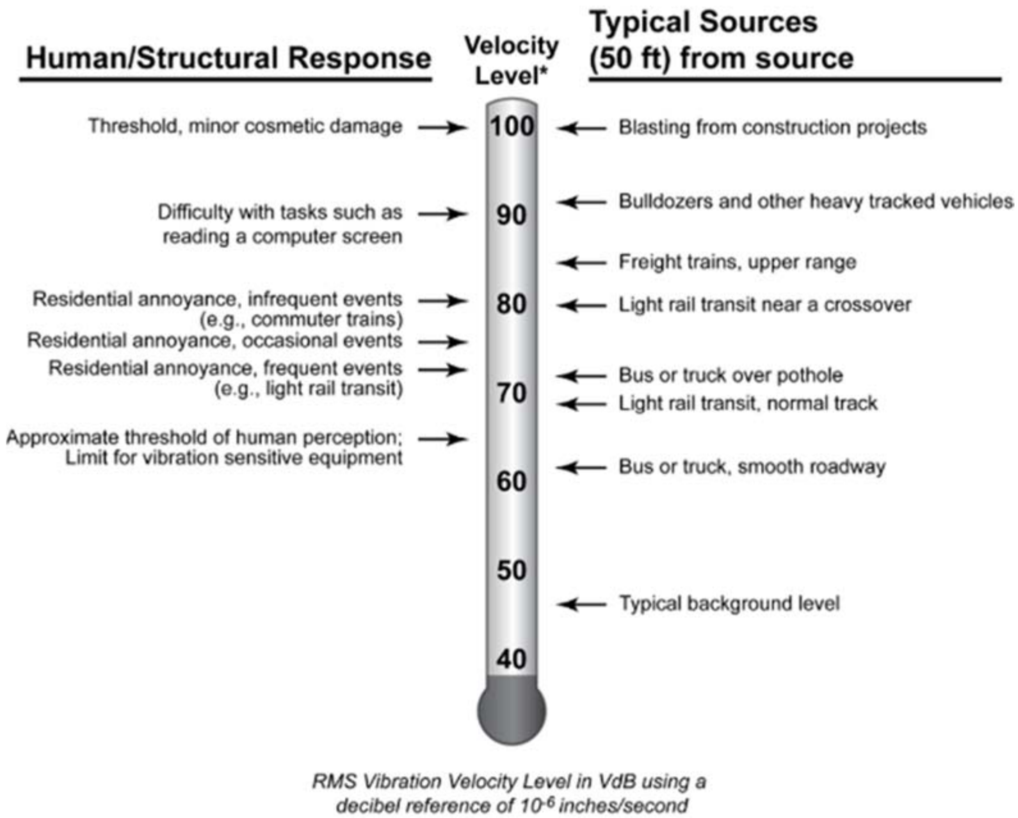
One potential community impact from the FWLE is vibration that is transmitted from the tracks through the ground to adjacent buildings. This is referred to as groundborne vibration. When evaluating human response, groundborne vibration is expressed in terms of decibels using the root mean square (RMS) vibration velocity. RMS is defined as the square root of the average of the squared amplitude of the vibration signal. To avoid confusion with sound decibels, the abbreviation VdB is used for vibration decibels. All vibration decibels in this report use a decibel reference of 1 micro-inch per second.

The potential impacts of rail transit groundborne vibration are as follows:

- Perceptible building vibration: The vibration of the floor or other building surfaces that the occupants feel. Experience shows that the threshold of human perception is around 65 VdB and that vibration that exceeds 75 to 80 VdB is perceived as intrusive and annoying to occupants.
- Rattle: The building vibration can cause rattling of items on shelves and hangings on walls, and various rattle and buzzing noises from windows and doors.
- Reradiated noise: The vibration of room surfaces radiates sound waves that are audible to humans (groundborne noise). Groundborne noise sounds like a low-frequency rumble. Usually, for a surface rail system such as the light rail train, the groundborne noise is masked by the normal airborne noise radiated from the transit vehicle and the rails.
- Damage to building structures: Although it is conceivable that vibration from a light rail system can damage fragile buildings, the vibration from rail transit systems is one to two orders of magnitude below the most restrictive thresholds for preventing building damage. Hence the vibration impact criteria focus on human annoyance, which occurs at much lower amplitudes than does building damage.

Vibration is an oscillatory motion that is described in terms of the displacement, velocity, or acceleration of the motion. The response of humans to vibration is very complex. However, the general consensus is that for the vibration frequencies generated by light rail trains, human response is best approximated by the vibration velocity level. Therefore, this study uses vibration velocity to describe light rail-generated vibration levels.

Exhibit 2-3 shows typical vibration levels from rail and non-rail sources as well as the human and structural response to such levels.



Source: FTA, 2006.

EXHIBIT 2-3
Typical Vibration Levels

Although there is relatively little research into human and building response to groundborne vibration, there is substantial experience with vibration from rail systems. In general, the collective experience indicates that:

- It is rare that groundborne vibration from transit systems results in building damage (even minor cosmetic damage). Therefore, the primary consideration is whether or not the vibration is intrusive to building occupants or interferes with interior activities or machinery.
- The threshold for human perception is approximately 65 VdB. Vibration levels in the range of 70 to 75 VdB often are noticeable but acceptable. Beyond 80 VdB, vibration levels are considered unacceptable.
- For human annoyance, there is a relationship between the number of daily events and the degree of annoyance caused by groundborne vibration. The FTA Guidance Manual includes an 8-VdB higher impact threshold if there are fewer than 30 events per day and a 3-VdB higher threshold if there are fewer than 70 events per day (FTA, 2006).

Often it is necessary to determine the contribution at different frequencies when evaluating vibration or noise signals. The 1/3-octave band spectrum is the most common procedure used to evaluate frequency components of acoustic signals. The term octave is borrowed from music, where it refers to a span of eight notes. The ratio of the highest frequency to the lowest frequency in an octave is 2:1. For a 1/3-octave band spectrum, each octave is divided into three bands, where the ratio of the lowest frequency to the highest frequency in each 1/3-octave band is $2^{1/3}$:1 (1.26:1). An octave consists of three 1/3 octaves. The 1/3-octave band spectrum of a signal is obtained by passing the signal through a bank of filters. Each filter excludes all components except those that are between the upper and lower range of one 1/3-octave band (FTA, 2006).

3.0 Affected Environment

Sound Transit examined the FWLE corridor to identify noise- and vibration-sensitive locations and to select locations where noise monitoring and vibration testing would be performed. The potential area of effect for the noise study was determined by modeling the worst-case operational noise levels and including all noise-sensitive properties within that area that have a potential for a noise impact. The potential area of effect for the vibration study was the same as for the noise study, for consistency.

The following sections describe the land use along the FWLE corridor, the existing noise-level measurements, and the current noise sources in the corridor. While a more detailed presentation of land use can be found in Section 4.2, Land Use, in Chapter 4 of the FWLE Draft Environmental Impact Statement (EIS), the following land uses are summarized for their potential sensitivity to noise and vibration. Most identified sensitive land uses are sensitive to both noise and vibration. The exceptions include outdoor parks, which may be noise-sensitive, depending on usage, but are not vibration sensitive, and vibration-sensitive equipment (such as an MRI), which is not sensitive to airborne noise.

3.1 Noise- and Vibration-Sensitive Receivers

This section provides an overview of the land uses and noise- and vibration-sensitive receivers along the two primary corridors being evaluated for FWLE alternatives—the SR 99 corridor and I-5 corridor. As discussed in Sections 4.1.1, Transit Noise Impact Criteria, and 4.2.1, Transit Vibration and Groundborne Noise Criteria, noise and vibration impacts under the FTA criteria (FTA, 2006) are based on land use type. Complete details on the FTA categories are provided in Section 4, Noise and Vibration Impact Criteria.

3.1.1 SR 99 Corridor

Over 5,000 noise-sensitive receivers were identified in the SR 99 corridor. Most receivers directly adjacent to the corridor are multi-family residential complexes and motels, with some single-family residences located farther away.

3.1.1.1 200th to Kent-Des Moines Road

The FWLE would begin at the Angle Lake Station at the southern end of the S 200th Street Extension (Seattle-Tacoma International Airport [Sea-Tac Airport] to S 200th Street), just west of SR 99. On the west side of SR 99, there is a Best Western Hotel at S 208th Street, a residential pocket to the west and south of the hotel, and then only commercial uses all the way to S 216th Street. From S 216th Street to Kent-Des Moines Road, commercial uses are dominant directly on SR 99, with residential uses directly behind. From S 216th Street to S 222nd Street, there are single-family homes, a few empty lots zoned for residential use, and the Majestic Bay Condominium complex. South of S 222nd Street and north of S 226th Street, there are mostly multi-family uses, including the Marina Club Apartments, the Seawind condominiums, the Sea Fox Apartments, the Bay Club Apartments, and the MistyWood Apartments, as well as the Citadel Church and the Open Door Baptist Church. Both churches are on SR 99 at S 224th

Street. Between S 226th Street and Kent-Des Moines Road, there are many single-family homes, almost all of which are shielded from SR 99 by apartment and condominium buildings.

On the east side of SR 99, there is the Sleep Inn Hotel, the Firs Mobile Home Park, America's Best Value Inn, and some commercial uses north of S 208th Street. The Willow Lake Apartments are located behind those commercial uses. South of S 208th Street are numerous single-family homes. Along SR 99 are the Falcon Ridge assisted living facility, the Viewpoint Apartments, the Jesus Christ Salt and Light Church, and the New West Hotel. There are numerous multi-family buildings from S 216th Street to S 224th Street that constitute hundreds of residential units. Pine Terrace, a mobile home park that consists of five parcels, is just south of S 216th Street. The Legend Motel, the Value Inn Motel, and the Stafford Care assisted living facility are located along SR 99 just north of S 224th Street. Similar land use continues from S 224th Street to Kent-Des Moines Road, with commercial uses along SR 99 and single-family homes and many multi-family dwellings located directly east of those commercial uses. The King's Arms Motel is located at the intersection of 30th Avenue S and Kent-Des Moines Road.

3.1.1.2 Kent-Des Moines Road to S 272nd Street

South of Kent-Des Moines Road and north of S 248th Street there are mostly commercial uses along SR 99, and smaller multi-family buildings are present directly west of these commercial uses on the west side of SR 99. These multi-family residences are mostly two-story, four-plex buildings. The Highline College (HC) campus is also in this area, and there is a 30-unit apartment complex south of S 236th Street, between the campus and SR 99. In addition, there is a new medical center and low-income multi-family housing (SeaMar Community Health Center) under construction at the intersection of SR 99 and S 242nd Street. The Alaska Trailer Park is immediately to the south of the campus, and there is a small condominium complex southwest of the park. The Lolani Apartments are on SR 99 between S 244th and S 246th Streets, and there are numerous empty lots behind commercial structures between S 244th and S 248th Streets that are zoned for residential use.

Continuing along the west side of SR 99 south of S 248th Street, there is a condominium complex along S 248th Street that is shielded from SR 99 by commercial uses. The other land uses behind the commercial properties (commonly called second line receivers) are single-family homes that occupy neighborhoods all the way south to S 260th Street. Beginning at S 252nd Street, there are undeveloped parcels along SR 99, all of which are zoned for commercial use. The Saddle Brook apartment complex is located at S 260th Street, and it includes a green space crossed by McSorley.

There are mostly commercial uses along the east side of SR 99 between Kent-Des Moines Road and S 240th Street. Behind these uses are the New Best Inn Motel, two mobile home parks, the Park of the Pines Church and conference center, and some multi-family buildings. From S 240th Street to S 252nd Street is the Midway Mobile Mansions mobile home park, some industrial and commercial uses and undeveloped parcels zoned for commercial use, the Midway Landfill (closed), and the Sunset and Crossland Motels. From S 252nd Street to S 260th Street, there are mostly commercial uses and the West Hill Mobile Manor mobile home park along SR 99. To the east of these are single-family homes, the Buena Casa Apartment Complex, and the Cottonwood Apartment Community. Between S 260th

Street and S 272nd Street, there are some commercial uses, several single-family homes, and several lots zoned for residential use.

Just south of S 260th Street on the west side of SR 99, there is a lone single-family home and two undeveloped parcels, one of which is owned by a sewer district and the other is zoned for residential use. The Travel Inn Motel is on SR 99 approximately 800 feet south of the S 260th Street intersection. West of the motel, between S 261st Place and S 263rd Place, there are three large parcels that have been subdivided and are in the process of being developed into single-family homes. Immediately west and south of the motel, between the new subdivision and SR 99, there are three other undeveloped parcels, two of which are owned by the City of Des Moines and the third is owned by the subdivision developer; all three are zoned for single-family use. Farther south along SR 99 is a vacant church, a single-family home, undeveloped commercial lots, and an undeveloped residential lot. Single-family homes are located west of all of the undeveloped lots between S 260th Street and S 268th Street.

South of 268th Street on the west side of the SR 99 intersection is the Woodmont Library. The Seacoma Mobile Home and RV Park is located to the west of the library. There are only commercial uses between these noise-sensitive uses and S 272nd Street.

3.1.1.3 S 272nd to Federal Way Transit Center

The Crestwood Senior Mobile Home Park, which is south of S 272nd Street, is partially shielded from SR 99 by some commercial structures. Farther south, there are only commercial uses directly along SR 99 until just north of S 279th Street. To the west and south of these commercial uses is a neighborhood of single-family homes. This neighborhood continues just past S 279th Street, at which point there is a sizable undeveloped parcel and five smaller parcels along SR 99. All of these properties are zoned for residential use. From S 284th Street to Dash Point Road there are numerous multi-family homes along SR 99, along with some low-density commercial uses, a place of worship (the Rissho Kosei Kai of Seattle), and undeveloped lands. The Church of Christ is located at the intersection of S 288th Street. To the west of these front-line uses there are single-family homes and smaller multi-family structures.

On the east side of SR 99 between S 272nd Street and S 288th Street there are mostly multi-family buildings and some commercial uses. There are some commercial uses and the Redondo Heights Park-and-Ride along SR 99, just south of S 272nd Street. Behind these commercial uses and to the south of the park-and-ride there are mostly large multi-family complexes. Between S 283rd Street and S 288th Street, the multi-family uses become denser, and there are several more large multi-family complexes in this area. The Federal Way Kindercare is located at the intersection of S 288th Street and 18th Avenue S.

On the west side of SR 99 south of S 288th Street, there are single-family homes behind The Church of Christ and the commercial uses that line SR 99. These homes continue all the way south to Dash Point Road. There are two empty lots zoned for multi-family residential use near Redondo Way S. There are also several other empty lots similarly zoned on either side of The View at Redondo apartment complex on SR 99 north of Dash Point Road. The Federal Way Motel is on SR 99 just south of Dash Point Road, and behind the hotel is Sacajawea Middle School and Park, which includes several athletic fields. South of the school are single-family homes that are separated from SR 99 by several undeveloped parcels zoned for commercial use. These homes continue to just north of S 304th Street. The new Federal Way High School, which is currently under construction, is located between S 304th Street and S 308th Street and will also have a new performing arts center located close to SR 99. There is an apartment building on the southwest corner of the intersection of SR 99 and S 308th Street. Behind the apartment building is a hair salon, a duplex, and a 12-unit apartment building that has west-facing balconies. Other than the apartment building, there are only commercial uses along SR 99 all the way down to S 312th Street. Behind the commercial buildings are the Bellridge Townhomes, the Southridge House apartment building, and the Emeritus senior care facility.

On the east side of SR 99 south of S 288th Street, there is an apartment building and a condominium complex that is partially shielded from SR 99 by a strip mall. Behind these uses and farther south are numerous single-family homes and some duplexes. South of S 293rd Street, the land use is similar, with commercial uses lining SR 99, multi-family homes to the east of the commercial uses, and single-family homes behind the multi-family dwellings. Near Dash Point Road there is a multistory condominium complex that faces SR 99. Between the intersection of SR 99 and 18th Avenue S and S 304th Street is the Lamb's Gate Church, Smart Start Day Care, and a large undeveloped parcel. The area between S 304th Street and S 308th Street is filled almost exclusively with multi-family buildings and a few commercial uses along SR 99. From S 308th Street to S 312th Street, there are mostly commercial uses, with multi-family homes to the east of those commercial uses. South of S 312th Street is a mix of commercial uses. Some of the commercial buildings in this area are currently vacant. Other uses in this area include the Federal Way Running Start Home School, the Clarion Hotel, and the Comfort Inn hotel.

3.1.2 I-5 Corridor

Over 3,000 noise-sensitive receivers are located along the I-5 corridor. Most of these are multi-family residential complexes located near the north and south ends of the corridor, while the central part of the corridor is primarily single-family residential.

3.1.2.1 200th Street to Kent-Des Moines Road

Alternatives that travel in the I-5 corridor would travel within the SR 99 corridor from the north end of the FWLE at the Angle Lake Station to S 208th Street. In general, from S 211th Street to S 317th Street, the alignment would run along the west side of the I-5 right-of-way owned by the Washington State Department of Transportation (WSDOT), and all of the area between the alignment and I-5 would remain public right-of-way for transportation uses. South of S 208th Street, there are several vacant properties that have been purchased by WSDOT as future right-of-way for the planned SR 509 extension. Some single-family residences remain in this area, as well as a group of four-plexes in the Legacy Place apartment complex and other multi-family homes.

Between I-5 and SR 99, land uses are primarily residential, with a Best Western Hotel and commercial uses along SR 99. Residential uses become denser between S 211th Street and S 221st Street. Just north of S 216th Street are some water storage tanks. Beginning at S 216th Street, multi-family homes predominate, and a 64-unit apartment complex and Pine Terrace mobile home park are south of S 219th Street. Midway Park and an electrical power substation are to the west of the corridor at

S 221st Street. There are some single-family homes south of the substation between I-5 and SR 99, but multi-family dwellings predominate all the way south to Kent-Des Moines Road. The Kings Arms Motel and a few more single-family homes are located at the end of the I-5 southbound off-ramp that exits onto Kent-Des Moines Road.

3.1.2.2 Kent-Des Moines Road to S 272nd

Immediately south of Kent-Des Moines Road, the New Best Inn Motel is located along 30th Avenue S, and to the south of the motel are several parcels owned by the Park of the Pines Church and conference center. To the west of I-5 are a mobile home park, Highline Water District administrative buildings, and some apartment buildings. There is a large neighborhood of virtually all single-family homes to the west of I-5 from S 252nd Street to S 260th Street. Situated between S 260th Street and S 272nd Street are the 240-unit Pembrooke apartment complex, a large area of undeveloped land that is the McSorley Creek wetland complex, a King County road maintenance facility (a commercial use), a newer development of single-family homes, and the Star Lake Park-and-Ride.

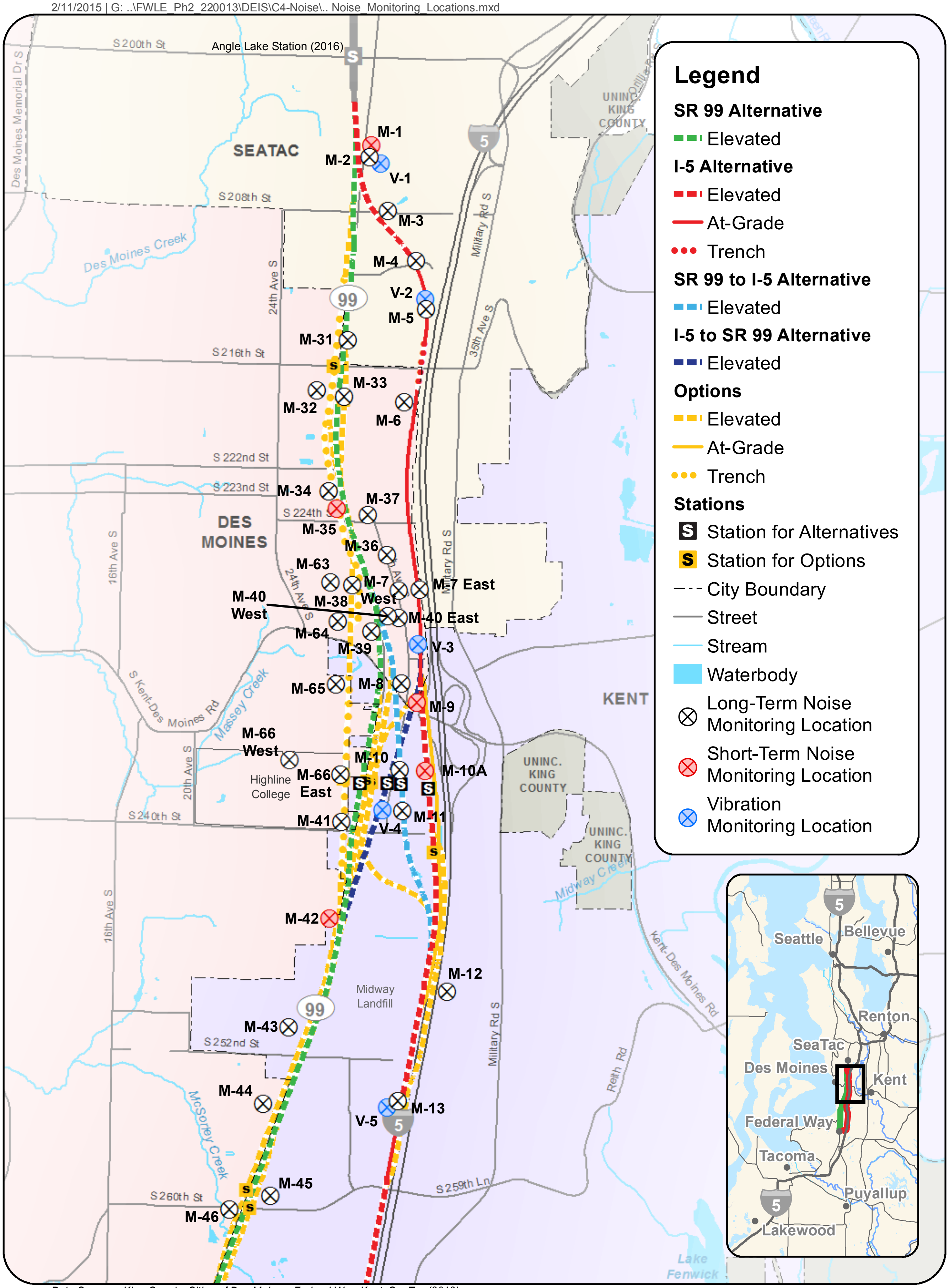
3.1.2.3 S 272nd to Federal Way Transit Center

South of S 272nd Street, across from the Star Lake Park-and-Ride, are a condominium and apartment complex and the Mark Twain Elementary School. Between the school and Military Road S are a neighborhood of single-family homes, a few vacant lots, and the Star Lake Church of God. Between Military Road and S 288th Street is another group of single-family residences. The Korean Methodist Church is located at the intersection of S 288th Street and 30th Avenue S. There is a very large mobile home park (Camelot Square) that occupies several parcels south of S 288th Street, and south of that park is a relatively new single-family residential development. The Church of Christ at Federal Way is located on Military Road S, at 301st Street. To the north of the church are a utilities facility building and some single-family residences. To the west of the church are single-family residences, and there are single-family residences all the way to S 304th Street as well.

The Faith Community Church is located on 28th Avenue S at S 308th Lane near S 309th Street. There are single-family residences and several empty lots between S 304th Street and the church. South of the church are more single-family residences and a commercial use. South of 312th Street, there is the Providence Landing apartment complex, a vacant lot, a group care home, one single-family residence, and Truman High School. Alternatives along I-5 would exit the WSDOT right-of-way at S 317th Street. To the south of S 317th Street is the Hampton Inn and Suites and the Courtyard Federal Way Hotel. The rest of the uses to the south are commercial. To the north of the alignment are several multi-family apartment and condominium complexes. Just north of the Federal Way Transit Center is the Senior City apartment building, and to the northwest of the transit center is the Clarion Hotel.

3.2 Noise Measurements

Sound Transit characterized the existing noise environment through onsite inspections and onsite noise monitoring. Monitoring was performed at 72 locations, including 57 long-term (24-hour or longer) sites and 15 short-term (15-minute) sites. Exhibits 3-1 and 3-2 show the FWLE alternatives, noise monitoring locations, and vibration testing locations.



Data Sources: King County, Cities of Des Moines, Federal Way, Kent, SeaTac (2013).

N

0 0.25 0.5 1 Miles

EXHIBIT 3-1

Noise and Vibration Monitoring Locations (North)

Federal Way Link Extension

Data Sources: King County, Cities of Des Moines, Federal Way, Kent, SeaTac (2013).

EXHIBIT 3-2

Noise and Vibration Monitoring Locations (South)

Some of these monitoring locations were used for purposes of more than one of the FWLE alternatives. Long-term monitoring was performed at noise-sensitive locations representative of nearby properties.

Short-term monitoring was also performed at other locations where long-term monitoring was not practical or where short-term data were used to supplement nearby long-term monitoring results. Sound Transit also performed short-term noise level readings and traffic counts at most of the long-term sites in preparation for any sound wall analysis that might be required for relocated sound walls along the project corridor. Sound Transit selected monitoring sites based on land use, existing noise sources, light rail alternative proximity and profile type, and the site's ability to represent nearby noise-sensitive land uses.

All noise measurements were taken in accordance with the American National Standards Institute (ANSI) procedures for community noise measurements and guidelines provided in the FTA Guidance Manual. Measurement locations were at least 5 feet from any solid structure to minimize acoustical reflections and at a height of 5 feet off the ground as recommended by FTA and ANSI standards. The noise measurements and accompanying traffic counts were also taken in accordance with FHWA and WSDOT standards to ensure their suitability for relevant analyses. These traffic counts are only used if substantial roadway realignments are planned as part of the project; at this time, none is planned. The equipment used for noise monitoring included Bruel & Kjaer Type 2238 sound-level meters. The meters were calibrated before and after measurement periods using a sound-level calibrator. Complete system calibration is performed on an annual basis by an accredited testing laboratory. The laboratory system calibration is traceable to the National Institute of Standards and Technology. The systems meet or exceed the requirements for an ANSI Type 1 noise measurement system.

For long-term monitoring locations, the Ldn was calculated using logarithmic energy averaging for the 24-hour data with a 10-dBA penalty for noise measured between 10:00 p.m. and 7:00 a.m. For short-term monitoring locations, the projected Ldn levels were calculated using formulas in the FTA Guidance Manual and comparison with other nearby long-term noise monitoring sites.

The following sections describe the existing noise environment by FWLE alternative. There is one sound wall along I-5 that could be affected by alternatives along I-5. If it were necessary to remove some or all of this sound wall as part of the project, it would need to be replaced or relocated to a new location.

3.2.1 SR 99 Corridor

The SR 99 corridor had 43 long-term and 11 short-term monitoring locations. Noise levels along this corridor are dominated by traffic noise from SR 99 and major arterial roadways such as Kent-Des Moines Road, S 272nd Street, S 312th Street, and S 320th Street. Aircraft flight also contributes to the noise environment in the northern part of the corridor.

The Ldn at first-line receivers along SR 99 north of Kent-Des Moines Road ranged from 65 dBA to 74 dBA (sites M-1, M-2, M-31, M-32, M-39, and M-8). The high Ldn noise levels are primarily due to the proximity of some receivers to SR 99, steady traffic flow along SR 99, and receivers that are elevated relative to the roadway along the east side of SR 99. The peak-hour noise level measured at a front-line church in the area (site M-35) was 66 dBA Leq. Second-line and other receiver noise levels along SR 99 in this area ranged from 63 dBA to 67 dBA (sites M-33, M-34, M-35, M-36, M-37, M-38, M-63, and M-64).

Ldn noise levels at monitoring locations south of Kent-Des Moines Road and north of 272nd Street along SR 99 ranged from 63 dBA to 71 dBA (sites M-41, M-44, M-45, M-46, M-48, and M-66 East). Because many of the monitoring sites in this segment are located farther from SR 99, the Ldn noise levels are somewhat lower than the first-line noise levels along SR 99 north of Kent-Des Moines Road.

Receivers on the east side of SR 99, between S 272nd Street and S 304th Street, are at generally higher elevations than the roadway. Conversely, receivers on the west side of SR 99 are generally below grade in this area. The relative noise levels reflect this difference. On the east side of the road, Ldn noise levels at first-line monitoring locations ranged from 65 to 73 dBA (sites M-51, M-53, and M-54). On the west side of the road, Ldn noise levels at both first and second-line monitoring locations were consistently between 61 and 63 dBA (sites M-50, M-52, M-56, and M-67). The peak-hour noise level measured at the Federal Way Motel (site M-55) was 71 dBA Leq.

Residential noise levels between S 304th Street and the Federal Way Transit Center along the SR 99 corridor ranged from 59 to 67 dBA (sites M-57, M-59, M-61, M-62), with the lowest levels being at the second-line Bellridge Condominiums to the west of SR 99.

Table 3-1 summarizes the noise monitoring results for the SR 99 corridor. Included in the table are the monitoring location number, address, land use, and type of measurement. The 24-hour Ldn is presented for all FTA Category 2 land uses (residences and buildings where people normally sleep), and the peak-hour Leq is presented for all other sites. For locations where short-term measurements were conducted, the Ldn noise levels were calculated from the short-term Leq measurements in accordance with the FTA Guidance Manual; therefore, both types of measures are provided at these locations. As is defined in Section 4.1.1, the Leq is used for the evaluation of sites with daytime use, while the Ldn is used for sites with sleeping quarters. For daytime-use locations where long-term measurements were conducted, the Leq noise levels were calculated as an average of daily peak-hour Leq measurements. Although the monitoring data are presented to the tenth of a dB, the FTA recommends presenting the noise analysis data for impact analysis (later in this report) in whole numbers only.

TABLE 3-1
SR 99 Corridor Noise Measurements

Monitoring Location[a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)[b]
M-1	20406 Pacific Hwy S (Sleep Inn)	Hotel	Short Term	65.6	63.6
M-2	20440 Int'l Blvd (The Firs Mobile Home Park)	Multi-family	Long Term		71.4
M-7 East	22700 30th Ave S (Newport Village Condominiums)	Multi-family	Long Term		77.8
M-7 West	22700 30th Ave S (Newport Village Condominiums)	Multi-family	Long Term		65.4
M-8	23215 30th Ave S	Single-family	Long Term		65.2
M-9	WSDOT right-of-way near King's Arms Motel	Hotel	Short Term	72.4	70.4

TABLE 3-1
SR 99 Corridor Noise Measurements

Monitoring Location[a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)[b]
M-10	23634 30th Ave S (Park of the Pines - Homes)	Single-family	Long Term		65.5
M-10A	23634 30th Ave S (Park of the Pines - Church)	Church	Short Term	69.5	N/A[c]
M-11	23828 30th Ave S	Municipal	Long Term	60.0	65.4
M-12	3320 S 248th Place	Single-family	Long Term		77.7
M-31	21428 Pacific Hwy S (Viewpoint Apartments)	Multi-family	Long Term		74.1
M-32	21814 Pacific Hwy S (Pine Terrace Mobile Home Park)	Multi-family	Long Term		69.0
M-33	2459 Pacific Hwy S (Majestic Bay Apartments)	Multi-family	Long Term		66.6
M-34	2616 S 224th St (Sea Fox Apartments)	Multi-family	Long Term		65.0
M-35	22323 Pacific Hwy S (Citadel Church)	Church	Short Term	65.6	N/A[c]
M-36	22516 30th Ave S	Single-family	Long Term		64.9
M-37	22323 30th Ave S	Single-family	Long Term		62.3
M-38	22700 28th Ave S (Access Condominiums)	Multi-family	Long Term		64.4
M-39	22855 Pacific Hwy S	Single-family	Long Term		65.9
M-40 East	22831 30th Ave S	Multi-family	Long Term		66.2
M-40 West	22831 30th Ave S	Multi-family	Long Term		74.4
M-41	2400 S 240th St (Highline College)	School	Long Term	63.5	64.7
M-42	24415 Pacific Hwy S (Iolani Apartments)	Multi-family	Short Term	60.9	58.9
M-44	2315 S 254th Ct	Single-family	Long Term		65.3
M-45	2424 S 260th St (West Hill Mobile Manor)	Multi-family	Long Term		63.4
M-46	2211 260th St	Single-family	Long Term		68.5
M-47	26421 Pacific Hwy S	Vacant	Short Term	75.1	N/A[c]
M-48	26636 19th Ave S	Single-family	Long Term		70.5
M-49 North	2211 S Star Lake Rd (Club Palisades Apartments North End)	Multi-family	Short Term	63.6	61.6
M-49 Central	2211 S Star Lake Rd (Club Palisades Apartments Pool Area)	Multi-family	Long Term		63.2
M-50	27805 16th Pl S	Single-family	Long Term		61.9
M-51	28120 18th Ave S - Mariposa Apartments	Multi-family	Long Term		73.2
M-52	28723 16th Ave S, Bldg G	Multi-family	Long Term		61.2
M-53	29353 18th Ave S	Multi-family	Long Term		64.8
M-54	29850 18th Ave S	Church and Single-family	Long Term	65.5	66.9
M-55	29815 Pacific Hwy S (Federal Way Motel)	Hotel	Short Term	71.4	69.4
M-56	1472 S 303rd St	Single-family	Long Term		62.4
M-57	30602 Pacific Hwy S (View at the Lake Apartments)	Multi-family	Long Term		66.9
M-58	31031 Pacific Hwy S (New Federal Way High School under construction)	School	Short Term	60.7	N/A[c]
M-59	1816 S 312th St	Single-family	Long Term		63.3
M-60	2502 S 317th St (Chelsea Court Condominiums)	Multi-family	Long Term		67.8
M-61	31611 20th Ave S (Clarion Hotel)	Hotel	Long Term		63.7

TABLE 3-1
SR 99 Corridor Noise Measurements

Monitoring Location[a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)[b]
M-62	1444 14th Ave S (Bellridge Condominiums)	Multi-family	Long Term		58.8
M-63	2670 S 227th Pl	Single-family	Long Term		62.8
M-64	22902 27th Ave S	Single-family	Long Term		63.4
M-65	23211 28th Ave S	Single-family	Long Term		62.8
M-66 East	Highline College (east parking lot)	School	Long Term	62.9	62.2
M-66 West	Highline College (north parking lot)	School	Long Term	63.3	66.2
M-67	29045 15th Pl	Single-family	Long Term		62.5
M-68	1600 SW Dash Point Rd (Sacajawea Park)	Park	Long Term	62.6	64.4
M-69	31622 Pacific Hwy (Comfort Inn)	Hotel	Short Term	58.1	56.1
M-70	2460 S 320th St (walkway between hotels)	Hotel	Short Term	64.5	62.5
M-71	32124 25th Ave (Best Western Plus Evergreen Inn & Suites)	Hotel	Long Term		75.2
M-72	2101 S 324th St (Belmor Park)	Multi-family	Long Term		68.4

[a] Sites shown on Exhibits 3-1 and 3-2.
[b] Projected Ldn levels for short-term monitoring sites have been calculated using formulas and methods in the FTA *Transit Noise and Vibration Impact Assessment* (FTA, 2006) and by comparison with other nearby long-term noise monitoring sites.
[c] These sites were only measured for peak-hour Leq, and no Ldn measure is required because these sites do not represent residential uses.
Ldn = 24-hour, time-averaged, A-weighted sound level; Leq = equivalent continuous sound level; N/A = not applicable

3.2.2 I-5 Corridor

For this analysis, the I-5 corridor had 28 long-term and 9 short-term monitoring locations. Noise levels along this corridor are dominated by traffic noise from I-5 and major arterial roadways such as Kent-Des Moines Road, S 272nd Street, S 288th Street, and S 320th Street. Aircraft flight also contributes to the noise environment in the northern part of the FWLE corridor.

Front-line receivers adjacent to I-5 had measured Ldn noise levels ranging from 70 dBA to 79 dBA along the entire corridor (sites M-5, M-7 East, M-12, M-13, M-17, M-19, M-23 North, M-23 South, M-27, M-28, M-29, and M-71). At the Camelot Square Mobile Home Park (M-23 North), which is behind an existing sound wall, the Ldn was 71 dBA, which is at the lower end of the range. For sites with a clear line of sight to the freeway, which include M-7 East, M-12, and M-28, the measured Ldn fell within a narrower range of 78 dBA to 79 dBA. Site M-27, which also has a clear line of sight to I-5 but also has 250 feet of intervening soft ground, had an Ldn of 74 dBA. The Best Western Plus Evergreen Inn & Suites (site M-71) had an Ldn of 75 dBA, which is a slightly lower noise level because it is farther away from the highway than the other front-line receivers.

Peak-hour measured Leq noise levels at the three front-line churches and the King's Arm Motel represented by receivers M-9, M-10A, M-22, and M-25 ranged from 70 dBA to 74 dBA. The peak-hour Leq for the Mark Twain Elementary School was 64 dBA, with the lower noise level due in part to a berm shielding the school from I-5 traffic noise. Truman High School, which is located farther from I-5, has a peak-hour Leq of 61 dBA. The outdoor uses at these schools are not as close to I-5 as some of the other measured sites, and in the case of Truman High School, it is shielded from the northbound lanes on I-5 by a large retaining wall that supports the high-occupancy vehicle ramps at S 317th Street.

The measured Ldn noise levels at second-line homes in the north end of the I-5 corridor ranged from 68 dBA to 69 dBA (sites M-3, M-4, and M-6). In the middle of the corridor, the second-line residential Ldn was 66 dBA (sites M-10 and M-15), and at the south end it was 68 dBA (site M-60).

Table 3-2 summarizes the noise monitoring results for the I-5 corridor. The table includes the monitoring location number, address, land use, and type of measurement, with the 24-hour Ldn for FTA Category 2 land uses and the peak-hour Leq for all other sites.

TABLE 3-2
I-5 Noise Measurements

Monitoring Location[a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)[b]
M-1	20406 Pacific Hwy S (Sleep Inn)	Hotel	Short Term	65.6	63.6
M-2	20440 Int'l Blvd (The Firs Mobile Home Park)	Multi-family	Long Term		71.4
M-3	3002 S 208th St (Willow Lake Apartments)	Single-family	Long Term		68.8
M-4	WSDOT right-of-way near 3120 S 211th St	Single-family	Long Term		68.2
M-5	WSDOT ROW near 21211 32nd Ave S	Single-family	Long Term		71.6
M-6	21815 31st Ave S	Single-family	Long Term		68.3
M-7 East	22700 30th Ave S (Newport Village Condominiums)	Multi-family	Long Term		77.8
M-7 West	22700 30th Ave S (Newport Village Condominiums)	Multi-family	Long Term		65.4
M-8	23215 30th Ave S	Single-family	Long Term		65.2
M-9	WSDOT right-of-way near King's Arms Motel	Hotel	Short Term	72.4	70.4
M-10	23634 30th Ave S (Park of the Pines - Homes)	Single-family	Long Term		65.5
M-10A	23634 30th Ave S (Park of the Pines - Church)	Church	Short Term	69.5	N/A[c]
M-11	23828 30th Ave S	Municipal	Long Term	60.0	65.4
M-12	3320 S 248th Place	Single-family	Long Term		77.7
M-13	25338 31st Ave S	Single-family	Long Term		74.3
M-15	2728 S 268th Pl S	Single-family	Long Term		66.6
M-16	2450 S Star Lake Rd (Mark Twain Elementary School)	School	Short Term	64.0	N/A[c]
M-17	2720 S 275th Place	Single-family	Long Term		70.6
M-19	28118 29th Ave S	Single-family	Long Term		69.5
M-22	2920 S 288th St (Kumran Methodist Church)	Church	Short Term	69.5	N/A[c]
M-23 North	3001 S 288th St (end of Sir Galahad Ct in Camelot Square Mobile Home Park)	Multi-family	Long Term		70.8
M-23 South	3001 S 288th St (223 Canterbury Dr in Camelot Square Mobile Home Park)	Multi-family	Long Term		72.3
M-25	30012 Military Rd (Church of Christ at Federal Way)	Church	Short Term	73.7	N/A[c]
M-27	2833 S 308th Lane (Studio)	Single-family	Long Term		74.3
M-27A	2833 S 308th Lane (Home)	Single-family	Short Term	66.6	64.6

TABLE 3-2
I-5 Noise Measurements

Monitoring Location[a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)[b]
M-28	31220 28th Ave S (Providence Landing Apartments)	Multi-family	Long Term		78.6
M-29	31524 28th Ave S	Single-family	Long Term		70.1
M-30	31453 28th Ave S (Truman High School)	School	Short Term	61.3	N/A[c]
M-36	22516 30th Ave S	Single-family	Long Term		64.9
M-37	22323 30th Ave S	Single-family	Long Term		62.3
M-40 East	22831 30th Ave S	Multi-family	Long Term		66.2
M-40 West	22831 30th Ave S	Multi-family	Long Term		74.4
M-60	2502 S 317th St (Chelsea Court Condominiums)	Multi-family	Long Term		67.8
M-61	31611 20th Ave S (Clarion Hotel)	Hotel	Long Term		63.7
M-70	2460 S 320th St (Walkway between Hotels)	Hotel	Short Term	64.5	62.5
M-71	32124 25th Ave (Best Western Plus Evergreen Inn & Suites)	Hotel	Long Term		75.2
M-72	2101 S 324th St (Belmor Park)	Multi-family	Long Term		68.4

[a] Sites shown on Exhibits 3-1 and 3-2.
[b] Projected Ldn levels for short-term monitoring sites have been calculated using formulas and methods in the FTA *Transit Noise and Vibration Impact Assessment* (FTA, 2006) and by comparison with other nearby long-term noise monitoring sites.
[c] These sites were only measured for peak-hour Leq, and no Ldn measure is required because these sites do not represent residential uses.
Ldn = 24-hour, time-averaged, A-weighted sound level; Leq = equivalent continuous sound level; N/A = not applicable

3.3 Vibration Measurements

3.3.1 Vibration Propagation Test Procedure

Line Source Transfer Mobility

LSTM represents the complex relationship between the vibration source—such as a train that excites the ground—and the resulting vibration of the ground surface. It is a function of vibration frequency and distance of the receiver from the source. In other words, LSTM is an indicator of the efficiency with which vibration energy is transmitted

The field test procedure for determining line source transfer mobility (LSTM) for at-grade sites is shown schematically on Exhibit 3-3. The test basically consists of dropping a heavy weight on the ground and measuring the force into the ground and the vibration response at several distances from the impact site. As shown on Exhibit 3-3, instruments for measuring the ground vibration in the vertical direction, usually accelerometers or geophones, are located in a line perpendicular to the impact line. The number of accelerometers and the distances from the impact line will vary depending on field conditions. For these tests, accelerometers were located at distances up to 200 feet from the impact line. All accelerometers were located outdoors. The impact line was typically 150 feet to 200 feet long, with the impacts at 11 positions at intervals of 15 feet.

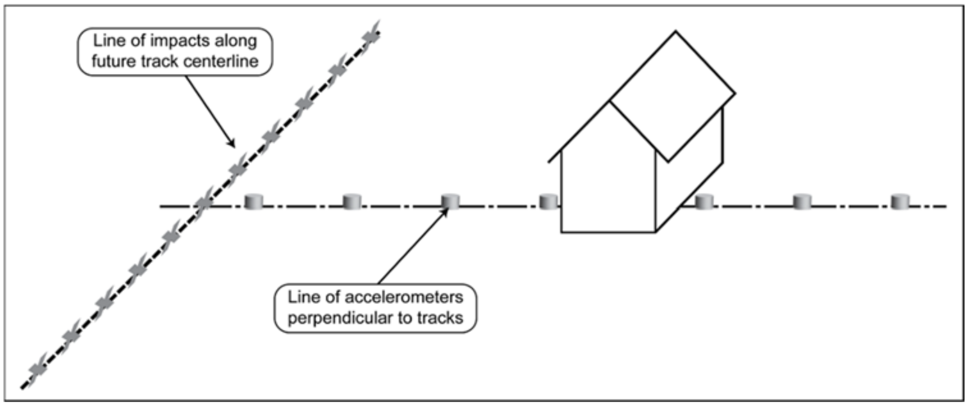


EXHIBIT 3-3
Schematic of Surface Vibration Propagation Test Procedure

Digital analysis is used to derive the relationship between the force into the ground and the vibration velocity at each of the measurement positions. The transfer function relationship between the exciting force and the resultant vibration velocity is referred to as the point source transfer mobility (PSTM) in this report. The LSTM is calculated by mathematically combining the PSTM functions into an estimate of LSTM.

3.3.2 Vibration Propagation Test Sites

The vibration test sites were selected based on a review of aerial photographs and a windshield survey of the land uses. Vibration propagation tests were performed at 12 sites in the study area. All sites were located close to FWLE alternative alignments. Sites V-1, V-7, V-8, and V-10 were located along SR 99. Sites V-2, V-5, V-6, V-9, V-11, and V-12 were located along I-5. Sites V-3 and V-4 were located along 30th Avenue S. A summary of the vibration propagation test sites and measurement distances is provided in Table 3-3. Detailed descriptions of each test site are provided in Appendix D. The detailed vibration test results, including the best-fit coefficients for the LSTMs, are provided in Appendix E.

TABLE 3-3
Summary of Vibration Propagation Test Sites

Test Site	Analysis Type	Vibration Measurement Distances from Impact Line (feet)[a]							
		A1	A2	A3	A4	A5	A6	A7	A8
Along SR 99									
V-1	Firs Mobile Home Park	25	38	50	63	75	100	25	50
V-7	Park-and-Ride on S 276th St	25	50	75	100	125	140	--	--
V-8	SR 99 & S 283rd St	25	50	75	100	125	140	--	--
V-10	Lake Apartments near S 308th St	25	50	75	100	125	150	--	--
Along I-5									
V-2	32nd Ave S & S 212th St	25	38	50	75	100	125	150	200
V-5	31st Ave S & S 254th St	25	50	75	100	125	150	175	200
V-6	Mark Twain School	25	50	75	100	125	150	--	--
V-9	Camelot Square Mobile Homes	25	50	75	100	125	150	--	--
V-11	Providence Landing Apartment on 28th Ave S	25	38	50	63	75	100	125	150
V-12	Truman High School	25	38	50	63	75	100	--	--

TABLE 3-3
Summary of Vibration Propagation Test Sites

Test Site	Analysis Type	Vibration Measurement Distances from Impact Line (feet)[a]							
		A1	A2	A3	A4	A5	A6	A7	A8
Along 30th Avenue S									
V-3	30th Ave S & S 225th Pl	25	38	50	75	100	125	160	200
V-4	3012 S 240th St	25	38	50	63	75	100	--	--

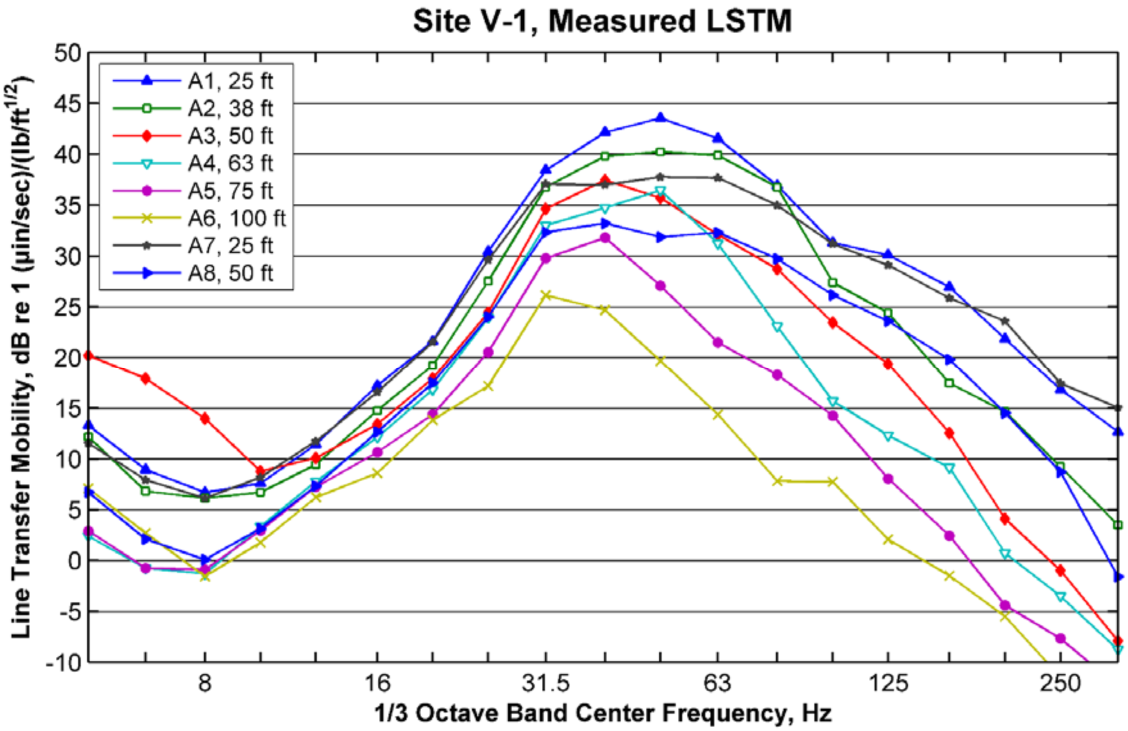
[a] The ground is excited using a drop hammer along a line called an impact line that simulates a line source such as a light rail train. The vibration responses are measured at several distances from the impact line. This provides the efficiency in which vibration energy is propagated through the soil.

3.3.3 Results of Vibration Propagation Tests

The measured LSTM and coherence for sites V-1 through V-12 are shown on Exhibit 3-4 through Exhibit 3-15. Coherence varies between 0 and 1 and is a measure of the "quality" of the LSTM results. A coherence close to 1 indicates that the vibration response and the force generated by the drop hammer are closely related. A coherence less than about 0.2 indicates a relatively weak relationship between the exciting force and the vibration response. Low coherence indicates that the vibration signal generated by the drop hammer was lower than the ambient vibration. This will happen when ambient vibration is relatively high, when the distance between the drop hammer and the accelerometer is relatively high, and when the soil is a poor transmitter of vibration at a specific frequency.

Higher LSTM indicates that vibration is transmitted more efficiently through the soil. The peak frequency of the LSTM is important because if the LSTM peak coincides with the force density level (FDL) peak, it will result in higher vibration at the sensitive receiver. Following are the observations from the vibration propagation test results; in the following summary, "good" coherence is defined as a coherence that is greater than or equal to 0.2:

- The transfer mobilities peaked between 31.5 and 63 Hz at all vibration sites except sites V-4 and V-9. The LSTM spectra of the 12 vibration sites showed similar attenuation with distance, and the LSTM peaks at 25 feet were within 10 decibels.
- For site V-4, the transfer mobility peaked between 40 and 50 Hz for the main accelerometer line, but the peak shifted to 63 and 80 Hz at the accelerometers at the façade of the apartment building.
- The coherences were good between 16 and 315 Hz at all measurement positions.
- For site V-9, the transfer mobility peaked at 40 Hz for the 25- and 50-foot positions. For the remaining measurement positions, the peak occurred between 25 and 31.5 Hz. The coherences were good between 20 and 315 Hz at all measurement positions.
- The coherence was good between 20 and 200 Hz for all sites except sites V-5 and V-8. The coherence for site V-5 was good between 20 and 160 Hz. The coherence for site V-8 was good between 10 and 125 Hz.



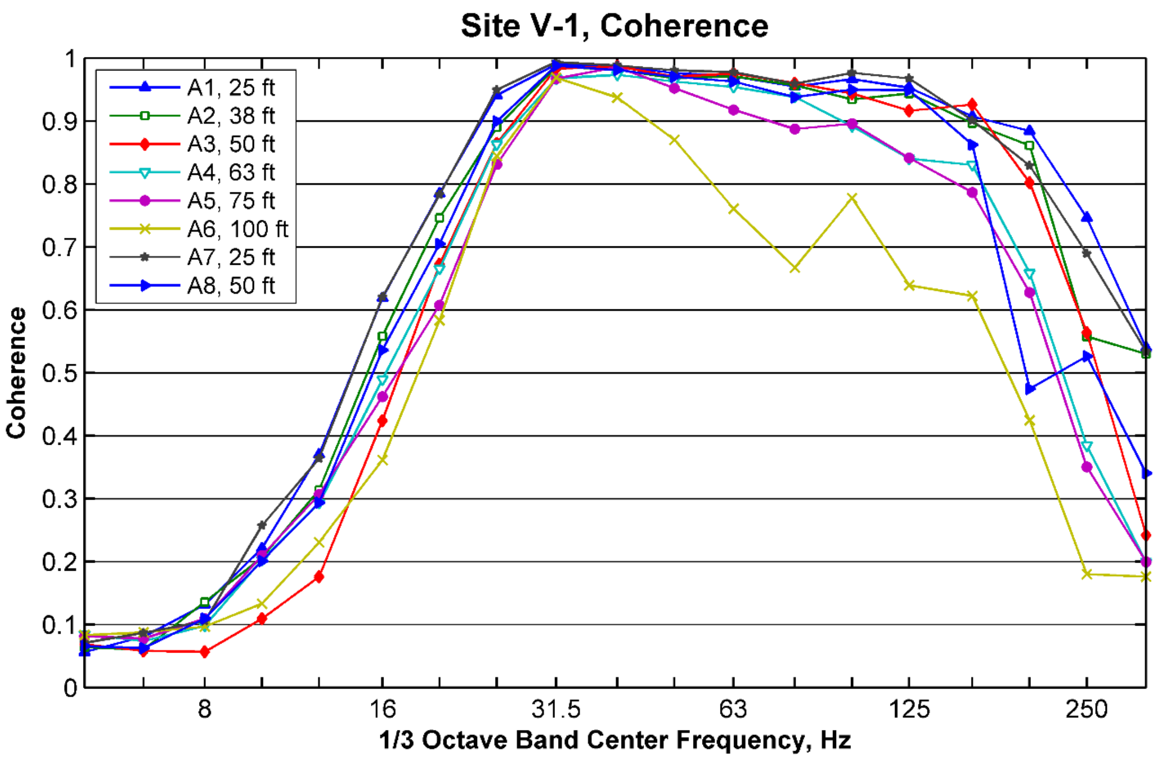
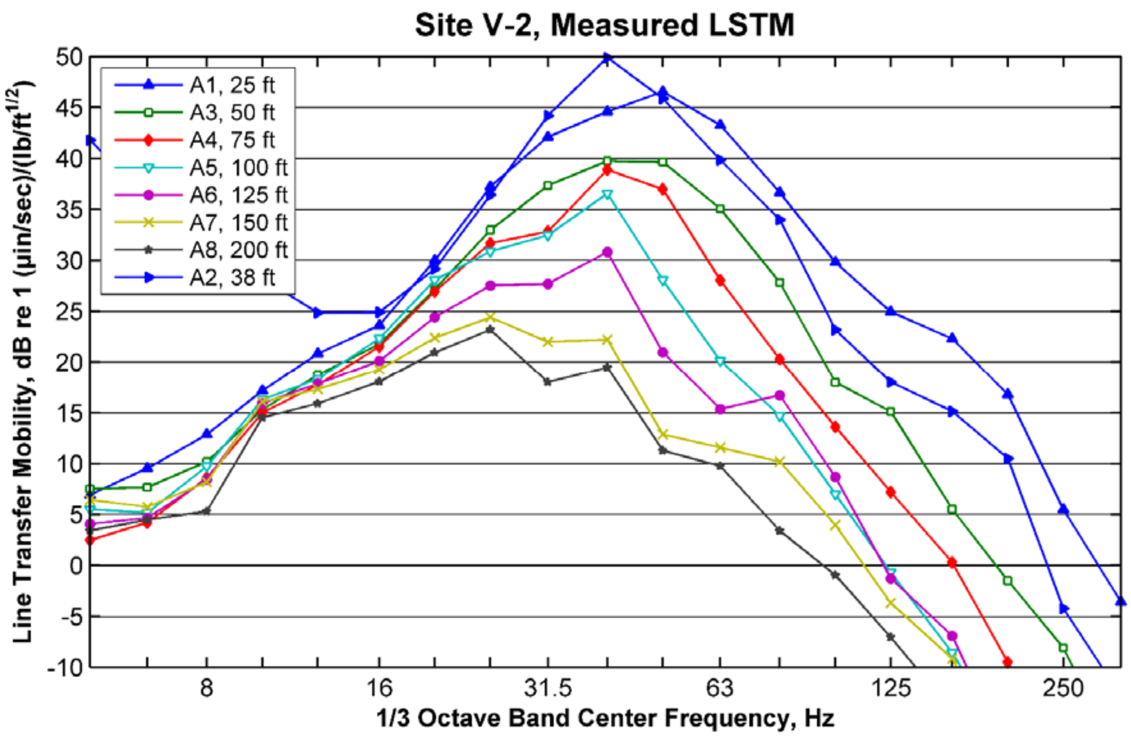


EXHIBIT 3-4
Measured LSTM and Coherence at Test Site V-1



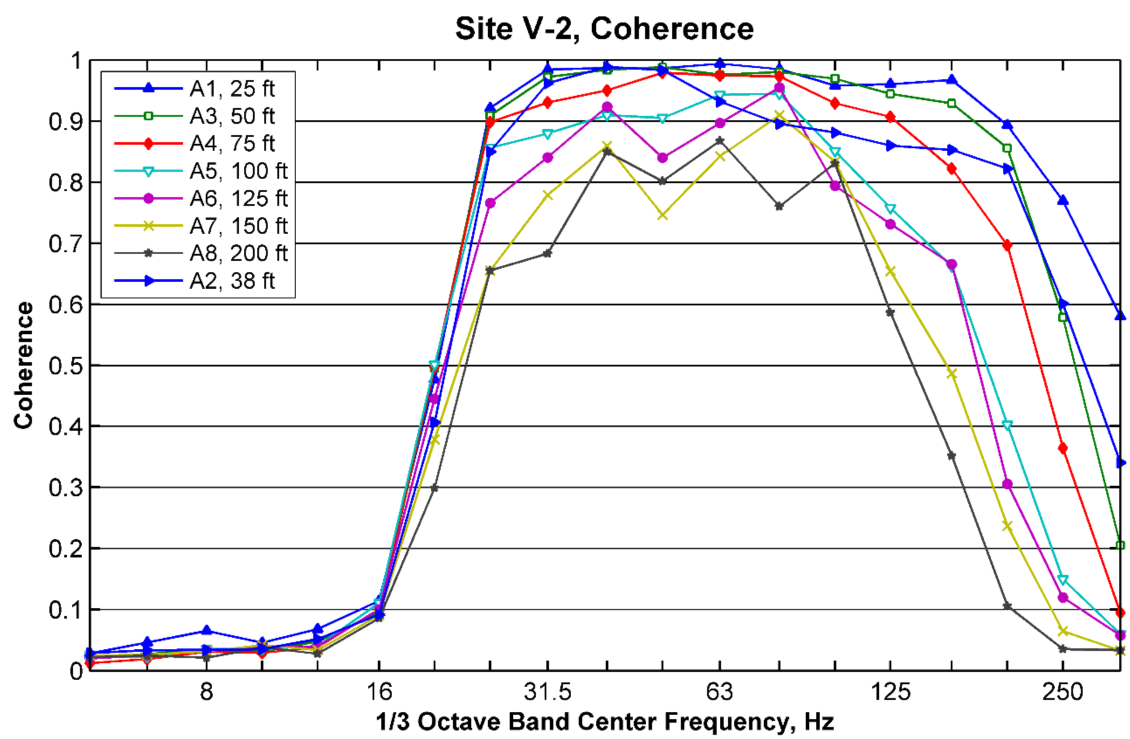


EXHIBIT 3-5
Measured LSTM and Coherence at Test Site V-2

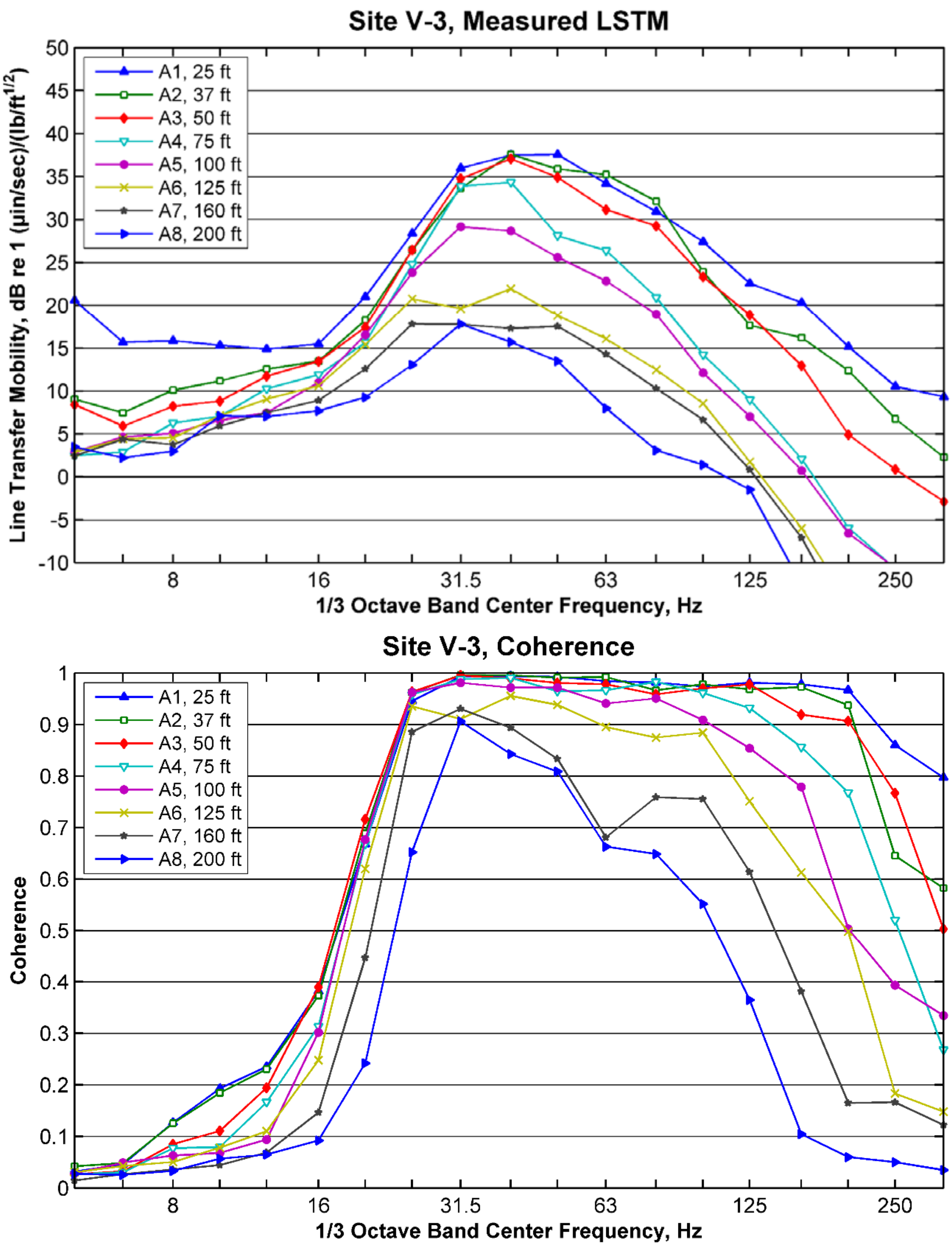


EXHIBIT 3-6
Measured LSTM and Coherence at Test Site V-3

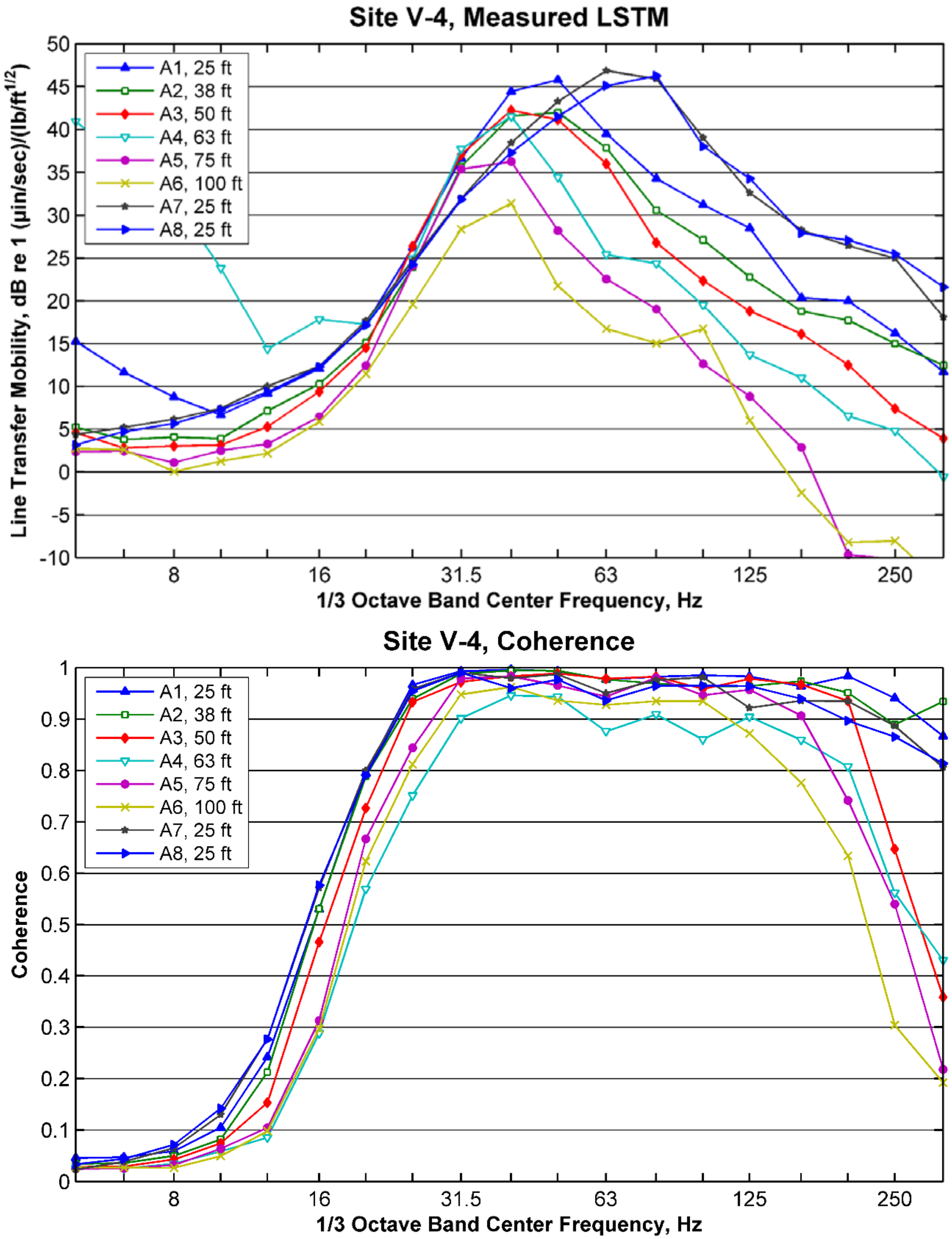
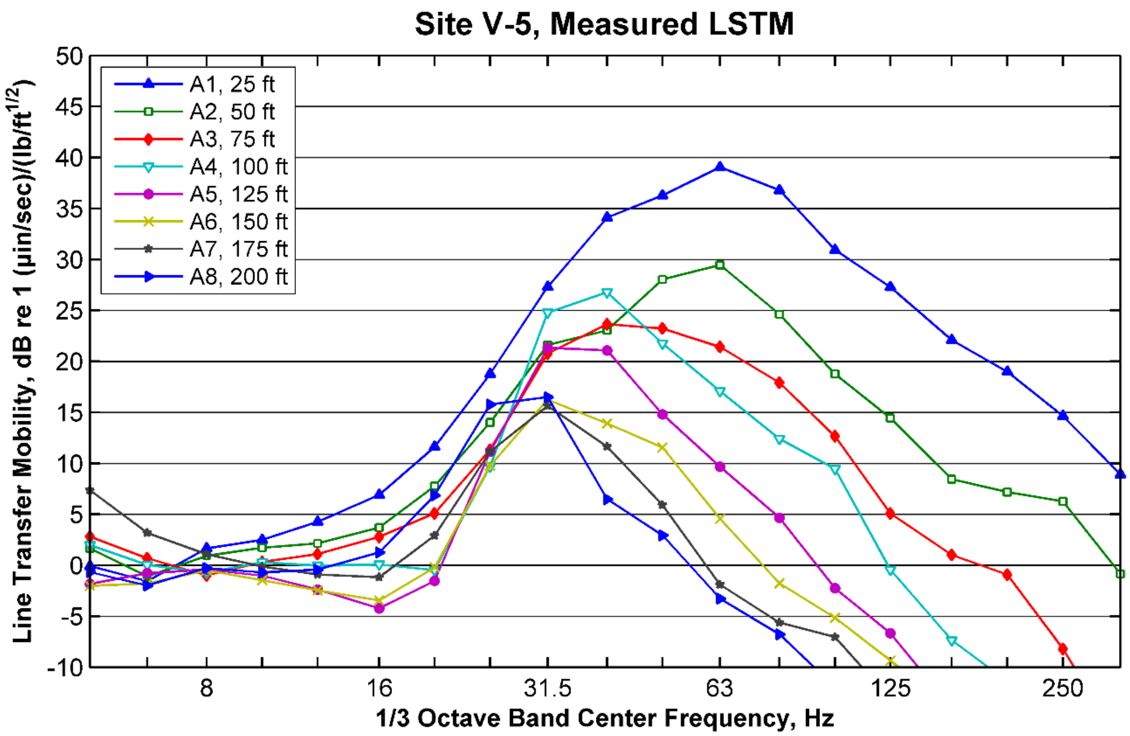


EXHIBIT 3-7
Measured LSTM and Coherence at Test Site V-4



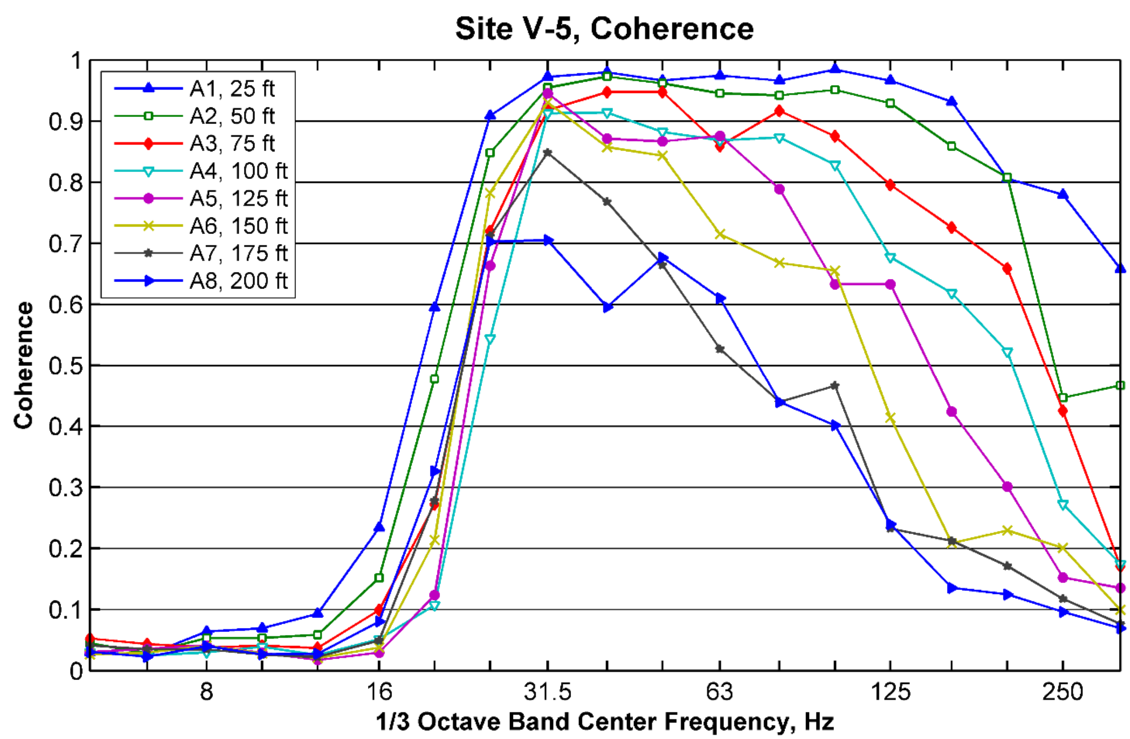


EXHIBIT 3-8
Measured LSTM and Coherence at Test Site V-5

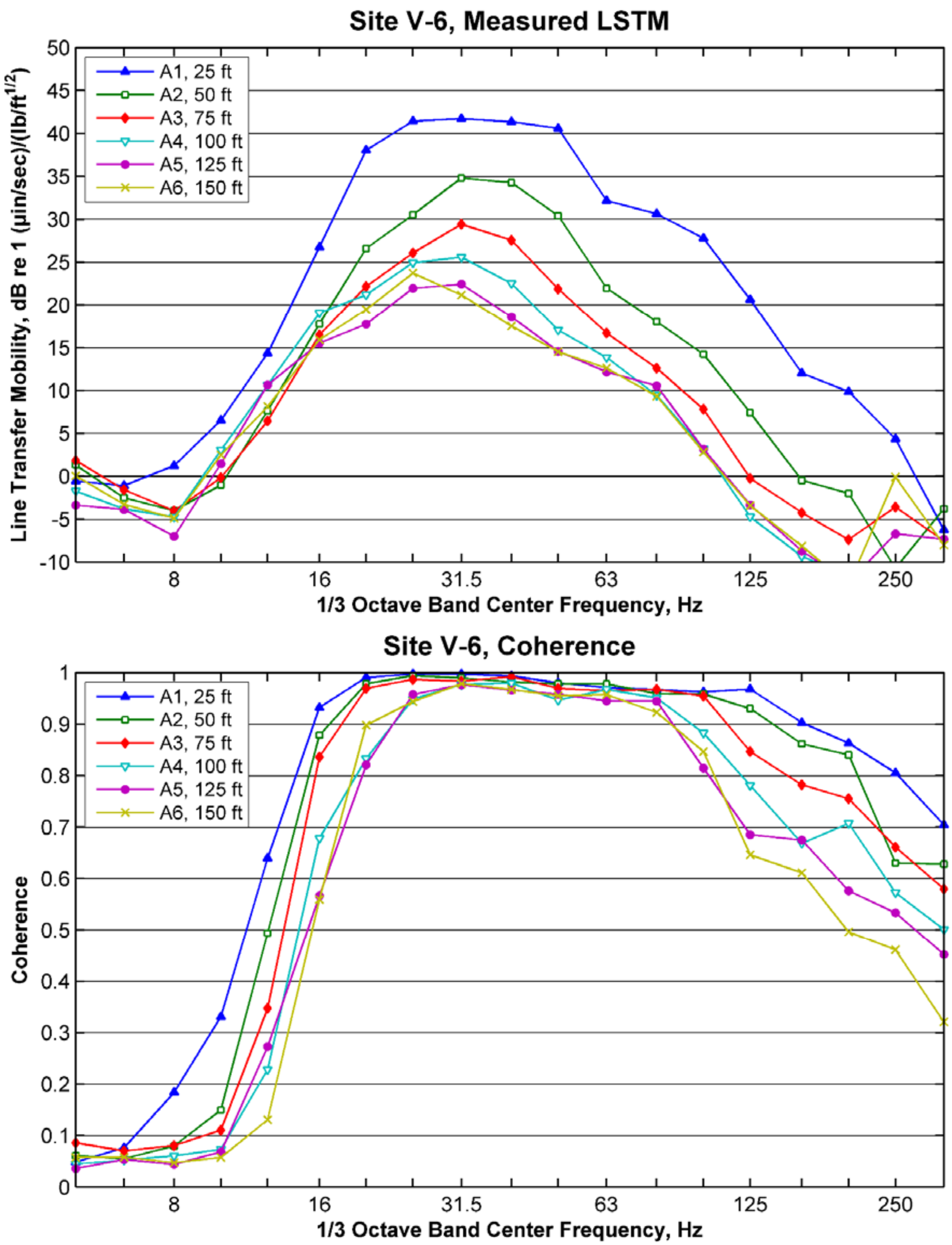


EXHIBIT 3-9
Measured LSTM and Coherence at Test Site V-6

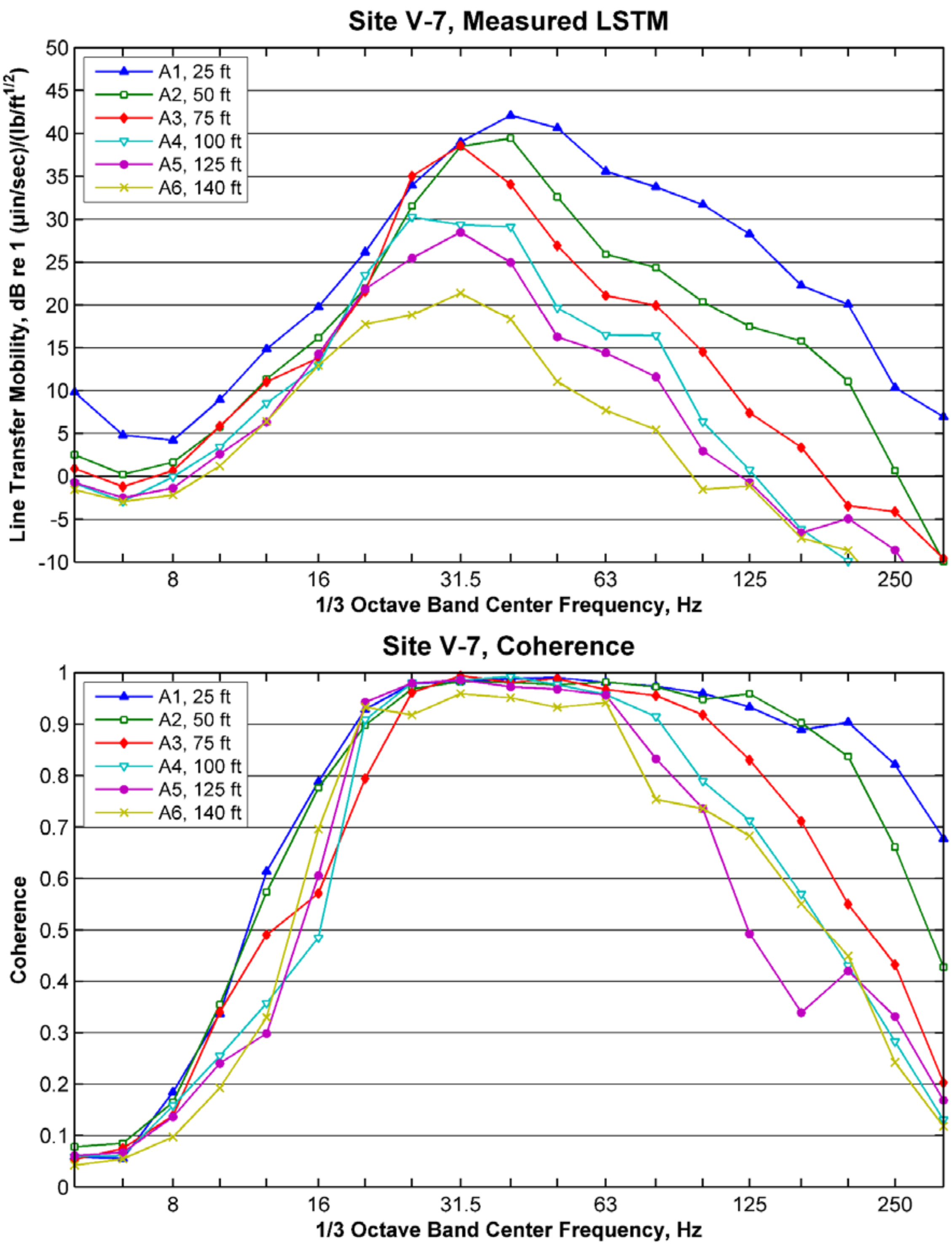


EXHIBIT 3-10
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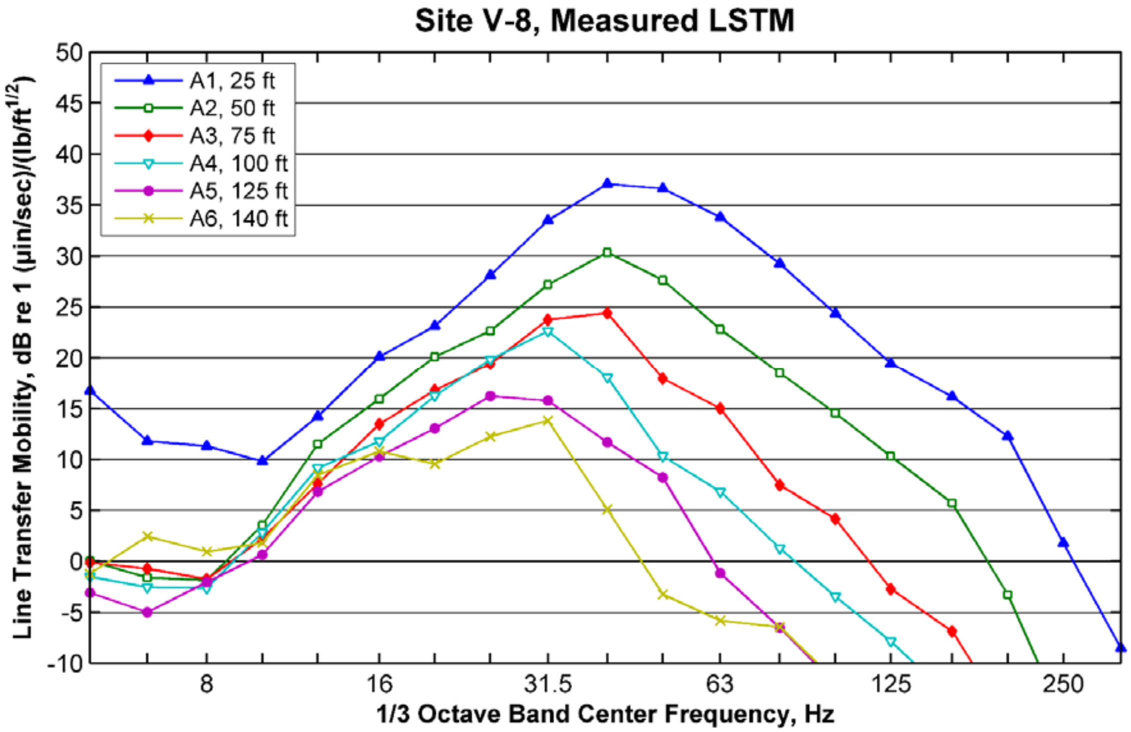


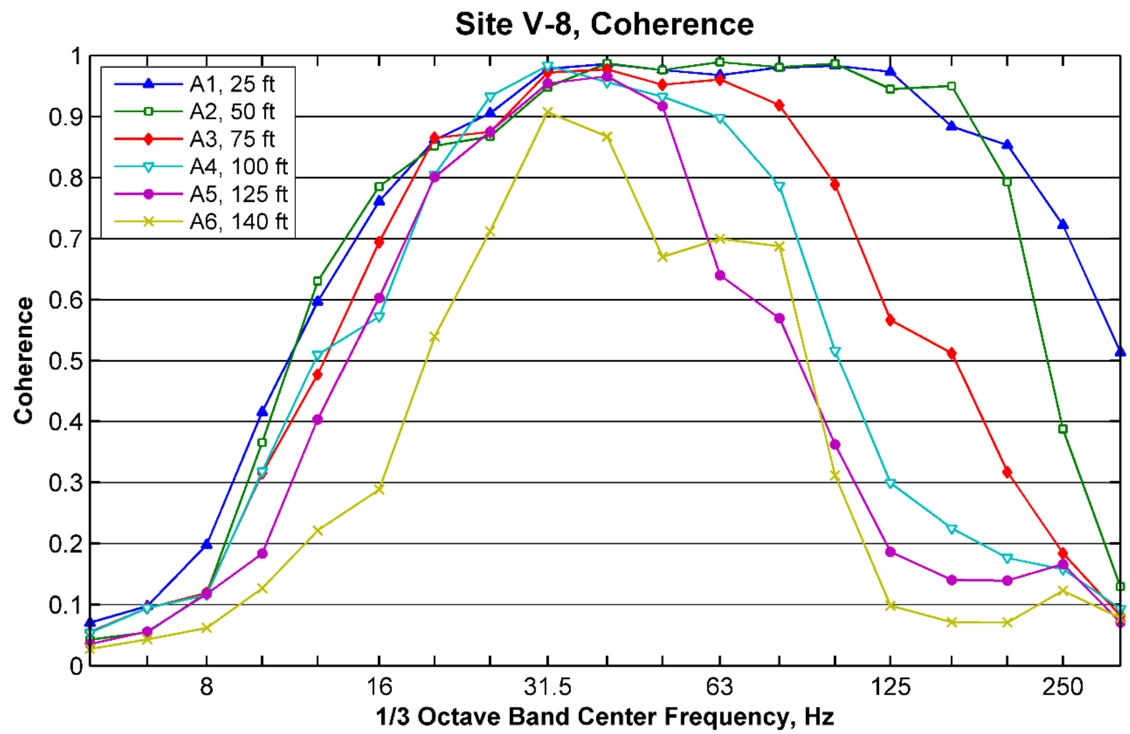
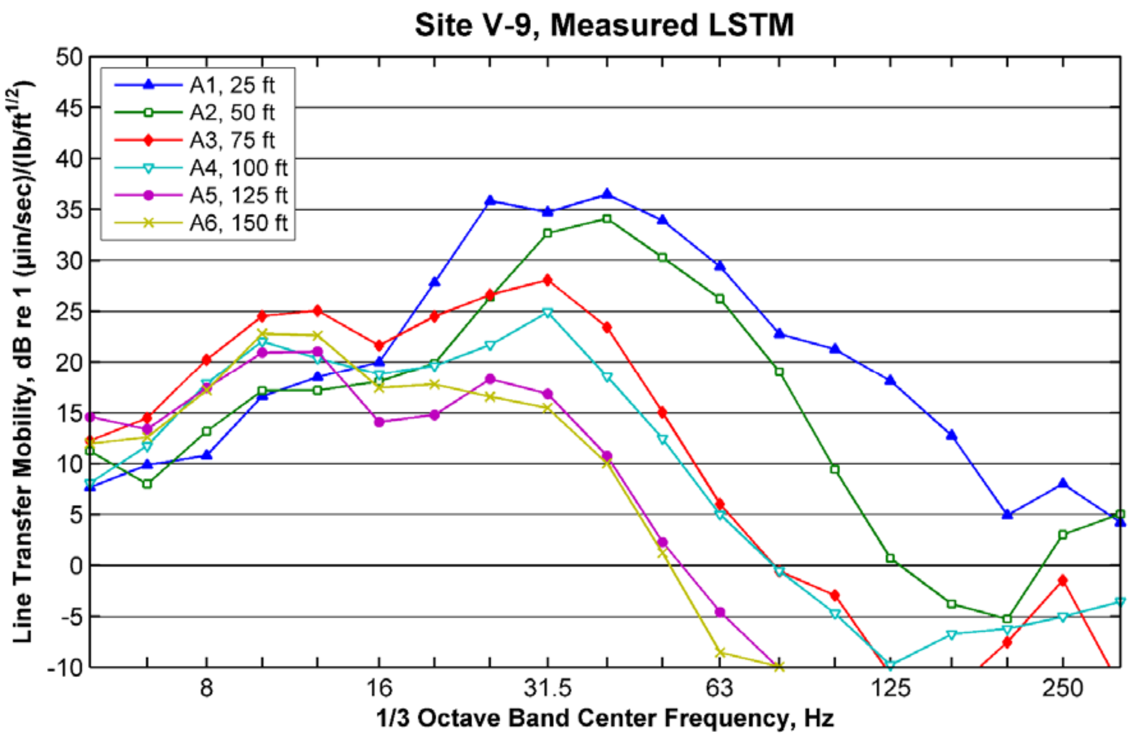


EXHIBIT 3-11
Measured LSTM and Coherence at Test Site V-8



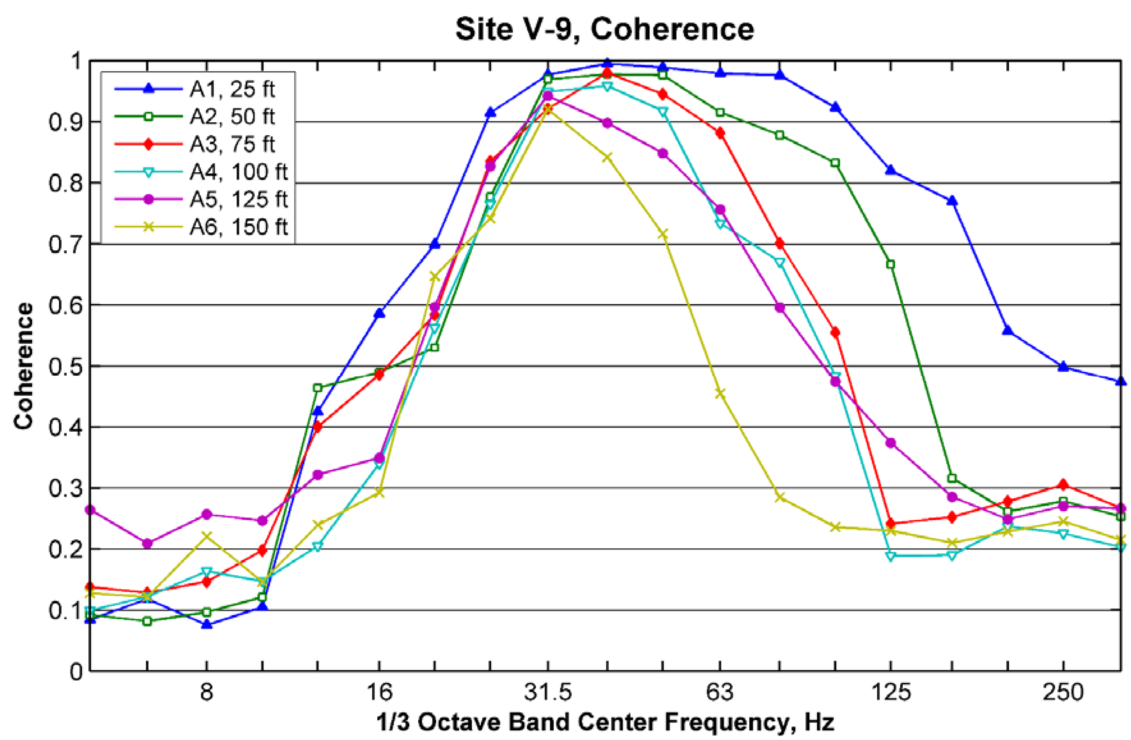
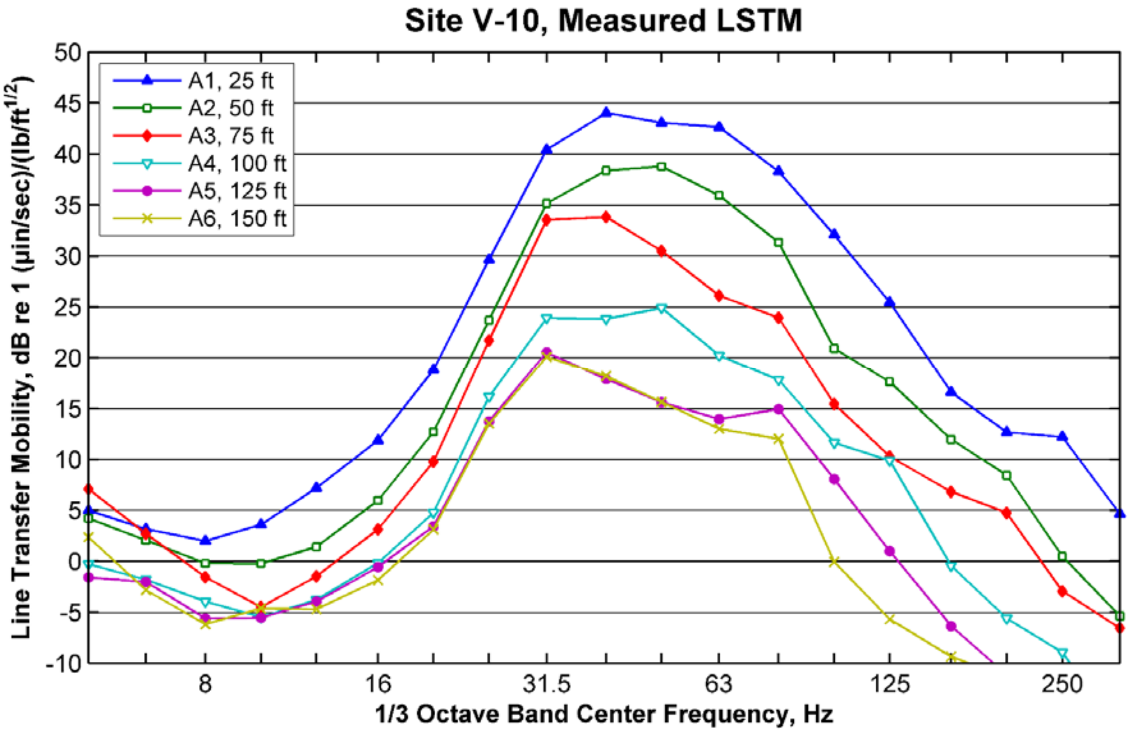


EXHIBIT 3-12
Measured LSTM and Coherence at Test Site V-9



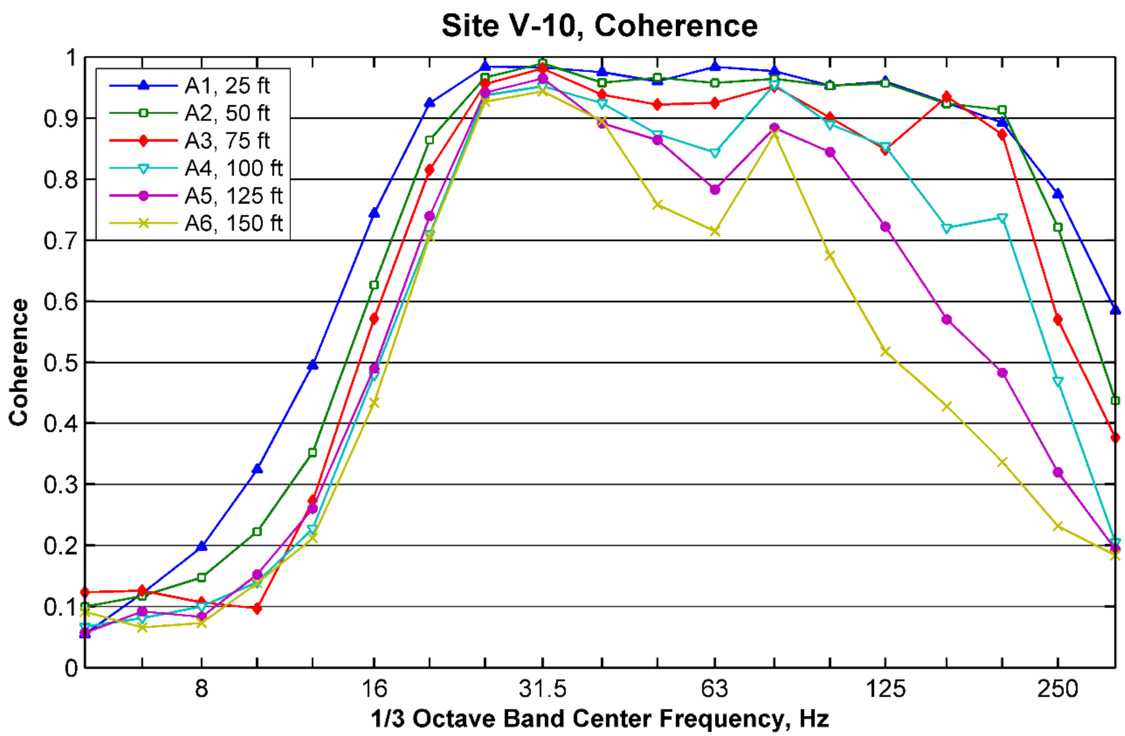


EXHIBIT 3-13
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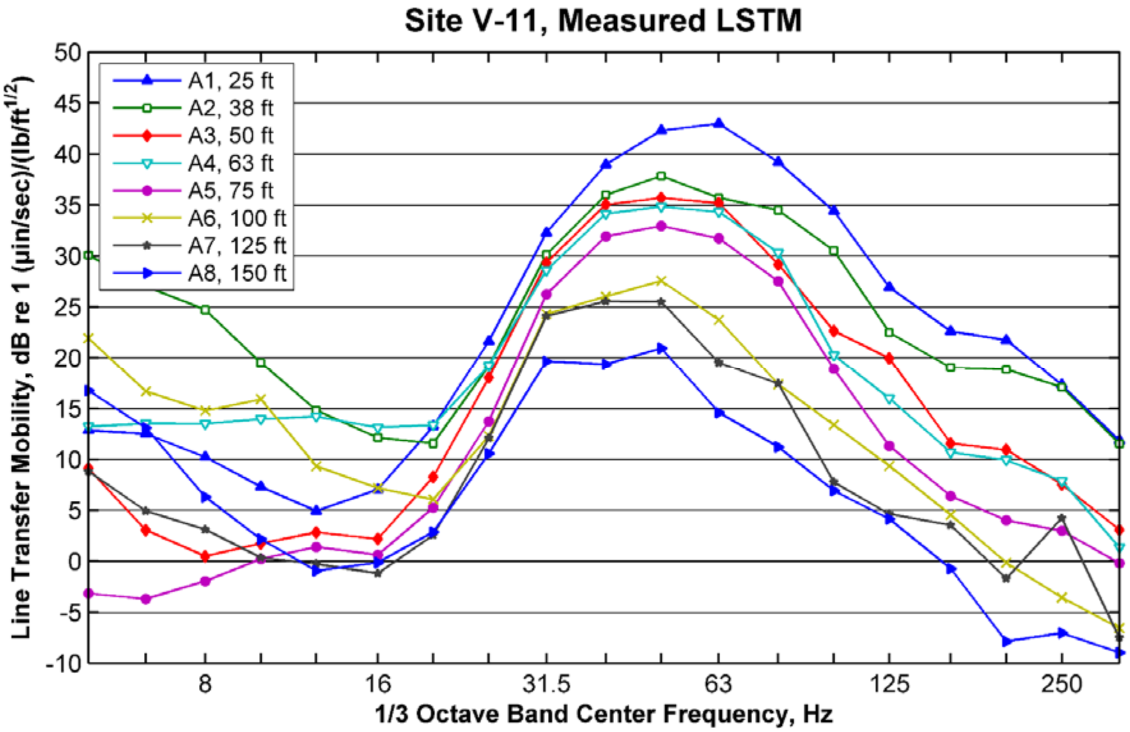

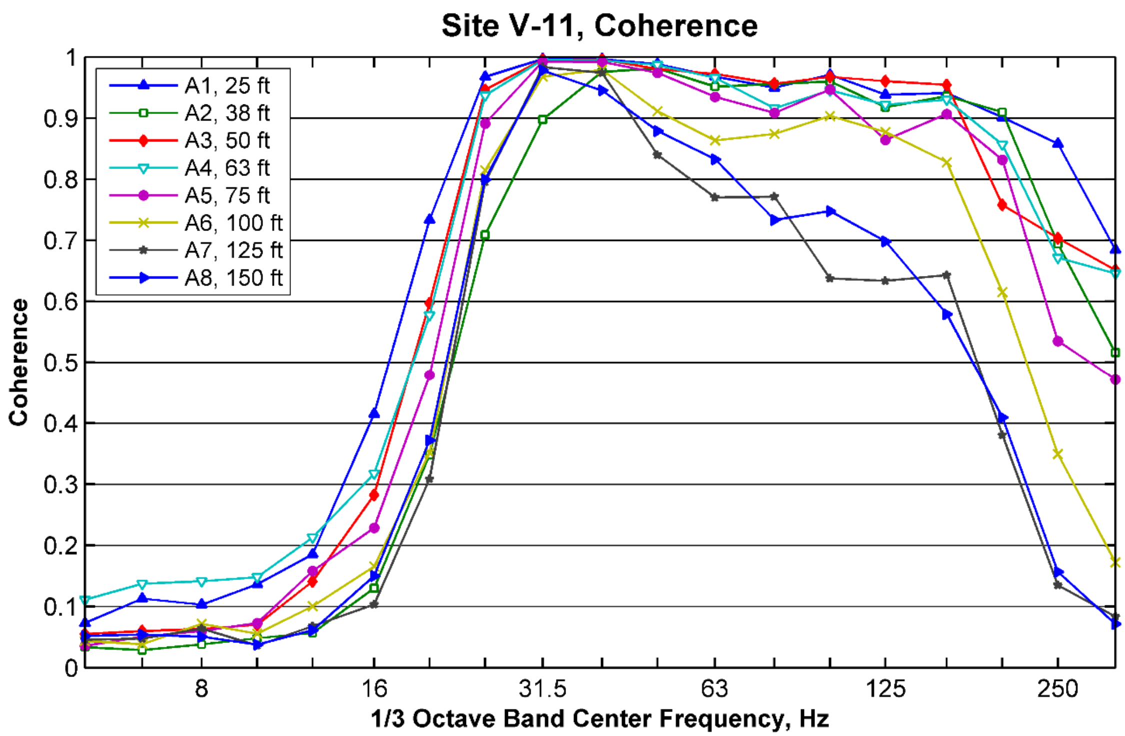

EXHIBIT 3-14
Measured LSTM and Coherence at Test Site V-11

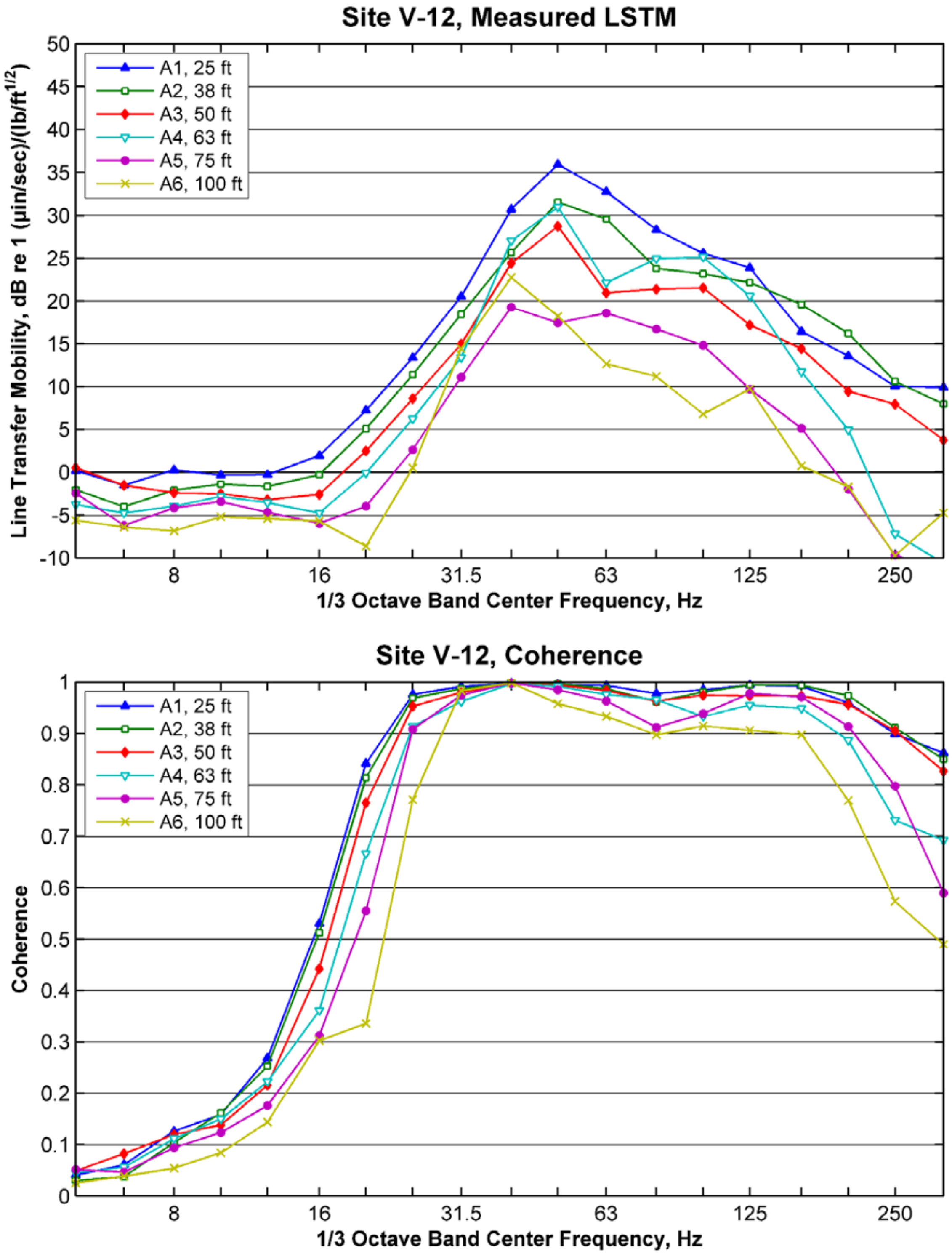

EXHIBIT 3-15
Measured LSTM and Coherence at Test Site V-12

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4.0 Noise and Vibration Impact Criteria

4.1 Noise Impact Criteria

The operation of a light rail system can cause noise that becomes a major public concern. Noise impacts can be caused by either transit operations (e.g., light rail operational noise, warning bells, ancillary facilities, and buses and park-and-ride lots at transit centers) or changes in traffic resulting from a roadway being widened or realigned for the project. The potential for increased exposure to traffic noise was also evaluated for noise-sensitive land uses. This could result from the development of new or extended roadways in station areas, or from the removal of buildings, walls, or berms that currently provide shielding from traffic noise. Impact criteria exist for each source of noise. This section summarizes what defines a noise impact, as applicable to the FWLE.

4.1.1 Transit Noise Impact Criteria

Noise impacts for the FWLE are determined based on the criteria defined in the FTA Guidance Manual (FTA, 2006). The FTA noise impact criteria are founded on well-documented research on community reaction to noise and are based on changes in noise exposure rated using a sliding scale. Although more transit noise is allowed in neighborhoods with high levels of existing noise, as existing noise levels increase, smaller increases in total noise exposure are allowed than in areas with lower existing noise levels. The FTA noise impact criteria group noise-sensitive land uses into the following three categories:

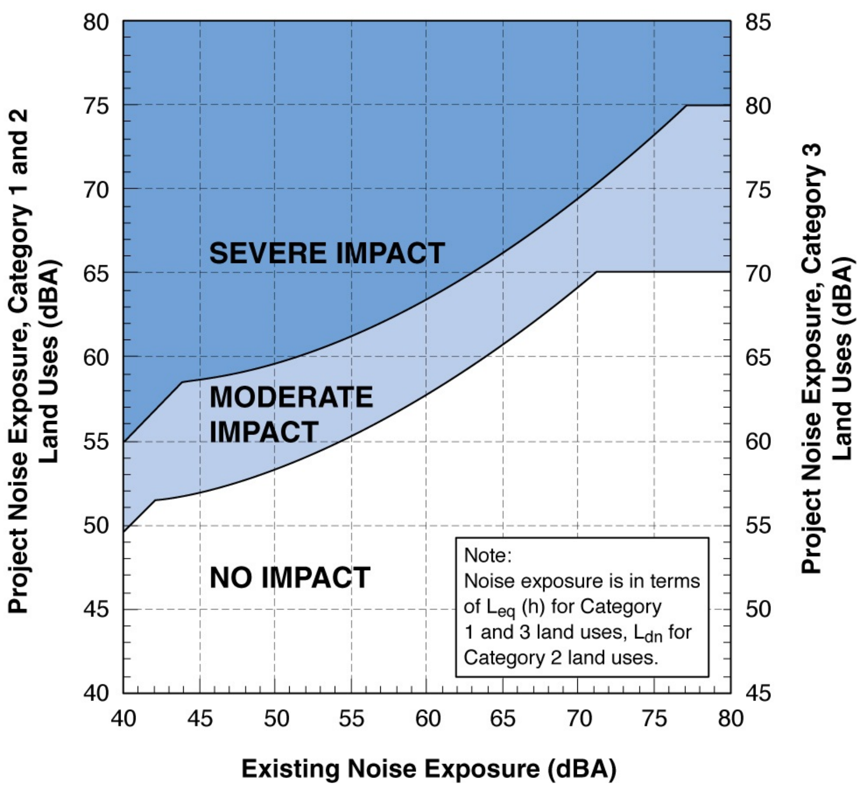
- **Category 1**: Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use. Also included in this category are recording studios and concert halls.
- **Category 2**: Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
- **Category 3**: Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, theaters, and churches where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material. Places for meditation or study associated with cemeteries, monuments, museums, campgrounds, and recreational facilities are also considered to be in this category. Certain historical sites and parks are also included, but their sensitivity to noise must be related to their defining characteristics, and generally parks with active recreational facilities are not considered noise-sensitive.

Ldn is used to characterize noise exposure for residential areas (Category 2). For other noise-sensitive land uses, such as outdoor amphitheaters and school buildings (Categories 1 and 3), the maximum 1-hour Leq during the facility's operating period is used.

The two levels of impact included in the FTA criteria (severe and moderate) are as follows:

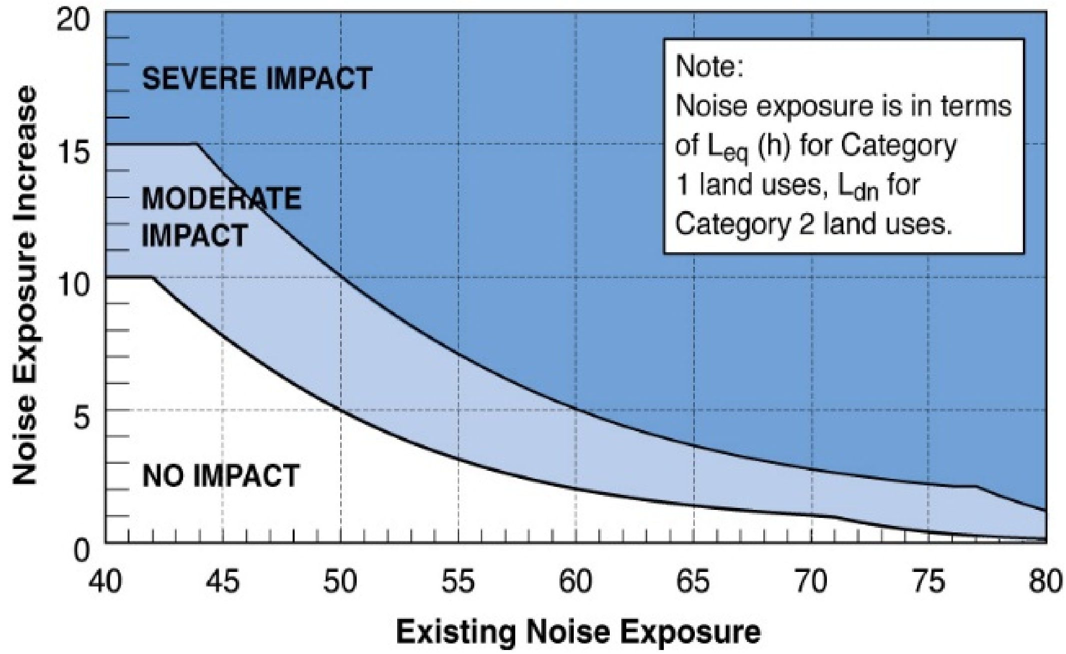
- **Severe Impact**: Project-generated noise in the severe impact range can be expected to cause a large percentage of people to be highly annoyed by the new noise and represents the most compelling need for mitigation. Noise mitigation will normally be specified for severe impact areas unless there are truly extenuating circumstances that prevent mitigation.
- **Moderate Impact**: In this range of noise impact, the change in the cumulative noise level is noticeable to most people but may not be sufficient to cause strong, adverse reactions from the community. In this transitional area, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These factors include the existing level, the projected level of increase over existing noise levels, the types and numbers of noise-sensitive land uses affected, the noise sensitivity of the properties, the effectiveness of the mitigation measures, community views, and the cost of mitigating noise to more acceptable levels.

The FTA noise impact criteria are summarized in graphical form on Exhibit 4-1, which shows the existing noise exposure and the allowable noise exposure from a transit project that would cause either moderate or severe impact. The future noise exposure, which is not shown in the exhibit, would be the combination of the existing noise exposure and the additional noise exposure caused by the light rail project. Exhibit 4-2 expresses the same criteria in terms of the increase in total or cumulative noise that can occur in the overall noise environment before an impact occurs. As shown on Exhibit 4-2, as existing noise exposure increases, an increasingly smaller increase in noise is permitted before an impact occurs. Table 4-1 provides the FTA noise impact criteria in tabular format.



Source: FTA, 2006.

EXHIBIT 4-1
FTA Project Noise Impact Criteria



Source: FTA, 2006.

EXHIBIT 4-2
Increase in Cumulative Noise Exposure Allowed by FTA Criteria

TABLE 4-1
FTA Noise Impact Criteria

Existing Noise Exposure Ldn or Leq[a]	Project Noise Exposure Impact Thresholds, Ldn or Leq[a] (all noise levels are in dBA)[b]			
	Category 1 or 2 Sites		Category 3 Sites	
	Impact	Severe Impact	Impact	Severe Impact
<43	Ambient + 10	> Ambient + 15	Ambient + 15	> Ambient + 20
43-44	52 – 58	>58	57 – 63	>63
45	52 – 58	>58	57 – 63	>63
46-47	53 – 59	>59	58 – 64	>64
48	53 – 59	>59	58 – 64	>64
49-50	54 – 59	>59	59 – 64	>64
51	54 – 60	>60	59 – 65	>65
52-53	55 – 60	>60	60 – 65	>65
54	55 – 61	>61	60 – 66	>66
55	56 – 61	>61	61 – 66	>66
56	56 – 62	>62	61 – 67	>67
57-58	57 – 62	>62	62 – 67	>67
59-60	58 – 63	>63	63 – 68	>68
61-62	59 – 64	>64	64 – 69	>69
63	60 – 65	>65	65 – 70	>70
64	61 – 65	>65	66 – 70	>70
65	61 – 66	>66	66 – 71	>71
66	62 – 67	>67	67 – 72	>72

TABLE 4-1
FTA Noise Impact Criteria

Existing Noise Exposure Ldn or Leq[a]	Project Noise Exposure Impact Thresholds, Ldn or Leq[a] (all noise levels are in dBA)[b]			
	Category 1 or 2 Sites		Category 3 Sites	
	Impact	Severe Impact	Impact	Severe Impact
67	63 – 67	>67	68 – 72	>72
68	63 – 68	>68	68 – 73	>73
69	64 – 69	>69	69 – 74	>74
70	65 – 69	>69	70 – 74	>74
71	66 – 70	>70	71 – 75	>75
72-73	66 – 71	>71	71 – 76	>76
74	66 – 72	>72	71 – 77	>77
75	66 – 73	>73	71 – 78	>78
76-77	66 – 74	>74	71 – 79	>79
>77	66 – 75	>75	71 – 80	>80

Source: FTA, 2006.
[a] Ldn is used for land uses where nighttime sensitivity is a factor; peak-hour Leq is used for land use involving only daytime activities. Severe impacts only occur if the predicted levels exceed (>) the values in the appropriate column.
[b] Category Definitions:
Category 1: Buildings or parks where quiet is an essential element of their purpose.
Category 2: Residences and buildings where people normally sleep. This includes residences, hospitals, and hotels where nighttime sensitivity is assumed to be of utmost importance.
Category 3: Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches.

The FTA Guidance Manual provides details on how parks are analyzed for noise in Chapter 3, Section 2, Application of Noise Impact Criteria, of the manual. The FTA assumes that parks are a special case, and how they are used and where they are located should be considered when considering whether or not a particular park, or an area in a park, is considered noise-sensitive. Parks that are used for outdoor recreation are typically not considered noise-sensitive. This includes parks with baseball diamonds, soccer fields, basketball courts, football fields, and other active recreation areas.

Parks that are noise-sensitive would be those where quiet is an essential element in their intended purpose or places where it is important to avoid interference with activities such as speech, meditation, and reading. The existing noise levels at a park can provide some indication of the sensitivity of its use. All parks along the FWLE corridor were evaluated for consideration under the FTA criteria, and based on the park locations and existing noise levels, none met the requirements for noise sensitivity under the FTA Category 3 criteria.

4.1.2 Traffic Noise Impact Criteria

Criteria for traffic noise impacts are from the FHWA Procedures for Abatement of Highway Traffic Noise and Construction Noise, *Code of Federal Regulations* (CFR) Title 23, Subchapter H, Section 772 (1982). A traffic noise impact occurs if predicted traffic noise levels approach the criteria levels for specific land use categories or substantially exceed existing noise levels (e.g., a 10-dbA increase). These levels are defined as noise abatement criteria (NAC), and are based on hourly Leq levels for the peak hour of traffic noise. The land use of greatest concern in the FWLE corridor would be Type B, which includes residences, motels, hotels, playgrounds, active sports areas, parks, schools, churches, libraries, and hospitals. The noise abatement criterion used to determine impacts on this land use is 67 dBA. Under WSDOT policy, a traffic noise impact occurs if predicted noise levels are within 1 dB of the NAC. Therefore, an impact on Type B land uses would occur at 66 dBA.

4.1.3 State Regulations and Local Noise Ordinances

Project operation and construction would take place in the cities of SeaTac, Des Moines, Kent, and Federal Way, all of which are in King County. Each of these cities has their own local noise ordinances that would be applicable to the FWLE.

The other codes evaluated for this project include the WAC noise control regulation. WAC Chapter 173-60, Maximum Environmental Noise Levels, establishes maximum noise levels permissible in identified environments, including residential, commercial, industrial, and construction areas. However, WAC 173-60-110 provides that:

> The department conceives the function of noise abatement and control to be primarily the role of local government and intends actively to encourage local government to adopt measures for noise abatement and control. Wherever such measures are made effective and are being actively enforced, the department does not intend to engage directly in enforcement activities.

Hence, the rules governing noise levels that are contained in WAC Chapter 173-60 do not apply when a local noise ordinance is in effect. Therefore, the various local noise ordinances would be applicable to the operation of FWLE ancillary facilities and project construction. Since several of the cities in which project operations and construction would occur have adopted portions of the WAC for purposes of their own noise ordinances, those WAC regulations are described below.

4.1.3.1 WAC Stationary Land Use Noise Criteria

For stationary land uses with noises originating from outside public roadways and rights-of-way, WAC Chapter 173-60 (Maximum Environmental Noise Levels) establishes three classes of property usage, called Environmental Designation for Noise Abatement (EDNA), and maximum allowable noise levels for each, as shown in Table 4-2.

TABLE 4-2
Washington State Noise Control Ordinance

EDNA Source of Noise	EDNA Receiver of Noise (Maximum Allowable Sound Level in dBA[a])		
	Residential	Commercial	Industrial
Residential	55	57	60
Commercial	57	60	65
Industrial	60	65	70

Source: WAC, Chapter 173-60.
[a] Between 10:00 p.m. and 7:00 am, the levels given above are reduced by 10 dBA for residential receiving property.

For example, the noise caused by a commercial property must be less than 57 dBA at the closest residential property line. From 10:00 p.m. to 7:00 a.m., the allowable maximum sound levels shown in Table 4-2 are reduced by 10 dBA at such a residential property line. The WAC contains short-term exemptions to the property line noise standards in Table 4-2 based on the minutes per hour that the noise limit is exceeded. These exceedances are outlined in Table 4-3.

TABLE 4-3
Washington State Exemptions for Short-Term Noise Exceedances

Minutes Per Hour	Adjustment to Maximum Sound Level
15	+5 dBA
5	+10 dBA
1.5	+15 dBA

Source: WAC, Chapter 173-60.

4.1.3.2 WAC Construction Noise Criteria

Generally, construction activities can be performed within the limits of the WAC regulations if the work is conducted during normal daytime hours (7:00 a.m. to 10:00 p.m.). If construction is performed during the nighttime, the contractor must still meet the WAC noise-level requirements presented in Table 4-2 or get a noise variance from the governing jurisdiction.

The WAC also contains a set of construction-specific allowable noise-level limits. These construction noise regulations are organized by type of noise and include general construction equipment; impulse equipment, such as jackhammers and pile-drivers; haul trucks; and safety alarms, such as back-up beepers.

Haul Truck Noise Criteria

Maximum permissible sound levels for haul trucks on public roadways are limited to 86 dBA for speeds of 35 miles per hour (mph) or less, and 90 dBA for speeds over 35 mph when measured at 50 feet (WAC, Chapter 173-62). For trucks operating within staging areas, the general construction equipment noise criteria would be used to determine compliance.

Noise Related to Back-up Alarms

Sounds created by back-up alarms are exempt from the allowable noise-level limits, except between 10:00 p.m. and 7:00 a.m. when “beep-beep” back-up alarms are essentially prohibited by the WAC in urban areas. During nighttime hours, other forms of back-up safety measures would need to be used and could include the use of smart back-up alarms, which automatically adjust the alarm level based on the background level, or switching off back-up alarms and replacing them with spotters. This criterion is included because, just like noise from construction activities, noise from back-up beepers would exceed the WAC nighttime criteria, even with the allowable exceedance, at distances up to 800 feet or more from the construction site.

4.1.3.3 City of SeaTac

The City of SeaTac Code does not expressly incorporate or refer to the state noise regulations in WAC Chapter 173-60; however, unlike the municipal codes of the other three cities in which the FWLE will be constructed and will operate, the SeaTac Code includes noise regulations that are specific to Sound Transit's operations.

SeaTac Municipal Code, Chapter 8.05.360 Noise

Chapter 8.05.360, the noise chapter of the SeaTac Criminal Code, prohibits public disturbance noises, such as frequent, repetitive, or continuous sounds in connection with motor vehicles, yelling, sound systems, and other noise sources that could cause public disturbances. This chapter states that sounds originating from construction sites are public disturbance noises between the hours of 10:00 p.m. and 7:00 a.m. on weekdays and 10:00 p.m. and 9:00 a.m. on weekends.

SeaTac Municipal Code, Chapter 13.240, Sound Transmission Code

This code, adopted in 1993 and updated in 2004, requires that all buildings constructed within the vicinity of the Sea-Tac Airport meet required noise reduction characteristics in order to protect the health and welfare of the public in certain nearby areas or zones. Portions of the FWLE corridor lie within these zones, but no such buildings will be constructed in connection with the FWLE.

SeaTac Municipal Code, Chapter 15.36 Design Standards for High Capacity Facilities

The purpose of Chapter 15.36 of the SeaTac Municipal Code is to provide the following design considerations when designing and constructing high-capacity transit (HCT) facilities in the City of SeaTac:

- Facilities and stations that are well designed
- Development of distinctive community focal points
- Connections between the HCT network, adjacent development, and community vehicular, pedestrian, and bicycle routes
- Adequate buffers between different types of land uses
- Use of alternative travel modes to single-occupant vehicles

Most of this section of the SeaTac Municipal Code has to do with actual design and the look and feel of any proposed HCT facilities. There are sections describing station design, elevated structures, and pedestrian crossings along with 26 other design criteria, most of which are not applicable to this noise study. In fact, the only direct consideration of noise is contained in Section 15.36.220, Buffering of Track Corridor. The light rail noise suppression section states that light rail vehicles and associated track shall utilize the best available noise suppression technology in order to minimize adverse impacts on adjacent properties. Sound Transit's track and fleet of light rail vehicles meets this requirement.

4.1.3.4 City of Des Moines

In Section 7.16.010 of its Municipal Code, the City of Des Moines has adopted WAC Chapters 173-60-020, 173-60-030, 173-60-040, 173-60-050, and 173-60-080, which contain the maximum permissible environmental noise level requirements discussed in Section 4.1.3.1 of this report. Hence, those chapters regulate noise that relates to construction of the FWLE in the city of Des Moines, as well as to ancillary equipment and facilities, such as park-and-ride lots and traction-power substations, in the same manner as the WAC. Because the daytime exemption for noise from construction activities found in WAC Section 173-60-050 has been specifically adopted by the City of Des Moines, most project construction can be performed within the limits of the City ordinance if the work is conducted during normal daytime hours (7:00 a.m. to 10:00 p.m.). If construction is performed during the nighttime, the contractor must still meet the WAC noise level criteria presented in Table 4-2 or get a noise variance from the City of Des Moines. The City has adopted WAC 173-60-080, which includes State criteria for a noise variance.

The City of Des Moines also forbids “Specific public disturbance noises,” the definition of which includes “frequent, repetitive, or continuous sounds that emanate from a structure that unreasonably disturbs or interferes with peace and comfort of the owners or possessors of real property…” (City of Des Moines Municipal Code Chapter 7.36).

Lastly, the City of Des Moines limits the generation of exterior noise levels in residentially zoned areas, at parks of local significance, and at historic or archaeological properties of local significance, to 55 dBA Ldn, or existing levels as of April 20, 1995, whichever is greater. For various kinds of sports areas, such as golf courses and ball fields, the limit is 60 dBA. Proponents of projects that would increase exterior noise levels beyond these limits must submit a noise mitigation plan to the community development department of the City for review and approval before required permits are issued to allow the project to proceed (City of Des Moines Municipal Code Chapter 18.38).

4.1.3.5 City of Kent

The City of Kent has maximum permissible environmental noise level requirements that are similar to those contained in the WAC (Kent Municipal Code Chapter 8.05). The City does not explicitly exempt noise generated by daytime construction activities from Chapter 8.05, but in Section 9.02.200 of the City’s criminal code regarding public disturbances, the City exempts noise from construction sites at all times in commercial areas that are not adjacent to residential areas and from 7:00 a.m. until 8:00 p.m. in all other areas. In addition, in the answers section of the Kent Code Enforcement Frequently Asked Questions web page, it states that construction is allowed between 7:00 a.m. and 10:00 p.m. seven days a week.

Sounds created by warning devices not operating continuously for more than 5 minutes, or by bells, chimes, and carillons, are entirely exempt from the City of Kent’s environmental noise level requirements (City of Kent Municipal Code Section 8.05.140(4)).

4.1.3.6 City of Federal Way

In Section 7.10.050 of its Code, the City of Federal Way adopts by reference the maximum environmental noise levels set forth in the State rules, including those in WAC Chapter 173-60. In addition, in Section 7.10.020, the City forbids public disturbance noises, including “frequent, repetitive or continuous sounds which emanate from any building, structure… which unreasonably disturbs or interferes with the peace and comfort of owners or possessors of real property,” but the City excludes from this prohibition sounds originating from construction sites and activities between 7:00 a.m. and 10:00 p.m. on weekdays and 9:00 a.m. and 8:00 p.m. on weekends. Warning horns or sirens attached to motor vehicles are also exempt. (City of Federal Way Revised Code Section 7.10.020(1)).

4.2 Groundborne Noise and Vibration Criteria

4.2.1 Transit Vibration and Groundborne Noise Criteria

Potential effects of rail transit groundborne vibration include perceptible building vibration, rattle noises, reradiated noise (groundborne noise), and cosmetic or structural damage to buildings. The vibration caused by light rail operations is well below what is considered necessary to cause even minor cosmetic damage to buildings. Therefore, the criteria for building vibration caused by transit operations are only concerned with potential annoyance of building occupants.

The FTA vibration impact criteria are based on the maximum indoor vibration level as a train passes. There are no impact criteria for outdoor spaces such as parks. The FTA Guidance Manual provides two sets of criteria: one based on the overall vibration velocity level for use in a General Vibration Impact Assessment and one based on the maximum vibration level in any 1/3 octave band (the band maximum level) for use with a Detailed Vibration Assessment, which was used for this analysis.

Table 4-4 shows the FTA General Assessment criteria for groundborne vibration from rail transit systems. As with the FTA noise criteria, there are three categories of sensitive land uses. However, the category definitions are different for noise and for vibration. The primary difference is in Category 1. For a noise assessment, Category 1 applies to land uses "…where quiet is an essential element of their intended purpose." For a vibration assessment, Category 1 applies to "buildings where vibration would interfere with interior operations...," which primarily applies to spaces that house sensitive research and laboratory equipment such as scanning electron microscopes. There are no buildings in the FWLE corridor that qualify as Category 1 vibration-sensitive land uses.

TABLE 4-4
FTA Impact Thresholds for Groundborne Vibration, General Impact Assessment

Land Use Category	Groundborne Vibration, VdB re 1 micro inch/sec			Groundborne Noise[a], dB re 20 micro Pascals		
	Frequent Events[b]	Occasional Events[c]	Infrequent Events[d]	Frequent Events[b]	Occasional Events[c]	Infrequent Events[d]
Category 1: Buildings where vibration would interfere with interior operations. Typically land uses include vibration-sensitive research and manufacturing, hospitals with vibration-sensitive equipment, and university research operations.	65	85	65	N/A[e]	N/A[e]	N/A[e]
Category 2: Residences and buildings where people normally sleep.	72	75	80	35	38	43
Category 3: Institutional land uses with primarily daytime uses.	75	78	83	40	43	48

Source: FTA, 2006.
Notes:
[a] For surface transit systems that are at-grade, on elevated structure, or in a trench, groundborne noise criteria are not applied to any of the three categories. However, the groundborne noise criteria is applied to special buildings such as concert halls and performing arts center.
[b] Frequent events are defined as more than 70 vibration events per day.
[c] Occasional events are defined as between 30 and 70 vibration events per day.
[d] Infrequent events are defined as less than 30 vibration events per day.
[e] Vibration-sensitive equipment is not sensitive to groundborne noise.
re = reference; micro-inch/sec = micro-inch per second; N/A = not applicable; VdB = vibration decibels

Unlike the FTA noise criteria, the vibration criteria do not incorporate any factor to account for the number of trains per day, with two exceptions: For "occasional service," the FTA impact thresholds are 3 VdB higher than for "frequent service," and for "infrequent service," the FTA impact thresholds are 8 VdB higher than for frequent service. FTA defines occasional service to be between 30 and 70 trains per day and infrequent service to be less than 30 trains per day. The frequent criteria are applicable to the FWLE because there would be more than 70 trains per day passing by any one location.

The FTA vibration thresholds do not specifically account for existing vibration. Although roadways in the study area, especially SR 99 and I-5, have substantial volumes of vehicular traffic, including buses and trucks, it is relatively rare that rubber-tired vehicles generate perceptible ground vibration unless there are irregularities in the roadway surface such as potholes or wide expansion joints.

The refined criteria for use with a Detailed Vibration Assessment are shown on Exhibit 4-4. For the detailed assessment, the predicted vibration levels in terms of the 1/3 octave band spectra are compared to the curves shown on Exhibit 4-4 to determine whether there would be impacts and the frequency range over which vibration mitigation would be required. An impact occurs when any spectral values exceed the applicable curve. The FTA interpretation of how each of the curves shown on Exhibit 4-4 should be applied is given in Table 4-5. The VC-A through VC-E curves are used to specify acceptable vibration limits for sensitive equipment, such as electron microscopes. Which curve to use depends on the sensitivity of the specific equipment that would be affected. With the exception of a few particularly sensitive pieces of equipment such as transmission electron microscopes or atomic force microscopes, the VC-C curve is adequate to avoid interfering with the operation of most sensitive equipment.

The use of the Detailed Vibration Assessment criteria is illustrated by the example vibration spectrum (the blue dashed line) shown on Exhibit 4-4. The maximum level of the vibration spectrum exceeds the "residential (night)" curve in the 50- and 63-Hz 1/3 octave bands. For this example, impact would be predicted for residential land uses and vibration mitigation would need to be evaluated, even though all of the 1/3 octave band levels fall below the "residential (day)" curve. Typical sensitive equipment and their appropriate VC-curves are listed in Table 4-5. Note that the FTA Guidance Manual does not provide a Detailed Vibration Assessment criterion for institutional land uses. However, where the General Assessment threshold is exceeded and the predicted vibration spectrum is available, it is reasonable to apply the residential (day) curve of the Detailed Vibration Assessment criteria to assess impacts. Because institutional land uses are used primarily during the day and the vibration level for annoyance would not be more stringent than residential land uses, this is a valid approach.

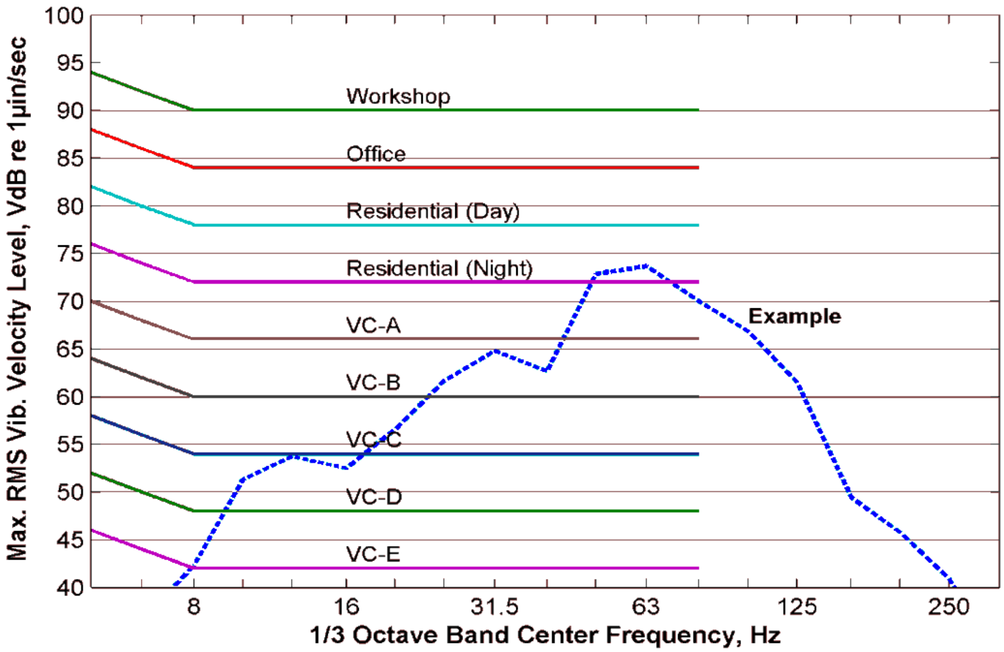


EXHIBIT 4-4
FTA Criteria for Detailed Vibration Assessment

TABLE 4-5
Interpretation of Vibration Criteria for Detailed Analysis

Criterion Curves	Maximum Level	Description of Uses
Workshop	90	Distinctly feelable vibration. Appropriate to workshops and non-sensitive areas.
Office	84	Feelable vibration. Appropriate to offices and non-sensitive areas.
Residential Day	78	Barely feelable vibration. Adequate for computer equipment and low-power optical microscopes (up to 20X).
Residential Night, Operating Rooms	72	Vibration not feelable, but groundborne noise may be audible inside quiet rooms. Suitable for medium-power optical microscope (100X) and other equipment of low sensitivity.
VC-A	66	Adequate for medium- to high-power optical microscopes (400X), microbalances, optical balances, and similar specialized equipment.
VC-B	60	Adequate for high-power optical microscopes (1,000X), inspection and lithography equipment to 3-micron line widths.
VC-C	54	Appropriate for most lithography and inspection equipment to 1-micron detail size.
VC-D	48	Suitable in most instances for the most demanding equipment, including electron microscopes operating to the limits of their capability.
VC-E	42	The most demanding criterion for extremely vibration-sensitive equipment.

Source: FTA, 2006.
[a] Maximum allowed vibration velocity in any 1/3 octave band over the range of 8 to 80 Hz.

The approach used for the FWLE vibration analysis is that the General Assessment criteria presented in Table 4-4 were used to identify potential vibration impacts. Then the Detailed Assessment criteria were applied to determine whether vibration mitigation would be warranted. The Detailed Vibration Assessment curve for the residential (day) was applied for institutional land uses and the residential (night) curve was used for residential land uses.

There are some buildings, such as concert halls, recording studios, and theaters, that can be very sensitive to vibration but do not fit into any of the three categories listed in Table 4-4 or can be associated with the curves on Exhibit 4-4. Because of the sensitivity of these buildings, they usually warrant special attention during the environmental evaluation of a transit project. Table 4-6 gives the FTA criteria for acceptable levels of groundborne vibration and groundborne noise for various categories of special buildings. The only special building in the FWLE corridor is the Performing Arts Center at the Federal Way High School property (under construction).

TABLE 4-6
Groundborne Noise and Vibration Impact Criteria for Special Buildings

Location	Groundborne Vibration Impact Levels (VdB re 1 micro-inch/sec)	Groundborne Noise Impact Levels (VdB re 1 micro-inch/sec)
Concert Halls	65	25
TV Studios	65	25
Recording Studios	65	25
Auditoriums	72	30
Theaters	72	35

Source: FTA, 2006.

4.2.2 Construction Vibration Criteria

Groundborne vibration related to human annoyance is generally related to root mean square vibration levels in VdB. Also, because of the short duration of construction vibration activities, annoyance often is not a serious issue. However, construction vibration, unlike vibration from train operations, has the potential to cause damage to structures at very close distances. Construction processes with the potential of causing structural damage include blasting (which would not be used for the FWLE), impact hammering, and pile-driving. Therefore, the primary concern regarding construction vibration relates to risk of damage. The potential risk of damage from construction vibration generally is assessed using peak particle velocity (PPV), which is the maximum vibration velocity amplitude generated by the construction activity. It is considered the appropriate metric for evaluating the potential for building damage because PPV is related to the stresses that are experienced by buildings.

The vibration damage risk thresholds for different building categories provided in the FTA Guidance Manual (FTA, 2006) are listed below:

- Reinforced concrete, steel, or timber: 0.5 inch per second (in./sec) PPV
- Engineered concrete and masonry: 0.3 in./sec PPV
- Nonengineered timber and masonry buildings: 0.2 in./sec PPV
- Buildings extremely susceptible to vibration damage: 0.12 in./sec PPV

The damage risk criterion of 0.5 in./sec PPV is appropriate for single- and multi-family residences along the FWLE alignment, and the criterion of 0.12 in./sec PPV is appropriate for extremely fragile buildings.

The thresholds for human annoyance due to construction vibration are the same as the General Assessment criteria applied for vibration from train operations. The following are the criteria to reduce potential for intrusive vibration at sensitive receivers:

- Annoyance to residential buildings during daytime: 0.022 in./sec PPV (75 VdB)
- Annoyance to daytime sensitive uses at residences and at schools, churches, and other institutional land uses: 0.016 in./sec PPV (72 VdB)

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5.0 Noise and Vibration Impact Analysis Assumptions and Methods

This section summarizes the models used to predict future noise and vibration levels for potential sources of community impacts related to the FWLE. These sources include light rail operation, changes in traffic related to the project, and construction activities.

5.1 Noise Assumptions and Methods

5.1.1 Operational Measures

This section describes the assessment approach for noise related to operating the light rail system. This includes noise from light rail operations, ancillary facilities, and wheel squeal. Sound Transit employs several operational measures to maintain low noise and vibration levels for its light rail trains. Table 5-1 lists operational and maintenance measures that Sound Transit performs on a regular basis and the benefit that each measure provides.

TABLE 5-1
System-wide Light Rail Operational and Maintenance Measures

Operational Measure	System Benefit
Rail grinding, maintenance, and replacement	As rails wear, both noise and vibration levels from light rail operations can increase. By grinding or replacing worn rails or correcting improper track alignment, noise and vibration levels will remain at the projected levels.
Wheel truing and replacement	Wheel truing is a method of grinding down flat spots (commonly called wheel flats) on the vehicle wheels. Flat spots occur primarily because of hard braking. When flat spots occur, they can cause increases in both the noise and vibration levels produced by the light rail vehicles.
Vehicle maintenance	Vehicle maintenance includes performing scheduled and general maintenance on items such as air conditioning units, bearings, wheel skirts, and other mechanical units on the light rail vehicles. Keeping the mechanical systems on the light rail vehicles in top condition will also help to maintain the projected levels of noise and vibration.
Operator training	Operators will be trained to operate light rail vehicles at the speeds given in the operation plan that was used for the analysis and to avoid “hard braking,” which can cause wheel flats and may also damage the track. Furthermore, by training operators to identify potential wheel flats and other mechanical problems with the light rail trains, proper maintenance can be performed in a timely manner.

5.1.2 Reference Light Rail Noise Levels

Sound Transit modeled noise from light rail operations using the methods described in the FTA Guidance Manual (FTA, 2006). Input to the model included measured reference noise levels for the new light rail vehicles that are currently being used on the Central Link light rail system. Reference measurements for light rail operations were taken along the ballast and tie (B&T) portion of the initial segment in south Seattle in March 2010. The measured reference noise level is 79 dBA Lmax for a single-car train traveling at 40 mph at a distance of 50 feet on B&T track.

The speeds used in this analysis are the track design speeds, and those are generally 55 mph throughout the project corridor, except on speed-limited curves and at stations. These speeds may be higher than actual speeds and assure a conservative noise impact analysis.

5.1.3 Alignment and Special Track Work

The plan and profile of the proposed light rail alignment, including the locations of special track work such as crossovers, and typical speeds were provided by the FWLE design engineers. The plan and profile drawings used are included in Appendix F, Conceptual Design Drawings, of the Draft EIS. The design information provided includes the elevation of the trackway, type of track (B&T, embedded, and direct-fixation [DF]) and the location and design of the station alternatives. The current design calls for B&T, embedded, and direct-fixation types of trackway.

Track crossovers are mechanical devices that enable light rail cars to be guided from one track to another at a junction point. Crossovers have a gap in the rails that is necessary for the flange of the light rail wheels to pass through at the location where the two tracks cross. As a wheel passes through the gap, there are increased noise and vibration levels. A frog is a rail-crossing structure that allows the train to cross over to another track or continue moving on the same track. A gap is provided on top of the frog so that vehicle wheels can pass regardless of which track is in use. According to the FTA Guidance Manual and measurements of the Central Link light rail system, standard frogs can increase noise levels by as much as 8 to 10 dB. Spring-rail frogs and movable-point frogs solve the added noise and vibration problem by closing the gap on the rails.

Flange-bearing frogs, another mitigation option, transfer the vehicle load from the wheel tread to the wheel flange and raise the light rail car up and over the gap, reducing noise and vibration levels. Each of these types of frogs produces noticeably lower noise levels than standard frogs. Depending on the type of crossover and angle between the crossover and mainline track, special frogs can reduce noise levels between 4 and 8 dBA compared to a standard frog.

Track Types

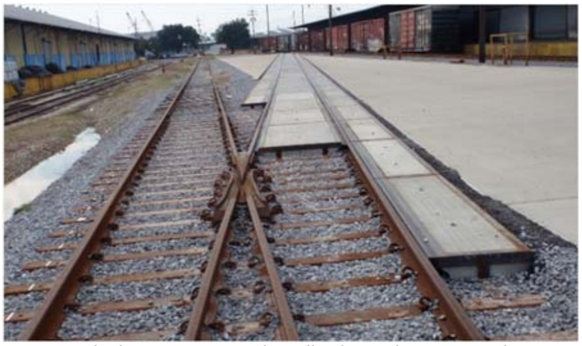
Continuously Welded Rail - Sound Transit uses continuously welded rail on all service tracks, preventing the noise and vibration common to butted rail installations.

Ballasted track - Ballasted track is a track structure consisting of rail, tie plates or fastenings, cross ties, and the ballast/subballast bed supported on a prepared subgrade. The subgrade may be a compacted embankment or fill section, an excavation or cut section, or a bridge structure. Ballasted track is generally the standard for light rail transit routes that are constructed on an exclusive right-of-way.

Direct-fixation track - DF track is a “ballastless” track structure in which the rail is mounted on DF fasteners that in turn are anchored to an underlying concrete slab. DF is generally the standard for light rail transit routes constructed on elevated structure. DF track is also used for construction of at-grade track under unusual circumstances, such as when there is a relatively short segment of at-grade track between two DF track structure decks.

Embedded track - Embedded track can be described as a track structure that is completely encased—except for the tops and gauge sides of the rails—within pavement. Embedded track is generally the standard for light rail transit routes constructed within public streets, pedestrian/ transit malls, or any area where rubber-tired traffic must operate.

(Source: Transportation Research Board, 2012)



Typical Crossover Tracks: Allowing trains to move from one trackway to another.

The type of frogs used for the FWLE would depend on the track type, crossover location, and proximity of noise-sensitive properties.

5.1.4 Light Rail Warning Bells

Sound Transit measured and validated train-mounted bells on light rail cars in October 2009, with several supplemental measurements in 2011 and 2012. Consistent with Sound Transit operating rules, this analysis assumes that train-mounted bells would be sounded twice as a train enters a station, and twice when the train leaves the station. The bells produce a maximum noise level of 80 dBA at 50 feet between 6:00 a.m. and 10:00 p.m. and are reduced to 72 dBA Lmax between 10:00 p.m. and 6:00 a.m. (although trains would not run between 1:00 a.m. and 5:00 a.m.).

5.1.5 Operational Plan

The Sound Transit operations schedule includes all other planned light rail expansions between now and 2030. The operations plan for this analysis reflects a future build-out of the regional light rail system established by the Sound Transit 2 (ST2) Plan (Sound Transit, 2008). This assumes light rail service is operating to Lynnwood Transit Center in the north and Overlake Transit Center in the east when FWLE is operational. Under this maximized future operational plan, the light rail trains would operate with four passenger cars during all periods of service.

The operating plan used in the analysis assumes four-car trains operating between 5:00 a.m. and 1:00 a.m. daily with the following headways:

- Peak (6:00 a.m. to 8:30 a.m. and 3:00 p.m. to 6:30 p.m.): 8-minute headways
- Midday and early evening (8:30 a.m. to 3:00 p.m. and 6:30 p.m. to 10:00 p.m.): 10-minute headways,
- Early morning and late evening (5:00 a.m. to 6:00 a.m. and 10:00 p.m. to 1:00 a.m.): 15-minute headways

Vehicle, track, and systems maintenance occurs between approximately 1:00 a.m. and 5:00 a.m. daily, outside of normal hours of light rail service. Based on preliminary operating plans, about two trains may be deployed between approximately 4:30 and 5:00 a.m. to stage trains for the beginning of morning service at FWLE stations. Similarly, about two trains may operate between approximately 1:00 and 1:30 a.m. along the FWLE as they return to the OMFs at the close of service each day.

5.1.6 Wheel Squeal and Wheel-Flanging Noise

Wheel squeal is caused by the oscillation of the wheel against the rail on curved sections of rail. Sound Transit measured wheel squeal noise levels at several different locations along the Central Link corridor and used these measurements as reference data. Based on these measurements, curves with radii of less than 600 feet can produce maximum wheel squeal noise levels of 80 dBA to 90 dBA at 50 feet.

Research into methods of reducing wheel squeal noise, including using non-oil-based lubricants (such as water) and friction modifiers, has found such methods effectively reduce or eliminate wheel squeal. The lubricants can be applied by personnel working trackside or by an automated applicator. It is a general policy of Sound Transit’s light rail design criteria manual (Sound Transit, 2012) to lubricate all curves with a radius of less than 600 feet that are located in noise-sensitive areas, and preparing all curves with a radius of less than 1,250 feet for lubrication. This means that if wheel squeal is identified on these curves that are between 600 and 1,250 feet after system operation begins, it is possible to add lubricators.

5.1.7 Light Rail Noise Projections

Noise impacts that would result from the FWLE were determined through the following approach:

- Sound Transit performed a land use survey of potential noise-sensitive receptors near the proposed light rail alignments. This process involved site visits and use of land-use maps and information.
- Sound Transit conducted long-term (multi-day) and short-term (15- to 20-minute) noise monitoring to establish existing noise levels for the potentially affected area. Ambient noise monitoring was taken at 72 locations along the project corridor. The criteria for selecting the monitoring locations included land use, existing ambient noise, number of sensitive receivers in the area, and level of expected impact.
- Field noise measurements were used to develop a set of existing ambient sound levels for the noise-sensitive receptors.
- Existing ambient sound levels were used to determine the noise impact criteria. The FTA criteria for noise impacts are based on the existing noise level and land use.
- Projections of light rail noise levels were made based on track type, train speed, number of passenger cars, and distance of receiver from tracks, with adjustments for shielding and ground attenuation. Adjustments based on track type, sound walls, elevated acoustical walls, and trench situations are shown in Table 5-2. Sound attenuation related to physical shielding from the elevated structure and other existing and planned structures was included in the analysis using acoustical formulas from the FTA Guidance Manual (FTA, 2006). Noise related to bells at stations and special track work was included in the analysis.
- Measured noise level reductions from existing noise barriers installed on the elevated guideway in Tukwila, Washington along the Central Link Light Rail System were used to assist in the final mitigation predictions.
- Sound Transit evaluated noise projections with respect to the FTA impact thresholds to determine whether a receiver would be affected by light rail operations.
- Where noise impacts were identified, mitigation recommendations followed the Sound Transit Noise Mitigation Policy.

5.1.8 Park-and-Ride Noise Projections

Sound Transit calculated operational noise levels from buses and vehicles that would use the light rail park-and-ride facilities using the methods outlined in the FTA Guidance Manual (FTA, 2006). Future bus and passenger traffic volumes for the different park-and-ride facilities are based on the predicted maximum number of parking spots, peak-hour bus operations, and hourly bus operation throughout the day, evening, and nighttime hours. Sound Transit used future park-and-ride operations to determine the noise levels at the residential areas near the proposed facilities.

TABLE 5-2
Light Rail Track-type and Shielding Adjustments

Track Type	Adjustment in Decibels (dB)
At-grade B&T track (ballast exposed)	0
Elevated structure	+4
Embedded track or retained-fill trackway	+3
Trench at least 4 to 6 feet below grade	-5
Crossover	+10
Acoustical sound walls on structure between 4 and 6 feet above the top of rail with some going as high as 8 feet. Walls on structure over 8 feet are not normally used because of wind loading and safety concerns.	Typical noise reduction of 8 to 15 decibels or more, as predicted using FTA formulas and verified with measured data during normal operations along the Tukwila segment.
Sound wall at-grade with an expected height of at least 6 feet above the grade of the trackway. An at-grade sound wall can go as high as 20 feet or more; however, for light rail only mitigation, the typical heights range from 4 to 8 feet.	Typical noise reduction of 8 to 12 decibels or more, as predicted using FTA formulas and verified with measured data during normal operations along the Tukwila segment.

As previously stated in Section 4.1.3, ancillary facilities must not only meet the FTA criteria but also the applicable state, county, or city criteria for noise. To identify potential impacts, Sound Transit projected operational noise levels for two different conditions:

- Typical 24-hour average Ldn
- Peak hour Leq

Sound Transit's noise analysis team calculated operational noise levels for the park-and-ride facilities at the nearest representative receivers' property lines. Sound Transit projected the 24-hour Ldn and the peak-hour Leq using the methods described in the FTA Guidance Manual. The noise analysts obtained future hourly bus volumes and park-and-ride lot access times from Sound Transit. The daily Ldn noise levels were compared to the FTA noise regulations provided in Section 4.1.1. The peak-vehicle-hour Leq was compared to the appropriate city or state ordinance described in Section 4.1.3.

The proposed park-and-ride facility sites are considered commercial uses under local noise control ordinances. As discussed in Section 4.1.3, the maximum allowable noise level for a commercial use next to a residential use is 57 dBA at the property line. The noise impact analysis under the local noise control ordinances is applicable to all passenger vehicles and buses only while they are on park-and-ride facility property. Buses on public roadways, or at existing bus stops on public roadways, are exempt under local noise control ordinances. The contribution of cars accessing the station was predicted using the number of parking spots and reference noise levels from the FTA (FTA, 2006).

For the local code noise analysis, Sound Transit projected the peak-hour Leq using the methods in the FTA Guidance Manual. Sound Transit then compared the projected peak-hour Leq with the daily maximum allowable noise level. The maximum allowable noise level for commercial uses is 62 dBA during daytime (7:00 a.m. to 10:00 p.m.) and 52 dBA during nighttime (10:00 p.m. to 7:00 am).

Tables 5-3 through 5-6 summarize the operational features used in this analysis associated with the stations and station options for each FWLE build alternative.

5.1.9 Traffic Noise

The potential to create or increase exposure to traffic noise as a result of the transit project was evaluated qualitatively. As defined in FHWA noise abatement policy (FHWA, 2006a), changes in the traffic noise environment could occur if the project creates new roadways or alters existing roadways in relation to noise-sensitive properties, or changes the pathway for traffic noise by removing or altering barriers (buildings, berms, or walls) that currently provide some level of shielding from traffic noise. These locations were identified and evaluated for potential traffic noise impacts based on existing noise measurements and FHWA impact criteria.

TABLE 5-3
SR 99 Park-and-Ride Analysis

Station	Operational Analysis	Park-and-Ride	Parking Spaces[a]	Bus Circulation and layover area	Notes
Kent/Des Moines SR 99 West	Required	Yes	1,000	Yes	500 structure spaces and 500 surface parking spaces
S 272nd Redondo	Required	Yes	1,397	Yes	700 new and 697 existing; all structure parking
Federal Way Transit Center	Required	Yes	1,590	Yes	400 new; all structure parking, in addition to 1,190 existing parking spaces at existing transit center
Station Options					
S 216th West	Not Required	No	0	No	Park-and-ride with bus stop on SR 99
S 216th East	Not Required	No	0	No	Park-and-ride with bus stop on SR 99
Kent/Des Moines HC Campus	Required	Yes	1,000	Yes	500 structure spaces and 500 surface parking spaces (not including 520 Highline College replacement parking spaces)
Kent/Des Moines SR 99 Median	Required	Yes	1,000	Yes	500 structure spaces and 500 surface parking spaces
Kent/Des Moines SR 99 East	Required	Yes	1,000	Yes	500 structure and 500 surface parking
S 260th West	Not Required	No	0	No	Park-and-ride with bus stop on SR 99
S 260th East	Not Required	No	0	No	Park-and-ride with bus stop on SR 99
S 272nd Redondo Trench	Required	Yes	1,397	Yes	700 new and 697 existing; all structure parking
Federal Way SR 99	Required	Yes	1,590	Yes	400 new; all structure parking, in addition to 1,190 existing parking spaces at existing transit center

[a] Parking spaces based on current conceptual design drawings assuming the maximum (i.e., interim terminus condition) parking supply at any one park-and-ride location.

TABLE 5-4
I-5 Park-and-Ride Analysis

Station	Operational Analysis	Park-and-Ride	Parking Spaces[a]	Park-and-Ride Bus Right-of-Way	Notes
Kent/Des Moines I-5	Required	Yes	1,000	Yes	500 structure spaces and 500 surface parking spaces
S 272nd Star Lake	Required	Yes	1,240	Yes	700 new and 540 existing spaces; all structure parking
Federal Way Transit Center	Required	Yes	1,590	Yes	400 new; all structure parking, in addition to 1,190 existing parking spaces at existing transit center
Station Options					
Kent/Des Moines At-Grade	Required	Yes	1,000	Yes	500 structure and 500 surface parking
Kent/Des Moines SR 99 East	Required	Yes	1,000	Yes	500 structure and 500 surface parking
Federal Way I-5	Required	Yes	1,590	Yes	400 new; all structure parking, in addition to 1,190 existing parking spaces at existing transit center
Federal Way S 320th Park-and-Ride	Required	Yes	1,277	Yes	400 new; all structure parking, in addition to 877 existing parking spaces at existing transit center

[a] Parking spaces based on current conceptual design drawings assuming the maximum (i.e., interim terminus condition) parking supply at any one park-and-ride location.

TABLE 5-5
SR 99 to I-5 Park-and-Ride Analysis

Station	Operational Analysis	Park-and-Ride	Parking Spaces[a]	Park-and-Ride Bus Right-of-Way	Notes
Kent/Des Moines 30th Ave East	Required	Yes	1,000	Yes	500 structure and 500 surface parking
S 272nd Star Lake	Required	Yes	1,240	Yes	700 new; all structure parking
Federal Way Transit Center	Required	Yes	1,590	Yes	Structure parking
Station Options					
S 216th West	Not Required	No	0	No	Park-and-ride with bus stop on SR 99
S 216th East	Not Required	No	0	No	Park-and-ride with bus stop on SR 99
Federal Way I-5	Required	Yes	400	Yes	Structure parking
Federal Way S 320th Park-and-Ride	Required	Yes	1,277	Yes	400 new; all structure parking

[a] Parking spaces based on current conceptual design drawings assuming the maximum (i.e., interim terminus condition) parking supply at any one park-and-ride location.

TABLE 5-6
I-5 to SR 99 Park-and-Ride Analysis

Station	Operational Analysis	Park-and-Ride	Parking Spaces[a]	Park-and-Ride Bus Right-of-Way	Notes
Kent/Des Moines 30th Ave W	Required	Yes	1,000	Yes	500 structure and 500 surface parking
S 272nd Redondo	Required	Yes	1,397	Yes	700 new and 697 existing; all structure parking
Federal Way Transit Center	Required	Yes	1,590	Yes	400 new; all structure parking, in addition to 1,190 existing parking spaces at existing transit center
Station Options					
S 260th West	Not Required	No	0	No	Park-and-ride with bus stop on SR 99
S 260th East	Not Required	No	0	No	Park-and-ride with bus stop on SR 99
S 272nd Redondo Trench	Required	Yes	1,397	Yes	700 new and 697 existing; all structure parking
Federal Way SR 99	Required	Yes	1,590	Yes	400 new; all structure parking, in addition to 1,190 existing parking spaces at existing transit center

[a] Parking spaces based on current conceptual design drawings assuming the maximum (i.e., interim terminus condition) parking supply at any one park-and-ride location.

5.2 Vibration Assumptions and Methods

Groundborne vibration is strongly influenced by localized geologic conditions such as soil stiffness, soil layering, and depth to bedrock. However, it is difficult to obtain information on subsurface conditions in sufficient detail so that computer models can be used to accurately predict ground vibration. As a result, most detailed predictions of ground vibration are based largely on empirical methods that involve measuring vibration propagation in the soil. The FTA Guidance Manual (FTA, 2006) defines three levels of vibration assessment:

- **Screening**: Generalized distances of potential impacts are used to quickly determine whether there is any potential for impacts.
- **General Vibration Assessment**: FTA provides a general curve of train vibration vs. distance that is used to estimate the vibration levels. The curve was developed by plotting measured vibration levels from a number of different rail transit systems against distance from the tracks and drawing a line through the top range of the data. The curve provides a conservative (high) estimate of potential vibration impacts. Adjustments are made to the general curve to account for factors such as speed and special track work.
- **Detailed Vibration Assessment**: A Detailed Vibration Assessment consists of using state-of-the-art tools to characterize how localized soil conditions affect the levels of groundborne vibration. The FTA Guidance Manual recommends using vibration propagation tests to measure how vibration would be transmitted from the train tracks through the ground and into the foundations of nearby buildings.

A detailed vibration assessment was performed for the FWLE alternatives based on vibration measurements performed at 12 sites along the project corridor. The measurement details are discussed in Section 3, Affected Environment.

5.2.1 Sources of Light Rail Vibration

Both the construction and operation of a light rail system generate vibration that is transmitted through the ground and into nearby buildings. It is rare for the vibration to be high enough to create a risk of structural damage to buildings. However, it is possible for construction vibration to approach risk thresholds for minor cosmetic damage. Construction and light rail operations both have the potential to generate vibration that may be intrusive to building occupants. The following vibration sources are associated with light rail systems:

- **Train operations**: Light rail operations can create groundborne vibration that can be intrusive to occupants of buildings close to the tracks. However, light rail operation vibration levels in general are well below the thresholds used to protect sensitive and fragile structures from damage. A key assumption in the vibration predictions is that optimal wheel and rail profiles would be maintained for the system through periodic truing of the wheels and rail grinding.
- **Special track work**: The wheel impacts at the frogs used at special track work for turnouts and switches increases vibration levels. A “frog” is a rail-crossing structure at track crossovers that allows the train to cross over to another track or continue moving on the same track. Flange-bearing frogs can reduce the impact of vibration. However, ramps on typical flange-bearing frogs are short enough that the transfer of the load is quite abrupt and generates substantial vibration in addition to noise. Use of flange-bearing frogs with longer ramps can reduce the vibration from special track work. Spring-rail and movable-point frogs can also reduce vibration substantially, although they are more expensive in terms of parts, installation, and maintenance.

5.2.2 Light Rail Vibration Prediction Methods

The predictions of groundborne vibration for this study follow the Detailed Vibration Assessment procedure of the FTA Guidance Manual (FTA, 2006). This is an entirely empirical method based on testing of the vibration propagation characteristics of the soil in the project corridor and measurements of the vibration characteristics of a similar light rail vehicle. As discussed in Section 3.0, vibration propagation tests were performed at 12 locations in the proposed corridor for the FWLE. The quantity derived from the propagation tests is referred to as the LSTM. The basic relationship used for the vibration predictions is:

Lv = FDL + LSTM

where:

Lv = Train vibration velocity measured at the ground surface

LSTM = Measured line source transfer mobility

FDL = Force density level, a function that characterizes the vibration forces generated by the train and track

(All quantities are expressed in decibels to use a consistent set of decibel reference values)

FDL is derived by measuring Lv and LSTM at a site where there are light rail vehicle operations. The FDL used in this analysis is based on measured FDL values of the existing Sound Transit Central Link light rail system (Rajaram and Wolf, 2014). Measurements were taken on at-grade B&T track, DF track in a trench, and DF track on an elevated structure to determine the FDL for different track types. The measured FDLs were available for DF tracks at 20, 25, 30, 35, 40, 45, 50, and 55 mph. The FDLs at all intermediate operational speeds for the FWLE were estimated by interpolating the measured values. For the B&T tracks, measured FDLs were available at 20, 25, 30, and 35 mph. The B&T track FDLs at all other speeds were calculated by using the speed-vibration relationship from the DF track and applying it to the measured B&T values.

The FDLs used for this analysis are shown on Exhibits 5-1 and 5-2. The FDLs show broad peaks at 10 Hz and 50 Hz for DF track and at 10 Hz and 63 Hz for B&T track. Above 160 Hz, the FDLs on Exhibits 5-1 and 5-2 are shown in gray because there was a high level of uncertainty at these frequencies in the measured data. At these higher frequencies, the FDL would tend to overpredict the vibration levels. A key assumption of the vibration model is that a low FDL would be maintained over the years through a program that maintains the desired wheel and rail profiles and proactively eliminates wheel flats.

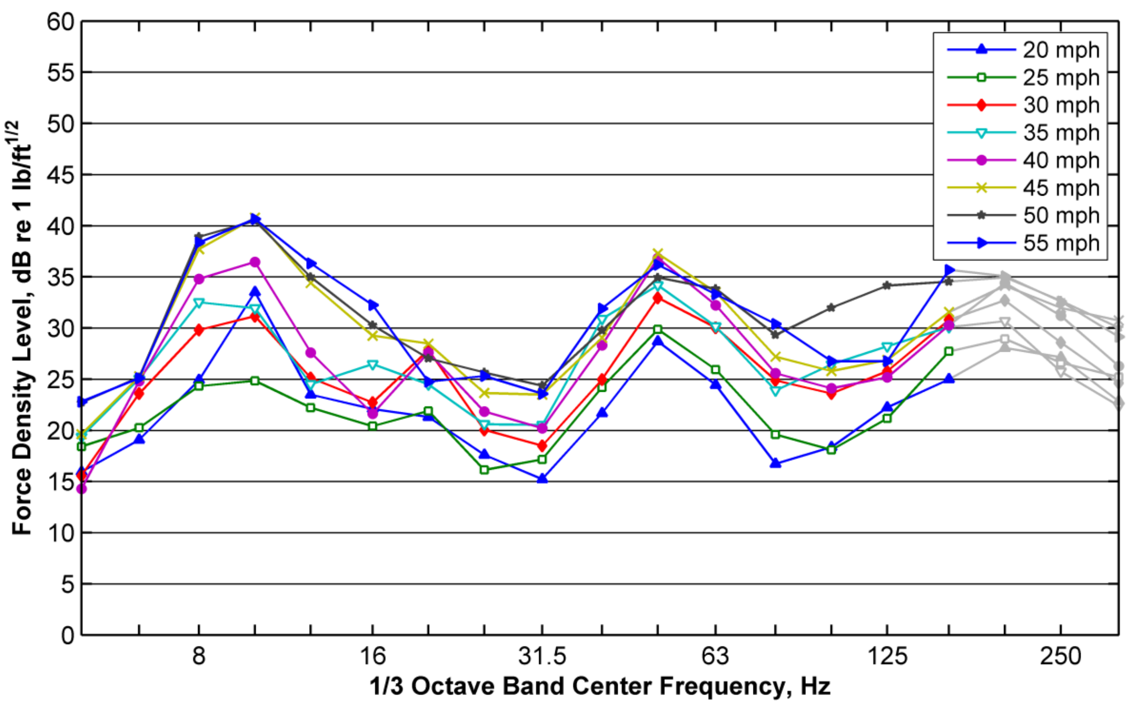


EXHIBIT 5-1
Force Density of DF Tracks at Different Speeds for Three-car Trains

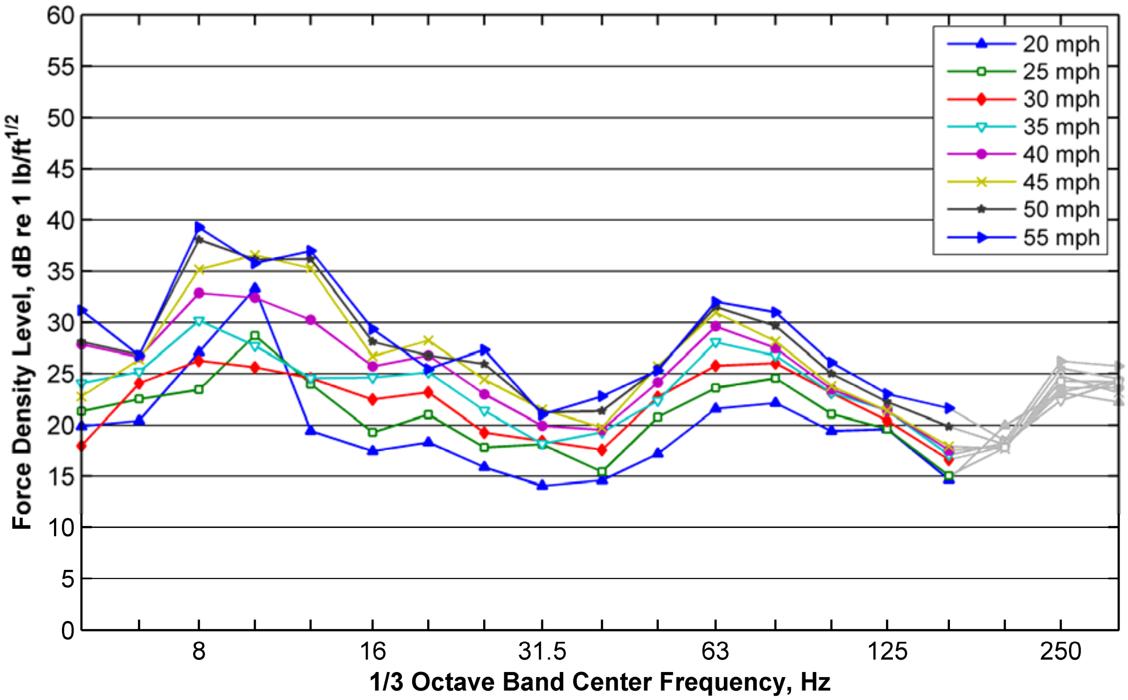


EXHIBIT 5-2
Force Density of B&T Tracks at Different Speeds for Three-car Trains

The LSTM results are discussed in Section 3.3. The approach used for predicting vibration from the operations of the FWLE system was to use a combined LSTM model that is a linear average of the measured LSTM from the 12 vibration test sites. Because the LSTM measurements were fairly consistent across all sites, this is a reasonable approximation of the actual LSTM over the study area.

The predictions for the FWLE indoor vibration include an adjustment factor of +5 dB to each 1/3 octave band to account for potential amplification effects inside buildings and provide a small safety factor for other sources of uncertainty in the predictions. When vibration is propagated from the ground to the building foundation, there is loss in vibration energy at the building's interface with the ground, which is commonly referred to as coupling loss. For the combined effect of coupling loss and floor amplification, the FTA Guidance Manual recommends a net adjustment of +1 dB for the vibration inside a typical residence. A recent Transit Cooperative Research Program (TCRP) study based on 35 outdoor-indoor vibration measurements in several cities in North America showed an average outdoor-indoor amplification of 0 dB with a standard deviation of approximately 5 dB (Zapfe et al., 2009, and McKenna, 2011). Therefore, an adjustment factor of +5 dB is a conservative approach that ensures that in the majority of cases the predicted vibration levels are higher than what would occur after the proposed project is operational. In addition, the vibration predictions for the FWLE assumed that 4-car trains would be operated. Because the FDLs on Exhibit 5-1 and Exhibit 5-2 are for three-car trains, a +0.5 dB adjustment was included in the vibration predictions to account for longer trains.

Exhibits 5-3 and 5-4 show the predicted overall vibration velocity level as a function of distance from the tracks for a variety of light rail vehicle speeds. These curves were used for the General Assessment of vibration impacts. Exhibits 5-5 through 5-12 show the 1/3 octave band spectra of the predicted indoor vibration at distances of 10, 50, 100, and 200 feet from the track centerline. These curves were used for the Detailed Assessment of vibration impacts. The predicted vibration levels shown on Exhibits 5-3 through 5-12 include the following adjustments:

- +5 dB for indoor amplification
- +0.5 dB for train length

The curves on Exhibits 5-5 through 5-12 are used as the basis for Detailed Assessment of impacts for residential and institutional land uses. These curves show that:

- The predicted vibration spectra for Category 2 (residential) land uses exceed the FTA Detailed Assessment impact threshold at distances less than 50 feet from the near track centerline for the B&T tracks at speeds ranging from 40 to 55 mph (Exhibits 5-5 through 5-8).
- Based on Exhibits 5-9 through 5-12, the predicted maximum vibration level at 50 feet from the near track centerline for the DF tracks is about 77 VdB at speeds ranging from 40 to 55 mph. This level exceeds the FTA Detailed Assessment impact threshold for Category 2 (residential) land uses at 50 feet. However, it is noteworthy that the DF tracks are always assumed to be on an elevated structure for this analysis. As shown on Exhibit 5-13, the elevated structure would reduce vibration levels by up to 10 dB at the peak frequencies (Rajaram and Wolf, 2014).

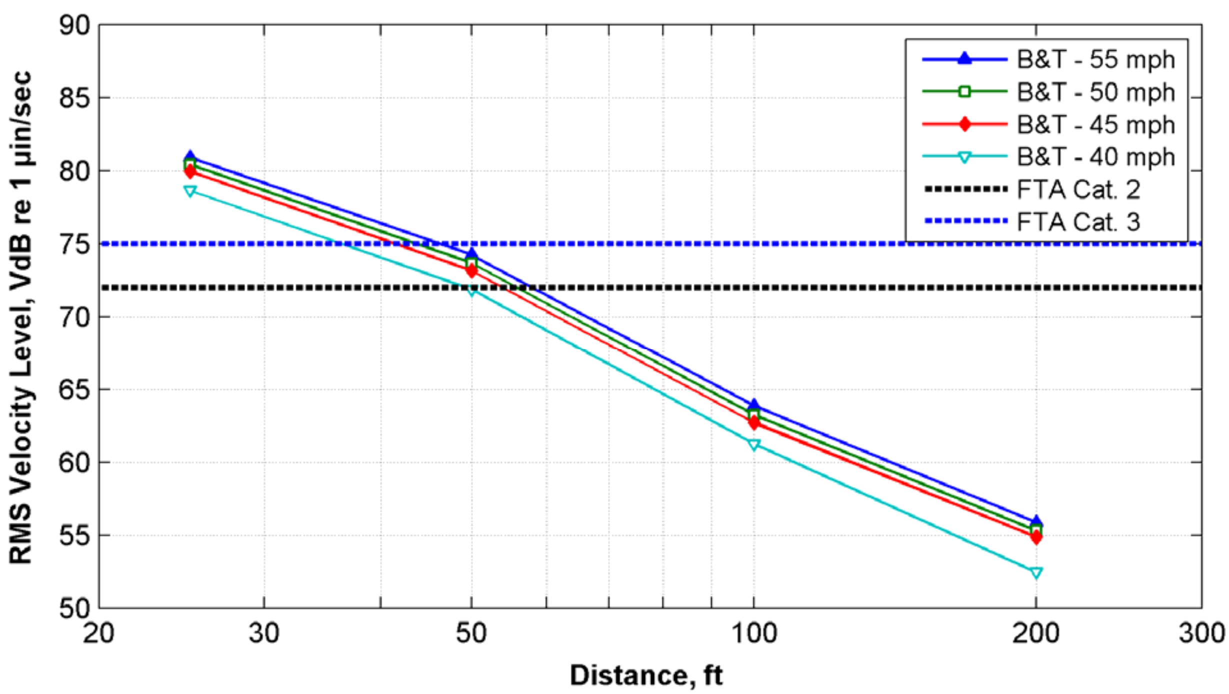


EXHIBIT 5-3
Predicted Overall Vibration Levels for B&T Track at Different Speeds

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

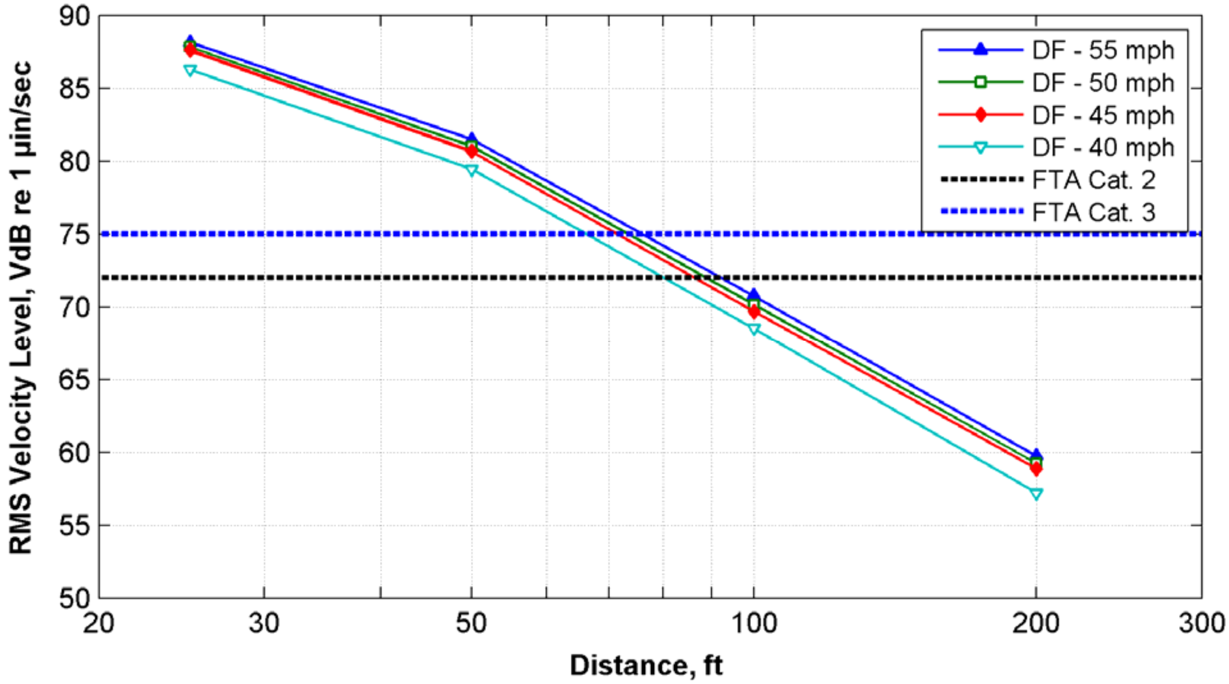


EXHIBIT 5-4
Predicted Overall Vibration Levels for DF Track at Different Speeds

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

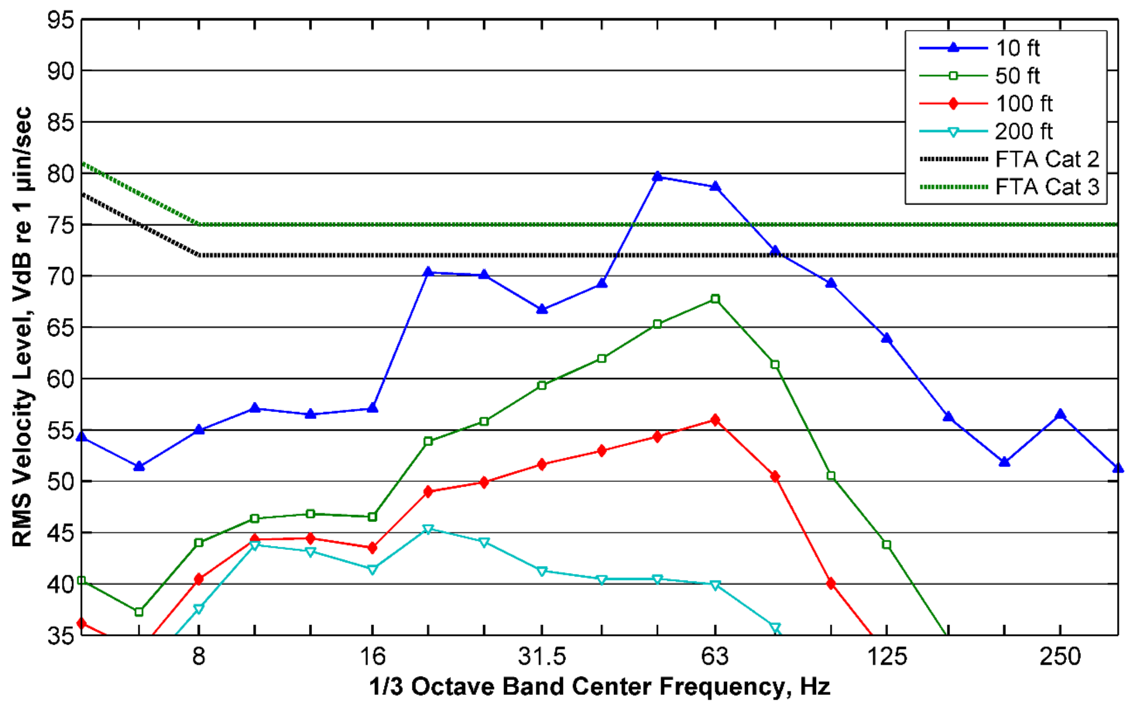


EXHIBIT 5-5
Predicted Vibration Levels for B&T Tracks at 40 mph

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

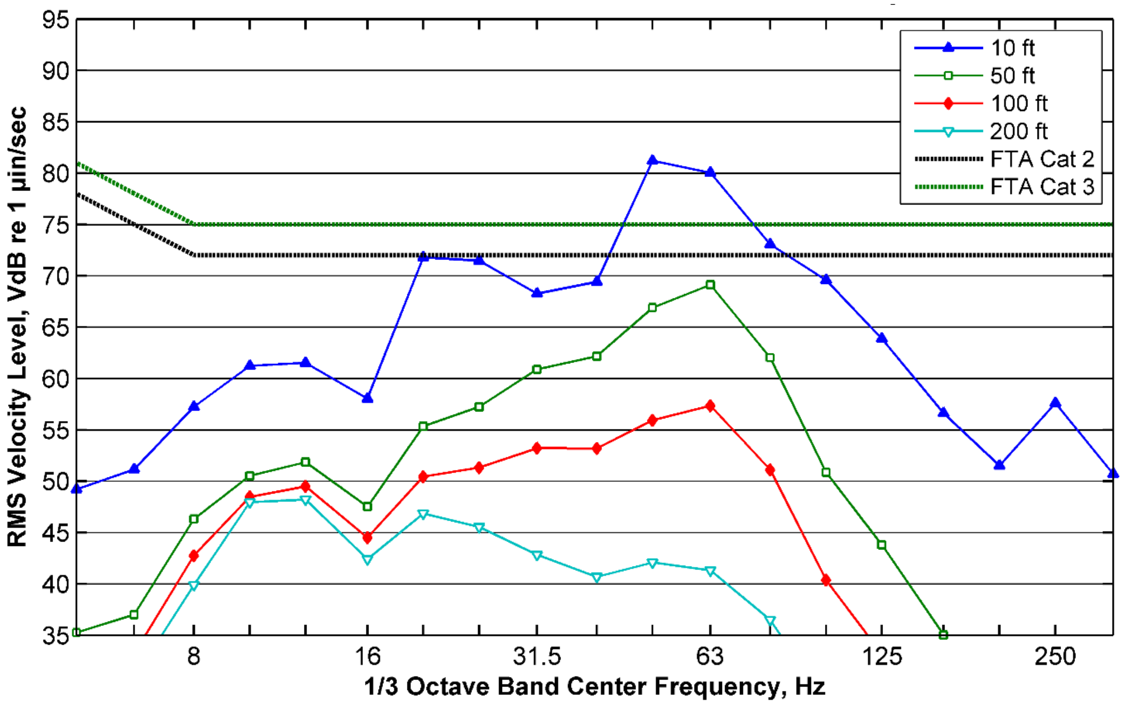


EXHIBIT 5-6
Predicted Vibration Levels for B&T Tracks at 45 mph

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

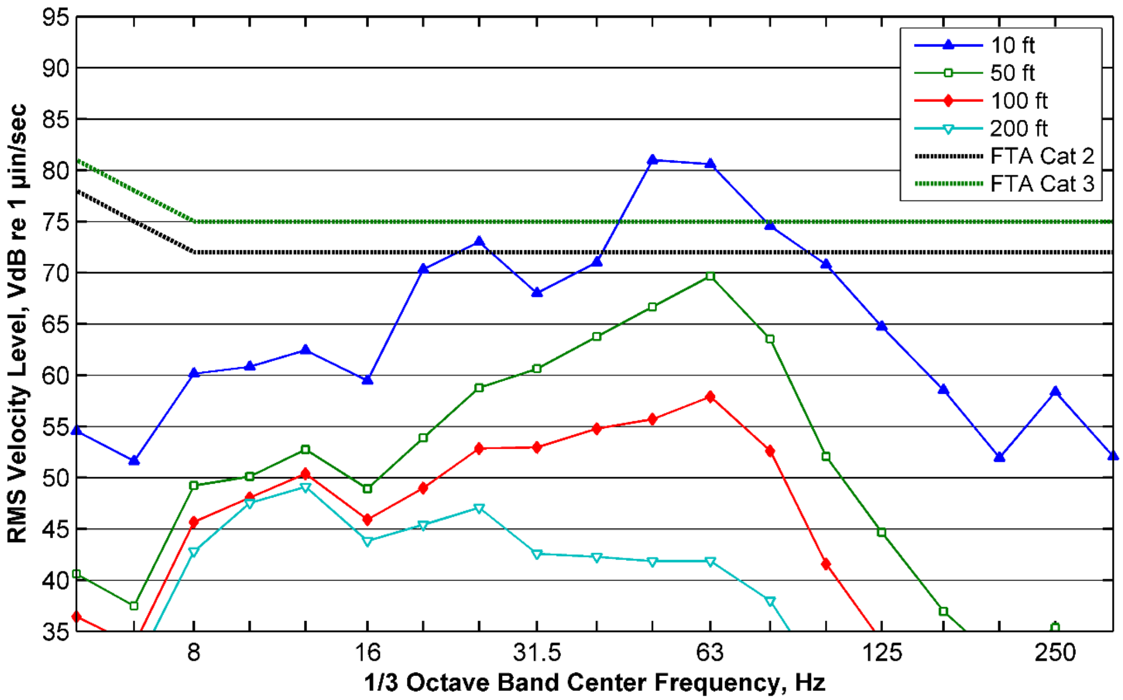


EXHIBIT 5-7
Predicted Vibration Levels for B&T Tracks at 50 mph

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

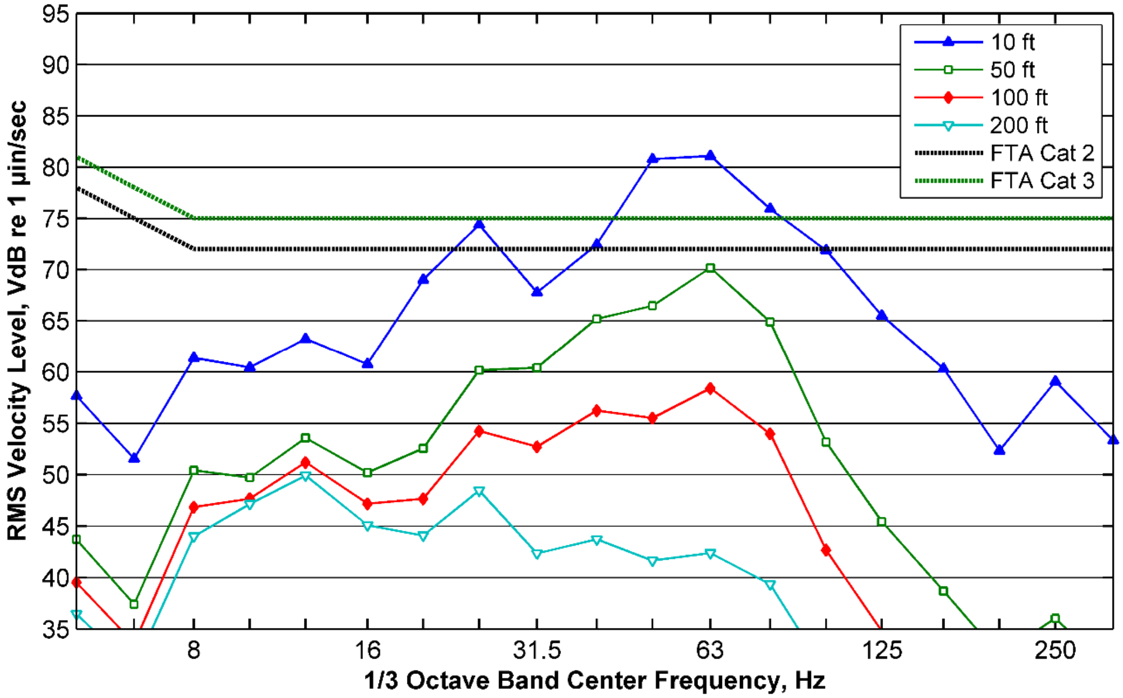


EXHIBIT 5-8
Predicted Vibration Levels for B&T Tracks at 55 mph

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

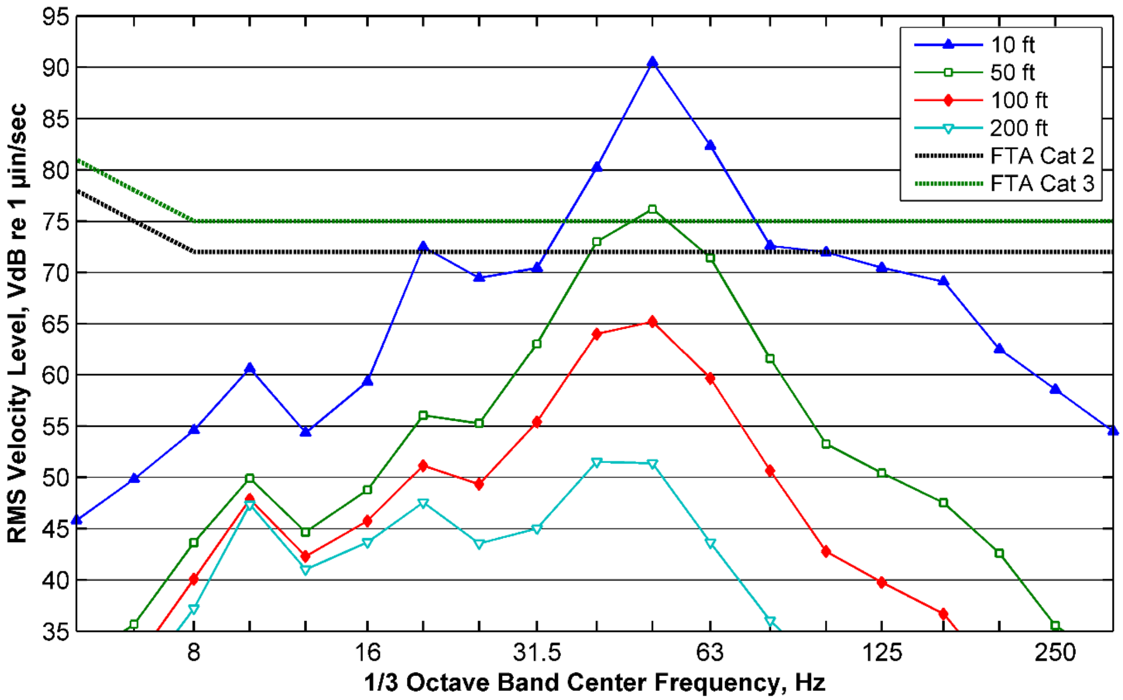


EXHIBIT 5-9
Predicted Vibration Levels for DF Tracks at 40 mph

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

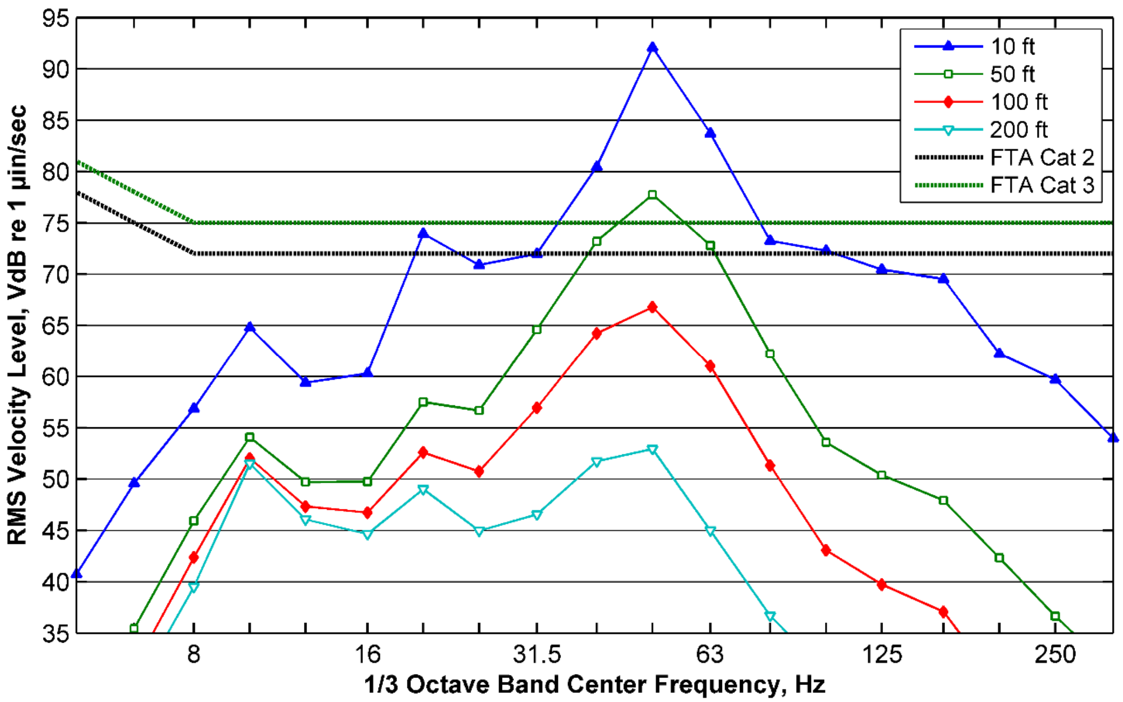


EXHIBIT 5-10
Predicted Vibration Levels for DF Tracks at 45 mph

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

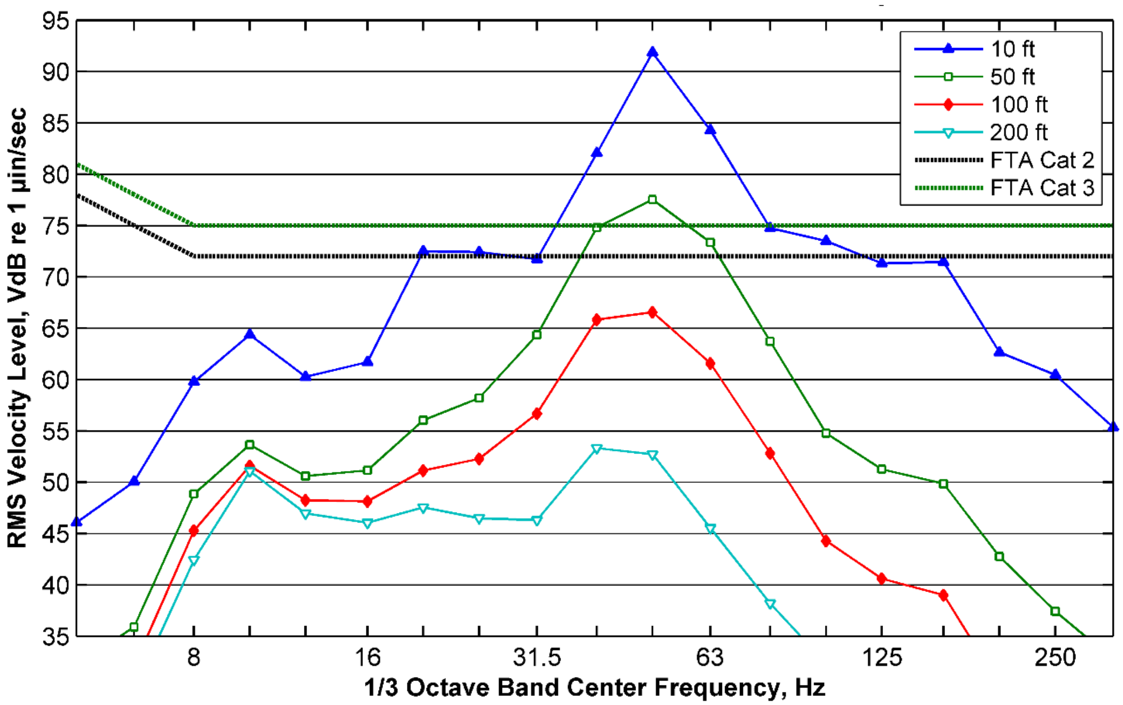


EXHIBIT 5-11
Predicted Vibration Levels for DF Tracks at 50 mph

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

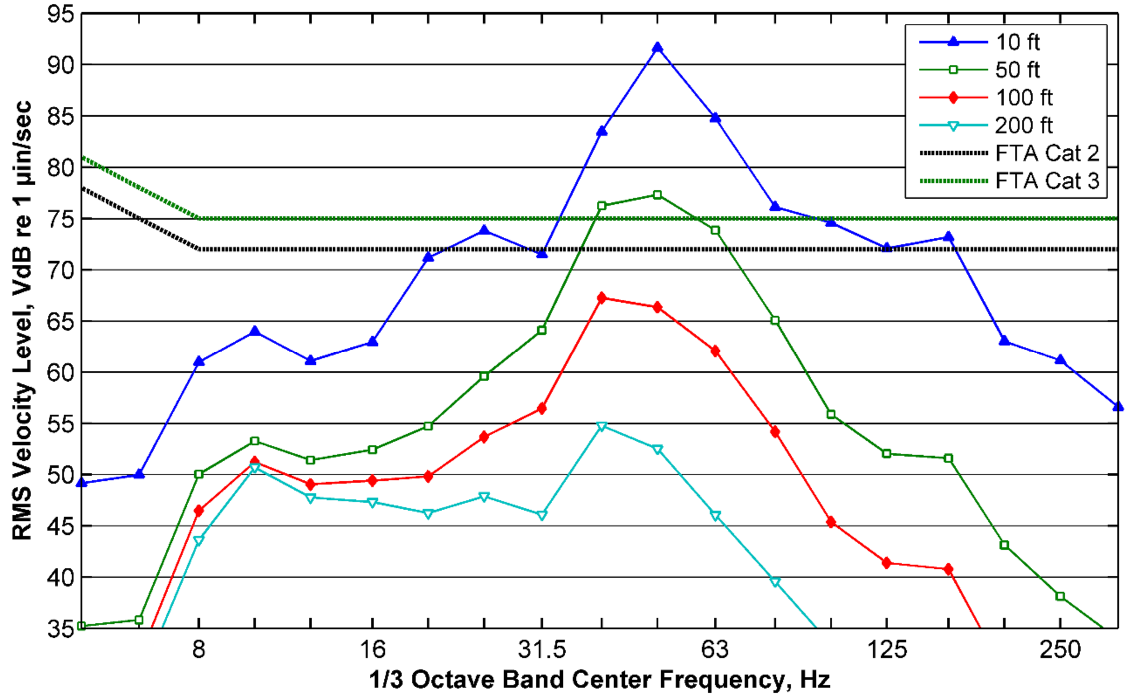


EXHIBIT 5-12
Predicted Vibration Levels for DF Tracks at 55 mph

Notes: FTA Cat.2 - FTA vibration impact thresholds for Category 2 receivers; FTA Cat.3 - FTA vibration impact thresholds for Category 3 receivers.

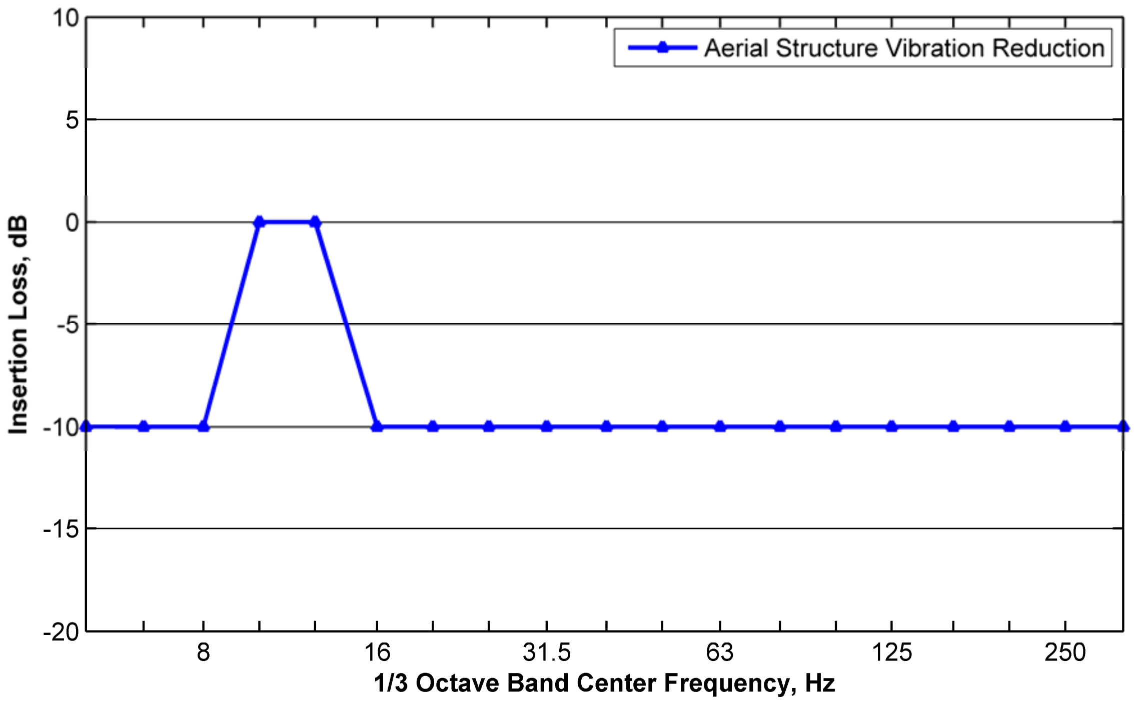


EXHIBIT 5-13
Vibration Reduction Resulting from Elevated Structure

The following adjustments were applied to estimate vibration levels in occupied spaces of buildings:

- Special track work: The additional vibration at special track work was accounted for by assuming a +10 dB amplification at distances less than 50 feet. At distances greater than 50 feet from the crossover frogs, the amplification was assumed to attenuate at the rate of 20*log (distance/50).
- Elevated structures: The vibration reduction from the elevated structure was assumed to be 10 dB at all frequencies except 10 Hz and 12 Hz (Exhibit 5-13). The curve on Exhibit 5-13 is based on measurements performed during the Central Link FDL tests.

6.0 Impact Assessment

6.1 Light Rail Noise Impacts

Sound Transit performed a detailed noise impact assessment based on the criteria discussed in Section 4 and on the methods and projections described in Section 5 of this report. For areas with noise impacts, potential noise mitigation measures are described in Section 8. Assessment details, including complete tabulated data of the project parcel identification, existing noise levels, project noise levels, criteria, and other information, are provided in Appendix B, Detailed Noise Impact Assessment Data. Table 6-1 provides a summary of the moderate and severe impacts for each of the four build alternatives and the number of additional or fewer impacts that each station option would have when compared to the primary alternative.

TABLE 6-1
Summary of Potential Moderate and Severe Noise Impacts

Alternative	Light Rail Impacts	
	Moderate	**Severe**
SR 99 Alternative	**2,211**	**1,515**
S 216th Station Options		
S 216th West Station Option	-76	-201
S 216th East Station Option	-14	--
Kent/Des Moines Station Options		
Kent/Des Moines HC Campus Station Option	-240	+86
Kent/Des Moines HC from S 216th West Station Option	-731	-311
Kent/Des Moines SR 99 Median Station Option	+14	-6
Kent/Des Moines SR 99 East Station Option	+35	-19
S 260th Station Options		
S 260th West Station Option	-107	-43
S 260th East Station Option	+31	-37
S 272nd Redondo Trench Station Option	-124	-395
Federal Way SR 99 Station Option	-24	+68
I-5 Alternative	**982**	**468**
Kent/Des Moines Station Options		
Kent/Des Moines At-Grade Station Option	-3	+44
Kent/Des Moines SR 99 East Station Option	+94	+9
Landfill Median Alignment Design Option	+24	+49
Federal Way City Center Station Options		
Federal Way I-5 Station Option	+20	--
Federal Way S 320th Park-and-Ride Station Option	-112	-8
SR 99 to I-5 Alternative	**1,452**	**738**
S 216th Station Options		
S 216th West Station Option	-76	-201
S 216th East Station Option	-14	--

TABLE 6-1
Summary of Potential Moderate and Severe Noise Impacts

Alternative	Light Rail Impacts	
	Moderate	Severe
Federal City Center Station Options		
Federal Way I-5 Station Option	+20	--
Federal Way S 320th Park-and-ride Station Option	-112	-8
I-5 to SR 99 Alternative	**1,629**	**1,313**
S 260th Station Options		
S 260th West Station Option	-53	-30
S 260th East Station Option	+31	-37
S 272nd Redondo Trench Station Option	-124	-395
Federal Way SR 99 Station Option	-24	+68

6.1.1 No Build Alternative

With or without the FWLE, traffic on I-5, SR 99, and ancillary roadways would increase. For roadways such as I-5, an increase in traffic volume of 1 to 2 percent per year is typical. For a roadway like SR 99, a greater increase is likely. Hence, in 2035 the daily traffic volume on I-5 and SR 99 would increase and cause a corresponding increase in traffic noise.

Because traffic on I-5 is the dominant source of noise for receivers near the I-5 corridor and because I-5 is already at or near capacity during peak periods, the maximum-hour Leq(h) at those receivers would not increase substantially unless the capacity is increased. In the future, one or more of the following cases might occur:

- A spreading of traffic to off-peak hours, resulting in more hours of the day with high traffic noise levels.
- Increased congestion, resulting in reduced speeds and lower noise levels during peak hours; the loudest hours would then occur during off-peak periods.

6.1.2 Build Alternatives

6.1.2.1 SR 99 Alternative

There would be 2,211 units with moderate noise impacts and an additional 1,515 units with severe noise impacts with the SR 99 Alternative. The impacts would be distributed throughout the length of the alternative, and many of the properties where impacts would occur are multi-family complexes or motels, which contributes to the high number of impacts. The impact numbers presented include schools, churches, and other noise-sensitive uses, in addition to residential units.

In the northern end of the corridor, north of the Kent-Des Moines Road, Category 2 severe noise impacts were identified at the Sky Way Inn, the Best Western Motel, the Sleep Inn Motel, the Legend Motel, the New West hotel, and the America’s Best Value Inn hotel. Severe noise impacts were also identified at single-family homes on S 222nd Street and 28th Avenue S, the Falcon Ridge Assisted Living Facility, the Viewpoint Apartments, the Pine Terrace Mobile Home Park, and the Stafford Senior Care

Facility. Because of the large number of multi-family units and hotels, there would be a large number of severe noise impacts in this section of the corridor. Noise impacts were also identified at several large multi-family complexes, including the Majestic Bay Condominiums (moderate and severe), the Marina Club Apartments, the Sea Fox Apartments, and the Willow Lake Apartments (all moderate), along with several smaller multiplex units located along 30th Avenue S. A group of single-family homes along 30th Avenue S was also identified with moderate noise impacts.

South of Kent-Des Moines Road, and north of S 272nd Street, severe noise impacts were identified at several multi-family complexes, including three complexes on 30th Avenue S, and several single-family homes. Severe noise impacts on mobile home parks include impacts at Tip-Top Mobile Home Park on S 240th Street, Midway Mobile Home Mansions, and the West Hill Mobile Manor. Moderate noise impacts were identified at several single-family homes on the west side of SR 99 between S 240th Street and S 268th Street. South of S 272nd Street, severe noise impacts were identified at several single-family and multi-family residences located along 16th Avenue, 16th Place S, and 15th Avenue S on the west side of the alignment. This includes severe noise impacts at several multiplex units located in the 28000 block of 16th Avenue S and two large complexes in the 27000 block of SR 99. Moderate noise impacts include several multi-family buildings along SR 99 between S 276th and S 288th Streets on the east side of the highway. Near the S 272nd Redondo Station, moderate noise impacts were identified at the Brookhaven Apartment complex and the Chelsea Court Condominiums.

Category 3 noise impacts include a severe noise impact at the easternmost part of the Federal Way High School, with operational noise levels just meeting the FTA severe impact criteria at the exterior of the new building. In addition, exterior noise levels at the future new Federal Way High School Performing Arts Center would result in a severe noise impact. It is important to note that the noise impact predicted for Federal Way High School is an exterior noise impact. The new school building, which is currently under construction, would be constructed with walls and windows that would prevent the noise from light rail operations having a noise impact inside the school. If this alternative is identified as the Preferred Alternative, additional acoustical testing could be performed to determine the exterior-to-interior noise reduction and verify that noise levels in classrooms, the performing arts center, and other noise-sensitive parts of the building are within the applicable standards. Based on a review of the proposed building construction, the interior noise levels at all noise-sensitive parts of the school are estimated to be 35 to 45 dB (or more) lower than the exterior noise levels; therefore, no interior noise impacts are expected.

Other Category 3 land uses (including schools, libraries, and churches) with noise impacts along the SR 99 corridor include the Citadel Church, the Open Door Baptist Church, the Seattle Full Gospel Church, the Woodmont Library, the Rissho Kosei Kai of Seattle Buddhist Learning Center, the Church of Christ West Campus, the Jesus Christ Salt and Light Church, and the Smart Start Day Care.

S 216th Station Options

The S 216th West Station Option would reduce the number of moderate and severe noise impacts because the alignment would be relocated in a trench along the west side of SR 99, farther away from several multi-family buildings. Some of the severe impacts, such as those at the Best Western, would be eliminated because the building would be relocated, but most severe impacts would be eliminated or reduced to moderate because the alignment would be located farther from noise-sensitive properties, such as Falcon Ridge Assisted Living, with additional shielding from the trench. The result is a net decrease in both moderate and severe impacts.

With the S 216th East Station Option, there would be slightly less moderate impacts, with the number of severe noise impacts remaining the same. The changes in noise impacts are all located along the east side of the alignment between S 216th Street and S 224th Street, with new moderate impacts at the West View Hotel and along 28th and 29th Avenues S. Finally, several homes with moderate noise impacts with the SR 99 Alternative would be displaced for the S 216th Street East Station Option.

Kent/Des Moines Station Options

With the Kent/Des Moines HC Campus Station Option, the overall noise impacts would be reduced as a result of moving the alignment off SR 99, which would reduce the noise impacts at several large multi-family units. Noise impacts would increase, however, at single-family residences along 27th Avenue S and 28th Avenue S, south of Kent/Des Moines Road. The overall result is an increase in severe impacts and a reduction in moderate noise impacts. When connecting to the S 216th West Station Option, the profile of the light rail would be a trench or at-grade for most of the area along the alignment north of Kent-Des Moines Road, resulting in a substantial reduction in both moderate and severe impacts. Because the alignment is located on the west side of SR 99, noise impacts at several multi-family residences on the east side of SR 99 would be eliminated. Impacts on the Citadel Church and Open Door Baptist Church would not occur with this combination because they would be displaced.

With the Kent/Des Moines SR 99 Median Station Option, there would be fewer severe noise impacts, and slightly more moderate noise impacts. The change in noise impacts is because the alignment and track crossover is relocated in the median of the roadway, farther away from noise-sensitive properties.

With the Kent/Des Moines SR 99 East Station Option, moderate noise impacts would increase, while severe noise impacts would decrease. New moderate noise impacts were identified along 30th Avenue S, while noise impacts on the west side of SR 99 are eliminated because the alignment is relocated on the east side of the highway.

260th Station Options

Under the S 260th West Station Option, severe and moderate noise impacts are reduced because the alignment is located on the west side of SR 99, farther away from two mobile home parks, the Sunset Hotel, and the Crossland Economy Studios hotel.

Under the S 260th East Station Option, the moderate noise impacts would increase while the severe noise impacts would decrease, for a net decrease in noise impacts. The reduced noise impacts are a result of the alignment being relocated on the east side of SR 99, away from the noise-sensitive properties on the west side of the highway.

S 272nd Redondo Trench Station Option

With the S 272nd Redondo Trench Station Option, a number of severe impacts would either be reduced to moderate or would not occur, and the number of moderate noise impacts would be reduced. This would result in an overall reduction in impacts. The reduction in severe impacts is because the alignment is moved off Highway 99 and placed in a trench from just south of S 268th Street to just south of S 279th Street.

Federal Way SR 99 Station Option

With the Federal Way SR 99 Station Option, there would be an increase in severe impacts and a decrease in moderate impacts related to changing displacements near the station. Moderate noise impacts at the Clarion Hotel would be eliminated, but new severe noise impacts would occur at the Comfort Inn Hotel, for a net increase in impacts.

6.1.2.2 I-5 Alternative

There would be moderate noise impacts on 982 units and severe noise impacts on 468 units with the I-5 Alternative. The impacts would be distributed throughout the entire length of the alternative, and many of the properties where impacts would occur are multi-family complexes or motels, which increases the number of impacts.

At the northern end of the corridor, severe noise impacts were identified at the Skyway Inn and America's Best Value Inn, as well as at the Sleep Inn, King's Arms, and New Best Inn motels. Additional severe noise impacts are also predicted at single-family homes on S 211th Street, S 219th Street, S 259th Court, and along 31st Lane S. Severe noise impacts at multi-family residences were identified at the Wintergreen Place Apartments, a mobile home park on 28th Avenue S, the Newport Village Condominiums, and the Silverwood Apartments.

Moderate impacts in the northern end of the corridor were identified at the Best Western hotel, the Sleep Inn motel, and at single-family homes on S 208th Street, S 211th Street, 31st Lane S, 32nd Lane S, 31st Avenue S, 35th Avenue S, S 224th Street, S 252nd Street, S 253rd Street, the area west of 30th Avenue S between S 252nd Street and S 260th Street, and between S 240th Street and S 260th Street on the east side of I-5. Moderate multi-family residence noise impacts were predicted for the Firs Mobile Home Park, the Willow Lake Apartments, the mobile home park on 28th Avenue S, the area west of 29th Avenue S at 220th Street, the Wintergreen Place Apartments, along 30th Avenue S and to the west between S 221st Street and Kent-Des Moines Road, Midway Mobile Home Mansions, and the Pembrooke apartment complex.

Noise impacts were also identified along the east side of I-5, from S 240th Street to just north of S 255th Street, along the part of the alignment that would be elevated. All impacts on the east side would be moderate and either just meet the FTA impact criteria or exceed it by only 1 to 2 dBA, with impacts occurring even though the alignment is on the west side of I-5.

In the southern end of the corridor, severe noise impacts are predicted at the Clarion Hotel. For single-family homes, severe noise impacts are predicted on Star Lake Road just north of Military Road, S 284th Street, S 304th Street, Military Road S at S 304th Street, and 28th Avenue S near S 317th

Street. The Camelot Square Mobile Home Park would also have severe noise impacts. Moderate impacts in the southern end of the corridor were identified at residences between the Mark Twain Elementary School and Military Road S and again between Military Road S and S 288th Street. Moderate single-family residence impacts were also identified at the pocket of homes just south of the Camelot Square Mobile Home Park and all the way to S 317th Street along Military Road S and 28th Avenue S. Multi-family noise impacts would occur at the Camelot Square Mobile Home Park, Providence Landing apartments, Willamette Court apartments, and the Senior City apartment building.

The Mark Twain Elementary School, located just south of S 272nd Street, is predicted to be 6 dB below the FTA impact criteria because the alignment would be in a deep, lidded trench between I-5 and the school. There are no other FTA Category 3 noise impacts under the I-5 Alternative.

Kent/Des Moines Station Options

With the Kent/Des Moines At-Grade Station Option, the number of moderate impacts would decrease slightly and the number of severe impacts would increase, with an overall increase in the total number of noise impacts. The change in noise impacts would be a result of the realignment of the guideway and fewer residential displacements. Nearly all of the additional severe impacts would occur at the Green Acres Mobile Home Park and surrounding apartments. Conversely, there would be a reduction in impacts at homes on the east side of I-5, and the Midway Mobile Home Mansions would no longer have moderate impacts. No Category 3 impacts were identified under the Kent/Des Moines At-Grade Station Option.

With the Kent/Des Moines SR 99 East Station Option, there would be an increase in both moderate and severe impacts. The King's Arms Motel would no longer have any impacts. Similarly, the Highline Court Apartments would not have any impacts, and the New Best Inn Motel would have only moderate impacts. The number of impacts at homes on the east side of I-5 would be reduced where the alignment is along SR 99 and transitioning back toward the interstate. No Category 3 impacts were identified under the Kent/Des Moines SR 99 East Station Option.

Landfill Median Alignment Option

With the Landfill Median Alignment Option, there would be additional moderate and severe noise impacts. The number of moderate impacts would increase along the east side of I-5 where the alignment would be in the I-5 median. In addition, the number of moderate impacts would increase where the alignment transitions back to the west side of I-5 because it would be elevated in a location that would be at-grade with the I-5 Alternative. For the same reason, the number of moderate impacts would decrease and the number of severe impacts would increase at the Pembrooke apartments on 27th Place S. No Category 3 impacts were identified under the Landfill Median Alignment Option.

Federal Way City Center Station Options

Relative to the I-5 Alternative, the Federal Way I-5 Station Option would have an overall increase in the number of noise impacts due to impacts at the Hampton Inn, Marriott Courtyard Hotel, Best Western Plus Inn and Suites, and a group care home on 28th Avenue S near S 317th Street. Conversely, the Clarion Hotel, Willamette Court apartments, and Senior City apartments would not have any impacts under this alternative. No Category 3 impacts were identified with the Federal Way I-5 Station Option.

With the Federal Way S 320th Park-and-Ride Station Option, the alignment would be farther away from several large multi-family complexes north of S 317th Street. The result would be a reduction in the total number of noise impacts, although there would be new moderate impacts at the Belmor Park Mobile Homes. No Category 3 impacts were identified under the Federal Way S 320th Park-and-Ride Station Option.

6.1.2.3 SR 99 to I-5 Alternative

With the SR 99 to I-5 Alternative, there would be 1,452 moderate noise impacts and 738 severe noise impacts. These numbers include impacts at residential units and FTA Category 3 land uses. North of Kent-Des Moines Road, the impacts would be the same as with the SR 99 Alternative. As the alignment transitions from SR 99 to I-5 in the vicinity of the Kent-Des Moines Road, there would be 147 severe and 272 moderate impacts. South of S 240th Street, the impacts would be the same as with the I-5 Alternative. The three Category 3 noise impacts identified under the SR 99 to I-5 Alternative are: the Citadel Church, the Open Door Baptist Church, and the Jesus Christ Salt and Light Church.

Impacts from station options would be the same as described above under the SR 99 or I-5 alternatives for applicable station and alignment options.

6.1.2.4 I-5 to SR 99 Alternative

With the I-5 to SR 99 Alternative, there would be 1,629 moderate noise impacts and 1,313 severe noise impacts. North of Kent-Des Moines Road, the impacts would be the same as with the I-5 Alternative. As the alignment transitions from I-5 to SR 99 in the vicinity of the Kent-Des Moines Road, there would be 57 severe and 145 moderate impacts. South of S 240th Street, the impacts would be the same as with the SR 99 Alternative.

Impacts from station options would be the same as described above under the SR 99 or I-5 alternatives for applicable station and alignment options with the exception of the S 260th West Station Option. Because the S 260th West Station Option modifies the alignment of the SR 99 Alternative beginning at the Kent-Des Moines Road, which is south of the start of the I-5 to SR 99 crossover, there is a slight difference in the total impacts for this station option. With this option, severe and moderate noise impacts are reduced because the alignment is located on the west side of SR 99, farther away from two mobile home parks and the Crossland Economy Studios hotel. This option would have more impacts with the I-5 to SR 99 Alternative than with the SR 99 Alternative because it would be closer to a motel and mobile home park on the east side of SR 99, south of S 240th Street.

6.1.3 Noise Impacts from Park-and-Rides and Stations

Noise from park-and-rides and stations with parking lots and garages was evaluated for noise impacts under the FTA and applicable local noise control ordinances. Mitigation for these impacts would be different than mitigation for light rail noise impacts, and both types of impacts would need to be mitigated. Table 6-2 provides a summary of the impacts for each park-and-ride and station by alternative. There would be no impacts under FTA criteria for any station.

TABLE 6-2
Summary of Projected Park-and-Ride and Station Noise Impacts

Alternative	FTA Impacts[a]		Local Ordinance Impacts (Leq)[b]	Potential Mitigation
	Mod	Sev		
SR 99 Alternative Stations				
Kent/Des Moines SR 99 West Station	0	0	8	Sound walls and station design
SR 99 Station Options				
Kent/Des Moines HC Campus Station Option	--	--	-8	N/A
Kent/Des Moines SR 99 Median Station Option	--	--	--	Sound walls and station design
Kent/Des Moines SR 99 East Station Option	--	--	--	Sound walls and station design
S 272nd Redondo Trench Station Option	--	--	--	N/A
Federal Way SR 99 Station Option	--	--	--	N/A
I-5 Alternative Stations				
Kent/Des Moines I-5 Station	--	--	--	N/A
S 272nd Star Lake Station	--	--	--	N/A
Federal Way Transit Center Station	--	--	--	N/A
I-5 Station Options				
Kent/Des Moines At-Grade Station Option	--	--	--	N/A
Kent/Des Moines SR 99 East Station Option	--	--	+8	Sound walls and station design
Federal Way I-5 Station Option	--	--	--	N/A
Federal Way S 320th Park-and-Ride Station Option	--	--	--	N/A
SR 99 to I-5 Alternative Stations				
Kent/Des Moines 30th Ave East Station	--	--	--	N/A
S 272nd Star Lake Station	--	--	--	N/A
Federal Way Transit Center Station	--	--	--	N/A
SR 99 to I-5 Station Options				
Federal Way I-5 Station Option	--	--	--	N/A
Federal Way S 320th Park-and-Ride Station Option	--	--	--	N/A
I-5 to SR 99 Alternative Stations				
Kent/Des Moines 30th Ave West Station	--	--	8	Sound walls and station design
S 272nd Redondo Station	--	--	--	N/A
Federal Way Transit Center Station	--	--	--	N/A
I-5 to SR 99 Station Option Impacts				
S 272nd Redondo Trench Station	--	--	--	N/A
Federal Way SR 99 Station Option	--	--	--	N/A

[a] Station impacts under the FTA criteria.
[b] Station impacts using the local noise code criteria.
N/A = not applicable

6.1.3.1 SR 99 Alternative Stations

Under the SR 99 Alternative, eight noise impacts are predicted under the local noise ordinance at a mobile home park near the Kent/Des Moines SR 99 West Station.

Although noise levels would increase by 2 to 3 dB in the immediate area, no noise impacts are predicted near the S 272nd Redondo Station or the Federal Way Transit Center Station.

SR 99 Station Options

The Kent/Des Moines HC Campus Station Option is predicted to have no noise impacts from the park-and-ride or station. The Kent/Des Moines SR 99 Median Station Option and the Kent/Des Moines SR 99 East Station Option are both predicted to have the same number of impacts as the Kent/Des Moines SR 99 West Station. There would be no station noise impacts with either the S 272nd Redondo Trench Station Option or the Federal Way SR 99 Station Option. All impacts are at sites that also have noise impacts under the FTA light rail analysis.

6.1.3.2 I-5 Alternative Stations

There are no station-related noise impacts predicted under the I-5 Alternative.

I-5 Station Options

The only I-5 station option that would have any impacts would be the Kent/Des Moines SR 99 East Station Option, with eight noise impacts at a mobile home park.

6.1.3.3 SR 99 to I-5 Alternative

There are no station-related noise impacts predicted under the SR 99 to I-5 Alternative. None of the station options would have any impacts.

6.1.3.4 I-5 to SR 99 Alternative

With the Kent/Des Moines 30th Avenue West Station there would be 8 noise impacts to a mobile home park. There would be no noise impacts at any other stations. None of the station options would have any impacts.

6.2 Traffic Noise Assessment

There are a few locations in the project corridor where new roads would be constructed or existing shielding would be removed (in the case of buildings) or relocated (in the case of existing sound walls). Predicted noise impacts from light rail operations, particularly from elevated alignments, can affect two to three rows of noise-sensitive receivers. Where the light rail alignment is within or adjacent to roadways or the highway, it is unlikely that potential increases in exposure to existing traffic noise would occur at properties not already identified as impacted by light rail noise. In addition, the light rail guideway (including sound barriers for light rail noise mitigation) and other project elements (such as garage structures or elevated stations) would provide some shielding from traffic noise. Areas with potential for increased traffic noise levels are described by alternative below. Traffic noise will be evaluated for the Preferred Alternative in the Final EIS for locations where the conditions described above occur.

6.2.1 SR 99 Alternative

There are multiple locations along the SR 99 corridor that currently equal or exceed 66 dBA during the peak hour of traffic noise. Because of the speed of vehicles on SR 99 and spacing between intervening buildings, traffic noise levels at or above 66 dBA are likely to occur up to 250 to 400 feet from the curb line of the roadway, depending on existing shielding and topographical conditions in the area. In areas with cross streets that are also major arterials with high traffic volumes, the area at or above the NAC could increase to over 400 feet from SR 99, as noise from some major arterials also currently meets or exceeds the NAC.

There are six areas where property acquisitions and/or roadway alterations associated with the SR 99 Alternative might result in traffic noise levels exceeding the NAC at nearby homes. These locations are:

- The new S 236th Lane that would be constructed for access to the Kent/Des Moines station and/or parking associated with the SR 99 Alternative and its options
- The S 272nd Redondo Station (including the trench option for this station), where a new road would be constructed for access to S 272nd Street
- S 224th Street where buildings would be removed for a traction power substation on the east side of SR 99
- Kent-Des Moines Road and S 240th Street, where buildings would be removed on the west side of the road for the alignment to the Kent/Des Moines Station
- South of S 240th Street, where buildings would be removed on the west side of the road for the alignment to the Kent/Des Moines Station
- S 304th Street, where a building would be removed on the east side of SR 99 for road widening

Properties that could have increased exposure to traffic noise in these areas would already be subject to light rail noise impacts and/or park-and-ride noise impacts (if located near a station). The design of the station and parking structures may provide new shielding and reduce the potential for traffic noise impacts.

6.2.1.1 SR 99 Station Options

For the SR 99 station options, exposure to traffic noise could occur at the following locations where buildings that currently provide shielding would be removed:

- S 216th Street, for both potential station options in this area
- West side of SR 99 between S 216th Street and Kent-Des Moines Road, where additional buildings would be removed with the HC Campus Station Option from S 216th West Station Option
- East side of SR 99 between Kent-Des Moines Road and S 240th Street, where buildings would be removed on the west side of the road for the alignment to the Kent/Des Moines Station
- Near S 246th Street for the S 260th West Station Option, where additional buildings would be removed for the alignment to this potential additional station
- Near S 260th Street for the S 260th East Station Option, where additional buildings would be removed for the alignment to this potential additional station

6.2.2 I-5 Alternative

Traffic noise at properties adjacent to I-5 may currently be influenced by physical shielding (e.g., from berms and other structures), noise walls, and topography. In most areas, existing noise levels are

66 dBA or greater. Based on measured noise levels and proximity to I-5 travel lanes, the NAC is exceeded at distances up to 400 to 600 feet from I-5, and most existing shielding is not effective at reducing noise levels. For example, typical daytime noise levels behind an existing traffic noise wall at the Camelot Square Manufactured Home Park were measured at 69 to 73 dBA Leq.

There are five areas where property acquisitions and/or roadway alterations associated with the I-5 Alternative might result in traffic noise levels exceeding the NAC at nearby homes. These locations are:

- From S 212th Street to Kent-Des Moines Road, where buildings would be removed and topography would be changed for the alignment
- The new S 236th Lane that would be constructed for access to the Kent/Des Moines station and/or parking
- The realignment of 28th Avenue S north of the Star Lake Park-and-Ride
- North of the Star Lake Park-and-Ride at S 272nd Street, where buildings would be displaced for the alignment
- Camelot Square Mobile Home Park, south of S 288th Street, where an existing sound wall would be relocated for the alignment

The design of the station and parking structures may also provide new shielding and reduce the potential for traffic noise impacts where they could occur near stations.

6.2.2.1 I-5 Station and Alignment Options

The only station or alignment option that would have potential for traffic noise impacts would be the Federal Way S 320th Park-and-Ride Station Option, where there would be a loss of shielding south of S 324th Street on the east side of the Belmor Mobile Home Park. The Kent/Des Moines At-Grade Station Option would have a station access road at S 242nd Street instead of S 236th Street, but there are no noise-sensitive land uses in this area.

6.2.3 SR 99 to I-5 Alternative

Potential for traffic noise impacts from the SR 99 to I-5 Alternative would be the same as both the SR 99 Alternative north of Kent/Des Moines Road and the I-5 Alternative south of S 240th Street. The Kent/Des Moines 30th Avenue East Station would also include the S 236th Lane extension and therefore would have potential for traffic noise impacts. As with the SR 99 and I-5 alternatives, mitigation for park-and-ride noise may mitigate any traffic noise impacts as well. Potential for traffic noise impacts from station options would be the same as for the potential additional stations at S 216th Street and the Federal Way S 320th Park-and-Ride Station Option.

6.2.4 I-5 to SR 99 Alternative

Potential for traffic noise impacts from the I-5 to SR 99 Alternative would be the same as both the I-5 Alternative north of Kent/Des Moines Road and the SR 99 Alternative south of S 240th Street. The Kent/Des Moines 30th Avenue West Station would also include the S 236th Lane extension and therefore would have potential for traffic noise impacts. As with the SR 99 and I-5 alternatives, mitigation for park-and-ride noise may mitigate any traffic noise impacts as well. Potential for traffic noise impacts from station options would be the same as for the potential additional stations at S 260th Street.

6.3 Vibration Impacts

This section presents the results of the detailed assessment of vibration impacts from train operations. The assessment was based on the FTA methodology discussed in Section 4, Noise and Vibration Impact Criteria. The inputs for the assessment include distance from the receivers to the tracks, train speeds, track type, and other relevant information such as proximity to special track work. The dwelling units for multi-family residences and hotels were grouped either based on relative proximity to the tracks, or based on the number of floors within the buildings. This grouping of dwelling units within the same parcel or building is identical for both noise and vibration analysis of the FWLE. The assessment is based on the conceptual design prepared for this Draft EIS. The results of the vibration assessment for each alternative and the options are discussed below.

6.3.1 SR 99 Alternative

The projected vibration impacts for the SR 99 Alternative are shown in Table 6-3. Vibration impacts are predicted at the Best Western Hotel because the edge of the nearest track for this alternative would be 10 feet from the facade of the building. Vibration impacts are predicted at 50 units of the hotel. The predicted maximum vibration level is 82 VdB at the 50-Hz 1/3-octave band.

TABLE 6-3
SR 99 Alternative, Potential Vibration Impacts for SR 99 Alternative

Address	Distance to Nearest Track (ft.)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
20717 International Blvd[a]	10	55	82	50	72	1	26
20717 International Blvd[b]	10	55	82	50	72	1	24
					Total	**2**	**50**

[a] Rooms located on the east side of the Best Western Hotel.
[b] Rooms located on the south side of the Best Western Hotel.

6.3.1.1 S 216th Station Options

No vibration impacts are predicted with the S 216th West Station Option because the Best Western Hotel is displaced for this option.

With the S 216th East Station Option, there would be an additional 16 units with impacts at the New West Hotel on International Blvd, as shown in Table 6-4. These would be in addition to vibration impacts at the Best Western Hotel with the SR 99 Alternative.

TABLE 6-4
Potential Vibration Impacts for S 216th East Station Option

Address	Distance to Nearest Track (ft.)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
21450 International Blvd[a]	15	45	80	50	72	1	16
					Total	**1**	**16**

[a] New West Hotel

Kent/Des Moines Station Options

The Kent/Des Moines HC Campus Station Option would have additional vibration impacts at a future multi-family residence at the SeaMar development (under construction), as shown in Table 6-5. The impacts are due to proximity of the tracks to the future residential units. The vibration levels are predicted to exceed the FTA impact criteria at 12 residences.

TABLE 6-5
Potential Vibration Impacts for Kent/Des Moines HC Campus Station Option

Address	Distance to Nearest Track (ft.)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
24215 Pacific Hwy[a]	10	55	81	63	72	1	4
24215 Pacific Hwy[a]	10	55	81	63	72	1	4
24215 Pacific Hwy[a]	10	55	81	63	72	1	4
					Total	**3**	**12**

[a] SeaMar multi-family residences with four units each in three floors (under construction).

The Kent/Des Moines HC Campus Station Option would also have additional vibration impacts when connecting to the S 216th West Station Option, as shown in Table 6-6. This is because of a lower profile north of Kent-Des Moines Road. Additional vibration impacts would occur at three single-family residences, a multi-family residence, and at multi-family residential units at the SeaMar development (under construction). The vibration levels are predicted to exceed the FTA impact thresholds at a total of 28 dwelling units at residences. Note that the vibration impact criterion is higher for the church because it is a FTA Category 3 land use. There would be a net decrease in impacts with this combination of options because the Best Western Hotel impacted by the SR 99 Alternative would be displaced, and those 50 impacts would no longer occur.

No additional vibration impacts are predicted for any of the other Kent/Des Moines station options.

TABLE 6-6
Potential Vibration Impacts for Kent/Des Moines HC Campus Station Option from S 216th West Station Options

Address	Distance to Nearest Track (ft.)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
2628 222nd St[a]	10	55	81	63	72	1	1
22620 28th Ave S[b]	45	55	72	63	72	1	5
22620 28th Ave S[b]	45	55	72	63	72	1	5
22620 28th Ave S[b]	45	55	72	63	72	1	3
2809 S 240th St[a]	10	55	81	63	72	1	1

TABLE 6-6
Potential Vibration Impacts for Kent/Des Moines HC Campus Station Option from S 216th West Station Options

Address	Distance to Nearest Track (ft.)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
2803 S 240th St [a]	25	55	78	63	72	1	1
24215 Pacific Hwy[c]	10	55	81	63	72	1	4
24215 Pacific Hwy[c]	10	55	81	63	72	1	4
24215 Pacific Hwy[c]	10	55	81	63	72	1	4
					Total	**9**	**28**

[a] Single-family residences.
[b] Multi-family residences.
[c] SeaMar multi-family residences with four units each in three floors (under construction).

S 260th Station Options

There would be twelve additional vibration impacts for the S 260th West Station Option compared to the SR 99 Alternative as shown in Table 6-7. The S 260th East Station Option would have two additional impacts, as shown in Table 6-8.

TABLE 6-7
Potential Vibration Impacts for S 260th West Station Option

Address	Distance to Near Track (ft.)	Speed (mph)	Maximum 1/3 Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
24215 Pacific Hwy[a]	15	55	80	50	72	1	4
24215 Pacific Hwy[a]	15	55	80	50	72	1	4
24215 Pacific Hwy[a]	15	55	80	50	72	1	4
					Total	**3**	**12**

[a] SeaMar multi-family residences with four units each in three floors (under construction).

TABLE 6-8
Potential Vibration Impacts for S 260th East Station Option

Address	Distance to Near Track (ft.)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
26430 SR 99[a]	10	55	82	50	72	1	1
26448 SR 99[a]	35	55	82	50	72	1	1
					Total	**2**	**2**

[a] Single-family residences.

S 272nd Redondo Trench Station Option

A summary of the vibration impact analysis is shown in Table 6-9. Vibration impacts are predicted at two single-family residences, two multi-family residences, and the Federal Way Motel for a total of 181 additional dwelling units.

TABLE 6-9
Potential Vibration Impacts for S 272nd Redondo Trench Station Option

Address	Distance to Near Track (ft.)	Speed (mph)	Maximum 1/3 Octave Vibration Level (VdB)	11/3-Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
1560 S 284th St[a]	30	55	73	63	72	1	1
28418 16th Ave S[b]	20	55	78	63	72	1	6

TABLE 6-9
Potential Vibration Impacts for S 272nd Redondo Trench Station Option

Address	Distance to Near Track (ft.)	Speed (mph)	Maximum 1/3 Octave Vibration Level (VdB)	11/3-Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
28418 16th Ave S[b]	20	55	78	63	72	1	6
28418 16th Ave S[b]	20	55	78	63	72	1	6
28611 16th Ave S[a]	30	55	74	50	72	1	1
29815 Pacific Hwy S[c]	10	55	82	50	72	1	13
29815 Pacific Hwy S[c]	10	55	87	50	72	1	14
27606 Pacific Hwy S[d]	10	40	89[e]	50	72	1	67
27606 Pacific Hwy S[d]	10	40	89[e]	50	72	1	67
					Total	**9**	**181**

[a] Single-family residences.
[b] Multi-family residences in the same building but different floors.
[c] Federal Way Motel.
[d] Multi-family residences in the same building but different floors.
[e] Includes +10-dB adjustment to account for amplification from the crossover frogs.

Federal Way SR 99 Station Option

There would be no additional vibration impacts for this option compared to the SR 99 Alternative.

6.3.2 I-5 Alternative

The predicted vibration impacts for the I-5 Alternative are shown in Table 6-10. Vibration impacts are predicted at two single-family residences, one multi-family residence, two motels, a mobile home park, and a 23-unit group care home. The predicted impacts at the sensitive receivers are a result of proximity to tracks.

TABLE 6-10
Potential Vibration Impacts for I-5 Alternative

Address	Distance to Near Track, ft.	Speed, mph	Maximum 1/3 Octave Vibration Level, VdB	1/3 Octave Band, Hz	Vibration Impact Criterion, VdB	No. of Potential Impacts	No. of Impacted Dwelling Units
20620 International Blvd[g]	25	45	75	50	72	1	34
3118 S 216th St[a]	40	55	73	63	72	1	2
3118 S 216th St[a]	40	55	73	63	72	1	2
22700 30th Ave S[c]	25	55	77	63	72	1	7
23226 30th Ave S[d]	20	55	78	50	72	1	20
3001 S 288th St[e]	40	55	73	63	72	1	53
3006 S 288th St[e]	25	55	78	63	72	1	79
30432 Military Rd S[b]	10	55	82	50	72	1	1
31228 28th Ave S[b]	70	55	87[h]	63	72	1	1
31524 28th Ave S[f]	20	45	81	50	72	1	23
					Total	**10**	**222**

[a] Multi-family residential units located in the same building but different floors.
[b] Single-family residences.
[c] Multi-family residence.
[d] East side of King's Arms Motel.
[e] Camelot Square mobile home park.
[f] The 23-unit group care home.
[g] West side of America's Best Value Inn.
[h] Includes +7-dB adjustment to account for amplification from the crossover frogs.

Kent/Des Moines Station Options

The Kent/Des Moines At-Grade Station Option would have one additional impact at a single-family residence (see Table 6-11). The Kent/Des Moines SR 99 Station Option would have 20 fewer impacts because the King's Arms Motel would be displaced with this option.

TABLE 6-11
I-5 Alternative, Potential Vibration Impacts for Kent/Des Moines At-grade Station Option

Address	Distance to Near Track (ft.)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3-Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
23208 30th Ave S[a]	30	55	73	50	72	1	1
					Total	**1**	**1**

[a] Single-family residence.

Landfill Median Alignment Option

There would be no additional vibration impacts with this option.

Federal Way City Center Station Options

There would be no additional vibration impacts with the Federal Way I-5 Station Option.

There would be additional vibration impacts at 25 homes inside the Belmor Mobile Home Park with the S 320th Park-and-Ride Station Option (Table 6-12). The mobile home park is located adjacent to the tail tracks at the end of the alignment and the trains would be moving very slowly, vibration impacts are predicted at the first row of residences because of the crossover. However, 23 impacts at a group care home would no longer occur, resulting in impacts on the same number of properties overall and a net increase of only 2 impacts.

TABLE 6-12
I-5 Alternative, Potential Vibration Impacts for Federal Way S 320th Park-and-Ride Station Option

Address	Distance to Near Track (ft.)	Speed (mph)	Maximum 1/3 Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
2101 S 324th St[a]	10	10	76	50	72	1	25
					Total	**1**	**25**

[a] Belmor Mobile Home Park.

6.3.3 SR 99 to I-5 Alternative

Table 6-13 summarizes the predicted vibration impacts from the SR 99 to I-5 Alternative. Vibration impacts are predicted at the Best Western Hotel, a duplex, a mobile home park, two single-family residences, and a 23-unit group care home.

Impacts from station options would be the same as described above under the SR 99 or I-5 alternatives for applicable station and alignment options.

TABLE 6-13
Potential Vibration Impacts for SR 99 to I-5 Alternative

Address	Distance to Near Track (ft.)	Speed (mph)	Maximum 1/3 Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
20717 International Blvd[a]	10	55	82	50	72	1	26
20717 International Blvd[b]	10	55	82	50	72	1	24
23205 30th Ave S[c]	10	55	82	50	72	1	2
3001 S 288th St[d]	40	55	73	63	72	1	53
3006 S 288th St[d]	25	55	78	63	72	1	79
30432 Military Rd S[e]	10	55	82	50	72	1	1
31228 28th Ave S[e]	70	55	87[g]	63	72	1	1
31524 28th Ave S[f]	20	45	81	50	72	1	23
					Total	**8**	**209**

[a] Rooms located on the east side of the Best Western Hotel.
[b] Rooms located on the south side of the Best Western Hotel.
[c] Duplex on 30th Avenue.
[d] The Camelot Square Mobile Home Park.
[e] Single-family residences.
[f] The 23-unit group-care home.
[g] Includes +7-dB adjustment to account for amplification from the crossover frogs.

6.3.4 I-5 to SR 99 Alternative

Table 6-14 summarizes predicted vibration impacts from the I-5 to SR 99 Alternative. The vibration impacts are predicted at three multi-family residences and a hotel.

TABLE 6-14
Potential Vibration Impacts for I-5 to SR 99 Alternative

Address	Distance to Near Track (ft.)	Speed (mph)	Maximum 1/3 Octave Vibration Level (VdB)	1/3 Octave Band (Hz)	Vibration Impact Criterion (VdB)	No. of Potential Impacts	No. of Impacted Dwelling Units
20620 International Blvd[e]	25	45	75	50	72	1	34
3118 S 216th St[a]	40	55	73	63	72	1	2
3118 S 216th St[a]	40	55	73	63	72	1	2
22700 30th Ave S[b]	25	55	77	63	72	1	7
					Total	**4**	**45**

[a] Multi-family residential units located in the same building but different floors.
[b] Multi-family residences.
[c] West side of the multi-family residential building.
[d] North side of the multi-family residential building.
[e] West side of America's Best Value Inn.

Impacts from station options would be the same as described above under the SR 99 or I-5 alternatives for applicable station and alignment options, except for the S 260th West Station Option. For this option, there would be no additional impacts because it would be located farther from the sensitive receivers on the west side of SR 99 that are impacted with this option when it connects to the SR 99 Alternative.

6.4 Groundborne Noise Impacts

This section discusses the groundborne noise (GBN) impacts from FWLE train operations. As discussed in Section 4, GBN impacts were not assessed for FTA Category 1, 2, and 3 sensitive receivers because the track for all alternatives and options is above or just below ground level, and airborne noise from normal operations is higher than that from GBN. The Performing Arts Center at Federal Way High School (currently under construction), which qualifies as a special building, would be located within 100 feet of the proposed tracks for the SR 99 Alternative and the I-5 to SR 99 Alternative. GBN levels at this location would be 35 dBA, which is 10 dBA above the FTA criterion of 25 dBA, resulting in a potential GBN impact on this facility from these alternatives. There are no special buildings near the I-5 Alternative and the SR 99 to I-5 Alternative.

6.4.1 SR 99 Alternative

The projected GBN impacts for the SR 99 Alternative are shown in Table 6-3. Groundborne noise impacts are predicted at the Federal Way High School Performing Arts Center.

TABLE 6-15
SR 99 Alternative, Potential Groundborne Noise Impacts for SR 99 Alternative

Address	Distance to Nearest Track (ft.)	Speed (mph)	Predicted GBN Levels	GBN Impact Criterion (dBA)	No. of Potential Impacts
31031 Pacific Hwy[a]	5	55	35[b]	25	1
				Total	**1**

[a] The Federal Way High School Performing Arts Center (under construction).
[b] The predictions are based on conservative assumptions and should be verified during final design.

6.4.2 I-5 to SR 99 Alternative

The projected GBN impacts for the I-5 to SR 99 Alternative are shown in Table 6-3. GBN impacts are predicted at the new Federal Way High School Performing Arts Center (under construction).

TABLE 6-16
I-5 to SR 99 Alternative, Potential Groundborne Noise Impacts for I-5 to SR 99 Alternative

Address	Distance to Nearest Track (ft.)	Speed (mph)	Predicted GBN Levels	GBN Impact Criterion (dBA)	No. of Potential Impacts
31031 Pacific Hwy[a]	5	55	35[b]	25	1
				Total	**1**

[a] The Federal Way High School Performing Arts Center (under construction).
[b] The predictions are based on conservative assumptions and should be verified during final design.

6.5 Construction

6.5.1 Construction Noise Impact Analysis

The construction noise analysis considers the temporary noise impacts that construction would cause in the project vicinity. These impacts would end when project construction was completed.

Noise related to construction would result from the operation of heavy equipment needed to construct various project components, including elevated structures, retaining walls, park-and-ride facilities, and stations. The contractor would be required to adhere to local ordinances regulating noise, as discussed in Section 4.1. Construction activities outside normal weekday daytime hours would require a noise variance from the city where the work is being performed if regulatory noise levels would be exceeded.

Equipment required to complete the FWLE would include construction equipment typically used for transportation construction projects. Table 6-17 lists the typical equipment used for this type of project, the activities it would be used for, and the corresponding maximum noise levels that would be produced when measured at 50 feet from the sources under normal use.

TABLE 6-17
Construction Equipment and Reference Noise Levels

Equipment	Expected Project Use	Lmax[a, b] (dBA)
Air compressors	Pneumatic tools and general maintenance (all phases)	70 to 76
Backhoe	General construction and yard work	78 to 82
Concrete pump	Pumping concrete	78 to 82
Concrete saws	Concrete removal and utilities access	75 to 80
Crane	Materials handling: removal and replacement	78 to 84
Excavator	General construction and materials handling	82 to 88
Forklifts	Staging area work and hauling materials	72
Haul trucks	Materials handling: general hauling	86
Jackhammers	Pavement removal	74 to 82
Loader	General construction and materials handling	86
Pavers	Roadway paving	88
Pile-drivers	Support for structures and hillsides	99 to 105
Power plants	General construction use: nighttime work	72
Pumps	General construction use: water removal	62
Pneumatic tools	Miscellaneous construction work	78 to 86
Tractor trailers	Material removal and delivery	86
Utility trucks	General project work	72
Vibratory equipment	Soil compaction and shoring up hillsides to prevent slides	82 to 88
Welders	General project work	76

[a] Typical maximum noise level under normal operation as measured at 50 feet from the noise source.
[b] Noise levels presented are based on measured data from the Portland Light Rail and I-5 Preservation and Hawthorne Bridge construction projects and other measured data, as well as U.S. Department of Transportation construction noise documentation and other construction noise sources.

Construction Noise

Several construction phases would be required to complete the FWLE. The *FHWA Roadway Construction Noise Model User's Guide* (FHWA, 2006b) and associated computer model were used to estimate project construction noise levels, as well as to predict the maximum noise levels for several different construction phases. The analysis assumes the worst-case average and maximum noise levels based on three major types of construction described below and shown in Table 6-18. The actual noise levels experienced during construction would generally be lower than those described in Table 6-18 because these are the maximum noise levels for each activity. The noise levels presented here are for short periods of maximum construction activity and would occur for limited periods of time.

TABLE 6-18
Noise Levels for Typical Construction Phases[a]

Scenario[b]	Equipment[c]	Lmax[d]	Leq[e]
Demolition, site preparation, and utilities relocation	Air compressors, backhoes, concrete pumps, cranes, excavators, forklifts, haul trucks, loaders, pumps, power plants, service trucks, tractor trailers, utility trucks, and vibratory equipment	88	87
Structures construction, track installation, and paving activities	Air compressors, backhoes, cement mixers, concrete pumps, cranes, forklifts, haul trucks, loaders, pavers, pumps, power plants, service trucks, tractor trailers, utility trucks, vibratory equipment, and welders	88	82
Miscellaneous activities	Air compressors, backhoes, cranes, forklifts, haul trucks, loaders, pumps, service trucks, tractor trailers, utility trucks, and welders	86	83

[a] Combined worst-case noise levels for all equipment at a distance of 50 feet from work site.
[b] Operational conditions under which the noise levels are projected.
[c] Normal equipment in operation under the given scenario.
[d] Lmax (dBA) is the highest maximum noise level for the construction equipment listed under the given scenario.
[e] Leq (dBA) is a 1-hour energy average noise emission for construction equipment operating under the given scenario.

Demolition, Site Preparation, and Utilities Relocation

Major noise-producing equipment in use during the site preparation stage of light rail construction would include saw cutters, concrete pumps, cranes, excavators, haul trucks, loaders, tractor-trailers, and vibratory equipment. Maximum noise levels could reach 82 dBA to 88 dBA at the nearest residences (i.e., within 50 to 100 feet) for normal construction activities during this phase. Other less-notable noise-producing equipment expected during this phase would include backhoes, air compressors, forklifts, pumps, power plants, service trucks, and utility trucks.

Structures Construction, Track Installation, and Paving Activities

The loudest noise sources in use during construction of elevated structures would include cement mixers, concrete pumps, cranes, pavers, haul trucks, and tractor-trailers. The cement mixers, cranes, and concrete pumps would be required for construction of the light rail superstructure. The pavers and haul trucks would be used to provide the final surface on the trackway during other phases of construction. Maximum noise levels would range from 82 dBA to 88 dBA at the closest receiver locations.

Miscellaneous Activities

Following heavy construction, general construction would still be required, such as installation of guideway railing, signage, and communication and power systems, as well as other miscellaneous activities. These less-intensive activities are not expected to produce noise levels above 80 dBA at 50 feet except during rare occasions, and even then only for short periods of time when combined maximum noise levels could reach 86 dBA Lmax at 50 feet. Using the information in Table 6-17, typical construction noise levels were projected for several distances from the project work area. Exhibit 6-1 is a graph of general construction noise level versus distance for phases of construction.

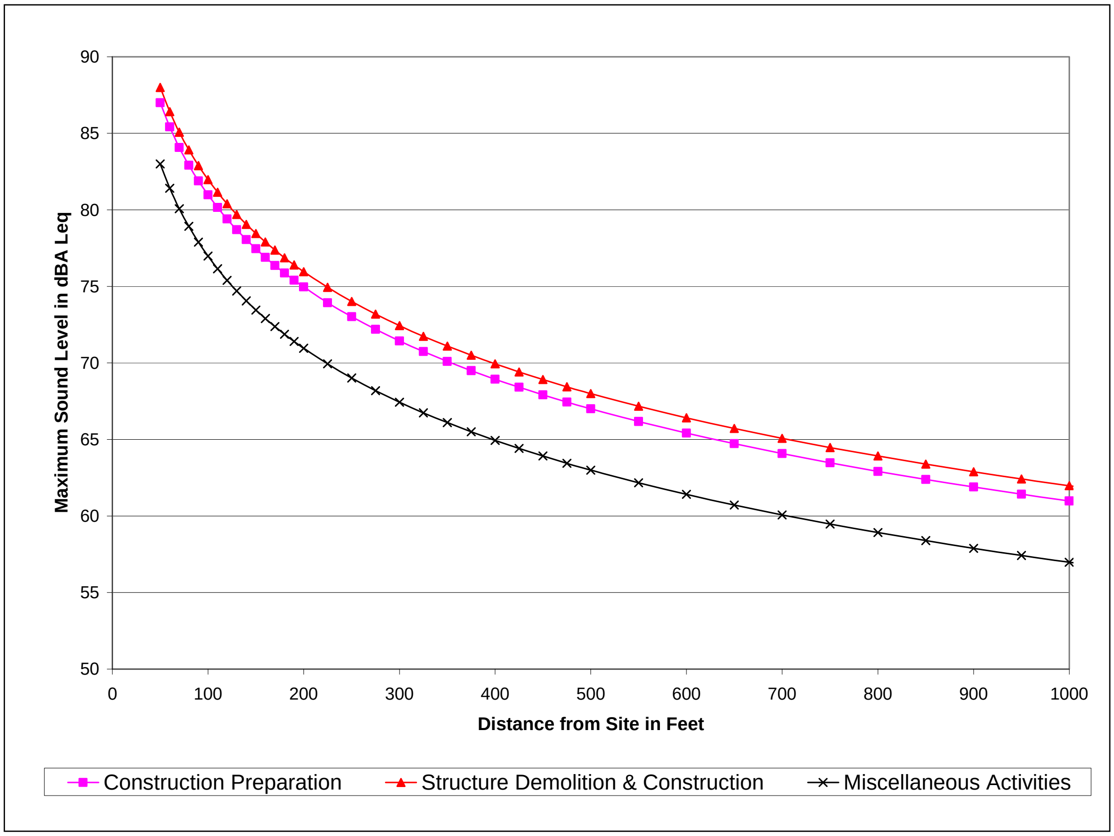


EXHIBIT 6-1
Maximum Noise Level versus Distance for Typical Construction Phases

Pile Driving

Pile driving would likely be required to support permanent structures such as piers for elevated structures and retaining tunnel walls. Pile driving can produce maximum short-term noise levels of 99 dBA to 105 dBA at 50 feet. Actual levels vary and depend on the distance and topographical conditions between the pile-driving location and the receiver location. Exhibit 6-2 is a graph of maximum pile-driving noise levels versus distance.

Nighttime Construction Activities

Some construction activities might be required during nighttime hours because of the nature of the construction or to avoid daytime traffic impacts or impacts on some adjacent land uses. In order to perform construction at night, a noise variance from the local governing agency would be required. If nighttime construction is deemed necessary, Sound Transit would work with each governing agency to obtain any necessary noise variance specific to project construction.

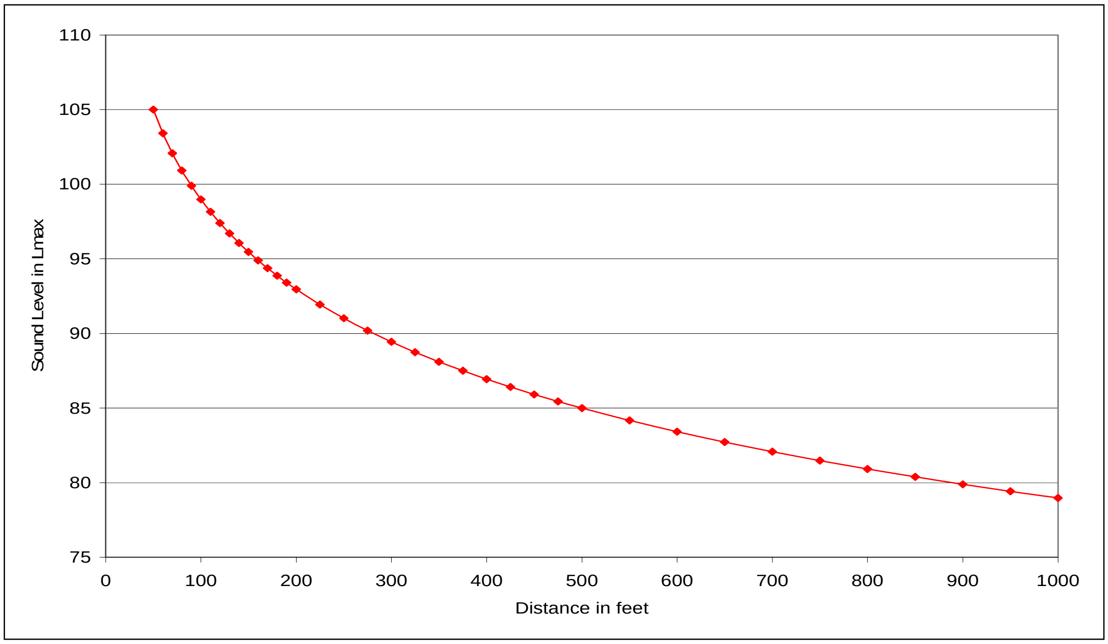


EXHIBIT 6-2
Pile-driving Noise Level versus Distance

6.5.2 Construction Vibration Impacts

Some of the high-vibration activities during construction would involve demolition of buildings, construction of elevated structures, excavation of trenches, pavement breaking, ground compaction, and other related construction activities. Construction of elevated structures would require deep pile foundations. A pile-driver is used to drive the piles into soil to provide support to columns of elevated structures. Traditional construction practices employ impact pile-drivers to build pile foundations. Pile-drivers that are driven by hydraulics have better control on the impact forces and can provide better efficiency in overcoming soil resistance.

The primary concern from construction activities is potential for damage to buildings. Because construction vibration is temporary, it is usually not a major concern for annoyance. The details of the construction means and methods for building this project are not available at this time. The major pieces of high-vibration construction equipment likely to be used in this project are listed in Table 6-19. Because there are several alternatives and options and design details such as location of columns are not available at this time, the construction vibration analysis focused on determining the distance beyond which the damage risk criteria and annoyance criteria would not be exceeded for the major vibration-generating pieces of equipment that are likely to be used for the FWLE. The results of the analysis are summarized in Table 6-19 and the analysis is based on reference peak particle velocity (PPV) levels for the construction equipment from the D to M Street Rail project in Tacoma, Washington, and the FTA Guidance Manual.

TABLE 6-19
Distance to Construction Vibration Impact Thresholds

Equipment	PPV Ref Level at 100 ft. (in./sec)	Distance to Impact Thresholds (feet)			
		Damage Criteria 0.5 in./sec PPV[a]	Damage Criteria 0.2 in./sec PPV[a]	Annoyance Criteria 0.016 in./sec PPV[b]	Annoyance Criteria 0.022 in./sec PPV[b]
Vibratory pile-driver	0.140	45	80	450	350
Impact pile-driver	0.200	55	100	550	425
Sonic pile-driver	0.213	14	23	120	100
Auger drill rig	0.011	8	15	80	65
Cranes	0.001	2	3	16	13
Dozer	0.011	8	15	80	65
Dump truck	0.010	8	15	80	65
Front-end loader	0.011	8	15	80	65
Jackhammer	0.003	4	7	32	26
Mounted hammer hoe ram	0.190	53	97	525	400

[a] The impact threshold for reinforced concrete, timber, or steel buildings is 0.5 in./sec PPV and the impact threshold for nonengineered timber and masonry buildings is 0.2 in./sec PPV.
[b] The impact threshold for annoyance is 0.016 in./sec for residential nighttime use (72 VdB) and 0.022 in./sec for institutional land use (75 VdB).

The key results of the analysis are:

- Most of the equipment can be operated without risk of damage at distances of 15 feet or greater from nonengineered timber and masonry buildings or at distances of 8 feet or greater from reinforced concrete buildings. The exceptions are the mounted hammer hoe ram and impact pile-drivers, which should generally only be operated at an approximate distance of 55 feet or greater from reinforced concrete buildings or a distance of 100 feet from nonengineered timber and masonry buildings.
- Use of alternate pile-driving methods can reduce construction vibration substantially. For example, sonic pile-drivers at lower settings can be operated at distances of 25 feet or greater from historic buildings. Annoyance thresholds at residential land uses can be exceeded from operations of impact pile-drivers and mounted hammer hoe rams at distances greater than 500 feet.
- Most construction equipment can be operated without exceeding the annoyance impact thresholds at distances greater than 80 feet from residential land uses.

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7.0 Potential Noise and Vibration Mitigation Measures

For locations where Sound Transit has identified potential noise impacts, mitigation measures would be considered and reviewed using Sound Transit's Light Rail Noise Mitigation Policy (Sound Transit, 2004). Under this Noise Mitigation Policy, potential mitigation measures would be considered for all noise impacts.

Sound Transit's noise mitigation policy is to mitigate both moderate and severe impacts beginning with source treatment, followed by treatments in the noise path. If source and path treatments are not sufficient to mitigate the impact, Sound Transit would evaluate and implement sound insulation at affected properties where the existing building does not already achieve sufficient exterior-to-interior reduction of noise levels. The following sections provide an introduction to the mitigation strategies normally used for light rail projects. Following this introduction are the mitigation strategies and measures proposed for the FWLE.

During final design, all impacts and potential mitigation measures would be reviewed for verification. If it is discovered that the mitigation can be achieved by less costly means, or if detailed analysis shows no impact, the mitigation measure may be eliminated.

7.1 Potential Noise Mitigation

This section discusses mitigation for noise generated by the operation of the FWLE. Potential mitigation measures for construction noise are discussed in Section 7.3.

7.1.1 Types of Noise Mitigation

7.1.1.1 Noise Source Mitigation

One of the most effective forms of noise mitigation is to reduce noise at the source. One form of source noise reduction is using light rail vehicles with low noise levels. Sound Transit has purchased state-of-the-art, lower-noise vehicles equipped with noise-reducing wheel skirts covering the wheel-rail interface. Several additional operational measures can also be used to reduce noise levels at the source. Table 5-1 (above) lists operational and maintenance measures that Sound Transit performs on a regular basis and the benefits that these measures provide. Source treatments that Sound Transit is currently using to minimize noise impacts include requiring wheel skirts, maintaining smooth tracks, performing vehicle maintenance and wheel truing, and conducting operator training.

Research into methods of reducing wheel squeal noise, including using non-oil-based lubricants (such as water) and friction modifiers, has found such methods effectively reduce or eliminate wheel squeal. The lubricants can be applied by personnel working trackside or by an automated applicator. It is the general policy of Sound Transit to install or prepare for lubrication on any curves with a radius of less than 1,000 feet near noise-sensitive properties. If wheel squeal is identified after system operation begins, it is possible to add lubricators.

When a light rail train travels over special trackwork for crossovers or turnouts, there is a loud clicking noise as the steel wheels go over the gap between the tracks. This can increase noise levels from the train by as much as 10 dBA compared with a smooth track with no gaps. Mitigation for noise impacts from special trackwork can include relocating the crossover or turnout away from noise-sensitive properties, or using special frogs that include gap-closing mechanisms or movable-point frogs, as described in Section 5.1.3. With standard rigid frogs, noise and vibration occurs when the wheels pass over the gap, but a movable-point frog eliminates the gap and one end of the frog moves in the direction of train travel. Other similar options for reducing noise from special trackwork include spring-rail or flange-bearing frogs. Relocation of special trackwork to more than 500 feet from noise-sensitive sites also could be used to eliminate the noise impact from the frogs.

7.1.1.2 Noise Path Mitigation

The next type of mitigation considered would be applied between the noise source and receiver. Typical noise path mitigation includes earth berms, sound walls, and buffer zones. Constructing barriers between the light rail tracks and the affected receivers would reduce noise levels by physically blocking the transmission of noise generated by light rail. Barriers can be constructed as walls or earth berms. Berms require more right-of-way than walls and are usually constructed with a 3-to-1 slope. For the FWLE, berms would not generally be feasible because of topographical conditions and limited right-of-way.

Two types of sound walls are typically used for transit projects. For at-grade segments, the noise barrier type is a standard concrete wall. On the elevated guideway, lightweight acoustical walls that place less load on the structure are used. Sound walls should be high enough to break the line of sight between the noise source and the receiver. The typical height for sound walls is 6 to 8 feet when at-grade and 4 to 6 feet when on elevated structures. Sound walls must also be long enough to prevent flanking of noise around the ends of the walls. Openings in sound walls for driveway connections or intersecting streets greatly reduce the effectiveness of these walls.

Buffer zones are undeveloped open spaces between the noise source and receiver. Buffer zones are created when an agency purchases land or development rights in addition to the normal right-of-way, so that future dwellings cannot be constructed close to the noise source. The FWLE corridor is an urban area where land is at a premium, so creating buffer zones is not a feasible form of noise mitigation because it would require substantially more project-related displacements.

7.1.1.3 Noise Receiver Mitigation

For situations where noise path mitigation would be either unfeasible or ineffective, Sound Transit would consider adding sound insulation to buildings. Sound insulation programs are developed to reduce the interior noise levels in sleeping and living quarters in residential land uses or in noise-sensitive areas such as schools and other institutional uses to within the guidelines set by the U.S. Department of Housing and Urban Development. Under these guidelines, interior noise levels for residential land uses should not exceed 45 dBA Ldn, and a form of fresh air exchange must be maintained. The air exchange can be achieved by opening a window or using a ventilation system. Sound insulation is normally only used on older dwellings with single-paned windows, or in buildings with double-paned windows that are no longer effective because of leakage. Sound insulation would not reduce exterior noise levels.

7.1.2 Transit Noise Mitigation

This section generally describes the potential noise mitigation measures that would be used for the light rail alternatives. The mitigation design is based on the current alignments as provided by the Sound Transit design team and are implemented to meet the requirements of the FTA and the Sound Transit Light Rail Noise Mitigation Policy (Sound Transit, 2004). However, if during final design Sound Transit determines that the relevant noise criterion could be achieved by a less costly means, or that the noise impact at that location would not occur even without mitigation (for example, a revised alignment), then the mitigation measure might be eliminated or modified as needed. Conversely, if any additional noise impacts were identified during final design, then Sound Transit would provide mitigation that is consistent with the Sound Transit Noise Mitigation Policy (Sound Transit, 2004).

Sound walls would be the primary form of noise mitigation for transit noise impacts. Appendix B, Detailed Noise Impact Assessment Data, provides complete details on mitigation, including projected noise levels with the proposed noise mitigation measures for each receiver. A summary of the alternative-specific mitigation measures is presented in the tables in each subsection below.

7.1.2.1 SR 99 Alternative Noise Mitigation

The primary noise mitigation measure for the SR 99 Alternative and options is sound walls, which are summarized in Table 7-1. Locations of sound walls are provided on the maps in Appendix C. Depending on the option, sound walls from 4 to 8 feet high may be required. With these sound walls, the majority of noise impacts would be mitigated. Any residual noise impacts would be mitigated with sound insulation if necessary.

7.1.2.2 I-5 Alternative Noise Mitigation

The primary noise mitigation measure for the I-5 Alternative and options is sound walls, summarized in Table 7-2. Sound walls ranging from 4 to 15 feet high may be required. The taller walls, higher than 6 to 8 feet, are used to mitigate impacts on the upper floors in multi-family units. With these sound walls, the majority of noise impacts would be mitigated. Any residual noise impacts would be mitigated with sound insulation if necessary. Based on the current conceptual design, all noise impacts at mobile home parks could be mitigated with sound walls.

7.1.2.3 SR 99 to I-5 Alternative Noise Mitigation

The primary noise mitigation measure for the SR 99 to I-5 Alternative and options is sound walls. Sound walls for the SR 99 to I-5 Alternative are listed in Table 7-3. With these sound walls, the majority of noise impacts would be mitigated. Any residual noise impacts would be mitigated with sound insulation if necessary.

TABLE 7-1
Summary of Potential Noise Impacts and Mitigation Measures – SR 99 Alternative and Options

Alternative	Proposed Noise Mitigation Measures for Impacts			
	Type	Total Length (not continuous)	Height	Number of Units for Insulation
SR 99 Alternative – West Side	**Sound wall and insulation**	**31,400 feet**	**4 - 8 feet**	**79**
SR 99 Alternative– East Side		**28,400 feet**	**4 - 8 feet**	
S 216th Station Options				
S 216 West Station Option – West Side	Sound wall and insulation	2,700 feet	4 feet	79
S 216 West Station Option – East Side		5,700 feet	4 - 7 feet	
S 216 East Station Option – West Side	Sound wall and insulation	4,000 feet	4 - 8 feet	79
S 216 East Station Option – East Side		4,900 feet	6 - 7 feet	
Kent/Des Moines Station Options				
Kent/Des Moines HC Campus Station Option – West Side	Sound wall and insulation	10,500 feet	4 - 8 feet	114
Kent/Des Moines HC Campus Station Option – East Side		7,900 feet	5 - 7 feet	
Kent/Des Moines HC Campus Station Option to S 216th West Station Option – West Side	Sound wall and insulation	3,300 feet	4 - 9 feet	79
Kent/Des Moines HC Campus Station Option to S 216th West Station Option – East Side		4,100 feet	4 - 6 feet	
Kent/Des Moines SR 99 Median Station Option – West Side	Sound wall and insulation	7,800 feet	4 - 7 feet	112
Kent/Des Moines SR 99 Median Station Option – East Side		7,700 feet	5 - 8 feet	
Kent/Des Moines SR 99 East Station Option - West Side	Sound wall and insulation	7,800 feet	4 - 7 feet	67
Kent/Des Moines SR 99 East Station Option - East Side		7,600 feet	7 feet	
S 260th Station Options				
S 260th West Station Option – West Side	Sound wall and insulation	9,200 feet	4 - 8 feet	80
S 260th West Station Option – East Side		4,600 feet	7 feet	
S 260th East Station Option – West Side	Sound wall and insulation	6,300 feet	4 - 7 feet	79
S 260th East Station Option – East Side		1,700 feet	8 feet	
S 272nd Redondo Trench Station Option – West Side	Sound wall and insulation	13,800 feet	4 - 8 feet	228
S 272nd Redondo Trench Station Option – East Side		10,700 feet	4 - 12 feet	
Federal Way SR 99 Station Option – West Side	Sound wall	400 feet	8 feet	79

TABLE 7-2
Summary of Potential Noise Impacts and Mitigation Measures – I-5 Alternative and Options

Alternative	Proposed Noise Mitigation Measures for Impacts			
	Type	Total Length (not continuous)	Height	Number of Units for Insulation
I-5 Alternative – West Side	**Sound wall and insulation**	**28,500 feet**	**4 - 15 feet**	**1**
I-5 Alternative – East Side	**Sound wall and insulation**	**10,700 feet**	**4 feet**	**1**
Kent/Des Moines Station Options				
Kent/Des Moines At-Grade – West Side	Sound wall and insulation	5,200 feet	5 feet	1
Kent/Des Moines At-Grade – East Side	Sound wall and insulation	3,500 feet	4 - 7 feet	1
Kent/Des Moines SR 99 East Station – West Side	Sound wall and insulation	3.000 feet	5 - 7 feet	1
Kent/Des Moines SR 99 East Station – East Side	Sound wall and insulation	6,400 feet	4 - 7 feet	1
Landfill Median Alignment Option – West side	Sound wall and insulation	5,600 feet	4 - 5 feet	1
Landfill Median Alignment Option – East Side	Sound wall and insulation	7,900 feet	4 feet	1
Federal Way City Center Station Options				
Federal Way I-5 Station Option – West Side	Sound wall and insulation	1,300 feet	15 feet	1
Federal Way I-5 Station Option – East Side	Sound wall and insulation	1,300 feet	7 feet	1
Federal Way S 320th Park-and-Ride Station Option – West Side	Sound wall and insulation	4,400 feet	9 - 12 feet	1

TABLE 7-3
Summary of Potential Noise Impacts and Mitigation Measures – SR 99 to I-5 Alternative

Alternative	Proposed Noise Mitigation Measures for Impacts			Number of Units for Insulation
	Type	Total Length (not continuous)	Height	
SR 99 to I-5 Alternative – West Side	**Sound wall and insulation**	**3,400 feet**	**4 - 8 feet**	**25**
SR 99 to I-5 Alternative – East Side	**Sound wall and insulation**	**5,100 feet**	**4 - 8 feet**	**25**
S 216th Station Options				
S 216 West Station Option – West Side	Sound wall and insulation	2,700 feet	4 feet	25
S 216 West Station Option – East Side	Sound wall and insulation	5,700 feet	4 - 7 feet	25
S 216 East Station Option – West Side	Sound wall and insulation	4,000 feet	4 - 8 feet	25
S 216 East Station Option – East Side	Sound wall and insulation	4,900 feet	6 - 7 feet	25
Landfill Median Alignment Option – West side	Sound wall and insulation	5,600 feet	4 - 5 feet	25
Landfill Median Alignment Option – East Side	Sound wall and insulation	7,900 feet	4 feet	25
Federal Way City Center Station Options				
Federal Way I-5 Station Option – West Side	Sound wall and insulation	1,300 feet	15 feet	25
Federal Way I-5 Station Option – East Side	Sound wall and insulation	1,300 feet	7 feet	25
Federal Way S 320th Park-and-Ride Station Option – West Side	Sound wall and insulation	4,400 feet	9 - 12 feet	25

7.1.2.4 I-5 to SR 99 Alternative Noise Mitigation

The primary noise mitigation measure for the I-5 to SR 99 Alternative and options is sound walls, summarized in Table 7-4. With these sound walls, the majority of noise impacts would be mitigated. Any residual noise impacts would be mitigated with sound insulation if necessary.

TABLE 7-4
Summary of Potential Noise Impacts and Mitigation Measures – I-5 to SR 99 Alternative

Alternative	Proposed Noise Mitigation Measures for Impacts			Number of Units for Insulation
	Type	Total Length (not continuous)	Height	
I-5 to SR 99 Alternative – West Side	**Sound wall and insulation**	**6,200 feet**	**4 - 7 feet**	**79**
I-5 to SR 99 Alternative – East Side		**3,900 feet**	**4 - 7 feet**	
S 260th Station Options				
S 260th West Station Option – West Side	Sound wall and insulation	3,700 feet	4 to 6 feet	79
S 260th West Station Option – East Side		3,000 feet	4 to 5 feet	
S 260th East Station Option – West Side	Sound wall and insulation	6,300 feet	4 - 7 feet	79
S 260th East Station Option – East Side		1,700 feet	8 feet	
S 272nd Redondo Trench Station Option – West Side	Sound wall and insulation	13,800 feet	4 - 8 feet	228
S 272nd Redondo Trench Station Option – East Side		10,700 feet	4 - 12 feet	
Federal Way SR 99 Station Option – West Side	Sound wall	400 feet	8 feet	79

7.1.3 Station Noise Mitigation

Noise impacts related to station operation would be mitigated with station design and sound walls. Station design would include incorporating noise barriers inside the station to block noise from the light rail, bells, and PA systems emanating from the station. In addition, whenever possible, stations and parking areas would be designed to minimize the generation and transmission of noise. Sound walls would also be used around the station bus layover areas and parking areas where necessary. Finally, sound insulation would be used to mitigate any residual noise impacts on nearby receivers.

7.1.4 Traffic Noise Mitigation

Potential traffic noise impacts could be mitigated in conjunction with the proposed light rail mitigation. In most of these areas, mitigation for impacts specific to traffic noise would be considered where mitigation for transit or park-and-ride noise impacts is not sufficient.

Additional mitigation may need to be considered for the realignment of 28th Avenue S and the north end of Camelot Square Mobile Home Park, where the I-5 Alternative would be elevated over S 288th Street and the existing sound wall would be relocated. The replacement sound wall would be modeled using future traffic volumes for the project design year (2035) to assure that it would continue to mitigate traffic noise into the future. The replacement sound wall would be designed such that there would be no new traffic noise impacts and no increase in the severity of any existing traffic noise impacts. The wall may also be designed to mitigate any light-rail-related noise impacts in addition to the traffic noise.

7.2 Potential Vibration Mitigation

This section discusses mitigation for vibration and groundborne noise from the operation of the FWLE. Potential mitigation measures for construction vibration are discussed in Section 7.3.

7.2.1 Types of Vibration Mitigation

A number of different approaches have been used by rail transit systems to reduce groundborne vibration. These measures range from very simple approaches, such as stiffening the floors at the receivers, to the very expensive, such as placing the entire track system on a concrete slab that is supported by springs (a floating slab) or constructing a building so that the entire building is supported by rubber or coil springs. The most common vibration mitigation measures used on light rail systems consist of placing some sort of resilient layer between the track and the soil. Some approaches for installing standard vibration mitigation measures with DF and B&T tracks are:

- High-compliance direct-fixation (HCDF) fasteners: DF track fasteners are used to attach rails directly to a concrete slab. They are standard on the subways and elevated structures of most modern rail transit systems. The stiffness of a standard DF track fastener is around 150,000 pounds per inch (lb./in.). Reducing the stiffness to around 110,000 lb./in. would marginally increase the cost. Going to a HCDF fastener (stiffness less than 60,000 lb./in.) would cost approximately twice as much as a standard DF fastener. The HCDF fasteners provide about 10 dB of vibration reduction at peak train vibration frequencies including 50- and 63-Hz 1/3-octave bands. HCDF fasteners have also been used on B&T track on the Massachusetts Bay Transportation Authority Red Line subway in Boston. Measurements showed that the fasteners provided vibration reduction similar to that found on DF tracks.

- Ballast mat: Ballast mats are designed to be placed under B&T track. They are resilient rubber mats that are placed between the subgrade and the ballast. Typical ballast mats can have a stiffness of 2,500 lb./in. The subgrade is a stiffer layer that could be thick concrete or asphalt. Concrete subgrades are expensive. Sometimes compacted soil is sufficient to serve as a stiff subgrade. Ballast mats provide about 10 dB of vibration reduction above 30 Hz.

- Tire-derived aggregate (TDA): TDA is recycled automobile tires that are shredded to pieces that are about 1 inch thick and 4 to 6 inches long. This mitigation measure consists of building the track on top of a layer of TDA. It is an innovative approach for recycling old automobile tires that has been successfully used as a vibration mitigation system on the Santa Clara Valley Transportation Authority and Denver Regional Transportation District light rail systems. A 12-inch layer of TDA was used for both the Santa Clara Valley and Denver installations, and all indications are that those designs are functioning as intended.

- Floating slab track: A floating slab consists of a concrete slab supported by elastomer or steel-coil springs. The frequency range at which a floating slab is effective depends on the thickness of the slab and the stiffness of the springs. Most North American floating slab systems use rubber pads that are 12 to 18 inches in diameter supporting a concrete slab that is 12 to 24 inches thick. Floating slabs are very effective at reducing vibration levels; however, they are also expensive.

- Alternative approaches: A number of alternative approaches have been proposed that may have applicability under specific circumstances. One example is underground barriers, something that several different Japanese rail systems have investigated recently. The basic concept is to use variations of an open trench or, when the propagation is through soft soils, a solid wall. Other examples include increasing the thickness of the concrete under the track, specifying straighter rails, and, when the track would traverse sections of very soft soil, building the track on top of pile foundation systems.

The vibration amplification from the banging that occurs when light rail vehicle wheels pass through switches generally results in a 10-dB increase at locations less than about 50 feet from the switch. Almost all of the increase in groundborne vibration and airborne noise occurs as the wheels pass through frogs. There are several alternatives to typical rail-bound manganese (RBM) frogs that would result in lower vibration and noise levels:

- Higher-number RBM frogs: The common RBM frog is designed for mainline freight track but is often used on transit systems. Wheel impacts as wheels cross the gap in the rail and when wheels hit the frog point typically increase vibration levels by approximately 10 VdB. The actual increase depends on the condition of the frog, how smoothly the wheel load is transferred from one side of the rail gap to the other, whether the movement over the frog is a straight-through or diverting move, the frog number, and the distance from the frog. Conceptually, higher-number frogs have a smaller angle between the rails and the transition over the gap is distributed over a greater distance, so the additional noise and vibration levels should be lower. However, there are no measurement results available that confirm that higher-number frogs generate less noise and vibration than lower-number frogs.
- Monoblock frogs: Monoblock frogs are basically milled out of a single block of steel. Because they are machined rather than cast, the tolerances can be tighter. Monoblock frogs are generally thought to create less noise and vibration than RBM frogs. Based on informal measurements performed at the Port Authority Trans-Hudson commuter rail system in New Jersey, it appears that the increase in noise and vibration levels with a good-condition monoblock frog is about half of that with a standard RBM frog.
- Flange-bearing frogs: Well designed and maintained, flange-bearing frogs can generate much less noise and vibration than standard RBM frogs. If the ramps in the frogs are too short and/or the frogs are not properly maintained, the noise and vibration benefits may be marginal. American Railway Engineering and Maintenance-of-Way Association standards suggest a speed limit of 24 mph for flange-bearing frogs on transit systems, so special approval from FTA may be necessary to operate at higher speeds.
- One-way low-speed (OWL) frogs: OWL frogs are designed for use when traffic in the diverting direction is infrequent and low-speed. Most OWL designs are flange-bearing in the diverting direction and have no break in the rail in the mainline direction. These are often referred to as “jump frogs” because in the diverting direction the wheels are lifted up and over the rail with some

form of flange-bearing ramps. A Vossloh representative said that the cost of their OWL is about $3,000 more than a standard RBM frog and about the same as a monoblock frog. Because the rail is solid in the main line direction, there would be little or no increase in noise and vibration. Vossloh, Progress Rail, and Nortrak all have variants of OWL frogs.

- Spring-rail and movable-point frogs: A movable-point frog eliminates the gap in the rail crossing by moving the point of crossing from side to side in sync with the direction of the turnout. In a spring-rail frog, the point is moved by the wheel flange of an approaching train, and loaded spring returns the point to its normal position after the train has passed. When properly designed, installed, and maintained, spring-rail and movable-point frogs produce up to 6 VdB less than standard frogs. These frogs can be substantially more expensive in terms of parts, installation, and maintenance.

7.2.2 Transit Vibration Mitigation

The vibration mitigation summary for all alternatives and options is presented in Table 7-5 through 7-8. The key points of mitigation in the tables are:

- HCDF fasteners are recommended for DF tracks.
- Ballast mats are recommended for B&T tracks.
- "Low-impact" frogs (LIFs) such as spring-rail or movable-point frogs are recommended in addition to ballast mats at locations where the impacts are a result of amplification at switches.

In addition, it is recommended that site-specific vibration tests be performed during final design at the locations where vibration impacts are predicted. When feasible, the tests should include outdoor-to-indoor vibration measurements to verify the results presented in this report.

TABLE 7-5
Summary of Vibration Impacts and Recommended Mitigation for SR 99 Alternative and Options

Alternative	Receiver Address	Recommended Mitigation	Total Length of Mitigation (feet)
SR 99 Alternative	**20717 International Blvd**	**HCDF**	**500**
	31031 Pacific Hwy S	**HCDF[a]**	**400**
S 216 East Station Option	Same as SR 99 Alternative (except for 20717 International Blvd, which would be displaced with this option)		
S 216 East Station Option	21450 International Blvd	HCDF	400
Kent/Des Moines HC Campus Station from S 216th West Station Option	2628 22nd St	Ballast mat	300
	22620 28th Ave S	Ballast mat	400
	2809 S 240th St 2803 S 240th St	Ballast mat	400
	24215 Pacific Hwy S	Ballast mat	500
Kent/Des Moines HC Campus Station Option	24215 Pacific Hwy S	Ballast mat	500
Kent/Des Moines SR 99 Median Station Option	Same as SR 99 Alternative		
Kent/Des Moines SR 99 East Station Option	Same as SR 99 Alternative		
S 260th West Station Option	24201 27th Ave S	HCDF	500

TABLE 7-5
Summary of Vibration Impacts and Recommended Mitigation for SR 99 Alternative and Options

Alternative	Receiver Address	Recommended Mitigation	Total Length of Mitigation (feet)
S 260th East Station Option	26430 Pacific Hwy S 26448 Pacific Hwy S	HCDF	500
	26550 Pacific Hwy S	HCDF	400
S 272nd Redondo Trench Station Option	1560 S 284th St 28418 16th Ave S 28611 16th Ave S	HCDF	900
	29815 Pacific Hwy S	HCDF	400
	27606 Pacific Hwy S	Ballast mat and LIF	400[b]
Federal Way SR 99 Station Option	Same as SR 99 Alternative		

[a] Mitigation for groundborne noise at the Federal Way High School Performing Arts Center.
[b] Length of ballast mat.

TABLE 7-6
Summary of Vibration Impacts and Recommended Mitigation for I-5 Alternative and Options

Alternative	Receiver Address	Recommended Mitigation	Total Length of Mitigation (feet)
I-5 Alternative	**3118 S 216th St**	**Ballast mat**	**400**
	22700 30th Ave S	**Ballast mat**	**400**
	23226 30th Ave S	**HCDF**	**400**
	3001 S 288th St	**Ballast mat**	**400**
	3006 S 288th St	**Ballast mat**	**400**
	30432 Military Rd S	**HCDF**	**400**
	31228 28th Ave S	**Ballast mat and LIF**	**300[a]**
	31524 28th Ave S	**Ballast mat**	**400**
	20620 International Blvd	**HCDF**	**400**
Kent/Des Moines At-Grade Station Option	23208 30th Ave S	HCDF	400
Kent/Des Moines SR 99 East Station Option	Same as I-5 Alternative		
Landfill Median Alignment Option	Same as I-5 Alternative		
Federal Way I-5 Station Option	Same as I-5 Alternative		
Federal Way S 320th Park-and-Ride Station Option	2101 S 324th St	LIF	--

[a] Length of ballast mat.

TABLE 7-7
Summary of Vibration Impacts and Recommended Mitigation for SR 99 to I-5 Alternative and Options

Alternative	Receiver Address	Recommended Mitigation	Total Length of Mitigation (feet)
SR 99 to I-5 Alternative	**20717 International Blvd**	**HCDF**	**500**
	23205 30th Ave S	**HCDF**	**400**
	3001 S 288th St	**Ballast mat**	**400**
	3006 S 288th St	**Ballast mat**	**400**
	30432 Military Rd S	**HCDF**	**400**
	31228 28th Ave S	**Ballast mat and LIF**	**400[a]**
	31524 28th Ave S	**Ballast mat**	**400**
S 216th West Station Option	Same as I-5 Alternative (except for 20717 International Blvd, which would be displaced with this option)		
S 216th East Station Option	21450 International Blvd	HCDF	400
Landfill Median Alignment Option	Same as SR 99 to I-5 Alternative		
Federal Way I-5 Station Option	Same as SR 99 to I-5 Alternative		
Federal Way S 320th Park-and Ride Station Option	Same as SR 99 to I-5 Alternative		

[a] Length of ballast mat.

TABLE 7-8
Summary of Vibration Impacts and Recommended Mitigation for I-5 to SR 99 Alternative and Options

Alternative	Start	Recommended Mitigation	Total Length of Mitigation (feet)
I-5 to SR 99 Alternative	**3118 S 216th St**	**Ballast mat**	**400**
	23030 30th Ave S	**HCDF**	**400**
	23110 30th Ave S	**HCDF**	**400**
	20620 International Blvd	**HCDF**	**400**
	31031 Pacific Hwy S	**HCDF[a]**	**400**
S 260th West Station Option	None		
S 260th East Station Option	Same as with SR 99 Alternative		
S 272nd Redondo Trench Station Option	Same as with SR 99 Alternative		
Federal Way SR 99 Station Option	Same as with SR 99 Alternative		

[a] Mitigation for groundborne noise at the Federal Way High School Performing Arts Center.

7.3 Potential Construction Mitigation

7.3.1 Construction Noise Mitigation

Construction noise impacts can be reduced with operational methods and scheduling, equipment choice, and acoustical treatments. In locations where existing sound walls would require relocation, the relocation would be completed as early in the construction process as practical so that the relocated walls would reduce noise from the ongoing construction activities. When required, Sound Transit or its contractor would seek the appropriate noise variance from the local jurisdiction. Noise control mitigation to meet local regulatory requirements, noise ordinances, and permit or variance conditions would be required. These measures could include:

- Install construction site noise barrier or wall by noise-sensitive receivers where appropriate.
- Use smart backup alarms during nighttime work that automatically adjust (lower) the alarm level or tone based on the background noise level, or switch off back-up alarms and replace with spotters.
- Use low-noise-emission equipment.
- Implement noise-deadening measures for truck loading and operations.
- Monitor and maintain equipment to meet noise limits.
- Use lined or covered storage bins, conveyors, and chutes with sound-deadening material.
- Use acoustic enclosures, shields, or shrouds for equipment and facilities.
- Install high-grade engine exhaust silencers and engine-casing sound insulation.
- Prohibit aboveground jack hammering and impact pile driving during nighttime hours.
- Minimize the use of generators or use whisper-quiet generators to power equipment.
- Limit use of public address systems.
- Use movable noise barriers at the source of the construction activity.
- Limit or avoid certain noisy activities during nighttime hours.

7.3.2 Construction Vibration Mitigation

Although no fragile structures have been identified in the project corridor, the following precautionary vibration mitigation strategies are recommended to minimize the potential for damage to any structures in the corridor:

- Pre-construction survey: Prior to beginning construction, a survey of the first row of buildings adjacent to the alignment should be completed. The survey should include inspection of building foundations and photographs of existing conditions and should be expanded if an important and potentially fragile structure is located within approximately 200 feet of the construction site, which should be included in the survey.
- Vibration limits: Construction vibration should be limited to a maximum of 0.5 in./sec for all buildings in the corridor. Should the pre-construction survey identify any buildings that are particularly sensitive to vibration, the vibration limit at these structures should be limited to 0.12 in./sec. In addition, to reduce annoyance, use of high-vibration construction equipment at nighttime should be limited near sensitive receivers such as residences, schools, and hospitals.
- Vibration monitoring: Vibration monitoring should occur at any buildings where the lower vibration limit is applicable and at any location where complaints about vibration are received from building occupants. Vibration monitoring should consist of measurements of vibration at the closest potentially sensitive structure during periods of construction when equipment that generates a substantial amount of groundborne vibration (such as mounted hammer hoe rams or pile-drivers) are in use. Vibration monitors should be equipped with an “alarm” feature to provide notification

that vibration impact criteria have been approached or exceeded. Where pile driving is employed near fragile structures, several hits should be monitored prior to starting the pile driving to make sure that the levels are below the limits. If vibration from the test hits approaches or exceeds the limits, the force of the pile-driver should be reduced until the vibration amplitudes at all sensitive buildings are below the applicable limit.

- Alternative construction procedures: If high-vibration construction activities must be performed close to structures, it may be necessary to use an alternative procedure that produces lower vibration levels. Examples of high-vibration construction activities include vibratory compaction and using hoe rams for demolition. Alternative procedures could include use of non-vibratory compaction and using a concrete saw in place of a hoe ram to break up pavement. Use of pile driving should be avoided close to sensitive receivers, and alternate construction procedures employed, such as using a hydraulic pile-driver at lower settings.

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