January 2022

# West Seattle and Ballard Link Extensions

**Draft** Environmental Impact Statement

# NOISE AND VIBRATION TECHNICAL REPORT

## Appendix N.3

Sound Transit

U.S. Department of Transportation
Federal Transit Administration

This page is intentionally left blank.

# West Seattle and Ballard Link Extensions
# Noise and Vibration Technical Report

January 2022

Sound Transit

This page is intentionally left blank.

# Table of Contents

## Figures

## Tables

## Attachments

This page is intentionally left blank.

# Acronyms and Abbreviations

| Acronym | Definition |
| --- | --- |
| Ccurv | force density level |
| dB | decibels |
| dBA | A-weighted decibels |
| FTA | Federal Transit Administration |
| FTA Guidance Manual | *Transit Noise and Vibration Impact Assessment Manual* |
| I.D. | identification |
| Ldn | day-night equivalent sound level |
| Leq | equivalent sound level |
| Lmax | maximum sound level |
| Lv | vibration velocity |
| SIFF | Seattle International Film Festival |
| Sound Transit | Central Puget Sound Regional Transit Authority |
| V.C. | vibration criteria |
| VdB | vibration velocity decibels |
| WSBLE | West Seattle and Ballard Link Extensions |
| WSDOT | Washington State Department of Transportation |

This page is intentionally left blank.

# 1 INTRODUCTION

## 1.1 Overview

Central Puget Sound Regional Transit Authority (Sound Transit) is proposing to expand Link light rail transit service from Downtown Seattle to West Seattle and Ballard (Figure 1-1). The West Seattle and Ballard Link Extensions (WSBLE) Project is an 11.8-mile corridor in the city of Seattle in King County, Washington, the most densely populated county of the Puget Sound region. The West Seattle Link Extension would be about 4.7 miles and include stations at SODO, Delridge, Avalon, and Alaska Junction. The Ballard Link Extension would be about 7.1 miles from Downtown Seattle to Ballard's Northwest Market Street area. It would include a new 3.3-mile light rail-only tunnel from Chinatown-International District to South Lake Union and Seattle Center/Uptown. Stations would serve the following areas: Chinatown-International District, Midtown, Westlake, Denny, South Lake Union, Seattle Center, Smith Cove, Interbay, and Ballard.

The WSBLE Project is part of the Sound Transit 3 Plan of regional transit system investments, funding for which was approved by voters in the region in 2016. The project would provide fast, reliable light rail in Seattle and connect to dense residential and job centers throughout the Puget Sound region, while the new Downtown Seattle light rail tunnel would provide capacity for the entire regional system to operate efficiently. The Puget Sound Regional Council (the regional metropolitan planning organization) and the City of Seattle have designated the following regional growth centers, Manufacturing/Industrial Centers, and urban villages in the project corridor:

- **Regional Growth Centers**. The project corridor includes three regional growth centers designated by the Puget Sound Regional Council and the City of Seattle: Seattle Downtown, South Lake Union, and Uptown. The First Hill/Capitol Hill growth center is also just east of the project corridor.
- **Manufacturing/Industrial Centers**. The project corridor includes two Manufacturing/Industrial Centers designated by the Puget Sound Regional Council: the Duwamish and Ballard Interbay Manufacturing/Industrial Centers. The City of Seattle has designated these areas as the Duwamish Manufacturing/Industrial Center and the Ballard Interbay Northend Manufacturing/Industrial Center.
- **Urban Villages**. There are two neighborhoods in the project corridor designated by the City of Seattle as urban villages: West Seattle Junction and Ballard neighborhoods.

These designations indicate that these areas will continue to increase in residential and/or employment density over the next 30 years.

Regional transit service in the project corridor includes regional bus service, light rail, Sounder commuter rail, Washington State Ferries, and Amtrak passenger rail service. Light rail currently operates between the Angle Lake Station in the city of SeaTac and the Northgate Station in Seattle, traveling through the Downtown Seattle Transit Tunnel. Extensions of light rail are under construction north to Lynnwood, east to Bellevue and Redmond, and south to Federal Way, and are anticipated to begin operation in 2024. Planned light rail extensions would continue south to Tacoma Dome, expected to begin service in 2032, and north to Everett, planned to begin service in 2037. The West Seattle Link Extension is scheduled to open in 2032. The Ballard Link Extension is scheduled to begin service in 2037. Depending on funding availability, service from Smith Cove to Ballard Station is scheduled to open in 2037 or 2039.

**Figure 1-1. West Seattle and Ballard Link Extensions Project Corridor**

Table 1-1 lists the WSBLE Project Build Alternatives for each extension (West Seattle and Ballard).

## 1.2 Purpose of Report

The purpose of this report is to document noise and vibration in the WSBLE Project vicinity and evaluate potential impacts associated with the proposed alternatives. This report covers both noise and vibration in the study area.

## Table 1-1. Summary of West Seattle and Ballard Link Extensions Build Alternatives

| Extension | Segment | Alternative | Alternative Abbreviation | Stations (and Station Profile) | Connections |
|---|---|---|---|---|---|
| **West Seattle** | **SODO** | **Preferred At-Grade** | **SODO-1a** | **SODO (At-Grade) or SODO Staggered Station Configuration (At-Grade)** | **All Duwamish Segment alternatives.** |
| West Seattle | SODO | At-Grade South Station Option | SODO-1b | SODO (At-Grade) | All Duwamish Segment alternatives. |
| West Seattle | SODO | Mixed Profile | SODO-2 | SODO (Elevated) | All Duwamish Segment alternatives. |
| **West Seattle** | **Duwamish** | **Preferred South Crossing** | **DUW-1a** | **None** | **All SODO Segment alternatives. All Delridge Segment alternatives.** |
| West Seattle | Duwamish | South Crossing South Edge Crossing Alignment Option | DUW-1b | None | All SODO Segment alternatives. All Delridge Segment alternatives. |
| West Seattle | Duwamish | North Crossing | DUW-2 | None | All SODO Segment alternatives. All Delridge Segment alternatives. |
| **West Seattle** | **Delridge** | **Preferred Dakota Street Station** | **DEL-1a** | **Delridge (Elevated)** | **All Duwamish Segment alternatives. Connects to WSJ-1, WSJ-2, and WSJ-4*.** |
| West Seattle | Delridge | Dakota Street Station North Alignment Option | DEL-1b | Delridge (Elevated) | All Duwamish Segment alternatives. Connects to WSJ-1, WSJ-2, and WSJ-4*. |
| **West Seattle** | **Delridge** | **Preferred Dakota Street Station Lower Height*** | **DEL-2a*** | **Delridge (Elevated)** | **All Duwamish Segment alternatives. Connects to WSJ-3a* and WSJ-3b*.** |

| Extension | Segment | Alternative | Alternative Abbreviation | Stations (and Station Profile) | Connections |
|---|---|---|---|---|---|
| West Seattle | Delridge | Dakota Street Station Lower Height North Alignment Option* | DEL-2b* | Delridge (Elevated) | All Duwamish Segment alternatives. Connects to WSJ-3a* and WSJ-3b*. |
| West Seattle | Delridge | Delridge Way Station | DEL-3 | Delridge (Elevated) | All Duwamish Segment alternatives. Connects to WSJ-1, WSJ-2, and WSJ-4*. |
| West Seattle | Delridge | Delridge Way Station Lower Height* | DEL-4* | Delridge (Elevated) | All Duwamish Segment alternatives. Connects to WSJ-3a* and WSJ-3b*. |
| West Seattle | Delridge | Andover Street Station | DEL-5 | Delridge (Elevated) | All Duwamish Segment alternatives. Connects to WSJ-1, WSJ-2 and WSJ-4*. |
| West Seattle | Delridge | Andover Street Station Lower Height* | DEL-6* | Delridge (Elevated) | All Duwamish Segment alternatives. Connects to WSJ-5*. |
| **West Seattle** | **West Seattle Junction** | **Preferred Elevated 41st/42nd Avenue Station** | **WSJ-1** | **Avalon (Elevated), West Seattle Junction (Elevated)** | **Connects to DEL-1a, DEL-1b, DEL-3, and DEL-5.** |
| **West Seattle** | **West Seattle Junction** | **Preferred Elevated Fauntleroy Way Station** | **WSJ-2** | **Avalon (Elevated), West Seattle Junction (Elevated)** | **Connects to DEL-1a, DEL-1b, DEL-3, and DEL-5.** |
| **West Seattle** | **West Seattle Junction** | **Preferred Tunnel 41st Avenue Station*** | **WSJ-3a*** | **Avalon (Tunnel), West Seattle Junction (Tunnel)** | **Connects to DEL-2a*, DEL-2b*, and DEL-4*.** |
| **West Seattle** | **West Seattle Junction** | **Preferred Tunnel 42nd Avenue Station Option*** | **WSJ-3b*** | **Avalon (Tunnel), West Seattle Junction (Tunnel)** | **Connects to DEL-2a*, DEL-2b* and DEL-4*.** |
| West Seattle | West Seattle Junction | Short Tunnel 41st Avenue Station* | WSJ-4* | Avalon (Elevated), West Seattle Junction (Tunnel) | Connects to DEL-1a, DEL-1b, DEL-3, and DEL-5. |

| Extension | Segment | Alternative | Alternative Abbreviation | Stations (and Station Profile) | Connections |
|---|---|---|---|---|---|
| West Seattle | West Seattle Junction | Medium Tunnel 41st Avenue Station* | WSJ-5* | Avalon (Retained Cut), West Seattle Junction (Tunnel) | Connects to DEL-6*. |
| **Ballard** | **SODO** | **Preferred At-Grade** | **SODO-1a** | **Not applicable** | **Connects to CID-1a*, CID-2a, and CID-2b.** |
| Ballard | SODO | At-Grade South Station Option | SODO-1b | Not applicable | All Chinatown-International District Segment alternatives. |
| Ballard | SODO | Mixed Profile | SODO-2 | Not applicable | Connects to CID-1a* and CID-2a. |
| Ballard | Chinatown-International District | 4th Avenue Shallow* [a] | CID-1a* | Stadium (existing station would be rebuilt) and International District/Chinatown (tunnel) | All SODO Segment alternatives. All Downtown Segment alternatives. |
| Ballard | Chinatown-International District | 4th Avenue Deep Station Option* | CID-1b | International District/Chinatown (Tunnel) | Connects to SODO-1b. Connects to DT-1. |
| Ballard | Chinatown-International District | 5th Avenue Shallow | CID-2a | International District/Chinatown (Tunnel) or International District/Chinatown Diagonal Station Configuration (Tunnel) | All SODO Segment alternatives. All Downtown Segment alternatives. |
| Ballard | Chinatown-International District | 5th Avenue Deep Station Option | CID-2b | International District/Chinatown (Tunnel) | Connects to SODO-1a and SODO-1b. Connects to DT-1. |
| **Ballard** | **Downtown** | **Preferred 5th Avenue/Harrison Street** | **DT-1** | **Midtown, Westlake, Denny, South Lake Union, and Seattle Center (Tunnel)** | **All Chinatown-International District Segment alternatives. Connects to SIB-1 and SIB-2.** |

| Extension | Segment | Alternative | Alternative Abbreviation | Stations (and Station Profile) | Connections |
|---|---|---|---|---|---|
| Ballard | Downtown | 6th Avenue/Mercer Street | DT-2 | Midtown, Westlake, Denny, South Lake Union, and Seattle Center (Tunnel) | Connects to CID-1a* and CID-2a. Connects to SIB-3. |
| **Ballard** | **South Interbay** | **Preferred Galer Street Station/Central Interbay** | **SIB-1** | **Smith Cove (Elevated)** | **Connects to DT-1. Connects to IBB-1a, IBB-2a*, and IBB-2b*.** |
| Ballard | South Interbay | Prospect Street Station/15th Avenue | SIB-2 | Smith Cove (Elevated) | Connects to DT-1. Connects to IBB-3 and IBB-1b. |
| Ballard | South Interbay | Prospect Street Station/Central Interbay | SIB-3 | Smith Cove (Retained cut) | Connects to DT-2. Connects to IBB-1a, IBB-2a*, and IBB-2b*. |
| **Ballard** | **Interbay/Ballard** | **Preferred Elevated 14th Avenue** | **IBB-1a** | **Interbay (Elevated), Ballard (Elevated)** | **Connects to SIB-1 and SIB-3.** |
| Ballard | Interbay/Ballard | Elevated 14th Avenue Alignment Option (from Prospect Street Station/15th Avenue) | IBB-1b | Interbay (Elevated), Ballard (Elevated) | Connects to SIB-2. |
| **Ballard** | **Interbay/Ballard** | **Preferred Tunnel 14th Avenue*** | **IBB-2a*** | **Interbay (Retained cut), Ballard (Tunnel)** | **Connects to SIB-1 and SIB-3.** |
| **Ballard** | **Interbay/Ballard** | **Preferred Tunnel 15th Avenue Station Option*** | **IBB-2b*** | **Interbay (Retained cut), Ballard (Tunnel)** | **Connects to SIB-1 and SIB-3.** |
| Ballard | Interbay/Ballard | Elevated 15th Avenue | IBB-3 | Interbay (Elevated), Ballard (Elevated) | Connects to SIB-2. |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

[a] The 4th Avenue Shallow Alternative (Alternative CID-1a*) would require the existing Stadium Station to be rebuilt to the west of its current location due to the tunnel portal, although the Ballard Link Extension would not connect to Stadium Station.

This page is intentionally left blank.

# 2 ENVIRONMENTAL NOISE AND VIBRATION BASICS

## 2.1 Noise Fundamentals and Descriptors

### 2.1.1 Understanding Sound

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, one tends 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. 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 to 20,000 hertz. 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 hertz are progressively and severely attenuated, as are high frequencies above 10,000 hertz. 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. Table 2-1 provides a list of different sounds, activities and transportation noise sources and the maximum noise levels typically experienced in dBA.

Another characteristic of environmental noise is that it is constantly changing. The noise level increasing 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, with higher noise levels during daytime hours 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).

### Table 2-1. Examples of Common Noise Sources and General Noise Levels

| Maximum Noise Level (approximate) | Examples of Sounds, Activities, and Transportation Noise Sources, Quietest to Loudest |
|---|---|
| 25 to 30 dBA | Acoustic Test Chamber<br>Quiet, rural area at night, crickets or wind noise, no traffic |
| 30 to 40 dBA | Quiet bedroom with no air systems running<br>Empty recording studio |
| 40 to 50 dBA | Quiet window air conditioner, indoors<br>Background noise inside a typical office space |
| 50 to 60 dBA | Normal conservation, two people at 4 to 6 feet<br>Typical television volume at 10 feet |
| 60 to 70 dBA | Automobile cruising, 50 miles per hour, 50 feet<br>Heated conservation, two to four people, 4 to 6 feet |
| 70 to 80 dBA | Vanpool bus cruising, 50 miles per hour, 50 feet<br>Medium truck (parcel delivery trucks) at 50 miles per hour, 50 feet |
| 86 dBA | Link light rail, 4-car train traveling at 55 miles per hour, measured at 50 feet |
| 80 to 90 dBA | Overland bus cruising, 50 miles per hour, 50 feet<br>Accelerating heavy loaded truck, 50 feet |
| 90 to 100 dBA | Multiple locomotives pulling 5000 feet train. 40 miles per hour, 100 feet<br>Loud shop tools (router, table saw), 5 feet |
| Over 100 dBA | Loud crowd at an indoor basketball game<br>Freight train horn at 100 feet<br>Jet takeoff at 250 feet |

Source: Adapted from Federal Transit Administration (FTA 2018) and measured noise levels. Link light rail noise levels from measurements in 2018 and 2019.

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), 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. Table 2-2 defines typical community noise levels in terms of Ldn. Most urban and suburban neighborhood Ldn noise levels range from 50 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 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.

**Table 2-2. Typical 24-hour Day-night Sound Levels and Land Use Compatibility**

| Day-Night Equivalent Noise Level in A-weighted Decibels | Description of Typical and Acceptable Land Use |
|---|---|
| Ldn below 50 dBA | Typically found in rural areas with no major roadways or other major noise sources nearby. Compatible with all noise-sensitive properties. |
| Ldn of 50 to 55 dBA | Typically found in quiet suburban residential neighborhoods not near any major roadways and with little nighttime activity. Compatible with all noise-sensitive properties. |
| Ldn of 55 to 60 dBA | Typically found in many residential areas with minor arterial roadways nearby, typical of many close in suburban and some urban residential areas. Compatible with all noise-sensitive properties. |
| Ldn of 60 to 65 dBA | Relatively noisy residential area. Usually a major road or airport is nearby. Considered normally acceptable for residential land use. |
| Ldn of 65 to 70 dBA | Noise levels in this range are typical for a noisy residential area that is close to a major freeway or the end of an airport runway. Considered marginally acceptable for a residential area. |
| Ldn of 70 to 75 dBA | Typical for areas directly adjacent to a major freeway or very near an airport. Not normally acceptable for residential use without noise mitigation measures. |
| Ldn greater than 75 dBA | Noise levels above 75 dBA Ldn are not acceptable for residential use and are only found near the ends of airport runways and adjacent to major highways. |

Source: Adapted from FTA 2018.

Ldn is the designated noise metric of choice for many federal agencies, including the Department of Housing and Urban Development, Federal Aviation Administration, Federal Transit Administration (FTA), and United States Environmental Protection Agency. Most federal and state agency criteria for noise impacts are based on some measurement of noise energy. For example, the Federal Aviation Administration and Department of Housing and Urban Development use Ldn and the Federal Highway Administration uses peak hour Leq. The noise impact criteria applicable to residential areas is included in the 2018 *FTA Transit Noise and Vibration Impact Assessment Manual* (FTA Guidance Manual) (FTA 2018) and uses both Leq and Ldn to characterize community noise.

### 2.1.2 Calculating Decibels

An important factor to recognize is that noise is measured on a decibel scale, and calculating the sound level for two noise sources is not achieved by simple addition. For example, combining two 60-dB noise sources does not give 120 dB (which is near the pain threshold), but yields 63 dB, which is lower than the volume at which most people listen to their TVs. For reference, if two noise sources are 10 dB apart, for example 50 dB and 60 dB, the sum of the two noise levels will simply be the louder of the two, in this case 60 dB. This is to say that for similar noise sources that are 10 dB apart in magnitude, a person would only be able to hear the louder of the two sources.

Examples of simplified decibel addition, based on the difference between the two levels, are provided in Table 2-3 for reference, to aid in the understanding of the total project noise and impact analysis presented in this report.

**Table 2-3. Decibel Addition Approximations**

| Difference between the Two Noise Sources | Amount Added to the Higher of the Two Noise Levels |
|---|---|
| 0 to 1 dB | 3 dB |
| 2 to 3 dB | 2 dB |
| 4 to 9 dB | 1 dB |
| 10 dB or more | 0 dB |

This information is important when considering the FTA criteria and what the total noise (existing and light rail noise) would be at any location. An increase of less than 3 dB is not typically perceptible to an average person. For example, if noise from light rail operations is 4 dB to 9 dB below the existing noise levels, the project-related increase in the total noise (light rail plus existing) would be approximately 1 dB or less, an increase which is not perceptible to an average person.

## 2.2 Vibration Fundamentals and Descriptors

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.

One potential community impact from a project like the WSBLE, 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 vibration velocity. Root mean square 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 velocity 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. The vibration impact criteria focus on human annoyance, which occurs at much lower amplitudes than does building damage.

Table 2-4 presents typical vibration levels from rail and non-rail sources as well as the human and structural response to such 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 the following:

- 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 2018).

**Table 2-4. Typical Vibration Level in Decibels and Human/Structural Responses**

| Vibration Level in VdB | Description of Typical Sources 50 Feet from Source and Human/Structural Response |
|---|---|
| Below 60 VdB | Typical background vibration levels. |
| 60 to 70 VdB | Light rail transit on a normal track; bus or truck on a smooth roadway. Approximate threshold of human perception and limit for vibration-sensitive equipment. |
| 70 to 80 VdB | Light rail transit near a crossover; bus or truck over pothole. Residential annoyance from infrequent events (e.g., commuter trains), residential annoyance from occasional events, and residential annoyance from frequent events (e.g., light rail transit). |
| 80 to 90 VdB | Bulldozers and other heavy tracked vehicles and freight trains. The typical human response would be difficulty with tasks such as reading a computer screen. |
| 90 to 100 VdB | Blasting from construction projects. This is the threshold for minor cosmetic damage. |

Source: Adapted from FTA 2018.

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 method 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 2018).

This page is intentionally left blank.

# 3 NOISE AND VIBRATION IMPACT CRITERIA

## 3.1 Noise Criteria

The operation of a light rail system can cause noise that becomes a public concern. Noise impacts can be caused by either transit operations (e.g., light rail operational noise, warning bells, and ancillary facilities) or changes in traffic noise exposure. For the WSBLE, the major noise source would be noise from Link light rail operations, as well as some additional noise from stations. An increase in traffic noise exposure 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 acoustical shielding from traffic noise.

Noise from project-related ancillary facilities can also be a source of noise, these would include maintenance and cleaning facilities, power substations, and park-and-rides. The maintenance and cleaning facilities for operations of the WSBLE will be at the existing Operations and Maintenance Facility Central. No park-and-rides are proposed as part of this project; therefore, no noise analysis for park-and-rides was needed. Substations are enclosed in buildings and do not produce noise levels that approach any state or local noise criteria.

There are several different noise impact criteria applicable to the WSBLE Project. Criteria from the FTA, Federal Highway Administration, Washington State Department of Transportation (WSDOT), and the City of Seattle were all reviewed and applied as appropriate to this analysis. This section summarizes those criteria and defines the project noise impact criteria applicable to the project.

### 3.1.1 Transit Noise Criteria

Noise impacts for the WSBLE are determined based on the criteria defined in the FTA Guidance Manual (FTA 2018). 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 places of worship 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 (moderate and severe) are as follows:

- **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.
- **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.

The FTA noise impact criteria for Category 2 and Category 3 land uses are summarized in Tables 3-1 and 3-2, which show 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 would be the combination of the existing noise exposure and the additional noise exposure caused by the light rail project. As existing noise exposure increases, an increasingly smaller increase in noise is permitted before an impact occurs.

Given the complex nature of these criteria, an example of the application of the criteria can be helpful in understanding how impacts are identified. For example, a residential land use (FTA Category 2) with an existing Ldn of 65 dBA would have no impact if noise from light rail operations were below 61 dBA Ldn, a moderate impact if the light rail noise were between 61 and 66 dBA, and a severe impact if light rail noise were above 66 dBA (see Table 3-1). This example shows how the light rail noise level could be *lower* than the *existing* noise levels, and still result in a noise impact. The example also demonstrates how the FTA criteria help to prevent increasing noise levels in areas that already have high levels of background noise. Furthermore, using the information from Table 2-3 (Decibel Addition Approximations), if the light rail operations were, for example, 62 dBA Ldn, the total future noise (existing 65 dBA Ldn plus the light rail's 62 dBA Ldn) would be approximately 67 dBA Ldn, or a 2-dB increase, which is not typically perceptible to an average person but would be an impact under FTA criteria.

### Table 3-1. FTA Transit Project Noise Impact Criteria for Category 1 and 2 Sites

| Existing Noise Exposure Ldn or Leq (dBA) [a] | Transit Noise Level for No Noise Impact | Transit Noise Level for a Moderate Noise Impact | Transit Noise Level for a Severe Noise Impact |
|---|---|---|---|
| <43 | <Ambient +10 | Ambient +10 to 15 | >Ambient +15 |
| 43 | <52 | 52 to 58 | >58 |
| 44 | <52 | 52 to 58 | >58 |
| 45 | <52 | 52 to 58 | >58 |
| 46 | <53 | 53 to 59 | >59 |

| Existing Noise Exposure Ldn or Leq (dBA) [a] | Transit Noise Level for No Noise Impact | Transit Noise Level for a Moderate Noise Impact | Transit Noise Level for a Severe Noise Impact |
|---|---|---|---|
| 47 | <53 | 53 to 59 | >59 |
| 48 | <53 | 53 to 59 | >59 |
| 49 | <54 | 54 to 59 | >59 |
| 50 | <54 | 54 to 59 | >59 |
| 51 | <54 | 54 to 60 | >60 |
| 52 | <55 | 55 to 60 | >60 |
| 53 | <55 | 55 to 60 | >60 |
| 54 | <55 | 55 to 61 | >61 |
| 55 | <56 | 56 to 61 | >61 |
| 56 | <56 | 56 to 62 | >62 |
| 57 | <57 | 57 to 62 | >62 |
| 58 | <57 | 57 to 62 | >62 |
| 59 | <58 | 58 to 63 | >63 |
| 60 | <58 | 58 to 63 | >63 |
| 61 | <59 | 59 to 64 | >64 |
| 62 | <59 | 59 to 64 | >64 |
| 63 | <60 | 60 to 65 | >65 |
| 64 | <61 | 61 to 65 | >65 |
| 65 | <61 | 61 to 66 | >66 |
| 66 | <62 | 62 to 67 | >67 |
| 67 | <63 | 63 to 67 | >67 |
| 68 | <63 | 63 to 68 | >68 |
| 69 | <64 | 64 to 69 | >69 |
| 70 | <65 | 65 to 69 | >69 |
| 71 | <66 | 66 to 70 | >70 |
| 72 | <66 | 66 to 71 | >71 |
| 73 | <66 | 66 to 71 | >71 |
| 74 | <66 | 66 to 72 | >72 |
| 75 | <66 | 66 to 73 | >73 |
| 76 | <66 | 66 to 74 | >74 |
| 77 | <66 | 66 to 74 | >74 |
| >77 | <66 | 66 to 75 | >75 |

Source: FTA 2018.

[a] The Ldn is used for FTA Category 2 sites, including residential land use and other sites where people sleep, and the peak hour Leq is used for Category 1 sites.

## Table 3-2. FTA Transit Project Noise Impact Criteria for Category 3 Sites

| Existing Noise Exposure Leq (dBA) | Transit Noise Level for No Noise Impact | Transit Noise Level for a Moderate Noise Impact | Transit Noise Level for a Severe Noise Impact |
|---|---|---|---|
| <43 | <Ambient +15 | Ambient +15 to 20 | >Ambient +20 |
| 43 | <57 | 57 to 63 | >63 |
| 44 | <57 | 57 to 63 | >63 |
| 45 | <57 | 57 to 63 | >63 |
| 46 | <58 | 58 to 64 | >64 |
| 47 | <58 | 58 to 64 | >64 |
| 48 | <58 | 58 to 64 | >64 |
| 49 | <59 | 59 to 64 | >64 |
| 50 | <59 | 59 to 64 | >64 |
| 51 | <59 | 59 to 65 | >65 |
| 52 | <60 | 60 to 65 | >65 |
| 53 | <60 | 60 to 65 | >65 |
| 54 | <60 | 60 to 66 | >66 |
| 55 | <61 | 61 to 66 | >66 |
| 56 | <61 | 61 to 67 | >67 |
| 57 | <62 | 62 to 67 | >67 |
| 58 | <62 | 62 to 67 | >67 |
| 59 | <63 | 63 to 68 | >68 |
| 60 | <63 | 63 to 68 | >68 |
| 61 | <64 | 64 to 69 | >69 |
| 62 | <64 | 64 to 69 | >69 |
| 63 | <65 | 65 to 70 | >70 |
| 64 | <66 | 66 to 70 | >70 |
| 65 | <66 | 66 to 71 | >71 |
| 66 | <67 | 67 to 72 | >72 |
| 67 | <68 | 68 to 72 | >72 |
| 68 | <68 | 68 to 73 | >73 |
| 69 | <69 | 69 to 74 | >74 |
| 70 | <70 | 70 to 74 | >74 |
| 71 | <71 | 71 to 75 | >75 |
| 72 | <71 | 71 to 76 | >76 |
| 73 | <71 | 71 to 76 | >76 |
| 74 | <71 | 71 to 77 | >77 |
| 75 | <71 | 71 to 78 | >78 |
| 76 | <71 | 71 to 79 | >79 |
| 77 | <71 | 71 to 79 | >79 |
| >77 | <71 | 71 to 80 | >80 |

Source: FTA 2018.

The FTA Guidance Manual provides details on how parks are analyzed for noise. 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 active 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 WSBLE corridor were evaluated for consideration under the FTA criteria and based on the park locations and existing noise levels, only those parks in quiet areas without active sports met the requirements for noise sensitivity under the FTA Category 3 criteria. Noise-sensitive parks include portions of the Longfellow Creek Natural Area in the Delridge Segment and the Southwest Queen Anne Greenbelt and Kinnear Park in the Interbay/Ballard Segment. All other parks are in areas with high existing noise levels or are active sports fields. Additional information on parks as related to noise and vibration is provided in Section 5, Affected Environment.

### 3.1.2 Traffic Noise Criteria

Criteria for traffic noise impacts are from the Federal Highway Administration Procedures for Abatement of Highway Traffic Noise and Construction Noise, Code of Federal Regulations 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 and are based on hourly Leq levels for the peak hour of traffic noise. The Federal Highway Administration has land use categories that are similar to the ones used by the FTA, although the Federal Highway Administration categories use letters instead of numbers. The land use of greatest concern in the WSBLE corridor are Federal Highway Administration Type B land uses, which include residences, motels, hotels, playgrounds, active sports areas, parks, schools, places of worship, 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 noise abatement criteria. Therefore, an impact on Type B land uses would occur at 66 dBA.

WSDOT is responsible for implementing the Federal Highway Administration regulations in Washington state. Under Federal Highway Administration and WSDOT regulations, any highway project receiving federal funds must have a noise analysis if it includes elements including new roadway or highway, substantial alteration of the alignment of an existing roadway or highway, or adding new capacity to an existing roadway or highway. The removal of physical shielding (e.g., building or topographical conditions), which provide traffic noise attenuation, also counts as an alteration of the alignment. There are some limited locations under some alternatives where project-related displacement may warrant a traffic noise study. The impact assessments for those areas are presented in Chapter 6, Impact Assessment.

### 3.1.3 Construction Noise Criteria

Project construction would take place in the city of Seattle. The city has its own municipal noise ordinance that would be applicable to the WSBLE. Noise impacts are assessed using the City of Seattle noise ordinance, which has more stringent criteria than the FTA criteria.

The maximum permissible sound levels from construction activities are governed by the Seattle Municipal Code, where Section 25.08 specifies permissible sound limits within Seattle. Seattle Municipal Code 25.08.410 sets forth separate sound limits for residential, commercial, and industrial districts. These districts, defined in Seattle Municipal Code 25.08.100, are based on the zoning of the affected properties. While districts are based on zoning, the two are not equivalent. For example, NC-1 is a commercial zone, but is considered a residential district. Table 3-3 shows the exterior sound level limits applicable to each district.

### Table 3-3. City of Seattle Exterior Sound Level Limits

| District of Sound Source | Residential Receiving Districts Leq (Lmax) (in dBA) | Commercial Receiving Districts Leq (Lmax) (in dBA) | Industrial Receiving Districts Leq (Lmax) (in dBA) |
|---|---|---|---|
| Residential | 55 (70) | 57 (72) | 60 (75) |
| Commercial | 57 (72) | 60 (75) | 65 (80) |
| Industrial | 60 (75) | 65 (80) | 70 (85) |

Source: Seattle Municipal Code 25.08.410, Exterior Sound Level Limits

Notes:

Measurement time is 1 minute for a constant sound source and 1 hour for a varying sound source.

During measurement intervals, maximum sound level (Lmax) may exceed Leq limits by no more than 15 dBA.

The exterior sound level limits shown in Table 3-3 may be modified under certain circumstances, as outlined in Seattle Municipal Code 25.08.420. These modifications are for certain times of the day, classification of receiving properties, and type of sound generated. These modifications to the exterior sound level limits include the following reductions:

- 10 dB at receiving properties within Residential districts during the nighttime hours of 10 p.m. and 7 a.m. on weekdays, 10 p.m. and 9 a.m. on weekends, and 10 p.m. and 9 a.m. on legal holidays.
- 5 dB for sources that carry a pure tone component.
- 5 dB for impulsive sources not measured with an impulse sound level meter.

These reductions are cumulative and independent of one another. Therefore, the permissible nighttime exterior sound level in a residential district from an impulsive, tonal source would be 20 dB less than the exterior sound level described in Table 3-3.

Modifications to the permissible exterior sound level limits shown in Table 3-3 are allowed for construction activities. Daytime, non-impact construction activities are subject to Seattle Municipal Code 25.08.425. For public projects such as Sound Transit projects, modifications are permitted to the exterior sound level limits in all zones between 7 a.m. and 10 p.m. on weekdays and between 9 a.m. and 10 p.m. on weekends and legal holidays. The modifications allowed under Seattle Municipal Code 25.08.425 include the following increases during daytime hours:

- 25-dB increase for equipment on construction sites, including but not limited to crawlers, tractors, dozers, rotary drills and augers, loaders, power shovels, cranes, derricks, graders, off-highway trucks, ditchers, trenchers, compactors, compressors, and pneumatic-powered equipment.
- 20-dB increase for portable powered equipment used in temporary locations in support of construction activities in any zone, maintenance activities on commercial property, or used in maintenance of public facilities, including but not limited to chainsaws, log chippers, lawn and garden maintenance equipment, and powered hand tools.

- 15-dB increase for powered equipment used in temporary or periodic maintenance or repair of the grounds and appurtenances of residential property, including but not limited to lawnmowers, powered hand tools, snow-removal equipment, and composters.

The resulting exterior sound level limits from construction activities are measured at the adjacent property line or 50 feet from the equipment generating the sound, whichever is greater. The resulting daytime construction sound limits are listed in Table 3-4.

### Table 3-4. City of Seattle Exterior Daytime Construction Sound Level Limits

| District of Sound Source | Residential Receiving Districts Leq (Lmax) (in dBA) | Commercial Receiving Districts Leq (Lmax) (in dBA) | Industrial Receiving Districts Leq (Lmax) (in dBA) |
|---|---|---|---|
| Residential | 80 (95) | 82 (97) | 85 (100) |
| Commercial | 82 (97) | 85 (100) | 90 (105) |
| Industrial | 85 (100) | 90 (105) | 95 (110) |

Source: Seattle Municipal Code 25.08.410 and Seattle Municipal Code 25.08.425.

Notes:

Measurement time is 1 minute for a constant sound source and 1 hour for a varying sound source.

During measurement intervals Lmax may exceed Leq limits by no more than 15 dBA.

Seattle Municipal Code 25.08.425 also includes modifications to the permissible exterior sound level limits for impact types of construction equipment, including equipment that create impulse sound or impact sound, or are used as impact equipment. Examples of this type of equipment are pavement breakers, pile drivers, jackhammers, and sandblasting tools. Impact construction equipment can exceed the exterior sound level limits in any 1-hour period between 8 a.m. and 5 p.m. on weekdays and 9 a.m. and 5 p.m. on weekends and legal holidays. However, sound levels associated with impact construction equipment are not allowed to exceed the values set forth in Table 3-5. These values are defined at the adjacent property line or 50 feet from the equipment, whichever is greater.

### Table 3-5. City of Seattle Daytime Impact Construction Sound Level Limits

| Activity During 1-Hour Period | Leq (dBA) |
|---|---|
| Continuous | 90 |
| 30 minutes | 93 |
| 15 minutes | 96 |
| 7.5 minutes | 99 |

Source: Seattle Municipal Code 25.08.425.

Note: Standard of measurement is a 1-hour Leq. Leq may be measured for times not less than 1 minute to project an hourly Leq.

In addition to providing modifications for exterior sound levels during construction, Seattle Municipal Code 25.08.425 also defines permissible limits for sound levels measured inside a commercial building adjacent to construction activities. Specifically, construction or maintenance equipment that exceeds the exterior sound level limits outlined in Table 3-4 when measured from the interior of buildings in a Commercial district is prohibited between the hours of 8 a.m. and 5 p.m. Seattle Municipal Code 25.08.425 states that “interior sound levels shall be measured only after every reasonable effort, including but not limited to closing windows and doors, is taken to reduce the impact of the exterior construction noise.”

Typically, noise reduction due to the barrier effect of the building (e.g., noise reduction from the exterior to interior of a building assuming all doors and windows are closed) is approximately 25 dB. This is equivalent to the code modification allowed for construction noise (25 dB). Those interior limits are usually satisfied when work complies with daytime exterior construction noise limits and is farther than 50 feet from a commercial building.

## 3.2 Vibration Criteria

Rail transit can result in vibration that results in perceptible building vibration, rattle noises, reradiated noise (groundborne noise), and cosmetic or structural damage to buildings. However, vibration caused by light rail operations is typically well below what would cause even minor cosmetic damage to buildings. Therefore, the criteria for building vibration caused by transit operations are primarily concerned with potential annoyance of building occupants. Vibration caused by construction equipment and activities is typically evaluated for potential damage to nearby buildings rather than annoyance because it is temporary.

### 3.2.1 Transit Vibration Criteria

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 vibration thresholds do not specifically account for existing vibration because it is very rare that even substantial volumes of vehicular traffic including trucks and buses would generate perceptible ground vibration unless there are irregularities in the roadway surface such as potholes or wide expansion joints. The FTA Guidance Manual (2018) recommends that where there are existing rail lines, existing vibration conditions should be considered when determining vibration impact criteria for a new transit project. For a discussion of locations where there are existing trains or transit vehicles in the corridor, see Section 5.3.1, Ambient Vibration Survey (Representative Sites).

Like noise, the sensitivity to vibration varies by land use type, and the criteria represent these sensitivities. Sensitive land use categories for vibration assessment are presented in Table 3-6 in order of sensitivity.

**Table 3-6. Land Use Categories for Vibration Assessment**

| Land Use Category | Land Use Type | Description of Land Use Category |
|---|---|---|
| Not applicable | Special Buildings | This category includes special-use facilities that are very sensitive to vibration and groundborne noise that are not included in the categories below and require special consideration. Examples of these facilities include concert halls, television and recording studios, and theaters. |
| 1 | High Sensitivity | This category includes buildings where vibration levels, including those below the threshold of human annoyance, would interfere with operations within the building. Examples include buildings where vibration-sensitive research and manufacturing equipment is conducted, hospitals with vibration-sensitive equipment, and universities conducting physical research operations. The building's degree of sensitivity to vibration is dependent on the specific equipment that will be affected by the vibration. |
| 2 | Residential | This category includes all residential land use and buildings where people normally sleep, such as hotels and hospitals. Transit-generated groundborne vibration and noise from subways or surface running trains are considered to have a similar effect on receivers. |
| 3 | Institutional | This category includes institutions and offices that have vibration-sensitive equipment and have potential for activity interference such as schools, places of worship, and doctors' offices. Commercial or industrial locations including office buildings are not included in this category unless there is vibration-sensitive activity or equipment within the building. As with noise, the use of the building determines the vibration sensitivity. |

Source: FTA 2018.

The FTA Guidance Manual (2018) 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. This analysis applied the detailed vibration assessment criteria. The thresholds for use with the detailed vibration assessments are shown on Figure 3-1 and Table 3-7. For the detailed assessment, the predicted vibration levels in terms of the 1/3-octave band spectra are compared to the curves shown on Figure 3-1 to determine whether there is impact and the frequency range over which vibration mitigation should be evaluated. If the predicted vibration levels are below the curves on Figure 3-1 over the entire spectra, no impact is predicted.

Table 3-7 gives a description of the land uses that correspond to each of the vibration criteria (V.C.) curves on Figure 3-1, which are designated V.C.-A through V.C.-E. The curves apply to vibration-sensitive equipment, such as microscopes or magnetic resonance imaging machines. The Residential (Day) curve is applied to institutional land uses (Category 3) such as places of worship and schools, and the Residential (Night) curve is applied to residential land uses (Category 2).

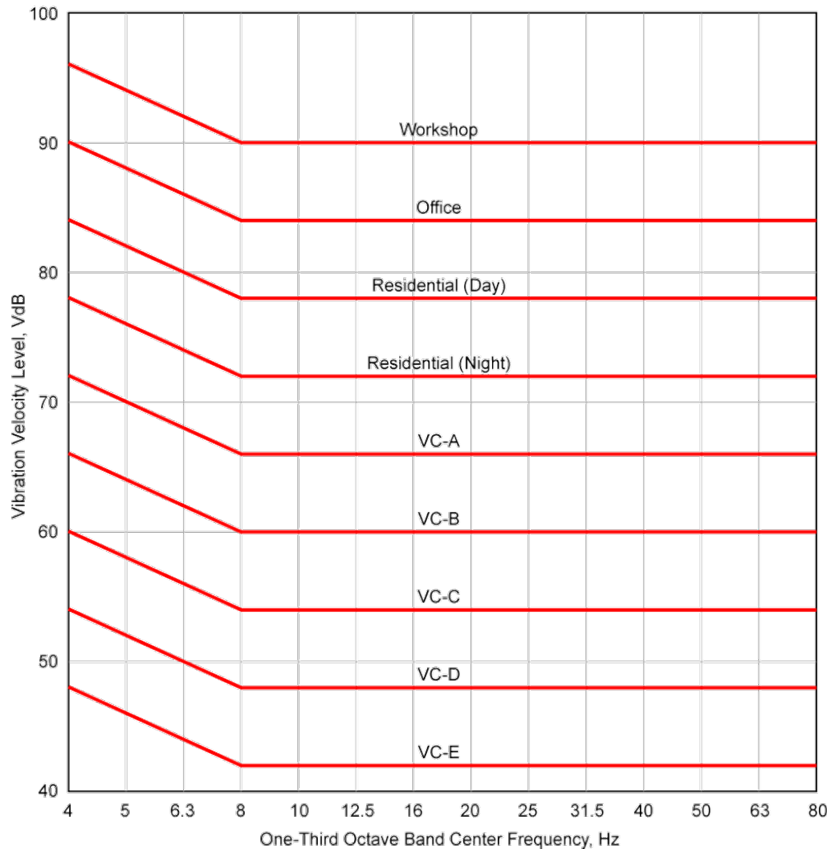
### Table 3-7. Interpretation of FTA Vibration Criteria for Detailed Analysis

| Criterion Curve | Maximum Vibration Velocity (VdB) [a] | Description of Use |
|---|---|---|
| Workshop | 90 | Distinctly detectable vibration; appropriate to workshops and non-sensitive areas |
| Office | 84 | Detectable vibration; appropriate to offices and non-sensitive areas |
| Residential day | 78 | Barely detectable vibration; adequate for computer equipment and low-power optical microscopes (up to 20 times power) |
| Residential night, operating rooms and sensitive hospital equipment | 72 | Vibration not detectable, but groundborne noise might be audible inside quiet rooms; suitable for medium-power optical microscopes (100 times power) and other equipment of low sensitivity |
| V.C.-A | 66 | Adequate for medium- to high-power optical microscopes (400 times power), microbalances, optical balances, and similar specialized equipment |
| V.C.-B | 60 | Adequate for high-power optical microscopes (1,000 times power) and inspection and lithography equipment up to 3 micron-line widths |
| V.C.-C | 54 | Appropriate for most lithography and inspection equipment to 1-micron detail size |
| V.C.-D | 48 | Suitable in most instances for the most demanding equipment, including electron microscopes operating to the limits of their capability |
| V.C.-E | 42 | The most demanding criterion for extremely vibration-sensitive equipment |

Source: FTA 2018.

[a] As measured in 1/3-octave bands of frequency over the frequency range of 8 to 80 hertz.

**Figure 3-1. FTA Criteria for Detailed Vibration Assessment**




### 3.2.2 Groundborne Noise Criteria

Some buildings, such as concert halls, recording studios, and theaters, can be particularly sensitive to groundborne noise. Because of their sensitivity, these buildings usually warrant special attention during the impact assessment. Table 3-8 gives criteria for acceptable levels of groundborne vibration and groundborne noise for various types of special buildings.

**Table 3-8. Groundborne Vibration and Noise Impact Criteria for Special Buildings**

| Type of Building or Room [a] | Groundborne Vibration Impact Levels for Frequent Events (VdB) [b] | Groundborne Noise Impact Levels for Frequent Events (dBA) [b] |
|---|---|---|
| Concert Halls | 65 VdB | 25 dBA |
| Television Studios | 65 VdB | 25 dBA |
| Recording Studios | 65 VdB | 25 dBA |
| Auditoriums | 72 VdB | 30 dBA |
| Theaters | 72 VdB | 35 dBA |

Source: FTA 2018.

[a] If the building will rarely be occupied when trains are operating, then there is no need to consider impact. As an example, consider locating a commuter rail line next to a concert hall; if no commuter trains will operate after 7 p.m., then trains would rarely interfere with the use of the hall.

[b] “Frequent events” are defined as more than 70 vibration events per day; most transit projects fall into this category.

Table 3-9 presents the groundborne noise impact criteria for three different land use types. Category 1 land uses are buildings where low ambient vibrations are essential for interior operations, such as laboratories. These spaces are generally not sensitive to groundborne noise and therefore no groundborne noise criteria is applicable to these spaces. Limits for spaces particularly sensitive to groundborne noise are covered in Table 3-8.

**Table 3-9. Groundborne Noise Impact Criteria for Frequent Events**

| Land Use Category | Groundborne Noise Impact for Frequent Events (decibels re 20 micropascals) [a] |
|---|---|
| Category 1: Buildings where low ambient vibration is essential for interior operations | Not applicable [b] |
| Category 2: Residences and buildings where people normally sleep | 35 dBA |
| Category 3: Institutional land uses with primarily daytime use | 40 dBA |

Source: FTA 2018.

[a] "Frequent Events" are defined as more than 70 vibration events of the same source per day; most rapid transit projects fall into this category.

[b] Vibration-sensitive equipment is generally not sensitive to groundborne noise.

### 3.2.3 Construction Vibration Criteria

Construction vibration was assessed for both potential damage to structures and annoyance. For potential vibration effects during construction, the FTA's recommended criteria on vibration levels is applied because there are no state, county, or municipal vibration regulations. The parameter normally used to assess potential construction vibration effects to structures is peak particle velocity, which is the maximum velocity recorded during a particular event, such as from a jackhammer. The FTA's recommended limits for construction vibration for four building categories are as follows:

- Reinforced concrete, steel, or timber: 0.5 inch per second peak particle velocity.
- Engineered concrete and masonry: 0.3 inch per second peak particle velocity.
- Nonengineered timber and masonry buildings: 0.2 inch per second peak particle velocity.
- Buildings extremely susceptible to vibration damage: 0.12 inch per second peak particle velocity.

Annoyance from groundborne noise and vibration is generally not assessed for construction activities because they are short-term in duration. However, potential interference with sensitive activities at Category 1 or Special Building land uses from groundborne noise and vibration due to construction are evaluated applying the criteria for operations in Tables 3-8 and 3-9. At Category 1 and Special Building land uses, groundborne noise and vibration from even short-term construction activities may interfere with sensitive research processes or planned performance or recording events that would disrupt the normal operations at those facilities. Potential annoyance at Category 2 (residential) and Category 3 (institutional) land uses were evaluated for reference using the operational criteria but were not used to identify potential construction vibration impacts. The exception is groundborne noise and vibration from tunnel muck and support trains, which are evaluated to meet the FTA criteria for operations based on annoyance because the tunnel support trains may run continuously over several years.

This page is intentionally left blank.

# 4 NOISE AND VIBRATION IMPACT ANALYSIS ASSUMPTIONS AND METHODS

## 4.1 Noise Assumptions and Methods

This section summarizes the approach used to identify and characterize noise sources and predict future noise levels for potential sources of community impacts related to the WSBLE. Project elements potentially influencing noise include light rail operation, track types and configuration, changes in traffic related to the project, and construction activities. Noise impacts from the operation and construction of the Build Alternatives were determined through noise and vibration modeling using FTA methods.

### 4.1.1 Operational Noise Elements

In order to evaluate noise resulting from a transit project, identifying and characterizing the various project elements that could generate or potentially affect noise levels is essential. Key elements pertaining to noise levels for the WSBLE Project are described in the following sections.

The plan and profile of the new light rail alignment, including the locations of special track work such as crossovers, and typical speeds were provided by the WSBLE design engineers. The plan and profile drawings used are included in Appendix J, Conceptual Design Drawings, of the Draft Environmental Impact Statement. The design information provided includes the elevation of the guideway, type of track (ballast-and-tie, embedded, and direct-fixation) and the location and design of the station alternatives.

#### 4.1.1.1 Light Rail Operational and Maintenance 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 4-1 lists operational and maintenance measures that Sound Transit performs on a regular basis and the benefit that each measure provides.

**Table 4-1. 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. |

#### 4.1.1.2 Reference Light Rail Noise Levels

Sound Transit modeled noise from light rail operations using the methods described in the FTA Guidance Manual (FTA 2018). Input to the model included measured reference noise levels for the new light rail vehicles that are currently being used on the existing Link light rail system. Reference measurements for light rail operations were taken from the *2019 Reference Noise and Vibration Levels for Link Light Rail Projects* (Sound Transit 2019). The measured reference noise levels include measured levels in 5-mile-per-hour increments for ballast-and-tie track, direct-fixation track, and embedded track.

The speeds used in this analysis are the track design speeds, which are generally 55 miles per hour throughout much of the South Interbay and Interbay/Ballard segments. In other areas, the light rail speed is limited by speed limited curves and reduced speed when accessing at stations. The speeds used in the analysis may be higher than actual speeds and assure a conservative noise impact analysis. More detailed information on how all this information is used to predict operational noise levels are provided in Section 4.1.2, Operational Noise Prediction Methods.

#### 4.1.1.3 Crossovers and Special Track Work

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 Link light rail system, standard frogs can increase noise levels by as much as 5 to 10 dB.

#### 4.1.1.4 Light Rail Warning Bells

Consistent with Sound Transit operating rules, 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 a.m. and 10 p.m. and are reduced to 72 dBA Lmax between 10 p.m. and 6 a.m. Sound Transit measured and validated train-mounted bells on light rail cars in October 2009, with several supplemental measurements in 2011 and 2012.

#### 4.1.1.5 Operations Plan

The operations plan for this analysis reflects a future build-out of the regional light rail system established by the Sound Transit 3 Plan (Sound Transit 2016). This assumes light rail service is operating to north to Everett, south to Tacoma, and east to Downtown Redmond. Under this maximized future operational plan, the light rail trains would operate with four passenger cars during all periods of service.

Train frequencies are established based on ridership demand and other service standards. Table 4-2 shows the new service schedule for weekdays. Weekend and holiday service levels are based on early and late service levels, as shown in the table.

**Table 4-2. Weekday Service Periods for Year 2042**

| Service Period | Time Period | Service Level | Train Frequency (Minutes) West Seattle Link Extension | Train Frequency (Minutes) Ballard Link Extension |
|---|---|---|---|---|
| Early morning | 5 a.m. to 6 a.m. | Early | 10 | 10 |
| Morning peak | 6 a.m. to 8:30 a.m. | Peak | 6 | 5 |
| Midday | 8:30 a.m. to 3 p.m. | Base | 10 | 10 |
| Afternoon peak | 3 p.m. to 6:30 p.m. | Peak | 6 | 5 |
| Evening | 6:30 p.m. to 10 p.m. | Base | 10 | 10 |
| Late Evening | 10 p.m. to 1 a.m. | Late | 15 | 15 |

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

#### 4.1.1.6 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 Link light rail corridor and used these measurements as reference data. Based on these measurements, curves with radii of less than 600 feet and potentially up to 1,250 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. As provided in the Sound Transit *Design Criteria Manual, Revision 5* (Sound Transit 2020), potential for wheel squeal shall be identified. Locations where tight-radius curves of 600 feet or less are near noise-sensitive receivers shall include wheel squeal mitigation measures in the project design. In addition, provisions for wayside lubrication shall be incorporated in the project design at all curves up to a 1,250-foot radius near commercial or residential areas. If audible wheel squeal or flanging noise are present on curve radii of 601 feet to 1,250 feet during pre-revenue service, then mitigation such as wayside lubrication shall be applied to the rail gauge face and wheel flange. Because the noise level from wheel squeal varies greatly depending on curve radius, train speed, and track type, modeling of squeal is not normally performed. However, all curves with radii up to 1,250 feet are identified in the impact analysis in Chapter 6, Impact Assessment.

#### 4.1.1.7 Light Rail Track Types

The track installation method can have an effect on noise levels emitted from light rail operations. First, all tracks on the Link light rail systems are continuously welded. Unlike freight rail tracks, which are butted, leaving a gap between tow rails that can increase noise and vibration levels, Sound Transit's welded rails provide a continuous smooth surface, reducing noise and vibration and improving the ride quality for patrons.

The overall track installation is generally performed using one of three methods: ballasted track, direct-fixation track or embedded track. Ballasted track is similar to freight rail tracks, with the track installed on concrete ties that are installed on top of the ballast, a crushed rock surface. Ballasted track is used mainly for at-grade guideways, and the ballast can absorb some of the noise making this the quietest of the three track installation methods. Direct-fixation track is guideway where the rails are installed with fasteners directly on a concrete plinth. This is also the method used on most all elevated structures and in tunnels. Due to the hard-reflective plinth surface, this method of track installation can increase the overall noise from the system by up to 3 dB for at-grade systems and 4 dB for elevated systems. The added noise from the elevated system is due, in part, to noise radiating directly from the structure.

The final type, embedded track, is usually a type of direct-fixation track embedded in a concrete slab or paved over to allow motor vehicles to drive over the tracks. This installation method is reserved for at-grade tracks with vehicles overcrossing. The only locations with embedded track in the WSBLE are at access points for hi-rail vehicles, the service trucks that can operate along the guideway for servicing. Table 4-3 summarizes the different track types and corrections used for the WSBLE noise analysis.

### Table 4-3. Light Rail Track-type Adjustments

| Track Type | Adjustment in Decibels |
|---|---|
| At-grade ballast-and-tie track (ballast exposed) | 0 |
| Elevated structure | +4 |
| Embedded track or retained-fill guideway | +3 |
| Trench at least 4 to 6 feet below-grade | -5 |

Source: FTA 2018.

### 4.1.2 Operational Noise Prediction Methods

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

- Sound Transit performed a land use survey of potential noise-sensitive receivers near the new 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 35 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 receivers.
- The existing ambient sound levels were also 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 for track crossovers are discussed in Section 4.1.1.3, Crossovers and Special Track Work, and adjustments based on track type are provided in Section 7.1, Operational Noise Mitigation. Typical noise reductions for sound walls, elevated acoustical walls, and trench situations are shown in Section 7.1. 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 2018). Noise related to bells at stations and special track work was included in the analysis as described in Section 4.1.1.4, Light Rail Warning Bells.
- 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 follow Sound Transit's Light Rail Noise Mitigation Policy (Sound Transit 2004).
- Measured noise-level reductions from existing noise barriers installed on the elevated guideway and at-grade track along the existing Link Light Rail System and information from the FTA Guidance Manual (2018) were used to assist in the final mitigation predictions.

### 4.1.3 Traffic Noise Prediction Methods

The potential to create or increase exposure to traffic noise as a result of the transit project must also be considered. As defined in Federal Highway Administration noise abatement policy (2011), 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 are identified and evaluated for potential traffic noise impacts based on existing noise measurements and Federal Highway Administration impact criteria.

### 4.1.4 Construction Noise Prediction Methods

Potential impacts from construction noise were evaluated using representative sound levels from various types of construction equipment provided in the FTA Guidance Manual (2018). Construction sound levels were predicted using the methodology detailed in Section 7 of the FTA Guidance Manual (2018), which analyzes the two loudest pieces of equipment expected for a particular construction activity. Resulting sound levels were compared to codified sound limits within the city of Seattle.

The analysis predicted sound levels from activities expected to produce the highest sound levels, require several months to complete, or require work during nighttime hours. These construction activities include elevated light rail construction, retained cut construction, tunneling, cut-and-cover station construction, and bridge construction over water crossings.

## 4.2 Vibration Assumptions and Methods

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 from train operations 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.

### 4.2.1 Operational Vibration Prediction Methods

To predict groundborne vibration associated with the WSBLE Project, the detailed vibration assessment procedure outlined in the FTA Guidance Manual (2018) was followed. This is an empirical model based on testing the vibration propagation characteristics of the soil in the project corridor and measurements of the vibration characteristics of existing Sound Transit light rail vehicles. As is discussed in Section 5.3.2, Vibration Propagation Tests, vibration propagation measurements were performed at surface and below-grade locations throughout the new WSBLE corridors.

The result of the vibration propagation tests is the line source transfer mobility, a measure of how efficiently vibration propagates through the soil. The force density level quantifies the vibration forces generated by the train and track. The basic relationship used for the vibration predictions is:

$$Lv = \text{Force Density Level} + \text{Line Source Transfer Mobility} + \text{Safety Factor}$$

Where: Lv is the train vibration velocity measured at the ground surface. Force density level is derived by measuring Lv and line source transfer mobility at a site where there are existing light rail vehicle operations. The force density levels used in this analysis are the measured force density level values of the existing Sound Transit Link light rail system (Rajaram 2019). The force density levels depend on speed and track type. The force density levels are available for speeds in increments of 5 miles per hour from 25 miles per hour to 55 miles per hour for ballast-and-tie and direct-fixation track structures. The force density level for the two track structure types at 55 miles per hour is shown on Figure 4-1. The force density levels include a 3-dB safety factor.

Elevated structures typically reduce vibration by about 10 dB relative to at-grade track. For this assessment, an adjustment of -10 dB was applied at all 1/3-octave band center frequencies except at 10 hertz and 12 hertz, as shown on Figure 4-2. This adjustment is based on force density level measurements of a Link aerial structure (Rajaram and Wolf 2014).

**Figure 4-1. Force Density Levels at 55 miles per hour for Direct-Fixation and Ballast-and-Tie Track Structures**

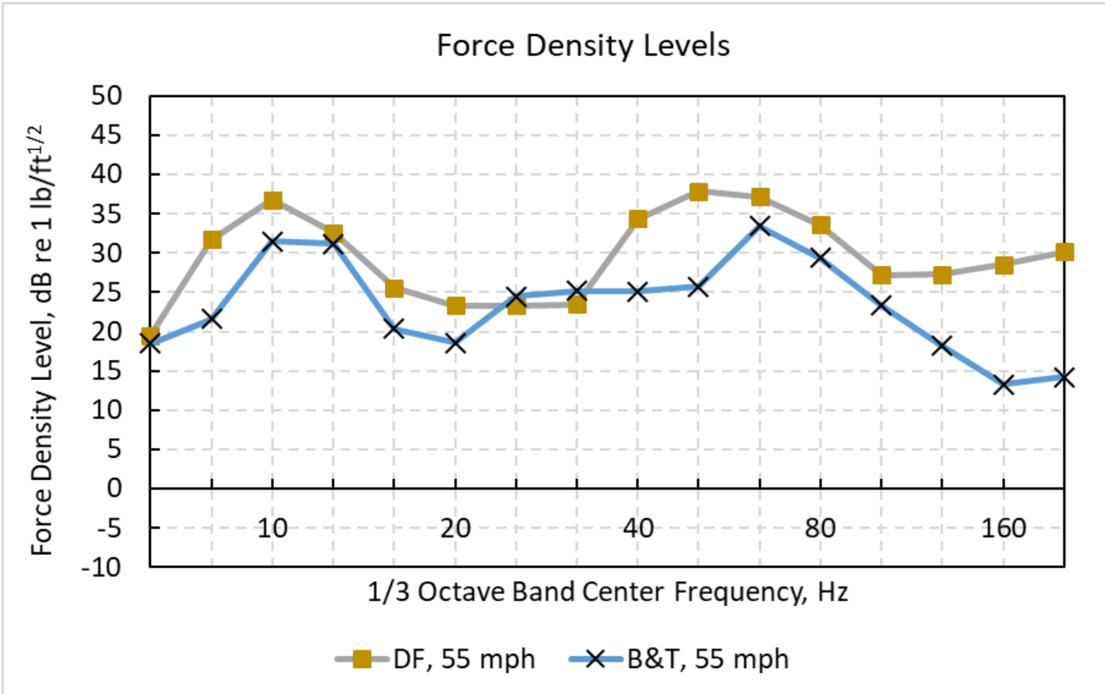
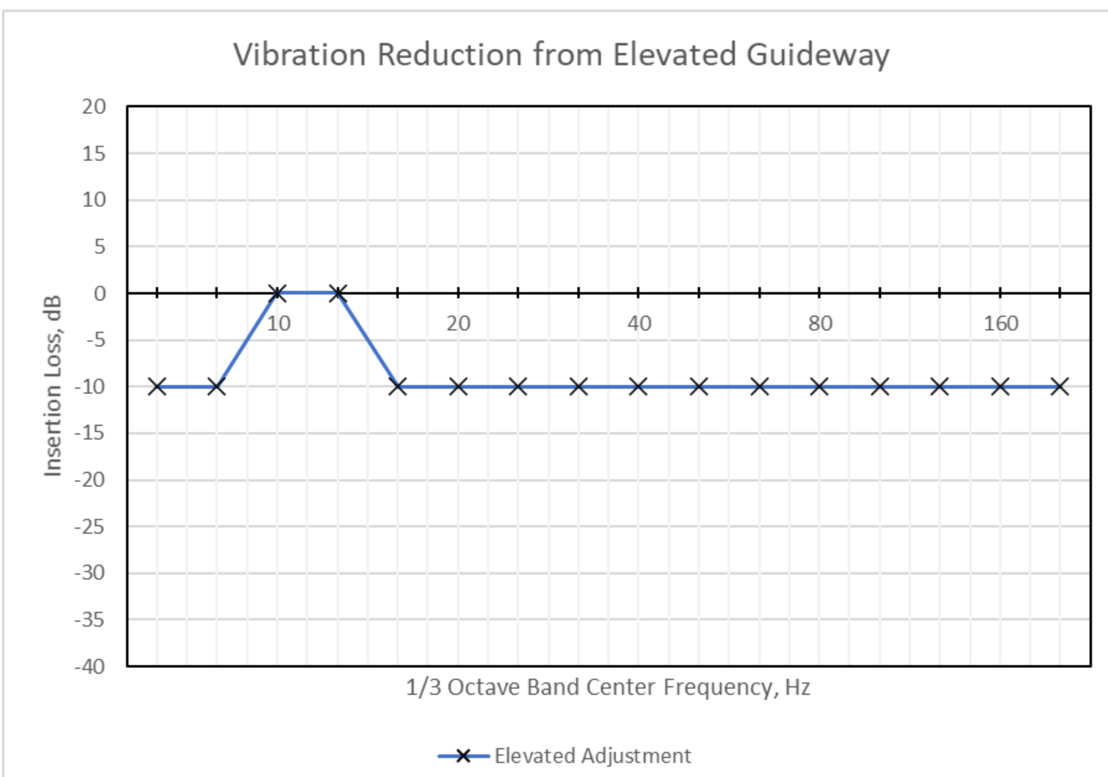



**Figure 4-2. Vibration Reduction from Elevated Track Structure**



The line source transfer mobility measurement sites and results are discussed in Section 5.3, Vibration Measurements. The approach used for predicting vibration from light rail operations throughout the study area was to develop three different line source transfer mobilities for different areas by averaging the data collected within those areas. The three areas are West Seattle, Downtown, and Interbay/Ballard. This is a reasonable approximation of the line source transfer mobility over the study area because the line source transfer mobility results showed similar trends within these groups. For Category 1 sensitive receivers where site-specific line source transfer mobility data were collected, the site-specific data were applied as opposed to the averaged data. Figures 4-3 to 4-6 show the line source transfer mobility curves for the different groups at 25 feet, 50 feet, 100 feet, and 200 feet, respectively. The borehole data are only shown at 100 feet and 200 feet because the data were usually collected at depths of 80 feet or greater. The line source transfer mobility data were applied to sensitive receivers throughout the study area as follows:

- Surface West Seattle: Applied to sensitive receivers near elevated, at-grade, or retained cut track in the West Seattle Junction, Delridge, or Duwamish segments.
- Borehole West Seattle: Applied to sensitive receivers near tunnel track in the West Seattle Junction, Delridge, or Duwamish segments.
- Borehole Downtown: Applied to sensitive receivers near tunnel track in the Downtown or South Interbay segments.
- Surface South Interbay and Interbay/Ballard: Applied to sensitive receivers near elevated, at-grade, or retained cut track in the South Interbay or Interbay/Ballard segments.
- Borehole Interbay/Ballard: Applied to sensitive receivers near tunnel track in the Interbay/Ballard Segment.

**Figure 4-3. Average Line Source Transfer Mobilities at 25 feet for West Seattle and Interbay/Ballard Surface Measurement Sites**

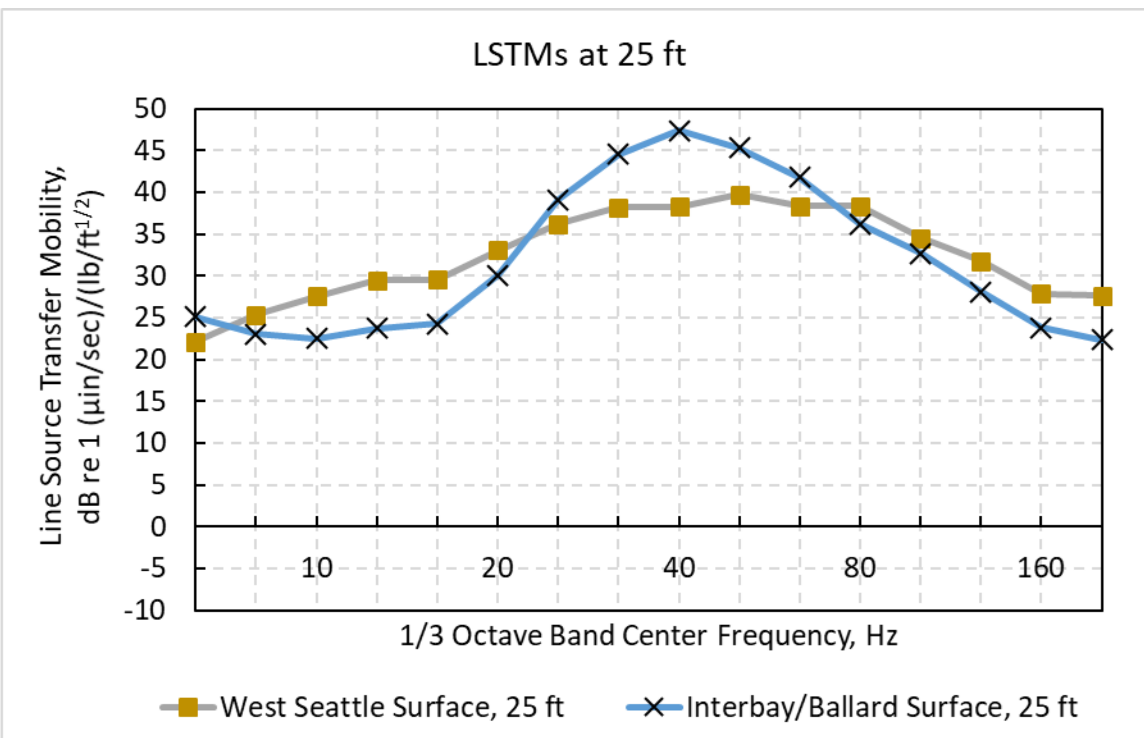


**Figure 4-4. Average Line Source Transfer Mobilities at 50 feet for West Seattle and Interbay/Ballard Surface Measurement Sites**

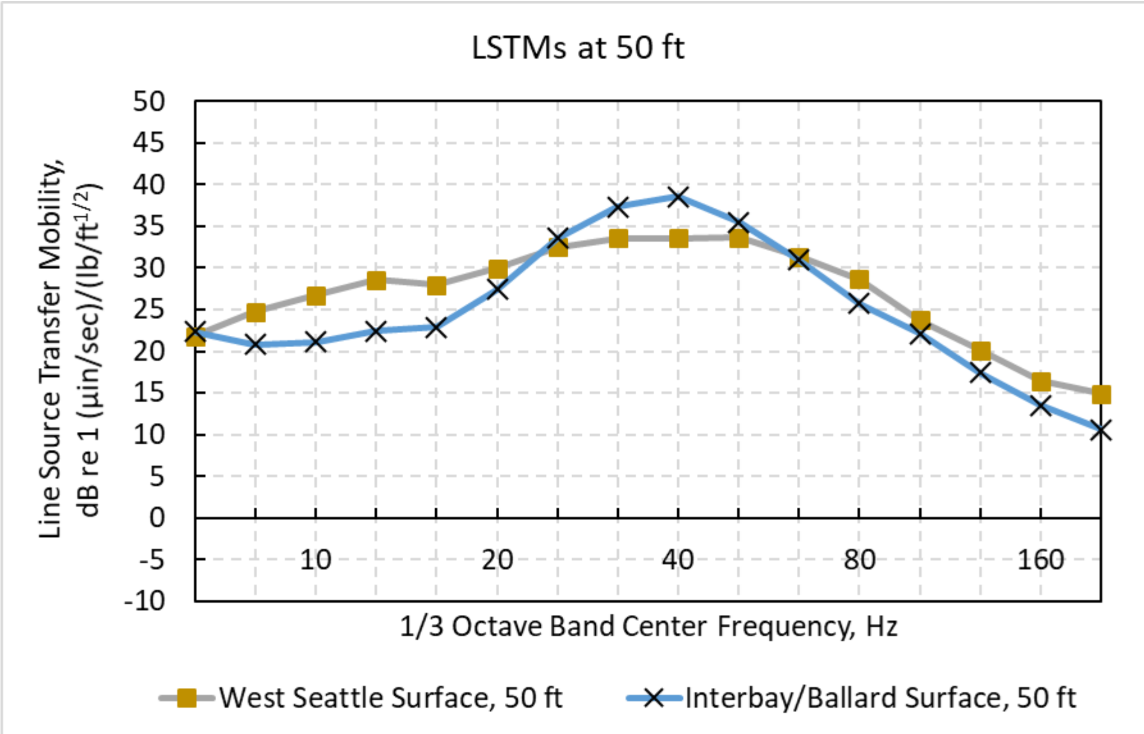



**Figure 4-5. Average Line Source Transfer Mobilities at 100 feet for Surface and Borehole Measurement Sites**

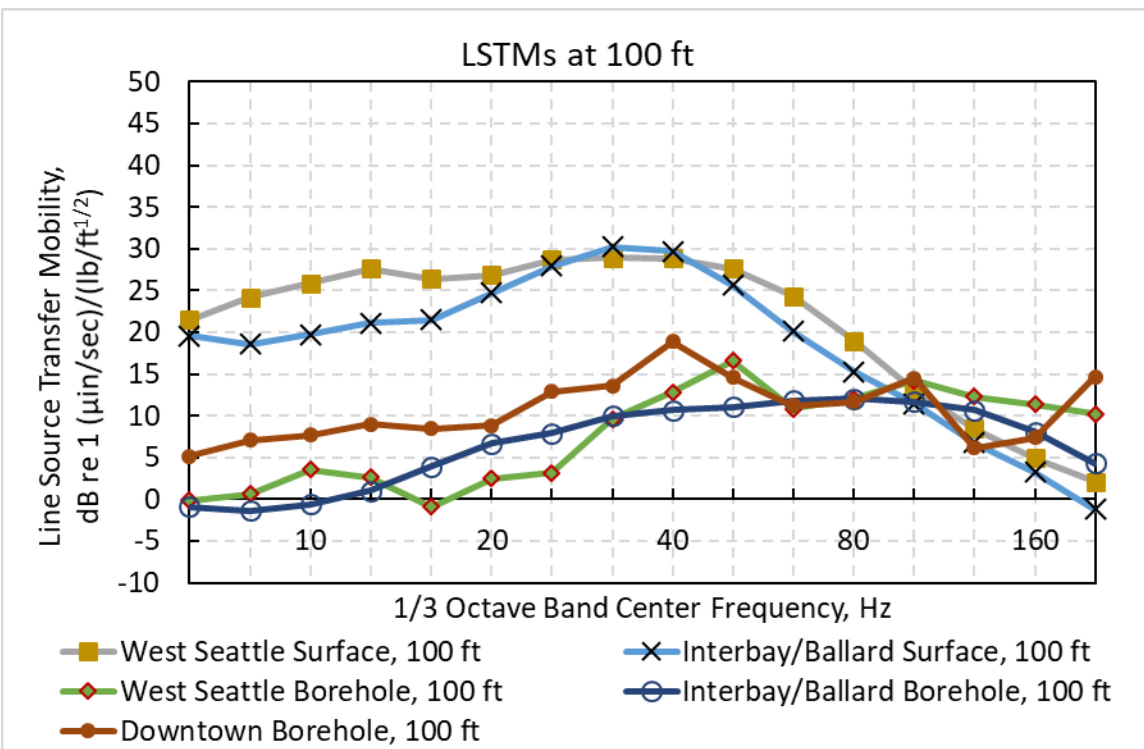
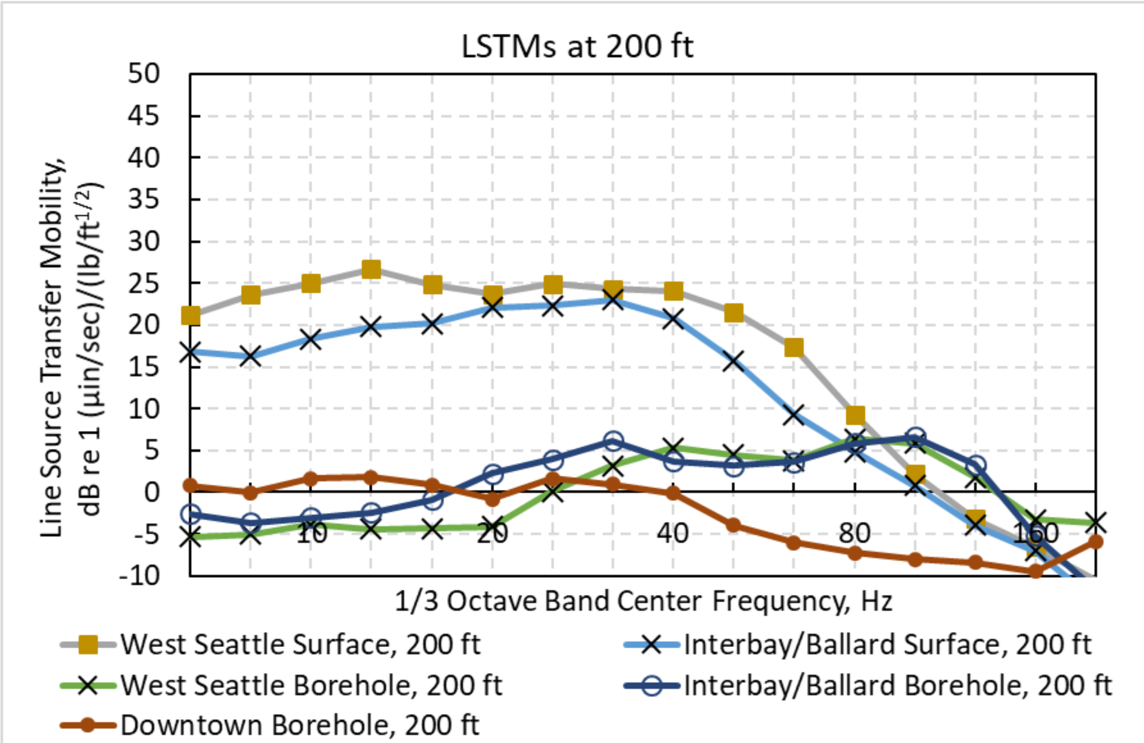


**Figure 4-6. Average Line Source Transfer Mobilities at 200 feet for Surface and Borehole Measurement Sites**




The prediction model includes a safety factor of +3 dB to each 1/3-octave band to account for uncertainties in the line source transfer mobility and potential uncaptured amplification effects inside buildings. When vibration is propagated from the ground to the building foundation there is loss in vibration energy at the buildings' interface with the ground, which is commonly referred to as coupling loss. Floor amplification may occur due to resonances of the floors and varies greatly, depending on the type of construction. For the combined effect of coupling loss and floor amplification, the FTA Guidance Manual (2018) recommends a net adjustment of +1 dB for the vibration inside a typical residence. A Transit Cooperative Research Program 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, McKenna 2011).

With the exception of Category 1 buildings with building-specific measurement data, it was assumed that the coupling loss and building amplification was a net 0-dB effect. The safety factor of +3 dB is a conservative approach that ensures that in the majority of cases the predicted vibration levels are higher than what would occur when the new project is operational. For Category 1 buildings with site-specific measurements, a measured building adjustment was applied to the predicted level. The measured building adjustments for those Category 1 buildings are presented in Attachment N.3H, Vibration Analysis of Category 1 Uses and Special Buildings.

Another source of vibration accounted for in the prediction model is special trackwork. The wheel impacts at the gaps in the rail at special trackwork for turnouts and switches increases vibration levels. The prediction model for this assessment applies the special trackwork adjustment recommended in the FTA Guidance Manual (2018): Wheel impacts are assumed to cause a localized increase in vibration of 10 VdB up to a distance of 100 feet and an increase in vibration of 5 VdB from 100 to 200 feet.

Track curvature can increase vibration levels. The prediction model assumes an increase in force density level (Ccurv) for tracks with curve radius less than 6,000 feet using the following formula:

$$\text{Ccurv(decibel)} = 3280\ \text{feet/radius (feet)}$$

The force density level adjustment for curves with radius less than 1,150 feet is limited to +3 dB.

Groundborne noise refers to the noise generated by groundborne vibration. The relationship between the predicted groundborne vibration, Lv, and the predicted groundborne noise is equal to the vibration velocity plus the A-weighting adjustment at the 1/3-octave band center frequency plus an adjustment to account for the conversion from vibration velocity level to sound pressure level (Krad), such as any acoustical absorption in the room. The FTA Guidance Manual (2018) recommends a Krad value of -5 for typical residential rooms. This analysis assumes a Krad value of -5 decibels for all sensitive receivers.

### 4.2.2 Construction Vibration Prediction Methods

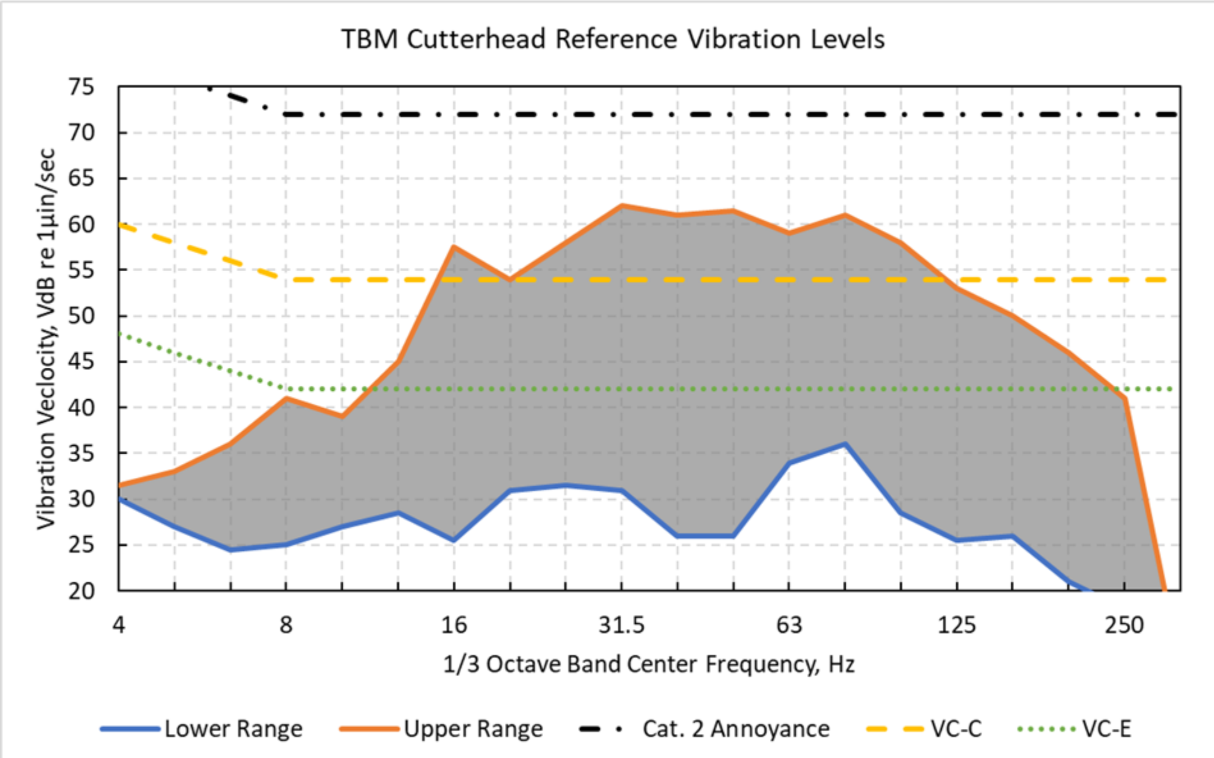
Vibration associated with construction of the WSBLE Project generally falls into two categories: tunneling operations and surface construction activities. Several different alignment alternatives are under consideration and detailed means and methods of construction have not been determined. Therefore, the construction vibration analysis focuses on determining the minimum distance between sensitive receivers and major vibration-generating equipment pieces that would exceed the construction vibration criteria. An analysis specific to Category 1 land uses in the study area has also been conducted to determine the potential for interference with sensitive activities at those facilities.

#### 4.2.2.1 Tunneling Construction Vibration

Many areas of the alignments under consideration include tunnels constructed by an earth pressure balance tunnel boring machine. The machine removes soil and rock via a rotating cutterhead at the front, followed by hydraulic thrust jacks that are temporarily extended to hold the tunnel wall in place. Each time the cutterhead advances 5 feet, the thrust jacks are retracted and replaced with concrete tunnel liner segments. The liner segments are delivered from the tunnel supply shaft to the tunnel boring machine via a temporary rail system, positioned on the tunnel wall by a vacuum erector and bolted into place with handheld pneumatic impact wrenches. The main sources of vibration during this process are tunnel boring machine cutterhead mining, thrust jack retraction during liner segment installation, and operation of the supply train for workers and materials. A vibration prediction model for these tunneling activities was developed using measured data from tunneling under the University of Washington main campus (Bergen and Schwarz 2015, Bergen et al. 2012).

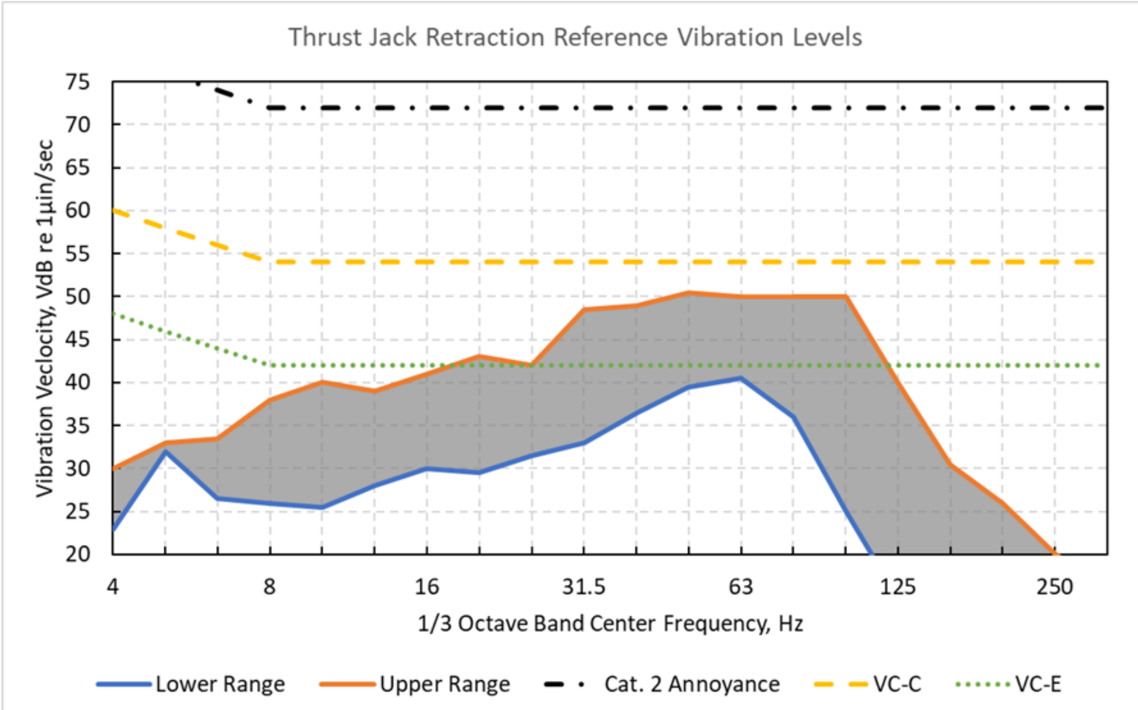
Operation of the tunnel boring machine cutterhead can generate a large range of vibration levels that is affected by underground features such as cobbles as well as the type of surrounding soil being tunneled through. Measurements conducted during tunneling under the University of Washington main campus suggest that vibration levels from the tunnel boring machine cutterhead are generally higher in areas of sandy soils and lower in clay/silt soils. Reference levels for the tunnel boring machine cutterhead vibration analysis have been based on those measurements at the University of Washington and are shown on Figure 4-7. A range of values are included to account for the variability in the cutterhead vibration levels due to depth, soil type, and underground features like cobbles. The reference levels were measured at distances ranging from 0 feet to over 200 feet horizontally along the surface from the tunnel centerline, and the range of reference levels are considered valid for those distances.

**Figure 4-7. Reference Vibration Levels for Tunnel Boring Machine Cutterhead Operation**




Vibration levels generated as the concrete liner segments are positioned and bolted into place are negligible, and usually below the existing ambient vibration levels at the surface. However, retraction of the hydraulic thrust jacks during the liner segment installation has the potential to generate high levels of vibration if it includes a hard stop, when the cylinders are retracted at full speed. Reference vibration levels of thrust jack retraction measured during the University of Washington tunnel construction are shown on Figure 4-8. The reference level range accounts for the variability in vibration levels due to the tunnel depth and nearby soil type and are considered valid for distances from 0 to 200 feet measured horizontally from the tunnel centerline.

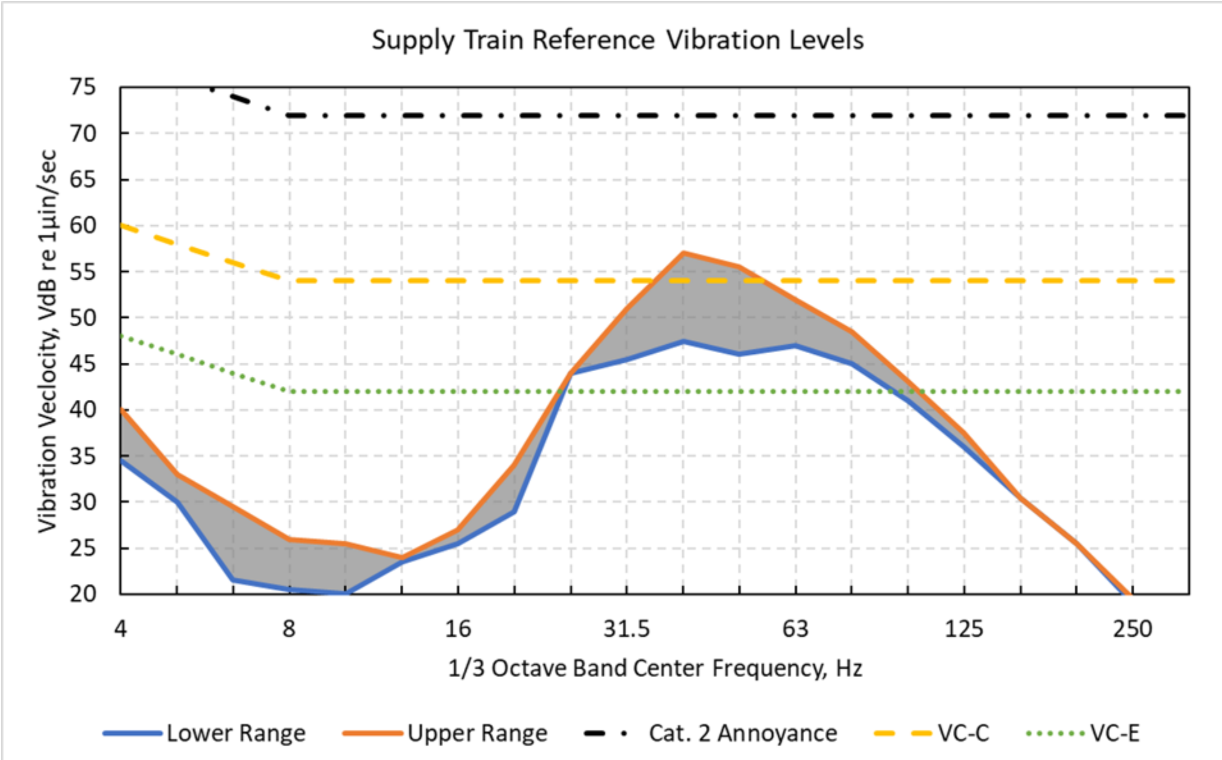
**Figure 4-8. Reference Vibration Levels for Thrust Jack Retraction**




The supply train may be used to transport workers and materials from the portal or tunnel supply shaft to the tunnel boring machine. A supply train typically travels at 12 miles per hour and consists of steel-wheeled flatbed trailers pulled by a diesel locomotive. The rail is progressively laid out in short sections as the boring machine travels along its path, and the rail often includes some level of damage on the running surface. Gaps of up to 3/4 inch between adjoining rail sections were noted during tunneling for the University Link project. Both the uneven rail running surface and the rail gaps contribute to higher vibration levels. Rail sections are installed either by using pre-assembled rail fastened to wooden ties, or by fastening the rail to temporary steel ties bolted directly to the tunnel invert.

Reference vibration levels for a supply train running at 12 miles per hour on uneven rail are shown on Figure 4-9 and are given as a range of values based on measurements conducted during the University of Washington tunnel construction. The range of values accounts for the variability in vibration levels due to the tunnel depth and nearby soil type and are considered valid for distances from 0 to 200 feet measured horizontally from the tunnel centerline.

**Figure 4-9. Reference Vibration Levels for Tunnel Boring Machine Supply Train (12 miles per hour with uneven rail)**




As discussed in Section 2.2, Vibration Fundamentals and Descriptors, groundborne noise is a low-frequency rumble caused by room surfaces radiating sound waves as they vibrate. A groundborne noise assessment is not included in most construction assessments because the airborne noise generated by the construction is typically higher than the groundborne noise. However, because there is no airborne noise path during tunneling a groundborne noise assessment has been conducted for these activities. The impact assessment is presented in Section 6.4.2.1, West Seattle Link Extension Surface Construction Impacts.

#### 4.2.2.2 Surface Construction Vibration

Surface construction activities often include the use of high-vibration equipment pieces, the most common of which are listed in Section 6.4.2, Surface Construction Vibration Impacts. The reference vibration levels for the analysis come from the FTA Guidance Manual (2018) and are shown as peak particle velocity levels, which quantify the maximum vibration velocity from a piece of equipment at a distance of 25 feet. The damage criteria for buildings as discussed in Section 3.2.2, Groundborne Noise Criteria, is in terms of peak particle velocity. However, the criteria for sensitive equipment and occupant annoyance (Section 3.2.1, Transit Vibration Criteria) is in VdB, which are a root mean square of a vibration velocity signal. The ratio of the peak particle velocity to the max root mean square level is called the crest factor and is typically between 4 and 5. A crest factor of 4 has been used for this analysis. The equation below is used to convert from peak particle velocity (inches per second) to a vibration level $L_v$ (VdB):

$$L_v = 20 \times \; log_{10}\left(\frac{peak\ particle\ velocity}{crest\ factor\ \times\ 10^{-6}}\right)$$

In most cases, construction equipment will not be operating at the 25-foot reference distance, so a distance correction is needed. The following equation is used to convert peak particle velocity reference values to a desired distance:

$$peak\ particle\ velocity_{equip} = peak\ particle\ velocity_{ref} \times \left( {D_{ref}}/{D_{equip}} \right)^{1.5}$$

where $D_{ref}$ is the reference distance (typically 25 feet) and $D_{equip}$ is the distance between the equipment and the sensitive receiver. Typically, the minimum distance each piece of equipment is expected to operate from a sensitive receiver is determined and vibration predictions are made based on that distance using the equation above. The predictions are compared to the criteria to determine whether impacts are expected. This type of analysis is not possible at this stage because detailed information about construction means and methods and site layouts are not available. Instead, the equation above was used to determine the distance from a sensitive receiver at which each piece of equipment would generate vibration levels equal to the impact threshold. The result of this analysis is presented in Section 6.4.2.

Although detailed means and methods of construction are not currently available, the use of impact or vibratory pile drivers is expected to be limited to the bridges over the Duwamish Waterway (also known as Duwamish River) and Salmon Bay for all Build Alternatives. Structural foundations for other elevated sections are expected to use shallow-spread footings or drilled shafts, which would most likely use equipment that falls under the lower-vibration Caisson Drilling category presented in Section 6.4.2. This should be verified in the construction noise and vibration control plan when means and methods are determined. In addition, use of small sheet pile cofferdams is anticipated for utility work in wet soil areas, which should be identified in the construction noise and vibration control plan. Vibration predictions for these areas should use the reference levels that reflect the installation method used for the cofferdams (pile-driving or drilling).

This page is intentionally left blank.

# 5 AFFECTED ENVIRONMENT

Sound Transit identified noise- and vibration-sensitive locations throughout the WSBLE corridor and selected locations where noise monitoring and vibration testing would be performed. The study area for noise is based on measured noise levels of the existing fleet of Sound Transit light rail vehicles, operational schedule, and train speeds, and is large enough to capture all potential noise impacts from system operations. Based on this information, the analysis includes noise-sensitive properties within at least 500 feet of the track alignments.

The potential area of effect for the vibration study is smaller compared to noise because vibration levels attenuate more rapidly. The potential area of effect for the vibration study is 200 feet from the track alignment for most land uses, such as residences and schools, and 450 feet from the track alignment for more vibration-sensitive land uses such as research laboratories or recording studios.

The following sections describe the land uses along the WSBLE corridor, the existing noise-level measurements, and the current noise sources in the corridor. A more detailed discussion of land use can be found in Sections 4.2.2 and 4.3.2, Land Use, of the Draft Environmental Impact Statement. The 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 a magnetic resonance imaging machine), which are not sensitive to airborne noise. The tunnel segments would not be exposed to airborne noise during operations. As such, sensitive receivers are only assessed for groundborne noise and vibration impacts and not airborne noise during operations.

## 5.1 Noise and Vibration Sensitive Receivers

This section provides an overview of the noise- and vibration-sensitive receivers along the corridors being evaluated for West Seattle Link Extension and Ballard Link Extension alternatives. Section 3, Noise and Vibration Impact Criteria, of this document defines the land use types considered as noise- and vibration-sensitive under the FTA assessment methodology (FTA 2018). For a more detailed presentation of land uses, see Sections 4.2.2 and 4.3.2 of the Draft Environmental Impact Statement.

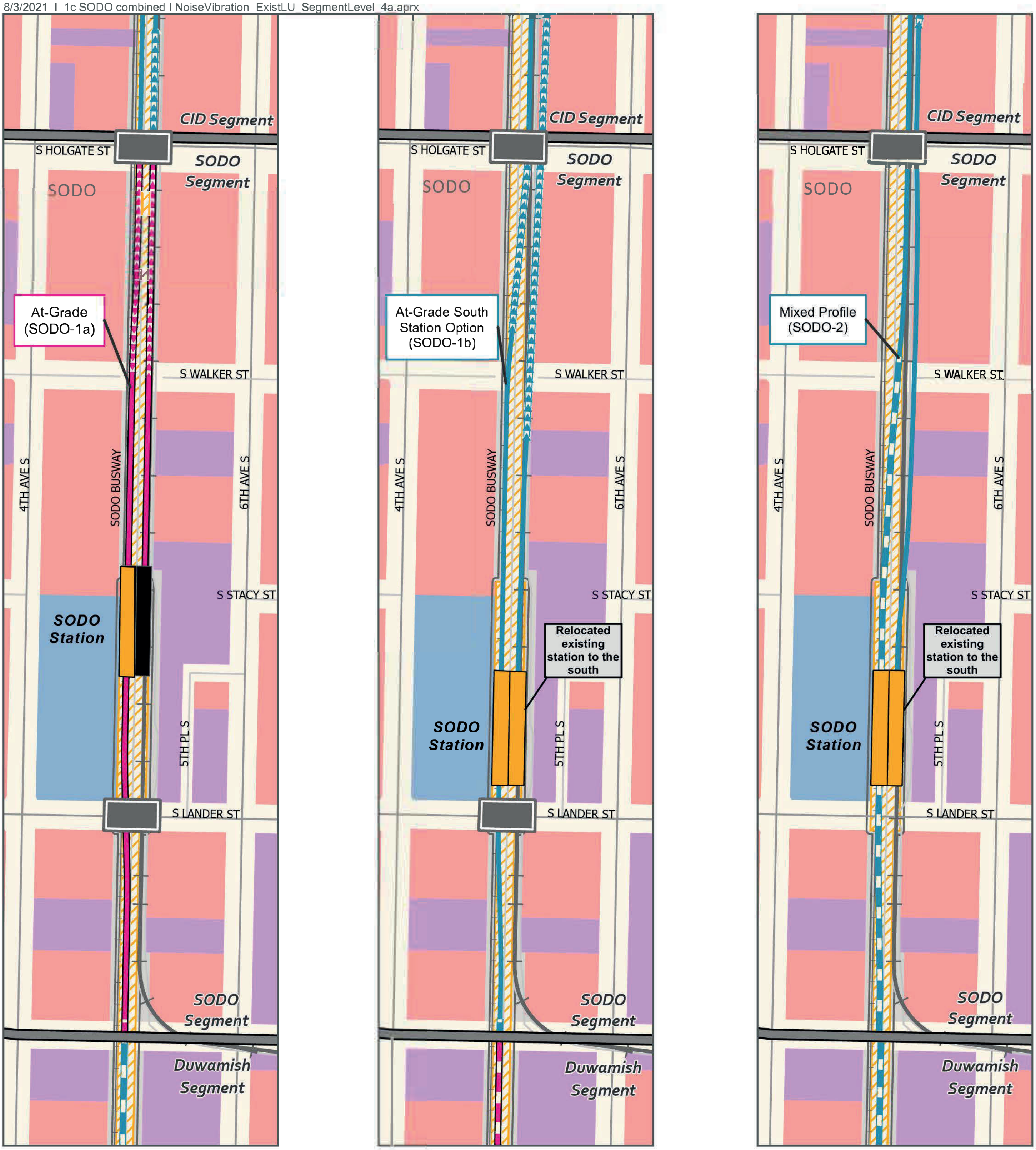
### 5.1.1 West Seattle Link Extension Sensitive Receivers

#### 5.1.1.1 SODO Segment

No noise- or vibration-sensitive properties were identified in the SODO Segment. Land uses in this segment are predominantly industrial and commercial (Figure 5-1). Alternatives in this segment would be a mix of at-grade and elevated options.

The SODO Trail, a 1-mile urban bicycle and pedestrian trail, runs along the east side of the light rail line between South Royal Brougham Way and South Forest Street. Based on the land uses, there was no noise or vibration analysis required.

8/3/2021 I 1c SODO combined I NoiseVibration_ExistLU_SegmentLevel_4a.aprx




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New
- Existing

- Segment Line
- Existing Link Light Rail
- Railroad
- SODO Busway
- Proposed Overpass

**Existing Land Uses**
- Commercial
- Industrial
- Public/Institutional
- Other

FIGURE 5-1
**Existing Land Uses**
West Seattle and Ballard Link Extensions - SODO Segment

*West Seattle and Ballard Link Extensions*

0 300 600 Feet
N

#### 5.1.1.2 Duwamish Segment

Similar to the SODO Segment, the Duwamish Segment is predominantly industrial and commercial land uses that are generally not noise- or vibration-sensitive (Figure 5-2). There are two Category 1 noise- or vibration-sensitive land uses. Secret Studio Records/Studio 1208 recording studio is both noise- and vibration-sensitive. Harbor Island Machine Works, a precision manufacturing company, is a Category 1 vibration-sensitive land use with vibration-sensitive equipment on Harbor Island. Category 2 noise- and vibration-sensitive land uses include residential areas at the west edge of the segment, as well as Fire Stations 14 and 36. A portion of the West Duwamish Greenbelt is located near Pigeon Point, but because of existing noise levels and because it is not designed to provide public access, it is not considered noise-sensitive under FTA criteria. A public staircase connects Southwest Marginal Place to Southwest Charlestown Street in this area, but it does not connect to or provide access to the trail system within the greenbelt. No other noise-sensitive land uses were identified in this segment.

Noise-sensitive land uses include fire stations, single- and multi-family housing, schools, and a recording studio, as described below.

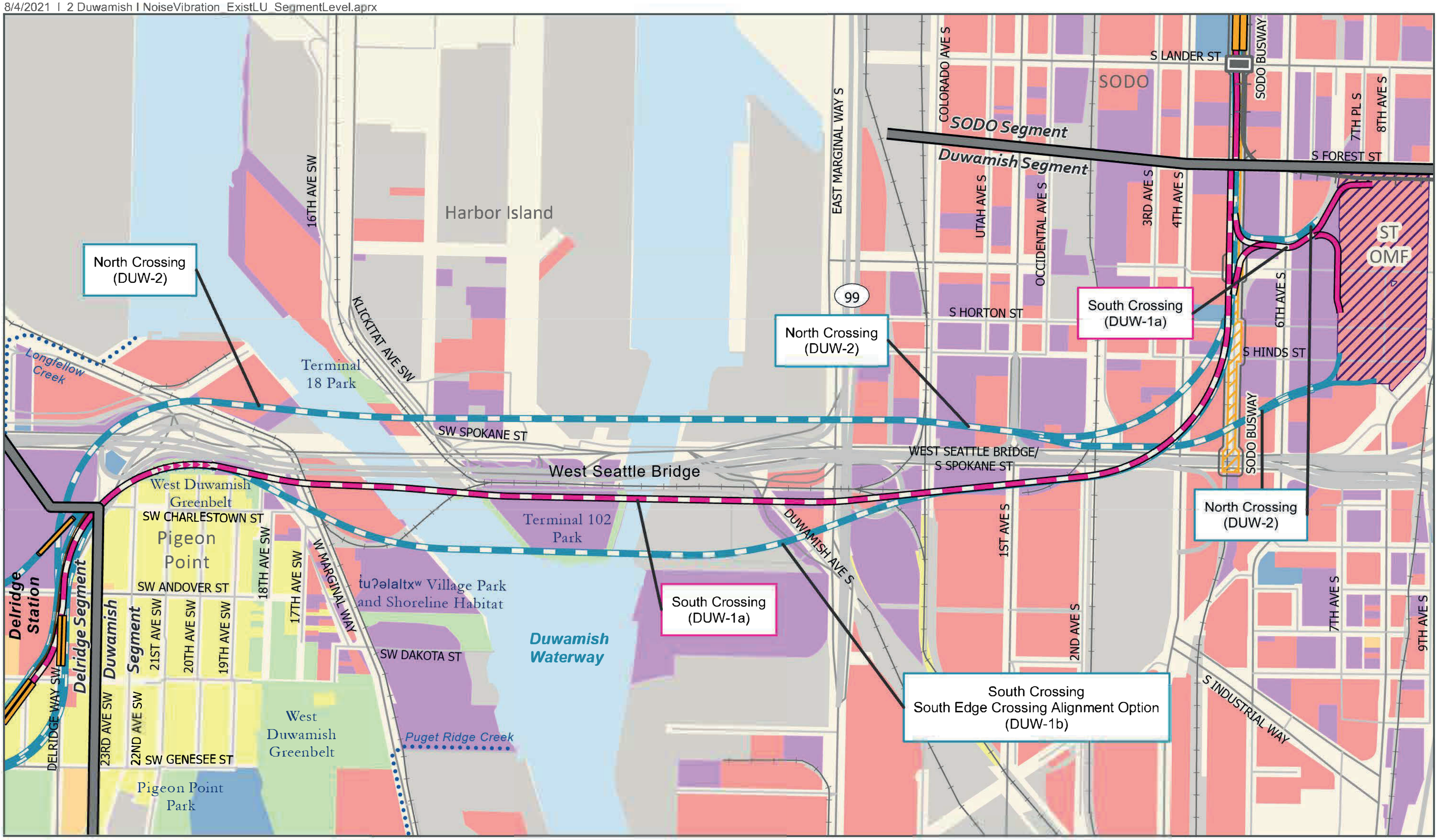
The Seattle Fire Department has two fire stations in this segment that are considered noise-sensitive because they have sleeping quarters (FTA Category 2): Fire Station 14 at 3224 4th Avenue South, and Fire Station 36 at 3600 23rd Avenue Southwest. On the west side of the segment, there are single- and multi-family residences in the Pigeon Point and Riverside communities. Single-family housing, public and institutional uses (Pathfinder K-8 School), the Delridge Connector Trail (paved bicycling and walking trail), and open space (West Duwamish Greenbelt) are all in the Pigeon Point community. The only part of West Duwamish Greenbelt that is near the Link light rail alignments are along the steep hillside near Pigeon Point, which is south of the West Seattle Bridge and not an area with public access; therefore, it is not considered noise-sensitive under FTA criteria. Secret Studio Records/Studio 1208 recording studio at 3856 23rd Avenue Southwest (FTA Category 1) is in this segment.

The residential and institutional vibration-sensitive land uses in the Duwamish Segment are the same as the noise-sensitive land uses. Harbor Island Machine Works at 3431 11th Avenue Southwest, a precision machining company, is the only Category 1 vibration-sensitive land use in the Duwamish Segment and Secret Studio Records/Studio 1208 recording studio at 3856 23rd Avenue Southwest, is the only special-use building.

#### 5.1.1.3 Delridge Segment

Noise-sensitive uses in the Delridge Segment include residential uses, schools and childcare centers, parks, and open spaces as described below.

Most of this segment is single or multi-family residential land uses (Figure 5-3). Several multi-family residential uses are concentrated along Southwest Avalon Way, north of Southwest Genesee Street. There is some non-noise-sensitive commercial development along Delridge Way Southwest. In addition to many residential uses, other noise-sensitive uses include Mode Music Studios at 3805 Delridge Way Southwest and the Youngstown Cultural Arts Center at 4408 Delridge Way Southwest (FTA Category 3).




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

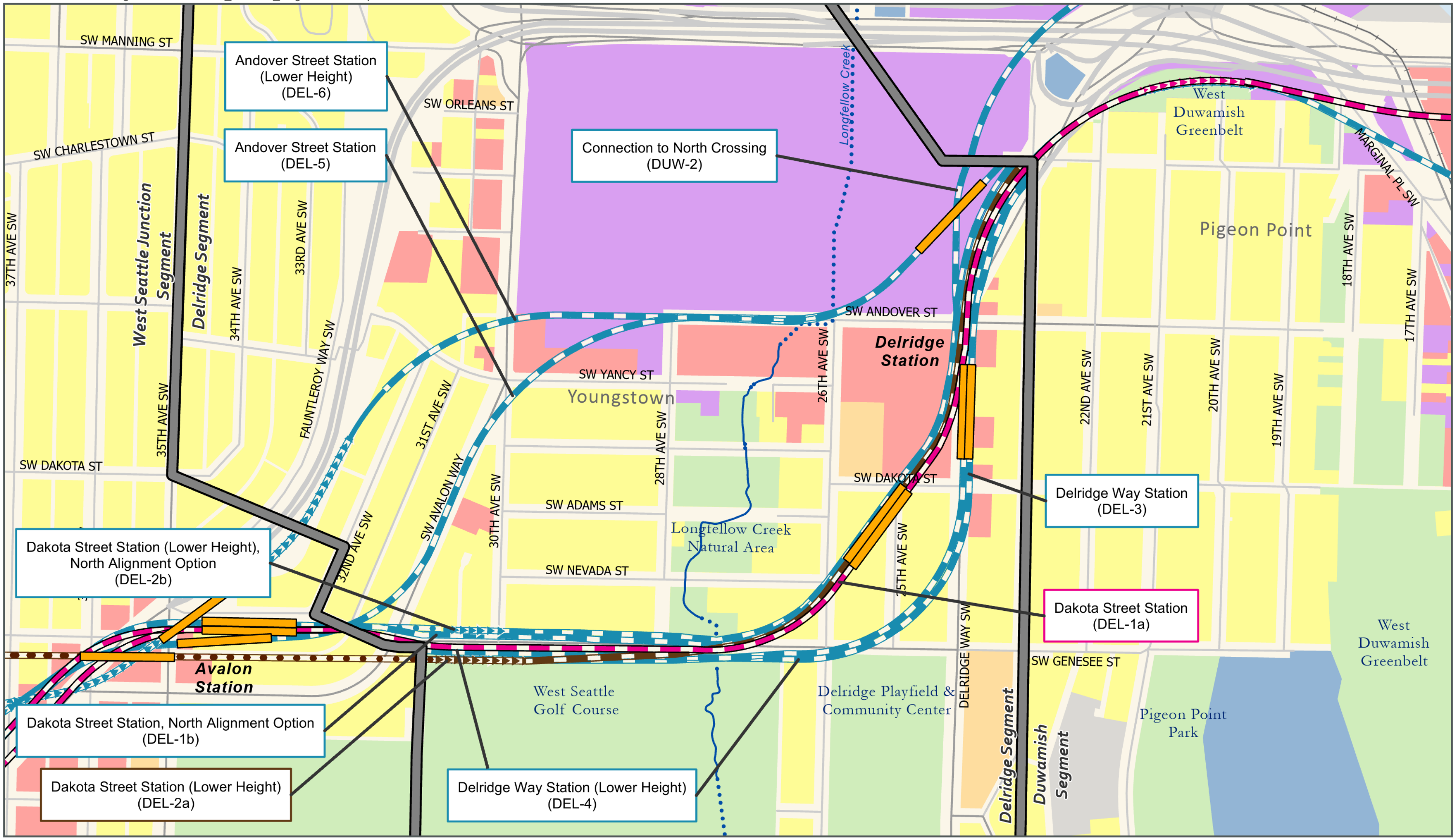
- Segment Line
- Existing Link Light Rail
- Railroad
- SODO Busway
- Proposed Overpass
- Sound Transit Operations and Maintenance Facility (ST OMF)
- Piped Stream
- Park

**Existing Land Uses**
- Commercial
- Industrial
- Mixed Use
- Park or Open Space
- Public/Institutional
- Residential
- Other

FIGURE 5-2
**Existing Land Uses**
West Seattle Link Extension - Duwamish Segment

*West Seattle and Ballard Link Extensions*

0 800 1,600 Feet
N




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Railroad
- Stream
- Piped Stream
- Park

**Existing Land Uses**
- Commercial
- Industrial
- Mixed Use
- Park or Open Space
- Public/Institutional
- Residential
- Other

FIGURE 5-3
**Existing Land Uses**
West Seattle Link Extension - Delridge Segment

*West Seattle and Ballard Link Extensions*

0 400 800 Feet N

Active and outdoor uses include the West Seattle Golf Course, Longfellow Creek Natural Area, and Delridge Playfield and Community Center; however, due to the locations and existing noise levels, only parts of the Longfellow Creek Natural Area were considered noise sensitive under FTA criteria. Noise sensitive parts of the Longfellow Creek Natural Area includes the parts of the park that have lower noise levels and are not near arterial roadways in the area, including Southwest Genesee Street. Locations selected for analysis included the trail just north of Northwest Nevada Street and the area near the Dragonfly Garden and Pavilion. A small portion of this segment is within the Duwamish Manufacturing and Industrial District and includes Nucor Steel, a steel manufacturing plant, also not considered noise-sensitive under FTA criteria.

In the Delridge Segment, the vibration-sensitive receivers are the same as the noise-sensitive receivers.

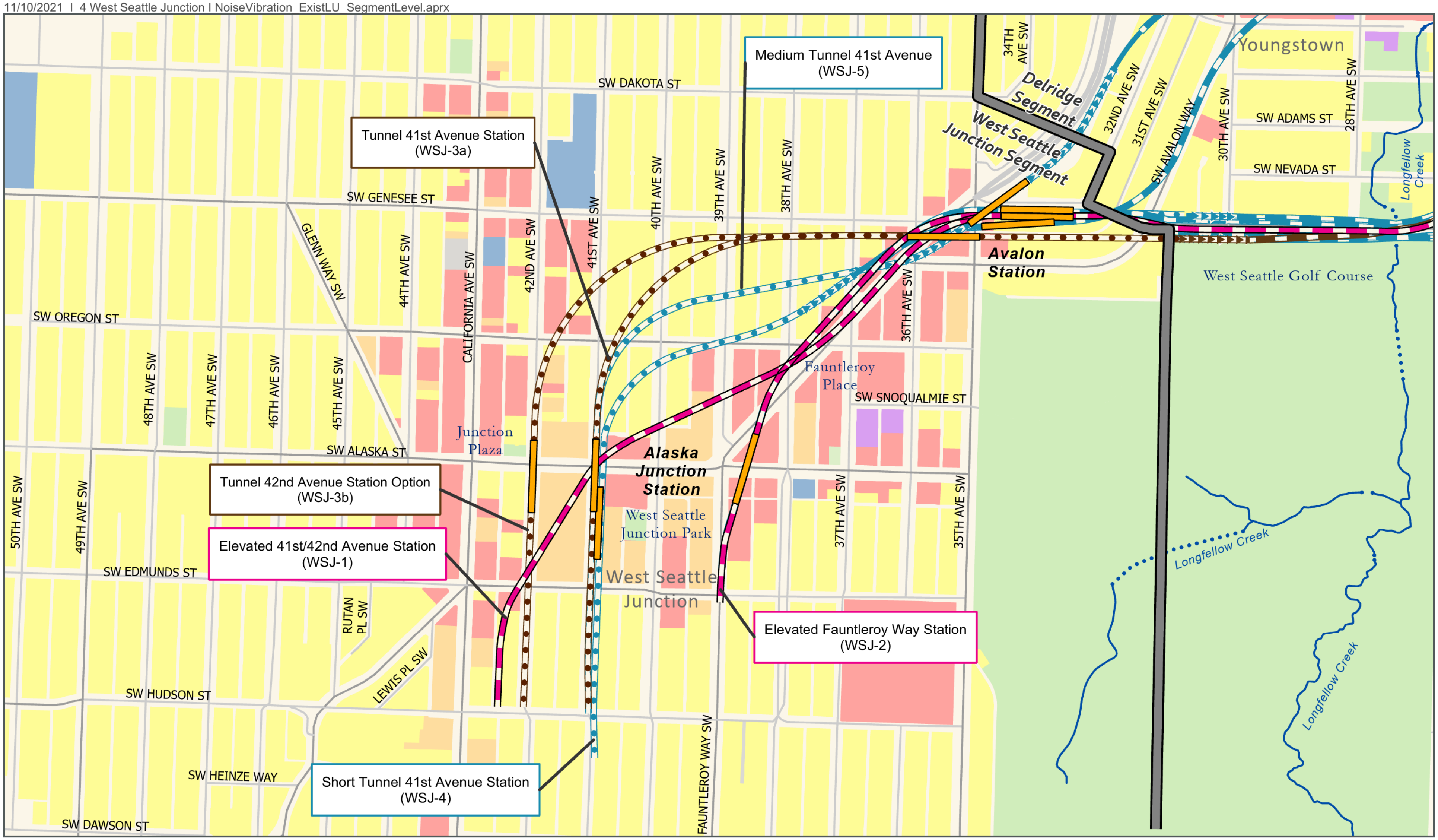
#### 5.1.1.4 West Seattle Junction Segment

Noise- and vibration-sensitive properties in the West Seattle Junction Segment include a mix of single- and multi-family residences, childcare centers, a fire station, and places of worship as described in the following paragraphs (Figure 5-4).

This segment includes the West Seattle Junction hub urban village, where there is an active mixed-use district serving the surrounding single- and multi-family residential areas. Fire Station 32 is in this segment at 3715 Southwest Alaska Street and is considered noise-sensitive because it has sleeping quarters (FTA Category 2). Commercial and mixed-use development is mostly clustered along Fauntleroy Way Southwest, Southwest Alaska Street, and California Avenue Southwest and includes childcare centers such as Bright Horizons at 4530 38th Avenue Southwest and the West Seattle Family Y.M.C.A. at 3622 Southwest Snoqualmie Street. The West Seattle Stadium is also in this segment; however, active sports complexes, including the West Seattle Stadium, are not considered noise- or vibration-sensitive under FTA criteria. Two places of worship are also in this segment, the Eastridge Church at 4500 39th Avenue Southwest and the Calvary Chapel West Seattle at 4217 Southwest Oregon Street.

Sensitive receivers within the screening distance of the tunnel alternatives are assessed for groundborne noise and vibration impacts, but not for airborne noise.

11/10/2021 I 4 West Seattle Junction I NoiseVibration_ExistLU_SegmentLevel.aprx




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Stream
- Piped Stream
- Park

**Existing Land Uses**
- Commercial
- Industrial
- Mixed Use
- Park or Open Space
- Public/Institutional
- Residential
- Other

0 500 1,000 Feet
N

FIGURE 5-4
**Existing Land Uses**
West Seattle Link Extension -
West Seattle Junction Segment

*West Seattle and Ballard Link Extensions*

### 5.1.2 Ballard Link Extension Sensitive Receivers

#### 5.1.2.1 SODO Segment

Similar to the West Seattle Link Extension (Section 5.1.1.1), land uses in the SODO Segment are predominantly industrial and commercial (Figure 5-1). No FTA noise- or vibration-sensitive properties were identified in this segment.

#### 5.1.2.2 Chinatown-International District Segment

In this segment, the alternatives are primarily belowground (tunnel) options except for between South Holgate Street and South Royal Brougham Way, where the alternatives are a mix of at-grade and tunnel profiles. There are no noise-sensitive land uses near the at-grade sections. Airborne noise analysis is not necessary for tunneled areas; therefore, noise-sensitive land uses were not identified for this segment.

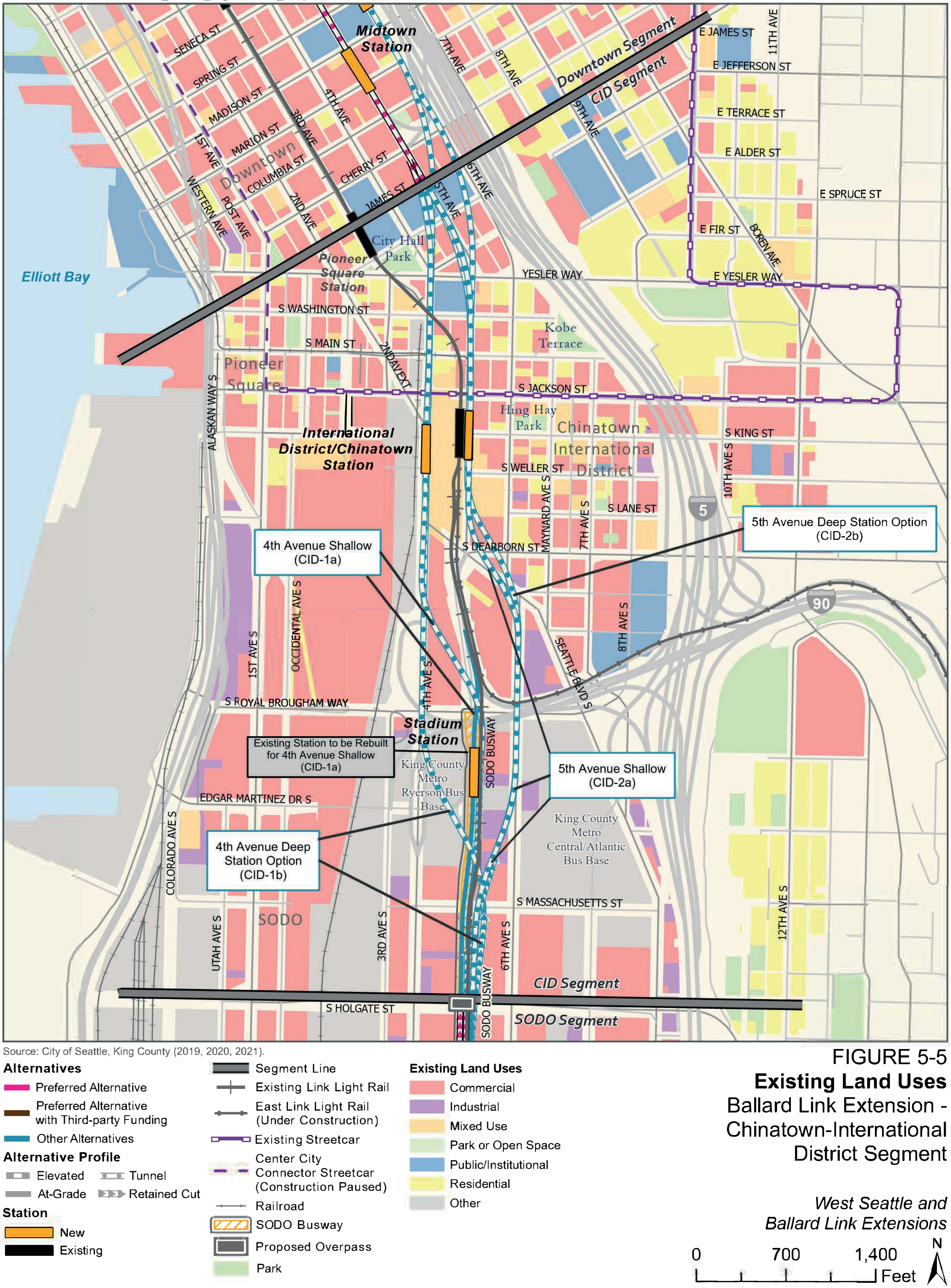
The vibration and groundborne noise-sensitive land uses in the Chinatown-International District Segment are primarily multi-family residences along 4th Avenue South and 5th Avenue South, north of Seattle Boulevard (Figure 5-5). Fire Station 10 at 105 5th Avenue and the King County Correctional Facility at 500 5th Avenue at the north end of the Chinatown-International District Segment are both considered residential land uses because they have sleeping quarters (FTA Category 2). The Inscape Arts and Culture Center at 815 Seattle Boulevard South is the only institutional land use in the segment (FTA Category 3).

#### 5.1.2.3 Downtown Segment

Airborne noise analysis is not necessary for tunneled areas; therefore, noise-sensitive land uses were not identified for the Downtown Segment.

The vibration-sensitive residential land uses in the Downtown Segment are primarily multi-family buildings and hotels (Figure 5-6). Institutional land uses in the Downtown Segment include places of worship, schools, and the Seattle Public Library-Central Library at 1000 4th Avenue. The places of worship in the Downtown Segment are the First Church of Christ Scientist at 900 Thomas Street, Plymouth Congregational Church at 1217 6th Avenue, and Saint Paul's Episcopal Church at 15 Roy Street. The schools in the Downtown Segment are Cornish College of the Arts at 1000 Lenora Street, Northeastern University Seattle at 401 Terry Avenue North, and the Young Child Academy at 557 Roy Street, which provides early-childhood education.

This segment also includes many receivers with high-vibration sensitivity (FTA Category 1 or special-use buildings). The South Lake Union neighborhood has several research institutions and biotechnology companies that have vibration-sensitive equipment. Seattle Center at 305 Harrison Street, at the northwest end of the segment, houses several performance venues and recording spaces that are sensitive to groundborne noise and vibration.

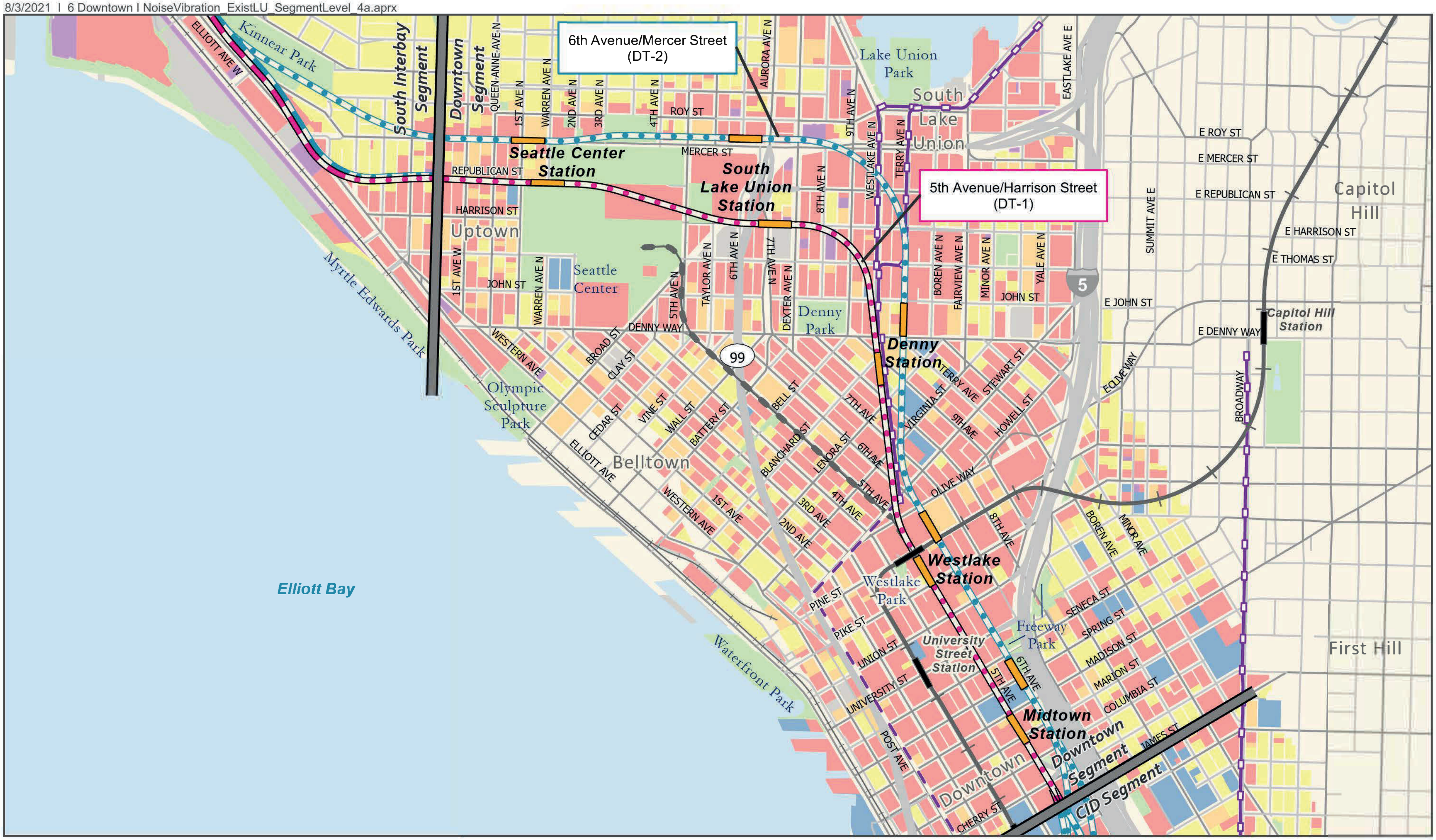



Source: City of Seattle, King County (2019, 2020, 2021).

FIGURE 5-5
**Existing Land Uses**
Ballard Link Extension - Chinatown-International District Segment

*West Seattle and Ballard Link Extensions*

8/3/2021 I 6 Downtown I NoiseVibration_ExistLU_SegmentLevel_4a.aprx




Source: City of Seattle, King County (2019, 2020, 2021).



FIGURE 5-6
**Existing Land Uses**
Ballard Link Extension - Downtown Segment

*West Seattle and Ballard Link Extensions*

Table 5-1 lists the Category 1 and Special Buildings in the Downtown Segment.

### Table 5-1. Vibration-Sensitive Receivers with High-Vibration Sensitivity in the Downtown Segment

| Occupant | Address | Description of Use |
|---|---|---|
| 5th Avenue Theatre | 1308 5th Avenue | Historic theater for musicals and other live performances |
| ACT Theatre | 700 Union Street | Theater for live plays |
| Kineta | 219 Terry Avenue North | Biotechnology company with lab space |
| Biodesix | 219 Terry Avenue North | Biotechnology company with lab space |
| Genewiz | 219 Terry Avenue North | Biotechnology company with lab space |
| Seattle Children's Research Institute Center for Global Infectious Disease Research | 307 Westlake Avenue North | Pediatric research center |
| Institute for Systems Biology | 401 Terry Avenue North | Non-profit research institution |
| Just Biotherapeutics | 401 Terry Avenue North | Biotechnology company with lab space |
| Juno Therapeutics | 400 Dexter Avenue North | Biopharmaceutical company with lab space |
| Allen Institute | 615 Westlake Avenue North | Non-profit bioscience research institution |
| University of Washington Medicine South Lake Union Campus | 850 Republican Street | Graduate medical school research labs |
| Cascade Public Media (KCTS 9 Television) | 401 Mercer Street (Seattle Center) | Public television studio |
| Seattle Opera and KING FM | 363 Mercer Street (Seattle Center) | Rehearsal space for Seattle Opera and broadcast space for KING FM |
| McCaw Hall | 321 Mercer Street (Seattle Center) | Concert hall that hosts the Seattle Opera and Pacific Northwest Ballet performances and Seattle Center Studios recording events |
| Pacific Northwest Ballet (Phelps Center) | 301 Mercer Street (Seattle Center) | Ballet Rehearsal Space and Expo Hall in basement level |
| Cornish Playhouse | 201 Mercer Street (Seattle Center) | Theater associated with the Cornish College of the Arts |
| Seattle Repertory Theatre | 155 Mercer Street (Seattle Center) | Two theaters (Bagley Wright and Leo K.) hosting regular live performances |
| Seattle International Film Festival (SIFF) Film Center | 305 Harrison Street (Seattle Center) | Jewelbox movie theater |
| The Vera Project | 305 Harrison Street (Seattle Center) | Music and art non-profit with performing and recording spaces |
| K.E.X.P. | 472 1st Avenue North (Seattle Center) | Radio station with recording studio, D.J. booths, and edit suites |

#### 5.1.2.4 South Interbay Segment

Noise-sensitive properties in the South Interbay Segment are mostly residential uses, parks, and open spaces. Single and multi-family residences are present along the east side of Elliott Avenue West and 15th Avenue West. Fire Station 20 at 2800 15th Avenue West is considered noise-sensitive because it has sleeping quarters (FTA Category 2). The Southwest Queen Anne Greenbelt at 12th Avenue West and West Howe Street and Kinnear Park at 899 West Olympic Place are both on the hillside above Elliott Avenue West and 15th Avenue West, in the south end of the segment and are considered noise-sensitive due to the existing noise levels and passive uses (FTA Category 3).

The Interbay P-Patch Community Garden at 2451 15th Avenue West, Interbay Golf Center at 2501 15th Avenue West, and the Interbay Athletic Complex at 3027 17th Avenue West, are all between 15th Avenue West and the BNSF Railroad heavy rail switching yard (Balmer Yard), north of West Wheeler Street and south of West Dravus Street. Because the facilities are in areas with high levels of existing background noise, and active use areas, they are not considered noise-sensitive by the FTA criteria. Much of the South Interbay Segment includes industrial and commercial land uses, including the BNSF Balmer Yard, and are not noise-sensitive under FTA criteria (Figure 5-7). Where the South Interbay Segment meets the Interbay/Ballard Segment, land uses include several large multi-family buildings, with commercial development along 15th Avenue West (which is not noise-sensitive), surrounded by residential housing to the east of 15th Avenue West.

This segment also includes receivers with high-noise sensitivity (FTA Category 1) (Table 5-2). Although these locations have activities inside the buildings that qualify for consideration of Category 1 noise analysis, the locations of the facilities along major arterials and near the BNSF Railway indicate that they have methods to accommodate the high existing noise levels, such as the installation of sound booths inside the buildings.

**Table 5-2. Noise, Category 1, and Special Building Sensitive Receiver Impacts in the South Interbay Segment**

| Occupant | Address | Description of Use |
|---|---|---|
| iHeart Media | 645 Elliott Avenue West | Radio station with recording booths |
| Victory Studios | 2247 15th Avenue West | Recording studio with isolated booths, editing suites, and video shoot rooms |

The vibration-sensitive land uses in the South Interbay Segment are similar to the noise-sensitive land uses. The vibration assessment includes residences near the tunnel portions near the Downtown and Interbay/Ballard Segment boundaries that are not assessed for airborne noise impact, as well as Category 1 land uses with vibration-sensitive equipment that are not noise-sensitive. Table 5-3 lists the vibration Category 1 and Special Buildings in the South Interbay Segment. Outdoor noise-sensitive land uses are not vibration-sensitive.

**Table 5-3. Vibration-Sensitive Receivers with High-Vibration Sensitivity in the South Interbay Segment**

| Occupant | Address | Description of Use |
|---|---|---|
| iHeart Media | 645 Elliott Avenue West | Radio station with recording booths |
| Nexelis | 645 Elliott Avenue West | Contract research organization with lab space |
| Luminex | 645 Elliott Avenue West | Laboratory space to assemble and test vibration-sensitive equipment with lasers |
| Victory Studios | 2247 15th Avenue West | Recording studio with isolated booths, editing suites, and video shoot rooms |

11/10/2021 I 7 South Interbay I NoiseVibration_ExistLU_SegmentLevel.aprx


Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Railroad
- Park

**Existing Land Uses**
- Commercial
- Industrial
- Mixed Use
- Park or Open Space
- Public/Institutional
- Residential
- Other

0 800 1,600 Feet
N

FIGURE 5-7
**Existing Land Uses**
Ballard Link Extension - South Interbay Segment
*West Seattle and Ballard Link Extensions*

#### 5.1.2.5 Interbay/Ballard Segment

Noise- and vibration-sensitive uses in the Interbay/Ballard Segment include residential uses, schools, a fire station, and places of worship, as described below.

Near the boundary of the South Interbay Segment and Interbay/Ballard Segment, there are several large multi-family residential buildings near West Dravus Street and north to West Nickerson Street. Properties near the Lake Washington Ship Canal are shipping-related commercial and industrial uses that are not noise-sensitive.

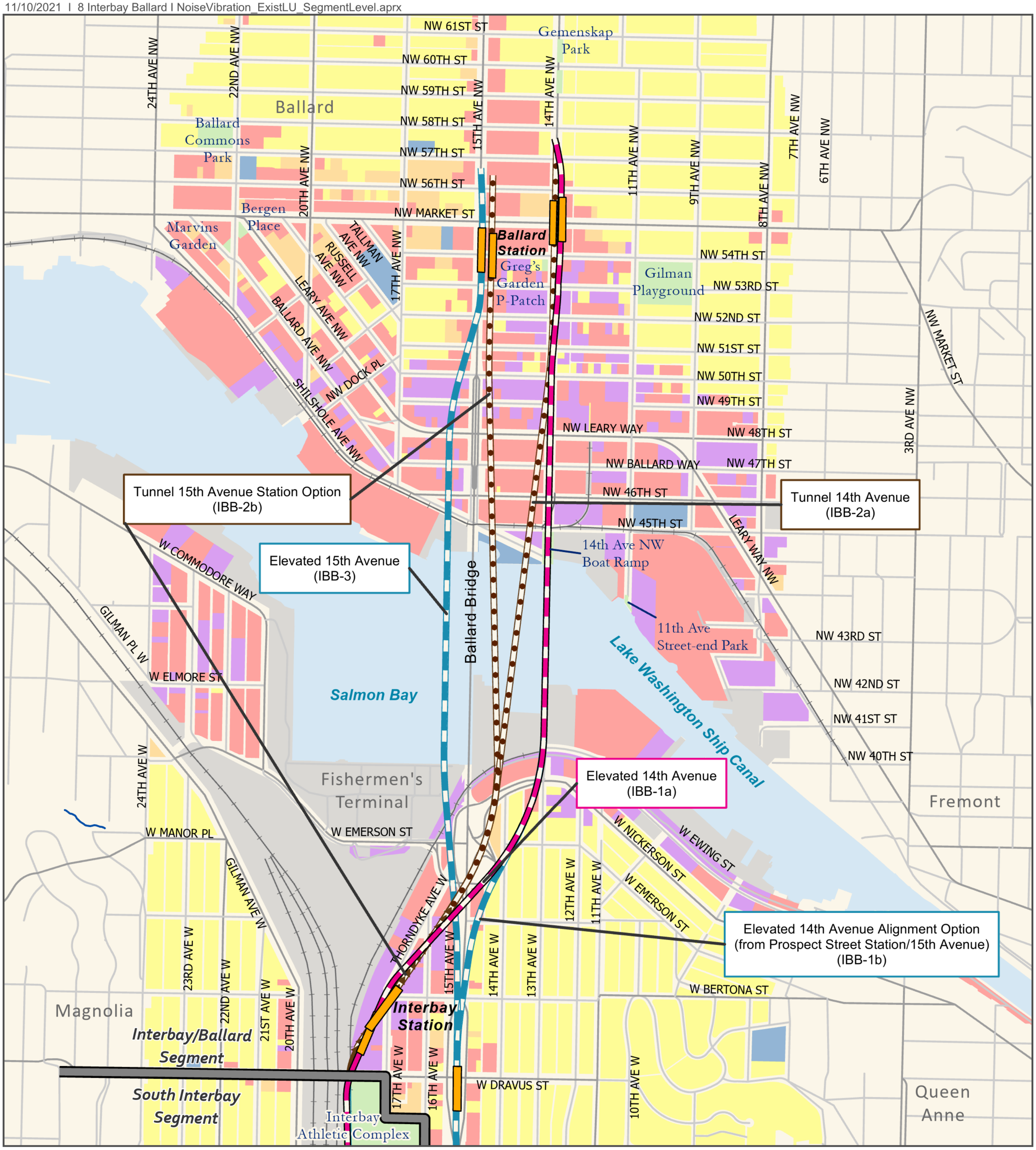
The Seattle Film Institute at 3210 16th Avenue West, is a noise- and vibration-sensitive use (FTA Category 1) and includes an editing booth, theater, and classrooms.

North of the Lake Washington Ship Canal to Northwest 50th Street, land uses are primarily commercial, industrial, and service uses, which are not considered noise-sensitive (Figure 5-8). The Seattle Maritime Academy is located along the canal at 4455 Shilshole Avenue Northwest and the Quest Church is on Northwest Leary Way and 14th Avenue Northwest at 1401 Northwest Leary Way. North of Northwest 50th Street, land uses transition to mixed commercial and single- and multi-family residential. Fire Station 18 at 1521 Northwest Market Street is considered noise-sensitive because it has sleeping quarters (FTA Category 2). Finally, the Saint Alphonsus Church and Parish School occupy several structures at the north end of the study area, between 15th Avenue Northwest and 14th Avenue Northwest, north of Northwest 57th Street and south of Northwest 59th Street.

The noise-sensitive land uses are also vibration-sensitive. Additional vibration-sensitive land uses that are not assessed for airborne noise impact are residences near the tunnel options and land uses with vibration-sensitive equipment that are not noise-sensitive. The sensitive receivers identified as having high-vibration sensitivity (FTA Category 1 or Special Buildings) are listed in Table 5-4.

### Table 5-4. Vibration-Sensitive Receivers with High-Vibration Sensitivity in the Interbay/Ballard Segment

| Occupant | Address | Description of Use |
|---|---|---|
| Friedman and Bruya | 3012 16th Avenue West | Analytical Laboratory |
| Seattle Film Institute | 3210 16th Avenue West | Private film school with editing booth, theater, and classrooms |
| Specialty Vet Path | 3450 16th Avenue West, Suite #303 | Veterinary diagnostic laboratory and research services |
| Bardahl Manufacturing | 1400 Northwest 52nd Street | Lubricant manufacturing company with laboratory |
| Vaupell Industrial Plastics | 1144 Northwest 53rd Street | High-precision molding |




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Railroad
- Stream
- Park

**Existing Land Uses**
- Commercial
- Industrial
- Mixed Use
- Park or Open Space
- Public/Institutional
- Residential
- Other

0 800 1,600 Feet

N

FIGURE 5-8
**Existing Land Uses**
Ballard Link Extension - Interbay/Ballard Segment

*West Seattle and Ballard Link Extensions*

## 5.2 Noise Measurements

Sound Transit characterized the existing noise environment through onsite inspections and onsite noise monitoring. Monitoring was performed at 35 locations, including 21 long-term (48-hour or more) and 14 short-term (30-minute) sites. Long-term monitoring was performed at locations representative of nearby residential use properties. Short-term monitoring was conducted near nonresidential use properties, such as parks and schools. Sound Transit also collected traffic counts at several of the short-term noise monitoring locations to predict noise impacts from changes to vehicle traffic.

Noise monitoring locations were selected based on land use, existing noise sources, proximity to light rail alternatives and profile types, representative land uses, and access allowed by the property owner (when not in the public right-of-way). Long-term noise monitoring was primarily used to establish the existing 24-hour Ldn along the corridor. Where long-term monitoring was not practical, short-term monitoring was conducted to supplement nearby long-term monitoring sites, and to support the traffic noise analysis.

Noise measurements were conducted in general accordance with the FTA Guidance Manual and the American National Standards Institute procedures for community noise measurements. Measurement locations were at least 5 feet from structures and 5 feet above the ground (where possible) to reduce the effects of acoustical reflections on the measurement results. Traffic counts accompanying the noise measurements were also taken in accordance with the Federal Highway Administration and WSDOT standards.

Equipment used for the noise monitoring included Brüel & Kjaer Type 2250, Svantek SV979, Svantek 958, Svantek SV971, and Svantek SV307 sound level meters. All sound monitoring equipment was calibrated before and after the measurements using acoustic calibrators. Measurement equipment was calibrated within 1 year of the measurement dates by an accredited testing laboratory traceable to the National Institute of Standards and Technology. All measurement equipment met or exceeded the requirements for an American National Standards Institute Type 1 noise measurement system.

Measurement periods that included rain or wet road conditions were excluded from the analysis. All Ldn values were calculated from a minimum of 48 hours of data.

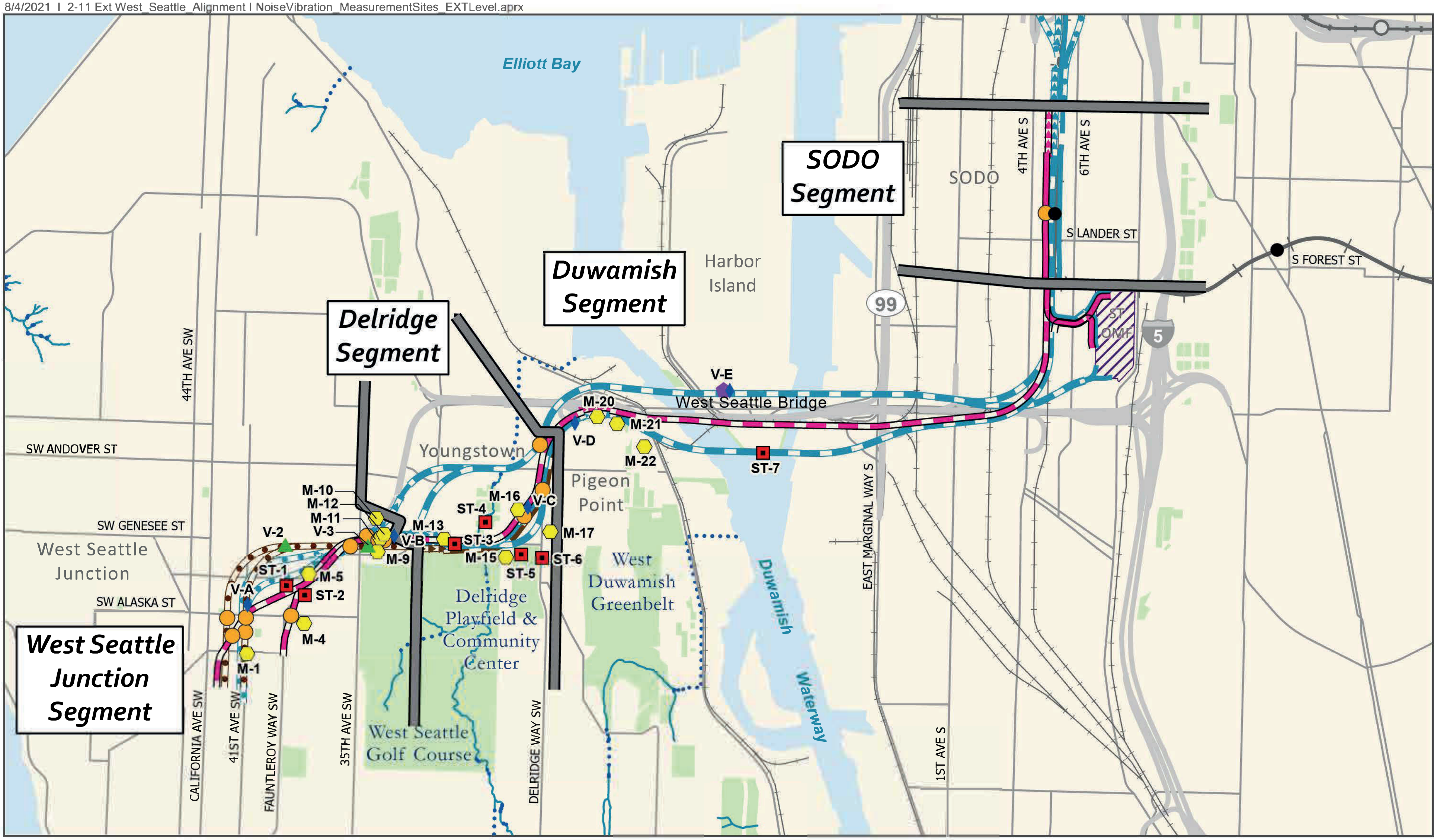
Short-term measurements were made twice per site, once in the morning between 7 a.m. and 10 a.m. and again in the afternoon between 3 p.m. and 7 p.m. The reported values from these measurements are the loudest overall Leq measured either in the morning or afternoon.

The following sections describe the existing noise environment in the West Seattle Link Extension and Ballard Link Extension. It should be noted that noise measurements were not taken in the SODO, Chinatown-International District, or Downtown segments because the alignment is either in tunnels or adjacent receivers did not warrant noise measurements.

Complete results of the monitoring along with photos of the system installations and locations are provided in Attachment N.3A, Noise Measurement Data, Site Details, and Photographs.

### 5.2.1 West Seattle Link Extension Existing Noise Measurement Results

The West Seattle Link Extension had 14 long-term and 7 short-term monitoring locations as shown on Figure 5-9. Sound levels in the West Seattle Link Extension area are dominated by traffic noise on major arterial roadways, such as the West Seattle Bridge, Fauntleroy Way Southwest, West Marginal Way Southwest, and Delridge Way Southwest. Table 5-5 summarizes ambient noise monitoring for the West Seattle Link Extension, which includes the monitoring locations, addresses, land use, and type of measurements. Although the noise monitoring location numbers may not be shown in order, the monitoring sites are generally presented from east to west.




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New
- Existing

- Segment Line
- Sound Transit Operations and Maintenance Facility (ST OMF)
- Existing Link Light Rail
- East Link Light Rail (Under Construction)
- Railroad
- Stream
- Piped Stream
- Park

**Noise Monitoring Sites**
- Short Term Monitoring Site
- Long Term Monitoring Site

**Vibration Measurement Sites**
- Existing Vibration Measurement
- At-grade Vibration Propagation
- Below-grade Vibration Propagation

0 0.5 1 Mile

N

FIGURE 5-9
**Noise and Vibration Measurement Sites**
West Seattle Link Extension

*West Seattle and Ballard Link Extensions*

## Table 5-5. Noise Measurements West Seattle Link Extension

| Segment | Monitoring Location | Address | Land Use Type | Type of Measurement | Leq (Daytime-hour Leq in dBA) | Ldn (24-hour Ldn in dBA) |
|---|---|---|---|---|---|---|
| Duwamish | ST-7 | 1011 Southwest Klickitat Avenue | Marina | Short-Term | 63 | 59 |
| Duwamish | M-22 | 3823 17th Avenue Southwest | Single-Family | Long-Term | 67 | 69 |
| Duwamish | M-21 | 3712 19th Avenue Southwest | Single-Family | Long-Term | 72 | 75 |
| Duwamish | M-20 | 3709 20th Avenue Southwest | Single-Family | Long-Term | 72 | 75 |
| Delridge | M-17 | 4143 23rd Avenue Southwest | Single-Family | Long-Term | 59 | 62 |
| Delridge | M-16 | 4106 26th Avenue Southwest | Single-Family | Long-Term | 52 | 54 |
| Delridge | ST-6 | 4408 Delridge Way Southwest | Community Center | Short-Term | 74 | 72 |
| Delridge | ST-5 | 4501 Delridge Way Southwest | Park | Short-Term | 74 | 69 |
| Delridge | M-15 | 4421 26th Avenue Southwest | Single-Family | Long-Term | 51 | 53 |
| Delridge | ST-4 | Longfellow Creek Legacy Trail | Park | Short-Term | 47 | 45 |
| Delridge | M-13 | 2848 Southwest Genesee Street | Single-Family | Long-Term | 60 | 60 |
| Delridge | ST-3 | 4470 35th Avenue Southwest | Park | Short-Term | 70 | 67 |
| West Seattle Junction | M-12 | 4143 32nd Avenue Southwest | Single-Family | Long-Term | 53 | 56 |
| West Seattle Junction | M-11 | 3225 Southwest Genesee Street | Single-Family | Long-Term | 56 | 59 |
| West Seattle Junction | M-10 | 4147 Fauntleroy Way Southwest | Single-Family | Long-Term | 70 | 73 |
| West Seattle Junction | M-9 | 3256 Southwest Avalon Way | Multi-family | Long-Term | 67 | 68 |
| West Seattle Junction | M-5 | 4450 38th Avenue Southwest | Single-Family | Long-Term | 66 | 68 |
| West Seattle Junction | ST-2 | 4530 38th Southwest Avenue | Right-of-Way | Short-Term | 69 | 67 |
| West Seattle Junction | ST-1 | 4500 39th Avenue Southwest | Right-of-Way | Short-Term | 58 | 55 |
| West Seattle Junction | M-4 | 4700 38th Avenue Southwest | Fire Station | Long-Term | 69 | 68 |
| West Seattle Junction | M-1 | 4023 Southwest Edmunds Street | Single-Family | Long-Term | 62 | 62 |

#### 5.2.1.1 SODO Segment

For the SODO Segment, there are no properties identified that are noise-sensitive under FTA criteria; therefore, no sound levels were measured in this segment.

#### 5.2.1.2 Duwamish Segment

Sound levels in the Duwamish Segment are governed almost entirely by traffic on the West Seattle Bridge and West Marginal Way Southwest, heavy truck traffic, heavy rail service, loading and unloading ships, and foghorns. The Ldn values in this segment ranged between 59 dBA and 75 dBA (M-20 to M-22 and ST-7) and peak hour Leq values ranged between 63 dBA and 72 dBA (M-20 to M-22 and ST-7). Median nighttime Leq levels ranged from 58 dBA to 67 dBA (M-20 to M-22).

#### 5.2.1.3 Delridge Segment

The Delridge Segment Ldn values range between 45 dBA and 72 dBA (M-13 to M-17 and ST-3 to ST-6) and peak hour Leq values range between 47 dBA and 74 dBA (M-13 to M-17 and ST-3 to ST-6). Median nighttime Leq values ranged between 42 dBA and 54 dBA (M-13 to M17). Traffic on arterial roadways such as Delridge Way Southwest and Southwest Genesee Street were the dominant sound sources in this segment. Other contributing sound sources include smaller roadways, aircraft noise, industrial facilities, and trains.

#### 5.2.1.4 West Seattle Junction Segment

The Ldn values in the West Seattle Junction Segment ranged from 55 dBA to 73 dBA (M-1 through M-12 and ST-1 to ST-2) and peak hour Leq ranged from 53 dBA to 70 dBA (M-1 through M-12 and ST-1 and ST-2). Median nighttime Leq values ranged from 48 dBA to 64 dBA (M1 to M12). Sound levels in this segment are primarily governed by traffic noise on nearby arterial roadways, such as Fauntleroy Way Southwest and 35th Avenue Southwest.

### 5.2.2 Ballard Link Extension Existing Noise Measurement Results

The Ballard Link Extension had seven long-term and seven short-term monitoring locations as shown on Figure 5-10. Sound levels in the Ballard Link Extension are dominated by traffic on arterial roadways such as Elliott Avenue West, 15th Avenue West/Northwest, and Northwest Leary Way. Other contributing sound sources include traffic on smaller roadways and aircraft noise. Table 5-6 summarizes ambient noise monitoring for the Ballard Link Extension, which includes the monitoring locations, addresses, land use, and type of measurements. Although the noise monitoring location numbers may not be shown in order, the monitoring sites are generally presented from the south end of the alignment moving north.

8/11/2021 I 2-12 Ext Ballard_Alignment I NoiseVibration_MeasurementSites_EXTLevel.aprx


Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New
- Existing

- Segment Line
- Existing Link Light Rail
- East Link Light Rail (Under Construction)
- Existing Streetcar
- Center City Connector Streetcar (Construction Paused)
- Railroad
- Stream
- Piped Stream
- Park

**Noise Monitoring Sites**
- Short Term Monitoring Site
- Long Term Monitoring Site

**Vibration Measurement Sites**
- Existing Vibration Measurement
- At-grade Vibration Propagation
- Below-grade Vibration Propagation

0 0.5 1 Mile

N

FIGURE 5-10
**Noise and Vibration Measurement Sites**
**Ballard Link Extension**

*West Seattle and Ballard Link Extensions*

## Table 5-6. Noise Measurements Ballard Link Extension

| Segment | Monitoring Location | Address | Land Use Type | Type of Measurement | Leq (Daytime-hour Leq in dBA) | Ldn (24-hour Ldn in dBA) |
|---|---|---|---|---|---|---|
| South Interbay | ST-8 | Queen Anne Greenbelt Trail (south end) | Park | Short-Term | 64 | 61 |
| South Interbay | M-26 | 1606 12th Avenue West | Single-Family | Long-Term | 59 | 63 |
| South Interbay | ST-9 | Queen Anne Greenbelt Trail (north end) | Park | Short-Term | 57 | 54 |
| South Interbay | ST-10 | 2451 15th Avenue West | Public | Short-Term | 62 | 59 |
| South Interbay | M-29 | 2557 14th Avenue West | Multi-family | Long-Term | 70 | 73 |
| Interbay/Ballard | ST-11 | 3027 17th Avenue West | Park | Short-Term | 56 | 54 |
| Interbay/Ballard | M-33 | 3457 14th Avenue West | Multi-family | Long-Term | 66 | 67 |
| Interbay/Ballard | ST-12 | 1401 Northwest Leary Way | Church | Short-Term | 66 | 63 |
| Interbay/Ballard | M-37 | 1408 Northeast 50th Street | Single-Family | Long-Term | 70 | 74 |
| Interbay/Ballard | ST-13 | 923 Northwest 54th Street | Park | Short-Term | 56 | 54 |
| Interbay/Ballard | M-38 | 1139 Northwest Market Street | Multi-family | Long-Term | 52 | 56 |
| Interbay/Ballard | M-39 | 5606 14th Avenue Northwest | Single-Family | Long-Term | 58 | 60 |
| Interbay/Ballard | M-40 | 5712 14th Avenue Northwest | Single-Family | Long-Term | 56 | 57 |
| Interbay/Ballard | ST-14 | 1415 Northwest 58th Street | Park | Short-Term | 59 | 56 |

#### 5.2.2.1 SODO Segment

Like the West Seattle Link Extension, within the SODO Segment there are no properties identified that are noise sensitive under FTA criteria; therefore, no sound levels were measured in this segment.

#### 5.2.2.2 Chinatown-International District Segment

There are no noise-sensitive land uses near the at-grade sections of the Chinatown-International District Segment. Airborne noise analysis is not necessary for tunneled areas; therefore, no sound levels were measured in this segment.

#### 5.2.2.3 Downtown Segment

Airborne noise analysis is not necessary for tunneled areas; therefore, no sound levels were measured in the Downtown Segment.

#### 5.2.2.4 South Interbay Segment

The Ldn values in the South Interbay Segment range between 54 dBA and 73 dBA (M-26 to M-29 and ST-8 to ST-10) and peak Leq values range between 57 dBA and 70 dBA (M-26 to M-29 and ST-8 to ST-10). Median nighttime Leq values ranged between 54 dBA and 63 dBA (M-26 to M-29). Dominant sound sources in this area include traffic on 15th Avenue West, Elliott Avenue West, and aircraft noise.

#### 5.2.2.5 Interbay/Ballard Segment

Sound levels in the Interbay/Ballard Segment are primarily governed by vehicle traffic on 15th Avenue West, Leary Way West, and aircraft noise. The Ldn values in this segment are between 54 dBA and 74 dBA (M-33 to M-40 and ST-11 to ST-14) and measured peak Leq values range from 52 dBA to 70 dBA (M-33 to M-40 and ST-11 to ST-14). Median nighttime Leq values ranged from 47 dBA to 64 dBA (M-33 to M-40).

## 5.3 Vibration Measurements

The vibration measurements completed for the assessment are (1) an ambient vibration survey and (2) vibration propagation measurements. The ambient measurement survey documents existing vibration levels near existing rail lines and at highly vibration-sensitive buildings such as research laboratories. The vibration propagation measurements are used to quantify how efficiently vibration travels through the soil and are used in the vibration prediction model. The vibration propagation measurements are completed at representative sites throughout the study area.

### 5.3.1 Ambient Vibration Survey (Representative Sites)

There are areas along the new project corridor that are subject to vibration from existing streetcar, light rail, and freight rail train operations. The FTA Guidance Manual (2018) recommends that where there are existing rail lines, existing vibration conditions be considered when determining vibration impact criteria for a new transit project. Both the existing vibration levels and the frequency with which the existing rail corridor is used are factors in determining the appropriate impact criteria.

#### 5.3.1.1 West Seattle Link Extension Ambient Vibration Survey (Representative)

There are existing freight operations in West Seattle, but they are beyond the screening distance of the vibration-sensitive receivers. No ambient vibration measurements were completed near existing rail lines in the West Seattle Link Extension study area. An existing vibration measurement was completed at Harbor Island Machine Works, a Category 1 vibration-sensitive receiver. The results of the ambient vibration measurement are shown in Attachment N.3H, Vibration Analysis of Category 1 Uses and Special Buildings.

#### 5.3.1.2 Ballard Link Extension Ambient Vibration Survey (Representative)

There are existing streetcar, light-rail, and freight train operations in the Ballard Link Extension study area. To help characterize existing environmental vibration along the new rail corridor, 1-hour ambient vibration measurements were completed at four sites. Table 5-7 summarizes the locations and results of the existing vibration measurements. Detailed maps and photos of the measurements are provided in Attachment N.3B, Vibration Measurement Site Photographs. The spectra of the existing train vibration levels measured at each site are shown on Figure 5-11, along with the impact criteria for residential (FTA Category 2) land uses. The levels reported in the figure and table are the average level of the train events observed over the 1-hour measurement period.

**Table 5-7. Measured Vibration Levels from Existing Train Operations**

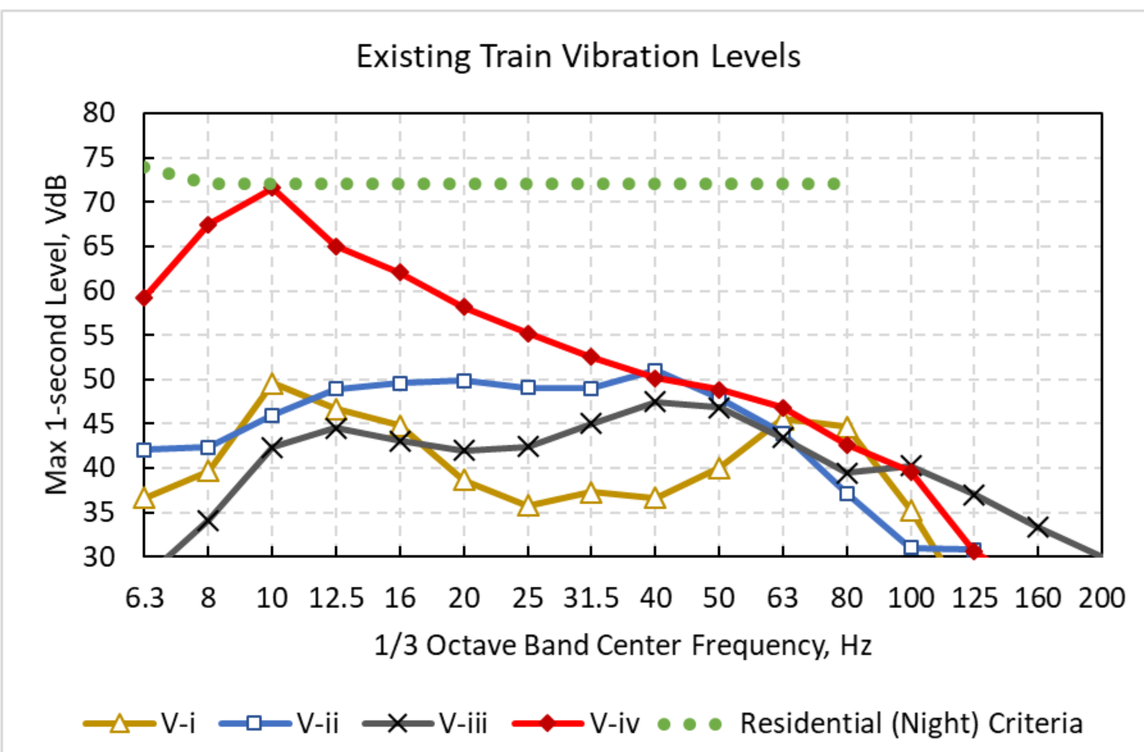
| Segment | Monitoring Location | Address | Measurement Date | Existing Vibration Source | Distance to Source (feet) | Vibration Level (VdB) [a] |
|---|---|---|---|---|---|---|
| Downtown | V-i | 4th Avenue and Main Street | December 9, 2019 | Light rail in tunnel | 25 [b] | 55 |
| Downtown | V-ii | 4th Avenue and Jefferson Street | December 9, 2019 | Freight train in tunnel | 25 [b] | 59 |
| Downtown | V-iii | West Lake and Virginia Street | December 9, 2019 | Streetcars on surface | 33 [c] | 55 |
| South Interbay | V-iv | The Helix pedestrian bridge | December 11, 2019 | Freight train on surface | 60 [c] | 74 |

[a] 1-second root mean square vibration velocity level, averaged from train events observed over a 1-hour period.

[b] Horizontal distance (along the surface) from sensor location to track centerline.

[c] Distance to the near track centerline.

**Figure 5-11. Measured 1/3-octave Band Vibration Levels from Existing Rail Lines in the Study Area**



The FTA Guidance Manual recommends that if existing vibration is below the criteria presented in Section 3.2, Vibration Criteria, the standard assessment criteria should be applied. The standard vibration criteria should also apply if the existing vibration is above the standard vibration criteria, but there is a significant increase in events.

Existing vibration levels from the Link light rail (Site V-i), freight operations in the tunnel (Site V-ii), and the South Lake Union Streetcar (Site V-iii) are below the impact criteria for Category 2 (residential) land uses. Existing vibration levels from freight operations in the South Interbay Segment (Site V-iv) is above the impact criteria for Category 2 land uses, but the observed frequency of freight trains was two to three train events per hour. The new Ballard Link Extension would more than double the number of train events. Therefore, the standard vibration criteria should apply in areas with existing train operations.

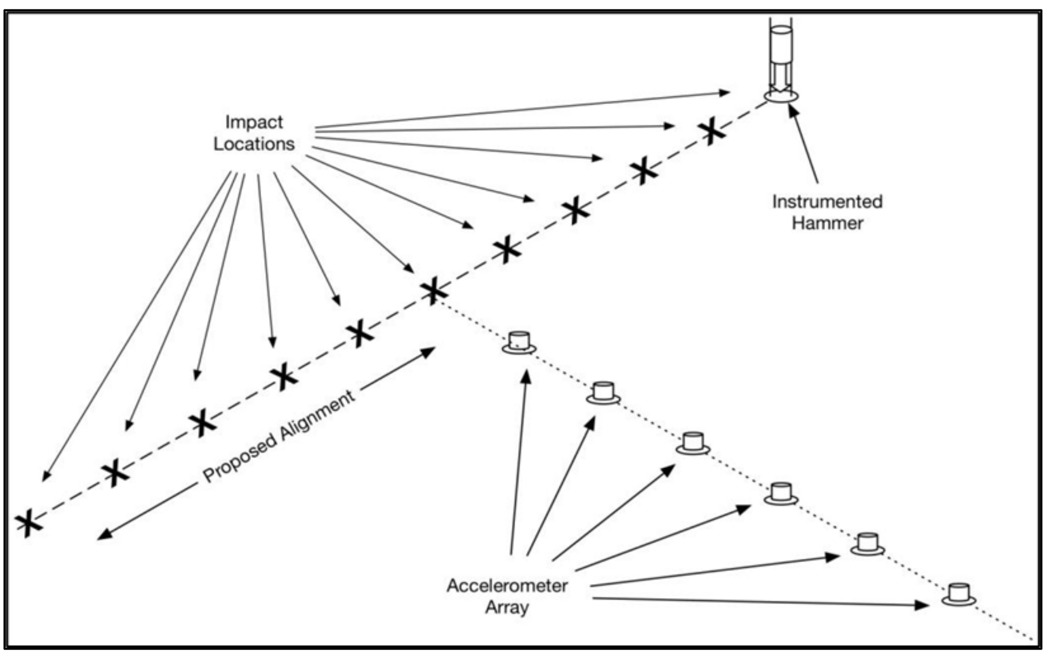
In addition, existing vibration measurements were completed at select highly vibration-sensitive buildings such as research laboratories and recording studios. The results of the ambient vibration measurements at highly vibration-sensitive buildings are shown in Attachment N.3H.

### 5.3.2 Vibration Propagation Tests

A vibration propagation test is used to determine the line source transfer mobility, which is a measure of how efficiently vibration travels through the earth. The field test procedure for determining the line source transfer mobility is shown schematically on Figure 5-12 for at-grade or surface sites. The measurement consists of dropping a heavy weight on to the ground surface and measuring the force imparted into the ground and the vibration response at sensors at several distances from the weight.

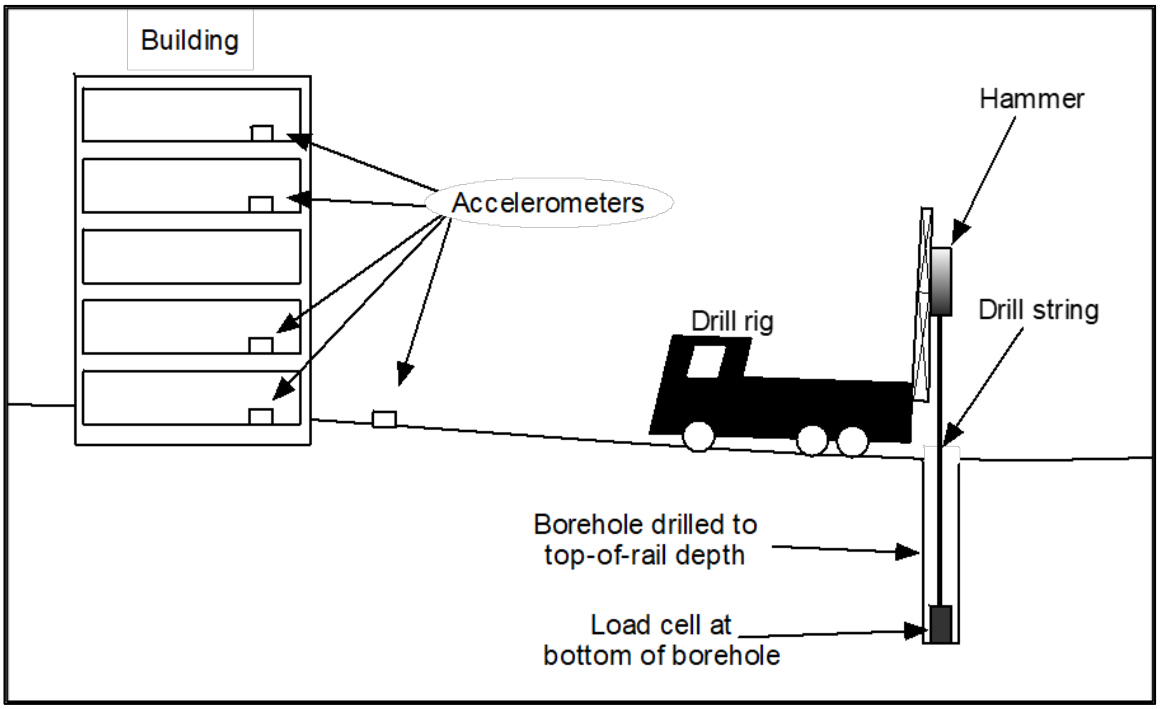
As shown on Figure 5-12, the weight is dropped at a line of discrete impact points to approximate the distributed line source of a light rail vehicle. The accelerometer sensors that measure the vibration response are placed in a line perpendicular to the line of impact points. The number of accelerometers and their distances from the impact line vary at each test site depending on field conditions.

**Figure 5-12. Schematic of Surface Vibration Propagation Test Procedure**



For tunnel and borehole sites, an impact hammer was used to generate vibration at the bottom of a borehole. Typically, data were collected at three depths: 10 feet above the depth of the track, at the depth of the track, and 10 feet below the depth of the track. The measured data from the three test depths were extrapolated to account for the length of the train instead of using a line of impact points as with the surface measurements. The accelerometer sensors that measure the vibration response were placed on the surface in a line extending away from the borehole. At some measurement locations, sensors were also placed inside of the building to measure the building response. Figure 5-13 shows a schematic of the borehole vibration propagation test procedure.

**Figure 5-13. Schematic of Borehole Vibration Propagation Test Procedure**




The vibration propagation test sites were selected based on a review of aerial photographs and a windshield survey of land uses. Vibration propagation tests have been completed at 22 sites in both the West Seattle Link Extension and Ballard Link Extension study areas. The results of the vibration propagation test are the line source transfer mobility and the coherence. Coherence is a measure of the quality of the line source transfer mobility results and varies between 0 and 1. A coherence value close to 1 indicates that the vibration response and the force generated by the dropped weight 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 results may occur when the ambient vibration is relatively high, the distance between the dropped weight and the sensor are relatively far, or when the soil is a poor transmitter of vibration at a particular frequency. Most measurement sites have coherence below 0.2 at frequencies less than 20 hertz, indicating the soil is a relatively poor transmitter of vibration at low frequencies. Many measurement sites have low coherence for the farthest sensor locations.

Higher line source transfer mobility levels indicate that vibrations are transmitted more efficiently through the soil. The frequency range with the highest line source transfer mobility values is important because it indicates the frequency range where vibration is transmitted most efficiently. If the frequency range with high line source transfer mobility values coincides with the frequency range in which the train produces the most energy, it would result in higher vibration at sensitive receivers.

Results for sites within the West Seattle Link Extension and Ballard Link Extension corridors are summarized below.

#### 5.3.2.1 West Seattle Link Extension Vibration Propagation Results

In the West Seattle Link Extension study area, surface propagation tests were completed at four sites in residential areas and at the Category 1 sensitive receiver Harbor Island Machine Works. Borehole propagation tests were completed at two sites in residential areas. A summary of the vibration propagation test sites and sensor locations is provided in Table 5-8. Surface vibration propagation test sites are labeled with letters and borehole propagation test sites are labeled with numbers. Photographs and aerial maps of each test site are provided in Attachment N.3B. Detailed vibration propagation measurement results, including the best-fit coefficients for the line source transfer mobilities, are provided in Attachment N.3C, Vibration Propagation Measurement Results.

### Table 5-8. Summary of Vibration Propagation Test Sites in the West Seattle Link Extension

| Segment | Test Site | Location | Sensor Positions (in feet or by location) |
|---|---|---|---|
| Duwamish | V-E (surface) | Harbor Island Machine Works, 3431 11th Avenue Southwest | 25, 50, 75, 100, 125, 150 |
| Duwamish | V-D (surface) | Bike path at 22nd Avenue Southwest at West Seattle Bridge | 29, 52, 75, 100, 125, 160, 200 |
| Delridge | V-C (surface) | Dakota Street at 25th Avenue Southwest | 25, 50, 75, 100, 125, 150, 195 |
| West Seattle Junction | V-B (surface) | Southwest Genesee Street at 32nd Avenue Southwest | 25, 50, 75, 100, 125, 150, 200 |
| West Seattle Junction | V-3 (borehole) | Alley at Southwest Genesee Street and 35th Avenue Southwest | 0, 45, 75, 105, 123, 150, 200 |
| West Seattle Junction | V-2 (borehole) | 39th Avenue Southwest at Southwest Genesee Street | 0, 25, 50, 75, 100, 150, 200 |
| West Seattle Junction | V-A (surface) | Alley on 41st Avenue Southwest, north of Southwest Alaska Street | 25, 50, 75, 100, 125, 150 |

Figures 5-14 and 5-15 show the measured vibration propagation test results at or close to 100 feet for surface measurement sites and at or close to 150 feet for borehole measurement sites, respectively. For the surface sites, the line source transfer mobility is presented, and for borehole sites, the point source transfer mobility is presented because it is not possible to measure at a line of impact points. The point source transfer mobility has lower amplitudes compared to the line source transfer mobility.

Observations from the vibration propagation test results were as follows:

- Surface sites:
  - Site V-E shows high line source transfer mobility levels at frequencies below 40 hertz and lower line source transfer mobility levels above 40 hertz. This site was on Harbor Island, which is composed of reclaimed land. The data from this site are only applied to Harbor Island Machine Works, the sensitive receiver where the data were collected.

- In general, the surface sites show the highest line source transfer mobility levels in the 30- to 60-hertz range, with levels decreasing at higher frequencies.
- The West Seattle Link Extension data show generally good agreement across different measurement sites with the exception of Site V-E. Site V-B does show more efficient vibration propagation at 40- and 50-hertz compared to the other sites.

- Borehole sites:
  - At borehole vibration propagation test sites, the transfer mobilities generally have flatter spectra than the surface sites. This generally results in lower levels in the 30- to 60-hertz range, but higher levels at higher frequencies.
  - The West Seattle Link Extension data show generally good agreement at the two borehole measurement sites.

**Figure 5-14. Measured Line Source Transfer Mobility at 100 feet for West Seattle Link Extension Surface Sites**

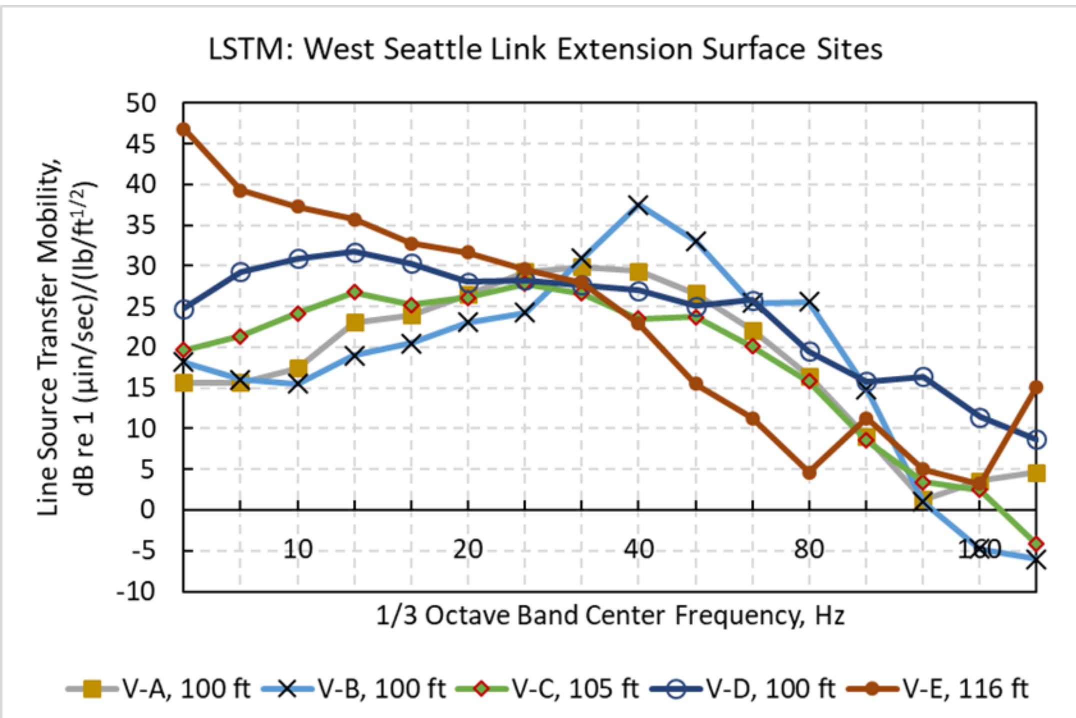
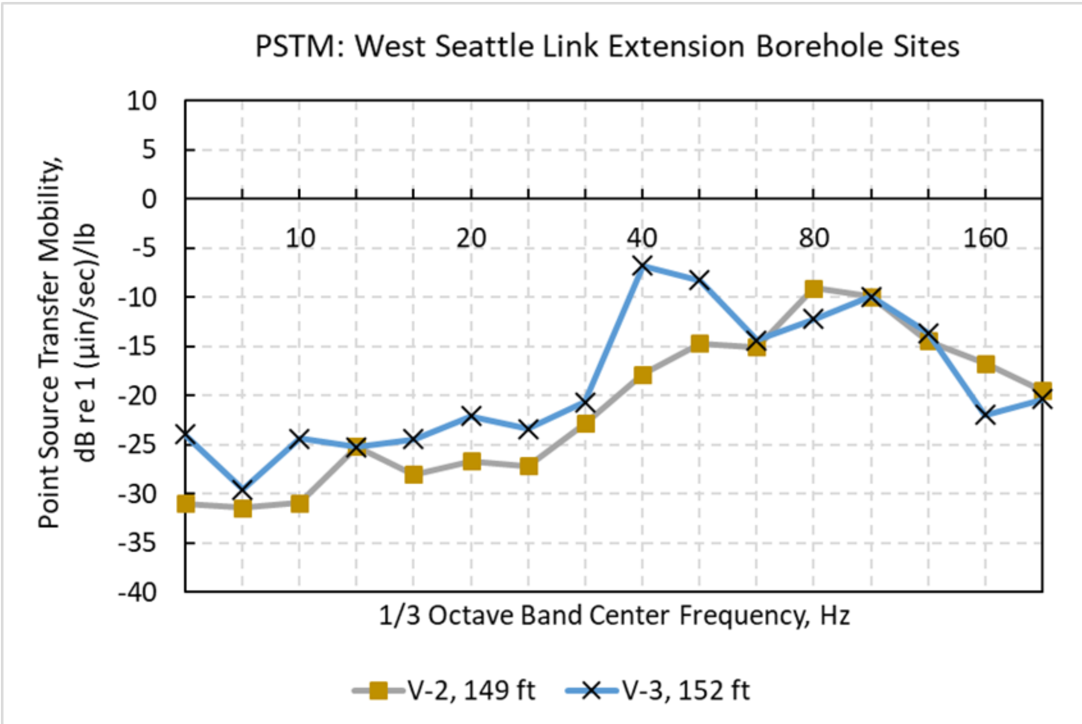


**Figure 5-15. Measured Point Source Transfer Mobility at 150 feet for West Seattle Link Extension Borehole Sites**




#### 5.3.2.2 Ballard Link Extension Vibration Propagation Results

In the Ballard Link Extension study area, surface propagation tests were completed at three sites in residential areas and at two Category 1 sensitive receivers: Victory Studios and the Seattle Film Institute. Borehole vibration propagation tests were completed at three locations in the Midtown and Westlake area near condominiums and hotels, at three locations in the Seattle Center area, and at two locations near residences in Ballard. The vibration propagation test sites in the Ballard Link Extension study area are listed in Table 5-9. Surface vibration propagation test sites are labeled with letters and borehole propagation test sites are labeled with numbers. Photographs and aerial maps of each test site are provided in Attachment N.3B. Detailed vibration propagation measurement results, including the best-fit coefficients for the line source transfer mobilities, are provided in Attachment N.3C.

**Table 5-9. Summary of Vibration Propagation Test Sites**

| Segment | Test Site | Location | Sensor Positions (in feet or by location) |
| --- | --- | --- | --- |
| Downtown | V-6 (borehole) | 5th Avenue and Marion Street, Downtown Seattle | 0, 25, 50, 75, 100, 135, -50 |
| Downtown | V-8 (borehole) | 7th Avenue and Westlake Avenue, Downtown Seattle | 0, 25, 50, 75, 100, 125 |
| Downtown | V-9 (borehole) | Thomas Street between Westlake Avenue and 9th Avenue | 5, 25, 45, 75, 120, 160 |

| Segment | Test Site | Location | Sensor Positions (in feet or by location) |
|---|---|---|---|
| Downtown | V-M (surface) | 219 Terry Avenue North (Kineta and Biodesix) | 20, parking area, basement, 1st floor hallway, 2nd floor hallway, and 3rd floor hallway |
| Downtown | V-N (surface) | 401 Terry Avenue North (Institute of Systems Biology and Just Biotherapeutics) | 15, 30, 109, receiving room, 2nd floor near mass spectrometer, 4th floor near mass spectrometer, 4th floor near north façade |
| Downtown | V-0 (surface) | 400 Dexter Avenue North (Bristol Myers Squibb) | 54, 118, parking level, ground floor, 2nd floor, 5th floor, 6th floor, and 9th floor |
| Downtown | V-10 (borehole) | University of Washington Medicine South Lake Union Campus | To be completed in 2021 |
| Downtown | V-11 (borehole) | Allen Institute | 30, 80, 120, 195, parking garage, electromagnetic suite, west wing, Suites 220, 320, 420, 520, 240, 440, and 270 |
| Downtown | V-12 (borehole) | Mercer Street at 4th Avenue North, Seattle Center (Cascade Public Media) | 34, 50, 115, 175, 225, K.C.T.S main studio, audio sweetening, and second floor recording area |
| Downtown | V-12a (surface) | 4th Avenue North at Mercer Street, Seattle Center (Seattle Opera and KING FM) | 18, 20, 40, Community Concert Hall, rehearsal hall, and recording booth |
| Downtown | V-13 (borehole) | Republican Street at 3rd Avenue North, Seattle Center (McCaw Hall, Seattle Center Studios, and Pacific Northwest Ballet) | 10, 50, 151, 212, 351, McCaw mechanical room, McCaw main hall, McCaw lecture hall, Pacific Northwest Ballet back hall, expo space |
| Downtown | V-14 (borehole) | Mercer Street at 2nd Avenue North, Seattle Center (Seattle Repertory Theatre and Cornish Playhouse) | 0, 65, 160, 181, 316, Cornish courtyard, Cornish lobby, Cornish theater, Bagley Wright pit, Bagley Wright Theater, Leo K. Theater |
| Downtown | V-15 (borehole) | Republican Street at 1st Avenue North, Seattle Center (K.E.X.P., the Vera Project, and SIFF Film Center) | 10, 80, 280, 400, K.E.X.P. D.J. booth, K.E.X.P. Edit room, K.E.X.P. Studio, and K.E.X.P. mastering room, Vera Performance space, Vera recording booth, and SIFF Theater |
| South Interbay | V-G (surface) | Victory Studios, 2247 15th Avenue West, Interbay | 25, 40, 75, 125, 175, Mad Animal Red Studio control room and booth, Fresh Made Studio A control room and booth, large shoot room, upstairs office |
| Interbay/Ballard | V-H (surface) | Seattle Film Institute, 3210 16th Avenue West | 25, 40, 60, 79, 110, 140, Seattle Film Institute Theater, mixing room, and edit booth |
| Interbay/Ballard | V-17 (borehole) | Nickerson Street cloverleaf, Interbay | 20, 50, 75, 100, 125, 150, 200 |
| Interbay/Ballard | V-I (surface) | West Emerson Street at 14th Avenue West | 25, 50, 75, 100, 125, 165, 200 |
| Interbay/Ballard | V-J (surface) | Northwest Leary Way at 14th Avenue Northwest | 25, 55, 75, 100, 125, 150, 200 |

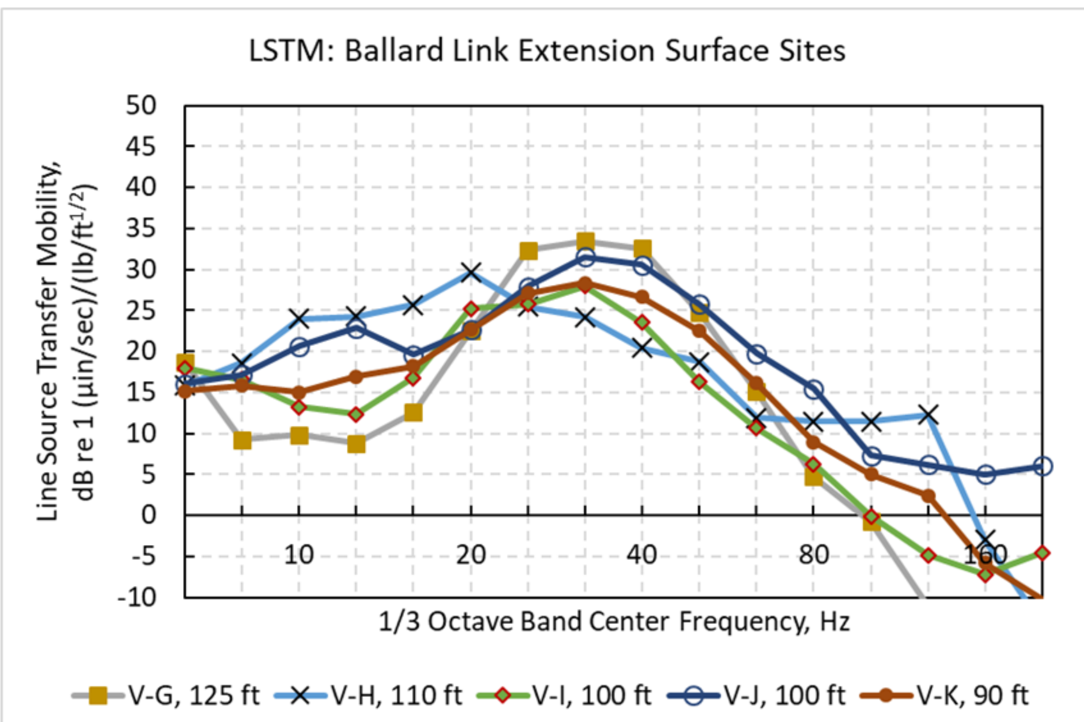
| Segment | Test Site | Location | Sensor Positions (in feet or by location) |
|---|---|---|---|
| Interbay/Ballard | V-K (surface) | Northwest 52nd Street at 15th Avenue Northwest | 30, 50, 75, 90, 125, 150, 200 |
| Interbay/Ballard | V-18 (borehole) | 14th Avenue Northwest at Northwest Market Street | 20, 50, 75, 100, 125, 150, 200 |

Figure 5-16 shows the measured vibration propagation test results for the surface sites at or close to 100 feet. Figures 5-17 and 5-18 show the measured vibration propagation test results at the borehole sites at or close to 150 feet in the Downtown and Interbay/Ballard segments, respectively. For the surface sites, the line source transfer mobility is presented, and for borehole sites, the point source transfer mobility is presented because it is not possible to measure at a line of impact points. The point source transfer mobility has lower amplitudes compared to the line source transfer mobility. Data from borehole sites V-11 and V-12 are not included in the figures, because those data were collected in fall 2020 after the majority of the analysis had been completed. Data from those sites are applied only to Category 1 sensitive receivers and are presented in Attachment N.3H.

Observations from the vibration propagation test results were as follows:

- Surface sites:
  - In general, the surface sites show the highest line source transfer mobility levels in the 30- to 60-hertz range, with levels decreasing at higher frequencies.
  - The Ballard Link Extension data show good agreement across different measurement sites.

**Figure 5-16. Measured Line Source Transfer Mobility at 100 feet for Ballard Link Extension Surface Sites**



- Borehole sites:
  - At borehole vibration propagation test sites, the transfer mobilities generally have flatter spectra than the surface sites. This generally results in lower levels in the 30- to 60-hertz range, but higher levels at higher frequencies.
  - The Downtown Segment data show a wide spread in point source transfer mobility levels across six different measurement sites. The highest levels were measured at Site V-15, which was at 1st Avenue North and Republican Street at the northwest corner of Seattle Center. Observation during drilling and review of the soil data is that the soil is very hard near the surface at this location. The wide variation at the other sites may be due to the complex built environment underground throughout the downtown area, which can affect vibration propagation.
  - The measured point source transfer mobility at Site V-17 is particularly low compared to other sites. The data were measured in the cloverleaf at West Nickerson Street. There is the potential that there are unusual soil conditions at this site from the construction of the overpass. The data are not used in the analysis to avoid underpredicting vibration levels.

**Figure 5-17. Measured Point Source Transfer Mobility at 150 feet for Interbay/Ballard Segment Borehole Sites**

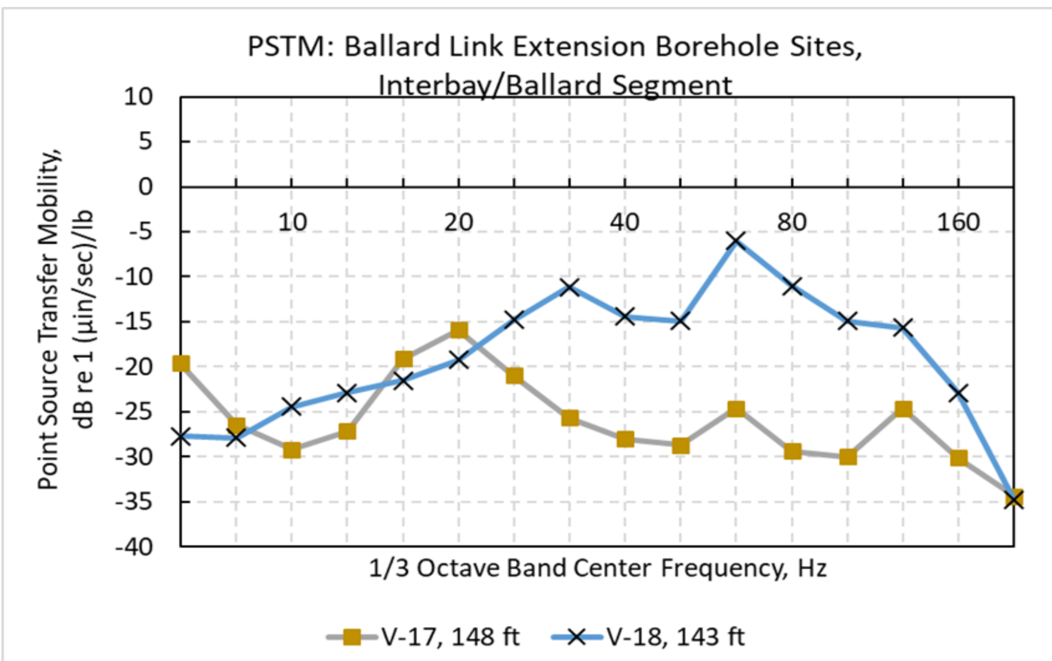
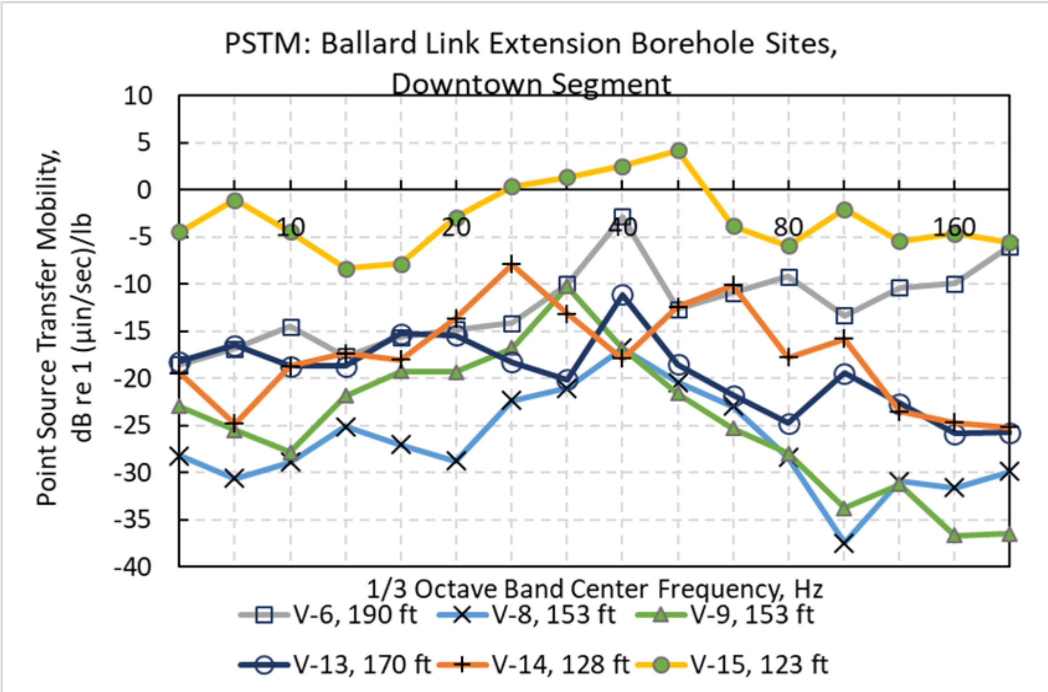


**Figure 5-18. Measured Point Source Transfer Mobility at 150 feet for Downtown Segment Borehole Sites**



# 6 IMPACT ASSESSMENT

Sound Transit performed a detailed noise and vibration impact assessment based on the criteria discussed in Chapter 3, Noise and Vibration Impact Criteria, using the methods and projections described in Chapter 4, Noise and Vibration Impact Analysis Assumptions and Methods, of this report. For areas with potential noise or vibration impacts, mitigation measures are evaluated and proposed as described in Chapter 7, Noise and Vibration Mitigation Measures. Potential noise and vibration impacts from light rail transit operations according to the FTA Guidance Manual (2018) are provided for the WSBLE in the following sections. An assessment of construction noise levels was also performed, and is described in Section 6.2, Construction Noise Impacts.

Assessment details are provided in the following attachments:

- Attachment N.3A: Noise Measurement Data, Site Details and Photographs.
- Attachment N.3B: Vibration Measurement Site Photographs.
- Attachment N.3C: Vibration Propagation Measurement Results.
- Attachment N.3D: Maps of Noise Impact Assessment.
- Attachment N.3E: Maps of Vibration Impact Assessment.
- Attachment N.3F: Tables of Noise Predictions.
- Attachment N.3G: Tables of Vibration Predictions.
- Attachment N.3H: Vibration Analysis of Category 1 Uses and Special Buildings.

Summary discussions of the results are provided in the following sections.

## 6.1 Operational Noise Impacts

### 6.1.1 West Seattle Link Extension

#### 6.1.1.1 Transit Noise Impact Analysis

This section provides the results of the detailed noise analysis for the West Seattle Link Extension. The study area for the West Seattle Link Extension is based on measured noise levels of the existing fleet of Sound Transit light rail vehicles, operational schedule, and train speeds, and is large enough to capture all potential noise impacts from system operations. System operations includes all light rail-related noise sources (wayside noise, bells, crossovers) ancillary facilities, and identification of areas with potential wheel squeal. Based on this information, the analysis includes noise sensitive properties within at least 500 feet of the track alignments. This amounts to over 70 analysis locations in the Duwamish Segment, over 450 in Delridge, and nearly 900 in the West Seattle Junction area. The locations analyzed include single and multi-family residences, fire stations, schools, daycares, a recording studio, parks, and other FTA noise-sensitive land uses.

Figures displaying the locations of noise impacts and tables with detailed noise analysis information are provided in Attachment N.3D and Attachment N.3F.

***No Build Alternative***

Under the No Build Alternative, traffic noise levels would continue to be dominated by major and minor arterial roadways, aircraft over flights, unrelated construction projects, and commercial, industrial, and residential activities. Because there would be no light rail construction or operations, no light rail-related noise impacts are predicted.

### *Build Alternatives*

The noise impacts are summarized by alternative and include moderate and severe impacts for each of the three FTA categories. A general discussion of impacts for each of the alternatives is also included. Detailed information on the impacts are provided graphically on area maps in Attachment N.3D and tables of the noise projections by receiver are provided in Attachment N.3F.

*SODO Segment*

There are no FTA noise-sensitive properties in the SODO Segment; therefore, no operational noise analysis was performed.

*Duwamish Segment*

Noise impacts for the Duwamish Segment are shown in Table 6-1 and on Figure 6-1. Detailed figures displaying the locations of noise impacts and tables with detailed noise analysis information are provided in Attachments N.3D and N.3F.

**Table 6-1. Summary of Light Rail Noise Impacts by Alternative for the Duwamish Segment**

| Alternative | Category 1 Noise Impacts | Category 2 Moderate Noise Impacts | Category 2 Severe Noise Impacts | Category 3 Noise Impacts | Total Noise Impacts |
|---|---|---|---|---|---|
| Preferred South Crossing (DUW-1a) [a] | 0 | 6 to 10 | 0 | 0 | **6 to 10** |
| South Crossing South Edge Crossing Alignment Option (DUW-1b) [a] | 0 | 10 to 12 | 0 | 0 | **10 to 12** |
| North Crossing (DUW-2) [a] | 0 | 1 | 0 | 0 | **1** |

Notes:

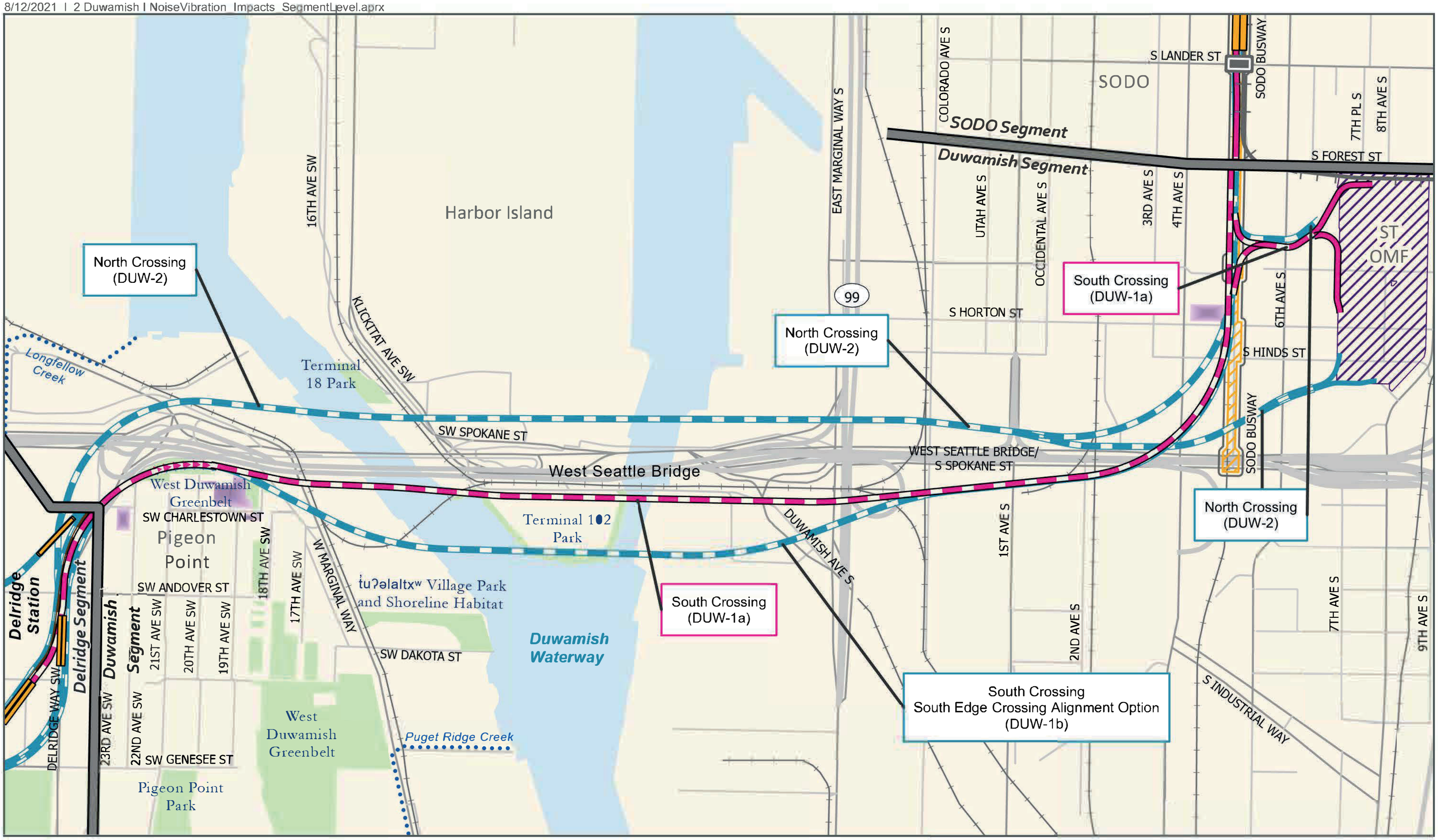
The numbers presented are the number of units, counted by individual residences, including individual units of multi-family structures, and number of structures for other uses, like schools, churches and parks. Category 2 parcels are evaluated with the 24-hour Ldn and Category 1 and 3 are evaluated with the peak hour Leq.

Ranges reflect differences from connecting to different alternatives in adjacent segments. The total impacts are based on individual alternatives and connection options and not the high and low of each impact type shown in the table.

[a] The Ballard Link Extension-only Minimum Operable Segment would result in a moderate noise impact at Fire Station 14 in the Duwamish Segment to connect the Ballard Link Extension-only Minimum Operable Segment to the existing Operations and Maintenance Facility Central.

The Duwamish Segment includes the area between South Forest Street at the east end of the segment and Southwest Charlestown Street at the west end of the segment.

Preferred Alternative DUW-1a and Option DUW-1b would have the most impacts in the Duwamish Segment. These alternatives could connect to any of the SODO and Delridge segment alternatives. Noise impact differences between the two alternatives are affected by four factors – retained cut segments, receiver elevation, track elevation, and track location across the Duwamish Waterway. Alternative DUW-2 would have the fewest noise impacts of all the Duwamish Segment alternatives. All alternatives except Alternative DUW-2 transition to a retained cut section along the West Duwamish Greenbelt. However, Option DUW-1b would cross the Duwamish Waterway on the south edge of Harbor Island; it would have both a lower track elevation than Preferred Alternative DUW-1a and a longer retained cut area along the West Duwamish Greenbelt, resulting in lower light rail noise levels.




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Existing Link Light Rail
- Railroad
- SODO Busway
- Proposed Overpass
- Sound Transit Operations and Maintenance Facility (ST OMF)
- Piped Stream
- Park
- Area of Noise Impact

FIGURE 6-1
**Noise Impacts (before mitigation)**
West Seattle Link Extension - Duwamish Segment

*West Seattle and Ballard Link Extensions*

0 800 1,600 Feet
N

The alignment for Alternative DUW-2 would be farther north than the other alternatives and far enough away from residential housing to not cause noise impacts.

The Ballard Link Extension-only Minimum Operable Segment would result in a moderate noise impact at Fire Station 14, as described in Section 6.1.2.2, Traffic Noise Impacts.

Preferred South Crossing Alternative (DUW-1a)

Preferred Alternative DUW-1a would have no severe noise impacts. Moderate noise impacts were identified at a cluster of single-family residences between 20th Avenue Southwest and 19th Avenue Southwest along Southwest Charlestown Street, where the alignment would be elevated, approaching Pigeon Point. Moderate noise impacts would occur at residences uphill from the guideway with minimal or no acoustical shielding. One moderate impact was identified at Fire Station 14 at 3224 4th Avenue South. Fire Station 36 at 3600 23rd Avenue Southwest would not have a noise impact because of the high existing noise levels and because of the distance and shielding from the elevated structure. Noise from the guideway would be shielded from impacting Seattle Fire Station 36 by the structure itself. The guideway would act as a noise barrier and would effectively block noise from going downward toward the Fire Station 36 building.

When connecting to Alternative DEL-3 or Alternative DEL-4*, Preferred Alternative DUW-1a would have fewer moderate noise impacts due to being farther from single and multi-family residences along 22nd Avenue Southwest.

When connecting to Alternative DEL-5 or Alternative DEL-6*, Preferred Alternative DUW-1a would have higher predicted noise impacts than the connections with Alternative DEL-3 or Alternative DEL-4* because it would be closer to multi-family residences on Southwest Charlestown Street and along 22nd Avenue Southwest.

Following Sound Transit policy and the discussion in Section 4.1.1.5, Operations Plan, the Duwamish Segment was reviewed for curves with the potential for wheel squeal. Under Preferred Alternative DUW-1a, there would be several curves located primarily near the existing Operations and Maintenance Facility Central. The first two curves with radii of 125 feet would be at the north and south of the entrance to the Operations and Maintenance Facility Central followed by a slightly wider curve just before the tracks branch off to the facility's connections. The northern connection would have the widest curve radius at 300 feet with two additional curve radii at the tail end of 130 feet and 110 feet. The south connection only would have two curves both with a radius of 130 feet. To the southwest of the facility, there would be one more curve before crossing the Duwamish Waterway with a 1,200-foot radius by 4th Avenue South, which may impact Fire Station 14. West of the Duwamish Waterway crossing there would be only one curve with a radius less than 1,250 feet, near Pigeon Point at the north end of 20th Avenue Southwest.

The only crossovers for Preferred Alternative DUW-1a would be for the Operations and Maintenance Facility Central access. They would consist of single and double crossovers at the facility's entrances and north and south the connection guideways. While most crossovers would be within commercial/industrial areas, the crossovers at the south entrance would be close to Fire Station 14 and therefore were included in the analysis.

South Crossing South Edge Crossing Alignment Option (DUW-1b)

Option DUW-1b would have no severe noise impacts. Moderate impacts that would affect single-family and multi-family residences were identified at the same areas as described under the Preferred Alternative DUW-1a, including Fire Station 14. However, Option DUW-1b would have slightly more noise impacts at residences on the east side of Pigeon Point than Preferred Alternative DUW-1a due to the southern alignment across Harbor Island.

Option DUW-1b would have the same curves at the existing Operations and Maintenance Facility Central as Preferred Alternative DUW-1a and only one curve with the potential for wheel squeal in the Pigeon Point area near the West Duwamish Greenbelt. This curve would have a 950-foot radius, and would be north of 20th Avenue Southwest near the West Seattle Bridge by single and multi-family residences.

North Crossing Alternative (DUW-2)

Alternative DUW-2 would have the least noise impacts for the Duwamish Segment. It would have no severe noise impacts and one moderate noise impact at Fire Station 14. It would not have impacts on any residential properties.

Most curves and crossovers for the Alternative DUW-2 would be for the Operations and Maintenance Facility Central access. This would include several curves, a 125-foot radius curve followed by three more curves at 150-foot, 300-foot, and 130-foot radii. There would also be a 1,250-foot radius curve between the north and south facility access near 4th Avenue South, which may affect Fire Station 14. The south facility access would have six curves with three of those curves having a radius between 1,100 and 1,000 feet. The remaining south curves would be at the far east end of the main guideway and have curve radii between 200 and 250 feet. There would be additional tight radius curves associated with the connection to the Operations and Maintenance Facility Central. Alternative DUW-2 would have one more curve after crossing west over the Duwamish Waterway between West Marginal Way Southwest and Chelan Avenue Southwest with a 900-foot curve radius, but this curve would be in a commercial and industrial area.

Several crossovers were identified for Alternative DUW-2, all associated with the north and south Operations and Maintenance Facility Central access. While the crossovers would be within commercial/industrial areas, the crossovers at the north facility contribute to impacts at Fire Station 14.

*Delridge Segment*

Noise impacts for the Delridge Segment are shown in Table 6-2 and Figure 6-2. Some of the impacts in this segment are in the Duwamish Segment; however, these impacts are caused by the alignment within the Delridge Segment. Impacts shown in Table 6-2 assume a connection to Preferred Alternative DUW-1a in the Duwamish Segment. Impacts would be reduced when connecting to Alternative DUW-2. Detailed figures displaying the locations of noise impacts and tables with detailed noise analysis information are provided in Attachments N.3D and N.3F.

The Delridge Segment generally includes the area between Southwest Charlestown Street (west of Delridge Way Southwest) at the east end of the segment and 31st Avenue Southwest at the west end of the segment. Alternative DEL-6* would have the fewest overall noise impacts because it would be farther from most residences, while Alternatives DEL-4* and DEL-5 would have the most overall noise impacts because they are closest to the greatest number of residences. Preferred Alternative DEL-2a* and Alternative DEL-5 would have the most severe noise impacts.

Both Preferred Alternative DEL-1a and Option DEL-1b would share similar track elevation, except along Southwest Genesee Street between 28th Avenue Southwest and Southwest Avalon Way, where Preferred Alternative DEL-1a would be on the south side of the Southwest Genesee Street right-of-way, while Option DEL-1b would shift to the north side of Southwest Genesee Street.

### Table 6-2. Summary of Light Rail Noise Impacts by Alternative for the Delridge Segment

| Alternative | Category 1 Noise Impacts | Category 2 Moderate Noise Impacts | Category 2 Severe Noise Impacts | Category 3 Noise Impacts | Total Noise Impacts |
|---|---|---|---|---|---|
| Preferred Dakota Street Station (DEL-1a) | 1 | 200 to 208 | 12 to 13 | 0 | **212 to 222** |
| Dakota Street Station North Alignment Option (DEL-1b) | 1 | 177 | 29 | 0 | **207** |
| Preferred Dakota Street Station Lower Height (DEL-2a)* | 1 | 187 | 44 | 0 | **232** |
| Dakota Street Station Lower Height North Alignment Option (DEL-2b)* | 1 | 150 | 27 | 0 | **178** |
| Delridge Way Station (DEL-3) | 1 | 205 | 2 | 0 | **208** |
| Delridge Way Station Lower Height (DEL-4)* | 1 | 210 | 26 | 0 | **237** |
| Andover Street Station (DEL-5) | 0 | 212 | 57 | 1 | **270** |
| Andover Street Station Lower Height (DEL-6)* | 0 | 100 | 1 | 1 | **102** |

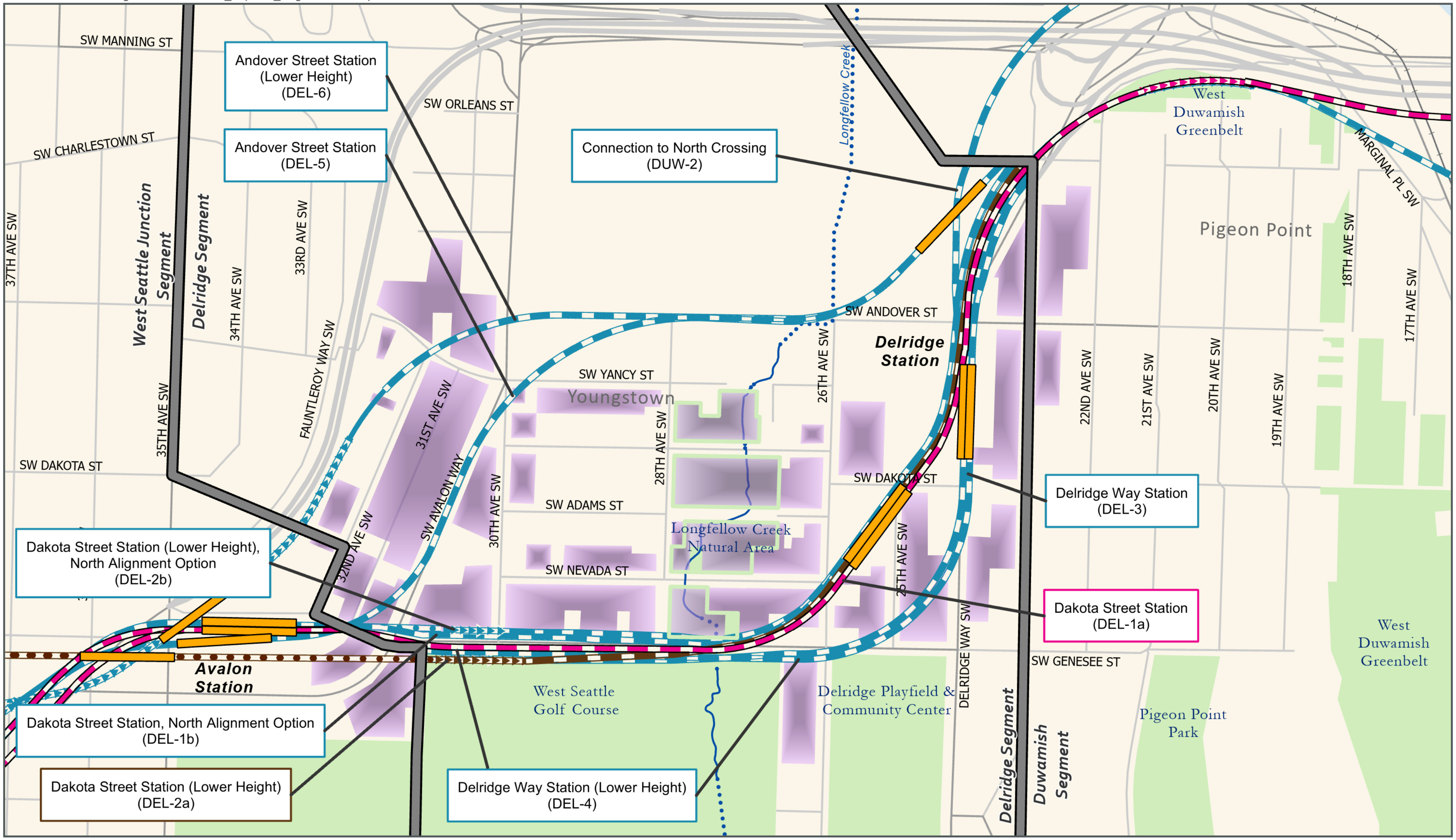
* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

Note: The numbers presented are the number of units, counted by individual residences, including individual units of multi-family structures, and number of structures for other uses, like schools, churches and parks. Category 2 parcels are evaluated with the 24-hour Ldn and Category 1 and 3 are evaluated with the peak hour Leq.

Preferred Alternative DEL-2a* and Option DEL-2b* would have similar alignments at lower elevations than Preferred Alternative DEL-1a and Option DEL-1b. Under Preferred Alternative DEL-2a*, the guideway would be along the northern edge of the West Seattle Golf Course at 4470 35th Avenue Southwest, south of Southwest Genesee Street, while Option DEL-2b* runs north of Southwest Genesee Avenue. Both alternatives would enter tunnel portals east of the West Seattle Junction Segment.

Both Alternatives DEL-3 and DEL-4* would travel farther south along Delridge Way than Preferred Alternative DEL-1a, Option DEL-1b, Preferred Alternative DEL-2a*, and Option DEL-2b*. While they both would have different guideway elevations, they would share similar alignments until Southwest Genesee Street between 28th Avenue Southwest and Southwest Avalon Way. Alternative DEL-3 would run along the south side of the Southwest Genesee Street right-of-way, while Alternative DEL-4* would travel along the northern edge of the West Seattle Golf Course, south of Southwest Genesee Street, just before the West Seattle Junction Segment.

Alternatives DEL-5 and DEL-6* would both be along Southwest Andover Street. Though they would have different guideway elevations, their alignments would be similar until they reach the intersection of 28th Avenue Southwest and Southwest Andover Street. From there, Alternative DEL-5 would turn south to travel along Southwest Avalon Way and Alternative DEL-6* would continue west before turning south just east of the West Seattle Bridge before entering a retained cut near the West Seattle Junction Segment.




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**

- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**

- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**

- New

- Segment Line
- Railroad
- Stream
- Piped Stream
- Park
- Area of Noise Impact

FIGURE 6-2

**Noise Impacts (before mitigation)**

West Seattle Link Extension - Delridge Segment

*West Seattle and Ballard Link Extensions*

0 400 800 Feet

N

Preferred Dakota Street Station Alternative (DEL-1a)

Preferred Alternative DEL-1a could connect to Preferred Alternative DUW-1a at the Duwamish Segment and Preferred Alternative WSJ-2 in the West Seattle Junction Segment. The range of impacts for Preferred Alternative DEL-1a would depend on the connection to the Duwamish Segment. When connecting to Preferred Alternative DUW-1a, Preferred Alternative DEL-1a would have the most impacts. When connecting to Alternative DUW-2, it would have the least moderate noise impacts predicted for the area north of the station. This alternative would have less severe noise impacts than other Delridge Segment alternatives except Alternatives DEL-3 and DEL-6*.

Most of the severe noise impacts would be concentrated within a five-story mixed-use apartment building, Youngstown Flats at 4040 26th Avenue Southwest, on the corner of Southwest Dakota Street and 26th Avenue Southwest, which would be in close proximity to the guideway and station. Other severe noise impacts would affect single-family residences on 23rd Avenue Southwest near Southwest Andover Street and at the southeast corner of 26th Avenue Southwest and Southwest Nevada Street along with upper floor units at a multi-family complex, The Edge Apartments at 3101 Southwest Avalon Way. Single-family residences along Delridge Way Southwest, Southwest Andover Street, 22nd Avenue Southwest, and 23rd Avenue Southwest are predicted to have moderate noise impacts due to proximity to the guideway and a double crossover. The station would contribute to a number of moderate noise impacts due to noise from the train mounted warning bells.

A smaller cluster of moderate noise impacts were identified at The Edge Apartments. Noise impacts at residences along 23rd Avenue Southwest and Southwest Andover Street would be from a combination of noise from the light rail operations and a nearby crossover.

West of the station, lower ambient noise levels would result in a lower impact criterion and nearly all the residences in between Southwest Adams Street and Southwest Nevada Street west of 26th Avenue Southwest are predicted to have moderate noise impacts. As the alignment would make its way onto Southwest Genesee Street, single- and multi-family residences on Southwest Nevada Street between 26th Avenue Southwest and 28th Avenue Southwest would have moderate noise impacts from a combination of low existing ambient noise levels, close proximity to the guideway, and noise from the station.

As described in Chapter 5, Affected Environment, there is one building in the Delridge Segment that meets the requirements for analysis under the FTA Category 1 criteria. Secret Studio Records/Studio 1208, on the southwest corner of 23rd Avenue Southwest and Southwest Andover Street, is a wooden-framed structure built in 1916 that has been converted to a recording studio, and is predicted to have a moderate noise impact.

A noise analysis was performed at the frequent use areas in Longfellow Creek Natural Area and no noise impacts were identified.

Following Sound Transit policy and the discussion in Section 4.1.1.6, Wheel Squeal and Wheel-Flanging Noise, the Delridge Segment was reviewed for curves with the potential for wheel squeal. Three curves at 1,250 feet or less were identified under Preferred Alternative DEL-1a. The first curve, with a 625-foot radius, would be along Delridge Way between Southwest Dakota Street and Southwest Andover Street. Another 625-foot radius curve would be just north of Southwest Genesee Street and slightly west of the intersection with 26th Avenue Southwest. The final curve at a 1,250-foot radius would be at the west end of the alternative on Southwest Genesee Street between 30th Avenue Southwest and Southwest Avalon Way.

Under the alternative, there would be one crossover along Delridge Way Southwest at the intersection with Southwest Andover Street. The crossover would be near single- and multi-family residences and was included in the light rail analysis. The crossover would contribute to noise impacts identified in this area.

Dakota Street Station North Alignment Option (DEL-1b)

Option DEL-1b shares a similar alignment and track elevation with Preferred Alternative DEL-1a in the northeast end of the segment. However, Option DEL-1b would transition to the north side of Southwest Genesee Street just east of 28th Street Southwest.

There would be several severe noise impacts with this alternative. The majority of the severe noise impacts would be at the Youngstown Flats, which would be in close proximity to the guideway and within 500 feet of station. Other severe impacts to single and multi-family residences would occur along 26th Avenue Southwest and Southwest Nevada Street. The remaining severe noise impacts would be at the west end of the alternative, and would affect multi-story apartment buildings on the southeast corner of Southwest Genesee Street and Southwest Avalon Way. All of these apartments would be in close proximity to the guideway as it would be approaching Avalon Station.

Moderate noise impacts were also identified for Option DEL-1b. In addition to the severe noise impacts, Youngstown Flats apartments would receive the largest cluster of moderate noise impacts, due to its close proximity to the elevated guideway and the station. Moderate impacts would occur at single- and multi-family residences along the west slope of Pigeon Point, along 22nd Avenue Southwest and 23rd Avenue Southwest. Moderate impacts were also identified South of Southwest Andover Street, along Delridge Way Southwest and 23rd Avenue Southwest at single- and multi-family residences.

Additional moderate noise impacts would occur on east of the station along 25th Avenue Southwest at Southwest Genesee Street and along Delridge Way south of Southwest Dakota Street. The alternative would travel on Southwest Genesee Street where single and multi-family residences on Southwest Nevada Street between 26th Avenue Southwest and 28th Avenue Southwest would have moderate noise impacts due to the close proximity to the guideway, noise from the station, and lower existing noise levels.

Option DEL-1b would have slightly fewer moderate noise impacts at single- and multi-family residences on Southwest Nevada Street between 30th Avenue Southwest and 28th Avenue Southwest than the Preferred Alternative DEL-1a because the alignment would travel along the north of side of Southwest Genesee Street rather than the south side, it could result in more residential displacements. Another cluster of moderate noise impacts was identified at The Edge Apartment buildings on Southwest Genesee Street between 30th Avenue Southwest and Southwest Avalon Way. These impacts would be caused by the close proximity to the guideway and station along with topographical conditions, which vary greatly, placing some receiver locations with balconies above the light rail tracks, increasing impacts. The last cluster of single- and multi-family residences with predicted moderate noise impacts would be between Southwest Avalon Way and 32nd Avenue Southwest on Southwest Genesee Street. Residences in this cluster would also be elevated and within 500 feet of the station.

Secret Studio Records/Studio 1208, on the southwest corner of 23rd Avenue Southwest and Southwest Andover Street, is predicted to have a moderate noise impact.

A noise analysis was performed at the frequent use areas in Longfellow Creek Natural Area and no noise impacts were identified.

Under Option DEL-1b, there would be a 625-foot radius curve just west of Delridge Way between Southwest Dakota Street and Southwest Andover Street followed by another 625-foot radius curve north of Southwest Genesee Street and west of 26th Avenue Southwest where the track would curve south to go west along Southwest Genesee Street. The last curve for the alternative, with an 1,800-foot radius, would be midway between 28th Avenue Southwest and 30th Avenue Southwest on Southwest Genesee Street.

Option DEL-1b would have only one crossover along Delridge Way Southwest at the intersection with Southwest Andover Street. The crossover would be near single- and multi-family residences and was included in the analysis. The crossover would contribute to noise impacts identified in this area.

Preferred Dakota Street Station Lower Height Alternative (DEL-2a)*

Preferred Alternative DEL-2a* could connect to Preferred Alternative WSJ-3a* or Preferred Option WSJ-3b* in the West Seattle Junction Segment. It would have a lower track alignment than Preferred Alternative DEL-1a in order to connect to these tunnel alternatives. The lower guideway elevations for the Preferred Alternative DEL-2a* would have more severe and moderate impacts than alternatives with higher profile guideway elevations.

Severe noise impacts along Delridge Way Southwest would be similar to Preferred Alternative DEL-1a, with most severe noise impacts at the upper level floors at Youngstown Flats. Additional severe noise impacts were identified at single- and multi-family residences along 23rd Avenue Southwest, south of Andover Street and 26th Avenue Southwest, near the station. Along Southwest Genesee Street, severe noise impacts would occur at most residences adjacent to the guideway between 28th Avenue Southwest and 30th Avenue Southwest due to close proximity to the guideway.

Moderate impacts were identified at single- and multi-family residences between the north end of 22nd Avenue Southwest and Delridge Way Southwest to Southwest Andover Street, due in part to the elevation of the receiver relative to the guideway, at the upper floors of multi-family buildings and the Pigeon Point hillside and the general proximity to the guideway and double crossover at Southwest Andover Street. Added noise from bells at the station would cause moderate noise impacts at those residences near the station. East of the station, moderate impacts were identified at single- and multi-family residences between 25th Avenue Southwest and Delridge Way Southwest at Southwest Genesee Street. To the west of the station, the largest cluster of moderate noise impacts would occur at lower level floors of the Youngstown Flats, in addition to the severe noise impacts, as well as at nearly all single- and multi-family residences along Southwest Adams Street and Southwest Nevada Street near 26th Avenue Southwest, where lower existing noise levels would result in a lower criteria level. Additional moderate noise impacts are also predicted at several single- and multi-family residences along Southwest Nevada Street, west of 28th Avenue Southwest.

Secret Studios Records/Studio 1208, on the southwest corner of 23rd Avenue Southwest and Southwest Andover Street, is predicted to have a moderate noise impact.

A noise analysis was performed at the frequent use areas in Longfellow Creek Natural Area and no noise impacts were identified.

Preferred Alternative DEL-2a* would only have two curves under 1,250 feet, both with a curve radius of 625 feet found just east of Delridge Way between Southwest Dakota Street and Southwest Andover Street and east as the guideway bends to turn west and travel along Southwest Genesee Street.

Preferred Alternative DEL-2a* would have one crossover along Delridge Way Southwest at the intersection with Southwest Andover Street. The crossover would be near single- and multi-family residences and was included in the light rail analysis. The crossover would contribute to noise impacts identified in this area.

Dakota Street Station Lower Height North Alignment Option (DEL-2b)*

Option DEL-2b* would generally share a similar track elevation and route with Preferred Alternative DEL-2a*, but the guideway would have a slightly higher elevation. West of the station, Option DEL-2b* would travel north of Southwest Genesee Street, rather than south, and would have a lower elevation for connection to the tunnel near the West Seattle Junction Segment. The higher guideway elevation would result in less severe and moderate noise impacts than Preferred Alternative DEL-2a*.

With this alternative, severe noise impacts would occur at single- and multi-family residences east of the guideway from 23rd Avenue Southwest at Delridge Way to Southwest Dakota Street. A number of factors would contribute to severe noise impacts in this area, including proximity to the guideway, elevation of receiver relative to the guideway, and proximity to a crossover. Severe noise impacts would also occur at single- and multi-family residences on 26th Avenue Southwest west of the station and at the Youngstown Flats. Other single- and multi-family residences that would have severe noise impacts are along Southwest Genesee Street between 28th Avenue Southwest and 30th Avenue Southwest.

The moderate noise impact locations would be similar to the moderate impacts under Preferred Alternative DEL-2a*. There would be less impacts with Option DEL-2b* because of the slightly higher guideway elevation, which would increase the structural shielding from the far track at many single- and multi-family units along Delridge Way Southwest, with less impacts along Southwest Genesee and Southwest Nevada streets due to track location and residential displacements.

Secret Studio Records/Studio 1208, on the southwest corner of 23rd Avenue Southwest and Southwest Andover Street, is predicted to have a moderate noise impact.

A noise analysis was performed at the frequent use areas in Longfellow Creek Natural Area and no noise impacts were identified.

Option DEL-2b* would have two curves with a curve radius of 625 feet found just west of Delridge Way Southwest between Southwest Dakota Street and Southwest Andover Street and as the guideway bends to turn west and travel along Southwest Genesee Street.

Under this option there would only be one crossover along Delridge Way Southwest at the intersection with Southwest Andover Street. The crossover would be near single- and multi-family residences and was included in the light rail analysis. The crossover would contribute to noise impacts identified in this area.

Delridge Way Station Alternative (DEL-3)

Alternative DEL-3 could connect to Preferred Alternative WSJ-1, Preferred Alternative WSJ-2, or Alternative WSJ-4*.

The only severe noise impacts were identified at several upper floor units at The Edge Apartments. These buildings would also have the highest number of moderate impacts for this alternative. Another cluster of moderate noise impacts would be found at the Youngstown Flats. While the apartment building would be farther from the guideway than with Preferred Alternative DEL-1a, Option DEL-1b, Preferred Alternative DEL-2a*, and Option DEL-2b*, the upper floors of the building would have impacts from this alternative. The double crossover north of the station, as well as the elevation of receiver relative to the guideway elevations on the upper floors of multi-family units and proximity to the guideway, would cause moderate noise impacts for single and multi-family residences from the north end of 22nd Avenue Southwest to Southwest Andover Street and at residences along 23rd Avenue Southwest, Delridge Way Southwest, and 25th Avenue Southwest south of Southwest Andover Street. Moderate residential noise impacts would extend on both sides of the guideway from Delridge Way Southwest to 30th Avenue Southwest, including some residences in between Southwest Genesee Street and Southwest Nevada Street.

Secret Studio Records/Studio 1208, on the southwest corner of 23rd Avenue Southwest and Southwest Andover Street, is predicted to have a moderate noise impact.

A noise analysis was performed at the frequent use areas in Longfellow Creek Natural Area and no noise impacts were identified.

Alternative DEL-3 would have a 625-foot radius curve north of Delridge Station on Delridge Way Southwest near the intersection with Southwest Andover Street. South of the Delridge Station, a 750-foot radius curve would be on Delridge Way Southwest between Southwest Dakota Street and Southwest Genesee Street followed by about 625-foot curve on 25th Avenue just north of Southwest Genesee Street as the guideway would begin to turn west.

Alternative DEL-3 would have one crossover along Delridge Way Southwest just at the intersection with 23rd Avenue Southwest. The crossover would be near single- and multi-family residences and was included in the analysis. The crossover would contribute to noise impacts identified in this area.

Delridge Way Station Lower Height Alternative (DEL-4)*

Alternative DEL-4* could connect to Preferred Alternative WSJ-3a* and Preferred Option WSJ-3b* in the West Seattle Junction Segment. This alternative would have the most moderate noise impacts of all the Delridge Segment alternatives. It would have the same alignment as Alternative DEL-3 but would have a lower track elevation, resulting in additional moderate and severe noise impacts.

One single-family residence between Southwest Dakota Street and Southwest Genesee Street on 25th Avenue Southwest would have a severe noise because of the elevation of the receiver relative to the guideway. Many of the other single- and multi-family residences in the area are predicted to have moderate noise impacts. Other severe noise impacts would occur at first row single- and multi-family housing on Southwest Genesee Street between 30th Avenue Southwest and 28th Avenue Southwest, while nearly all other residences within this block would have moderate noise impacts due to second and third row acoustical shielding provided by buildings directly in front of them. One single-family residence on the southeast corner of Southwest Nevada Street and 28th Avenue would have a severe noise impact despite being further away from the guideway due to the elevation of the receiver relative to the guideway and lack of shielding.

The largest concentration of moderate noise impacts would occur where the guideway would be lower and the alignment transitions from Delridge Way Southwest to travel west along Southwest Genesee Street, between 23rd Avenue Southwest and 26th Avenue Southwest. Another concentration of moderate noise impacts would occur at the Youngstown Flats. While the apartment building would be further from the guideway, impacts would occur at the upper floors, which are in close proximity to the station. The double crossover north of the station, as well as high receiver elevation and proximity to the guideway, would cause moderate noise impacts for single- and multi-family residences along 22nd Avenue Southwest near Southwest Charleston and south towards Southwest Andover Street. As the guideway would decrease in elevation, it would cause moderate noise impacts for residences from 26th Avenue Southwest to 30th Avenue Southwest. West of 30th Avenue Southwest, moderate impacts are predicted for The Edge Apartments, which would be in close proximity to the guideway.

Secret Studio Records/Studio 1208, on the southwest corner of 23rd Avenue Southwest and Southwest Andover Street, is predicted to have a moderate noise impact.

A noise analysis was performed at the frequent use areas in Longfellow Creek Natural Area and no noise impacts were identified.

Alternative DEL-4* would have a 625-foot radius curve north of Delridge Station on Delridge Way Southwest near the intersection with Southwest Andover Street. South of Delridge Station, a 750-foot radius curve would be on Delridge Way Southwest between Southwest Dakota Street and Southwest Genesee Street followed by about 625-foot curve on 25th Avenue Southwest, just north of Southwest Genesee Street as the guideway would begin to turn west.

There would be one crossover in Alternative DEL-4* along Delridge Way Southwest at the intersection with 23rd Avenue Southwest. The crossover would be near single- and multi-family residences and was included in the light rail analysis. The crossover would contribute to noise impacts identified in this area.

<u>Andover Street Station Alternative (DEL-5)</u>

Alternative DEL-5 could connect to Preferred Alternative WSJ-1, Preferred Alternative WSJ-2, and Alternative WSJ-4* in the West Seattle Junction Segment. This alternative would travel west of Delridge Way Southwest and head south until turning west along Southwest Andover Street. It then would turn south on Southwest Avalon Way. This alternative would have the most overall noise impacts and most severe noise impacts compared to the other Delridge Segment alternatives.

All of the severe noise impacts would be at multi-family apartments and condominiums, with the largest concentration starting at the corner of Southwest Avalon Way between Southwest Andover Street and Southwest Genesee Street. Not only would the buildings be close to the guideway, but many severe impacts would occur at upper floor units overlooking the guideway.

Residences predicted to have moderate impacts include the lower floors of the Youngstown Flats and the nearby single-family residences on 26th Avenue Southwest. While the structures would be more than 300 feet away from the guideway, the area itself has lower noise levels than other surrounding areas and there is little, if any, acoustical shielding. Moderate noise impacts would occur for first row residences along Southwest Yancy Street between 28th Avenue Southwest and 30th Avenue Southwest, including housing for Transitional Resources (a non-profit behavioral health center and supportive housing facility), as well as single and multi-family residences on the east corners of Southwest Dakota Street and Southwest Adams Street at 30th Avenue Southwest. A moderate noise impact was identified for a vacant church on the east side of Southwest Avalon Way.

West of the guideway along Southwest Avalon Way, moderate noise impacts were identified at all first-row housing with no acoustical shielding between Southwest Yancy Street and Southwest Genesee Street. Another cluster of moderate noise impacts was identified at several multi-story apartment buildings on Southwest Genesee Street and between Southwest Avalon Way and 30th Avenue Southwest as well as single- and multi-family homes along 32nd Avenue Southwest. Many of the buildings that would have moderate noise impacts have limited to no acoustical shielding, and would just meet the moderate noise level criteria, at 1 to 2 dB over the criteria level. First-row single- and multi-family residences on Southwest Avalon Way, including Transitional Resources group residences, are also predicted to have moderate noise impacts. Residences in this area would have lower local noise levels and also just meet the moderate noise level criteria.

A noise analysis was performed at the frequent use areas in Longfellow Creek Natural Area and no noise impacts were identified.

Alternative DEL-5 would have three curves with a radius under 1,250 feet. The first with a 625-foot radius would be just slightly west of the intersection with Delridge Way Southwest and Southwest Andover Street. As the guideway would begin to turn south before traveling along Southwest Avalon Way, a 1,000-foot radius curve would be on Southwest Yancy Street at the intersection with 28th Avenue Southwest and Southwest Avalon Way. The final curve of 625 feet would be west of Southwest Avalon Way near the intersection with Southwest Genesee Street where the track would begin to curve east again before Avalon Station in the West Seattle Junction Segment.

<u>Andover Street Station Lower Height Alternative (DEL-6)*</u>

Alternative DEL-6* could connect only to Alternative WSJ-5* in the West Seattle Junction Segment. This alternative would travel southwest of Delridge Way Southwest and then travel west across Southwest Andover Street before turning south again along the east side of the West Seattle Bridge as it transitions to Fauntleroy Way Southwest. This alternative would have the fewest severe noise impacts and the fewest moderate noise impacts.

Only one severe noise impact would occur for Alternative DEL-6* at a single-family residence on 32nd Avenue Southwest between Southwest Andover Street and Southwest Genesee Street.

The largest concentration of moderate impacts would be found at the Youngstown Flats and a single-family residence across from the apartment building on 26th Avenue Southwest. First-row housing along 32nd Avenue Southwest between Southwest Yancy Street and Southwest Genesee Street are also predicted to have moderate noise impacts.

A noise analysis was performed at the frequent use areas in Longfellow Creek Natural Area and one moderate noise impact would occur from light rail operations.

Three curves were identified for Alternative DEL-6*. The first, a 625-foot radius curve, would be just southwest of Delridge Station and north of Southwest Andover Street slightly east of the intersection with Charlestown Street. A 950-foot radius curve would be near Southwest Yancy Street at the north end of 32nd Avenue Southwest. The last curve, with a 675-foot radius, would be at the Delridge-West Seattle Junction border east of West Seattle Bridge. There are no crossovers within Alternative DEL-6*.

*West Seattle Junction Segment*

Noise impacts for the West Seattle Junction Segment are shown in Table 6-3 and Figure 6-3. Impacts shown in Table 6-3 for Preferred Alternative WSJ-1, Preferred Alternative WSJ-2, and Alternative WSJ-4* assume a connection to Preferred Alternative DEL-1a in the Delridge Segment. Connections to other Delridge Segment alternatives could result in some moderate impacts changing to severe impacts, but the overall number of impacts would be similar. Preferred Alternative WSJ-3a* and Preferred Option WSJ-3b* would be entirely in tunnels and would not have any airborne noise impacts; therefore, they are not discussed further in this section. Detailed figures displaying the locations of noise impacts and tables with detailed noise analysis information are provided in Attachments N.3D and N.3F.

## Table 6-3. Summary of Light Rail Noise Impacts by Alternative for the West Seattle Junction Segment

| Alternative | Category 1 Noise Impacts | Category 2 Moderate Noise Impacts | Category 2 Severe Noise Impacts | Category 3 Noise Impacts | Total Noise Impacts |
|---|---|---|---|---|---|
| Preferred Elevated 41st/42nd Avenue Station (WSJ-1) | 0 | 299 | 100 | 1 | 400 |
| Preferred Elevated Fauntleroy Way Station (WSJ-2) | 0 | 302 to 375 | 10 to 99 | 0 | 351 to 401 |
| Preferred Tunnel 41st Avenue Station (WSJ-3a)* | 0 | 0 | 0 | 0 | 0 |
| Preferred Tunnel 42nd Avenue Station Option (WSJ-3b)* | 0 | 0 | 0 | 0 | 0 |
| Short Tunnel 41st Avenue Station (WSJ-4)* | 0 | 128 | 0 | 0 | 128 |
| Medium Tunnel 41st Avenue Station (WSJ-5)* | 0 | 6 | 0 | 0 | 6 |

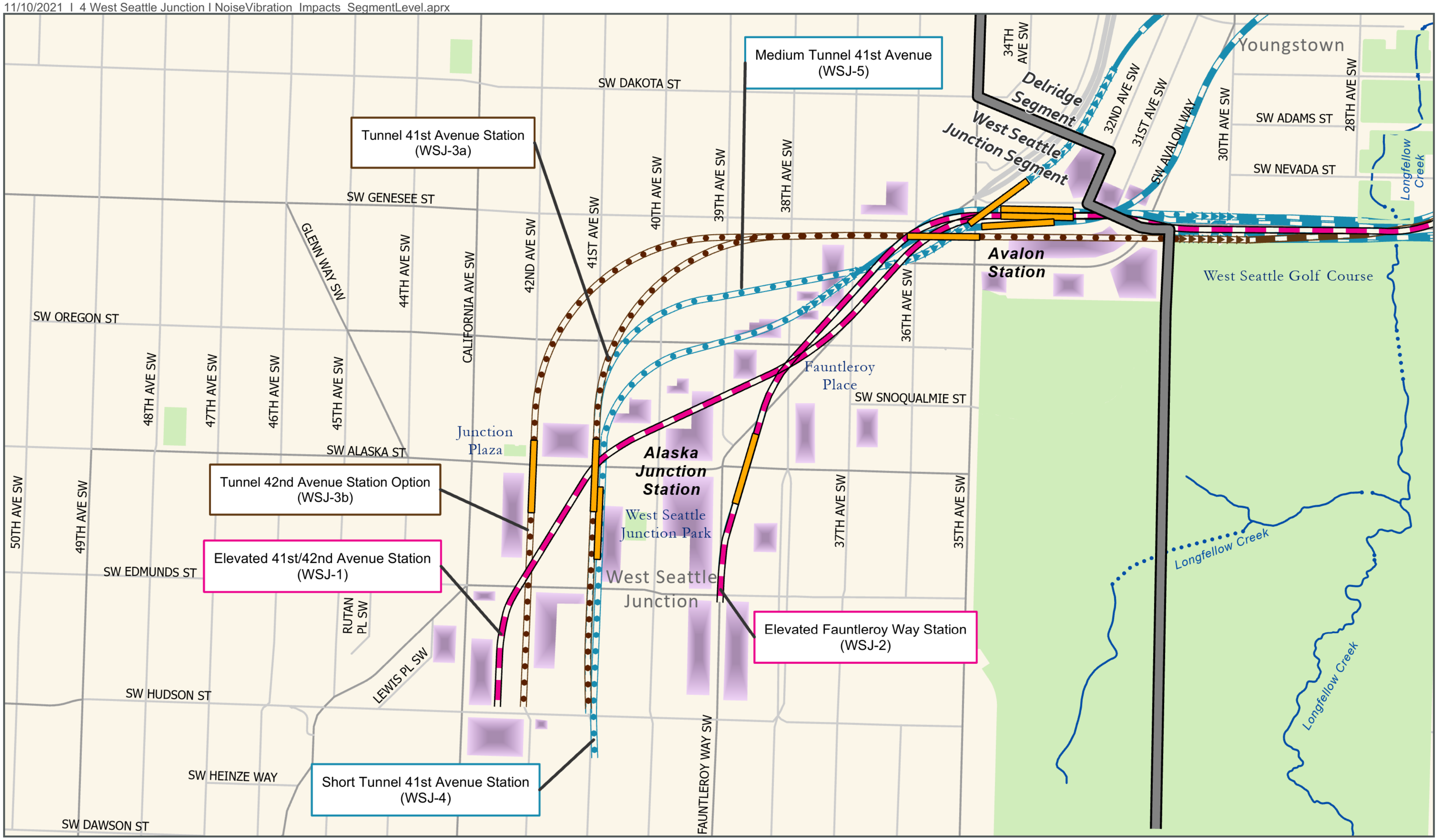
* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

Note: The numbers presented are the number of units, counted by individual residences, including individual units of multi-family structures, and number of structures for other uses, like schools, churches, and parks. Category 2 parcels are evaluated with the 24-hour Ldn and Category 1 and 3 are evaluated with the peak hour Leq.

The West Seattle Junction Segment includes the area generally west of 31st Avenue Southwest between Southwest Charlestown Street and Southwest Hudson Street. A noise impact analysis was performed for Preferred Alternative WSJ-1, Preferred Alternative WSJ-2, Alternative WSJ-4*, and Alternative WSJ-5*. All other West Seattle Junction alternatives are entirely within tunnels in this segment and therefore would not result in noise impacts from light rail operation.

Of the analyzed alternatives, Preferred Alternatives WSJ-1 and WSJ-2 would have the most overall noise impacts and Alternative WSJ-5* would have the least overall noise impacts and no severe noise impacts. Each alternative would have two stations, Avalon Station and Alaska Junction Station. However, Alternatives WSJ-4* and WSJ-5* would enter into a tunnel before the Alaska Junction Station and therefore would have a lower guideway elevation than the other two elevated alternatives. Preferred Alternative WSJ-1 would be aligned west of Fauntleroy Way Southwest, between 41st Avenue Southwest and 42nd Avenue Southwest, while Preferred Alternative WSJ-2 would be along Fauntleroy Way Southwest.

Preferred Alternative WSJ-3a* and Preferred Option WSJ-3b* are below ground in tunnels with no potential for operational noise impacts on sensitive resources; therefore, no operational noise analysis was performed.




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Stream
- Piped Stream
- Park
- Area of Noise Impact

FIGURE 6-3
**Noise Impacts (before mitigation)**
West Seattle Link Extension - West Seattle Junction Segment

*West Seattle and Ballard Link Extensions*

Preferred Elevated 41st/42nd Avenue Station Alternative (WSJ-1)

Preferred Alternative WSJ-1 could connect to Preferred Alternative DEL-1a, Option DEL-1b, Alternative DEL-3, and Alternative DEL-5 in the Delridge Segment. The alternative would travel along the south side of Southwest Genesee Street between 31st Avenue Southwest and Fauntleroy Way Southwest. The alternative would transition to the west side of Fauntleroy Way Southwest. The guideway would turn south in the vicinity of 41st Avenue Southwest and Southwest Alaska Street and continue south to Southwest Hudson Street terminating with a tail track on the west side of 42nd Avenue Southwest. It is the longest West Seattle Junction Segment alternative that was analyzed and would have the most severe impacts.

The largest cluster that would have both severe and moderate noise impacts includes most of the multi-story apartments and condominiums on the north side of Southwest Avalon Way between Southwest Genesee and 35th Avenue Southwest. This block of housing would be adjacent to Avalon Station. Buildings closest to the guideway would have severe impacts at the uppermost floors. Other floors and buildings would have moderate noise impacts.

One category 3 noise impact would occur at a church on the northwest corner of 39th Avenue Southwest and Southwest Oregon Street, due to close proximity to the guideway. Several single- and multi-family residences on 40th Avenue Southwest would have severe noise impacts due to proximity to the guideway and lack of structural shielding. They would also be in direct line of sight of the double crossover north of Alaska Junction Station. Another cluster of predicted severe noise impacts would occur at a multi-story mixed-use apartment building on the northwest corner of Southwest Alaska Street and 41st Avenue Southwest. The impacted apartments would be less than 50 feet from the guideway, within 500 feet of Alaska Junction Station and overlook the guideway. The remaining apartments would face the guideway, but would be farther away, and would have moderate noise impacts. Other severe noise impacts would include multi-story apartments on the west side of 42nd Avenue Southwest within 50 feet of Alaska Junction Station; the remaining apartments would have moderate noise impacts. South of Avalon Station, single and multi-family residences on California Avenue Southwest would all have both moderate and severe noise impacts, with the closest building to the guideway having a severe impact for the top floor. At the end of the alignment, a multi-story apartment building on the southeast corner of California Avenue Southwest and Southwest Hudson Street would have several severe impacts for the uppermost floors due to high receiver elevation and close proximity (20 feet) to the guideway; the remaining residences for the north half of the block would have moderate noise impacts.

Additional moderate noise impacts would occur at several multi-family units on 42nd Avenue Southwest, 41st Avenue Southwest, and 40th Avenue Southwest. The affected units would all be within 500 feet of the Alaska Junction Station. Moderate noise impacts are also predicted at a multi-story building within 500 feet of Alaska Junction Station at the north corner of California Avenue Southwest and Erskine Way Southwest, a multi-story apartment building with 300 feet of the double crossover on 40th Avenue Southwest, and several multi-family units, which have minimal or no acoustical shielding from noise at Alaska Station.

The residences along the northwest corner of Fauntleroy Way Southwest and 37th Avenue north of the alignment would have moderate impacts primarily because of guideway proximity and no acoustical shielding. The single- and multi-family residences along 40th Avenue Southwest that would also have moderate noise impacts are affected by proximity to the guideway and being within 300 feet of the double crossover with minimal to no shielding.

Following Sound Transit policy and the discussion in Section 4.1.1.5, the West Seattle Junction Segment was reviewed for curves with the potential for wheel squeal. Preferred Alternative WSJ-1 has three curves with the potential for wheel squeal. All of the curves would have a 625-

foot radius. These curves would be on Fauntleroy Way Southwest between Southwest Avalon Way and 35th Avenue Southwest as the guideway turns southwest along Fauntleroy Way Southwest, at the intersection of Southwest Alaska Street and 41st Avenue Southwest before Alaska Junction Station, and just west of intersection of Southwest Edmunds Street and 42nd Avenue Southwest after Alaska Junction Station.

Preferred Alternative WSJ-1 would have one crossover on the elevated trackway near 40th Avenue Southwest between Southwest Oregon Street and Southwest Alaska Street. The crossover would contribute to noise impacts in this area.

Preferred Elevated Fauntleroy Way Station Alternative (WSJ-2)

Preferred Alternative WSJ-2 could connect to Preferred Alternative DEL-1a, Option DEL-1b, Alternative DEL-3, and Alternative DEL-5. This alternative would travel along the south side of Southwest Genesee Street between 31st Avenue Southwest and Fauntleroy Way Southwest. It would then head southwest on Fauntleroy Way Southwest and continue along the west side of Fauntleroy Way Southwest. The guideway would cross to the east side of Fauntleroy Way Southwest south of Southwest Oregon Street. The alternative would terminate with tail tracks within the Fauntleroy Way Southwest right-of-way just past Southwest Edmunds Street.

Preferred Alternative WSJ-2 would have the most overall and most moderate noise impacts of all the West Seattle Junction Segment alternatives.

The largest concentration of severe noise impacts would be at Fauntleroy Way Southwest near the end of the alignment at a four-story apartment building. One other severe noise impact would occur at a single-family residence at the intersection of Southwest Oregon Street and 38th Avenue Southwest, where the structure would be in close proximity to the guideway, have no acoustical shielding from the guideway, and would be within 300 feet of a double crossover just north of Alaska Junction Station.

When connecting to Alternative DEL-5, some moderate noise impacts would change to severe noise impacts at multi-story apartment buildings on Southwest Avalon Way between Southwest Genesee Street and 35th Avenue Southwest. It would also have more severe impacts when connecting to Alternative DEL-5 than it would connecting to Preferred Alternative DEL-1a.

Moderate noise impacts for this alternative would occur at single- and multi-family residences starting from the southwest corner of Southwest Genesee Street and Southwest Avalon Way and continue to 35th Avenue Southwest, affecting residences north and south of the guideway. Affected residences would be in close proximity to the guideway, have no acoustical shielding, or a combination of both. All residences with moderate noise impacts would be within 500 feet of Avalon Station. The largest concentration of moderate noise impacts is predicted for several multi-story apartment complexes south of Avalon Station.

At 36th Avenue Southwest and Southwest Genesee Street a small cluster of single- and multi-family residences would have moderate noise impacts due to close guideway proximity, no acoustical shielding, and being within 500 feet of Avalon Station. The double crossover between Avalon Station and Alaska Junction Station would be primarily responsible for the moderate noise impacts on 37th Avenue Southwest.

Another concentration of identified moderate noise impacts would be at two apartment buildings to the west of Alaska Junction Station on the corners of Southwest Alaska Street and Fauntleroy Way Southwest. Both buildings would have high receiver elevations and their uppermost floors would overlook or be at level with Alaska Junction Station. They also would be in close proximity to the guideway and would not have any acoustical shielding. To the east of Alaska Junction Station, all the mixed-use, multi-story residences on 38th Avenue Southwest between

Fauntleroy Way Southwest and Southwest Alaska Street would have moderate noise impacts. These buildings would be near the guideway and have no acoustical shielding due in part to the high receiver elevations. The buildings would be within 500 feet of Alaska Junction Station or 300 feet of the double crossover and in some cases, both. The last cluster of moderate noise impacts would occur on both the east and west sides of Fauntleroy Way Southwest between Southwest Edmunds Street and Southwest Hudson Street.

With Preferred Alternative WSJ-2, two 625-foot radius curves would be between Avalon Station and Alaska Junction Station. The first would be at the intersection of 36th Avenue Southwest and Fauntleroy Way Southwest where the guideway turns southwest and the second curve at the intersection of Fauntleroy Way Southwest and 38th Avenue Southwest as the guideway angles closer to south. A remaining curve with a 750-foot radius would be at Fauntleroy Way Southwest between Southwest Alaska Street and Southwest Edmunds Street after Alaska Junction Station and before the end of the light rail line.

There would be only one crossover within this alternative, on the elevated trackway along Fauntleroy Way Southwest at the intersection with Southwest Oregon Street. The crossover would contribute to noise impacts in this area.

Short Tunnel 41st Avenue Station Alternative (WSJ-4)*

Alternative WSJ-4* could connect to Preferred Alternative DEL-1a, Option DEL-1b, Alternative DEL-3, or Alternative DEL-5. The alternative would travel along the south side of Southwest Genesee Street from 31st Avenue Southwest to the west side of Fauntleroy Way Southwest. It would continue along the west side of Fauntleroy Way Southwest on elevated guideway before transitioning to at-grade near 37th Avenue Southwest. It would then turn west near Southwest Oregon Street and transition into a tunnel with a portal in the vicinity of Southwest Oregon Street and 38th Avenue Southwest. The alternative would have few moderate noise impacts and no severe noise impacts.

The majority of moderate noise impacts would occur at residences near Avalon Station and would primarily affect multi-family residences along Southwest Avalon Way between 35th Avenue Southwest and Southwest Genesee Street. Other single- and multi-family residences that would have moderate impacts are around the intersection of Southwest Genesee Street and 32nd Avenue Southwest. West of Avalon Station, multi-family residences on the north side of Southwest Genesee Street between 36th Avenue Southwest and 37th Avenue Southwest would have moderate noise impacts because of their proximity to the guideway and no acoustical shielding.

Alternative WSJ-4* would only have two curves at a 1,250-foot radius or less. The first would be a 625-foot radius curve at the intersection of Fauntleroy Way and Southwest Genesee Street after Avalon Station where the track turns southwest. The final curve would be within the cut-and-cover portion of the guideway just before entering the tunnel portal and therefore would not have an impact on surrounding residences.

Medium Tunnel 41st Avenue Station Alternative (WSJ-5)*

Alternative WSJ-5* would only connect to Alternative DEL-6*. Beginning in the Delridge Segment, the alternative begins in a retained cut south of Southwest Yancy Street and follows the east side of the West Seattle Bridge connection to Southwest Genesee Street in the West Seattle Junction Segment. The alignment enters a tunnel at Southwest Genesee Street and 37th Avenue Southwest. This alternative would have the least overall noise impacts for the above-grade alternatives and no severe noise impacts.

Moderate noise impacts are predicted along 32nd Avenue Southwest just north of the intersection with Southwest Genesee Street. The single-family residences would have moderate noise impacts due to the close proximity to the guideway and little to no acoustical shielding.

Alternative WSJ-5* would have a 675-foot radius curve that would be shared with Alternative DEL-6*. It would be at the Delridge Segment/West Seattle Junction Segment boundary east of West Seattle Bridge/Fauntleroy Way. There are no Category 1 Land Uses in the West Seattle Junction Segment. There are no noise-sensitive parks in the West Seattle Junction Segment.

#### 6.1.1.2 Traffic Noise Impact Analysis

This section provides an analysis of project-related areas considered for traffic noise impacts in the West Seattle Link Extension area. There are potential traffic revisions planned as part of the West Seattle Link Extension along with some removal of shielding that could result in increased traffic noise levels. As required by the FTA, if the transit project could result in traffic noise impacts, then the project must also evaluate the traffic noise and identify impacts and provide mitigation consistent with agency policy. In most locations, the slight modifications to traffic or removal of shielding are not predicted to cause a measurable change in traffic noise levels and no traffic noise analysis is required. Locations where increased traffic noise levels could cause new project related traffic noise impacts are evaluated below.

##### *No Build Alternative*

Under the No Build Alternative, traffic noise levels would continue to be dominated by major and minor arterial roadways including traffic on the West Seattle Bridge. Other major roadways with high levels of traffic noise include 4th Avenue South and Alaskan Way in the SODO and Duwamish segments. Roadways with major contributions to noise in the Delridge Segment area include Delridge Way Southwest, Southwest Genesee Street, Southwest Avalon Way, Fauntleroy Way Southwest, and 35th Avenue Southwest. Major roadways in the West Seattle Junction Segment area include Fauntleroy Way Southwest and 35th Avenue Southwest in addition to Southwest Alaska Street, and California Avenue Southwest. These roadways would continue to be major noise sources in these areas.

##### *Build Alternatives*

Although there are some displacements and roadway modifications planned for the West Seattle Link Extension, most are not predicted to result in any new traffic noise impacts.

Within the Delridge Segment, under Alternative DEL-6*, several residences along the east side of 32nd Avenue Southwest could be exposed to noise from the West Seattle Bridge roadway due to the removal of existing residential structures on the west side of 32nd Avenue Southwest. A preliminary traffic noise analysis was performed for the residences that would lose acoustical shielding from Fauntleroy Way Southwest/West Seattle Bridge traffic noise. Based on the preliminary analysis, although noise levels would be expected to increase by 3 to 6 dB over existing conditions, due to the distance from the highway to the residences of over 240 feet, noise levels would remain well below the Federal Highway Administration impact criteria, and therefore no noise impacts were identified.

No other traffic noise related issues were identified for the West Seattle Link Extension.

### 6.1.2 Ballard Link Extension

#### 6.1.2.1 Transit Noise Impact Analysis

Noise levels were predicted at all noise-sensitive properties within approximately at least 500 feet of any of the Build Alternatives. There are no noise-sensitive receivers in the SODO Segment or in the Chinatown-International District Segment where the alternatives would be aboveground. An airborne noise analysis was not conducted where the alternatives would be in tunnels (Chinatown-International District and Downtown segments). In the South Interbay Segment, about 2,000 receiver locations (single- and multi-family units and other structures) were analyzed. In the Interbay/Ballard Segment, about 1,400 receivers were analyzed.

Figures displaying the locations of noise impacts and tables with detailed noise analysis information are provided in Attachments N.3D and N.3F.

***No Build Alternative***

Under the No Build Alternative, noise levels along the Ballard Link Extension corridors would continue to be dominated by traffic on major and minor arterial roadways, aircraft over flights, unrelated construction projects, and commercial, industrial and residential activities. Because there would be no light rail construction or operations, no light rail-related noise impacts are predicted.

***Build Alternatives***

The noise impacts are summarized by alternative and include moderate and severe impacts for each of the three FTA categories. A general discussion of impacts for each of the alternatives is also included. Detailed information on the impacts are provided graphically on area maps in Attachment N.3D, and tables of the noise projections by receiver are provided in Attachment N.3F.

*SODO Segment*

There are no FTA noise-sensitive properties in the SODO Segment; therefore, no operational noise analysis was performed.

The Ballard Link Extension-only Minimum Operable Segment would result in a moderate noise impact at Fire Station 14 in the West Seattle Link Extension Duwamish Segment. The fire station would be affected by the Ballard Link Extension when the Ballard Link Extension-only Minimum Operable Segment is connected to the existing Operations and Maintenance Facility Central.

*Chinatown-International District Segment*

In the Chinatown-International District Segment, the alignments are either below ground in tunnels with no potential for operational noise impacts on sensitive resources or in areas with no FTA noise-sensitive properties; therefore, no operational noise analysis was performed.

*Downtown Segment*

In the Downtown Segment, the alternatives are in tunnels with no potential for operational noise impacts on sensitive resources; therefore, no operational noise analysis was performed.

*South Interbay Segment*

Noise impacts for the South Interbay Segment alternatives are shown in Table 6-4 and Figure 6-4. Detailed figures displaying the locations of noise impacts and tables with detailed noise analysis information are provided in Attachments N.3D and N.3F.

### Table 6-4. Summary of Noise Impacts by Alternative in the South Interbay Segment

| Alternative | Category 1 Noise Impacts | Category 2 Moderate Noise Impacts | Category 2 Severe Noise Impacts | Category 3 Noise Impacts | Total Noise Impacts |
|---|---|---|---|---|---|
| Preferred Galer Street Station/Central Interbay (SIB-1) | 1 [a] | 418 | 37 | 0 | 456 |
| Prospect Street Station/15th Avenue (SIB-2) | 2 [a] | 599 | 144 | 0 | 745 |
| Prospect Street Station/Central Interbay (SIB-3) | 0 | 532 | 0 | 0 | 532 |

[a] Noise impacts at Category 1 buildings in this segment are for the building exterior; however, as described below, the interior noise levels at all Category 1 impacts are predicted to meet operational requirements of the business.

Notes:

The numbers presented are the number of units, counted by individual residences, including individual units of multi-family structures, and number of structures for other uses, like schools, churches, and parks. Category 2 parcels are evaluated with the 24-hour Ldn and Category 1 and 3 are evaluated with the peak hour Leq.

Noise impacts at Category 1 buildings in this segment are for the building exterior; however, as described below, the interior noise levels at all Category 1 impacts are predicted to meet operational requirements of the business.

The South Interbay Segment includes the area between 2nd Avenue West in Uptown and West Dravus Street (west of 17th Avenue West) and West Barrett Street (east of 17th Avenue West) in Interbay.

Alternative SIB-2 would have the most overall noise impacts. Preferred Alternative SIB-1 would have the least overall noise impacts, but Alternative SIB-3 would have the least severe noise impacts.

As described in Section 5, Affected Environment, there are two buildings in the South Interbay Segment that meet part, or all, of the requirements for analysis under the FTA Category 1 criteria. Locations considered for Category 1 noise analysis in the South Interbay Segment are shown in Table 6-5, with potential noise impacts discussed in the following sections.

11/10/2021 I 7 South Interbay I NoiseVibration_Impacts_SegmentLevel.aprx


Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Railroad
- Park
- Area of Noise Impact

FIGURE 6-4
**Noise Impacts (before mitigation)**
Ballard Link Extension - South Interbay Segment

*West Seattle and Ballard Link Extensions*

0 800 1,600 Feet
N

### Table 6-5. Noise, Category 1, and Special Building Sensitive Receiver Impacts in the Ballard Link Extension

| Occupant | Alternative | Segment | Address | Description of Use |
|---|---|---|---|---|
| iHeart Media | SIB-1<br>SIB-2 | South Interbay | 645 Elliott Avenue West | Radio station with recording booths |
| Victory Studios | SIB-2 | South Interbay | 2247 15th Avenue West | Recording studio with isolated booths, editing suites, and video shoot rooms |

<u>Preferred Galer Street Station/Central Interbay Alternative (SIB-1)</u>

Preferred Alternative SIB-1 would connect to Preferred Alternative DT-1 in the Downtown Segment, and could connect to Preferred Alternative IBB-1a, Preferred Alternative IBB-2a*, or Preferred Option IBB-2b* in the Interbay/Ballard Segment. It would have the least noise impacts in the South Interbay Segment regardless of the connection option.

All severe impacts would occur near the downtown tunnel portal at multi-family residences on West Mercer Place and Elliott Avenue West. Moderate impacts would also occur between the downtown tunnel portal and where the alignment would transition toward Balmer Rail Yard (along 9th Avenue West, 10th Avenue West, and West Olympic Place).

Moderate noise impacts would occur at several single- and multi-family residences along 20th Avenue West, West Barrett Street, and Thorndyke Avenue West. Even though the alignment is on the opposite side of Balmer Rail Yard from these residences, the rail yard is in a depressed cut between the guideway and the residences, and light rail noise levels are predicted to meet the criteria for moderate impacts along the southern part of this area due in part to higher speed through this area. Due to reduced noise as the trains slow to enter the Interbay Station in the Interbay/Ballard Segment, noise levels at residences closer to West Dravus Street, including at the apartments along 17th Avenue, would be below the FTA impact criteria under Preferred Alternative SIB-1.

Noise levels from light rail operations at Kinnear Park and the Southwest Queen Anne Greenbelt would be below the FTA criteria due to the distance from the guideway to frequently used areas in the parks.

Following Sound Transit policy and the discussion in Section 4.1.1.5, the South Interbay Segment was reviewed for curves with the potential for wheel squeal. Under Preferred Alternative SIB-1, there would be a curve with a radius of 850 feet as the guideway transitions from the tunnel to an elevated structure along Elliott Avenue West, and Preferred Alternative SIB-1 would have two more tight radius curves, one just north of the Smith Cove Station and the second at the connection to the Interbay/Ballard Segment at the West Dravus Street overcrossing. All identified curves would be near noise-sensitive land uses and therefore would be equipped with lubrication or prepared for lubrication to be used in the event wheel squeal occurs during initial testing.

Preferred Alternative SIB-1 would have a crossover just past the curve as the guideway transitions from the tunnel to an elevated structure along Elliott Avenue West. This crossover would be near multi-family residences along West Mercer Place and Elliott Avenue West and was included in the light rail analysis. The crossovers would contribute to noise impacts identified in this area. Preferred Alternative SIB-1 also would have two crossovers and a 420-foot storage track just north of the Smith Cove Station; however, there would be no noise-sensitive uses near these crossovers.

Under Preferred Alternative SIB-1, a moderate noise impact was identified at the exterior of iHeart Media, a Category 1 land use in the 645 Elliott Building. This building is a reinforced concrete multi-floor commercial structure equipped with commercial-grade non-operable windows. The business, iHeart Media, has operations inside the building, which is between Elliott Avenue West, a busy four-lane major arterial roadway, and the mainline of the BNSF Railway. Because the noise analysis is for the exterior of the building, and the predicted noise from light rail operations are not predicted to result in notable change in the exterior noise levels, the exterior noise impacts at this building are not predicted to affect operations of this business.

Prospect Street Station/15th Avenue Alternative (SIB-2)

Alternative SIB-2 would connect to Preferred Alternative DT-1 in the Downtown Segment, and Option IBB-1b and Alternative IBB-3 in the Interbay/Ballard Segment. It would have the most noise impacts. The number of noise impacts is due to the guideway running along the dense residential area above 15th Avenue West at speeds of up to 55 miles per hour. This alternative would also have the most severe noise impacts in this segment.

Severe noise impacts were identified on 15th Avenue West, and Gilman Drive West. A severe noise impact would also occur at Fire Station 20 on 15th Avenue West. Additional severe noise impacts are also predicted at the same locations near the downtown tunnel portal identified under Preferred Alternative SIB-1, with severe noise impacts on West Mercer Place and Elliott Avenue West. Moderate noise impacts were identified along most of the entire corridor, starting at the tunnel portal and continuing through to the Interbay/Ballard Segment.

Light rail noise levels at the two noise-sensitive parks in this segment (Kinnear Park and Southwest Queen Anne Greenbelt) would be below the FTA criteria under Alternative SIB-2.

Curves under 1,250-foot radii and crossovers were also identified under Alternative SIB-2. There would be a curve with a radius of 850 feet as the guideway transitions from the tunnel to an elevated structure along Elliott Avenue West. In addition, Alternative SIB-2 would have a crossover just past the curve as the guideway transitions from the tunnel to an elevated structure along Elliott Avenue West.

Under Alternative SIB-2, moderate noise impacts were also identified at the Category 1 645 Elliott Building. As described under Preferred Alternative SIB-1, the predicted noise from light rail operations are not predicted to result in notable change in the exterior noise levels, the exterior noise impacts at this building are not predicted to affect operations of these business.

The other potential Category 1 impact is at the Victory Studios, at 2247 15th Avenue West, just south of the Interbay Golf Center and is only affected under Alternative SIB-2. This building is a two-story masonry structure where the lower floor is below the grade of 15th Avenue West. This building is also directly on 15th Avenue West, in an industrial area, with high traffic volumes. Although it is possible for slight increases in the noise levels outside the building, light rail operations are not predicted to affect the interior operations at this building given the building's locations and existing noise environment.

Prospect Street Station/Central Interbay Alternative (SIB-3)

Alternative SIB-3 would connect only to Alternative DT-2 in the Downtown Segment, and to Preferred Alternative IBB-1a, Preferred Alternative IBB-2a*, and Preferred Option IBB-2b* in the Interbay/Ballard Segment. It is the only alternative with no severe noise impacts. It would have moderate noise impacts along 13th Avenue West, 14th Avenue West, and 15th Avenue West near West Boston and West Newton streets. Alternative SIB-3 would also have moderate noise impacts near West Dravus Street at the connection to the Interbay/Ballard Segment. Under this alternative, the speed of the light rail would be slightly higher than under Preferred Alternative SIB-1 due to track curvature and station location. As a result, Alternative SIB-3 would have additional noise impacts along 20th Avenue West closer to West Dravus Street and would have noise impacts at the multi-family buildings along 17th Avenue West, which accounts for the majority of noise impacts under this alternative.

No light rail noise impacts are predicted at the Kinnear Park or the Southwest Queen Anne Greenbelt. Alternative SIB-3 does not have any curves with a radius of less than 1,250 feet. Alternative SIB-3 has one crossover along Elliott Avenue West, just north of the tunnel portals, which contributes to noise levels from transit operations.

There are no Category 1 noise impacts under Alternative SIB-3.

*Interbay/Ballard Segment*

Figures displaying the locations of noise impacts and tables with detailed noise analysis information are provided in Attachments N.3D and N.3F.

The Interbay/Ballard Segment includes the area between West Dravus Street (west of 17th Avenue West) and West Barrett Street (east of 17th Avenue West) in Interbay to Northwest 58th Street in Ballard.

Noise impacts for the Interbay/Ballard Segment alternatives are shown in Table 6-6 and on Figure 6-5. Preferred Alternative IBB-2a* and Preferred Option IBB-2b* would not have any noise impacts in the Interbay/Ballard Segment because the alignment transitions to a retained cut segment before going into the tunnel and is shielded from the nearby multi-family buildings.

**Table 6-6. Summary of Noise Impacts by Alternative in the Interbay/Ballard Segment**

| Alternative | Category 1 Noise Impacts [a] | Category 2 Moderate Noise Impacts | Category 2 Severe Noise Impacts | Category 3 Noise Impacts | Total Noise Impacts |
|---|---|---|---|---|---|
| Preferred Elevated 14th Avenue (IBB-1a) | 0 | 214 to 237 | 132 to 164 | 0 | 369 to 378 |
| Elevated 14th Avenue Alignment Option (from Prospect Street Station/15th Avenue) (IBB-1b) | 1 | 531 | 173 | 0 | 705 |
| Preferred Tunnel 14th Avenue (IBB-2a)* | 0 | 0 | 0 | 0 | 0 |
| Preferred Tunnel 15th Avenue Station Option (IBB-2b)* | 0 | 0 | 0 | 0 | 0 |
| Elevated 15th Avenue (IBB-3) | 0 | 267 | 89 | 0 | 356 |

[a] Exterior noise impacts and interior noise levels are predicted to meet operational requirements of the business.

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

Notes:

The numbers presented are the number of units, counted by individual residences, including individual units of multi-family structures, and number of structures for other uses, like schools, churches, and parks. Category 2 parcels are evaluated with the 24-hour Ldn and Category 1 and 3 are evaluated with the peak hour Leq.

Ranges reflect differences from connecting to different alternatives in adjacent segments. The total impacts are based on individual alternatives and connection options and not the high and low of each impact type shown in the table.


Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Railroad
- Stream
- Park
- Area of Noise Impact

0 800 1,600 Feet N

FIGURE 6-5
**Noise Impacts (before mitigation)**
Ballard Link Extension - Interbay/Ballard Segment

*West Seattle and Ballard Link Extensions*

There was only one Category 1 sensitive receiver for the Interbay/Ballard Segment, the Seattle Film Institute at 3210 16th Avenue West. This facility is just west of 15th Avenue West along the ramp for southbound traffic from 15th Avenue West to access West Dravus Street. This building would only be affected by Option IBB-1b.

Preferred Elevated 14th Avenue Alternative (IBB-1a)

The total severe and moderate impacts vary depending on the connection option with the South Interbay Segment, the change in track elevation, location of crossovers, and the wider track separation required to accommodate light rail storage tracks (pocket tracks) proposed for just north of the Interbay Station. All severe noise impacts are along 13th and 14th avenues West and on West Emerson Street. When connecting to Alternative SIB-3 in the South Interbay Segment, several moderate impacts would become severe impacts along West Ruffner Street and 14th Avenue West. Other noise impacts under Preferred Alternative IBB-1a would remain the same regardless of the South Interbay Segment alternative selected, with mostly moderate noise impacts. No impact was identified at the Saint Alphonsus Church and Parish School due to limited speeds and use on the trail tracks north of the station.

No FTA Category 1 uses would be affected by Preferred Alternative IBB-1a.

Following Sound Transit policy and the discussion in Section 4.1.1.5, the Interbay/Ballard Segment was reviewed for curves with the potential for wheel squeal. Under Preferred Alternative IBB-1a, there would be a curve with a radius of 650 feet just north of the West Dravus Street overpass and an additional 650-foot radius curve just north of Interbay Station. Preferred Alternative IBB-1a would have double crossovers on 14th Avenue Northwest, between 51st and 52nd streets, which can increase noise from transit operations.

Elevated 14th Avenue Alignment Option (from Prospect Street Station/15th Avenue) (IBB-1b)

Option IBB-1b would have the most noise impacts and the most severe noise impacts. The higher total number of noise impacts is due to being along 15th Avenue West at the south end of the segment, where there is a high density of single- and multi-family residences. Severe noise impacts would occur along 14th Avenue West, West Emerson Street, West Ruffner Street, and 15th Avenue West. North of Salmon Bay the noise impacts would be the same as Preferred Alternative IBB-1a.

There was only one Category 1 sensitive receiver for the Interbay/Ballard Segment, the Seattle Film Institute. This building is in an area with high levels of existing background noise.

Noise levels at the exterior of the building are predicted to meet or exceed the Category 1 criteria; however, noise from the light rail operations are not predicted to affect the interior operations at this building.

Option IBB-1b has no curves with a radius of less than 1,250 feet. Under Option IBB-1b that connects to Alternative SIB-2, there are two crossovers providing access to a 420-foot storage track just north of the Interbay Station near Thorndyke Avenue West and 17th Avenue West, which may increase noise from transit operations in this area.

Preferred Tunnel 14th Avenue Alternative (IBB-2a)*

Under Preferred Alternative IBB-2a*, there were no noise impacts identified. North of the Interbay station the alignment would transition to a retained cut to the tunnel, and all noise sensitive properties would be below the criteria. There are no FTA Category 1 land uses, or crossovers affecting any noise sensitive properties under Preferred Alternative IBB-2a*. This alternative would have a curve with a radius of 650 feet just north of the West Dravus Street overpass.

Preferred Tunnel 15th Avenue Station Option (IBB-2b)*

Noise related to light rail operations under Preferred Option IBB-2b* is the same as described under Preferred Alternative IBB-2a*, including the locations of curves and crossovers.

Elevated 15th Avenue Alternative (IBB-3)

Alternative IBB-3 would have slightly more moderate noise impacts then Preferred Alternative IBB-1a; however, it would have a lower number of severe noise impacts. The reduced number of severe noise impacts is due, in part, to the alignment transitioning to the west side of 15th Avenue West, away from the dense residential area east of 15th Avenue West. Severe impacts were identified on the south side of the ship canal at one multi-family building and two single-family residences. North of the Ship Canal, the Elevated 15th Avenue Alternative would have severe noise impacts at multi-family residences on Northwest 51st and 52nd streets, with all other noise impacts in the moderate category. Lower total number of impacts are predicted north of Salmon Bay due to the increased number of commercial uses along the 15th Avenue Northwest when compared to 14th Avenue Northwest, where there are more residential land uses. There would be no noise impact at Fire Station 18 due to the slow speed and higher ambient noise levels. No impact was identified at the Saint Alphonsus Church and Parish School due to limited speeds and use on the trail tracks north of the station.

There are no FTA Category 1 uses affected by Alternative IBB-3.

Alternative IBB-3 would have a 900-foot radius curve along 15th Avenue Northwest, between 52nd and 53rd streets, along with two crossovers providing access to a 420-foot storage track just north of the Interbay Station along 15th Avenue West.

#### 6.1.2.2 Traffic Noise Impact Analysis

The project was reviewed for potential traffic noise impacts and a summary of the results follows. This section provides a general discussion of project-related areas considered for traffic noise impacts in the Ballard Link Extension project corridors.

***No Build Alternative***

Under the No Build Alternative, traffic noise levels would continue to be dominated by major and minor arterial roadways, including traffic on major roadways in the SODO, Chinatown-International District, Downtown, South Interbay, and Interbay/Ballard segments. Major roadways in those areas where the Ballard Link Extension would be above grade include Elliott Avenue West, 15th Avenue West, West Dravus Street, West Nickerson Street, and Northwest Market Street.

***Build Alternatives***

There are no major traffic revisions planned as part of the Ballard Link Extension; therefore, no traffic noise analysis was completed.

## 6.2 Construction Noise Impacts

Construction noise was analyzed using the methodology established in the FTA Guidance Manual (2018) to document predicted noise impacts from the project's construction. This analysis was conducted for a variety of different construction activities that are anticipated to generate the highest sound levels, require nighttime construction, or are expected to require several months to complete.

An assessment of construction noise levels was performed with noise metrics that can be compared with the city of Seattle construction noise ordinance. The Seattle Municipal Code Chapter 25.08 was used for the criteria for construction noise level limits, along with noise allowances from the Seattle Noise Ordinance for construction activities.

The following activities are expected to produce the highest sound levels, would be done during nighttime hours, or require several months to complete:

- Elevated Light Rail Construction.
- Retained Cut Construction.
- Tunneling.
- Cut-and-Cover Station Construction.
- Bridge Construction Over Water Crossings.

Table 6-7 lists the types of construction equipment used in the analysis with representative sound levels established in the FTA Guidance Manual (2018), which are Leq sound levels 50 feet from the equipment. Construction sound levels were predicted using the methodology detailed in Section 7 of the FTA Guidance Manual (2018), which analyzes the two loudest pieces of equipment expected for a particular activity.

### Table 6-7. Construction Equipment Sound Levels

| Construction Equipment | Sound Level at 50 feet Leq (in dBA) |
|---|---|
| Air Compressor | 80 |
| Backhoe | 80 |
| Concrete Mixer | 85 |
| Concrete Pump | 82 |
| Crane | 83 |
| Excavator | 81 |
| Generator | 82 |
| Impact Pile Driver | 101 |
| Jackhammer | 88 |
| Loader | 80 |
| Pneumatic Tools | 85 |
| Roller | 85 |
| Truck | 84 |

Source: FTA 2018.

Predicted sound levels from elevated light rail construction, retained cut construction, tunneling, cut-and-cover station construction, and bridge construction over water crossings are listed in Table 6-8.

**Table 6-8. Predicted Construction Sound Levels**

| Construction Activity | Construction Equipment | Sound Level at 50 feet Leq (dBA) [a] |
|---|---|---|
| Elevated Light Rail Construction | Cranes, excavators, concrete pumps, pneumatic tools | 85 to 87 |
| Retained Cut Construction | Cranes, backhoes, jackhammers, excavators, pneumatic tools, concrete mixers | 84 to 89 |
| At-Grade Construction | Excavators, backhoes, concrete mixers, concrete pumps, haul trucks, loaders | 86 to 87 |
| Ground Improvements | Generators, air compressors, loaders, haul trucks, concrete mixers | 80 to 87 |
| Tunneling | Excavators, backhoes, haul trucks, loaders | 84 to 86 |
| Cut-and-Cover Station Construction | Excavators, backhoes, haul trucks, loaders, vibratory rollers | 84 to 88 |
| Bridge Construction Over Water Crossings | Cranes, pile drivers, concrete mixer, concrete pumps | 87 to 101 |

Source: FTA 2018.

[a] The sound levels show the two loudest pieces of equipment operating at the same time.

## 6.2.1 Construction Noise Sources

### 6.2.1.1 Elevated Light Rail Construction

Alternatives requiring construction of elevated light rail structures include the Duwamish, Delridge, and West Seattle Junction segments in West Seattle Link Extension and South Interbay and Ballard/Interbay segments in the Ballard Link Extension.

Demolition of existing structures and relocation of utilities would likely be required in several of these work areas before beginning heavy civil construction. Once heavy civil construction begins, construction activities may include the following:

- Footings and Drilled Shafts – Elevated guideway construction would likely begin with preparation work to construct foundations that may consist of shallow spread footings or drilled shafts. Excavators and cranes would likely be used during this work.
- Concrete Guideway Columns and Piers – Following the foundations, concrete guideway columns and piers that support the guideway could be constructed. Equipment anticipated to be used during this work could include cranes and concrete pumps.
- Elevated Guideway and Falsework – The elevated guideway superstructure could be constructed of either cast-in-place or pre-cast reinforced concrete. Falsework would be required where cast-in-place construction is used to support the superstructure while the concrete is poured and cures. Loud equipment anticipated to be used could include cranes and pneumatic tools.
- Elevated Station Construction – Construction of the elevated stations would be similar to construction of the guideway but include construction of station platforms and include the use of cranes and pneumatic tools.

The loudest sources of noise would be from cranes and pneumatic tools. Sounds levels from elevated light rail construction may exceed 87 dBA at 50 feet from construction activities.

#### 6.2.1.2 Retained Cut Construction

Alternatives with areas requiring retained cut construction include the Duwamish, Delridge, and West Seattle Junction segments for the West Seattle Link Extension and the South Interbay segment for the Ballard Link Extension. Construction activities may include the following:

- Demolition of Existing Structures – Retained cut construction may involve demolition of existing structures and clearing and grading. Existing structures would need to be removed before excavation. Demolition may include the use of cranes and jackhammers.
- Excavation – After any existing structures would be removed, excavation activities could begin. Equipment used during excavation may include excavators and backhoes.
- Construction of Guideways – Excavation may be necessary to construct the subgrade, track slabs, drainage structures, and below-grade light rail infrastructure. The work may include the use of cranes and pneumatic tools.
- Construction of Retaining Walls – In some locations, subsurface anchors, or tiebacks may be required to support the retaining walls. Dewatering may also be necessary in some locations. Retaining wall construction could include the use of cranes and concrete mixers.

The loudest sources of construction noise would be from jackhammers and other demolition equipment, as well as concrete mixers, cranes and pneumatic tools. Sound levels from retained cut construction could be over 89 dBA at 50 feet from construction activities.

#### 6.2.1.3 At-Grade Construction

At-grade construction is anticipated to occur primarily within the SODO and Chinatown-International District segments. Preferred Alternative SODO-1a and Option SODO-1b include construction of the at-grade SODO Station. Construction activities may include the following:

- Shallow Excavations – Construction of at-grade guideways would be similar to typical road construction and would involve shallow excavations to construct the subgrade, track, and station platform slabs. Equipment used during this process may include haul trucks, loaders, excavators, and backhoes.
- Concrete Pours – After excavation concrete would be poured to form the station platform slabs and may include concrete mixers, and concrete pumps.

The loudest noise sources would be concrete mixers and haul trucks. Sound levels from at-grade construction could be over 87 dBA at 50 feet from construction activities.

#### 6.2.1.4 Ground Improvements

Ground improvements may be needed to address weak soils in order to build on them and may be needed throughout the project corridor. Ground improvements may be necessary in the Duwamish, SODO, and Chinatown-International District segments, which are predominantly fill material on top of tide flats.

Ground improvements may include jet grouting, ground freezing, rock displacement, or a combination of these methods. Construction equipment may include generators, air compressors, loaders, haul trucks, and concrete mixers. Construction noise from ground improvements could be over 87 dBA at 50 feet from the construction activities. The loudest sound sources would be concrete mixers and haul trucks.

#### 6.2.1.5 Tunneling

Alternatives with areas requiring mined tunnel construction would include the Delridge and West Seattle Junction segments in the West Seattle Link Extension and the Chinatown-International District, Downtown, South Interbay, and Interbay/Ballard segments in Ballard Link Extension. Although tunneling may occur under several noise-sensitive properties throughout the project corridor, above-grade construction, which would be concentrated near the tunnel portals and underground station locations are the primary locations for potential construction noise impacts. Construction activities near the tunnel portals may include the following:

- Portal and Shaft Excavation – Tunnel construction requires tunnel portals at the beginning and end of each tunnel for launch and retrieval of equipment. On hillsides, portals may be dug directly into the hillside, while in flatter areas, an access shaft or pit would be excavated from the surface. Soil stabilization would be necessary to support excavation of access shafts or pits. At several locations these pits would also serve as below-grade stations after tunneling has been completed. Construction of portals or shafts would likely require the use of excavators and backhoes.
- Transporting Spoils – Once tunneling is underway, spoils would be transported back to the tunnel portals and hauled off the site. Spoils would likely be loaded into trucks, or depending on the portal location, by barge or train for removal from the site. Transporting spoils would likely require trucks and loaders. Ventilation fans would also run continuously to supply fresh air to construction crews working inside the tunnel.

The loudest construction sound sources would be excavators and haul trucks. Also, ventilation fans would likely run continuously to provide fresh air to construction crews working inside the tunnel. Sound levels near the tunnel portals may be over 86 dBA at 50 feet from construction activities.

#### 6.2.1.6 Cut-and-Cover Construction

Cut-and-cover construction would be used for below-grade station construction, except for some stations in the Downtown Segment, which could be mined. Construction activities during cut-and-cover work may include the following:

- Excavation – Cut-and-cover construction involves excavating from the surface, similar to retained cut construction. Excavation may include the use of excavators and backhoes.
- Transporting Spoils – As excavation is underway the excavated materials would likely need to be removed from the site. Removal of excavated materials would likely require the use of trucks and loaders.
- Backfill – Cut-and-cover construction also requires backfilling with imported fill or suitable excavated material after construction of the lid or station roof. This may require the use of trucks and rollers.

The loudest sources of noise would include haul trucks and vibratory rollers. Sound levels may be over 88 dBA at 50 feet from construction activities.

#### 6.2.1.7 Bridge Construction Over Water Crossings

Alternatives with areas requiring bridge construction include the Duwamish Segment to cross the Duwamish Waterway in the West Seattle Link Extension and in the Interbay/Ballard Segment to cross Salmon Bay in the Ballard Link Extension. Bridge construction may include the following construction activities:

- Construct Temporary Work Trestles, Piles and Install Cofferdams – Temporary work trestles may need to be constructed to support material deliveries and operation of heavy equipment. Construction of temporary work trestles would be accomplished by driving or vibrating steel-pipe piles into the ground and constructing bents, framing, and decking. In-water bridge foundations may require using sheet-pile cofferdams to control groundwater and would be driven or vibrated into place. Piles may also be vibrated or drilled directly into the water for one guideway column in the Duwamish Segment for Preferred Alternative DUW-1a. Temporary work trestle and cofferdam construction may require impact pile drivers and cranes.
- Construct Bridge Segments - Bridge superstructures would follow construction of the bridge foundations. Cranes and concrete mixers would likely be used during construction of the bridge segments.

The loudest type of construction equipment would be pile drivers. During pile installation sound levels may exceed 101 dBA at 50 feet from pile-driving. Other construction activities would likely be 87 dBA at 50 feet.

### 6.2.2 West Seattle Link Extension

#### 6.2.2.1 No Build Alternative

Under the No Build Alternative, construction would not take place and no impacts from construction noise would occur.

#### 6.2.2.2 Build Alternatives

Residential neighborhoods are near the west end of the Duwamish Segment, within the Delridge Segment and the West Seattle Junction Segment. Noise impacts from construction activities are most likely to occur at residential properties within these segments. The SODO and Duwamish segments are mostly comprised of industrial and commercial properties.

***SODO Segment***

The SODO Segment is between South Forest Street and South Holgate Street and is within an industrial district. The closest residential properties are nearly 0.5 mile away and east of Interstate 5. Therefore, no construction noise impacts are expected.

***Duwamish Segment***

Properties within the Duwamish Segment are primarily industrial. There is a residential district west of West Marginal Way Southwest and south of the West Seattle Bridge in Pigeon Point.

All three alternatives would include construction of elevated guideway from the SODO Segment and a bridge over the Duwamish Waterway. Preferred Alternative DUW-1a and Option DUW-1b would cross the Duwamish Waterway on a new bridge south of the West Seattle Bridge and transition into a retained cut at the north side of Pigeon Point before connecting to the Delridge Segment. Alternative DUW-2 would construct a new bridge to the north of the West Seattle Bridge and remain elevated until connecting to the Delridge Segment.

The closest residential properties are approximately 100 feet from Preferred Alternative DUW-1a and Option DUW-1b. These properties would be near the transition from elevated structures to retained cut and would experience construction noise from both types of construction. Sound levels from elevated construction are expected to be up to 81 dBA and up to 83 dBA during retained cut construction. These activities are expected to exceed the city’s construction noise limits and result in noise impacts at nearby residential properties around Pigeon Point.

Alternative DUW-2 is approximately 500 feet from residential properties and does not require retained cut construction. Because Alternative DUW-2 is farther from residential properties than the other alternatives, it is expected to result in the least noise impacts.

Bridge construction would likely take place in industrial districts on the shore of the Duwamish Waterway and Harbor Island, or in the water. The loudest sound levels would likely be generated from pile-driving during construction of the temporary work trestle, piles, and cofferdams. Sound levels during pile-driving are expected to exceed 101 dB at 50 feet from the work. Nearby noise sensitive properties may experience sound levels up to 78 dBA during pile-driving. Construction of the bridge may take 3 to 4 years to complete.

Nighttime construction may be required at locations along the elevated guideway where it crosses over roadways, such as the West Seattle Bridge and West Marginal Way Southwest.

### *Delridge Segment*

The Delridge Segment is mostly made up of residential districts. Industrial districts are north of Southwest Andover Street and a commercial district is between Southwest Andover Street and residences south of Southwest Yancy Street.

All of the Delridge Segment alternatives would include elevated guideway between the Duwamish Segment and the station. The location of the station varies between alternatives and could be on Delridge Way Southwest between Southwest Andover Street and Southwest Dakota Street, between Southwest Dakota Street and Southwest Genesee Street, or north of Southwest Andover Street to the west of Delridge Way Southwest. Nighttime construction could be necessary in areas crossing over roadways.

West of the station the light rail would remain elevated to the West Seattle Junction Segment under Preferred Alternative DEL-1a, Option DEL-1b, Alternative DEL-3, and Alternative DEL-5. The alignment would enter a retained cut for Alternative DEL-6* near 32nd Avenue Southwest.

All alternatives would require guideway construction within 50 feet of residential properties. This may result in sound levels of up to 87 dBA and would likely exceed Seattle construction sound limits.

Tunnel construction would be necessary under Preferred Alternative DEL-2a*, Option DEL-2b*, and Alternative DEL-4*.Tunnel portals would be constructed at Southwest Genesee Street near 30th Avenue Southwest and may take up to 2 years to build. Tunneling would typically occur 20 to 24 hours per day, 6 to 7 days per week. Nighttime construction may include removing spoils from the site and material deliveries. Ventilation fans could be necessary to supply fresh air to construction crews working inside the tunnel and would likely operate continuously. Tunnel construction may last for 1 to 2 years.

Tunnel portals would be within a residential district and the closest residential properties would be approximately 50 feet away. Sound levels at these properties may by up to 86 dBA and exceed the city’s construction sound limits and result in noise impacts.

Construction of Alternative DEL-5 and Alternative DEL-6* may result in the least noise impacts at residential properties because a portion of the alignment would be within industrial and commercial districts and farther away from noise-sensitive properties than other alternatives.

### *West Seattle Junction Segment*

The West Seattle Junction Segment includes residential and commercial districts. Residential properties are throughout the segment and commercial properties are generally between Southwest Alaska Street and Southwest Edmunds Street.

Elevated guideway construction would be necessary to construct the Preferred Alternative WSJ-1, Preferred Alternative WSJ-2, and northern portion of Alternative WSJ-4*. The Avalon Station would be elevated under these three alternatives. Nighttime construction may be required when crossing over roadways. The elevated guideway may take 1 to 2 years to complete and the construction of Avalon Station may take 3 years.

Properties within residential districts would be within 50 feet of elevated construction under Preferred Alternatives WSJ-1 or WSJ-2. These properties would likely experience construction sound levels of up to 87 dBA which exceeds Seattle construction noise limits and would result in noise impacts.

The remaining four alternatives would include construction of a tunnel and underground Alaska Junction Station. Construction of the underground station would use cut-and-cover construction and take 4 to 6 years to build.

Because the tunnels in the West Seattle Junction Segment would be shorter, shallower tunnels than in other segments, the tunnel could be built using a tunnel boring machine or sequential excavation mining. Both tunneling methods would require ventilation fans on the surface to supply fresh air into the tunnel and would run continuously. Nighttime work would likely be necessary to remove spoils from the portal area. Tunneling may take 1 to 2 years to construct.

The tunnel options with tunnel portals closest to residential districts in the West Seattle Junction Segment would be Preferred Alternative WSJ-3a*, Preferred Option WSJ-3b*, and Alternative WSJ-5*. Residential districts would be approximately 50 feet from the tunnel portals and may experience sound levels up to 86 dBA. These sound levels would exceed the city's construction sound limits and would result in noise impacts.

Preferred Alternatives WSJ-1 and WSJ-2 may result in less impacts at noise-sensitive properties than other alternatives which require tunneling. Although tunneling would take place underground, night work at the tunnel portals may last several years, whereas elevated construction may only require night work when crossing over roadways and the overall construction duration may be less than construction of a below-grade station and tunnel.

### 6.2.3 Ballard Link Extension

#### 6.2.3.1 No Build Alternative

Under the No Build Alternative, construction would not take place and no impacts from construction noise would occur.

#### 6.2.3.2 Build Alternatives

Most noise-sensitive properties in the Ballard Link Extension would be in the north end of the Downtown Segment, South Interbay Segment, and Interbay/Ballard Segment. Construction in these areas would have the greatest potential for noise impacts at residential properties. The SODO, Chinatown-International District, and most of the Downtown segment alternatives would be mostly within commercial and industrial districts.

***SODO Segment***

The Ballard Link Extension SODO Segment is the same as described for the West Seattle Link Extension in Section 6.2.2.2, Build Alternatives.

The closest noise-sensitive properties are nearly 0.5 mile away, east of Interstate 5, and no noise impacts are predicted.

### *Chinatown-International District Segment*

Commercial and industrial districts are in the Chinatown-International District Segment. There are no residential districts near the segment and the closest residential district is south of South Dearborn Street on the east side of Interstate 5. Although there are no nearby residential districts near the segment there are mixed use properties with residences in commercial districts, such as Uwajimaya and the Publix Hotel. Residential use properties within commercial districts are treated the same as commercial properties within the city of Seattle.

All of the Build Alternatives would require construction of tunnels and the below-grade International District/Chinatown Station. However, the tunneling and station construction methods vary between alternatives.

Alternatives CID-1a* and CID-2a would use a cut-and-cover tunnel, whereas the other alternatives would use a tunnel boring machine. Alternatives CID-1a* and CID-2a would construct the International District/Chinatown Station using cut-and-cover construction and may take 4 to 6 years to complete. The diagonal station configuration for Alternative CID-2a would avoid cut-and-cover construction along 5th Avenue South, which could potentially reduce some construction noise for nearby noise sensitive properties. Option CID-1b* and Option CID-2b would construct the station using mining and may require 6 to 7 years to build.

Bored tunnel construction may require work 20 to 24 hours per day, 6 to 7 days per week. Although most tunneling activities would take place underground, spoils may be removed from the site at the tunnel portals during nighttime hours. In addition to removal of spoils, ventilation fans at tunnel portals, stations, and access areas may run 24 hours per day to supply fresh air into the tunnel. Sound levels near tunnel portals may be up to 86 dBA at a distance of 50 feet from the construction activities. These sound levels would exceed construction sound limits within the city of Seattle.

Options CID-1b* and CID-2b may result in less noise impacts than the shallow alternatives (Alternatives CID-1a* and CID-2a) because the International District/Chinatown Station would be constructed using mining and not cut-and-cover methods, which may minimize the amount of work that occurs above grade.

### *Downtown Segment*

Most of the properties in the Downtown Segment would be within commercial districts and consist mostly of commercial, high-rise residential, and mixed-use buildings. Noise within the city of Seattle at residential properties that are within commercial districts is treated the same as commercial properties.

Tunneling in the Downtown Segment would be constructed using a tunnel boring machine. Tunneling would likely take place 20 to 24 hours per day, 6 to 7 days per week. Spoils from tunneling would be transported to the tunnel portal for removal from the site. Removal of the spoils and material deliveries may take place at night. Ventilation fans may also run 24 hours per day at tunnel portals, stations, and access areas to supply fresh air into the tunnel.

Westlake Station would be a mined cavern with spoils from station construction likely removed at station entrances and require 6 to 7 years to complete. Cut-and-cover construction would be required on portions of 5th Avenue and Madison Street near the Midtown Station for Preferred Alternative DT-1 when connecting to all the Chinatown-International District Segment alternatives except Alternative CID-2a. This work would be near residential use properties, the Seattle Public Library-Central Library, and hotels within commercial districts. Properties within 70 feet of construction could experience sound levels above the daytime construction noise limits regulated by the City of Seattle during cut-and-cover construction, which would result in noise impacts at these properties. Mined station construction when connecting to Alternative CID-2a would have lower potential for noise impacts.

Alternative DT-2 would have station construction closer to hotels on Pine Street, which could experience some disruption. Alternative DT-2 may result in higher construction noise levels at nearby multi-family residential properties and hotels due to the shorter distance to station construction activities. Construction noise impacts are not expected for the Westlake Station, because it would be a mined station and there are no residential properties in close proximity to areas of surface construction.

The Denny, South Lake Union, and Seattle Center stations for both Downtown Segment alternatives would be built using cut-and-cover construction. Excavation of these stations would be completed before the arrival of the tunnel boring machine to allow the machine to be pulled through the cut-and-cover box and continue tunneling to the next station. Construction of these stations may take 4 to 6 years to complete. Cut-and-cover construction may result in sound levels of up to 87 dBA at nearby properties, which exceed the daytime construction limits regulated by the City of Seattle. This work would likely result in construction noise impacts at nearby residential properties.

Cut-and-cover construction of the Seattle Center Station for Preferred Alternative DT-1 would likely result in noise impacts at the Northwest Rooms at Seattle Center, which house several noise-sensitive spaces including K.E.X.P., the Vera Project, the SIFF Film Center, and the A/NT Art Gallery. The construction noise would also impact spaces in the north end of Seattle Center, including Seattle Repertory Theatre and Cornish Playhouse. Cut-and-cover construction of the Seattle Center Station for Alternative DT-2 could result in noise impacts at the Seattle Repertory Theatre and Cornish Playhouse. Most of these noise-sensitive spaces are on the perimeter of the building and face Republican Street. The loudest construction phase is expected to be near the beginning of construction during the cutting and removal of the existing street, which would likely include the use of impact equipment such as jackhammers or hoe rams. Construction noise would likely decrease during excavation as work begins to take place within the excavated area.

#### *South Interbay Segment*

Properties within the South Interbay Segment are primarily industrial and residential. Most residential properties are to the east of 15th Avenue West and Elliott Way West on Queen Anne Hill. Other residential properties are west of 15th Avenue West in Magnolia neighborhood.

Tunneling and portal construction would be necessary under all three alternatives. Preferred Alternative SIB-1 and Alternative SIB-2 would include construction of a tunnel portal between 5th Avenue West and 3rd Avenue West on West Republican Street. Part of this portal would be in a residential district and next to residential districts to the north. Portal construction may result in sound levels of up to 84 dBA at nearby residential properties, which exceed the city’s construction sound limits at would likely result in noise impacts.

Alternative SIB-3 would have a longer tunnel with a tunnel portal near West Prospect Street. The tunnel portal would be within an industrial district, but next to residences on the hillside east of the portal area. Construction of the tunnel portals may take up to 2 years under all three alternatives.

Retained cut construction may be required near the Magnolia Bridge under Alternatives SIB-2 and SIB-3. Construction would happen within the Southwest Queen Anne Greenbelt, which is near a residential district and may require 1 year to complete. The closest residences would be east of the Southwest Queen Anne Greenbelt on top of Queen Anne. Preferred Alternative SIB-1 would not include retained cut construction.

Much of the construction in the South Interbay Segment would include elevated light rail construction requiring approximately 1 to 2 years to complete. Unlike Preferred Alternative SIB-1 and Alternative SIB-2 that would immediately transition from the tunnel west of 5th Avenue West to elevated guideway, Alternative SIB-3 would remain in a tunnel or retained cut until approximately West Blaine Street and would include the least amount of elevated guideway construction. Nightwork would likely be required in areas where the elevated guideway crosses roadways, such as over 15th Avenue West, Elliott Avenue West, the West Galer Street Flyover, and Magnolia Bridge.

It is likely that Preferred Alternative SIB-1 would result in the least noise impacts at noise-sensitive properties because the alignment would be typically farther way from residences than the other alternatives and does not require retained cut construction.

#### *Interbay/Ballard Segment*

Properties within the Interbay/Ballard Segment are mostly industrial and commercial. Single- and multi-family residences are near the north end of the segment and south of Salmon Bay to the west of 20th Avenue West and east of 15th Avenue West.

Preferred Alternative IBB-1a and Option IBB-1b would require construction within the residential district on the north end of Queen Anne Hill (southeast of the Ballard Bridge) and in the residential district north of Northwest Market Street in Ballard. Elevated construction in the residential district southeast of the Ballard Bridge may generate sound levels of up to 87 dBA at nearby residences. These levels would exceed the construction limits regulated by the Seattle noise ordinance and would result in noise impacts at nearby residential properties. Alternative IBB-3 would not require construction within a residential district and is expected to result in the least noise impacts at noise-sensitive receivers. Nighttime construction may occur at locations where the elevated guideway crosses roadways.

Preferred Alternative IBB-1a, Option IBB-1b, and Alternative IBB-3 would construct a bridge over Salmon Bay. Bridge construction may take 4 to 5 years to complete and would take place in industrial districts near the shore of Salmon Bay or within the waterway. During construction, the loudest sound levels would likely be produced by pile-driving related to the temporary work trestles and cofferdams. During impact pile-driving, sound levels may exceed 101 dB at 50 feet.

Preferred Alternative IBB-2a* and Preferred Option IBB-2b* would construct a tunnel between the Interbay and Ballard stations. Tunneling would require constructing portals at both ends of the tunnel to launch and retrieve a tunnel boring machine. Construction of the portals may take up to 2 years to complete. Preferred Alternative IBB-2a* would likely result in more noise impacts than Preferred Option IBB-2b* because the north portal is near a residential district. Sound levels in this residential area may be up to 84 dBA during the construction of the portal. These levels would exceed the permissible levels governed by the Seattle noise code and would result in noise impacts at nearby residential properties.

Tunnel construction typically occurs between 20 and 24 hours per day, 6 to 7 days per week. Transportation of the spoils and material deliveries may take place at the tunnel portals during nighttime hours. Ventilation fans may also run for 24 hours a day at tunnel portals, stations, and access areas to supply fresh air to construction crews. Tunnel construction is anticipated to take 2 to 2.5 years to complete. Tail tracks and the Ballard Station associated with the tunnel alternatives would be built using cut-and-cover techniques and take 4 to 6 years to complete. Cut-and-cover construction could result in sound levels up to 88 dBA at the residential zone north of the Preferred Alternative IBB-2a*. These levels would exceed the limits specified by the Seattle noise ordinance and would result in noise impacts at nearby residences.

Noise generated by tunneling is expected to be similar in areas near Interbay Station under both tunneling alternatives.

## 6.3 Operational 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 4.2, Vibration Assumptions and Methods. 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 trackwork.

### 6.3.1 West Seattle Link Extension

#### 6.3.1.1 No Build Alternative

The No Build Alternative would not result in any change to the existing vibration environment. There are no projected vibration impacts for the No Build Alternative.

#### 6.3.1.2 Build Alternatives

Tables 6-9 and 6-10 and Figures 6-6 and 6-7 summarize the number of groundborne noise and vibration impacts by alternative for segments where impacts were predicted. A discussion of key differences between alternatives follows. Attachment N.3E includes detailed maps that show the locations of sensitive receivers with projected impact and Attachment N.3G contains tables with the projected vibration and groundborne noise levels for all sensitive receivers.

***SODO Segment***

Based on the land use review, there were no FTA vibration-sensitive properties in the SODO Segment; therefore, no vibration impacts were identified.

***Duwamish Segment***

None of the alternatives in the Duwamish Segment are projected to have impacts. The alternatives would be mostly elevated, which reduces vibration levels by about 10 dB compared with at-grade track.

Alternative DUW-2 is near Harbor Island Machine Works, a precision manufacturing company with vibration-sensitive equipment, but the projected vibration level from light rail operations would not exceed the applicable limit.

***Delridge Segment***

Vibration impacts are shown on Table 6-9 and Figure 6-6. Groundborne noise impacts were not assessed for elevated alternatives. Preferred Alternative DEL-1 and Alternative DEL-3 would have the most impacts in the Delridge Segment. The impacts would be at the same multi-family building, the Golden Tee Apartments, near the intersection of Southwest Genesee Street and Southwest Avalon Way.

Option DEL-1b, Preferred Alternative DEL-2a*, Option DEL-2b*, and Alternative DEL-4* would not have any impacts. The sensitive receivers closest to these options would be displaced as part of the project and the projected vibration levels at the nearest remaining sensitive receivers would be below the criteria.

For Alternative DEL-5 and Alternative DEL-6*, there would be impacts at the residences closest to the alignment. Alternative DEL-6* would impact several single-family residences. Alternative DEL-5 would impact a multi-family building at 30th Avenue Southwest and Southwest Dakota Street with more dwelling units, and therefore would have more impacts.

### Table 6-9. Summary of Vibration Impacts by Alternative in the Delridge Segment

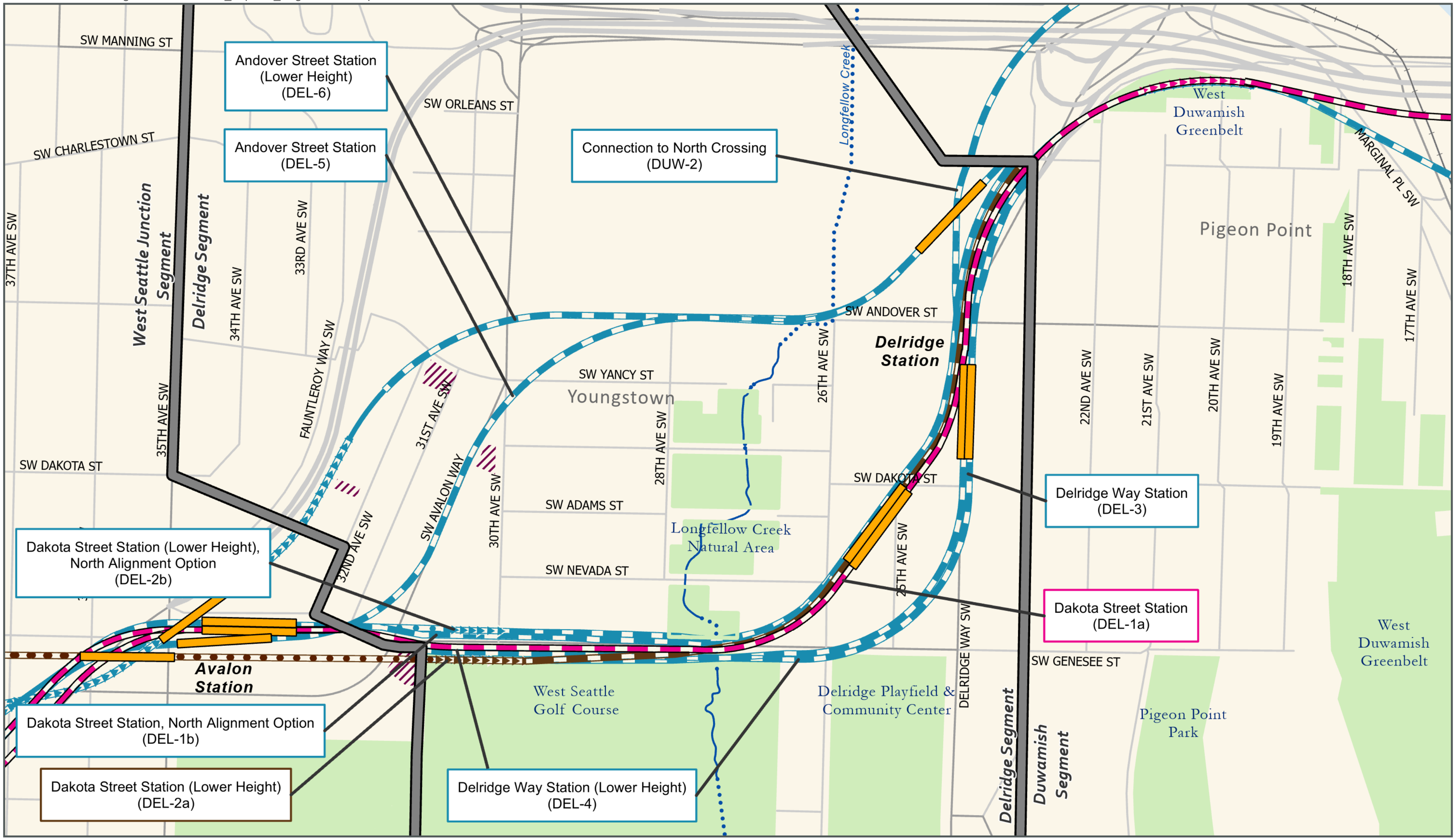
| Alternative | Category 1 Vibration Impacts | Category 2 Vibration Impacts | Category 3 Vibration Impacts | Total Vibration Impacts | Distance Range (feet) [a] | Range of exceedance (dB) [b] |
|---|---|---|---|---|---|---|
| Preferred Dakota Street Station (DEL-1a) | 0 | 12 | 0 | 12 | 44 | <1 |
| Dakota Street Station North Alignment Option (DEL-1b) | 0 | 0 | 0 | 0 | Not applicable | Not applicable |
| Preferred Dakota Street Station Lower Height (DEL-2a)* | 0 | 0 | 0 | 0 | Not applicable | Not applicable |
| Dakota Street Station Lower Height North Alignment Option (DEL-2b)* | 0 | 0 | 0 | 0 | Not applicable | Not applicable |
| Delridge Way Station (DEL-3) | 0 | 12 | 0 | 12 | 42 | <1 |
| Delridge Way Station Lower Height (DEL-4)* | 0 | 0 | 0 | 0 | Not applicable | Not applicable |
| Andover Street Station (DEL-5) | 0 | 9 | 0 | 9 | 27 | <1 |
| Andover Street Station Lower Height (DEL-6)* | 0 | 3 | 0 | 3 | 50 to 76 | 1 to 4 |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

Note: Numbers presented are individual residences (including units at multi-family structures) for FTA Category 2 land uses and number of structures for FTA Category 1 and 3 land uses.

[a] The slant distance between the near track and the façade of the sensitive receivers with impact, in feet. For alternatives with no impact, no distance is provided.

[b] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria. For alternatives with no impact, no value is provided.




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

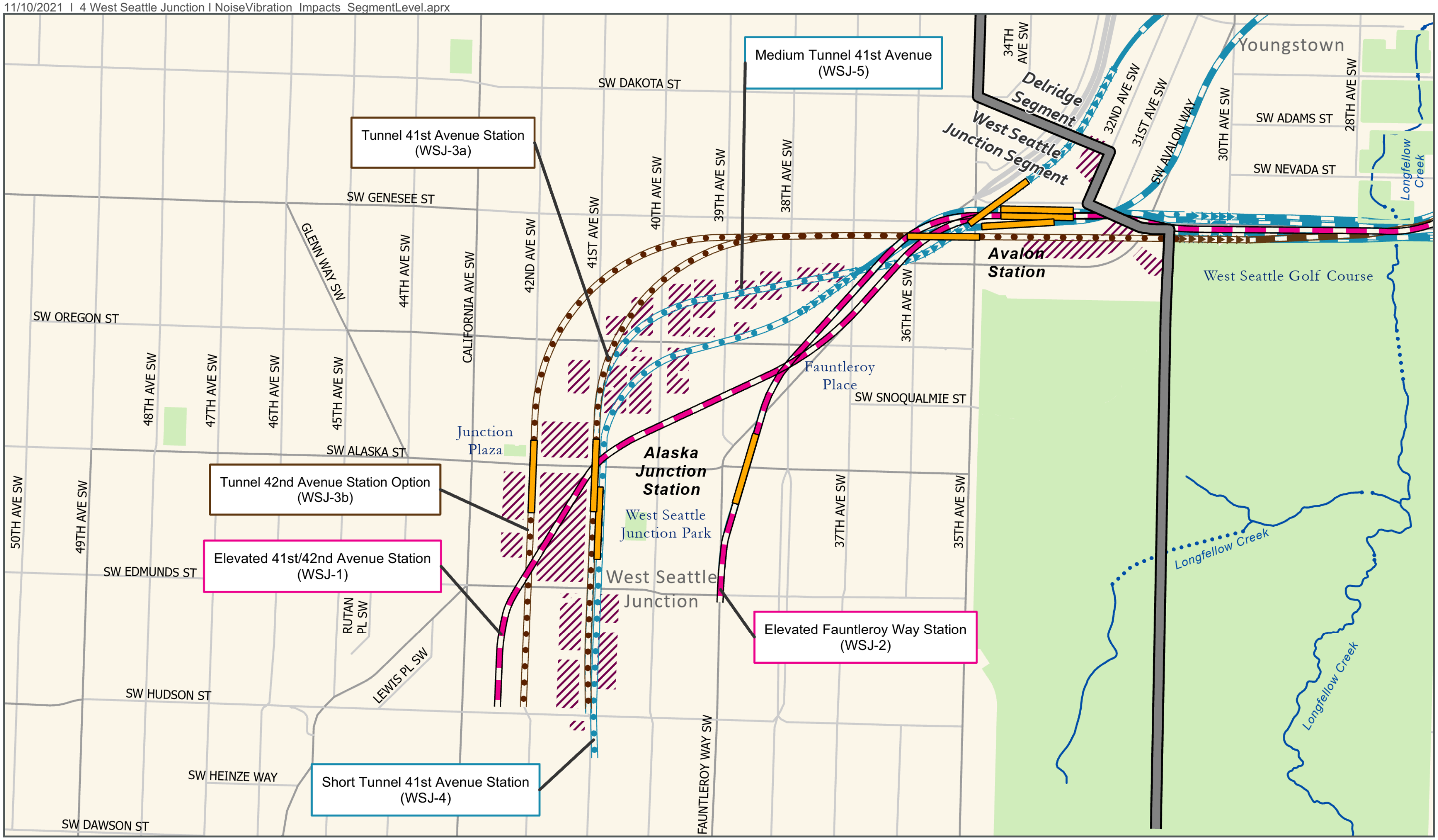
**Station**
- New

- Segment Line
- Railroad
- Stream
- Piped Stream
- Park
- Area of Vibration or Groundborne Noise Impact

FIGURE 6-6
**Vibration Impacts (before mitigation)**
West Seattle Link Extension - Delridge Segment

*West Seattle and Ballard Link Extensions*

0 400 800 Feet
N




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Stream
- Piped Stream
- Park
- Area of Vibration or Groundborne Noise Impact

FIGURE 6-7
**Vibration Impacts (before mitigation)**
West Seattle Link Extension - West Seattle Junction Segment

*West Seattle and Ballard Link Extensions*

0 500 1,000 Feet
N

***West Seattle Junction Segment***

Groundborne noise and vibration impacts are shown on Table 6-10 and Figure 6-7. In the West Seattle Junction Segment, the tunnel alternatives would have more impacts than the elevated alternatives because the elevated structures would reduce vibration levels by about 10 dB. All of the impacts for the tunnel alternatives would be from groundborne noise.

Preferred Option WSJ-3b* would have the most impacts, which would be concentrated in multi-family buildings along 42nd Avenue Southwest near Southwest Alaska Street and east of Avalon Station along Southwest Avalon Way. Preferred Alternative WSJ-2 would have no impacts because of the vibration reduction provided by the elevated structure.

Preferred Alternative WSJ-1 would have impacts near a crossover north of the Alaska Junction Station but would have a low number of impacts overall because of the low density of residences near the crossover and the vibration reduction provided by the elevated structure.

For Preferred Alternative WSJ-3a*, groundborne noise impacts would occur where the tunnel becomes shallower east of the Avalon Station and near the crossover south of the Alaska Junction Station. Preferred Alternative WSJ-3a* would have impacts at fewer residential dwelling units when connecting to Option DEL-2b* compared to connecting with Preferred Alternative DEL-2a* because the tunnel would be deeper when connecting to Option DEL-2b*.

Preferred Option WSJ-3b* would have the most impacts, but the projected impacts are concentrated in a few multi-family buildings east of the Avalon Station and south of the Alaska Junction Station near a crossover.

Alternative WSJ-4* would have a lower number of impacts compared to Alternative WSJ-5*. Both alternatives would have impacts at the residences near crossover locations and where the tunnel is shallowest. Alternative WSJ-5* would have a greater number of projected impacts because the tunnel would be under a greater length of residential area.

## 6.3.2 Ballard Link Extension

### 6.3.2.1 No Build Alternative

The No Build Alternative would not result in any change to the existing vibration environment. There are no projected vibration impacts for the No Build Alternative.

### 6.3.2.2 Build Alternatives

The following sections summarize the number and location of groundborne noise and vibration impacts by alternative for segments where vibration impacts are predicted. A discussion of key differences between alternatives is provided. Attachment N.3E includes detailed maps that show the locations of sensitive receivers with projected impact, and Attachment N.3G contains tables with the projected vibration and groundborne noise levels for all sensitive receivers.

***SODO Segment***

Based on the land use review, there were no FTA vibration-sensitive properties in the SODO Segment; therefore, no vibration impacts were identified.

## Table 6-10. Summary of Groundborne Noise and Vibration Impacts by Alternative in the West Seattle Junction Segment

| Alternative | Category 1 Vibration or Groundborne Noise Impacts | Category 2 Vibration Impacts | Category 2 Groundborne Noise Impacts | Category 3 Vibration or Groundborne Noise Impacts | Total Vibration or Groundborne Noise Impacts | Distance Range (feet) [a] | Range of Exceedance (dB) [b] |
|---|---|---|---|---|---|---|---|
| Preferred Elevated 41st/42nd Avenue Station (WSJ-1) | 0 | 7 | Not applicable [c] | 0 | 7 | 120 to 186 | 1 to 2 |
| Preferred Elevated Fauntleroy Way Station (WSJ-2) | 0 | 0 | Not applicable [c] | 0 | 0 | Not applicable | Not applicable |
| Preferred Tunnel 41st Avenue Station (WSJ-3a)* | 0 | 0 | 24 to 199 | 0 | 24 to 199 | 64 to 130 | 0 to 6 |
| Preferred Tunnel 42nd Avenue Station Option (WSJ-3b)* | 0 | 0 | 269 to 430 | 0 | 269 to 430 | 64 to 95 | 0 to 7 |
| Short Tunnel 41st Avenue Station (WSJ-4)* | 0 | 0 | 153 | 0 | 153 | 55 to 106 | 0 to 10 |
| Medium Tunnel 41st Avenue Station (WSJ-5)* | 0 | 0 | 205 | 0 | 205 | 56 to 119 | 0 to 16 |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

Notes:

Numbers presented are individual residences (including units at multi-family structures) for FTA Category 2 land uses and number of structures for FTA Category 1 and 3 land uses.

Ranges reflect differences from connecting to different alternatives in adjacent segments.

[a] The slant distance between the near track and the façade of the sensitive receivers with impact, in feet. For alternatives with no impact, no distance is provided.

[b] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria. For alternatives with no impact, no distance is provided.

[c] Groundborne noise is not assessed for elevated alternatives.

### Chinatown-International District Segment

Table 6-11 and Figure 6-8 summarize the vibration and groundborne noise impacts for the Chinatown-International District Segment. Alternative CID-1a*, Option CID-1b*, and Option CID-2b would not result in any vibration impacts due to their deeper profile.

Alternative CID-2a would impact multi-family residential units east of 5th Avenue South when connecting to either Downtown Segment alternatives. The diagonal station configuration would have a greater number of impacts because it would pass closer to a greater number of dwelling units. When connecting to Alternative DT-2, Alternative CID-2a would have additional impacts at a multi-family residential property at South Washington Street and 5th Avenue South.

### Downtown Segment

Table 6-12 and Figure 6-9 summarize the vibration and groundborne noise impacts for the Downtown Segment. Preferred Alternative DT-1 would not impact any residential or institutional land uses. Alternative DT-2 would impact a multi-family building near the crossover west of the Seattle Center Station.

The projected levels for Category 1 and special-use sensitive receivers are presented in Table 6-13 for Preferred Alternative DT-1 and Table 6-14 for Alternative DT-2. Preferred Alternative DT-1 would impact the following Category 1 or special-use sensitive receivers: Seattle Repertory Theatre, the SIFF Film Center, the Vera Project, and K.E.X.P, which are all located in Seattle Center. Alternative DT-2 would impact two buildings on the University of Washington Medicine South Lake Union Campus.

**Table 6-11. Summary of Groundborne Noise and Vibration Impacts by Alternative in the Chinatown-International District Segment**

| Alternative | Category 1 Vibration or Groundborne Noise Impacts | Category 2 Vibration Impacts | Category 2 Groundborne Noise Impacts | Category 3 Vibration or Groundborne Noise Impacts | Total Vibration or Groundborne Noise Impacts | Distance Range (feet) [a] | Range of Exceedance (dB) [b] |
|---|---|---|---|---|---|---|---|
| 4th Avenue Shallow (CID-1a)* | 0 | 0 | 0 | 0 | 0 | Not applicable | Not applicable |
| 4th Avenue Deep Station Option (CID-1b)* | 0 | 0 | 0 | 0 | 0 | Not applicable | Not applicable |
| 5th Avenue Shallow (CID-2a) | 0 | 0 | 24 to 74 | 0 | 24 to 74 | 81 to 90 | 2 to 5 |
| 5th Avenue Deep Station Option (CID-2b) | 0 | 0 | 0 | 0 | 0 | Not applicable | Not applicable |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

Notes:

Numbers presented are individual residences (including units at multi-family structures) for FTA Category 2 land uses and number of structures for FTA Category 1 and 3 land uses.

Ranges reflect differences from connecting to different alternatives in adjacent segments. The total impacts are based on individual alternatives and connection options and not the high and low of each impact type shown in the table.

[a] The slant distance between the near track and the façade of the sensitive receivers with impact, in feet. For alternatives with no impact, no distance is provided.

[b] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria. For alternatives with no impact, no distance is provided.


Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New
- Existing

- Segment Line
- Existing Link Light Rail
- East Link Light Rail (Under Construction)
- Existing Streetcar
- Center City Connector Streetcar (Construction Paused)
- Railroad
- SODO Busway
- Proposed Overpass
- Park
- Area of Vibration or Groundborne Noise Impact

FIGURE 6-8
**Vibration Impacts (before mitigation)**
Ballard Link Extension - Chinatown-International District Segment

*West Seattle and Ballard Link Extensions*

0 700 1,400 Feet
N

## Table 6-12. Summary of Groundborne Noise and Vibration Impacts by Alternative in the Downtown Segment

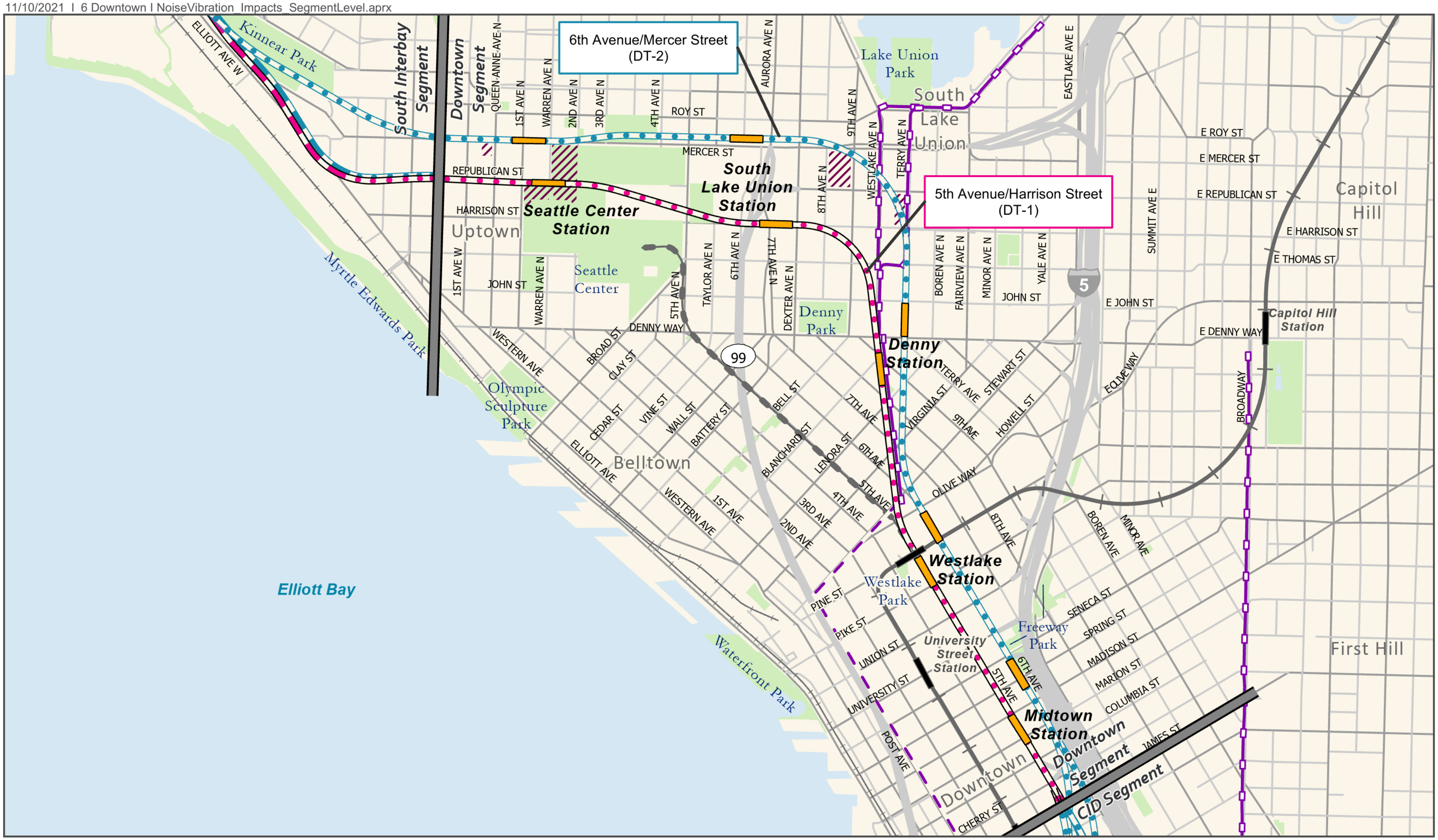
| Alternative | Category 1 Vibration or Groundborne Noise Impacts | Category 2 Vibration Impacts | Category 2 Groundborne Noise Impacts | Category 3 Vibration or Groundborne Noise Impacts | Total Vibration or Groundborne Noise Impacts | Distance Range (feet) [a] | Range of Exceedance (dB) [b] |
|---|---|---|---|---|---|---|---|
| Preferred 5th Avenue/Harrison Street (DT-1) | 4 | 0 | 0 | 0 | 4 | 94 to 121 | 7 to 13 |
| 6th Avenue/ Mercer Street (DT-2) | 2 | 0 | 34 | 0 | 36 | 87 to 115 | 3 to 11 |

Note: Numbers presented are individual residences (including units at multi-family structures) for FTA Category 2 land uses and number of structures for FTA Category 1 and 3 land uses.

[a] The slant distance between the near track and the façade of the sensitive receivers with impact, in feet. For alternatives with no impact, no distance is provided.

[b] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the Category 2 or Category 3 criteria. For alternatives with no impact, no distance is provided. Category 1 exceedances are provided in a separate table.

11/10/2021 I 6 Downtown I NoiseVibration_Impacts_SegmentLevel.aprx




Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New
- Existing

- Segment Line
- Existing Link Light Rail
- Monorail
- Existing Streetcar
- Center City Connector Streetcar (Construction Paused)
- Railroad
- Park

- Area of Vibration or Groundborne Noise Impact

FIGURE 6-9
**Vibration Impacts (before mitigation)**
Ballard Link Extension - Downtown Segment

*West Seattle and Ballard Link Extensions*

0 1,000 2,000 Feet
N

**Table 6-13. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the Preferred 5th Avenue Harrison Street Alternative (DT-1)**

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit, (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| 5th Avenue Theatre | 153 | 55 | 50 | 72 | 20 | 35 | Does not exceed |
| ACT Theatre | 679 | 55 | 31 | 72 | <0 | 35 | Does not exceed |
| Kineta/Biodesix/ Genewiz (219 Terry Avenue North) | 364 | 35 | 23 | 48 | Not applicable | Not applicable | Does not exceed |
| Seattle Children's Research Institute Center for Global Infectious Disease Research | 112 | 35 | 42 | 48 | Not applicable | Not applicable | Does not exceed |
| Institute For Systems Biology/Just Biotherapeutics (401 Terry Avenue North) | 685 | 35 | 27 | 54 | Not applicable | Not applicable | Does not exceed |
| Juno Therapeutics | 152 | 35 | 43 | 48 | Not applicable | Not applicable | Does not exceed |
| Allen Institute | 1129 | 35 | 35 | 48 | Not applicable | Not applicable | Does not exceed |
| University of Washington Medicine South Lake Union Campus | 483 | 35 | 24 to 29 | 48 | Not applicable | Not applicable | Does not exceed |
| Cascade Public Media (KCTS 9 television) | 354 | 45 | 38 | 65 | 1 | 25 | Does not exceed |
| Seattle Opera, KING FM | 347 | 45 | 41 | 65 | 6 | 25 | Does not exceed |

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit, (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| McCaw Hall and Seattle Center Studios, Main Theater | 278 | 45 | 55 | 65 | 0 | 25 | Does not exceed |
| Pacific Northwest Ballet (Phelps Center), Expo Hall | 205 | 45 | 47 | 72 | <0 | 35 | Does not exceed |
| Cornish Playhouse Theater | 167 | 45 | 54 | 72 | 28 | 35 | Does not exceed |
| Seattle Repertory Leo K Theatre | 121 | 30 | 70 | 72 | 48 | 35 | 13 |
| SIFF Film Center | 94 | 45 | 65 | 72 | 45 | 35 | 10 |
| The Vera Project Recording Booth | 102 | 30 | 72 | 72 | 38 | 30 | 8 |
| K.E.X.P. D.J. Booth | 111 | 55 | 66 | 65 | 32 | 25 | 7 |

[a] Predictions use building-specific measurement data and apply the data to the most sensitive location in the building. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the decibel reference level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

**Table 6-14. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the 6th Avenue/Mercer Street Alternative (DT-2)**

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| 5th Avenue Theatre | 225 | 55 | 43 | 72 | 10 | 35 | Does not exceed |
| ACT Theatre | 371 | 55 | 37 | 72 | <0 | 35 | Does not exceed |
| Kineta/Biodesix/ Genewiz (219 Terry Avenue North) | 118 | 45 | 45 | 48 | Not applicable | Not applicable | Does not exceed |
| Seattle Children's Research Institute Center for Global Infectious Disease Research | 364 | 45 | 32 | 48 | Not applicable | Not applicable | Does not exceed |
| Institute For Systems Biology/Just Biotherapeutics (401 Terry Avenue North) | 102 | 45 | 44 to 53 | 54 | Not applicable | Not applicable | Does not exceed |
| Juno Therapeutics | 857 | 45 | 32 | 48 | Not applicable | Not applicable | Does not exceed |
| Allen Institute | 221 | 45 | 41 | 48 | Not applicable | Not applicable | Does not exceed |
| University of Washington Medicine South Lake Union Campus | 87 | 45 | 54 to 59 | 48 | Not applicable | Not applicable | 6 to 11 |
| Cascade Public Media (KCTS 9 Television) | 213 | 45 | 40 | 65 | 3 | 25 | Does not exceed |
| Seattle Opera and KING FM | 152 | 45 | 47 | 65 | 13 | 25 | Does not exceed |
| McCaw Hall and Seattle Center Studios, Main Theater | 171 | 45 | 56 | 65 | 15 | 25 | Does not exceed |

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| Pacific Northwest Ballet (Phelps Center), Expo Hall | 177 | 45 | 46 | 72 | 11 | 35 | Does not exceed |
| Cornish Playhouse Theater | 175 | 45 | 44 | 72 | 17 | 35 | Does not exceed |
| Seattle Repertory Leo K Theatre | 191 | 45 | 53 | 72 | 28 | 35 | Does not exceed |
| SIFF Film Center | 512 | 45 | 32 | 72 | <0 | 35 | Does not exceed |
| The Vera Project Recording Booth | 508 | 45 | 36 | 72 | <0 | 30 | Does not exceed |
| K.E.X.P. D.J. Booth | 508 | 30 | 22 | 65 | <0 | 25 | Does not exceed |

[a] Predictions use building-specific measurement data and apply the data to the most sensitive location in the building. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the reference decibel level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

### *South Interbay Segment*

Table 6-15 and Figure 6-10 summarize the vibration and groundborne noise impacts for the South Interbay Segment. Preferred Alternative SIB-1 and Alternative SIB-2 would have the most impacts at residential dwelling units. There would be impacts at multi-family residences along West Republican Street near the tunnel portal. Near the elevated guideway after exiting the tunnel, there would be an impact at a residential building very close to the new alignment where the track structure curves onto Elliott Avenue West at West Republican Street and at residences near the crossover close to West Mercer Place.

### Table 6-15. Summary of Groundborne Noise and Vibration Impacts by Alternative in the South Interbay Segment

| Alternative | Category 1 Vibration or Ground-borne Noise Impacts | Category 2 Vibration Impacts | Category 2 Ground-borne Noise Impacts | Category 3 Vibration or Ground-borne Noise Impacts | Total Vibration or Ground-borne Noise Impacts | Distance Range (feet) [a] | Range of Exceedance (dB) [b] |
|---|---|---|---|---|---|---|---|
| Preferred Galer Street Station/Central Interbay (SIB-1) | 0 | 148 | 203 | 0 | 351 | 18 to 83 | 5 to 12 |
| Prospect Street Station/15th Avenue (SIB-2) | 1 | 148 | 203 | 0 | 352 | 17 to 82 | 0 to 12 |
| Prospect Street Station/Central Interbay (SIB-3) | 0 | 0 | 0 | 0 | 0 | Not applicable | Not applicable |

Note: Numbers presented are individual residences (including units at multi-family structures) for FTA Category 2 land uses and number of structures for FTA Category 1 and 3 land uses.

[a] The slant distance between the near track and the façade of the sensitive receivers with impact, in feet. For alternatives with no impact, no distance is provided.

[b] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria. For alternatives with no impact, no distance is provided.

Alternative SIB-2 would have vibration impacts at the same residential properties as Preferred Alternative SIB-1. There would also be a groundborne noise impact at Victory Studios, a Category 1 sensitive receiver on 15th Avenue West.

Alternative (SIB-3) would not have any vibration impacts.

The projected vibration and groundborne noise levels for the Category 1 sensitive receivers in the South Interbay Segment are shown in Tables 6-16 to 6-18. The building at 645 Elliott Avenue West houses recording studios and private laboratory space, but no impacts are projected. The predicted levels for this building do not include site-specific vibration propagation data because the property owner did not agree to a right-of-entry. However, a -5 dB building adjustment was included in the predicted level because the property manager described that the building was constructed to attenuate vibration from the adjacent freight tracks. Based on the description, a -5 dB adjustment is conservative, and the actual attenuation is likely to be more, particularly at higher frequencies. At Victory Studios, an impact would occur with Alternative SIB-2, where the track is within 100 feet of the building. More information on the measurement results and predicted levels for other locations in the building are included in Attachment N.3H.


Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- Tunnel
- At-Grade
- Retained Cut

**Station**
- New

- Segment Line
- Railroad
- Park
- Area of Vibration or Groundborne Noise Impact

0 800 1,600 Feet
N

FIGURE 6-10
**Vibration Impacts (before mitigation)**
Ballard Link Extension - South Interbay Segment

*West Seattle and Ballard Link Extensions*

### Table 6-16. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the Preferred Galer Street Station/Central Interbay Alternative (SIB-1)

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| iHeart Media/ Nexeli/ Luminex (645 Elliott Avenue) | 90 | 55 | 60 | 65 | 22 | 25 | Does not exceed |
| Victory Studios, Mad Animals Recording Booth | 831 | 55 | 32 | 65 | <0 | 25 | Does not exceed |

[a] Predictions use building-specific measurement data. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the reference decibel reference level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

### Table 6-17. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the South Interbay Segment Prospect Street Station/15th Avenue Alternative (SIB-2)

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| iHeart Media/ Nexelis/ Luminex (645 Elliott Avenue) | 91 | 55 | 60 | 65 | 21 | 25 | Does not exceed |
| Victory Studios, Mad Animals Recording Booth | 68 | 55 | 62 | 65 | 33 | 25 | 8 |

[a] Predictions use building-specific measurement data. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the reference decibel reference level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

### Table 6-18. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the Prospect Street Station/Central Interbay Alternative (SIB-3)

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| iHeart Media/ Nexelis/ Luminex (645 Elliott Avenue) | 299 | 55 | 55 | 65 | 4 | 25 | Does not exceed |
| Victory Studios, Mad Animals Recording Booth | 512 | 55 | 36 | 65 | <0 | 25 | Does not exceed |

[a] Predictions use building-specific measurement data. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the reference decibel level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

#### *Interbay/Ballard Segment*

Table 6-19 and Figure 6-11 summarize the vibration and groundborne noise impacts for the Interbay/Ballard Segment. Alternative IBB-3 would have no impacts. Option IBB-1b would have the most impacts. The impacts south of Salmon Bay would be at multi-family residences on 15th Avenue West near the south end of the Ballard Bridge. North of Salmon Bay, Option IBB-1b and Preferred Alternative IBB-1a would impact the same multi-family residences near Northwest 50th Street and 14th Avenue Northwest. Preferred Alternative IBB-2a* would impact one single-family residence near Northwest 54th Street that is near a crossover and the Seattle Maritime Academy on the north end of Salmon Bay. None of the impacts from the other alternatives would be caused by crossovers. Preferred Option IBB-2b* would have one impact at the Seattle Maritime Academy.

The projected vibration and groundborne noise levels for Category 1 sensitive receivers for the Interbay/Ballard Segment are shown in Tables 6-20 to 6-24. No vibration or groundborne noise impact is projected at these sensitive receivers with any alternative. Site-specific vibration propagation data were collected at the Seattle Film Institute and details of the measurement results are presented in Attachment N.3H. Existing vibration levels were measured at Specialty Vet Path, where they have had interference with vibration from another tenant in the building. The results of those measurements are also presented in Attachment N.3H. Bardahl Manufacturing and Vaupell Industrial Plastics did not respond to inquiries from the project team, and assumptions on the sensitivity of their equipment is based on information from their websites. The vibration limit for Friedman and Bruya, an environmental testing lab, is based on a phone interview where they described their vibration-sensitive equipment as turbo molecule pumps. No site-specific measurements were completed at Friedman and Bruya.

## Table 6-19. Summary of Groundborne Noise and Vibration Impacts by Alternative in the Interbay/Ballard Segment

| Alternative | Category 1 Vibration or Groundborne Noise Impacts | Category 2 Vibration Impacts | Category 2 Groundborne Noise Impacts | Category 3 Vibration or Groundborne Noise Impacts | Total Vibration or Groundborne Noise Impacts | Distance Range (feet) [a] | Range of Exceedance (dB) [b] |
|---|---|---|---|---|---|---|---|
| Preferred Elevated 14th Avenue (IBB-1a) | 0 | 35 to 39 | Not applicable [c] | 0 | 35 to 39 | 13 to 37 | 0 to 15 |
| Elevated 14th Avenue Alignment Option (IBB-1b) | 0 | 43 | Not applicable [c] | 0 | 43 | 17 to 28 | 4 to 11 |
| Preferred Tunnel 14th Avenue (IBB-2a)* | 0 | 0 | 1 | 1 | 2 | 97 to 183 | 0 to 7 |
| Preferred Tunnel 15th Avenue Station Option (IBB-2b)* | 0 | 0 | 0 | 1 | 1 | 139 | 3 |
| Elevated 15th Avenue (IBB-3) | 0 | 0 | Not applicable [c] | 0 | 0 | Not applicable | Not applicable |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

Notes:

Numbers presented are individual residences (including units at multi-family structures) for FTA Category 2 land uses and number of structures for FTA Category 1 and 3 land uses.

Ranges reflect differences from connecting to different alternatives in adjacent segments.

[a] The slant distance between the near track and the façade of the sensitive receivers with impact, in feet. For alternatives with no impact, no distance is provided.

[b] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria. For alternatives with no impact, no distance is provided.

[c] Groundborne noise is not assessed for elevated alternatives.


Source: City of Seattle, King County (2019, 2020, 2021).

**Alternatives**
- Preferred Alternative
- Preferred Alternative with Third-party Funding
- Other Alternatives

**Alternative Profile**
- Elevated
- At-Grade
- Tunnel
- Retained Cut

**Station**
- New

- Segment Line
- Railroad
- Stream
- Park
- Area of Vibration or Groundborne Noise Impact

FIGURE 6-11
**Vibration Impacts (before mitigation)**
Ballard Link Extension - Interbay/Ballard Segment

*West Seattle and Ballard Link Extensions*

0 800 1,600 Feet
N

### Table 6-20. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the Preferred Elevated 14th Avenue Alternative (IBB-1a)

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| Friedman and Bruya | 898 | 55 | 51 | 72 | Not applicable | Not applicable | Does not exceed |
| Seattle Film Institute, Edit Booth | 641 | 30 | 45 | 65 | <0 | 25 | Does not exceed |
| Bardahl Manufacturing | 192 | 55 | 55 | 72 | Not applicable | Not applicable | Does not exceed |

Note: Specialty Vet Path and Vaupell Industrial Plastics were not evaluated because they would be displaced by this alternative.

[a] Predictions use building-specific measurement data. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the reference decibel level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

### Table 6-21. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the Elevated 14th Avenue Alignment Option (from Prospect Street Station/15th Avenue) (IBB-1b)

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| Friedman and Bruya | 133 | 35 | 50 | 72 | Not applicable | Not applicable | Does not exceed |
| Seattle Film Institute, Edit Booth | 117 | 45 | 62 | 65 | 16 | 25 | Does not exceed |
| Specialty Vet Path | 304 | 55 | 57 | 66 | 66 | Not applicable | Does not exceed |
| Bardahl Manufacturing | 177 | 55 | 55 | 72 | 72 | Not applicable | Does not exceed |

Note: Vaupell Industrial Plastics was not evaluated because it would be displaced by this alternative.

[a] Predictions use building-specific measurement data. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the decibel reference level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

### Table 6-22. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the Preferred Tunnel 14th Avenue Alternative (IBB-2a)*

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| Friedman and Bruya | 913 | 30 | 46 | 72 | Not applicable | Not applicable | Does not exceed |
| Seattle Film Institute, Edit Booth | 626 | 30 | 46 | 65 | 1 | 25 | Does not exceed |
| Bardahl Manufacturing | 168 | 55 | 65 | 72 | Not applicable | Not applicable | Does not exceed |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

Note: Specialty Vet Path and Vaupell Industrial Plastics were not evaluated because they would be displaced by this alternative.

[a] Predictions use building-specific measurement data. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the decibel reference level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

### Table 6-23. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the Preferred Tunnel 15th Avenue Station Option (IBB-2b)*

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| Friedman and Bruya | 913 | 30 | 46 | 72 | Not applicable | Not applicable | Does not exceed |
| Seattle Film Institute, Edit Booth | 629 | 55 | 57 | 65 | 8 | 25 | Does not exceed |
| Bardahl Manufacturing | 257 | 55 | 56 | 72 | Not applicable | Not applicable | Does not exceed |
| Vaupell Industrial Plastics | 647 | 30 | 26 | 72 | Not applicable | Not applicable | Does not exceed |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

Note: Specialty Vet Path was not evaluated because it would be displaced by this alternative.

[a] Predictions use building-specific measurement data. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the decibel reference level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

### Table 6-24. Summary of Groundborne Noise and Vibration Predictions for Category 1 Land Uses and Special Buildings for the Elevated 15th Avenue Alternative (IBB-3)

| Sensitive Receiver [a] | Distance (feet) [b] | Speed (miles per hour) | Predicted Vibration (VdB) [c] | Vibration Limit (VdB) | Predicted Groundborne Noise (dBA) [d] | Groundborne Noise Limit (dBA) | Range of Exceedance (dB) [e] |
|---|---|---|---|---|---|---|---|
| Friedman and Bruya | 134 | 35 | 49 | 72 | Not applicable | Not applicable | Does not exceed |
| Seattle Film Institute, Edit Booth | 114 | 55 | 64 | 65 | 23 | 25 | Does not exceed |
| Specialty Vet Path [f] | 144 | 55 | 59 | 66 | Not applicable | Not applicable | Does not exceed |
| Bardahl Manufacturing | 333 | 30 | 45 | 72 | Not applicable | Not applicable | Does not exceed |
| Vaupell Industrial Plastics [f] | 720 | 30 | 44 | 72 | Not applicable | Not applicable | Does not exceed |

[a] Predictions use building-specific measurement data. Detailed data and prediction methodology are provided in Attachment N.3H.

[b] The slant distance between the near track and the façade of the sensitive receiver, in feet.

[c] Predicted maximum 1/3-octave band vibration level; decibels referenced to 1 micro inch per second.

[d] Groundborne noise limits do not apply to Category 1 spaces but do apply to Special Buildings. Groundborne noise levels may be less than zero if the predicted level is less than the decibel reference level of 20 micro Pascals.

[e] The decibel amount that the vibration (VdB) or groundborne noise (dBA) would exceed the applicable criteria.

[f] This sensitive receiver would be displaced by this alternative and therefore was not evaluated.

## 6.4 Construction Vibration Impacts

As discussed in Section 4.2.2, Construction Vibration Prediction Methods, construction vibration generally falls into the categories of tunneling activities and surface construction activities. The vibration from tunneling muck and support trains are compared to the FTA criteria for operations because this can be a relatively long-term activity. For surface construction activities which are temporary in nature, the construction vibration criteria from Section 3.2.3, Construction Vibration Criteria, are applied. The construction vibration criteria were developed to avoid potential damage risk to buildings, while the operational vibration criteria were developed to avoid annoyance for Category 2 and Category 3 sensitive receivers. Category 1 and special-use buildings are evaluated using the FTA criteria for operations for all construction activities, because exceedances of those limits may interfere with operations inside the building. The construction vibration criteria also apply to historic buildings, which may be particularly susceptible to construction damage. Construction vibration impacts specific to historic buildings were not assessed. Historic buildings should be taken into account when updating the construction vibration assessment during final design when more information on construction means and methods is known.

### 6.4.1 Tunneling Vibration Impacts

The three major sources of vibration from tunneling are the cutterhead operation, thrust jack retraction during concrete liner installation, and operation of the supply train. The range of vibration levels expected from the three activities and the relevant criteria are shown on Figures 4-7 to 4-9. As shown in the figures, the range of expected levels for all three activities would be below the operational criteria for annoyance for Category 2 (residential) land uses, and therefore would also be below the criteria for institutional land uses, which have a higher limit.

#### 6.4.1.1 West Seattle Link Extension Tunneling Vibration Impacts

There are no Category 1 or special-use buildings near tunnel alternatives in the West Seattle Link Extension study area. The expected vibration levels from tunneling would be below the operational criteria for annoyance for Category 2 (residential) and Category 3 (institutional) land uses. Therefore, there would be no vibration impact from tunneling in the West Seattle Link Extension study area. The predicted levels from tunneling activities relative to the Category 2 and Category 3 limits are shown on Figures 4-7 through 4-9. The predicted levels from tunneling operations are also below the most restrictive criteria for building damage.

#### 6.4.1.2 Ballard Link Extension Tunneling Vibration Impacts

The expected levels from tunneling would be below the operational criteria for annoyance for Category 2 (residential) and Category 3 (institutional) land uses in the Ballard Link Extension study area. The predicted levels from tunneling activities relative to the Category 2 and Category 3 limits are shown on Figures 4-7 through 4-9. These levels would also be below the most restrictive criteria for building damage.

Category 1 and special-use buildings have stricter limits that are specific to the building use. The predicted levels and criteria for Category 1 and special-use buildings are shown in Table 6-25 for the tunnel boring machine cutterhead and supply train tunneling activities. The predicted levels for the thrust-jack is more than 5 dB below the impact threshold for all sensitive receivers.

There are projected vibration impacts from the supply train at sensitive receivers for both Downtown Segment alternatives. For Preferred Alternative DT-1, vibration impact is projected at Seattle Children's Research Institute and K.E.X.P. For Alternative DT-2, vibration impact is projected at 219 Terry Avenue with tenants Kineta, Biodesix, and Genewiz; at 401 Terry Avenue, with tenants Institute of Systems Biology and Just Biotherapeutics; at the Allen Institute; and at the closest buildings on the University of Washington Medicine South Lake Union Campus. The predicted levels assume a supply train with steel wheels on steel rail and are based on the data measured under the University of Washington campus presented in Section 4.2.2, Construction Vibration Prediction Methods, and the vibration propagation data measured in the Downtown Segment.

## Table 6-25. Vibration Predictions for Category 1 and Special Buildings during Tunneling

| Receiver Name | Minimum Distance to Tunnel Centerline (feet) | Vibration Limit (VdB) | Maximum Cutterhead Vibration (VdB) | Maximum Supply Train Vibration (VdB) | Project Alternative with Vibration Exceedance |
|---|---|---|---|---|---|
| 5th Avenue Theatre | 151 | 72 | 56 | 63 | None |
| ACT Theatre | 372 | 72 | 48 | 45 | None |
| Kineta, Biodesix, Genewiz (219 Terry Avenue North) | 118 | 48 | 60 | 67 | DT-2 |
| Seattle Children's Research Institute Center for Global Infectious Disease Research | 112 | 48 | 60 | 68 | DT-1 |
| Institute of Systems Biology, Just Biotherapeutics (401 Terry Avenue North) | 102 | 54 | 62 | 70 | DT-2 |
| Juno Therapeutics | 153 | 48 | 56 | 62 | DT-1 |
| Allen Institute | 221 | 48 | 52 | 55 | DT-2 |
| University of Washington Medicine South Lake Union Campus | 102 | 48 | 62 | 70 | DT-2 |
| Cascade Public Media (KCTS 9 Television) | 213 | 65 | 48 | 46 | None |
| Seattle Opera and KING FM [a] | 152 | 65 | 56 | 62 | None |
| McCaw Hall | 171 | 65 | 54 | 60 | None |
| Pacific Northwest Ballet (Phelps Center) | 177 | 78 | 54 | 59 | None |
| Cornish Playhouse | 166 | 72 | 54 | 61 | None |
| Seattle Repertory Theatre | 121 | 72 | 59 | 67 | None |
| SIFF Film Center | 135 | 72 | 58 | 65 | None |
| The Vera Project | 102 | 72 | 62 | 70 | None |
| K.E.X.P. | 11 | 65 | 60 | 69 | DT-1 |
| iHeart Media, Nexelis, Luminex (645 Elliott Avenue) | 299 | 65 | 49 | 49 | None |
| Victory Studios | No tunnel alternative | 65 | Not applicable | Not applicable | None |
| Friedman and Bruya | No tunnel alternative | 72 | Not applicable | Not applicable | None |
| Seattle Film Institute | No tunnel alternative | 65 | Not applicable | Not applicable | None |
| Specialty Vet Path | Tunnel alternative is a full take | 66 | Not applicable | Not applicable | None |
| Bardahl Manufacturing | 168 | 72 | 54 | 60 | None |
| Vaupell Industrial Plastics | 118 | 72 | 43 | 35 | None |

Note: The predicted levels for the thrust-jack is more than 5 dB below the impact threshold for all sensitive receivers.

[a] Predictions use building-specific measurement data and apply the data to the most sensitive location in the building. Detailed data and prediction methodology are provided in Attachment N.3H.

Mitigation measures are discussed in Section 7.3.2, Proposed Operational Vibration Mitigation.

Groundborne noise has been evaluated for tunneling operations because there is no airborne noise path. Thresholds for groundborne noise due to train operations have been applied as the annoyance thresholds for tunneling activities. The thresholds are 35 dBA and 40 dBA for Category 2 and Category 3 land uses, respectively. Table 6-26 shows the range of expected groundborne noise levels based on data measured under the University of Washington campus presented in Section 4.2.2, Construction Vibration Prediction Methods, which show very high variability. Vibration from the tunnel boring machine cutterhead may reach as high as 40 dBA, which would exceed the criteria for Category 2 land uses and equal the criteria for Category 3 land uses. The highest groundborne noise levels are typically caused by very localized underground features such as cobbles, so it is not possible to identify precise locations where the groundborne noise criteria are most likely to be exceeded.

### Table 6-26. Range of Predicted Groundborne Noise Levels During Tunneling

| Vibration Source | Groundborne Noise Prediction (dBA) [a] |
|---|---|
| Tunnel Boring Machine Cutterhead | 14 to 40 |
| Thrust Jack Retraction | 13 to 29 |
| Supply Train with steel wheels and jointed rails | 24 to 28 |

[a] Range is based on measured data from 0 to 200 feet from tunnel.

Groundborne noise criteria for various special-use buildings are presented in Table 6-27. The predicted levels are based on the data measured under the University of Washington campus presented in Section 4.2.2 and the vibration propagation data measured in the Downtown Segment. Category 1 land uses are not typically sensitive to groundborne noise. There is projected groundborne noise impact from both the tunnel boring machine cutterhead and the supply train for special-use buildings for both Downtown Segment alternatives. Groundborne noise levels from the thrust-jack are more than 5 dB below the impact threshold. For Preferred Alternative DT-1, impacts are projected at Seattle Repertory Theatre, the Vera Project, and K.E.X.P. For Alternative DT-2, impact is projected at Cascade Public Media (KCTS 9 Television), Seattle Opera, and McCaw Hall. Mitigation measures are discussed in Section 7.3.2.

### 6.4.2 Surface Construction Vibration Impacts

The primary concern from construction activities is the potential for damage to buildings. Because the details of the construction means and methods for this project may change from what is described in Chapter 2, Environmental Noise and Vibration Basics, are not available at this time and there are several alternatives, the construction vibration analysis focused on determining the distance beyond which the damage risk criteria and annoyance criteria would not be exceeded.

Table 6-28 shows the distance at which vibration from different pieces of construction equipment is expected to be equal to different thresholds for potential damage, rounded up to the nearest 10 feet. The highest vibration-generating construction activity that could occur would be pile-driving. Several receivers have the potential to be impacted by pile-driving in areas where bridge construction is planned.

## Table 6-27. Groundborne Noise Predictions at Special Buildings During Tunneling

| Receiver Name | Distance to Tunnel Centerline (feet) | Applicable Vibration Criteria | Maximum Cutterhead Groundborne Noise (dBA) | Maximum Supply Train Groundborne Noise (dBA) | Alternative with Groundborne Noise Exceedance |
|---|---|---|---|---|---|
| 5th Avenue Theatre | 151 | 35 | 30 | 34 | None |
| ACT Theatre | 372 | 35 | 10 | 13 | None |
| Cascade Public Media (KCTS 9 Television) | 213 | 25 | 22 | 26 | DT-2 |
| Seattle Opera | 152 | 25 | 30 | 34 | DT-2 |
| McCaw Hall | 171 | 25 | 27 | 31 | DT-2 |
| Pacific Northwest Ballet (Phelps Center) | 177 | 40 | 26 | 30 | None |
| Cornish Playhouse | 166 | 35 | 28 | 32 | None |
| Seattle Repertory Theatre | 121 | 35 | 36 | 40 | DT-1 |
| SIFF Film Center | 135 | 40 | 33 | 37 | None |
| The Vera Project | 507 | 40 | 40 | 44 | DT-1 |
| K.E.X.P. | 507 | 25 | 38 | 42 | DT-1 |

Note: The predicted levels for the thrust-jack is more than 5 dB below the impact threshold for all sensitive receivers.

## Table 6-28. Distance to Vibration Thresholds for Construction Equipment Pieces

| Equipment | Peak Particle Velocity Reference Level at 25 feet (inch per second) | Distance to 0.5 inch per second Damage Criteria (feet) [a] | Distance to 0.2 inch per second Damage Criteria (feet) [a] | Distance to Category 3 Annoyance Criteria (feet) [b] | Distance to Category 2 Annoyance Criteria (feet) [b] |
|---|---|---|---|---|---|
| Impact Pile Driver [c] | 0.644 to 1.518 | 30 to 60 | 60 to 100 | 240 to 420 | 300 to 530 |
| Sonic Pile Driver [c] | 0.17 to 0.734 | 20 to 40 | 30 to 60 | 100 to 260 | 130 to 330 |
| Hoe Ram | 0.089 | 10 | 20 | 70 | 80 |
| Large Bulldozer | 0.089 | 10 | 20 | 70 | 80 |
| Caisson Drilling | 0.089 | 10 | 20 | 70 | 80 |
| Loaded Trucks | 0.076 | 10 | 20 | 60 | 80 |
| Jackhammer | 0.035 | 5 | 10 | 40 | 50 |
| Small Bulldozer | 0.003 | 5 | 5 | 10 | 10 |

[a] Thresholds defined in Section 3.2.2, Groundborne Noise Criteria: 0.5 inch per second for reinforced concrete, steel, or timber and 0.2 inch per second for nonengineered timber and masonry buildings.

[b] Annoyance limits of 75 VdB for Category 3, and 72 VdB for Category 2 on projects with frequent events (>70 per day).

[c] Reference levels and distances cover a range from typical to high amounts of vibration from the equipment.

The results in Table 6-28 show that equipment other than pile drivers can operate without risk of damage at distances of 10 feet or greater from reinforced concrete buildings (0.5 inch per second threshold) and 20 feet or greater from non-engineered timber and masonry buildings (0.2 inch per second threshold), which are the most common types of buildings in the study area. The mitigation measures discussed in Section 7.3.2 should be considered when operating equipment within the damage criteria distances listed in Table 6-28. Plans to operate within these minimum distances should be avoided, as practical, when developing construction means and methods. During final design, a construction vibration impact assessment would be developed to address all Category 1 receivers and locations where operations may be within these minimum distances and consider use of the vibration-reducing measures discussed in Section 7.3.2.

In addition to the distance to the construction vibration damage criteria, Table 6-28 also presents the distance to the operations annoyance criteria for reference. Most surface construction activities would be temporary in nature, and the construction vibration damage criteria are of most concern. However, the operations annoyance criteria may be important for some conditions, such as nighttime construction or longer-term activities.

#### 6.4.2.1 West Seattle Link Extension Surface Construction Impacts

For the West Seattle Link Extension in the area of the Duwamish Waterway bridge, single-family residences in the Pigeon Point and Riverside neighborhoods west of the waterway and the Harbor Island Machine Works building have the potential to be impacted by pile-driving. Within the Duwamish Segment, pile-driving for the new light rail bridge over the Duwamish Waterway could result in potential cosmetic damage to structures within 100 feet of pile locations if an impact pile driver is used. For Preferred Alternative DUW-1a, some of the Harbor Marina buildings on Harbor Island may be within 100 feet of pile locations. For Option DUW-1b, there are unlikely to be any buildings within 100 feet of pile locations. For Alternative DUW-2, the Harbor Island Machine Works and Meltec buildings on Harbor Island are likely to be within 100 feet of pile locations. Harbor Island Machine Works is a Category 1 vibration land use where vibration from pile-driving may disrupt business operations. Detailed vibration predictions and mitigation measures would be included in a Vibration Control Plan for this property because of its vibration sensitivity. Alternative construction methods that do not use impact pile-driving may be used for areas with buildings closer than 100 feet.

Using the criteria for potential building damage, construction vibration impacts can be avoided from other surface construction activities by following best-management practices and maintaining a 20-foot distance between buildings and large construction equipment such as hoe rams, large bulldozers, and caisson drilling, as shown in Table 6-28.

#### 6.4.2.2 Ballard Link Extension Surface Construction Impacts

For the Ballard Link Extension near the new Ship Canal crossing, pile-driving could result in potential cosmetic damage to structures within 100 feet of pile locations. For Preferred Alternative IBB-1a and Option IBB-1b, the Seattle Maritime Academy, the commercial parcel north of the Seattle Maritime Academy (4422 Shilshole Avenue Northwest), and some structures at the Salmon Bay terminals may be within 100 feet of piling locations. For Alternative IBB-3, the United Electric Motor repair shop, Pono Ranch Restaurant, and some buildings at Fishermen’s Terminal may be within 100 feet of piling locations. As shown in Table 6-28, pile-driving activities at these distances may have the potential to generate vibration levels that exceed the damage criteria. Alternative construction methods that do not use impact pile-driving may be used for these areas, as discussed in Section 7.4, Construction Vibration Mitigation.

Construction vibration impact using the criteria for potential damage to buildings can be avoided from other surface construction activities by following best management practices and maintaining a 20-foot distance between buildings and large construction equipment such as hoe rams, large bulldozers, and caisson drilling, as shown in Table 6-28. The exception is for Category 1 and special-use buildings where more strict thresholds apply and vibration may interfere with operations. Table 6-29 lists equipment and the distance at which the predicted level is equal to the various vibration criteria curves for Category 1 buildings near at-grade or elevated alignments. A qualitative assessment of surface construction vibration predictions at Category 1 and special-use buildings is presented in Table 6-30. For several special-use buildings, construction activities such as caisson drilling, hoe rams, and bulldozers are projected to exceed the criteria for the closest alternatives. The projections show that the means and methods of construction may be restricted based on the vibration criteria at these buildings. Projected impacts are:

- Downtown Segment:
    - For Preferred Alternative DT-1, K.E.X.P., The Vera Project, SIFF Film Center, Seattle Repertory Theatre, and The Cornish Playhouse may have impacts from the construction of the Seattle Center Station for and Juno Therapeutics may have impacts from the construction of the South Lake Union Station.
    - For Alternative DT-2, Seattle Repertory Theatre may have impacts for the construction of the Seattle Center Station and Kineta, Biodesix, and Genewiz may have impacts from the construction of the South Lake Union Station.
    - Vibration from activities during station construction such as hydromills, caisson drilling, hoe rams, jackhammers, and bulldozers are projected to exceed the criteria for the alternatives closest to the above buildings. Restrictions on construction activities to outside of business hours, strategic layout of the construction site, or alternative means may be required to meet the criteria.
- South Interbay Segment:
    - For Preferred Alternative SIB-1, iHeart Media, Nexelis, and Luminex may have impacts from the construction of the elevated guideway.
    - For Alternative SIB-2, iHeart Media, Nexelis, Luminex, and Victory Studios may have impacts from the construction of the elevated guideway.
    - Vibration from activities such as caisson drilling, hoe rams, or bulldozers are projected to exceed the criteria for the alternatives closest to the above buildings. Restrictions on construction activities to outside of business hours or alternate means may be required to meet the criteria.
- Interbay/Ballard Segment:
    - For Option IBB-1b, the Seattle Film Institute may have impacts from the construction of the elevated guideway.
    - For Alternative IBB-3, Seattle Film Institute and Specialty Vet Path may have impacts from the construction of the elevated guideway.

- Vibration from activities such as caisson drilling, hoe rams, or bulldozers are projected to exceed the criteria for the alternatives closest to the above buildings. Restrictions on construction activities to outside of business hours or alternate means may be required to meet the criteria.

Surface construction vibration has not been assessed for Category 1 or special-use buildings near tunnel alignments. However, vibration from surface construction may be of concern if these buildings are close to tunnel portals or station construction. These activities should be assessed in the Construction Vibration Control Plan.

### Table 6-29. Distance to Vibration Criteria Curve Thresholds for Construction Equipment Pieces

| Equipment [a] | Distance to V.C.-A (feet) [b] | Distance to V.C.-B (feet) | Distance to V.C.-C (feet) | Distance to V.C.-D (feet) | Distance to V.C.-E (feet) |
|---|---|---|---|---|---|
| Impact Pile Driver [c] | 467 to 827 | 740 to 1310 | 1173 to 2077 | 1858 to 3292 | 2945 to 5217 |
| Sonic Pile Driver [c] | 192 to 509 | 304 to 807 | 483 to 1279 | 765 to 2028 | 1212 to 3214 |
| Vibratory Roller | 221 | 351 | 556 | 880 | 1395 |
| Hoe Ram | 125 | 198 | 313 | 497 | 787 |
| Large Bulldozer | 125 | 198 | 313 | 497 | 787 |
| Caisson Drilling | 125 | 198 | 313 | 497 | 787 |
| Loaded Trucks | 112 | 178 | 282 | 447 | 709 |
| Jackhammer | 67 | 106 | 168 | 267 | 423 |
| Small Bulldozer | 13 | 21 | 33 | 52 | 82 |

[a] Reference levels from FTA Guidance Manual (2018) are available in Table 6-28.

[b] Because the strictest criteria for special-use buildings is only 1 VdB lower than the V.C.-A curve (see Tables 3-7 and 4-8), the V.C.-A results can be used for special-use buildings by adding 5 to 10 feet to the distances.

[c] Reference levels and distances cover a range from typical to high levels of vibration from the equipment

### Table 6-30. Vibration Predictions at Special Buildings During Surface Construction

| Receiver | Vibration Limit (VdB) | Distance (feet) | Alternatives with Exceedance | Activities with Exceedance |
|---|---|---|---|---|
| K.E.X.P. | 65 | 8 | DT-1 | Hydromill (slurry wall), caisson drilling, hoe ram, jackhammer, bulldozer |
| The Vera Project | 72 | 8 | DT-1 | Hydromill (slurry wall), caisson drilling, hoe ram, jackhammer, bulldozer |
| SIFF Film Center | 72 | 8 | DT-1 | Hydromill (slurry wall), caisson drilling, hoe ram, jackhammer, bulldozer |
| Seattle Repertory Theatre | 72 | 8 | DT-1, DT-2 | Hydromill (slurry wall), caisson drilling, hoe ram, jackhammer, bulldozer |

| Receiver | Vibration Limit (VdB) | Distance (feet) | Alternatives with Exceedance | Activities with Exceedance |
|---|---|---|---|---|
| Cornish Playhouse | 72 | 8 | DT-1 | Hydromill (slurry wall), caisson drilling, hoe ram, jackhammer, bulldozer |
| Juno Therapeutics | 65 | 8 | DT-1 | Hydromill (slurry wall), caisson drilling, hoe ram, jackhammer, bulldozer |
| Kineta, Biodesix, Genewiz (219 Terry Avenue North) | 65 | 40 | DT-2 | Hydromill (slurry wall), caisson drilling, hoe ram, jackhammer, bulldozer |
| iHeartMedia, Nexelis, Luminex (645 Elliott Avenue) | 65 | 89 [a] | SIB-1, SIB-2 | Caisson drilling, hoe ram, bulldozer |
| Victory Studios | 65 | 68 [a] | SIB-2 | Caisson drilling, hoe ram, bulldozer |
| Friedman & Bruya | 72 | 133 [a] | none | none |
| Seattle Film Institute | 65 | 114 [a] | IBB-1b | Caisson drilling, hoe ram, bulldozer |
| Specialty Vet Path | 66 | 144 [a] | IBB-3 | Caisson drilling, hoe ram, bulldozer |
| Bardahl Manufacturing | 72 | 177 [a] | none | none |
| Vaupell Industrial Plastics | 72 | 647 [a, b] | none | none |

[a] Distance listed is the distance to centerline. Analysis assumes construction could be 25 feet closer than the distance to near track.

[b] Closer alternatives would result in a displacement of this business.

## 6.5 Indirect Impacts

Indirect noise and vibration impacts include increased noise and/or vibration levels near the project that could be associated with transit-oriented development, typically traffic and construction noise and vibration. Although noise associated with future development could increase noise in the project corridor, any increase would be expected to be minimal and any new developments would be required to meet the City of Seattle noise regulations. Most vehicle traffic and other sources of environmental vibration are below the levels of human perception and would not constitute an indirect impact.

## 6.6 Cumulative Impacts

### 6.6.1 Operation

The FTA's methodology for noise and vibration analysis reflects both cumulative ambient noise conditions from land uses and activities from past and present activities in combination with project-specific noise and vibration impacts. All WSBLE Project noise impacts could be mitigated depending on the alternatives chosen. Most vibration impacts can also be mitigated; however, there could be residual vibration impacts in some segments.

The light rail vibration might occur concurrently with vibration from heavy trucks on rough roads and local construction activities. Cumulative vibration levels in most areas are not expected to differ from existing vibration levels. Exceptions to this would include areas that have extremely rough roadways with potholes or cracks, which would increase vibration levels from passing trucks and other heavy vehicles, and areas near active construction sites where equipment could cause short-term increases in vibration levels.

No other reasonably foreseeable future actions are expected to cause notable vibration impacts during project operation, so cumulative vibration impacts are not expected. Although Sound Transit is committed to mitigating project noise impacts, light rail would still create a new noise source and, therefore, would contribute to cumulative noise in the project corridor. In addition, the indirect impact of WSBLE Project, combined with local land use policies, could attract more development around rail stations, which might result in more intense urban activities in some station areas, therefore adding cumulative noise to the surroundings.

### 6.6.2 Construction

During construction, the WSBLE Project would contribute noise and vibration impacts along with other nearby transportation and private development construction projects, and cumulative impacts would be anticipated. This is particularly true for the tunnel alternatives in the Downtown Segment, where construction of high-rise buildings is proposed near WSBLE Project alternatives. However, many projects currently planned might be completed before WSBLE Project construction. Any construction activities would have to comply with the City of Seattle's noise regulations or require a noise variance from the City. Where necessary, Sound Transit would monitor noise and vibration during construction to minimize related disturbances on residential and other sensitive areas and work with other adjacent projects to limit nighttime noise and vibration impacts.

# 7 NOISE AND VIBRATION MITIGATION MEASURES

For locations where Sound Transit has identified potential noise impacts, mitigation measures will be considered and reviewed using Sound Transit's light rail Link Noise Mitigation Policy (Motion No. M2004-08, Sound Transit 2004). Under this policy, potential mitigation measures will be considered for all noise impacts where reasonable and feasible.

Sound Transit's noise mitigation policy is to mitigate 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 will evaluate and implement sound insulation at affected properties where the existing building does not already achieve sufficient exterior-to-interior reduction of noise levels. Sound Transit practice is to mitigate both FTA moderate and severe impacts. Detailed tables of noise levels for each receiver location, before and after mitigation, are provided in Attachment N.3F.

Where potential vibration impacts are identified, vibration mitigation measures will be considered. Vibration mitigation measures focus on reducing the source of vibration, with path and building treatment being considered as secondary measures. Sections 7.1.1, Transit Noise Mitigation Approaches, and 7.1.2, Traffic Noise Mitigation Approaches, introduce the mitigation strategies normally used for light rail projects. Following this introduction, Section 7.1.3, Proposed Operational Noise Mitigation, presents the mitigation strategies and measures proposed for the WSBLE Project.

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

## 7.1 Operational Noise Mitigation

This section discusses mitigation for noise generated by the operation of the WSBLE Project. Potential mitigation measures for construction noise are discussed in Section 7.2, Construction Noise Mitigation.

### 7.1.1 Transit Noise Mitigation Approaches

Several types of noise mitigation measures can be used to reduce noise levels and mitigate noise impacts. First, to minimize noise effects and the subsequent need for their mitigation, Sound Transit has incorporated several noise-reducing project design elements into the West Seattle and Ballard Link light rail projects. These include the noise-reducing effects from elevated structures and retained-cut segments where project-related design reduces noise from light rail operations through physical shielding. For areas where these types of design options are not available, other forms of mitigation are considered and are discussed in order of application in the following sections (e.g., source, path, or receiver).

#### 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 4-1 lists operational and maintenance measures that

Sound Transit performs on a regular basis and the benefits that these measures provide. Crossovers, special track work, and adjustments based on track type are provided in Table 7-1. Typical noise reductions for sound walls, elevated acoustical walls, and trench situations are also shown in Table 7-1. 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.

### Table 7-1. Light Rail Noise-shielding Adjustments

| Track Type | Adjustment in Decibels |
| --- | --- |
| Acoustical sound walls on structures between 4 and 6 feet above the top of rail with some going as high as 8 feet. Walls on structures over 8 feet are not normally used because of wind loading and safety concerns. | Typical noise reduction of 6 to 15 dB or more, as predicted using FTA formulas and verified with measured data during normal operations along the existing light rail line in Tukwila. |
| Sound wall at-grade with an expected height of at least 6 feet above the grade of the guideway. 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 4 to 12 dB or more, as predicted using FTA formulas and verified with measured data during normal operations along the Tukwila segment. |

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 lubricators on curves with a radius of 600 feet or less and prepare for lubrication on any curves with a radius of less than 1,250 feet near noise-sensitive properties. If wheel squeal is identified after system operation begins, it is possible to add lubricators. There are also some additional considerations that will be reviewed as related to installation and use of lubricants. For example, on some guideways with steeper grades, lubricants on the rails can make track maintenance more difficult and prevent the use of hi-rail vehicles. In some cases, the lubricator may need to be disabled from time to time to facilitate maintenance activities and wayside noise levels and noise from wheel squeal could increase during these brief periods. Once work is completed, the wayside lubricants would be reactivated.

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 moveable-point frogs.

With standard rigid frogs, noise and vibration occurs when the wheels pass over the gap in the rail, but a moveable-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. Flange-bearing frogs 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. The type of frogs used for the WSBLE would depend on the track type, crossover location, and proximity of noise-sensitive properties.

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 Path Noise 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 WSBLE, berms would not be feasible because of topographical conditions and limited right-of-way. Therefore, walls would be used where appropriate.

Two types of sound walls are typically used for transit projects: For at-grade areas, the noise barrier type is a standard concrete wall, while 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 (or more) 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 WSBLE corridor is an urban area that is heavily developed, so creating buffer zones is not a feasible form of noise mitigation because it would require substantially more project-related property acquisition and displacements.

#### 7.1.1.3 Receiver Noise 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 an Ldn of 45 dBA, 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 Traffic Noise Mitigation Approaches

Potential traffic noise impacts could be mitigated either alone or in conjunction with the light rail mitigation.

In West Seattle, the displacement of residences along 32nd Avenue Southwest under Alternative DEL-6* required an analysis for traffic noise impacts at residences with increased exposure to West Seattle Bridge traffic noise. The area was analyzed, and no traffic noise impacts were identified. In the Ballard Link Extension, there are some locations in the

Interbay/Ballard Segment where removal of structures would occur, but no increase in traffic noise levels are predicted.

### 7.1.3 Proposed Operational Noise Mitigation

For most identified noise impacts, sound walls were the selected method of reducing noise levels, consistent with Sound Transit's Link Noise Mitigation Policy (Sound Transit 2004). Sound walls would be effective at eliminating most predicted noise impacts in both the West Seattle Link and Ballard Link extensions. Details on the locations and heights for the new walls are provided by project and segment in the following sections. The sound walls presented here were evaluated using 100-foot-long panel segments and the actual wall segments would be much shorter in length, typically 12 to 14 feet long. In addition, during final design, the walls would be optimized further based on any revisions to the project design; therefore, the final wall lengths and heights may vary from those presented here, based on updated design elements and land uses along the corridor. Also, because detailed station design was not available for all stations, and because most station design includes noise-reducing elements, mitigation near some stations is quantified using an equivalent sound wall. In fact, for most stations, these design elements would be sufficient to mitigate noise from light rail operations.

#### 7.1.3.1 West Seattle Link Extension Noise Mitigation

Noise mitigation for the West Seattle Link Extension includes sound walls along the elevated structures and along some at-grade retained-cut segments. Because of the height of some structures in the West Seattle area, not all noise impacts can be mitigated with sound walls. For those sites where sound walls would not be effective, building sound insulation will be examined. Details on the mitigation measures for the West Seattle Link Extension are detailed in the following sections. Maps showing the locations of sound walls are provided in Attachment N.3D.

***SODO Segment***

There are no FTA noise impacts in the SODO Segment of the West Seattle Link Extension and therefore, no noise mitigation is proposed.

***Duwamish Segment***

Sound walls are summarized by alternative in Tables 7-2 through 7-4. Project station numbering is provided in each of the tables as a reference for the wall locations. With the proposed mitigation, all impacts would be mitigated.

Under Preferred Alternative DUW-1a and Option DUW-1b, a 400-foot-long, 4-foot-tall sound wall would be required along the east side of the elevated light rail structure for Seattle Fire Station 14, on 4th Avenue South. Two additional sound walls would also be needed under Preferred Alternative DUW-1a and Option DUW-1b along the Pigeon Point area, east and west of the retained-cut sections of the guideway.

Under Preferred Alternative DUW-1a, the following sound walls would be needed:

- One 400-foot-long, 4-foot-tall wall on the west side of the structure to provide mitigation to Fire Station 14.
- A second, 600-foot-long wall ranging in height from 4 to 6 feet on the south side of the elevated structure to provide mitigation to the east side of the Pigeon Point area.

- A third, 400-foot-long, 4-foot-tall wall on the south side of the structure to provide mitigation for the western slope of Pigeon Point.

### Table 7-2. Summary of Sound Walls for the Preferred South Crossing Alternative (DUW-1a)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | West | 173+00 | 177+00 | 4 feet | 400 feet |
| At-grade-level and elevated sound wall [a] | East | 256+00 | 262+00 | 4 to 6 feet | 600 feet |
| Elevated sound wall [b] | East | 266+00 | Continued in Delridge | 4 feet | 400 feet |

[a] Sound wall would be shorter in length when connecting to Alternatives DEL-3 or DEL-4*. There would be no sound wall when connecting to Alternatives DEL-5 or DEL-6*.

[b] Sound wall would be shorter in length when connecting to Alternatives DEL-3 or DEL-4*. The sound wall would be longer in length when connecting to Alternative DEL-6*.

### Table 7-3. Summary of Sound Walls for the South Crossing South Edge Crossing Alignment Option (DUW-1b)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | West | 173+00 | 177+00 | 4 feet | 400 feet |
| Elevated sound wall | East | 256+00 | 259+00 | 4 feet | 300 feet |
| Elevated sound wall | East | 269+00 | Continued in Delridge | 4 feet | 200 feet |

### Table 7-4. Summary of Sound Walls for the North Crossing Alternative (DUW-2)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | West | 173+00 | 178+00 | 4 feet | 500 feet |

The wall lengths would be reduced slightly under Option DUW-1b as a result of the longer retained-cut section and different guideway elevation. The retained-cut segment of guideway eliminates noise impacts along the central part of the Pigeon Point area.

Under Alternative DUW-2, the only sound wall required is for Fire Station 14, on 4th Avenue South. The 500-foot-long, 4-foot-tall wall would be slightly longer than the wall under Preferred Alternative DUW-1a and Option DUW-1b because the guideway curves in front of the fire station. The sound wall details are provided in Table 7-4.

#### *Delridge Segment*

Sound walls are summarized by alternative in Tables 7-5 through 7-12. Project station numbering is provided in each of the tables as a reference for the wall locations.

Under Preferred Alternative DEL-1a, the following sound walls would be needed:

- A sound wall from the Duwamish Segment would continue along the east side of the elevated guideway to the curve on to Southwest Genesee Street, ending approximately 400 feet west of 26th Avenue Southwest. A shorter length would be needed when connecting to Alternative DUW-2 in the Duwamish Segment.
- Sound walls on the west side of the elevated structure along Southwest Delridge Way and along Southwest Genesee Street, continuing to the West Seattle Junction Segment.

Sound walls on the east side of the elevated guideway on Southwest Genesee Street east of Southwest Avalon Way, continuing to the West Seattle Junction Segment. Noise mitigation no less effective than a 4-foot sound wall would also be integral on both sides of the Delridge Station. Mitigation no less effective than a 4-foot wall means that the station design would include elements that would provide the same reduction as a wall that was at least 4 feet above the top or rail. Due to different installation techniques of the rails that are unknown at this time, the noise mitigation in some areas, for example stations, are specified using this terminology. All sound walls would have a height of 4 feet to 6 feet and with the proposed mitigation, all impacts under Preferred Alternative DEL-1a would be mitigated. The new walls also would provide noise mitigation for the FTA Category 1 Secret Studio Records/Studio 1208. Table 7-5 summarizes the sound walls for Preferred Alternative DEL-1a.

Noise mitigation under Option DEL-1b would be the same as described for Preferred Alternative DEL-1a and would also be effective at mitigation of all noise impacts.

### Table 7-5. Summary of Sound Walls for the Preferred Dakota Street Station Alternative (DEL-1a)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall [a] | East | Continued from Duwamish Segment | 294+00 | 4 feet | 2,400 feet |
| Elevated sound wall | West | 282+00 | Continues in West Seattle Junction | 4 to 6 feet | 2,700 feet |
| Elevated sound wall | East | 306+00 | Continues in West Seattle Junction | 4 feet | 300 feet |

[a] Sound wall would be shorter in length when connecting to Alternative DUW-2.

Noise mitigation under Option DEL-1b would be the nearly the same as described for Preferred Alternative DEL-1a with one change in sound wall height from 4 feet to 6 feet at the southwest corner of Southwest Avalon Way and Southwest Genesee Street before dropping back down to 4 feet at the Delridge and West Seattle Junction segments border. Table 7-6 summarizes the sound walls for Option DEL-1b.

### Table 7-6. Summary of Sound Walls for the Dakota Street Station North Alignment Option (DEL-1b)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | East | Continued from Duwamish Segment | 293+00 | 4 feet | 2,300 feet |
| Elevated sound wall | West | 282+00 | Continues in West Seattle Junction | 4 to 6 feet | 2,700 feet |
| Elevated sound wall | East | 306+00 | Continues in West Seattle Junction | 4 to 6 feet | 300 feet |

Under Preferred Alternative DEL-2a* the location and lengths of sound walls for the west side of the guideway are the same as described under Preferred Alternative DEL-1a; however, because of the lower track alignment, many of the sound walls along Delridge Way Southwest and Southwest Genesee Street would be taller, ranging from 4 to 8 feet tall. Sound walls along the eastside of the guideway would also be the same as with Preferred Alternative DEL-1a with slightly taller walls of 4 to 6 feet, continuing from the Duwamish Segment to Southwest Genesee Street, ending approximately 400 feet west of 26th Avenue Southwest. Noise mitigation no less effective than a 4-foot sound wall would also be integral on both sides of the Delridge Station. The new walls would also provide noise mitigation for the FTA Category 1 Secret Studio Records/Studio 1208. Table 7-7 summarizes the sound walls for Preferred Alternative DEL-2a*.

Even with sound walls of up to 8 feet, the following nine units would not be mitigated:

- Two top-floor (sixth-floor) units at the multi-family building, Youngstown Flats at 4040 26th Southwest.
- Four units at the multi-family building, The Edge Apartments at 3014 Southwest Genesee Street.
- Three units at 3120 Avalon Way.

All noise impacts identified would be to the exterior of the units. The Youngstown Flats is a newly constructed building; given current construction requirements for double-pane windows and wall insulation, interior noise levels at these units are likely within Department of Housing and Urban Development requirements. The Edge Apartments was constructed in 1958, prior to many current building requirements, and has no outdoor uses, and therefore may be a candidate for sound insulation such as improved windows and fresh air exchange systems. The final building, 3120 Avalon Way, is a newer building (constructed in 2002) and therefore would have double-pane windows. The impacts that could not be mitigated are on the upper floor of this six-floor building. If this alternative is selected, additional testing may be performed at each of these three buildings. The purpose of the testing would be to determine the interior noise levels from transit operations and to verify compliance that they meet the Department of Housing and Urban Development requirements or provide recommended acoustical improvements. However, with the sound walls and building insulation as needed, the interior noise levels would be within Department of Housing and Urban Development requirements, and all noise impacts would be mitigated. Table 7-7 summarizes the sound walls for Preferred Alternative DEL-2a*.

### Table 7-7. Summary of Sound Walls for the Preferred Dakota Street Station Lower Height Alternative (DEL-2a)*

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | East | Continued from Duwamish Segment | 294+00 | 4 feet | 2,400 feet |
| Elevated sound wall | West | 282+00 | Tunnel Portal | 4 to 8 feet | 2,400 feet |

Option DEL-2b* would be to the north along Southwest Genesee Street and would remove several of the buildings near Southwest Avalon Way. The sound walls would be similar to Preferred Alternative DEL-2a*, with wall heights ranging from 4 feet to 8 feet. Noise mitigation no less effective than a 4-foot sound wall would also be integral on both sides of the Delridge Station. The new walls also provide noise mitigation for the FTA Category 1 Secret Studio Records/Studio 1208. Under this alternative, there are approximately eight top-floor (sixth-floor) units at the Youngstown Flats that could not be mitigated with walls. The impacts at the Youngstown Flats under Option DEL-2b* are slightly different than Preferred Alternative DEL-2a* because the elevation of the track and station location are slightly different. This slight change in the track and station location increases the number of impacts remaining, even with an 8-foot sound wall. If this alternative is selected, additional testing may be performed at those units where noise mitigation was not predicted to resolve impacts. The purpose of the testing would be to determine the interior noise levels from transit operations and verify that they meet the Department of Housing and Urban Development requirements for residences. With the sound walls and building insulation as needed, the interior noise levels would be within Department of Housing and Urban Development requirements. Table 7-8 summarizes the sound walls for Option DEL-2b*.

**Table 7-8. Summary of Sound Walls for the Dakota Street Station Lower Height North Alignment Option (DEL-2b)***

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | East | Continued from Duwamish Segment | 294+00 | 4 feet | 2,400 feet |
| Elevated sound wall | West | 282+00 | Tunnel Portal | 4 to 8 feet | 2,400 feet |

Under Alternative DEL-3, the following sound walls would be needed:

- Sound walls on the east side of the guideway continuing from the Duwamish Segment to Southwest Genesee Street and ending approximately 100 feet west of 26th Avenue Southwest.
- Sound walls on the west side of the guideway along Delridge Way Southwest south of Southwest Andover Street and ending along Southwest Genesee Street approximately 500 feet east of Delridge Way Southwest.
- Sound walls on the west side of the structure from the north end of the Delridge Station to the connection in the West Seattle Junction Segment.
- Sound walls on the east side of the elevated guideway along Southwest Genesee Street east of Southwest Avalon Way, continuing to the West Seattle Junction Segment.

Noise mitigation no less effective than a 4-foot sound wall would also be integral along the east side of the Delridge Station. The new walls also provide noise mitigation for the FTA Category 1 Secret Studio Records/Studio 1208. With the new sound walls, all noise impacts are mitigated. Table 7-9 summarizes the sound walls for Alternative DEL-3.

**Table 7-9. Summary of Sound Walls for the Delridge Way Station Alternative (DEL-3)**

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | East | Continued from Duwamish Segment | 298+00 | 4 to 6 feet | 2,700 feet |
| Elevated sound wall | East | 306+00 | 309+00 | 4 feet | 300 feet |
| Elevated sound wall | West | Delridge Station | Continues in West Settle Junction | 4 to 6 feet | 3,300 feet |

Under Alternative DEL-4*, the following sound walls would be needed:

- Sound walls on the east side of the guideway continuing from the Duwamish Segment to Southwest Genesee Street and ending approximately 100 feet west of 26th Avenue Southwest.

- Sound walls on the west side of the structure from the north end of the Delridge Station to the connection in the West Seattle Junction Segment.

Noise mitigation under Alternative DEL-4* would range from 4-foot- to 8-foot-tall walls to account for the lower track elevations. Even with the walls, four units on the upper floor at the multi-family building at 3014 Southwest Genesee Street are predicted to meet or exceed the FTA criteria. Therefore, the upper floor units in this multi-family building may be candidates for sound insulation. If this alternative is selected, additional testing may be performed. The purpose of the testing would be to determine the interior noise levels from transit operations and to verify that they meet the Department of Housing and Urban Development requirements for residences or to provide recommended structural improvements. However, with the sound walls and building insulation as needed, the interior noise levels would be within Department of Housing and Urban Development requirements, and all noise impacts would be mitigated. Table 7-10 summarizes the sound walls for Alternative DEL-4*.

**Table 7-10. Summary of Sound Walls for the Delridge Station Lower Height Alternative (DEL-4)***

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| At-grade-level and elevated sound wall | East | Continued from Duwamish Segment | 297+00 | 4 to 6 feet | 2,500 feet |
| At-grade-level and elevated sound wall | West | 280+00 | Tunnel Portal | 4 to 8 feet | 3,000 feet |

For Alternative DEL-5, the following sound walls would be needed:

- The continuation of the 4-foot-tall sound wall on the east side of the guideway in the Duwamish Segment for an additional 200 feet, providing noise mitigation for residences along Southwest Delridge Way and 23rd Avenue Southwest.
- A second, 4-foot-tall, east-side sound wall continuing from just east of 26th Avenue Southwest to just east of 28th Avenue, providing noise mitigation for the Youngstown Flats multi-family building.
- A third, 4-foot-tall, east-side sound wall with a parallel, 4- to 8-foot-tall, sound wall on the west side from just west of 28th Avenue Southwest to the connection to the West Seattle Junction Segment.

There are up to 15 multi-family residences in a nine-floor building at 3050 Southwest Avalon Way that are well above the guideway and could not be mitigated with sound walls; however, this building was constructed in 2018, has no external uses at the upper floors, and given current construction requirements for double-pane windows and wall insulation, interior noise levels at these units are likely within Department of Housing and Urban Development requirements. If this alternative is selected, additional testing may be performed at those units where noise mitigation was not predicted to resolve impacts. The purpose of the testing would be to determine the interior noise levels from transit operations and to verify that they meet the Department of Housing and Urban Development requirements for residences or to provide recommended structural improvements. With the sound walls and building insulation as needed, the interior noise levels would be within Department of Housing and Urban Development requirements. Table 7-11 summarizes the sound walls for Alternative DEL-5.

### Table 7-11. Summary of Sound Walls for the Andover Street Station Alternative (DEL-5)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | East | 278+00 | 282+00 | 4 feet | 400 feet |
| Elevated sound wall | East | 287+00 | Continues in West Seattle Junction | 4 feet | 1,800 feet |
| Elevated sound wall | West | 292+00 | Continues in West Seattle Junction | 4 to 8 feet | 1,300 |

Noise mitigation for Alternative DEL-6* begins at the connection to the Duwamish Segment, with a continued sound wall just east of the Delridge Station. Alternative DEL-6* would also have a sound wall along the east side of the guideway for mitigation at the Youngstown Flats multi-family building. Sound walls would also be required along the east side of the guideway from just east of 28th Avenue Southwest, continuing to the tunnel portal to the West Seattle Junction Segment. Finally, a 6- to 8-foot-tall sound wall would be needed along the west side of the guideway for approximately 600 feet starting at Southwest Avalon Way. The sound walls are sufficient to mitigate all potential noise impacts under Alternative DEL-6*. Table 7-12 summarizes the sound walls for Alternative DEL-6*.

### Table 7-12. Summary of Sound Walls for the Andover Street Station Lower Height Alternative (DEL-6)*

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | East | Continued from Duwamish Segment | 273+00 | 4 feet | 200 feet |
| Elevated sound wall | East | 278+00 | 285+00 | 4 feet | 700 feet |
| At-grade-level and elevated sound wall | East | 292+00 | Continues in West Seattle Junction | 4 to 8 feet | 1,300 feet |
| At-grade-level and elevated sound wall | West | 292+00 | 300+00 | 4 to 8 feet | 800 feet |

#### *West Seattle Junction Segment*

Preferred Alternative WSJ-1 would continue sound walls on both sides of the guideway from the Delridge Segment, including at the Avalon Station. Sound walls up to 8 feet tall would be required for the upper floors of the multi-family units south of the station area. The walls on the east and south side of the guideway would continue to the west side of 35th Avenue Southwest, where land use changes to commercial and no mitigation is needed. On the west and north side of the guideway, the walls end at 35th Avenue Southwest and start again near 37th Avenue Southwest, continuing at 4 to 8 feet tall to the end of the alignment near Southwest Hudson Street. Sound walls would also be needed along the east and south of the guideway near Southwest Oregon Street, 40th Avenue Southwest and from Southwest Alaska Street to the end of the guideway.

Because of the severe noise impacts and building elevations, sound walls would not be sufficient to fully mitigate the noise impacts at the following locations:

- Two units at a multi-family building at 3250 Southwest Avalon Way.
- A single-family residence on 40th Avenue Southwest.
- Upper floor units at the multi-family building at 4100 Southwest Alaska Street.
- Upper floor units at the multi-family building at 5000 California Avenue Southwest.

The noise impact at the single-family residence on 40th Avenue Southwest is due in part to the double crossover and requires special trackwork mitigation in addition to the sound wall. The remaining sites would be considered for sound insulation as needed, but the buildings at 3250 Southwest Avalon Way and 4100 Southwest Alaska Street are newer construction and would be equipped with double-pane windows. The multi-family building at 5000 California Avenue Southwest was constructed in 1984 and had a major remodel performed in 2018 that may have included installation of improved windows. If this alternative is selected, additional testing may be performed at each of these buildings. The purpose of the testing would be to determine the interior noise levels from transit operations and to verify that they meet the Department of Housing and Urban Development requirements for residences or to provide recommended structural improvements. With the sound walls, special trackwork, and building insulation as needed, the interior noise levels would be within Department of Housing and Urban Development requirements, and all noise impacts would be mitigated. Table 7-13 summarizes the sound walls for Preferred Alternative WSJ-1.

### Table 7-13. Summary of Sound Walls for the Preferred Elevated 41st/42nd Avenue Station Alternative (WSJ-1)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | West | Continued from Delridge Segment | 315+00 | 4 feet | 600 feet |
| Elevated sound wall | West | 323+00 | Project Terminus | 4 to 8 feet | 3,000 feet |
| Elevated sound wall | East | Continued from Delridge Segment | 316+00 | 4 to 8 feet | 700 feet |
| Elevated sound wall | East | 329+00 | 332+00 | 4 feet | 300 feet |
| Elevated sound wall | East | 337+00 | 339+00 | 4 feet | 200 feet |
| Elevated sound wall | East | 343+00 | Project Terminus | 4 feet | 1,400 feet |

Preferred Alternative WSJ-2 would also continue the sound walls from the Delridge Segment on both sides of the alignment and include the same noise mitigation at the station. Sound walls would also be needed on the west side of the structure (north) near 36th Avenue Southwest to the Alaska Junction Station. Sound walls on the east side of the guideway (south) would resume south of Southwest Oregon Street to and including the Alaska Junction Station with mitigation equivalent to a 6-foot wall. North of the Alaska Junction Station, 4-foot sound walls would continue to mitigate sound from light rail operations on the trail tracks. Sound insulation would be considered for upper floors of a multi-family building on Southwest Avalon Way and three multi-family buildings on Fauntleroy Way Southwest (4800, 4830, and 4831) near the project terminus. All of the buildings were constructed in the 1980s and would be considered for sound insulation and tested to verify the interior noise levels from transit operations meet the Department of Housing and Urban Development requirements for residences if this alternative is selected. With the set of noise mitigation measures (i.e., walls and sound insulation), all noise impacts would be mitigated. Table 7-14 summarizes the walls proposed for Preferred Alternative WSJ-2.

### Table 7-14. Summary of Sound Walls for the Preferred Elevated Fauntleroy Way Station Alternative (WSJ-2)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall [a] | East | Continued from Delridge Segment | 316+00 | 4 to 6 feet | 600 feet |
| Elevated sound wall | West | Continued from Delridge Segment | 337+00 | 4 feet | 2,800 feet |
| Elevated sound wall | East | 331+00 | Project Terminus | 4 to 8 feet | 1,600 feet |
| Elevated sound wall | West | 342+00 | Project Terminus | 4 to 6 feet | 500 feet |

[a] Sound wall would be shorter in length when connecting to Option DEL-1b.

Under Preferred Alternative WSJ-3a* and Preferred Option WSJ-3b*, the alignment is entirely in a tunnel in the West Seattle Junction Segment and no noise impacts were identified and no mitigation is required.

Alternative WSJ-4* would continue the sound walls from the Delridge Station on both sides of the alignment and include noise mitigation at the Avalon Station. The 4- to 6-foot-tall walls would mitigate noise from the station. An additional 4-foot sound wall would be required along the west and north side of the guideway from near 36th Avenue Southwest to just prior to the tunnel portal. All impacts would be mitigated. Table 7-15 summarizes the new sound wall.

### Table 7-15. Summary of Sound Walls for the Short Tunnel 41st Avenue Station (WSJ-4)*

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | West | Continued from Delridge | 315+00 | 4 feet | 600 feet |
| Elevated sound wall | East | Continued from Delridge | 315+00 | 4 to 6 feet | 600 feet |
| Elevated sound wall | West | 319+00 | 327+00 | 4 feet | 800 feet |

Alternative WSJ-5* would continue the sound walls from the Delridge Segment on the east side of the trackway. The 4- to 6-foot sound walls just prior to Avalon Station would mitigate noise coming from the retained-cut segment. Table 7-16 summarizes the new wall.

### Table 7-16. Summary of Sound Walls for the Medium Tunnel 41st Station Alternative (WSJ-5)*

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| At-grade-level | East | Continued from Delridge Segment | 308+00 | 4 to 6 feet | 300 feet |

#### 7.1.3.2 Ballard Noise Mitigation

Noise mitigation for the Ballard Link Extension includes sound walls along the elevated structures and along some at-grade retained-cut segments. Because of the topographical conditions along 15th Avenue West and upper floors elevations at some multi-family units, not all noise impacts can be mitigated with sound walls. For those sites where sound walls would not be effective, building sound insulation will be examined. Details on the mitigation measures for the Ballard Link Extension are detailed in the following sections. Maps showing the locations of sound walls are provided in Attachment N.3D.

#### *SODO Segment*

There would be no FTA noise impacts in the SODO Segment of the Ballard Link Extension; therefore, no noise mitigation is proposed.

#### *Chinatown-International District Segment*

There would be no FTA noise impacts in the Chinatown-International District Segment; therefore, no project noise mitigation is proposed.

#### *Downtown Segment*

There would be no FTA noise impacts in the Downtown Segment and therefore no project noise mitigation is proposed.

#### *South Interbay Segment*

Under Preferred Alternative SIB-1, three sound walls totaling approximately 3,400 to 3,500 feet are proposed. All sound walls would be along the sides of the elevated structures or along the transition from elevated guideway to the downtown tunnel portals. Along the north/east side of the guideway, sound walls would be from the tunnel portal along West Republican Street, continuing to West Mercer Place. A second east-side wall would extend from the north end of Kinnear Park, continuing to the north and providing mitigation for impacts identified near, and along, 10th and 11th Avenue West. Sound walls along the west side include a wall along the west side of the tracks near the tunnel portal and an additional wall for impacts along 20th Avenue West near Thorndyke Avenue Northwest. The sound walls vary in height from 4 to 8 feet in height and provide mitigation for most noise impacts under this alternative.

Noise impacts would occur at the upper floors of multi-family units that are above the guideway where sound walls would not be effective. Noise mitigation at the receiver would be considered for those locations where sound walls are not effective and interior noise levels would exceed Department of Housing and Urban Development-recommended interior noise levels. As described in Section 7.1.1.3, Receiver Noise Mitigation, receiver mitigation could include upgraded windows and air exchange systems. Receivers to be considered would include:

- Multi-family building at 601 West Mercer Place, constructed in 1995.
- Multi-family building at 507 West Mercer Place, constructed in 1963, with upgraded sliding glass doors installed throughout in 2019.
- Multi-family building at 500 5th Avenue West, constructed in 1968.

Noise mitigation could result in slightly longer sound walls, depending on the alternative that Preferred Alternative SIB-1 connects to in the Interbay/Ballard Segment. Table 7-17 summarizes Preferred Alternative SIB-1 sound walls. With the proposed mitigation, all impacts would be mitigated.

### Table 7-17. Summary of Sound Walls for the Preferred Galer Street Station/Central Interbay Alternative (SIB-1)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| At-grade and elevated sound walls | East | 105+00 | 121+00 | 4 to 8 feet | 1,700 feet |
| Elevated sound wall | East | 129+00 | 141+00 | 4 to 6 feet | 1,200 feet |
| Elevated sound wall | West | 205+00 | 211+00 | 4 feet | 600 feet |

With Alternative SIB-2, sound walls near the downtown segment and the tunnel portal would be the same as described for Preferred Alternative SIB-1. Additional sound walls would be required along the east side of the elevated guideway for most of the alignment along 15th Avenue West, with the wall continuing into the Interbay/Ballard Segment. The estimated length is between 8,400 and 8,500 feet depending on the alternative connecting to in the Interbay/Ballard Segment, with wall heights between 4 and 8 feet.

As described in Section 7.1.1.3, noise mitigation at the receiver would be considered for those locations where sound walls are not effective and interior noise levels would exceed Department of Housing and Urban Development-recommended interior noise levels. This would include evaluation of impacts in the following areas:

- Multi-family building at 2557 14th Avenue West, constructed in 1988.
- Multi-family building at 2530 15th Avenue West, constructed in 2000.
- Multi-family building at 601 West Mercer Place, constructed in 1995.
- Multi-family building at 507 West Mercer Place, constructed in 1963, with upgraded sliding glass doors installed throughout in 2019.
- Multi-family building at 500 5th Avenue West, constructed in 1968.

Table 7-18 summarizes Alternative SIB-2 sound walls. With the proposed mitigation, all impacts would be mitigated.

### Table 7-18. Summary of Sound Walls for the Prospect Street Station/15th Avenue Alternative (SIB-2)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | West | 178+00 | 182+00 | 4 feet | 400 feet |
| Elevated sound wall | West | 201+00 | 203+00 | 4 feet | 200 feet |
| At-grade and elevated sound wall | East | 105+00 | 121+00 | 4 to 8 feet | 1,600 feet |
| Elevated sound wall | East | 126+00 | 160+00 | 4 feet | 3,000 feet |
| Elevated Sound wall | East | 166+00 | 169+00 | 6 feet | 300 feet |
| Elevated sound wall | East | 172+00 | 202+00 | 4 to 8 feet | 3,000 feet |

With Alternative SIB-3, sound walls would be required on the east side of the elevated structure between West Blaine Street and West Boston Street and also on the east side and west side of the alignment near West Dravus Street. The walls' total length would be approximately 3,400 feet, with heights of 4 to 6 feet.

With the proposed mitigation packages, all project-related light rail noise impacts would be mitigated, regardless of the alternative selected. Table 7-19 summarizes the sound walls for Alternative SIB-3.

### Table 7-19. Summary of Sound Walls for the Prospect Street Station/Central Interbay Alternative (SIB-3)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | West | 209+00 | 217+00 | 4 feet | 800 feet |
| Elevated sound wall | East | 164+00 | 182+00 | 4 to 6 feet | 1,800 feet |
| Elevated sound wall | East | 209+00 | 217+00 | 4 feet | 800 feet |

#### *Interbay/Ballard Segment*

For Preferred Alternative IBB-1a, four 4-foot-tall sound walls are proposed. When connecting to Preferred Alternative SIB-1 in the South Interbay Segment, the walls would total 5,200 feet in length. When connecting to Alternative SIB-3 in the South Interbay Segment, the length of the walls could be extended to 5,900 feet, with longer walls required south of the Salmon Bay crossing. The sound walls would start on the east side of the guideway just south of where the light rail alignment crosses over 15th Avenue West and continue to just south of West Nickerson Street. Additional sound walls would also be required on the west side of the structure between West Ruffner Street and West Nickerson Street south of Salmon Bay. On the north side of Salmon Bay, the walls would be continuous along both sides of the structure to north of Northwest 53rd Street with an additional wall on the east side of the structure starting at Northwest 50th Street, to the Ballard Station. All noise impacts would be mitigated with the new walls. Table 7-20 summarizes the Preferred Alternative IBB-1a sound walls.

### Table 7-20. Summary of Sound Walls for the Preferred Elevated 14th Avenue Alternative (IBB-1a)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall [a] | East | 228+00 | 241+00 | 4 feet | 1,300 feet |
| Elevated sound wall | West | 236+00 | 242+00 | 4 feet | 600 feet |
| Elevated sound wall | East | 279+00 | Project Terminus | 4 feet | 2,100 feet |
| Elevated sound wall | West | 288+00 | Project Terminus | 4 feet | 1,200 feet |

[a] Sound wall would be longer in length when connecting to Alternative SIB-3.

Under Option IBB-1b, the length of the walls would be extended to approximately 8,200 feet because of increased impacts between the Interbay Station/15th Avenue West and West Ruffner Street. North of Salmon Bay, the walls would be the same as provided under Preferred Alternative IBB-1a. Table 7-21 summarizes the sound walls for Option IBB-1b.

All noise impacts would be mitigated with the noise mitigation package.

With Preferred Alternative IBB-2a* and Preferred Option IBB-2b*, there would be no noise impacts and no noise mitigation is proposed.

With Alternative IBB-3, 4,700 feet of 4-foot-tall sound walls would be needed. The southern wall would be along the east side of the guideway starting at the South Interbay connection, continuing to the Interbay Station and then to just north of West Ruffin Street. On the north side of Salmon Bay, walls would be required on the west side of the guideway from Northwest 50th Street to the Ballard Station. All noise impacts would be mitigated with the new walls. Table 7-22 summarizes the Alternative IBB-3 sound walls.

### Table 7-21. Summary of Sound Walls for the Elevated 14th Avenue Alignment Option (from Prospect Street Station/15th Avenue) (IBB-1b)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | East | 202+00 | 236+00 | 4 feet | 3,400 feet |
| Elevated sound wall | West | 203+00 | 212+00 | 4 feet | 900 feet |
| Elevated sound wall | West | 229+00 | 235+00 | 4 feet | 600 feet |
| Elevated sound wall | East | 279+00 | Project Terminus | 4 feet | 2,100 feet |
| Elevated sound wall | West | 288+00 | Project Terminus | 4 feet | 1,200 feet |

### Table 7-22. Summary of Sound Walls for the Elevated 15th Avenue Alternative (IBB-3)

| Mitigation | Side of Track | Start Station | End Station | Wall Height | Wall Length |
|---|---|---|---|---|---|
| Elevated sound wall | East | 202+00 | 227+00 | 4 feet | 2,500 feet |
| Elevated sound wall | West | 202+00 | 206+00 | 4 feet | 400 feet |
| Elevated sound wall | West | 272+00 | Project Terminus | 4 feet | 1,800 feet |

## 7.2 Construction Noise Mitigation

Construction activities will be required to comply with codified sound limits. Nighttime construction would require a noise variance from the City of Seattle. Noise mitigation would likely be required for construction activities to comply with Seattle Municipal Code or variance sound level limits. These noise mitigation measures may include the following, as appropriate:

- Schedule construction activities to occur during daytime hours, or if nighttime construction is unavoidable, schedule the loudest construction activities for daytime hours.
- Install construction noise barriers between the construction site and noise-sensitive properties at tunnel portals, or other construction areas where nighttime construction or long periods of construction are anticipated.
- Use backup warning devices that are the least intrusive broadband type on all equipment or use backup observers as permitted by law.
- Use low-noise emission equipment.
- Use bed lining such as soil, gravel, or rubber in all haul truck beds.
- Monitor and maintain equipment to meet noise limits.
- Use lined or covered storage bins, conveyors, and chutes with sound-deadening material.
- Use radios for all long-range communication onsite; no yelling should be permitted except in case of an emergency.
- Limit use of public address systems.
- Remove any material or debris spilled on pavement by hand sweeping and avoid scraping type equipment or activity will be used to clean pavement surfaces.

- Limit engine idling to not more than two minutes when vehicles or equipment are not directly engaged in work activity.
- Locate stationary equipment away from noise-sensitive properties to the extent possible.
- Where practical, minimize the use of generators or use generators in sound-rated enclosures.
- Operate equipment to minimize banging, clattering, buzzing, and other annoying types of noises.
- To the extent feasible, configure the construction site in a manner that keeps noisier equipment and activities as far as practicable from noise-sensitive locations and nearby buildings.
- Provide enclosures for stationary equipment and barriers around particularly noisy areas of the site.
- Phase start-up of equipment and avoid simultaneous high-noise activities.
- Fit equipment with high-grade engine exhaust silencers and/or engine shrouds.
- Additional coordination of the construction activities and scheduling may also be necessary with sensitive land uses along the corridor, including recording studios, performance arts centers, and other highly sensitive land uses.
- Sound Transit would prepare a construction management plan in coordination with Seattle Center that would include measures to minimize impacts during larger events where construction noise could interfere with the activity.
- Sound Transit will work with the Seattle Public Library-Central Library managers to develop a set of construction noise mitigation measures based on predicted construction noise levels and the exterior-to-interior noise reduction characteristics of the library. Given the high levels of existing noise levels in this area, the windows at the library are expected to be high grade commercial windows that are not operable (do not open), which would maintain interior noise levels adequate for library operations in high noise areas. Based on this assumption, the level of noise mitigation needed during construction, which could include installation of noise-reducing curtains, appropriate scheduling information, and other construction noise mitigation like those described above, will be determined when more details on construction methods are finalized (Preferred Alternative DT-1 only).

## 7.3 Operational Vibration Mitigation

### 7.3.1 Vibration Mitigation Approaches

Several different approaches have been used by rail transit systems to reduce groundborne vibration and groundborne noise. The most common vibration mitigation measures used on light rail systems consist of placing a resilient layer between the track and the soil. Some standard approaches for vibration mitigation measures with direct-fixation track are as follows:

- High-resilience fasteners: Direct-fixation track fasteners are used to attach the rail to the concrete track slab in a tunnel or on an elevated structure. High-resilience fasteners include a soft, high-resilience element (nominal vertical static stiffness of 60,000 pounds force inch and a dynamic to static ratio of 1.4:1) to provide greater vibration isolation than standard rail fasteners in the vertical direction.

- Floating slabs: Floating slab consists of a concrete slab supported by elastomer springs on a concrete foundation. The elastomer springs could be a continuous mat or individual springs. The frequency range at which a floating slab is effective depends on the thickness of the slab and the stiffness of the springs. Floating slabs are very effective at reducing vibration levels, particularly at low frequencies. However, they are also very expensive.
- Low-impact special trackwork: The impacts of vehicle wheels over rail gaps at special trackwork locations such as turnouts and switches can increase vibration levels by up to 10 dB. If special trackwork cannot be located away from vibration-sensitive receivers, another approach is to use low-impact frogs. Spring-rail and moveable point frogs allow the flangeway gap to remain closed in the main traffic direction for revenue service trains and can almost completely reduce the vibration increase caused by special trackwork. Monoblock frogs are milled out of a single block of steel and their tolerances can be tighter than a traditional frog, which reduces the vibration increase. Flange-bearing frogs include a ramp to support the flange of the wheel to minimize banging. Well-designed monoblock and flange-bearing frogs can reduce the vibration level increase by about half compared to a standard frog.
- Alternative approaches: There are alternative vibration mitigation approaches that may be applied under specific circumstances. Examples include increasing the thickness of the concrete under the track, specifying straighter rails, and building the track on top of pile foundation systems when the track would traverse very soft sections of soil.

The typical vibration mitigation measure for ballast-and-tie track is ballast mat; however, there would be no vibration exceedances in ballast-and-tie track areas.

### 7.3.2 Proposed Operational Vibration Mitigation

Proposed vibration mitigation for all alternatives for the West Seattle Link Extension is summarized in Section 7.3.2.1 and for the Ballard Link Extension in Section 7.3.2.2. Vibration mitigation is proposed for all sensitive receivers where there would be impacts. Locations of vibration impacts are shown in the maps in Attachment N.3E. The key points of mitigation are as follows:

- High-resilience fasteners are proposed for most vibration and groundborne noise exceedances for direct-fixation track for tunnels or elevated structure.
- Low-impact frogs are proposed at locations where exceedances are predicted as a result of amplification from special trackwork. Moveable point frogs and monoblock frogs are examples of low-impact frogs that provide different levels of vibration reduction. Moveable point frogs are proposed as a low-impact frog where the projected levels exceed the limit by more than 5 dB. Monoblock frogs are proposed as a low-impact frog where the projected levels exceed the limit by less than 5 dB. Low-impact frogs with similar performance could be used in place of the proposed frog.
- Continuous-mat floating slabs are proposed where impacts are predicted at highly sensitive Category 1 land uses where high-resilience fasteners would not provide sufficient mitigation.

If pile-driving is planned within 100 feet of structures, alternative methods of pile installation or vibration monitoring would be considered. Pre-construction surveys would be conducted to document the existing conditions of buildings and the contractor would be responsible for repairing damage due to the project. During final design, all impacts and proposed mitigation measures would be reviewed for verification.

During final design, the vibration analysis will be refined before finalizing mitigation measures. Increasing the distance between the track and the closest sensitive receiver by removing buildings may eliminate the need for track-based mitigation. Site-specific vibration measurements at locations where vibration exceedances are predicted could also be used to refine the predicted vibration levels and mitigation recommendations.

#### 7.3.2.1 West Seattle Link Extension

The West Seattle Link Extension would likely use high-resilience fasteners and low-impact frogs to mitigate vibration impacts. The following sections describe the mitigation recommendations for each segment. High-resilience fasteners are used to connect the rail to the track slab and are softer than traditional fasteners, which allows them to absorb some of the vibration that is transmitted from the rail into the ground. The lifespan is similar to traditional fasteners, and no special maintenance is required. A frog is a component of special trackwork where there is a gap in the rail to allow one rail to cross another. The impacts of vehicle wheels over rail gaps can cause high levels of noise and vibration. Low-impact frogs are designed to reduce the impact forces at the gap, and as a result produce lower noise and vibration levels.

***SODO Segment***

There would be no vibration impacts for any alternatives in the SODO Segment; therefore, no vibration mitigation measures are proposed.

***Duwamish Segment***

There would be no vibration impacts for any alternatives in the Duwamish Segment; therefore, no vibration mitigation measures are proposed.

***Delridge Segment***

There would be no vibration impacts for Option DEL-1b, Preferred Alternative DEL-2a*, Option DEL-2b*, and Alternative DEL-4*. Impacts and proposed mitigation for the following alternatives would be as follows:

- Preferred Alternative DEL-1a would have a vibration impact at multi-family residential buildings east of the Delridge Station. The proposed mitigation is high-resilience fasteners.
- Alternative DEL-3 would have a vibration impact at one multi-family building near the curve at the intersection of Southwest Genesee Street and Southwest Avalon Way. The proposed mitigation measure is high-resilience fasteners.
- Alternative DEL-5 would have vibration impacts at the multi-family building at the intersection of Southwest Dakota Street and 30th Avenue Southwest. The proposed mitigation measure is high-resilience fasteners.
- For Alternative DEL-6*, there would be vibration impacts at the buildings near the intersection of Yancy Street and 32nd Avenue Southwest and at a building near the retained cut portion of the alignment on 32nd Avenue Southwest. The proposed mitigation measure is high-resilience fasteners.

Table 7-23 through Table 7-26 summarize the proposed mitigation measures for the Delridge Segment Build Alternatives with vibration impacts.

**Table 7-23. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Preferred Dakota Street Station Alternative (DEL-1a)**

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| DEL-1a | WS1094 | 12 | Reassessment (exceeds by less than 1 dB)/High-resilience direct-fixation fasteners | SB-W 305+00 | SB-W 309+00 | 400 |

**Table 7-24. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Delridge Way Station Alternative (DEL-3)**

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| DEL-3 | WS1094 | 12 | Reassessment (exceeds by less than 1 dB)/High-resilience direct-fixation fasteners | SB-W 305+00 | SB-W 309+00 | 400 |

**Table 7-25. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Andover Street Station Alternative (DEL-5)**

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| DEL-5 | WS82100 | 9 | High-resilience direct-fixation fasteners | SB-W 294+00 | SB-W 298+00 | 400 |

**Table 7-26. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Andover Street Station Lower Height Alternative (DEL-6)***

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| DEL-6* | WS7154, WS7120, WS7117 | 3 | High-resilience direct-fixation fasteners | SB-W 294+00 | SB-W 305+00 | 1,100 |

### West Seattle Junction Segment

There would be no vibration impacts for Preferred Alternative WSJ-2. Impacts and proposed mitigation for the remaining West Seattle Junction Segment Build Alternatives would be as follows:

- For Preferred Alternative WSJ-1, there would be groundborne noise impacts at parcels close to a crossover. The proposed mitigation is a low-impact frog, such as a monoblock frog.
- For Preferred Alternative WSJ-3a*, there would be groundborne noise impacts at residences east of the Avalon Station where the tunnel would be shallower and at residences near the curve between Southwest Oregon Street and Southwest Alaska Street. The proposed mitigation measure in this area is high-resilience fasteners. Site-specific vibration propagation data at residences near Avalon Station may show that mitigation is not necessary, because most of the projected levels exceed the criteria by less than 2 dB, which is less than the safety factor applied in the prediction model. There would also be a groundborne noise impact near the special trackwork south of the Alaska Junction Station. The proposed mitigation is a low-impact frog, such as a moveable point frog. Site-specific vibration propagation data may show that a monoblock or flange-bearing frog provides sufficient mitigation.
- The proposed mitigation for Preferred Option WSJ-3b* is similar to the recommendations for Preferred Alternative WSJ-3a*. Groundborne noise impacts would occur at residences east of Avalon Station where the tunnel would be shallower. The proposed mitigation measure in this area is high-resilience fasteners. There would also be groundborne noise impacts at residences on 42nd Avenue Southwest near the crossover south of the Alaska Junction Station. The proposed mitigation is a low-impact frog, such as a moveable point frog. The projected groundborne noise levels at two of the buildings exceeds 10 dB, so site-specific vibration propagation testing is proposed to verify additional mitigation measures are not necessary.
- For Alternative WSJ-4*, here would also be groundborne noise impacts near the crossover south of the Alaska Junction Station and at the receivers north of the same station where the tunnel depth is shallower. The proposed mitigation for the special trackwork is a low-impact frog, such as a moveable point frog. The proposed mitigation for the other groundborne noise impacts is high-resilience fasteners.
- For Alternative WSJ-5*, there would be groundborne noise impact east of Avalon Station. There would also be groundborne noise impacts near the crossover south of the Alaska Junction Station and at the receivers between the Alaska Junction Station and Avalon Station where the tunnel would be shallower compared to some of the other alternatives. The proposed mitigation for the special trackwork is a low-impact frog, such as a moveable point frog or spring-rail frog. The proposed mitigation for the other impacts is high-resilience fasteners.

Tables 7-27 through 7-31 summarize, by alternative, the proposed mitigation measures for the West Seattle Junction Segment.

### Table 7-27. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Preferred Elevated 41st/42nd Avenue Station Alternative (WSJ-1)

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| WSJ-1 | WS5114, WS5115, WS6391, WS6390, WS6387 | 7 | Low-impact frog, monoblock | SB-W 336+00 | SB-W 336+00 | Not applicable |

### Table 7-28. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Preferred Tunnel 41st Avenue Station Alternative (WSJ-3a)*

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| WSJ-3a* (*when connecting to DEL-2a* only*) | WS5167, WS61000, WS60900, WS2422, WS2420, WS2418, WS2416, WS60800 | 161 [a] | High-resilience direct-fixation fasteners | SB-W 306+00 | SB-W 315+00 | 900 |
| WSJ-3a* | WS2280, WS2282, WS2284, WS2286, WS2290, WS2264, WS2268 | 14 | High-resilience direct-fixation fasteners | SB-W 336+00 | SB-W 343+00 | 700 |
| WSJ-3a* | WS1010, WS2204, WS2210, WS2208, WS2206 | 24 | Low-impact frog, moveable point | SB-W 350+00 | SB-W 350+00 | Not applicable |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

[a] Preferred Alternative WSJ-3a* with connection to Preferred Alternative DEL-2a* would have impacts at the same 24 units as the original Preferred Alternative WSJ-3a*, with 198 additional units for a total of 242 impacted units.

### Table 7-29. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Preferred Tunnel 42nd Avenue Station Option (WSJ-3b)*

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| WSJ-3b* (*when connecting to DEL-2a* only*) | WS5167, WS61000, WS60900, WS2422, WS2420, WS2418, WS2416, WS60800 | 161 | High-resilience direct-fixation fasteners | SB-W 306+00 | SB-W 315+00 | 900 |
| WSJ-3b* | WS2158, WS1006 | 269 | Low-impact frog, moveable point | SB-W 354+00 | SB-W 354+00 | Not applicable |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

### Table 7-30. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Short Tunnel 41st Avenue Station Alternative (WSJ-4)*

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| WSJ-4* | WS6555, WS6554, WS6545, WS5122, WS5123, WS5125, WS5126, WS5130, WS5131, WS5132, WS5133, WS5127, WS5124, WS6395, WS6394, WS6383, WS6382, WS6381, WS6380, WS6390, WS6392, WS6393, WS6377, WS6376, WS6375, WS6372, WS2262, WS2272, | 124 | High-resilience direct-fixation fasteners | SB-W 329+00 | SB-W 343+00 | 1400 |

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| | WS2264, WS2266, WS2273, WS2276, WS2278, WS6374, WS6391, WS5116, WS51000 | | | | | |
| WSJ-4* | WS1010, WS2218, WS2220, WS2222, WS2224, WS2226, WS2228, WS2232, WS2234, WS6115 | 29 | Low-impact frog Moveable-point | SB-W 349+00 | SB-W 349+00 | Not applicable |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

### Table 7-31. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Medium Tunnel 41st Avenue Station Alternative (WSJ-5)*

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| WSJ-5* | WS5195, WS5196, WS5197, WS5200, WS5201 | 5 | High-resilience direct-fixation fasteners | SB-W 303+00 | SB-W 308+00 | 500 |
| WSJ-5* | WS6586, WS6585, WS6582, WS6581, WS6580, WS6574, WS6575, WS6576, WS6564, WS6563, WS6562, WS6561, WS6552, WS6551, WS6547, | 164 | High-resilience direct-fixation fasteners | SB-W 318+00 | SB-W 340+00 | 2,200 |

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| | WS6550, WS2354, WS6542, WS6541, WS6540, WS6537, WS6536, WS2330, WS2332, WS2334, WS2336, WS2320, WS2318, WS3004, WS6385, WS51000, WS2262, WS2280, WS2282, WS2284, WS2286, WS2290, WS2272, WS2264, WS2268, WS2276, WS2246, WS2248, WS2250 | | | | | |
| WSJ-5* | WS1010, WS2204, WS2210, WS6113, WS2208, WS2206, WS2202, WS2200 | 30 | Low-impact frog, moveable point | SB-W 345+00 | SB-W 345+00 | Not applicable |
| WSJ-5* | WS1010, WS6192, WS2196, WS2204, WS2210, WS6113, WS2208, WS2206, WS2202, WS2200, WS2190, WS2188, WS2194, WS2192 | 36 | High-resilience direct-fixation fasteners | SB-W 340+00 | SB-W 352+00 | 1,200 |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement, some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

#### 7.3.2.2 Ballard Link Extension

The Ballard Link Extension would likely use high-resilience fasteners and low-impact frogs to mitigate vibration impacts. The following sections describe the mitigation recommendations for each segment. High-resilience fasteners are used to connect the rail to the track slab and are softer than traditional fasteners, which allows them to absorb some of the vibration that is transmitted from the rail into the ground. The lifespan is similar to traditional fasteners, and no special maintenance is required. A frog is a component of special trackwork where there is a gap in the rail to allow one rail to cross another. The impacts of vehicle wheels over rail gaps can cause high levels of noise and vibration. Low-impact frogs are designed to reduce the impact forces at the gap, and as a result produce lower noise and vibration levels.

##### *SODO Segment*

There would be no vibration impacts for any alternatives in the SODO Segment; therefore, no vibration mitigation measures are proposed.

##### *Chinatown-International District Segment*

There would be no vibration impacts for Alternative CID-1a*, Option CID-1b*, or Option CID-2b, so no vibration mitigation measures are proposed. Impacts and proposed mitigation for Alternative CID-2a would be as follows:

- Alternative CID-2a would a have groundborne noise impact at different buildings near the International District/Chinatown Station depending on the connection option or tunnel type. The proposed mitigation measure for Alternative CID-2a impact is high-resilience fasteners.

Table 7-32 summarizes the proposed mitigation measures for Alternative CID-2a.

**Table 7-32. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the 5th Avenue Shallow Alternative (CID-2a)**

| Alternative | Sound Transit Right-of-way I.D. | Dwelling Units | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| CID-2a [a] | BD50000, BD5014, BD800000 | 24-74 | High-resilience direct-fixation fasteners | 60+0 | 72+00 | 550 to 1,100 |
| CID-2a (*with connection to DT-2 only*) | BD60100 | 50 [b] | High-resilience direct-fixation fasteners | 51+50 | 55+50 | 400 |

[a] Range of mitigation depends on construction method. Specific properties affected, and length and location of mitigation would vary by construction method.

[b] Alternative CID-2a with connection to Alternative DT-2 would have impacts at the same 24 units as the original Alternative CID-2a, with 50 additional units for a total of 74 impacted units.

##### *Downtown Segment*

Impacts and proposed mitigation for the Downtown Segment Build Alternatives would be as follows:

- Preferred Alternative DT-1 would have vibration and groundborne noise impacts at recording studios and performance spaces in Seattle Center. The proposed mitigation measure for the impacts at Seattle Center is high-resilience fasteners.

- Alternative DT-2 would have vibration impacts at two buildings at the University of Washington South Lake Union Medical Campus with highly sensitive research spaces. The proposed mitigation measure for the impacts should be finalized during a future design stage when site-specific vibration propagation data can be collected. The predicted vibration levels at these locations exceed the criteria by more than 5 dB at 40 hertz and above, assuming little to no vibration attenuation provided by the building. The predicted vibration levels at these locations exceed the criteria by less than 5 dB at 40 hertz and above, when assuming some building attenuation. The following mitigation measures are proposed for different levels of exceedance:
    - If the predicted exceedance is greater than or equal to 5 dB at 40 hertz and above, a continuous-mat floating slab should be installed. The resonant frequency and insertion loss of the continuous-mat floating slab should be designed based on site-specific measured data. If no measured data are available, the continuous-mat floating slab should be designed to achieve at least 12 dB of reduction at 40 hertz and above at the University of Washington South Lake Union Medical Campus.
    - If the predicted exceedance is less than 5 dB at 40 hertz and above, high-resilience fasteners should be installed.

  Alternative DT-2 would also have groundborne noise impacts at residences near a crossover west of the Seattle Center Station. A low-impact frog is proposed as a mitigation measure.

Tables 7-33 and 7-34 summarize the proposed mitigation measures for the Downtown Segment. As noted above, the mitigation for the predicted vibration impacts in South Lake Union for Alternative DT-2 should be finalized in a future design phase with site-specific vibration propagation measurements. Additional information on the prediction assumptions and proposed mitigation measures for these sensitive receivers are presented in Attachment N.3H.

### Table 7-33. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Preferred 5th Avenue/Harrison Street Alternative (DT-1)

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| DT-1 | BD1222, BD10144 | 4 | High-resilience direct-fixation fasteners | NB-B 79+00 | NB-B 88+00 | 900 |

### Table 7-34. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the 6th Avenue/Mercer Street Alternative (DT-2)

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| DT-2 | BD3112, BD1194 | 2 | Continuous-mat floating slab or high-resilience direct-fixation fasteners | NB-B 56+00 | NB-B 64+00 | 800 |
| DT-2 | BD61500 | 34 | Low-impact frog - monoblock | NB-B 101+00 | NB-B 101+00 | Not applicable |

### *South Interbay Segment*

There would be no vibration impacts for Alternative SIB-3, so no vibration mitigation measures are proposed. Impacts and proposed mitigation for the remaining South Interbay Segment Build Alternatives would be as follows:

- For Preferred Alternative SIB-1, there would be groundborne noise impacts at the multi-family residences near the tunnel along West Republican Street. The proposed mitigation measure is high-resilience fasteners. Near the elevated portion, there would be vibration impacts at residences near a crossover and at a residential building very close to the new alignment where the track structure curves onto Elliott Avenue West. The proposed mitigation measure at the special trackwork is a low-impact frog such as a monoblock frog. The proposed mitigation at the other building is high-resilience fasteners.
- For Alternative SIB-2, the proposed mitigation measures for Category 2 land uses are the same as for Preferred Alternative SIB-1. High-resilience fasteners are also the proposed mitigation measure for the impact at Victory Studios.

Tables 7-35 and 7-36 summarize the proposed mitigation measures for the South Interbay Segment.

### Table 7-35. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Preferred Galer Street Station/Central Interbay Alternative (SIB-1)

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| SIB-1 | BD1244, BD2168 | 203 | High-resilience direct-fixation fasteners | NB-B 95+50 | NB-B 101+00 | 550 |
| SIB-1 | BD62300 | 25 [a] | High-resilience direct-fixation fasteners | NB-B 106+00 | NB-B 110+50 | 450 |
| SIB-1 | BD1296, BD1294, BD1292, BD5260, BD5257 | 123 | Low-impact frog – moveable point | NB-B 115+00 | NB-B 115+00 | Not applicable |

[a] Preferred Alternative SIB-1 with connection to Preferred Alternative IBB-1a would have impacts at the same 326 units as the original Preferred Alternative SIB-1, with 25 additional units for a total of 351 impacted units.

**Table 7-36. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Prospect Street Station/15th Avenue Alternative (SIB-2)**

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| SIB-2 | BD1244, BD2168 | 203 | High-resilience direct-fixation fastener | NB-B 95+50 | NB-B 101+00 | 900 |
| SIB-2 | BD62300 | 25 | High-resilience direct-fixation fastener | NB-B 106+00 | NB-B 110+50 | 450 |
| SIB-2 | BD1296 | 123 | Low-impact frog – moveable point | NB-B 115+00 | NB-B 115+00 | Not applicable |
| SIB-2 | BD1372 | 1 | High-resilience direct-fixation fastener | NB-B 177+00 | NB-B 181+00 | 400 |

### *Interbay/Ballard Segment*

There would be no vibration impacts for Alternative IBB-3, so no vibration mitigation measures are proposed. Impacts and proposed mitigation for the remaining Interbay/Ballard Segment Build Alternatives would be as follows:

- For Preferred Alternative IBB-1a, high-resilience fasteners are proposed for the vibration impacts. A reassessment of the projected vibration levels during final design may show that vibration mitigation is not needed where the predicted vibration level exceeds by a small amount.
- For Option IBB-1b, high-resilience fasteners are also proposed to mitigate the vibration impacts. For Option IBB-1b, the impact north of Salmon Bay would be the same as Preferred Alternative IBB-1a.
- For Preferred Alternative IBB-2a*, there would be a groundborne noise impact at the Maritime Academy on the north shore of Salmon Bay. The proposed mitigation measure is high-resilience fasteners. There would also be a vibration impact at one building near a crossover. The proposed mitigation is a low-impact frog, such as a monoblock frog.
- For Preferred Option IBB-2b*, there would be groundborne noise impact at the Maritime Academy on the north shore of Salmon Bay. The proposed mitigation measure is high-resilience fasteners.

Tables 7-37 through 7-40 summarize the proposed mitigation measures for the Interbay/Ballard Segment.

### Table 7-37. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for Preferred Elevated 14th Avenue Alternative (IBB-1a)

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| IBB-1a | BD2384 [a] | 4 | Reassessment (exceeds by less than 1 dB)/High-resilience direct-fixation fasteners | NB-B 233+50 | NB-B 237+00 | 400 |
| IBB-1a | BD3344 | 24 | High-resilience direct-fixation fasteners | NB-B 237+50 | NB-B 242+00 | 450 |
| IBB-1a | BD3368 | 11 | High-resilience direct-fixation fasteners | NB-B 278+50 | NB-B 281+50 | 400 |

[a] The parcel would not be an impact when connecting to Alternative SIB-3, and no mitigation would be necessary.

### Table 7-38. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for the Elevated 14th Avenue Alignment Option (from Prospect Street Station/15th Avenue) (IBB-1b)

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| IBB-1b | BD63000 | 8 | High-resilience direct-fixation fasteners | NB-B 217+00 | NB-B 221+00 | 400 |
| IBB-1b | BD3344 | 24 | High-resilience direct-fixation fasteners | NB-B 230+00 | NB-B 234+00 | 400 |
| IBB-1b | BD3368 | 11 | High-resilience direct-fixation fasteners | NB-B 278+50 | NB-B 281+50 | 400 |

### Table 7-39. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for Preferred Tunnel 14th Avenue Alternative (IBB-2a)*

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| IBB-2a* | BD6392 | 1 | Low-impact frog - monoblock | NB-B 287+00 | NB-B 287+00 | Not applicable |
| IBB-2a* | BD2398 | 1 | High-resilience direct-fixation fasteners | NB-B 260+00 | NB-B 264+00 | 400 |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

**Table 7-40. Summary of Vibration and Groundborne Noise Impacts and Proposed Mitigation for Preferred Tunnel 15th Avenue Station Option (IBB-2b)***

| Alternative | Sound Transit Right-of-way I.D. | Number of Impacts | Proposed Mitigation | Start Station | End Station | Approximate Length of Mitigation (feet) |
|---|---|---|---|---|---|---|
| IBB-2b* | BD2398 | 1 | High-resilience direct-fixation fasteners | NB-B 260+00 | NB-B 264+00 | 400 |

* As described in the introduction to Chapter 2, Alternatives Considered, of the Draft Environmental Impact Statement, at the time the Sound Transit Board identified alternatives for study in the Draft Environmental Impact Statement some alternatives were anticipated to require third-party funding based on early cost estimates. The asterisk identifies these alternatives and the alternatives that would only connect to these alternatives in adjacent segments.

## 7.4 Construction Vibration Mitigation

The primary means of mitigating vibration from construction activities is to require the contractor to prepare a detailed Construction Vibration Control Plan. The contractor will prepare the plan in conjunction with the contractor's specific equipment and methods of construction. Key elements of a plan are as follows:

- Contractor's specific equipment types.
- Schedule and methods of construction.
- Identification of all Category 1 and special-use buildings near construction sites.
- Methods for projecting construction vibration levels.
- Construction vibration limits.
- Specific vibration-control measures where predicted levels exceed the limits.
- Methods for responding to community complaints.

### 7.4.1 Potential Surface Construction Vibration Mitigation

Construction should be carried out in compliance with Sound Transit specifications and all applicable local regulations. Specific construction vibration mitigation measures should be developed during the design phase when more detailed construction means and methods information is available. The following mitigation measures should be applied as needed to minimize construction vibration impacts:

- **Pre-construction survey:** Prior to the start of construction, a survey of buildings including inspection and photographs of building foundations should be completed near construction areas. All potentially fragile structures within 200 feet should be included.
- **Construction timing:** Nighttime construction in residential neighborhoods should be avoided and businesses coordinated with to avoid interfering with sensitive daytime activities. Additional coordination of the construction activities and scheduling may also be necessary with sensitive land uses along the corridor, including recording studios, performance arts centers, and other highly sensitive land uses. Local ordinances should be followed unless variances are obtained.
- **Equipment location:** Stationary construction equipment should be as far as possible from vibration-sensitive sites.
- **Continuous vibration monitoring:** Monitoring can be implemented at particularly sensitive receivers, such as Category 1 or special-use buildings with low vibration limits.

- **Alternative construction methods:** Alternative construction methods should be used, where practical, to minimize the use of impact and vibratory equipment (e.g., pile-drivers and compactors).

### 7.4.2 Potential Tunneling Vibration Mitigation

As discussed in Section 6.4.1, there may be vibration impacts from the supply train and projected groundborne noise impact from the supply train and tunnel boring machine cutterhead at highly sensitive buildings for both Downtown Segment alternatives. The following present options for reducing vibration from tunneling activities.

Tunnel boring machine cutterhead vibration is inherent to the operation of the machine, and the range of vibration experienced at sensitive receivers is largely dependent on the soil conditions at the cutterhead. Unfortunately, no mitigation measures exist to reduce tunnel boring machine cutterhead vibration levels, but vibration from the cutterhead would be temporary as the tunnel boring machine advances past the sensitive land uses (roughly 6 days for each bore as discussed in Section 6.4.1). Vibration monitoring and coordination with Category 1 and special-use buildings while the tunnel boring machine is passing can be used to minimize interruption of operations.

The vibration caused by the thrust jack retraction is not predicted to create damage or annoyance impacts and no mitigation is required. If complaints were to occur, they could be addressed by modifying the thrust jacks so that the cylinders are retracted slowly and eliminate the hard stop.

Options for mitigating vibration levels from the supply train include:

- Reducing the operating speed. Reducing the speed of the train from 12 miles per hour to 6 miles per hour provides a reduction in 1/3-octave band vibration levels from 2 to 7 VdB.
- Smoothing the running surface.
- Reducing the size of gaps between rail sections.
- Adding a rubber pad between the ties and the tunnel invert can also help reduce vibration levels from the supply train.
- Using rubber tire supply train vehicles, which generally reduce vibration to levels below the existing ambient, particularly at frequencies above 10 hertz.

A comparison of the vibration attenuation provided by these supply train mitigation methods is provided in Figure 7-1. The attenuation provided by the rubber-tire-vehicle above 10 hertz is estimated assuming vibration levels of 35 VdB, because the measured data above 10 hertz were below the ambient level. Supply train mitigation should be applied in the Downtown Segment, where vibration impact is predicted at several highly sensitive land uses. Figure 7-2 shows the maximum vibration levels measured from the rubber tire vehicles that were used during boring of the University Link Extension tunnel. No data are available above 10 hertz, suggesting that the measured levels were at or below the existing ambient vibration at higher frequencies. As shown on Figure 7-2, vibration levels from rubber tire vehicles are well below the Category 2 threshold and are below the V.C.-E threshold (very demanding vibration criterion for extremely vibration-sensitive equipment) at most frequencies. Only Category 1 receivers that are highly sensitive to low-frequency vibration have the potential to be impacted by the operation of rubber tire vehicles during tunneling. Finally, in some locations, additional coordination of the construction activities and scheduling may be necessary to minimize impacts at sensitive land uses along the corridor, including recording studios, performance arts centers, and other highly sensitive land uses.

**Figure 7-1. Attenuation Levels Provided by Supply Train Mitigation Methods**

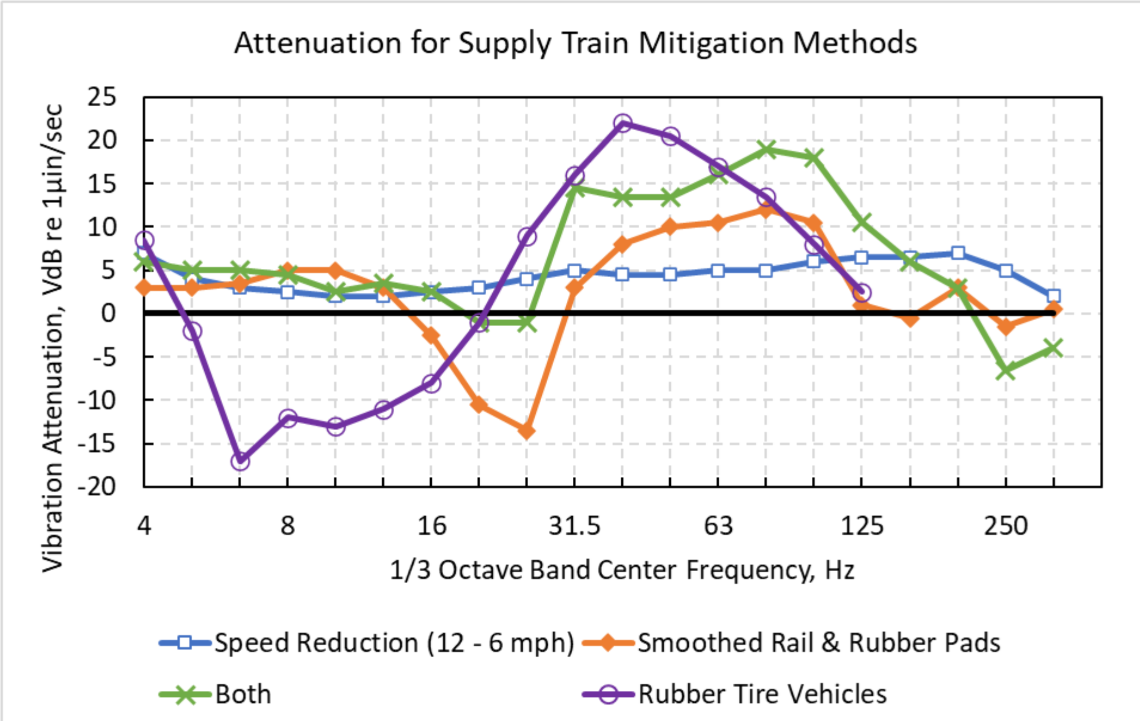
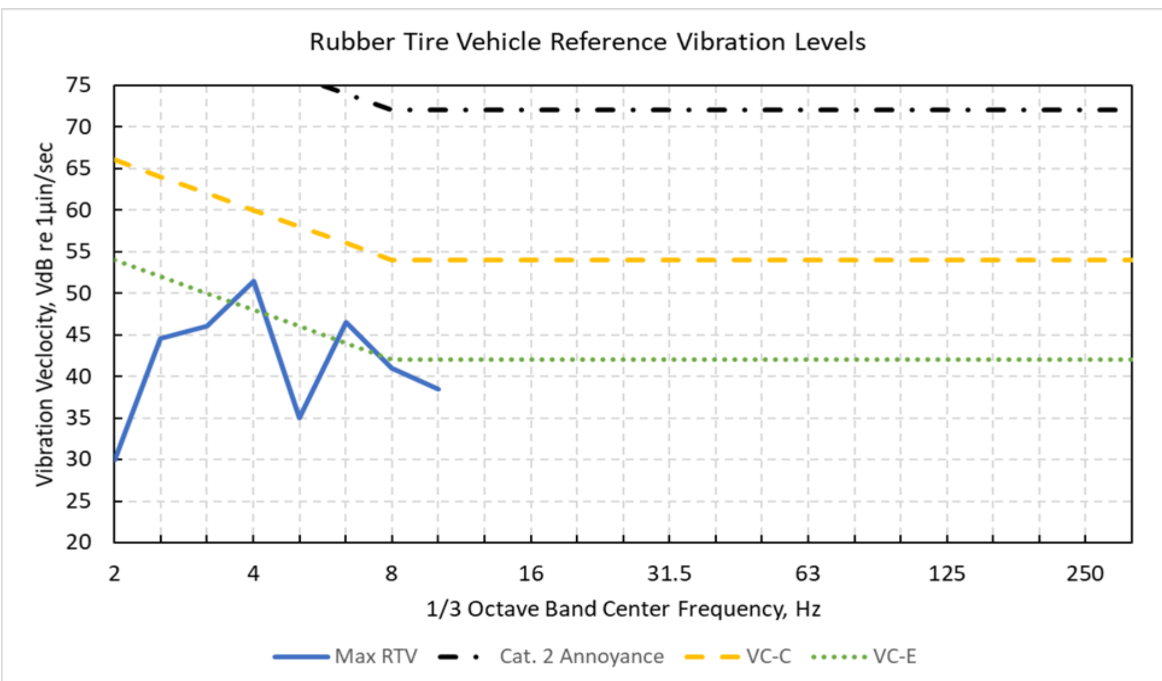



**Figure 7-2. Reference Vibration Levels for Rubber Tire Supply Vehicles**



This page is intentionally left blank.

# 8 REFERENCES

Bergen, T.F. and T.J. Schwarz. 2015. *Tunnel Construction Vibration Predictions for University of Washington Central Campus*. Report prepared for McMillen Jacobs Associates. August 28.

Bergen, T., D. Watry, and D. Adams. 2012. *Northgate Link Tunneling and Surface Construction Vibration Predictions at the University of Washington Campus*. Report prepared for Jacobs Associates. September 6.

Federal Highway Administration. 2011. *Highway Traffic Noise: Analysis and Abatement Guidance*. FHWA-HEP-10-025. December. Original June 2010 and revised December 2010. https://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/analysis_and_abatement_guidance/revguidance.pdf. December.

Federal Transit Administration (FTA). 2018. *Transit Noise and Vibration Impact Assessment* (FTA Guidance Manual). FTA Report No. 0123. Office of Planning and Environment. September.

McKenna, S. 2011. A Study of Building Amplification from Groundborne Vibration. Presented at Noise-Con 2011, Portland, OR. July 25 through 27.

Rajaram, S. 2019. *2019 Reference Noise and Vibration Levels for Link Light Rail Projects.* Sound Transit Notice to Designer TU-1004. Seattle, WA.

Rajaram, S. and S. Wolf. 2014. *Final Vibration Measurements of Existing Sound Transit Trains*. Report prepared for Parsons Brinckerhoff and HJH. May 22.

Sound Transit. 2004. Motion M2004-08: Sound Transit Link Noise Mitigation Policy. Seattle, WA. https://www.soundtransit.org/st_sharepoint/download/sites/PRDA/FinalRecords/2004/Motion%20M2004-08.pdf. February.

Sound Transit. 2016. *Sound Transit 3, The Regional Transit System Plan for Central Puget Sound* (ST3). Adopted June 23, 2016. http://soundtransit3.org/document-library.

Sound Transit. 2019. *2019 Reference Noise and Vibration Levels for Link Light Rail Projects.* November.

Sound Transit. 2020. *Design Criteria Manual, Revision 5*. February.

Zapfe, J., H. Saurenman, and S. Fidell. 2009. *Groundborne Noise and Vibration in Buildings Caused by Rail Transit*. Prepared for the Transit Cooperative Research Program, Transportation Research Board of the National Academies. Project D-12. November.

**GIS References**

City of Seattle. 2019. Seattle Geo Data. Data for city boundaries, zoning, land use (existing and future), Seattle transportation network, streetcar line, parks resources, railroad, storm sewer, utilities (stormwater), environmental considerations application, shorelines and related infrastructure. https://data-seattlecitygis.opendata.arcgis.com/.

King County. 2019. King County Open Data Portal. Data for aerial imagery, streets, tax parcels, building footprint, zoning, census data, city boundaries, parks and open spaces, transit facilities, slopes, wetlands, wellhead protection areas, streams, waterbodies. https://data.kingcounty.gov/.

This page is intentionally left blank.

# APPENDICES

Appendices for this technical report are provided on the attached flash drive.

This page is intentionally left blank.