SOUNDTRANSIT
RIDE THE WAVE

Lynnwood Link Extension

Technical Report

Noise and Vibration

401 South Jackson Street
Seattle, WA 98104-2826

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North Corridor Transit Partners
PARAMETRIX + PARSONS BRINCKERHOFF

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D Vibration Impacts by Build Alternative
E Vibration Propagation Data
F Maps of Noise Wall Mitigation Locations

Acronyms and Abbreviations

ANSI	American National Standards Institute
BVR	Building Vibration Response
CFR	Code of Federal Regulations
dB	decibel
dBA	unit of A-weighted sound level in decibels
DNR	Department of Natural Resources
EDNA	Environmental Designation for Noise Abatement
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FDL	Force Density Level
FHWA	Federal Highway Administration
FST	floating slab track
FTA	Federal Transit Administration
GIS	geographic information system
HUD	Department of Housing and Urban Development
HVAC	heating, ventilation, and air conditioning
Hz	Hertz
I-5	Interstate 5
Ldn	24-hour, time-averaged, A-weighted sound level (day-night)
Leq	equivalent continuous sound level
Lmax or Lm	maximum noise level
Lnn	the sound level exceeded "n" percent of the time
LSR	Line Source Response (equivalent to Line Source Transfer Mobility, TMline)
Lv	vibration velocity level
mph	miles per hour
NAC	Noise Abatement Criteria
NEPA	National Environmental Policy Act
NIST	National Institute of Standards and Technology

PPV	peak particle velocity
PSR	Point Source Response
rms	root mean square
SEPA	State Environmental Act
Sound Transit	Central Puget Sound Regional Transit Authority
SR	State Route
ST2	Sound Transit 2
TDA	tire-derived aggregate
V	velocity
VdB	decibel unit for vibration level
VTA	Santa Clara Valley Transportation Authority
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation

Part 1: Noise

1 INTRODUCTION AND SUMMARY

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

Section 1 of this report describes the background and results of the assessment. Section 2 discusses environmental noise basics, and Section 3 describes the existing noise conditions and measurement results. The criteria and methods used to assess noise impacts are presented in Sections 4 and 5, respectively. Future No Build noise conditions projections are described in Section 6. Section 7 summarizes the impact assessment, and Section 8 outlines potential mitigation measures. Attachment A includes noise monitoring details; Attachment B provides detailed noise impact assessment data; and Attachment C presents noise impact maps by affected alternative.

2 ENVIRONMENTAL NOISE BASICS

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

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

Sound is measured using a sound-level meter with a microphone designed to respond accurately to all audible frequencies. However, the human hearing system does not respond equally to all frequencies. Low-frequency sounds below about 400 Hz are progressively and severely attenuated, as are high frequencies above 10,000 Hz. To approximate the way humans interpret sound, a filter circuit with frequency characteristics similar to the human hearing mechanism is built into sound-level meters. Measurements with this filter enacted are called A-weighted sound levels, expressed in A-weighted decibels (dBA). Community noise is usually characterized in terms of the A-weighted sound level. Figure 2-1 illustrates the A-weighted levels of common sounds.

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.

Another characteristic of environmental noise is that it is constantly changing. The noise level increase when a train passes is an example of a short-term change. The lower average noise levels occur during nighttime hours, when activities are at a minimum, and higher noise levels during daytime hours are caused by daily patterns of noise-level fluctuation. The instantaneous A-weighted sound level is insufficient to describe the overall acoustic "environment." Thus, it is common practice to condense the fluctuating noise levels into a single number, called the "equivalent" sound level (Leq). Leq can be thought of as the steady sound level that represents the same sound energy as the varying sound levels over a specified time period (typically 1 hour or 24 hours). Often the Leq values over a 24-hour period are used to calculate cumulative noise exposure in terms of the day-night equivalent sound level (Ldn, also abbreviated DNL), which is

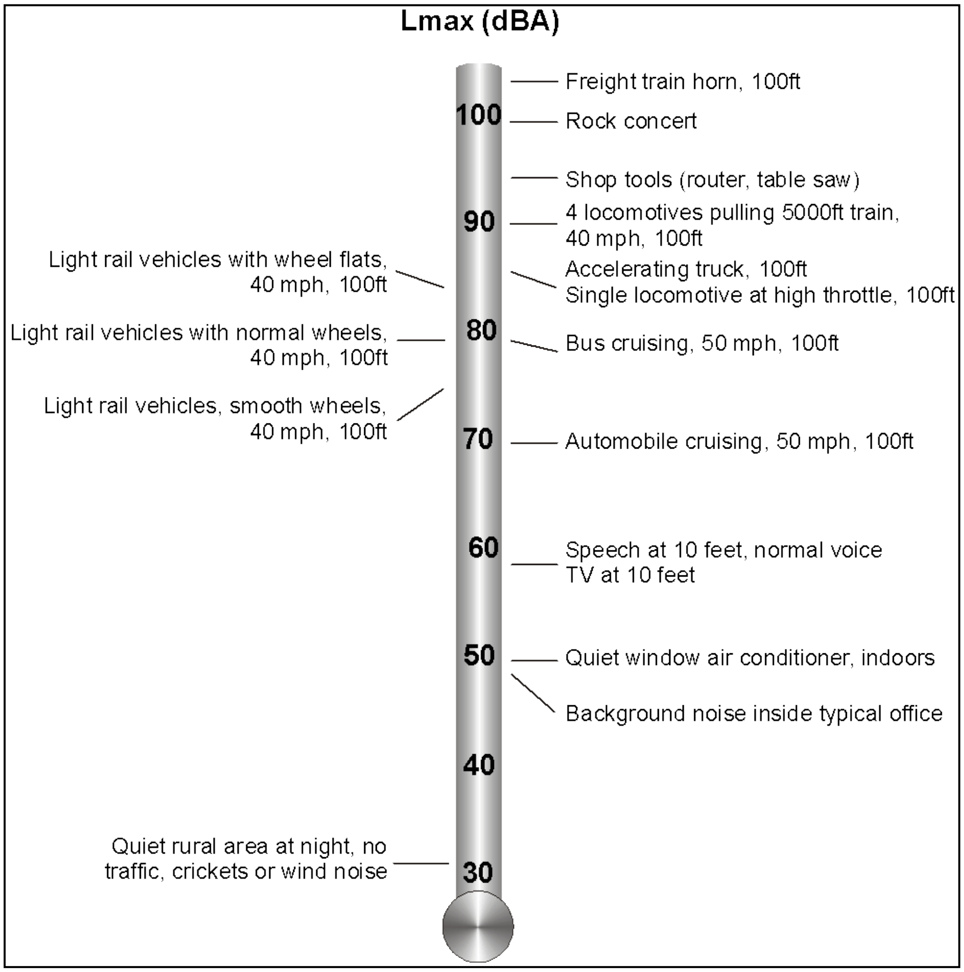


Figure 2-1. Comparison of Various Noise Levels

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 pm to 7 am). 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. Figure 2-2 defines typical community noise levels in terms of Ldn. Most urban and suburban neighborhoods are usually in the range of Ldn 50 dBA to 70 dBA. An Ldn of 70 dBA is a relatively noisy environment that might be found at buildings on a busy surface street, close to a freeway, or near a busy airport and would usually be considered unacceptable for residential land use without special measures taken to enhance outdoor-indoor sound insulation. Residential neighborhoods that are not near major sound sources are usually in the range of Ldn 55 dBA to 60 dBA. If there is a freeway or moderately busy arterial nearby, or any nighttime noise, Ldn is usually in the range of 60 to 65 dBA.

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

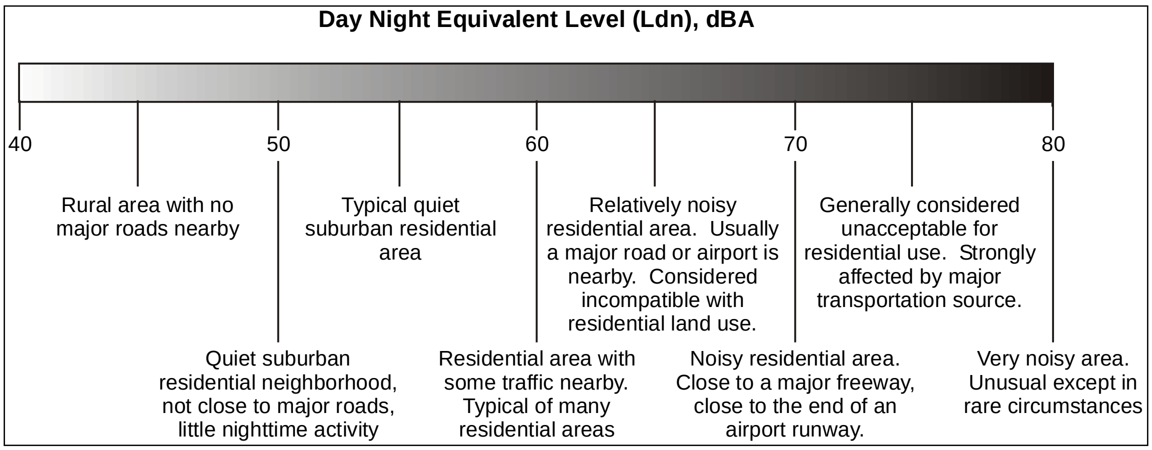


Figure 2-2. Examples of Typical Outdoor Noise Exposure

The Washington Administrative Code (WAC) uses the maximum noise level with a set of allowable exceedances in their noise control ordinance, which is applicable to the noise analysis of ancillary facilities such as park-and-ride lots and maintenance facilities, as well as construction activities. To qualify the allowable exceedances, the commonly used noise metric—the Lnn—is used for compliance verification. The sound level descriptor Lnn is defined as the sound level exceeded "n" percent of the time. For example, the L25 is the sound level exceeded 25 percent of the time; therefore, during a 1-hour measurement, an L25 of 60 dBA means the sound level equaled or exceeded 60 dBA for 15 minutes during that hour. More detailed information on the WAC is provided in Section 4.3.1.

3 AFFECTED ENVIRONMENT

Sound Transit examined the project corridor to identify noise-sensitive locations and select locations where noise monitoring would be performed. In accordance with current FTA manual guidance (FTA 2006) regarding light rail projects, Sound Transit used the 350-foot screening distance (measured from each proposed station, rail, and park-and-ride location) in preparing the land use portion of this report and to identify locations where the project might cause noise impacts. The following sections describe the land use along the project corridor, the existing noise-level measurements, and the current noise sources in the project corridor. Figures 3-1 and 3-2 show the different alternatives and noise monitoring locations.

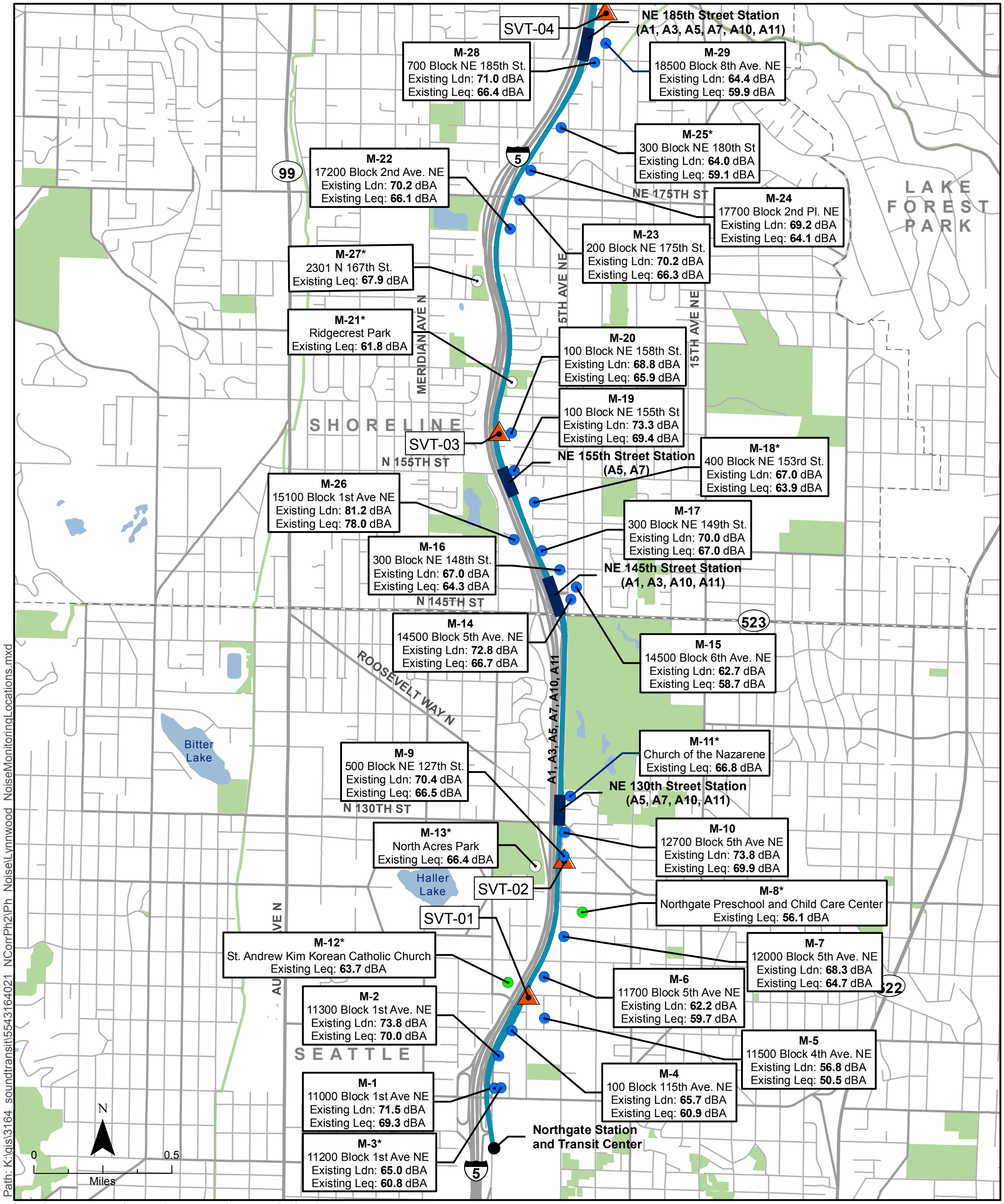
3.1 Land Use

This section provides an overview of the land uses along the proposed corridor. Noise impacts under the FTA regulations are based on the land use type. Complete details on the regulatory categories are provided in Section 4, Noise Impact Criteria. Figures 3-3 and 3-4 show the land uses in the project vicinity.

3.1.1 Segment A

The Lynnwood Link Extension would begin at the northern end of the Northgate Link Extension, between Interstate 5 (I-5) and Northgate Mall. On the east side of I-5 south of Northgate Way, there are only commercial uses, including the shopping mall fronted by a parking lot. There is a free-standing restaurant in the northwest corner of the parking lot. North of Northgate Way is the Northgate Apartments complex (11200 1st Avenue NE), which consists of approximately 25 buildings. North of this complex is the Northgate West condominiums at 11300 1st Avenue NE. East of the condominiums are the Citigate apartments. All but one building in the Citigate complex is shielded from I-5 and the potential light rail alignment by the condominiums.

Continuing northward on the east side of I-5, single-family residences predominate beginning just south of NE 115th Street and going north past Roosevelt Way NE to 131st Place. A string of properties beginning at the corner of 5th Avenue NE and NE 123rd Street and continuing northward consist of newly constructed multifamily units that would be acquired as part of the project. These properties abut an existing noise wall running along I-5. The Seattle Arabic Baptist Church is located at 13130 5th Avenue NE, just south of where the proposed light rail alignment would begin running alongside the Jackson Park Golf Course. The northern boundary of the golf course is NE 145th Street. On the west side of I-5 in this area, there are four nonresidential noise-sensitive uses: the Northgate Elementary School at 11700 1st Avenue NE; the Korean Catholic Church, which is just west of Northgate Elementary School; Northacres Park, which is immediately south of North 130th Street/Roosevelt Way NE; and the Lakeside Schools campus, which is southwest of the NE 145th Street/I-5 interchange.



Data Sources: (King County, Snohomish County, WSDOT, Sound Transit)

Noise Monitor Locations
- FTA Land-use Category 2
- FTA Land-use Category 3
- General Ambient Noise Location
- Surface Vibration Test Location

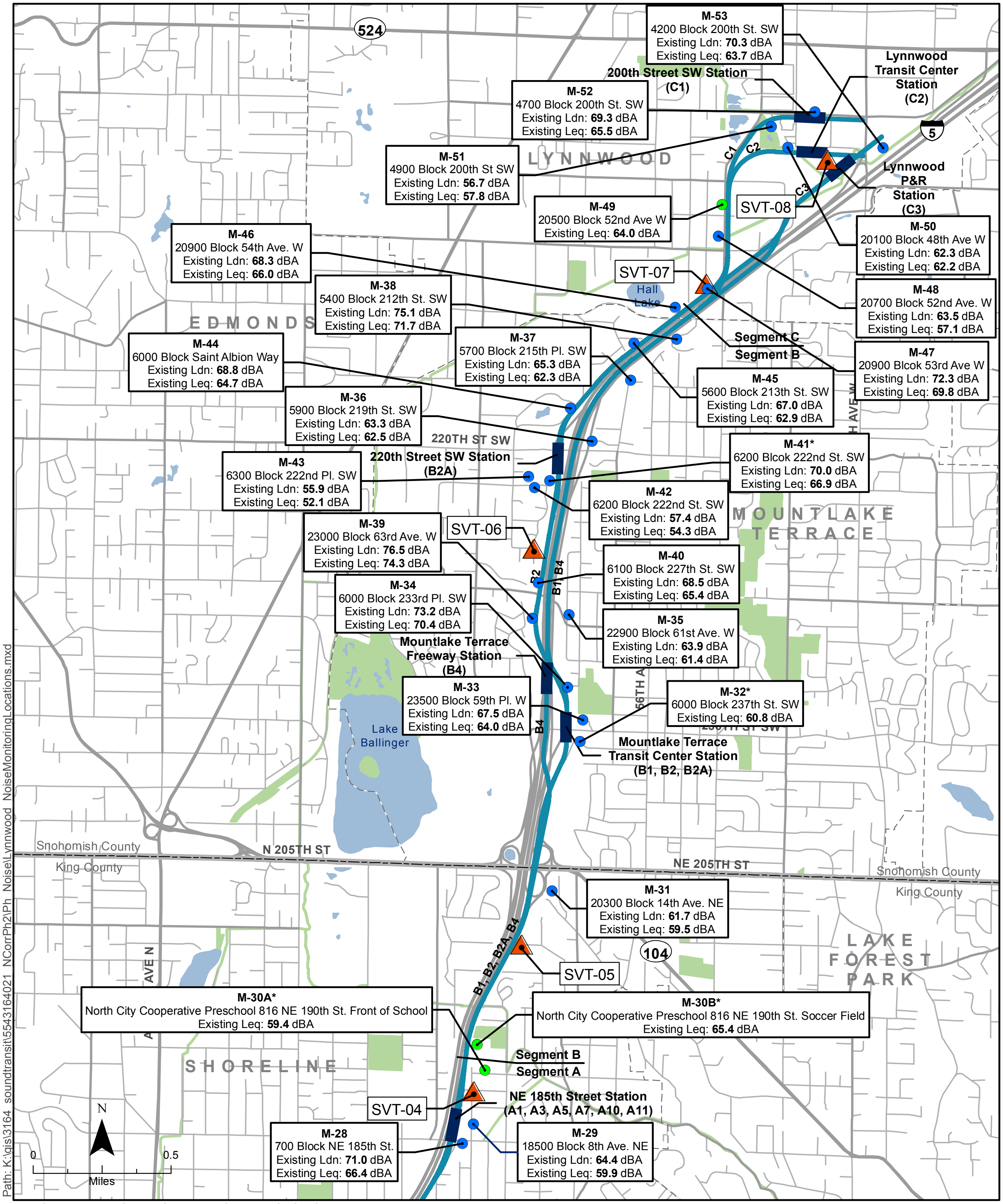
- Light Rail Alternatives
- Station Location
- Roadway
- Local Street

- City Boundary
- County Boundary
- Waterbody

Notes: - Ldn values for residences and hotels only.
- Noise Monitor Locations displayed with an asterisk (M-32*) are short term monitoring sites.

Figure 3-1
Noise Monitor and Surface Vibration Test Locations
Segment A

Lynnwood Link Extension



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Data Sources: (King County, Snohomish County, WSDOT, Sound Transit)

Noise Monitor Locations

- FTA Land-use Category 2
- FTA Land-use Category 3
- General Ambient Noise Location
- Surface Vibration Test Location

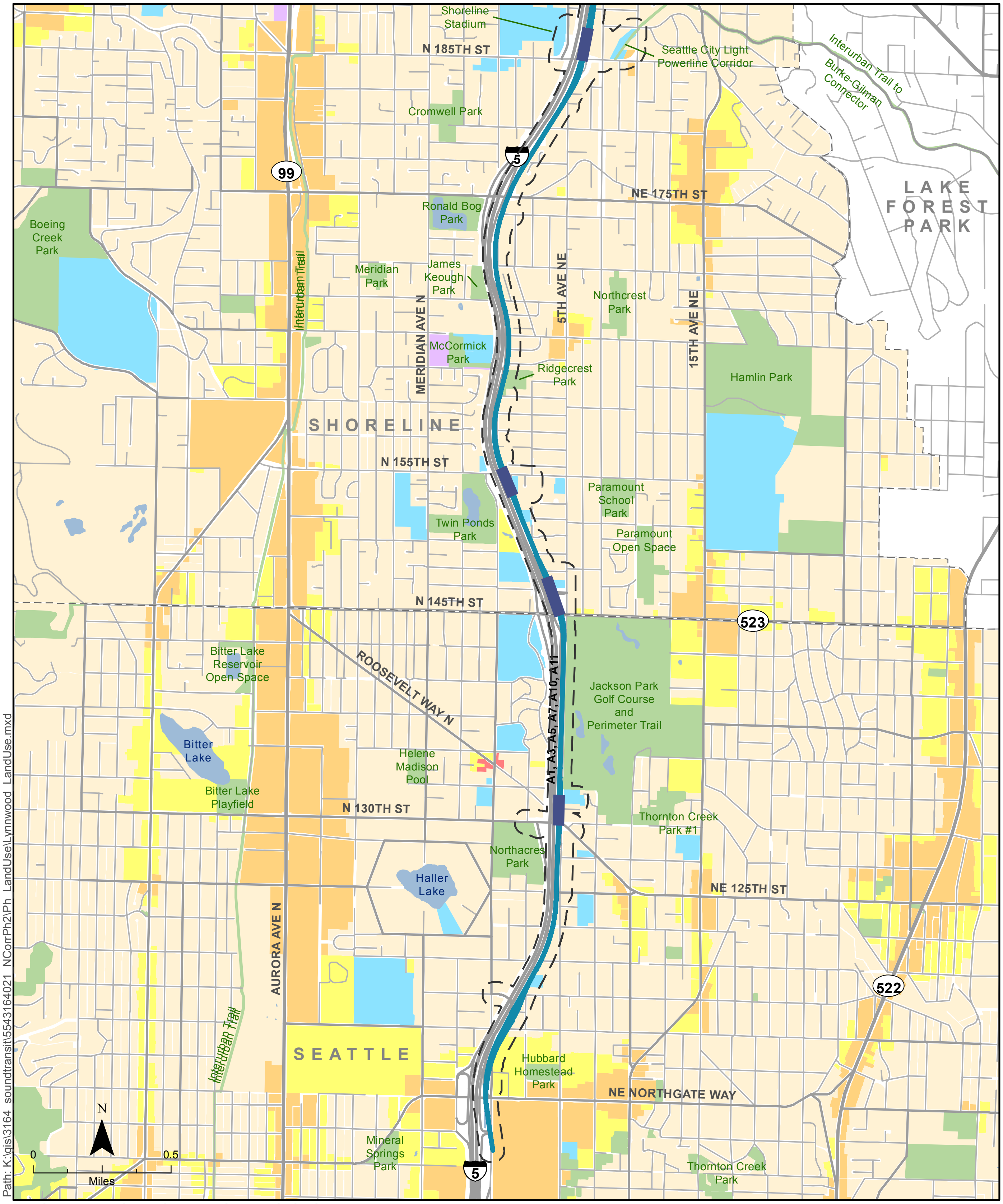
- Light Rail Alternatives
- Station Location
- Roadway
- Local Street

- City Boundary
- County Boundary
- Waterbody

Notes: - Ldn values for residences and hotels only.
- Noise Monitor Locations displayed with an asterisk (M-32*) are short term monitoring sites.

Figure 3-2
Noise Monitor and Surface Vibration Test Locations Segments B and C

Lynnwood Link Extension



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Data Sources: (King County, Snohomish County, WSDOT, Sound Transit)

- Commercial
- Industrial/Warehouse
- Institutional/Public
- Single Family Residential
- Multi Family Residential
- Mixed Use (Residential/Commercial)
- Light Rail Alternatives
- Station Location
- Project Study Area
- Park
- Roadway
- Local Street
- City Boundary
- County Boundary
- Waterbody

Figure 3-3
Existing Land Use
Segment A

Lynnwood Link Extension

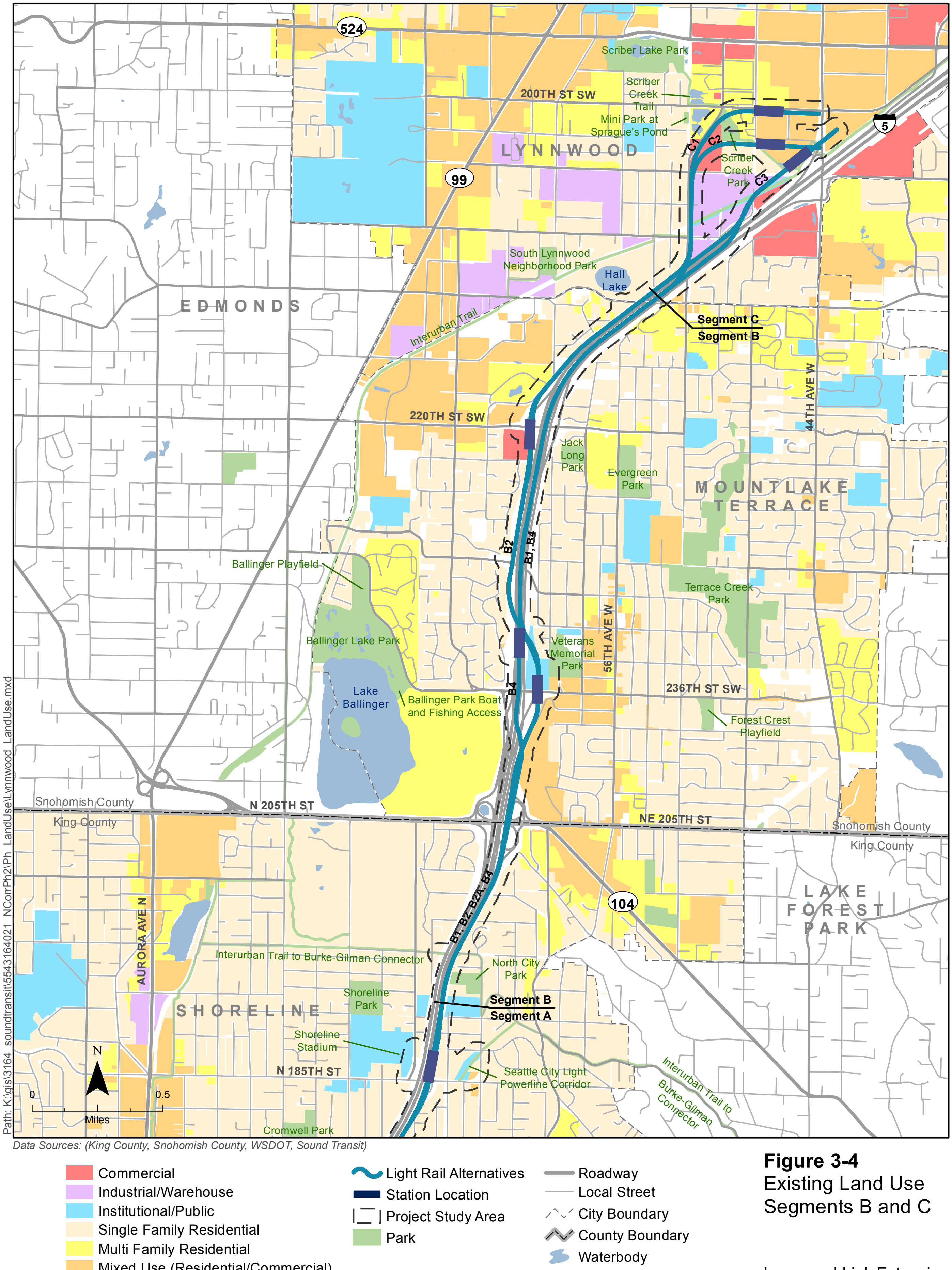

Figure 3-4
Existing Land Use
Segments B and C

On the east side of I-5, north of NE 145th Street and the currently existing park-and-ride lot and south of NE 155th Street, there is another stretch of single-family homes. Also in this area is the Resurrection Fellowship Church of God at 225 NE 152nd Street. North of that church is a parcel of undeveloped land and the Shoreline Fire Department Station. On the west side of I-5, uses of note include three churches and Aegis Senior Living, an assisted living facility at 14900 1st Avenue NE.

Between NE 155th Street and NE 175th Street, on the east side of I-5, the project corridor is all residential except for Ridgecrest Park, which is between NE 161st and NE 163rd streets, and an undeveloped parcel of land on the southeast corner of North 175th Street and the I-5 northbound off-ramp. This parcel is owned by the Washington Department of Natural Resources (DNR). On the west side of I-5, land uses include the St. Barnabas Anglican Church at 2340 N 155th Street, an undeveloped parcel of land just north of the church, an expansive transit facility at North 165th Street, James Keough Park north of the transit facility, and the Ronald Bog, which borders NE 175th Street.

Between NE 175th Street and NE 185th Street, land use on the east side of I-5 is all single-family homes. On the west side of the freeway, an undeveloped parcel south of NE 185th Street that fronts I-5 is owned by the DNR (King County parcel number 6084100050). There is also an undeveloped parcel owned by the Shoreline Water District at the far northeastern point of Segment A (King County parcel number 6084100040).

Segment A extends to just south of NE 194th Street and North City Park on the east side of I-5. Between NE 185th Street and North City Park are residential land uses, with a strip of land to the east dedicated solely to power transmission lines (King County parcel number 0526049039). North of this residential area and south of North City Park is the North City Cooperative Preschool and an adjacent recreational field. On the west side of I-5, noise-sensitive land uses include a pocket of homes between I-5 and the Shoreline School District football field and the Evergreen Baptist Church.

3.1.2 Segment B

Segment B begins just south of NE 194th Street on the east side of I-5 near North City Park. In this area, there is a pocket of residential land uses adjacent to the I-5 pedestrian overpass. North of 195th Street and south of the I-5/State Route (SR) 104 interchange is another area of predominantly single-family homes. Near SR 104, there are multifamily apartments and a four-unit condominium complex at 20101 14th Avenue NE. Other land uses in the area include a commercial storage facility and a 31-unit apartment complex at 20333 15th Avenue NE. North of the interchange but south of 236th Street SW consists of predominantly commercial land uses, including a strip mall, movie theatres, an office building, and the Studio 6 hotel. The former site of the Evergreen Elementary School abuts the proposed light rail route just south of 236th Street SW. Between the former school site and these commercial uses is a 4.87-acre piece of undeveloped land (Snohomish County Parcel number 27043200401600). Facing the former school across I-5 is the Nile Shrine and Nile Golf Course and Country Club.

North of 236th Street SW/Lakeview Drive and on the east side of I-5 is the Mountlake Terrace Transit Center, Veterans Memorial Park, and residential uses north to 230th Street SW (228th Street SW on the west side of I-5). On the west side of I-5, there are only residences between 236th Street SW/Lakeview Drive and 228th Street SW (230th Street SW on the east side of I-5).

Residential land uses predominate in the project corridor on the east side of I-5 from 230th Street SW north to 220th Street SW. Near the I-5/220th Street SW interchange, second-line noise receivers would include Jack Long Park and a recreational field. At the interchange, homes abut the I-5 northbound on-ramp. Just north, at 21705 58th Avenue West, is a school affiliated with the City Church. Surrounding the school are several undeveloped parcels all associated with the church/school (Snohomish County parcel numbers 00619900001401, 00619900001402, 00619900001102, and 00619900005300). Homes in this area only partially shield the school from I-5. After the bend in I-5 north of the school, the 106-unit Maple Glen apartment complex is at 5402 212th Street SW, and just south of that complex is a duplex at 5509 214th Place SW. East of the complex are numerous multifamily residences and a small store. Just north of the complex and north of 212th Street SW is a vacant, triangular-shaped property that was formerly a service station. Farther north of 212th Street SW are some single-family homes and another vacant piece of land.

On the west side of I-5 between 228th Street SW and 220th Street SW, land uses include some single-family homes relatively close to I-5. Just south of 220th Street SW is the Mountlake Terrace Cooperative Preschool and just north of 220th Street SW is Mountlake Terrace City Hall. The 320-unit Lakeside Apartments complex is north of City Hall. There are two undeveloped parcels adjacent to I-5 as it begins to bend northeast (Snohomish County parcel numbers 00619900005000 and 00619900004800), and immediately northwest is a large recreational area at Hall Lake. Beyond this recreational area, land uses along the project corridor are residential northward to the northern end of Segment B, just past 212th Street SW.

3.1.3 Segment C

Segment C begins just north of 212th Street SW on the west side of I-5 or in between the north and southbound lanes of the freeway, depending on the alternative. Land use on the west side of I-5 is residential from 212th Street SW north to 52nd Avenue West. Northeast of 52nd Avenue West is one single-family residence (20909 52nd Avenue West), and then land uses transition to commercial. Near 50th Avenue West are a warehouse and distribution facility and the Interurban Trail. East of 52nd Avenue West are several vacant parcels, state and private office buildings, and Scriber Creek Park. Other land uses near the Segment C alternatives include the Park Five Apartment complex at 20104 48th Avenue West, the 76-unit Cedar Creek condominium complex at 4800-4920 200th Street SW, the Oxford Square apartment complex at 4807 200th Street SW, the Cambridge Square apartment complex at 4727 200th Street SW, the Marriott Courtyard Hotel at 4220 200th Street SW, and the La Quinta Motel at 4220 Alderwood Mall Boulevard.

3.2 Existing Noise Environment

Sound Transit characterized the existing noise environment through on-site inspections and on-site noise monitoring. Monitoring was performed at 55 locations, including 41 long-term (24-hour or greater) and 14 short-term (15-minute) sites. Long-term monitoring was performed at noise-sensitive locations representative of nearby properties. Short-term monitoring was also performed at other locations where long-term monitoring was not practical or where short-term data were used to supplement nearby long-term monitoring results. Sound Transit also performed short-term noise level readings and traffic counts at all of the long-term sites in preparation for the noise wall analysis that would be required for all relocated noise walls along the project corridor. Sound Transit selected monitoring sites based on land use, existing noise sources, light rail alternative proximity and profile type, and the site's ability to represent nearby noise-sensitive land uses.

All noise measurements were taken in accordance with the FTA guidance manual and the American National Standards Institute (ANSI) procedures for community noise measurements and guidelines provided in the FTA guidance manual. Measurement locations were at least 5 feet from any solid structure to prevent acoustical reflections and at a height of 5 feet off the ground as required by FTA and ANSI standards. The noise measurements and accompanying traffic counts were also taken in accordance with FHWA and WSDOT standards to ensure their suitability for relevant analyses. The equipment used for noise monitoring included Bruel & Kjaer Type 2238 sound level meters. The meters were calibrated before and after measurement periods using a sound-level calibrator. Complete system calibration is performed on an annual basis by an accredited testing laboratory. The laboratory system calibration is traceable to the National Institute of Standards and Technology (NIST). The systems meet or exceed the requirements for an ANSI Type 1 noise measurement system.

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

The following sections describe the existing noise environment by project segments. Segments A and B both have numerous existing noise walls along I-5 that might be affected by the proposed project. If it were necessary to remove any noise wall or noise wall portion as part of the project, it would need to be replaced or relocated to a new location such that it would maintain future noise levels that are equal to, or less than, the current noise levels.

3.2.1 Segment A

Segment A had 20 long-term and 11 short-term monitoring locations. Noise levels along the proposed light rail alternative route in Segment A are dominated by traffic noise from I-5 and major arterial roadways such as NE Northgate Way, 1st Avenue NE, 5th Avenue NE, NE 130th Street, NE 145th Street, NE 155th Street, and NE 185th Street.

The Ldn at first-line receivers near Segment A in the Northgate area ranged from 72 dBA to 74 dBA (sites M-1, M-2, M-9, M-10, and M-27). The high Ldn noise levels are primarily because of the constant traffic flow along I-5, in addition to noise on local major and minor arterials. Peak-hour noise levels measured at two schools, two churches, and other outdoor locations ranged from 69 dBA to 70 dBA Leq (sites M-8, M-11, M-12, M-13, M-21, M-27, and M-30).

Ldn noise levels at monitoring locations south of Jackson Park Golf Course along 5th Avenue NE ranged from 68 dBA to 74 dBA. Peak-hour noise levels measured at these same locations ranged from 65 dBA to 70 dBA Leq. In all cases, measured noise levels were higher at receivers closer to the I-5/NE 130th Street interchange.

In the residential neighborhood north of NE 145th Street between 5th Avenue NE and I-5, the measured Ldn ranged from 67 dBA to 70 dBA (sites M16 and M17). Peak-hour noise levels at these homes ranged from 64 dBA to 67 dBA Leq. As with other locations in Segment A, the major noise source is I-5 and major arterial roadways.

Near the proposed NE 155th Street Station, the measured Ldn was 73 dBA at site M19 and the peak-hour noise level was 69 dBA Leq. Noise levels in that area are dominated by vehicles on I-5, and to a lesser extent, by local traffic on NE 155th Street and other arterial roadways.

At the NE 185th Street/I-5 overpass, represented by site M-28, the measured front-line Ldn was 71 dBA. At a second-line site (M-29), the Ldn was 64 dBA. Peak-hour noise levels at these two locations were 66 dBA and 60 dBA Leq, respectively. Noise levels here are dominated by I-5, with additional noise from arterial roadways.

Table 3-1 summarizes the noise monitoring effort for Segment A, which includes the monitoring location number, address, land use, and type of measurement. The peak hour Leq is presented for all sites but the 24-hour Ldn is presented for only FTA Category 2 land uses, such as residences and hotels. Although the monitoring data are presented to the tenth of a dB, FTA recommends presenting the noise analysis data for impact analysis in whole numbers only.

Table 3-1. Segment A Noise Measurements

Monitoring Location[a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)[b]
M-1	11012 1st Avenue NE (Northgate Apartments)	Multifamily	Long term	69.3	71.5
M-2	11300 1st Avenue NE (Northgate West Condominiums)	Multifamily	Long term	70.0	73.8
M-3	11200 1st Avenue NE (Northgate Apartments)	Multifamily	Short term	60.8	65.0
M-4	133 115th Avenue NE	Single family	Long term	60.9	65.7
M-5	11516 4th Avenue NE	Single family	Long term	50.5	56.8
M-6	11725 5th Avenue NE	Single family	Long term	59.7	62.2
M-7	12042 5th Avenue NE	Single family	Long term	64.7	68.3
M-8	12345 8th Avenue NE (Northgate Preschool and Child Care Center)	School	Short term	56.1	N/A[C]

Table 3-1. Segment A Noise Measurements

Monitoring Location[a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)[b]
M-9	502 NE 127th Street	Single family	Long term	66.5	70.5
M-10	12740 5th Avenue NE	Single family	Long term	69.9	73.8
M-11 #1	13130 5th Avenue NE (Church of the Nazarene and Parish Home) - Morning	Church and Single family	Short term	66.8	68.0
M-11 #2	13130 5th Avenue NE (Church of the Nazarene and Parish Home) - Afternoon	Church and Single family	Short term	66.7	68.0
M-12	11700 1st Avenue NE (St. Andrew Kim Korean Catholic Church)	Church	Short term	63.7	N/A[C]
M-13	12718 1st Avenue NE	Public	Short term	66.4	N/A[C]
M-14	14526 5th Avenue NE	Single family	Long term	66.7	72.8
M-15	14549 6th Avenue NE	Single family	Long term	58.7	62.7
M-16	348 NE 148th Street	Single family	Long term	64.3	67.0
M-17	314 NE 149th Street	Single family	Long term	67.0	70.1
M-18	405 NE 153rd Street	Single family	Short term	63.9	70.0
M-19	132 NE 155th Street	Single family	Long term	69.4	73.3
M-20	123 NE 158th Street	Single family	Long term	65.9	68.8
M-21	108 NE 161st Street	Public	Short-term	61.8	N/A[C]
M-22	17205 2nd Avenue NE	Single-family	Long-term	66.1	70.2
M-23	211 NE 175th Street	Single family	Long term	66.3	70.2
M-24	17748 2nd Place NE	Single family	Long term	64.1	69.2
M-25	350 NE 180th St	Single-family	Short-term	59.1	63.0
M-26	15100 1st Avenue NE (Aegis Senior Living)	Multifamily	Long term	78.0	81.2
M-27	2350 N 167th Street	Public	Short term	67.9	N/A[C]
M-28	721 NE 185th Street	Single family	Long term	66.4	71.0
M-29	18528 8th Avenue NE	Single family	Long term	59.9	64.4
M-30A	816 NE 190th Street (North City Cooperative Preschool)	School	Short term	59.4	N/A[C]

[a] Sites shown on Figures 3-1 and 3-2.

[b] Projected Ldn levels for short-term monitoring sites have been calculated using formulas and methods in the FTA *Transit Noise and Vibration Impact Assessment* (FTA 2006) and comparison with other nearby long-term noise monitoring sites.

[c] These sites were only measured for peak-hour Leq, and no Ldn measure is required because these sites do not represent residential uses.

dBA = decibel with A-weighting, FTA = Federal Transit Administration, Ldn = 24 hour, time-averaged, A-weighted sound level, Leq = equivalent continuous sound level, N/A = not applicable

3.2.2 Segment B

Segment B had 14 long-term and 3 short-term monitoring locations. Noise levels along the proposed light rail alternative route in Segment B are dominated by traffic noise from I-5 and major arterial roadways such as SR 104 and 220th Street SW.

Behind the Mountlake Transit Center Station at site M33, measured Ldn was 67.5 dBA and the peak-hour Leq was 64.0 dBA. Just north of the station on the bluff overlooking the transit center and I-5, the measured Ldn at site M-34 was 73 dBA and the peak-hour noise level was 70 dBA Leq. At site M-34, homes are not shielded from traffic noise on I-5, and they have a clear line of sight to the freeway. Likewise, at site M-39 on the west side of I-5, the Ldn was 77 dBA. For sites with some shielding from I-5, like site M-35, the Ldn was reduced to 64 dBA.

Measured Ldn at homes west of the school building located at 6205 222nd Street SW (sites M-42 and M-43) ranged from 56 to 57 dBA. Peak hour Leq at these homes ranged from 52 to 54 dBA. Peak-hour Leq on the east side of the school building at site M-41, facing I-5, was 66.9 dBA.

Table 3-2 summarizes the noise monitoring effort for Segment B, which includes the monitoring location number, address, land use, and type of measurement, with the peak hour Leq for all sites and the 24-hour Ldn for FTA Category 2 land uses.

Table 3-2. Segment B Noise Measurements

Monitoring Location[a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)[b]
M-30B	816 NE 190th Street (North City Cooperative Preschool)	School	Short term	65.4	N/A[C]
M-31	20313 14th Avenue NE	Single family	Long term	59.5	61.7
M-32	Grassy median across from 6002 and 5906 237th Street SW	Right-of-way	Short term	60.8	N/A[c]
M-33	23504 59th Place West	Single family	Long term	64.0	67.5
M-34	6005 233rd Place SW	Single family	Long term	70.4	73.2
M-35	22905 61st Avenue West	Single family	Long term	61.4	64.0
M-36	5905 219th Street SW	Single family	Long term	62.5	63.3
M-37	5709 215th Place SW	Single family	Long term	62.3	65.4
M-38	5402 212th Street SW	Multifamily	Long term	71.7	75.1
M-39	23005 63rd Avenue West	Single family	Long term	74.3	76.5
M-40	6103 227th Street SW	Single family	Long term	65.4	68.5
M-41	6205 222nd Street SW	School	Short term	66.9	N/A[C]
M-42	6206 222nd Street SW	Single family	Long term	54.3	57.4
M-43	6302 222nd Place SW	Single family	Long term	52.1	55.9
M-44	6102 Saint Albion Way	Multifamily	Long term	64.7	68.9
M-45	5632 213th Street SW	Single family	Long term	62.9	67.0
M-46	20908 54th Avenue West #1	Single family	Long term	66.0	68.4

[a] Sites shown on Figure 3-2.

[b] Projected Ldn levels for short-term monitoring sites have been calculated using formulas and methods in the FTA *Transit Noise and Vibration Impact Assessment* (FTA 2006) and comparison to other nearby long-term noise monitoring sites.

[c] These sites were only measured for peak hour Leq, and no Ldn measure is required because these sites do not represent residential uses.

dBA = decibel with A-weighting, FTA = Federal Transit Administration, Ldn = 24 hour, time-averaged, A-weighted sound level, Leq = equivalent continuous sound level, N/A = not applicable

3.2.3 Segment C

Segment C had seven long-term and no short-term monitoring locations. Noise levels along the proposed light rail alternative routes in Segment C are dominated by traffic noise from I-5 and major arterial roadways such as 52nd Avenue West and 200th Street SW.

The existing Ldn at homes west of 52nd Avenue West and adjacent to I-5 was characterized by site M-47, with a measured Ldn noise level of 72 dBA and a peak-hour Leq of 70 dBA. North along 52nd Avenue West, the measured Ldn at sites M-48 and M-49 ranged from 64 dBA to 65 dBA, and peak-hour Leq ranged from 57 dBA to 64 dBA. In this area, the major noise sources are traffic on 52nd Avenue West, 208th Street SW, and 208th Street SW, with background noise from I-5.

The results from monitoring locations near the Lynnwood Transit Center where noise measurements were taken vary depending on their proximity to major roadways. Major noise sources in this area include traffic on 200th Street SW, Cedar Valley Road, and, for sites near the existing transit center, 44th Avenue West. At the three multifamily buildings near and along 200th Street SW (site M-52), and at the Marriott Courtyard Hotel along I-5 (site M-53), the measured Ldn ranged from 69 dBA to 70 dBA. Peak-hour Leq at these locations ranged from 64 dBA to 66 dBA. Noise levels at the multifamily residences that abut Scriber Creek Park and are shielded from 200th Street SW, Cedar Valley Road, and the transit center are quieter. Measured Ldn at sites M-50 and M-51 ranged from 57 dBA to 62 dBA, and peak-hour Leq ranged from 58 dBA to 62 dBA.

Table 3-3 summarizes the noise monitoring for Segment C, which includes the monitoring location number, address, land use, and type of measurement, with the peak hour Leq for all sites and the 24-hour Ldn for FTA Category 2 land uses.

Table 3-3. Segment C Noise Measurements

Monitoring Location[a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA)[b]
M-47	20929 53rd Avenue West	Single family	Long term	69.8	72.4
M-48	20706 52nd Avenue West	Single family	Long term	57.1	63.5
M-49	20526 52nd Avenue West (Cedar Valley Grange)	Public	Long term	64.0	N/A[C]
M-50	20128 48th Avenue West, Bldg. C, Apt. #30 (Park Five Apartments)	Multifamily	Long term	62.2	62.3
M-51	4900 200th Street SW, Bldg. C (Cedar Creek Condominiums)	Multifamily	Long term	57.8	56.7
M-52	4727 200th Street SW, Apt. A101 (Cambridge Apartments)	Multifamily	Long term	65.5	69.3
M-53	4220 200th Street SW (Courtyard Marriott)	Hotel	Long term	63.7	70.3

[a] Sites shown on Figure 3-2.

[b] Projected Ldn levels for short-term monitoring sites have been calculated using formulas and methods in the FTA *Transit Noise and Vibration Impact Assessment* (FTA 2006) and comparison with other nearby long-term noise monitoring sites.

c These sites were only measured for peak hour Leq, and no Ldn measure is required because these sites do not represent residential uses.

dBA = decibel with A-weighting, FTA = Federal Transit Administration, Ldn = 24 hour, time-averaged, A-weighted sound level, Leq = equivalent continuous sound level, N/A = not applicable

4 NOISE IMPACT CRITERIA

The operation of a light rail system can cause noise from transit operations (e.g., light rail operational noise, warning bells, maintenance facilities, ancillary facilities, and buses and park-and-ride lots at transit centers) or changes in traffic resulting from a roadway being widened or realigned for the project; different criteria exist for each source of noise. This section summarizes what defines a noise impact, as applicable to the Lynnwood Link Extension.

4.1 Transit Noise Impact Criteria

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

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

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

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

- Severe Impact: Project-generated noise in the severe impact range can be expected to cause a large percentage of people to be highly annoyed by the new noise and represents the most compelling need for mitigation. Noise mitigation will normally be specified for severe impact areas unless there are truly extenuating circumstances that prevent mitigation.

- Moderate Impact: In this range of noise impact, the change in the cumulative noise level is noticeable to most people but may not be sufficient to cause strong, adverse reactions from the community. In this transitional area, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These factors include the existing level, the projected level of increase over existing noise levels, the types and numbers of noise-sensitive land uses affected, the noise-sensitivity of the properties, the effectiveness of the mitigation measures, community views, and the cost of mitigating noise to more acceptable levels.

The FTA noise impact criteria are summarized in graphical form in Figure 4-1, which shows the existing noise exposure and the allowable noise exposure from the 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. Figure 4-2 expresses the same criteria in terms of the increase in total or cumulative noise that can occur in the overall noise environment before an impact occurs.

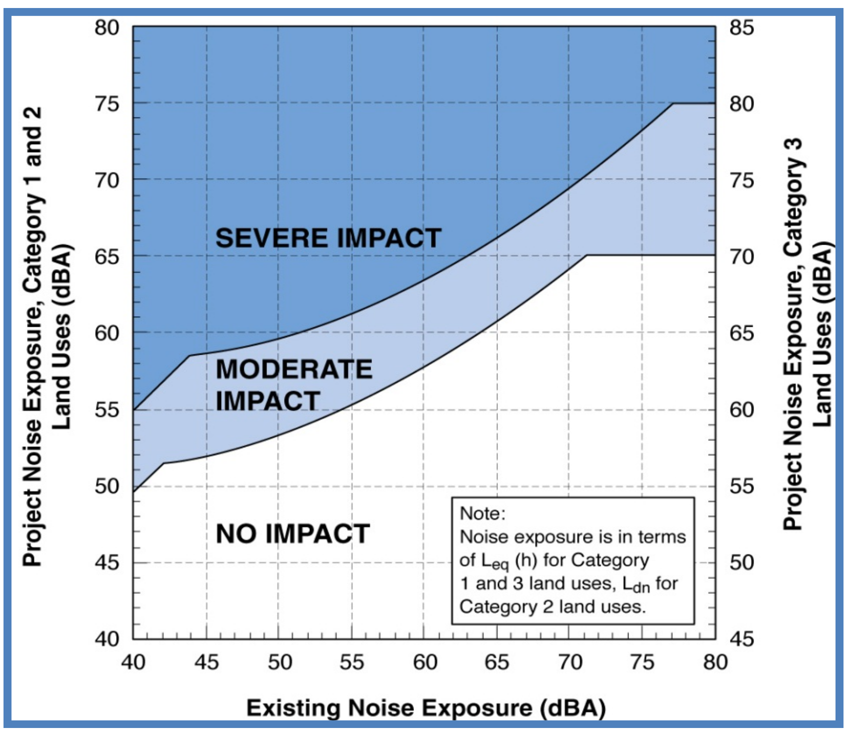

Figure 4-1. FTA Project Noise Impact Criteria

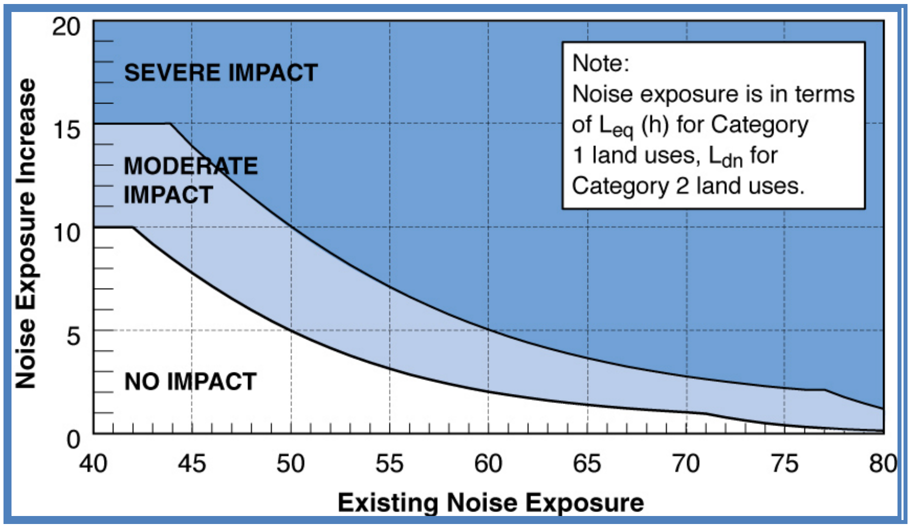

Figure 4.2. Increase in Cumulative Noise Exposure Allowed by FTA Criteria

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

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

4.2 Traffic Noise Impact Criteria

Consistent with the FTA guidance manual, Sound Transit used FHWA methodology and criteria to evaluate traffic noise impacts. The criteria for highway noise impacts are taken from Title 23 of the Code of Federal Regulations (CFR) Part 772, Procedures for Abatement of Highway Traffic Noise and Construction Noise. Table 4-1 lists the traffic noise abatement criteria.

Under the FTA and FHWA criteria, projects that include construction of new highways, reconstruction of existing highways that includes significantly changing either the horizontal or vertical profile, or an increase in the number of through-traffic lanes require a traffic noise analysis. A significant change in the horizontal or vertical profile occurs when the change is likely to result in increased noise levels on developed lands that are perceptible to an average person. In Washington, this is typically defined as a 3-dBA increase. A review of the project corridor did not identify any roadway or highway improvements that are predicted to cause an increase of 3 dBA or more as a direct result of the Lynnwood Link Extension. The slight changes in roadway alignments related to the project are not likely to produce noise increases that would be noticeable over the dominant noise from I-5 and other major arterial roads. However, a traffic noise analysis is also required whenever existing noise walls or other shielding will be relocated or removed as part of a project. Because of the relocation of several existing noise walls, modification of existing physical shielding, and removal of existing shielding structures, the FHWA criteria are provided because they will be used in the analysis for any potential traffic noise impacts related to the project.

4.2.1 FHWA and WSDOT Traffic Noise Criteria

Under the FHWA criteria, a noise impact occurs if projected noise levels approach the FHWA levels listed in Table 4-1 or substantially exceed existing noise levels. Each state defines its own quantitative levels considered to approach or substantially exceed existing noise levels. The Washington State Department of Transportation (WSDOT) is responsible for implementing the FHWA regulations in Washington. Under WSDOT policy, a traffic noise impact occurs if projected noise levels are within 1 dB of the FHWA criteria; therefore, a residential impact occurs at 66 dBA Leq and many commercial impacts occur at 71 dBA Leq. WSDOT also considers a 10-dB increase in noise a substantial increase impact, regardless of the existing noise level. Potential noise from park-and-ride lots were assessed using the local noise criteria, which is discussed later in Section 4.3.1 for construction noise.

Table 4-1. Noise Abatement Criteria (NAC) by Land Use Category

Activity Category	Activity Criteria in hourly Leq (dBA)		Evaluation Location	Activity Description
	FHWA NAC	WSDOT NAC		
A	57	56	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose
B[1]	67	66	Exterior	Residential (single-family and multifamily units)
C[1]	67	66	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, daycare centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools , television studios, trails, and trail crossings

Table 4-1. Noise Abatement Criteria (NAC) by Land Use Category

Activity Category	Activity Criteria in hourly Leq (dBA) FHWA NAC	WSDOT NAC	Evaluation Location	Activity Description
D	52	51	Interior	Auditoriums, daycare centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios
E[1]	72	71	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties, or activities not included in A–D or F
F	--	--	--	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing
G	--	--	--	Undeveloped lands that are not permitted

Notes:
[1]Includes undeveloped lands permitted for this activity category.
dBA = decibel with A-weighting, FHWA = Federal Highway Administration, Leq = equivalent continuous sound level, WSDOT = Washington State Department of Transportation

4.3 State and Local Noise Ordinances

Project operation and construction would take place in Seattle and Shoreline in King County, and in Mountlake Terrace and Lynnwood in Snohomish County, so several different noise ordinances would be applicable to the operation of ancillary facilities, such as park-and-ride lots, traction-power substations, and maintenance facilities, along with project-related construction activities. Most cities in Washington, including all those in the project corridor, rely, at least in part, on the WAC, Chapter 173-60, Maximum Environmental Noise Levels, for residential, commercial, and industrial noise limits, along with construction noise limits. The City of Seattle has a set of specific construction criteria that would need to be followed for all construction work in Segment A. The City of Seattle has developed construction noise criteria that are more stringent than the WAC; therefore, project construction in Seattle would be governed by the Seattle Noise Code. Construction work in other segments would need to adhere to the ordinances applicable in the individual jurisdictions, which are based on the WAC noise control ordinance. These local noise ordinances can include different provisions from the state law.

4.3.1 Washington Administrative Code

The Washington State Noise Control Ordinance (together with local noise regulations) applies to general construction activities, park-and-ride lots, and maintenance facilities. The WAC exempts mobile noise sources, including freight rail, aircraft in flight, and vehicles traveling in public right-of-way, as well as safety warning devices (i.e., alarm bells). For stationary land uses with noises originating from outside public roadways and rights-of-way, the Washington State Noise Control Ordinance defines three classes of property usage, called Environmental Designation for Noise Abatement (EDNA), and maximum allowable noise levels for each, as shown in Table 4-2. For example, the noise caused by a commercial property must be less than 57 dBA at the closest residential property line. From 10:00 pm to 7:00 am, the allowable maximum sound levels shown in Table 4-2 are reduced by 10 dBA. The WAC contains short-term exemptions to the property line noise standards in Table 4-2 based on the minutes per hour that the noise limit is exceeded. These exceedances are outlined in Table 4-3.

Table 4-2. Washington State Noise Control Regulation

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

[a] Between 10:00 pm and 7:00 am, the levels given above are reduced by 10 dBA for residential receiving property.
dBA = decibel with A-weighting

Table 4-3. Washington State Exemptions for Short-Term Noise Exceedances

Minutes Per Hour	Adjustment to Maximum Sound Level
15 (L_{25})	+5 dBA
5 ($L_{8.3}$)	+10 dBA
1.5 ($L_{2.5}$)	+15 dBA

dBA = decibel with A-weighting

WAC Construction Noise Criteria

Aside from the City of Seattle, the jurisdictions in the project corridor follow the WAC for construction noise regulation. Most project construction can be performed within the limits of the WAC noise ordinance if the work is conducted during normal daytime hours (7:00 am to 10:00 pm). If construction is performed during the nighttime, the contractor must still meet the WAC noise-level requirements presented in Table 4-2 or get a noise variance from the governing jurisdiction.

The State of Washington has also developed a set of construction-specific allowable noise-level limits that would apply to the construction of the Lynnwood Link Extension. These construction noise regulations are organized by type of noise and include general construction equipment;

impulse equipment, such as jackhammers and pile-drivers; haul trucks; and safety alarms, such as back-up beepers.

Haul Truck Noise Criteria

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

Noise Related to Back-up Alarms

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

4.3.2 City of Seattle

The City of Seattle has maximum permissible environmental noise level requirements that are similar to those contained in the WAC (Seattle Municipal Code [SMC] Chapter 25.08; SMC Section 25.08.410). These sound level limits are outlined in Section 4.3.1 of this report and are presented in Table 4-2. However, while the WAC does not define a noise descriptor to be used for purposes of applying the limits shown in Table 4-2, the City of Seattle has explicitly mandated that the Leq descriptor be used. In addition, during a measurement interval, maximum noise levels (Lmax) may exceed the Leq exterior sound level limits shown in Table 4-2 by no more than 15 dBA (SMC Section 25.08.410(B)).

The SMC also imposes the following three limitations on the maximum permissible sound level limits, which are more restrictive than the WAC:

- Between 10:00 pm and 7:00 am during weekdays, and between 10:00 pm and 9:00 am on weekends and legal holidays, the exterior sound level limits established by SMC Section 25.08.410 are reduced by 10 dB(A) where the receiving property lies within a residential district of the city.
- For any source of sound (other than an electrical substation) that has a pure tone component, the exterior sound level limits established under SMC Section 25.08.410 are reduced by 5 dBA.
- For any source of sound that is impulsive and not measured with an impulse sound level meter, the exterior sound level limits established under SMC Section 25.08.410 are reduced by 5 dBA.

Construction Noise Criteria

Under SMC Section 25.08.425, the sound level limits established by SMC Section 25.08.410 may be exceeded for non-impact construction equipment used on public projects, such as the Lynnwood Link Extension, between 7:00 am and 10:00 pm on weekdays, and between 9:00 am and 10:00 pm on weekends and legal holidays, by no more than the following:

- **25 dBA** 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 dBA** for portable-powered equipment used in temporary locations in support of construction activities or used in the maintenance of public facilities, including, but not limited to, chainsaws, log chippers, lawn and garden maintenance equipment, and hand-powered tools.
- **15 dBA** 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.

For impact types of equipment, including, but not limited to, pavement breakers, pile-drivers, jackhammers, sandblasting tools, or other types of equipment that create impulse sound or impact sound, the sound level limits established by SMC Section 25.08.425 may be exceeded in any 1-hour period between 8:00 am and 5:00 pm on weekdays and 9:00 am and 5:00 pm on weekends and legal holidays. The sound level for impact types of equipment may exceed the following:

- Leq 90 dBA continuously
- Leq 93 dBA for 30 minutes
- Leq 96 dBA for 15 minutes
- Leq 99 dBA for 7.5 minutes

Sound levels in excess of Leq 99 dBA are prohibited unless authorized by variance, and impact equipment that produces sound levels less than 90 dBA must comply with the non-impact equipment sound level requirements between 7:00 am and 10:00 pm on weekdays and 9:00 am and 10:00 pm on weekends and legal holidays.

The sound levels for all types of construction equipment are measured at the property line of the receiver or at a distance of 50 feet from the equipment making the sound, whichever is greater. Furthermore, any type of equipment that exceeds the sound level limits when measured from the interior of buildings within a commercial district is prohibited between 8:00 am and 5:00 pm.

Haul Truck Noise Criteria

Sounds created by motor vehicles, including haul trucks, are exempt from Seattle's maximum permissible environmental noise level requirements on public roadways, although maximum permissible sound levels for haul trucks on public roadways are limited to 95 dBA (SMC Section

25.08.430 et seq.). However, the requirements do apply to vehicles operating off highways, such as trucks at staging areas, when the sounds are received within a residential district.

Noise Related to Back-Up Alarms

Sounds created by warning devices or alarms not operated continuously for more than 30 minutes per incident are exempt from the City of Seattle noise control requirements (SMC Section 25.08.530). For nighttime construction activity, the noise from the alarms would be required to meet the WAC, be addressed in permit conditions, or be replaced with spotters.

4.3.3 City of Shoreline

The City of Shoreline does not have any maximum permissible environmental noise level requirements that are similar to those contained in the WAC (as outlined in Section 4.3.1 of this report) or otherwise. Therefore, the WAC noise control code will be used for ancillary equipment and park-and-ride facilities.

Construction Noise Criteria

Sounds originating from construction sites including, but not limited to, sounds from construction equipment, power tools, and hammering, between 10:00 pm and 7:00 am on weekdays and 10:00 pm and 9:00 am on weekends constitute "public disturbance noise" (Shoreline Municipal Code Section 9.05.010(C)(8)). Hence, noise from construction activities is permitted on weekdays between 7:00 am and 10:00 pm and on weekends between 9:00 am and 10:00 pm. The City of Shoreline does not have any laws or regulations that address construction noise variances. Therefore, if necessary, City officials would need to be contacted for specific requirements relating to the granting of such variances.

4.3.4 City of Mountlake Terrace

The City of Mountlake Terrace does not have any maximum permissible environmental noise level requirements that are similar to those contained in the WAC (as outlined in Section 4.3.1 of this report) or otherwise. Therefore, the WAC noise control code will be used for ancillary equipment and park-and-ride facilities.

Construction Noise Criteria

Sounds created by blasting and sounds originating from construction sites as a result of construction activity are only considered a nuisance when performed between 10:00 pm and 7:00 am (Mountlake Terrace Municipal Code Section 8.20.010(D)(2) and (D)(3)). Hence, sounds from construction activities are exempt every day of the week between 7:00 am and 10:00 pm. The City of Mountlake Terrace does not have any laws or regulations that address construction noise variances. Therefore, if necessary, City officials would need to be contacted for specific requirements relating to the granting of such variances.

4.3.5 City of Lynnwood

The City of Lynnwood has maximum permissible environmental noise level requirements that are similar to those contained in the WAC (Lynnwood Municipal Code Section 10.12.500). These requirements are outlined in Section 4.3.1 of this report.

Sounds created by warning devices not operating continuously for more than 5 minutes, or bells, chimes, and carillons are entirely exempt from the City of Lynnwood's environmental noise level requirements (Lynnwood Municipal Code Section 10.12.500(F)(4)).

Construction Noise Criteria

Sounds originating from construction sites as a result of construction activity are exempt from the City of Lynnwood environmental noise level requirements between 10:00 pm and 7:00 am every day of the week (Lynnwood Municipal Code Section 10.12.500(E)).

None of the terms or prohibitions contained in Lynnwood's general environmental noise level requirements applies to any City vehicle while engaged in necessary public business. Those terms or prohibitions do not apply to any excavations or repairs of bridges, utilities, streets, or highways performed by or on behalf of the City of Lynnwood, Snohomish County, or the State of Washington (Lynnwood Municipal Code Section 10.12.300(C)). The City of Lynnwood does not have any laws or regulations that address construction noise variances. Therefore, if necessary, City officials would need to be contacted for specific requirements relating to the granting of such variances.

5 NOISE IMPACT ANALYSIS METHODS

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

5.1 Operational Measures

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

Table 5-1. Systemwide Light Rail Operational and Maintenance Measures

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

5.2 Reference Light Rail Noise Levels

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

5.3 Alignment and Special Trackwork

A plan and profile of the proposed light rail alignment, including the locations of special trackwork, such as crossovers, and typical speeds, were obtained from project design engineers. The design information included the elevation of the trackway, type of track (ballast and tie, embedded, aerial, and direct fixation) and the location and design of the station alternatives. The current design calls for ballast and tie, aerial, and direct fixation types of trackway.

Track crossovers are mechanical devices that enable light rail cars to be guided from one track to another at a junction point. Crossovers have a gap in the rails that is necessary for the flange of the light rail wheels to pass through at the location where the two tracks cross. As a wheel passes through the gap there is increased noise and vibration levels. According to the FTA guidance manual and measurements of the Central Link light rail system, standard frogs, which are crossover components, can increase noise levels by as much as 8 to 10 dB.

Spring switch and movable point frogs solve the added noise and vibration problems by closing the gap on the rails. Flange-bearing frogs, another mitigation option, transfer the vehicle load from the wheel tread to the wheel flange and raise the light rail car up and over the gap, reducing noise and vibration levels. Each of these types of frogs produce notably lower noise levels than standard frogs, and depending on the type of crossover and angle between the crossover and mainline track, special frogs, like those described, can reduce noise levels between 4 and 8 dBA compared to a standard frog. The type of frogs used for the Lynnwood Link Extension would depend on the track type, crossover location, and proximity of noise-sensitive properties.

5.4 Light Rail Warning Bells

Sound Transit measured and validated train-mounted bells on light rail cars in October 2009, with several supplemental measurements over the last 2 years. Consistent with Sound Transit operating rules, this analysis assumes that train-mounted bells would be sounded twice as a train enters a station, and twice when the train leaves the station. The bells produce a maximum noise level of 80 dBA Lmax at 50 feet between 6:00 am and 10:00 pm and are reduced to 72 dBA Lmax between 10:00 pm and 6:00 am.

5.5 Operational Plan

The Sound Transit operations schedule includes all other planned light rail expansions between now and 2030. The operations plan for this analysis is taken from the Sound Transit 2 (ST2) Plan, which assumes service to Lynnwood as well as the East Link Extension would be complete and running. Under this plan, the majority of light rail trains would operate with four passenger cars, with two-car trains during late night hours.

The operating plan used in the analysis was taken from the highest potential service for the 2030 ridership model, which uses the following train lengths and headways:

- Peak (6:00 am to 8:30 am and 3:00 pm to 6:30 pm): 4-minute headways, four-car trains
- Midday and early evening (8:30 am to 3:00 pm and 6:30 pm to 10:00 pm): 5-minute headways, four-car trains from 8:30 am to 3:00 pm and two-car trains after 6:30 pm
- Early morning and late evening (5:00 am to 6:00 am and 10:00 pm to 1:00 am): 7.5-minute headways, four-car trains early morning, and two-car trains late evening

5.6 Wheel Squeal and Wheel-Flanging Noise

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

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

Sound Transit examined the project corridor for curves with radii of 600 feet or less and identified no such curves. There are curves in Segment C with radii of 800 feet. Under Alternatives C1 and C2 with Option 1, the curve from the I-5 median to 52nd Avenue West has a radius of 800 feet. Also, under Alternatives C1 and C2 with both design options, the curve from Cedar Valley Road to the transit station also has a radius of 800 feet. Sound Transit would prepare the light rail tracks along these curves to accept automated lubricators in case wheel squeal is noted during the initial system testing.

5.7 Light Rail Noise Projections

Noise impacts that would result from the Lynnwood Link Extension were determined through the following approach:

1. Sound Transit performed a land use survey of potential noise-sensitive receptors near the proposed light rail alignments. This process involved site visits and use of area land-use maps and information from other project team members.
2. Sound Transit conducted long-term (multi-day) and short-term (15- to 30-minute) noise monitoring to establish existing noise levels for the potentially affected area. Ambient noise monitoring was taken at 55 locations along the corridor. The criteria for monitoring location selection included land use, existing ambient noise, number of sensitive receivers in the area,

and level of expected impact. Traffic counts were also taken at several sites that will be used for future traffic noise modeling as part of noise wall relocation.

3. Field noise measurements were used to develop a set of existing ambient sound levels for the noise-sensitive receptors.
4. Existing ambient sound levels were used to determine the noise impact criteria. The FTA criteria for noise impact are based on the existing noise level and land use.
5. Projections of light rail noise levels were made based on track type, train speed, number of passenger cars, and distance of receiver from tracks, with adjustments for shielding and ground attenuation. Adjustments based on track type, noise walls, elevated acoustical walls, and retained cut situations are shown in Table 5-2. Noise related to bells at stations and special trackwork was also included in the analysis. For this analysis, measured noise reductions taken in Tukwila, Washington, as part of Sound Transit's commitment to maintain a quiet system, were used in the analysis.
6. Sound Transit evaluated projections with respect to impact thresholds to determine if a receiver would be affected by light rail operations.
7. Where noise impacts were identified, mitigation was considered. Mitigation recommendations followed the Sound Transit Noise Mitigation Policy and were considered reasonable and feasible if made.

Table 5-2. Light Rail Track-Type and Shielding Adjustments

Track Type	Adjustment in Decibels (dB)
At-grade ballast and tie-track (ballast exposed)	0
Elevated structure	+4
Embedded track or retained-fill trackway	+3
Retained cut with at least 4 to 6 feet below grade	-5
Crossover	+10
Acoustical noise walls on structure	-12 to 15 decibels with A-weighting (dBA) (based on measured data on the Tukwila segment)
Relocated noise wall at-grade with an expected height of at least 6 feet above the grade of the trackway	-12 (based on measured data on the Tukwila segment)

5.8 Park-and-Ride Noise Projections

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

As previously stated in Section 4.3, ancillary facilities must not only meet the FTA criteria but also meet the applicable state, county, or city criteria for noise. The Cities of Shoreline, Mountlake Terrace, and Lynnwood use the WAC regulations for noise control. The City of Seattle code, while having a more specific noise control ordinance, is also similar to the WAC for the purpose of ancillary facility noise analysis. To identify potential impacts, Sound Transit projected operational noise levels for three different conditions:

- Typical 24-hour average Ldn
- Peak-vehicle hour Leq
- Typical maximum noise levels from layover buses and vehicles at the park-and-ride (Lmax)

Sound Transit's noise analysis team calculated operational noise levels for the park-and-ride facilities at the nearest representative receivers' property line. Sound Transit projected the 24-hour Ldn and the peak-vehicle hour Leq using the methods described in the FTA guidance manual (2006). The Lmax from buses at park-and-ride service and layover areas and passenger vehicles at park-and-ride lots were also taken from the FTA guidance manual. The noise analysts obtained future hourly bus volumes and park-and-ride lot access times from Sound Transit. The daily Ldn noise levels were compared to the FTA noise regulations provided in Section 4.1. The peak-vehicle hour Leq and Lmax were compared to the appropriate city or state ordinance described in Section 4.3.

The proposed park-and-ride facility sites are considered commercial uses under the WAC and City of Seattle codes, and most of the receiving sites near the proposed park-and-ride facilities are residential. As shown in Table 4-2, the maximum allowable noise level for a commercial use to a residential use is 57 dBA at the property line. The noise impact analysis under the WAC and Seattle codes required two different types of noise analysis (the Leq and the Lmax).

For the Leq noise analysis, Sound Transit compared the projected peak operational hour Leq with the daily maximum allowable noise level including the +5 dBA allowable exceedance. This metric was selected because the +5 dBA exceedance can be measured with an L25 noise level, which is typically equal to the hourly Leq. The maximum allowable +5 dBA noise level for commercial uses is 62 dBA during daytime (7:00 am to 10:00 pm) and 52 dBA during nighttime (10:00 pm to 7:00 am). Sound Transit projected the peak hour Leq using the methods in the FTA guidance manual (2006). This criterion is applicable for all passenger vehicle traffic accessing parking lots and garages and buses that have routes or parking on park-and-ride properties. Buses on public roadways, or at existing bus stops on public roadways, are exempt from the WAC and Seattle noise ordinance (see WAC 173-60-050 Exemptions (4) (a) and Seattle Ordinance 25.08.480—Motor vehicle exemptions). It is important to note that the noise emissions from buses must meet the new and used vehicle standards in the WAC and Seattle noise ordinances.

For the analysis of the NE 130th Street park-and-ride in Seattle, the Lmax was compared directly to the criteria with the +15 dBA allowable exceedance. For the Lmax noise analysis comparison with WAC, including the +15 dBA maximum allowable exceedance noise level, Sound Transit used the Lmax from a typical bus accelerating away from a normal passenger stop. Because the Lmax is always greater than or equal to the L2.5, using the Lmax ensures a conservative analysis. The next step in this process is to determine the number of buses during the peak hours that will be accessing the park-and-ride. Because the +15 dBA maximum exceedance is limited to 90 seconds per hour, and typical bus acceleration lasts for 2 to 3 seconds, no more than 30 to 45 buses per hour would be allowed to exceed the+15 dBA criteria. In order to maintain a conservative analysis, the analyst assumed that if more than 30 buses per hour would use a specific area, the acceleration time would meet, or exceed 90 seconds. The maximum allowable +15 dBA noise level for commercial uses under the WAC and Seattle codes is 72 dBA during daytime hours and 62 dBA during nighttime hours. Therefore, in order to have an impact from the Lmax, the noise level must exceed the criteria (62 dBA nighttime or 72 dBA daytime) and at least 30 buses must access the park-and-ride during a single hour.

The Lmax for diesel bus operations, the major noise source at park-and-rides, is 79 dBA Lmax at 50 feet (FTA 2006). Although it is possible that some of the buses could use newer technology and produce less noise, the diesel bus was selected for this analysis. For buses using the layover areas and departing the park-and-rides, an Lmax of 76 dBA, which is based on measured noise levels of similar buses, was used to account for initial acceleration from stops.

Table 5-3 summarizes the total number of parking spots for the transit centers and Table 5-4 summarizes the number of buses expected at each of the transit stations based on the time of day. The reference noise levels for park-and-ride operations for the peak-hour noise analysis and the 24-hour Ldn are provided in Table 5-5. Reference noise levels are provided for the parking lots and bus operations while at the park-and-ride.

Table 5-3. Passenger Vehicle Parking Spaces and Type

Station	Option	Parking Spaces[a]	Notes
NE 130th Street	Option 1	90	Surface Lot
NE 130th Street	Option 2	100	Surface Lot
NE 145th Street	All NE 145th Street	500	Parking Garage
NE 155th Street	All NE 155th Street	500	Parking Garage
NE 185th Street	Options 1 and 2	500	Parking Garage
NE 185th Street	Option 3	360	Surface Lots
Mountlake Terrace Transit Center or Freeway Station	All Options	880	Parking Garage and Surface Lots
220th Street SW Station	All Options	200	Parking Garage and Surface Lots
Lynnwood Transit Center	All Options	1,900	Parking Garage and Surface Lots

[a] Parking spaces based on current design drawings

Table 5-4. Bus Trips by Park and Ride Option and Time of Day[a]

Station	Morning Peak 6:00 am to 7:00 am	Daytime Peak 5:00 pm to 6:00 pm	Daytime Trips 7:00 am to 10:00 pm	Nighttime Trips 10:00 pm to 7:00 am
NE 130th Street	8	8	120	16
NE 145th Street	24	24	360	48
NE 155th Street	24	24	360	48
NE 185th Street	44	44	620	84
Mountlake Terrace Transit Center or Freeway Station	44	44	532	84
220th Street SW Station	4	6	25	3
Lynnwood Transit Center	112	96	972	176

a. Estimated maximum number of buses accessing each of the park-and-ride options.

Table 5-5. Reference Park-and-Ride Facility Noise Levels at 50 Feet

Station	Park-and-Ride Option	Peak Hour Leq (dBA)[a]		24-hour Ldn (dBA)[b]	
		Buses 6:00–7:00 am	Vehicles 6:00–7:00 am	Ldn Buses	Ldn Vehicles
NE 130th Street	All options	N/A[c]	46	51	44
NE 145th Street	All options	N/A[c]	53	56	51
NE 155th Street	All options	N/A[c]	53	56	51
NE 185th Street	Option 1, 2	57	53	58	51
NE 185th Street	Option 3	57	52	58	49
Mountlake Terrace Transit Center or Freeway Station	All Mountlake Terrace options	57	56	58	53
220th Street SW Station	All options	46	49	44	47
Lynnwood Transit Center	Lynnwood Transit Center	61	59	61	56
Lynnwood Transit Center	Option 1, 2	61	59	61	56
Lynnwood Transit Center	200th Street SW	61	57	61	54

[a] Worst-case hourly Leq. For buses, the noise level was projected using the maximum number of buses at the park-and-ride in a single hour; for vehicles, the noise levels were projected assuming all parking spots would be occupied in a single hour.

[b] 24-hour Ldn projections that are based on the number of buses and vehicles predicted to access the park-and-ride throughout the daytime and nighttime hours.

[c] All bus traffic for this station option is on existing public roadways, at or near existing bus stops, and is therefore exempt from the local noise ordinances.

N/A = not applicable

5.9 Traffic Noise

Under the FTA guidance, traffic noise is only evaluated if the proposed project is a joint FTA and FHWA project, the mass transit portions of the project are adjacent to or within FHWA-funded portions of the project, and the project is located where highway noise predominates throughout the day and night. Under WSDOT criteria, to qualify for a substantial movement in the vertical or horizontal alignment of an existing highway, that change in the alignment must increase noise levels by 3 dBA or more. The Lynnwood Link Extension would not include any new highways, or propose to add any new through lanes to any existing roadways or highways. Although some local arterial roadways and access ramps proposed as part of the project would be slightly realigned, none were projected to cause a 3-dBA increase in traffic noise levels; therefore, a traffic noise analysis was not required as part of this study. Project roadway modifications would not increase noise levels because of the existing dominant noise from I-5 and the major arterial roadways, including Northgate Way, Roosevelt Way, North 130th Street, 5th Avenue NE, NE 145th Street, NE 175th Street, NE 185th Street, Ballinger Way (SR 104), 236th Street SW, 200th Street SW, and 44th Avenue West.

Because the Lynnwood Link Extension may relocate several noise walls along I-5, the project would be responsible for replacing these walls with new walls that will maintain the same level of abatement at noise-sensitive properties currently protected by the walls. Further, the new relocated walls should not result in any new traffic noise impacts or increase the severity of any existing noise impacts. As the project design progresses, the design of the relocated noise walls will be evaluated to confirm that they will be effective. All proposed walls will be reviewed by WSDOT to ensure the walls meet the requirements of the FHWA for replacement noise walls.

6 FUTURE NO BUILD CONDITIONS

In the absence of construction of the proposed project, traffic on I-5 and ancillary roadways will increase. For roadways such as I-5, an increase in traffic volume of 1 to 2 percent per year is typical. Hence, in 35 years the daily traffic volume on I-5 will increase and cause a corresponding increase in traffic noise. Because I-5 is already at or near capacity during peak periods, the maximum-hour Leq(h) will not increase substantially unless the capacity is increased. In the future, one or more of the following cases might occur:

- A spreading of traffic to off-peak hours, resulting in more hours of the day with high-traffic noise levels.
- Increased congestion, resulting in reduced speeds and lower noise levels during peak hours; the loudest hours would then occur during off-peak periods.
- An increase in capacity to accommodate traffic demand, which would qualify as an FHWA and WSDOT Type 1 project and be evaluated individually for noise impact.

A doubling of traffic volumes, although unlikely, could cause an increase in current traffic noise levels of approximately 3 dBA if all other conditions remain the same. An increase in the traffic noise levels of 3 dBA is normally perceptible to most people. Of course, this projected increase in noise levels caused by an increase in I-5 traffic assumes a roadway-carrying capacity that can support such a volume in a manner that still allows for the free flow of traffic. Traffic that is at a standstill or traveling significantly less than the posted speeds produce even less noise. A general rule is a reduction of approximately 3 dBA for each reduction of 10 mph until the speeds slow to 25 to 30 mph, when motor noise, acceleration, and other traffic-related noise sources keep traffic noise fairly constant.

While traffic on I-5 is the dominant source of noise for many receivers in the project corridor, many receivers are also affected by noise from traffic on ancillary roadways. The projected annual volume increases on these roadways could be greater than 1 to 2 percent. Therefore, future noise levels at some homes might increase by more than 3 dBA over what they are now. Changes in ancillary roadway alignments and traffic control measures could also affect future noise levels at some homes. Roadway projects that would have a significant effect on traffic noise levels would require their own individual analysis under the National Environmental Policy Act (NEPA) or State Environmental Policy Act (SEPA), depending on the funding source.

7 FUTURE BUILD CONDITIONS

Sound Transit performed a detailed noise impact assessment based on the criteria discussed in Section 4 and on the methods and projections described in Section 5 of this report. For areas with noise impacts, noise mitigation measures are provided in Section 8. Detailed sheets, including complete tabulated data of the project parcel identification, existing noise levels, project noise levels, criteria, and other information, are provided in Attachment B.

7.1 Considerations of Traffic Noise, Existing Noise Barriers, and Removal of Shielding

Because the light rail alignment is proposed directly adjacent to I-5 (either along on the west or east sides) between existing residential and commercial land use, many of the existing noise walls constructed for traffic noise abatement would need to be relocated. Any existing noise walls that would be relocated would be required to meet FHWA and WSDOT requirements and achieve equal or better noise reduction. In addition, in some locations (currently estimated to be approximately 1,000 linear feet), the modification of the existing terrain or the removal of existing structures could result in the removal of shielding that could cause an increase in traffic noise levels at some residences. For these areas, new noise walls might be necessary, and complete traffic noise modeling of I-5 will be required. Any property noted as a full displacement as part of construction for a specific alternative was not included in that alternative's noise analysis.

Prior to modeling the traffic along I-5, more detailed information would be required, including survey information of the existing terrain and the base and top of the existing noise walls. In addition, Sound Transit will need to consult and coordinate with WSDOT to ensure that the traffic noise analysis is performed in conformance with state and federal regulations.

During the updated noise wall analysis, Sound Transit will consider and discuss potential noise reflections from one side of I-5 to the opposite side. Given the width of I-5 in most locations, the added distance and existing noise walls, reflected noise is not likely to be an issue. Table 5-1 provides details on the amount of shielding used for this analysis.

7.2 Transit Noise Impact Analysis

Sound Transit based the evaluation of the potential environmental noise impacts from the project alternatives on the change in the environmental noise level that would be caused by each project alternative and the number of dwelling units potentially affected by project noise. The transit noise methodology, as discussed in Section 5 of this report, is consistent with the FTA guidance manual (FTA 2006). Also, as defined in Sections 5.3 and 5.4, special trackwork, including crossovers and alarm bells at stations, are included in the analysis. Sound Transit also applied the FTA noise assessment methodology to the park-and-ride facilities and transit centers.

Because of the large number of properties analyzed for noise impacts, this report only provides a summary of the impacts. Attachment B provides complete tabulated data, including the project parcel identification, existing noise levels, project noise levels, criteria, and other information. Attachment C contains detailed maps showing all parcels analyzed, noise impacts, severity of impacts, and potential mitigation measures.

7.2.1 Segment A

Table 7-1 provides a summary of the moderate and severe impacts for each of the proposed Segment A alternatives. As Table 7-1 shows, the elevated alternatives would have more impacts than the at-grade alternatives. This is partly a result of the relocated noise walls for the at-grade alternatives, which would also reduce the noise from light rail operations. Details on noise impacts under the Segment A alternatives are provided in the following sections.

Table 7-1. Summary of Potential Transit Noise Impacts in Segment A

Alternative	Station Option	Moderate Light Rail Impacts	Severe Light Rail Impacts	Total Impacts
Alternative A1	NE 145th Street Option 1 NE 185th Street Option 1	134	49	183
Alternative A3	NE 145th Street Option 2 NE 185th Street Option 2	146	211	357
Alternative A5	NE 130th Street Option 1 NE 155th Street Station NE 185th Street Option 3	119	107	226
Alternative A7	NE 130th Street Option 2 NE 155th Street Station NE 185th Street Option 2	165	202	367
Alternative A10	NE 130th Street Option 1 NE 145th Street Option 1 NE 185th Street Option 3	107	112	219
Alternative A11	NE 130th Street Option 2 NE 145th Street Option 2 NE 185th Street Option 2	146	206	352

Note: Also see Section 7.3 for park-and-ride noise impacts.

Alternative A1: At-grade/Elevated with NE 145th Street and NE 185th Street Stations

Under Alternative A1, there would be 134 moderate impacts and 49 severe impacts. All noise impacts under Alternative A1 would be at single-family and multifamily residences. No noise impacts were identified at any institutional uses, such as schools, churches, or any hospitals or other noise-sensitive medical uses. As part of the project, approximately 7,900 feet of existing noise walls would be relocated in Segment A under Alternative A1, and, whenever possible, these relocated noise walls would also be used to reduce noise from light rail operations.

Noise impacts are predicted at 97 multifamily units in two different complexes just north of Northgate Way along 1st Avenue NE. These impacts include 16 severe impacts that would result from the added noise associated with an elevated profile and proximity to the multifamily units. There would also be seven single-family residences that meet the FTA moderate impact criteria between NE 115th Street and NE 131st Place, near the south end of the Jackson Park Golf Course. The low number of noise impacts north of NE 115th Street would partly be a result of relocating 1,500 feet of existing noise walls, and placing the light rail alignment west of the noise walls along the east side of I-5.

Between NE 131st Place and NE 145th Street, land use consists of the Jackson Park Golf Course, which is not noise-sensitive. North of NE 145th Street and south of NE 158th Street, the relocation of an additional 1,200 feet of noise walls would keep the noise impacts to a minimum, with 26 moderate and 15 severe impacts identified. The severe impacts would be along elevated guideways. Because of the proposed station at NE 145th Street, trains would be required to slow as they enter and exit the platforms; therefore, project noise levels and impacts would be reduced in this area.

Between NE 158th Street and NE 175th Street, there would be 11 noise impacts, including 5 in the FTA severe category. The 11 impacts were determined assuming the relocation of approximately 3,400 feet of noise walls on the east side of I-5, with the light rail alignment placed on the I-5 side of the noise wall.

North of NE 175th Street to the connection with Segment B, there would be 14 moderate impacts and 13 severe impacts. Approximately 1,800 feet of noise wall would be relocated through this area, reducing the potential noise impact from light rail operations. As with the previous section of Segment A, most severe impacts would be along the elevated guideway sections.

Alternative A3: Mostly Elevated with NE 145th and NE 185th Street Stations

Under Alternative A3, there would be 146 moderate impacts and 211 severe impacts. The noise impacts would be at single-family and multifamily residences, the North City Cooperative Preschool on NE 190th Street, and two churches. No noise impacts were identified at any other institutional uses, such as schools, or at any hospitals or other noise-sensitive medical uses. As part of the project, approximately 2,100 feet of existing noise walls would be relocated in Segment A by the elevated guideway; the relocated noise walls would not be effective at reducing noise from light rail operations at most locations because of the track elevation. As a result of the unshielded aerial guideway, before considering mitigation, there would be substantially more noise impacts from Alternative A3 than from Alternative A1.

Noise impacts are predicted at 109 multifamily units in three different complexes just north of Northgate Way along 1st Avenue NE. These impacts include 64 severe impacts that would result from the added noise associated with an elevated profile. There would also be 85 noise impacts between NE 115th Street and NE 131st Place, near the south end of the Jackson Park Golf Course. These 85 noise impacts would include severe impacts at 56 single-family residences, 2 multifamily residences, and the Latvian Evangelical Lutheran Church. All severe impacts would be caused, in part, by the added noise from an elevated guideway and low existing noise levels because of shielding from I-5 by the existing noise wall.

Between NE 131st Place and NE 145th Street, land use consists of the Jackson Park Golf Course, which is not noise-sensitive. North of NE 145th Street and south of NE 158th Street, 52 noise impacts were identified, including 29 moderate and 23 severe impacts. The severe impacts would be along the elevated guideway.

Between NE 158th Street and NE 175th Street, there would be 16 noise impacts, including 8 in the FTA severe category. The 16 impacts were determined assuming the relocation of approximately 2,100 feet of noise walls on the east side of I-5, with the light rail alignment placed on the I-5 side of the noise wall.

North of NE 175th Street to the connection with Segment B, there would be 95 noise impacts, including 38 moderate impacts and 57 severe impacts. As with the previous Segment A area discussed, the severe impacts would be related to the added noise from the elevated guideway and lack of shielding from relocated noise walls.

Alternative A5: At-grade/Elevated with NE 130th, NE 155th, and NE 185th Street Stations

Under Alternative A5, there would be 119 moderate impacts and 107 severe impacts. Noise impacts would include single-family and multifamily residences along with one church. No noise impacts were identified at any institutional uses, such as schools, or at any hospitals or other noise-sensitive medical uses. As part of the project, approximately 8,200 feet of existing noise walls would be relocated in Segment A under Alternative A5, and, whenever possible, these relocated noise walls would also be used to reduce noise from light rail operations.

Sound Transit predicts noise impacts at 109 multifamily units in three different complexes just north of Northgate Way along 1st Avenue NE. These 109 impacts include 64 severe impacts that would be caused by the added noise associated with an elevated profile. There would also be 27 single-family residences that meet the impact criteria between NE 115th Street and NE 131st Place, near the south end of the Jackson Park Golf Course. These 27 impacts would include 11 severe impacts (9 at single-family residences and 2 at multifamily residences) and 16 moderate noise impacts. The severe impacts would be a result of the elevated guideway. Compared with Alternative 1, there would be a greater number of severe impacts in this area because the guideway would be closer to the two multifamily units near Northgate Way. Under Alternative A1, the alignment would remain on the west side of 1st Avenue NE, while under Alternative A5, the alignment would be along the east side of 1st Avenue NE, resulting in a notably higher number of impacts. The station at NE 130th Street would not cause any noise impacts.

Between NE 131st Place and NE 145th Street, land use consists of the Jackson Park Golf Course, which is not noise-sensitive. North of NE 145th Street and south of NE 158th Street, 38 moderate and 10 severe impacts were identified, even with the relocation of an additional 1,100 feet of noise walls, because of the elevated guideway. One of the moderate impacts would be at the Resurrection Fellowship Church of God, with the other 38 at single-family residences. Most severe impacts would be along elevated guideway sections at single-family residences. Alternative A5 would result in fewer impacts near NE 155th Street than with Alternative A1 because of a reduced speed to serve the station and displacement of several residences north of NE 155th Street that otherwise would experience noise impacts.

Between NE 158th and NE 175th streets, there would be 11 noise impacts, including 5 in the FTA severe category. The 11 impacts were determined assuming the relocation of approximately 3,400 feet of noise walls, with the light rail alignment placed on the I-5 side of the noise wall.

North of NE 175th Street to the connection with Segment B, there would be 14 moderate impacts and 17 severe impacts. Approximately 1,800 feet of noise wall would be relocated through this area, reducing the potential noise impact from light rail operations.

Alternative A7: Mostly Elevated with NE 130th, NE 155th, and NE 185th Street Stations

Under Alternative A7, there would be 165 moderate impacts and 202 severe impacts. Without mitigation, Alternative 7 would have the most noise impacts of any of the Segment A alternatives. The higher number of impacts would be caused, in part, by the higher noise levels associated with the elevated guideway structure. Noise impacts under Alternative A7 would affect single-family and multifamily residences along with two churches. No noise impacts were identified at any other institutional uses, such as schools, or at any hospitals or other noise-sensitive medical uses. As part of the project, approximately 2,100 feet of existing noise walls would be relocated in Segment A; however, because the guideway would be elevated, the relocated noise walls would not be effective at reducing noise from light rail operations at most locations. Under Alternative A7, noise impacts from the Northgate Transit Center to NE 115th Street would the same as predicted for Alternative A3, with 45 moderate and 64 severe impacts predicted at 109 multifamily units in three different complexes just north of Northgate Way along 1st Avenue NE.

From NE 115th Street to the south end of the Jackson Park Golf Course, 26 moderate and 54 severe impacts were identified, including two severe impacts at multifamily units and a severe impact at the Latvian Evangelical Lutheran Church. All severe impacts would occur adjacent to and result from the added noise from an elevated guideway. There would be no impacts at the golf course.

North of NE 145th Street and south of NE 158th Street, 67 noise impacts were identified, including 48 moderate and 19 severe impacts. All impacts in this area, with the exception of one church (the Resurrection Fellowship Church of God), would be on single-family residences, and the severe impacts would primarily be along elevated sections of the guideway.

Between NE 158th Street and NE 175th Street, noise impacts under Alternative A7 would be the same as under Alternative A3, with 16 noise impacts, including 8 in the FTA severe category. The 16 impacts were determined assuming the relocation of approximately 2,100 feet of noise walls on the east side of I-5, with the light rail alignment placed on the I-5 side of the noise wall.

North of NE 175th Street to the connection with Segment B, Alternative A7 noise impacts would be the same as under Alternative A3, with 95 noise impacts predicted, including 38 moderate impacts and 57 severe impacts.

Alternative A10: At-grade/Elevated with NE 130th, NE 145th, and NE 185th Stations

Under Alternative A10, there would be 107 moderate impacts and 112 severe impacts. Noise impacts would include single-family and multifamily residences; no noise impacts were identified at any institutional uses, such as schools and churches, or at any hospitals or other noise-sensitive medical use locations. As part of the project, approximately 8,100 feet of existing noise walls would be relocated in Segment A under Alternative 10, and whenever possible, these relocated noise walls would also be used to reduce noise from light rail operations.

Noise impacts would occur at 109 multifamily units in three different complexes just north of Northgate Way along 1st Avenue NE. These 109 impacts include 64 severe impacts that would be caused by the added noise associated with an elevated profile. There would also be 27 single-family residences that meet the impact criteria between NE 115th Street and NE 131st Place, near the south end of the Jackson Park Golf Course. These 27 impacts would include 11 severe impacts (nine at single-family residences and two at multifamily residences) and 16 moderate noise impacts. The severe impacts would be a result of the elevated guideway. Compared with Alternative A1, there would be a greater number of severe impacts in this area under Alternative A10 because the guideway would be closer to the two multifamily units near Northgate Way. Under Alternative A1, the alignment would remain on the west side of 1st Avenue NE, while under Alternative A10 (and A5), the alignment would be along the east side of 1st Avenue NE, resulting in a notably higher number of impacts. There would be no noise impacts from just north of NE 126th Street northward to NE 145th Street. The station at NE 130th Street would not cause any noise impacts. Between NE 131st Place and NE 145th Street, land use consists of the Jackson Park Golf Course, which is not noise-sensitive.

Under Alternative 10, there would be 41 noise impacts north of NE 145th Street to NE 158th Street, with 15 of these being severe impacts. All impacts in this section of Segment A would be on single-family residences.

Between NE 158th and NE 175th streets, there would be 11 noise impacts, including 5 in the FTA severe category. The 11 impacts reflect the relocation of approximately 3,400 feet of noise walls, with the light rail alignment placed on the I-5 side of the noise wall.

North of NE 175th Street to the connection with Segment B, there would be 14 moderate impacts and 17 severe impacts. Approximately 1,800 to 1,900 feet of noise wall would be relocated through this area, reducing the potential noise impact from light rail operations.

Alternative A11: Mostly Elevated with NE 130th, NE 145th, and NE 185th Street Stations

Under Alternative A11, there would be 146 moderate impacts and 206 severe impacts. All noise impacts under Alternative A11 would be at single-family and multifamily residences, along with an impact at the Latvian Evangelical Lutheran Church and at the North City Cooperative Preschool on NE 190th Street. No noise impacts were identified at any other institutional uses, hospitals, or other noise-sensitive medical uses. As part of the project, approximately 3,400 feet of existing noise walls would be relocated in Segment A because of the elevated guideway. The relocated noise walls would not be effective at reducing noise from light rail operations at most locations because the track would be elevated.

From the Northgate Transit Center north to NE 131st Street, noise impacts under Alternative A11 would be the same as described under Alternative A7, with 71 moderate impacts and 118 severe impacts. From NE 145th Street to NE 175th Street, noise impacts would be the same as Alternative A3, with 37 moderate impacts and 31 severe impacts. North of NE 175th Street to Segment B, noise impacts would also be the same as predicted under Alternative A3, with 38 moderate and 57 severe impacts.

7.2.2 Segment B

Table 7-2 provides a summary of the moderate and severe transit noise impacts for the Segment B alternatives. As Table 7-2 shows, Alternatives B2 and B2A would have more impacts than the other Segment B alternatives. This is partly related to Alternatives B1 and B4 being placed in the center of I-5 for much of this segment; in addition, an increased distance from the residences to the guideway also would reduce noise levels from light rail operations. The only difference between Alternatives B2 and B2A is the addition of the 220th Street Station, which would result in a reduced speed for station access, and reduce the noise level near the station and the total number of noise impacts by two. The connection modification to Segments A and C, where the track elevations would be different, depending on the connection, would not change the number or severity or cause any additional noise impacts. Details on noise impacts under the Segment B alternatives are provided in the following sections.

Table 7-2. Summary of Potential Transit Noise Impacts for Segment B

Alternative	Station Option	Moderate Light Rail Impacts	Severe Light Rail Impacts	Total Impacts
Alternative B1	Mountlake Terrace Transit Center Station	101	30	131
Alternative B2	Mountlake Terrace Transit Center Station	121	52	173
Alternative B2A	Mountlake Terrace Transit Center Station 220th Street SW Station	119	52	171
Alternative B4	Mountlake Terrace Freeway Station	89	36	125

Note: Also see Section 7.3 for park-and-ride noise impacts.

Alternative B1: East Side to Mountlake Terrace Transit Center to Median

Under Alternative B1, there would be 101 moderate impacts and 30 severe impacts. All noise impacts under Alternative B1 would be at single-family and multifamily residences; no noise impacts were identified at any institutional uses, such as schools, or at any hospitals or other noise-sensitive medical use locations. Under Alternative B1, there would be no relocated noise walls.

Between the north end of Segment A, near NE 190th Street, to 236th Street SW near the Mountlake Transit Center, Sound Transit predicted noise impacts at 39 single-family and multifamily residences on the east side of I-5. North of the Mountlake Terrace Transit Center Station, as the alignment transitions to the center of I-5, there would be an additional 12 moderate noise impacts on the east side of I-5 near 232nd Street SW.

When the light rail alignment is in the center of I-5, there would be an additional 63 moderate and 2 severe impacts on the west side of I-5. Sixteen of these 63 moderate impacts would be along a hillside with no physical shielding from I-5 or the new light rail alignment in the center of the freeway. There would be one noise impact at the end of an existing noise wall on 227th Street SW because the wall might not have sufficient height or length to mitigate noise from the light rail. In a similar situation, a single-family residence along the west side of I-5 along 62nd Avenue West at 222nd Street SW also would experience a moderate impact because of its location at the end of an existing noise wall.

Sound Transit also identified noise impacts at up to 40 units at a multifamily complex west of 60th Avenue West, on Albion Way. In addition, 4 moderate and 2 severe noise impacts would occur in the single-family residential area near 213th Street SW.

Alternative B2: East Side to Mountlake Terrace Transit Center to West Side

Under Alternative B2, there would be 121 moderate impacts and 52 severe impacts. Most identified noise impacts under Alternative B2 would be at single-family and multifamily residences, with a noise impact also identified at the Mountlake Terrace Preschool. Sound Transit predicted no other noise-sensitive uses with noise impacts. Under Alternative B2, there would be approximately 900 feet of noise walls that would be relocated.

Between the northern end of Segment A, near NE 190th Street, north to Gateway Boulevard, noise impacts under Alternative B2 would be the same as under Alternative B1, with 13 moderate impacts and 26 severe impacts. As with other elevated guideway sections, the added noise from the elevated guideway would be the main reason for the severe impacts. North of Gateway Boulevard to 232nd Street SW, just north of the Mountlake Terrace Transit Center Station, 21 single-family residences on the east side of I-5 would experience impacts, including 7 impacts considered severe under FTA regulations. The severe impacts would all be along the elevated guideway. An additional 13 moderate noise impacts are predicted at single-family homes on the east side of I-5 between 232nd Street SW and 220th Street SW due to the clear line-of-sight from the residences to the trackway.

When the alignment transitions to the west side of I-5 and into a retained cut, Sound Transit predicted 23 single-family noise impacts south of 220th Street SW. These 23 impacts include the Mountlake Terrace Preschool and the relocation of 400 feet of noise walls along the west side of I-5. Of these 23 impacts, 6 severe impacts are expected at the single-family homes immediately to the south of the school due to the proximity of the alignment.

North of 220th Street SW, there would be 77 noise impacts on single-family and multifamily residences. These 77 impacts would include severe noise impacts at 13 single-family and multifamily residences. Two severe impacts near 212th Street SW would be caused, in part, by a double crossover, with the remaining 27 severe impacts resulting from speed and proximity to the residences, along with some sections of the elevated guideway.

Alternative B2A: Optional 220th Street SW Station (Elevated)

Noise impacts under Alternative B2A would be the same as under B2, except for 2 fewer moderate noise impacts along 220th Place SW related to the reduced speed at the 220th Street SW Station. Therefore, there would be 119 moderate and 52 severe noise impacts under Alternative B2A, with 73 moderate and 40 severe single-family residence impacts and 46 moderate and 12 severe multifamily residence impacts.

Alternative B4: East Side to Mountlake Terrace Freeway Station to Median

Under Alternative B4, there would be 89 moderate impacts and 36 severe impacts. All noise impacts under Alternative B4 would be at single-family and multifamily residences. Sound Transit did not identify noise impacts at any schools, parks, churches, or medical facilities. Under Alternative B4, there would be no noise wall relocations planned.

Between the connection to Segment B and Gateway Boulevard, there would be 8 moderate and 32 severe noise impacts on single-family residences along the east side of the alignment. The severe impacts would be located at single-family and multifamily units in the vicinity of Forest Park Drive NE, south of Ballinger Way NE (also known as SR 104).

North of Ballinger Way NE, the light rail alignment transitions to the center of I-5, and there would be 5 moderate and 2 severe impacts along 237th Street SW. Sound Transit predicted 10 additional moderate noise impacts at single-family residences overlooking I-5 on, and near, 61st Avenue West, on the east side of I-5. In the same general area, but on the west side of I-5, there would be an additional 19 moderate noise impacts at single-family residences along 63rd Avenue West and the general vicinity.

There would be 2 additional moderate noise impacts at the end point of existing noise walls at 227th Street SW and at 222nd Street SW. North of 220th Street SW, there would be up to 40 moderate noise impacts on multifamily residences. There would be 5 moderate and 2 severe noise impacts on the single-family residences east of 60th Avenue West and 212th Street SW. The 2 severe impacts would be due in part to the location of a light rail crossover.

7.2.3 Segment C

Table 7-3 provides a summary of the moderate and severe impacts predicted for each of the Segment C alternatives. As Table 7-3 shows, the alternatives using 52nd Avenue West (i.e., both options under each of Alternatives C1 and C2) would have more impacts than the alternatives that remain along I-5. This is related to the single-family and multifamily residences that would be affected for the 200th Street SW Station option and, to a lesser extent, the transit center station option. Also, the primary difference between Option 1 and Option 2 connections is whether or not the light rail alignment would be in the middle of I-5 (Option 1) or west of I-5 (Option 2). The middle of I-5 options could only connect to Segment B Alternatives B1 and B4, while the west of I-5 options would connect to Segment B Alternatives B2 and B2A. No noise walls would be relocated as part of the project under any of the Segment C alternatives. Details on noise impacts under the Segment C alternatives are provided in the following sections.

Table 7-3. Summary of Potential Transit Noise Impacts for Segment C

Alternative	Station Option	Moderate Light Rail Impacts	Severe Light Rail Impacts	Total Impacts
Alternative C1, Option 1	200th Street SW Station	125	113	238
Alternative C1, Option 2	200th Street SW Station	118	113	231
Alternative C2, Option 1	Lynnwood Transit Center	50	62	112
Alternative C2, Option 2	Lynnwood Transit Center	41	64	105
Alternative C3, Option 1	Park-and-Ride Option 1 Park-and-Ride Option 2	5	1	6
Alternative C3, Option 2	Park-and-Ride Option 1 Park-and-Ride Option 2	12	8	20

Note: Also see Section 7.3 for park-and-ride noise impacts.

Alternative C1: 52nd Avenue West to 200th Street SW, with Option 1

Sound Transit predicts that Alternative C1 with Option 1 would have 238 noise impacts (125 moderate and 113 severe noise impacts). The noise impacts would include one moderate impact at the River of Life Christian Center.

Beginning at the connection to Segment B, Sound Transit identified 22 moderate and 10 severe noise impacts. These would include impacts on 2 multifamily residential units, 1 church, 19 single-family residences (moderate), and 10 single-family residences (severe) noise impacts. All of these impacts would be along I-5 and near the 52nd Avenue West corridor, east of 206th Street SW.

There would be an additional 206 noise impacts between 206th Street SW and the 200th Street SW Station. This includes 103 moderate impacts and 103 severe noise impacts. The higher number of impacts in this short area is related to the multifamily units along this alignment. These include the Park Five Apartments with 24 moderate impacts, the Cedar Creek Condominiums with 12 moderate and 36 severe impacts, the Oxford Square Apartments with 54 severe impacts, and the Cambridge Court Apartments with 44 moderate impacts. The remaining 36 noise impacts, including 13 severe, would be at single-family residences near 52nd Avenue West and Cedar Valley Road.

Alternative C1: 52nd Avenue West to 200th Street SW, with Option 2

Alternative C1 with Option 2 would have 231 noise impacts (118 moderate and 113 severe). Seven single-family residences and a church that would have moderate noise impacts under Alternative C1 with Option 1 would not have impacts under Option 2. The reduced impacts would be related to a slightly slower speed and slightly different alignment along the curve from I-5 to 52nd Avenue West, resulting in noise at the residences and the church being 1 to 2 dB below the FTA criteria. However, other impacts in the area would result in noise mitigation that would also benefit these residences and the church to the same extent as if impacts were identified.

North of 208th Street SW, the noise impacts under Alternative C1 with Option 2 would be the same as described under Alternative C1 with Option 1, with 103 moderate impacts and 103 severe impacts. As with Option 1, the majority of impacts would be at the four multifamily complexes near the 200th Street SW Station.

Alternative C2: 52nd Avenue West to Lynnwood Transit Center, with Option 1

Alternative C2 with Option 1 would have 112 noise impacts (50 moderate and 62 severe). The noise impacts include one moderate impact at the River of Life Christian Center. As with the Alternative C1 options, there would be several noise impacts along the elevated guideway from I-5 to and along 52nd Avenue West. There would be 32 noise impacts, including 22 moderate and 10 severe impacts along the connection from Segment B to 206th Street SW. North of 206th Street SW to the Lynnwood Transit Center Station there would be an additional 28 moderate and 52 severe noise impacts, including 24 severe impacts at the Park Five Apartments and 18 severe impacts at the Cedar Creek Condominiums.

Alternative C2: 52nd Avenue West to Lynnwood Transit Center, with Option 2

Alternative C2 with Option 2 would result in 105 noise impacts (41 moderate and 64 severe). As described under Alternative C1 with Option 1, the different light rail speed and alignment would result in fewer impacts near the curve from I-5 to 52nd Avenue West. There would be 25 noise impacts, including 13 moderate and 12 severe, along the connection from Segment B to 206th Street SW.

North of 206th Street SW to the Lynnwood Transit Center Station, noise impacts would be the same as under Option 1, with 28 moderate and 52 severe noise impacts.

Alternative C3: Along I-5 to Lynnwood Park-and-Ride, with Option 1

Alternative C3 with Option 1 would result in 6 noise impacts (5 moderate and 1 severe). All impacts are located at single-family homes near I-5 along 52nd Avenue West and 53rd Avenue West. The lower number of noise impacts under this alternative and option, when compared with the other Segment C alternatives, would be related to the light rail alignment remaining in the I-5 median through areas with residences. All 6 noise impacts would be along I-5, just north of the connection to Segment B.

Alternative C3: Along I-5 to Lynnwood Park-and-Ride, with Option 2

Alternative C3 with Option 2 would result in 20 noise impacts (12 moderate and 8 severe). All impacts are located at single-family homes and one apartment near I-5 along 52nd, 53rd and 54th Avenues West. The number of impacts under this alternative option would be lower than Alternatives C1 and C2 because the light rail alignment would remain alongside I-5 and only affect residences near the connection to Segment B. Alternative C3 with Option 2 would have more noise impacts than Option 1 because Option 2 would be closer to the residences near 52nd Avenue West. All noise impacts would be along I-5, just north of the connection to Segment B.

7.3 Park-and-Ride Facilities

This section provides the results of the noise analysis for the proposed park-and-ride facilities. The analysis methods and reference values used for this analysis are provided in Section 5.8. The combination of park-and-ride facilities is based on alternative selection. The park-and-ride locations, options, impacts and their associated light rail alternatives are provided in Table 7-4.

Table 7-4. Summary of Park-and-Ride Facility Impacts by Alternatives and Options

Alternative	NE 130th Street Station	NE 145th Street Station	NE 155th Street Station	NE 185th Street Station
Alternative A1	N/A	Option 1 (No impacts)	N/A	Option 1[a] (15 impacts)
Alternative A3	N/A	Option 2 (No impacts)	N/A	Option 2 (9 impacts)
Alternative A5	Option 1 (No impacts)	N/A	No Options (6 impacts)	Option 3 (12 impacts)

Table 7-4. Summary of Park-and-Ride Facility Impacts by Alternatives and Options

Alternative	NE 130th Street Station	NE 145th Street Station	NE 155th Street Station	NE 185th Street Station
Alternative A7	Option 2 (No impacts)	N/A	No Options (6 impacts)	Option 2 (9 impacts)
Alternative A10	Option 1 (No impacts)	Option 1 (No impacts)	N/A	Option 3 (12 impacts)
Alternative A11	Option 2 (No impacts)	Option 2 (No impacts)	N/A	Option 2 (9 impacts)

N/A = not applicable

b. Includes impacts from buses at the station drop-off and layover area.

7.3.1 Segment A

NE 130th Street Station Option 1

Under Alternatives A5 and A10 with the NE 130th Street Station Option 1, no park-and-ride impacts are predicted. The analysis results are provided in Table 7-5.

Table 7-5. Summary of NE 130th Street Station Option 1 Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	Seattle Code Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
13041 Roosevelt Way	5 SFR west of I-5	43	32	29	72	66	None
502 NE 130th Street	2 SFR at Roosevelt Way	48	34	31	74	66	None
12740 5th Avenue NE	2 SFR south of 30th Street	43	32	29	74	66	None
510 131st Place NE	3 SFR south of church lot	57	39	36	72	66	None
13130 5th Avenue NE	Church residence	54	37	35	67	63	None
13085 8th Court NE	2 SFR east of church parking	52	36	33	66	62	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.
i. Not applicable because vehicles and buses on public roadways are exempt.

NE 130th Street Station Option 2

Under Alternatives A7 and A11 with the NE 130th Street Station Option 2, there would be no noise impacts from park-and-ride operations. The analysis results are provided in Table 7-6.

Table 7-6. Summary of NE 130th Street Station Option 2 Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	Seattle Code Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
13041 Roosevelt Way	5 SFR west of I-5	42	31	28	72	66	None
502 NE 130th Street	2 SFR at Roosevelt Way	42	31	28	74	66	None
12740 5th Avenue NE	2 SFR south of 30th Street	39	30	27	74	66	None
510 131st Place NE	3 SFR south of Church lot	45	33	30	72	66	None
13130 5th Avenue NE	Church residence	45	33	30	67	63	None
13085 8th Court NE	2 SFR east of church parking	46	33	30	66	62	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence
c. Lmax from vehicles or buses on park-and ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property
f. Existing Ldn from Section 3.2
g. FTA criteria for 24-hour Ldn for category 2 land uses
h. Number and type of noise impact from park-and-ride alternative

NE 145th Street Station Option 1

Under Alternatives A1 and A10 with the 145th Street Station Option 1, there would be no noise impacts from park-and-ride operations. These results are provided in Table 7-7.

Table 7-7. Summary of NE 145th Street Station Option 1 Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	Seattle Code Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
501 NE 145th Street	1 SFR on NE 145th Street	43	39	36	74	66	None
14512 5th Avenue NE	2 SFR on 5th Avenue NE	45	39	37	74	66	None
14526 5th Avenue NE	4 SFR on 5th Avenue NE	46	40	37	73	66	None
14556 5th Avenue NE	3 SFR on 5th Avenue NE	51	43	40	73	66	None
14570 5th Avenue NE	3 SFR on 5th Avenue NE	50	42	39	73	66	None
358 NE 148th Street	2 SFR on NE 148th Street	61	48	45	73	66	None
336 NE 148th Street	4 SFR on NE 148th Street	60	47	44	72	66	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

NE 145th Street Station Option 2

Under Alternatives A3 and A11 with the NE 145th Street Station Option 2, there would be no noise impacts from park-and-ride operations. The results are provided in Table 7-8.

Table 7-8. Summary of NE 145th Street Station Option 2 Park-and-Ride Noise Analysis

		Seattle Code Analysis		FTA Analysis			
Representative Address[a]	**Homes Represented Location**[b]	**Lmax**[c]	**Leq**[d]	**Ldn**[e]	**Existing Ldn**[f]	**FTA Criteria**[g]	**Impact Type and Criteria Exceeded**[h]
501 NE 145th Street	1 SFR on NE 145th Street	46	40	37	74	66	None
14512 5th Avenue NE	2 SFR on 5th Avenue NE	48	41	38	74	66	None
14526 5th Avenue NE	4 SFR on 5th Avenue NE	49	42	39	73	66	None
14556 5th Avenue NE	3 SFR on 5th Avenue NE	52	43	40	73	66	None
14570 5th Avenue NE	3 SFR on 5th Avenue NE	49	42	39	73	66	None
345 NE 148th Street	3 SFR on NE 148th Street	50	42	39	73	66	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

NE 155th Street Station Option 1

Under Alternatives A5 and A7 with the NE 155th Street Station, there would be noise impacts at three residences directly east of the parking garage, two residences south of the parking garage, and also at the fire station to the west of the parking garage. These noise impacts are predicted to occur during the early morning hour of 6:00 am to 7:00 am and are related to vehicles accessing the parking garage. The analysis assumes that all 500 parking spaces would be filled between 6:00 am and 7:00 am; therefore, this can be considered a worst-case noise scenario. These noise level projections will be reviewed when more detailed information on the garage design is available. The updated analysis will include any shielding from the garage structure that would be predicted to reduce noise levels, possibly below the City of Shoreline nighttime noise criteria. However, for this analysis, the worst-case unshielded noise levels are presented. The analysis results are provided in Table 7-9.

Table 7-9. Summary of NE 155th Street Station Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	Seattle Code Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
110 NE 155th Street	2 SFR on NE 155th Street	50	42	39	71	66	None
132 NE 155th Street	3 SFR on NE 155th/156th Streets	56	45	42	71	66	None
151 NE 156th Street	3 SFR on NE 156th Street	59	47	44	71	66	None
303 NE 155th Street and 15455 4th Avenue NE	2 SFR on NE 155th Street and 4th Avenue NE	**67**	51	48	68	63	3 SFR with WAC Lmax from parking garage
15451 4th Avenue NE and 15240 3rd Avenue NE	2 SFR on 3rd Avenue NE and 4th Avenue NE	**67**	51	48	71	66	2 SFR with WAC Lmax from parking garage
145 NE 155th Street	Fire Department	**67**	51	48	71	66	Fire Department with WAC Lmax from parking garage

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

NE 185th Street Station Option 1

Under Alternative A1 with the NE 185th Street Station Option 1, Sound Transit identified 15 single-family residences that would experience noise impacts related to buses accessing the station drop-off and layover area off 8th Avenue NE, and continuing along the new bus-only route to the elevated station. Fifteen residences are predicted to exceed the Lmax nighttime criteria (Lmax of 62 dBA or more for more than 15 minutes in any 1 nighttime hour) because there is an estimated 44 buses per hour between 6:00 am and 7:00 am. In addition, two of these residences would also have Leq impacts. All noise impacts would be related to the noise from buses entering and leaving the drop-off and layover area near residences on 8th Avenue NE and leaving the drop-off and layover area near residences on NE 185th Street. The analysis results are provided in Table 7-10.

Table 7-10. Summary of NE 185th Street Station Option 1 Park-and-Ride Noise Analysis[a]

Representative Address[b]	Homes Represented Location[c]	WAC Analysis		FTA Analysis			Impact Type and Criteria Exceeded[i]
		Lmax[d]	Leq[e]	Ldn[f]	Existing Ldn[g]	FTA Criteria[h]	
18523 8th Avenue NE	4 SFR on 8th Avenue NE	66	49	51	65	61	4 SFR with WAC Lmax impacts from buses at the station drop-off and layover area
18529 8th Avenue NE	1 SFR on 8th Avenue NE	69	50	52	63	60	1 SFR with WAC Lmax impact from buses at the station drop-off and layover area
18533 8th Avenue NE	1 SFR on 8th Avenue NE	75	52	54	63	60	1 SFR with WAC Lmax and Leq impacts from buses at the station drop-off and layover area
18547 8th Avenue NE	1 SFR on 8th Avenue NE	73	52	53	63	60	1 SFR with WAC Lmax and Leq impacts from buses at the station drop-off and layover area
18534 8th Avenue NE	3 SFR on 8th Avenue NE	73	51	53	63	60	3 SFR with WAC Lmax impacts from buses at the station drop-off and layover area
18528 8th Avenue NE	1 SFR on 8th Avenue NE	69	50	51	63	60	1 SFR with WAC Lmax impact from buses at the station drop-off and layover area
18522 8th Avenue NE	1 SFR on 8th Avenue NE	66	48	50	63	60	1 SFR with WAC Lmax impact from buses at the station drop-off and layover area
18516 8th Avenue NE	1 SFR on 8th Avenue NE	64	48	49	63	60	1 SFR with WAC Lmax impact from buses at the station drop-off and layover area
721 NE 185th Street	2 SFR on NE 185th Street	64	47	49	71	66	2 SFR with WAC Lmax impacts from buses at the park-and-ride
18556 5th Avenue NE	1 SFR on 5th Avenue NE	50	42	39	63	60	None
338 NE 185th Street	1 SFR on NE 185th Street	50	42	39	64	61	None
330 NE 185th Street	1 SFR on NE 185th Street	49	42	39	63	60	None

a. Includes impacts from buses at the station drop-off and layover area.
b. Address of representative parcel used in modeling.
c. Number and type of land use: SFR = single-family residence.
d. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
e. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
f. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
g. Existing Ldn from Section 3.2.
h. FTA criteria for 24-hour Ldn for category 2 land uses.
i. Number and type of noise impact from park-and-ride alternative.

Note: Values in red meet or exceed the project noise impact criteria.

NE 185th Street Station Option 2

Under Alternatives A3, A7, and A11 with the NE 185th Street Station Option 2, Sound Transit identified nine single-family residences that would experience noise impacts related to the buses accessing the park-and-ride facility. Nine residences are predicted to exceed the Lmax nighttime criteria of 62 dBA because there is an estimated 44 buses per hour between 6:00 am and 7:00 am. In addition, three of these residences would also have Leq impacts. All noise impacts are related to noise from buses entering the park-and-ride near residences on 8th Avenue NE, buses leaving the park-and-ride near residences on NE 185th Street, and passenger vehicles accessing the parking garage. The analysis results are provided in Table 7-11.

Table 7-11. Summary of NE 185th Street Station Option 2 Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	WAC Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
18516 8th Avenue NE	1 SFR on 8th Avenue NE	63	49	49	63	60	1 SFR with WAC Lmax impact from buses at the park-and-ride
18522 8th Avenue NE	1 SFR on 8th Avenue NE	65	49	50	63	60	1 SFR with WAC Lmax impact from buses at the park-and-ride
18528 8th Avenue NE	1 SFR on 8th Avenue NE	68	50	51	63	60	1 SFR with WAC Lmax impact from buses at the park-and-ride
18534 8th Avenue NE	1 SFR on 8th Avenue NE	72	51	52	63	60	1 SFR with WAC Lmax impact from buses at the park-and-ride
18540 8th Avenue NE	2 SFR on 8th Avenue NE	74	52	53	63	60	2 SFR with WAC Lmax and Leq impacts from buses and vehicles at the park-and-ride
18547 8th Avenue NE	1 SFR on 8th Avenue NE	75	53	54	63	60	1 SFR with WAC Lmax and Leq impacts from buses and vehicles at the park-and-ride
721 NE 185th Street	2 SFR on NE 185th Street	64	49	49	71	66	2 SFR with WAC Lmax impacts from buses at the park-and-ride

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

Note: Values in red meet or exceed the project noise impact criteria.

NE 185th Street Station Option 3

Under Alternatives A5 and A10 with the NE 185th Street Station Option 3, Sound Transit identified 12 single-family residences that would experience noise impacts related to buses accessing the park-and-ride on NE 8th Avenue. Twelve residences are predicted to exceed the Lmax nighttime criteria of 62 dBA because there is an estimated 44 buses per hour between 6:00 am and 7:00 am. In addition, six of these residences would also have Leq impacts. The noise impacts would be related to noise from buses and passenger vehicles entering and leaving the park-and-ride near residences on 8th Avenue NE. The analysis results are provided in Table 7-12.

Table 7-12. Summary of NE 185th Street Station Option 3 Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	WAC Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
18504 8th Avenue NE	1 SFR on 8th Avenue NE	**74**	**52**	53	74	66	1 SFR with WAC Lmax and Leq impacts from buses and vehicles at the park-and-ride
18510 8th Avenue NE	1 SFR on 8th Avenue NE	**73**	**52**	53	68	63	1 SFR with WAC Lmax and Leq impacts from buses and vehicles at the park-and-ride
18516 8th Avenue NE	1 SFR on 8th Avenue NE	**69**	51	52	65	61	1 SFR with WAC Lmax impact from buses at the park-and-ride
18342 8th Avenue NE	1 SFR on 8th Avenue NE	**66**	48	50	68	63	1 SFR with WAC Lmax impact from buses at the park-and-ride
731 NE 185th Street	2 SFR on NE185th Street	**64**	48	49	70	65	2 SFR with WAC Lmax impact from buses at the park-and-ride
18522 8th Avenue NE	1 SFR on 8th Avenue NE	**66**	50	51	63	60	1 SFR with WAC Lmax impact from buses at the park-and-ride
18528 8th Avenue NE	1 SFR on 8th Avenue NE	**69**	51	52	63	60	1 SFR with WAC Lmax impact from buses at the park-and-ride
18534 8th Avenue NE	1 SFR on 8th Avenue NE	**73**	**52**	53	63	60	1 SFR with WAC Lmax and Leq impacts from buses and vehicles at the park-and-ride
18540 8th Avenue NE	2 SFR on 8th Avenue NE	**74**	**52**	53	63	60	2 SFR with WAC Lmax and Leq impacts from buses and vehicles at the park-and-ride
18547 8th Avenue NE	1 SFR on 8th Avenue NE	**73**	**52**	53	63	60	1 SFR with WAC Lmax and Leq impacts from buses and vehicles at the park-and-ride
814 NE 185th Street	1 SFR on 8th Avenue NE	52	39	36	68	63	None
18525 10th Avenue NE	1 SFR on 10th Avenue NE	52	40	37	66	62	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

Note: Values in red meet or exceed the project noise impact criteria.

7.3.2 Segment B

Mountlake Terrace Transit Center

Under Alternatives B1, B2, and B2A with the Mountlake Terrace Transit Center Station option, Sound Transit identified four single-family residences that would experience noise impacts. The Lmax noise impacts would be related to the noise from buses leaving the park-and-ride along the eastern layover route. Because there are 44 buses predicted to use the park-and-ride during the peak hour between 6:00 am and 7:00 am, this is an exceedance of the Lmax criteria. The analysis results are provided in Table 7-13.

Table 7-13. Summary of Mountlake Terrace Transit Center Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	WAC Analysis Lmax[c]	WAC Analysis Leq[d]	WAC Analysis Ldn[e]	FTA Analysis Existing Ldn[f]	FTA Analysis FTA Criteria[g]	Impact Type and Criteria Exceeded[h]
6002 233rd Place SW	2 SFR on 233rd Place SW	57	46	45	72	66	None
23504 59th Place SW	4 SFR on 59th Place SW	67	51	52	68	63	4 SFR with WAC Lmax impacts from buses at the park-and-ride
5906 236th Street SW	1 SFR on 236th Street SW	56	47	47	62	59	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.
Note: Values in red meet or exceed the project noise impact criteria.

Mountlake Terrace Freeway Station

Under Alternative B4 with the Mountlake Terrace Freeway Station option, park-and-ride noise impacts would be the same as with the Mountlake Terrace Transit Center Station option. The analysis results are provided in Table 7-14.

Table 7-14. Summary of Mountlake Terrace Freeway Station Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	WAC Analysis Lmax[c]	WAC Analysis Leq[d]	WAC Analysis Ldn[e]	FTA Analysis Existing Ldn[f]	FTA Analysis FTA Criteria[g]	Impact Type and Criteria Exceeded[h]
6002 233rd Place SW	2 SFR on 233rd Place SW	57	46	45	72	66	None
23504 59th Place SW	4 SFR on 59th Place SW	67	51	52	68	63	4 SFR with WAC Lmax impacts from buses on the park-and-ride
5906 236th Street SW	1 SFR on 236th Street SW	56	47	47	62	59	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

Note: Values in red meet or exceed the project noise impact criteria.

220th Street SW Station Option

Under Alternative B2A with the 220th Street SW Station option, the alternative would have the same impacts as B2 would have at the Mountlake Terrace Transit Station Park-and-Ride, and there would be no additional noise impacts from vehicles accessing the second station's 200th Street SW parking area. The analysis results are provided in Table 7-15.

Table 7-15. Summary of 220th Street SW Station Option Park-and-Ride Noise Analysis

		WAC Analysis			FTA Analysis		
Representative Address[a]	Homes Represented Location[b]	Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	Impact Type and Criteria Exceeded[h]
6305 220th Place SW	1 SFR on 220th Place SW	47	41	38	72	66	None
6303 220th Place SW	1 SFR on 220th Place SW	48	41	39	73	66	None
6302 220th Place SW	1 SFR on 220th Place SW	48	41	38	74	66	None
6304 220th Place SW	1 SFR on 220th Place SW	47	40	37	75	66	None
6305 221st Place SW	1 SFR on 220th Place SW	47	39	37	76	66	None
6303 221st Place SW	1 SFR on 220th Place SW	47	39	37	77	66	None
6302 221st Place SW	1 SFR on 220th Place SW	46	39	36	78	66	None
6303 222nd Street SW	1 SFR on 220th Place SW	45	38	35	79	66	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: SFR = single-family residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

7.3.3 Segment C

Alternative C1: 200th Street SW Station

Under the 200th Street SW Station Park-and-Ride option, Sound Transit identified that several of the multifamily units near the proposed facility would experience noise impacts. Based on building plans from the complexes, 55 units were identified that would have noise impacts, including 4 units at the Park Five complex, 10 units at the Oxford complex, and 41 units at the Cambridge Square complex. All impacts would be related to noise from buses accessing the reconfigured bus facility and, to a lesser extent, from passenger vehicles accessing the parking areas off 48th Avenue West. The analysis results are provided in Table 7-16.

Table 7-16. Alternative C1: 200th Street SW Station Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	WAC Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
20104 48th Avenue West (Park Five Bldg. A)	4 MFR on 48th Avenue West	58	**53**	51	62	59	4 MFR with WAC Leq impacts from buses and vehicles
20104 48th Avenue West (Park Five Bldg. C)	4 MFR on 48th Avenue West	56	**52**	50	67	63	10 MFR with WAC Leq impacts from buses and vehicles
4807 200th Street SW (Oxford Square SE corner on 200th Street SW)	10 MFR on 200th Street SW	55	**52**	50	69	64	14 MFR with WAC Leq impacts from buses and vehicles
4727 200th Street SW (Cambridge Square SW corner on 200th Street SW)	21 MFR on 200th Street SW	56	**52**	50	69	64	14 MFR with WAC Leq impacts from buses and vehicles
4727 200th Street SW (Cambridge Square SE corner on 200th Street SW)	20 MFR on 200th Street SW	48	**52**	50	69	64	13 MFR with WAC Leq impacts from buses and vehicles

a. Address of representative parcel used in modeling.
b. Number and type of land use: MFR = multifamily residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

Note: Values in red meet or exceed the project noise impact criteria.

Alternative C2: Lynnwood Transit Center

Under the Lynnwood Transit Center Station configuration with Alternative C2, Sound Transit identified that five of the multifamily units at the Park Five complex would experience noise impacts. All impacts would be related to noise from buses accessing the reconfigured bus facility with a slight increase in the overall noise from passenger vehicles accessing the parking garage. The analysis results are provided in Table 7-17.

Table 7-17. Alternative C2: Lynnwood Transit Center Station Park-and-Ride Noise Analysis

Representative Address[a]	Homes Represented Location[b]	WAC Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
20104 48th Avenue West (Park Five Bldg. A)	4 MFR on 48th Avenue West	58	53	51	62	59	4 MFR with WAC Leq impacts from buses
4807 200th Street SW (Oxford Square SE corner on 200th Street SW)	10 MFR on 200th Street SW	53	50	48	67	63	None
4727 200th Street SW (Cambridge Square SW corner on 200th Street SW)	14 MFR on 200th Street SW	54	51	49	69	64	None
4727 200th Street SW (Cambridge Square center of complex on 200th Street SW)	14 MFR on 200th Street SW	56	51	49	69	64	None
4727 200th Street SW (Cambridge Square SE corner on 200th Street SW)	13 MFR on 200th Street SW	54	51	49	69	64	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: MFR = multifamily residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.
Note: Values in red meet or exceed the project noise impact criteria.

Alternative C3

With Alternative C3, there would be two options for developing the station and park-and-ride garage, but there would not be noise impacts with either option. The analysis results are provided in Tables 7-18 and 7-19.

Table 7-18. Alternative C3: Lynnwood Park-and-Ride Station Option 1 Noise Analysis

Representative Address[a]	Homes Represented Location[b]	WAC Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
20104 48th Avenue West (Park Five Bldg. A)	4 MFR on 48th Avenue West	43	44	41	62	59	None
4807 200th Street SW (Oxford Square SE corner on 200th Street SW)	10 MFR on 200th Street SW	53	50	48	67	63	None
4727 200th Street SW (Cambridge Square SW corner on 200th Street SW)	14 MFR on 200th Street SW	54	51	49	69	64	None
4727 200th Street SW (Cambridge Square center of complex on 200th Street SW)	14 MFR on 200th Street SW	56	51	49	69	64	None
4727 200th Street SW (Cambridge Square SE corner on 200th Street SW)	13 MFR on 200th Street SW	54	51	49	69	64	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: MFR = multifamily residence
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

Table 7-19. Summary of Lynnwood Park-and-Ride Station Option 2 Noise Analysis

Representative Address[a]	Homes Represented Location[b]	WAC Analysis		FTA Analysis			Impact Type and Criteria Exceeded[h]
		Lmax[c]	Leq[d]	Ldn[e]	Existing Ldn[f]	FTA Criteria[g]	
20104 48th Avenue West (Park Five Bldg. A)	4 MFR on 48th Avenue West	43	45	42	62	59	None
4807 200th Street SW (Oxford Square SE corner on 200th Street SW)	10 MFR on 200th Street SW	53	50	48	67	63	None
4727 200th Street SW (Cambridge Square SW corner on 200th Street SW)	14 MFR on 200th Street SW	54	51	49	69	64	None
4727 200th Street SW (Cambridge Square center of complex on 200th Street SW)	14 MFR on 200th Street SW	56	51	49	69	64	None
4727 200th Street SW (Cambridge Square SE corner on 200th Street SW)	13 MFR on 200th Street SW	54	51	49	69	64	None

a. Address of representative parcel used in modeling.
b. Number and type of land use: MFR = multifamily residence.
c. Lmax from vehicles or buses on park-and-ride property (62 nighttime, 72 daytime criteria). Vehicles and buses on public roadways are exempt.
d. Peak-hour Leq for analysis, typically between 6:00 am and 7:00 am (52 dBA nighttime).
e. 24-hour Ldn noise from park-and-ride, includes vehicles in parking areas and buses on park-and-ride property.
f. Existing Ldn from Section 3.2.
g. FTA criteria for 24-hour Ldn for category 2 land uses.
h. Number and type of noise impact from park-and-ride alternative.

7.4 Construction Noise Impact Analysis

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

Noise related to construction would result from the operation of heavy equipment needed to construct various project components, including bridges, retaining walls, roads, park-and-ride facilities, and stations. The contractor would be required to adhere to local ordinances regulating noise, as discussed in Section 4.3. Construction activities outside normal weekday daytime hours would require a noise variance from the City or County where the work is being performed if regulatory noise levels are exceeded.

Equipment required to complete the Lynnwood Link Extension would include construction equipment typically used for transportation construction projects. Table 7-20 lists the typical equipment used for this type of project, the activities they would be used for, and the corresponding maximum noise levels that would be produced when measured at 50 feet from the sources under normal use.

Table 7-20. Construction Equipment and Reference Noise Levels

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

[a] Typical maximum noise level under normal operation as measured at 50 feet from the noise source.

[b] Noise levels presented are based on measured data from the Portland Light Rail and I-5 Preservation and Hawthorne Bridge construction projects and other measured data, as well as U.S. Department of Transportation construction noise documentation and other construction noise sources.

dBA = decibel with A-weighting, Lmax = maximum noise level

7.4.1 Construction Noise

Several construction phases would be required to complete the Lynnwood Link Extension. The FHWA Construction Noise Model (2006) was used to provide an estimate of the project construction noise levels, as well as to predict the maximum noise levels for several different construction phases. The analysis assumes the worst-case average and maximum noise levels based on three major types of construction described below and shown in Table 7-21. The actual noise levels experienced during construction would generally be lower than those described in Table 7-21 because these are the maximum noise levels for each activity. The noise levels presented here are for short periods of maximum construction activity and would occur for a limited period of time.

Table 7-21. Noise Levels for Typical Construction Phases[a]

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

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

7.4.2 Demolition, Site Preparation, and Utilities Relocation

Major noise-producing equipment in use during the preparation stage of light rail construction could include saw cutters, concrete pumps, cranes, excavators, haul trucks, loaders, tractor-trailers, and vibratory equipment. Maximum noise levels could reach 82 dBA to 94 dBA at the nearest residences (i.e., within 50 to 100 feet) for normal construction activities during this phase. Other less-notable noise-producing equipment expected during this phase would include backhoes, air compressors, forklifts, pumps, power plants, service trucks, and utility trucks.

7.4.3 Structures Construction, Track Installation, and Paving Activities

The loudest noise sources in use during construction of elevated structures would include cement mixers, concrete pumps, cranes, pavers, haul trucks, and tractor-trailers. The cement mixers, cranes, and concrete pumps would be required for construction of the light rail superstructure. The pavers and haul trucks would be used to provide the final surface on the trackway, roadways, and ramps modified during other phases of construction. Maximum noise levels would range from 82 dBA to 94 dBA at the closest receiver locations.

7.4.4 Miscellaneous Activities

Following heavy construction, general construction would still be required such as installation of bridge railing, signage, roadway striping, and communication and power systems, as well as other miscellaneous activities. These less-intensive activities are not expected to produce noise levels above 80 dBA at 50 feet except during rare occasions, and even then only for short periods of time when maximum noise levels could reach 91 dBA Lmax at 50 feet. Using the information in Table 7-21, typical construction noise levels were projected for several distances from the project work area. Figure 7-1 is a graph of general construction noise level versus distance for phases of construction.

7.4.5 Pile-Driving

Pile-driving would likely be required to support permanent structures such as piers for elevated structures and retaining tunnel walls. Pile-driving can produce maximum short-term noise levels of 99 dBA to 105 dBA at 50 feet. Actual levels can vary and would depend on the distance and topographical conditions between the pile-driving location and the receiver location. Figure 7-2 is a graph of maximum pile-driving noise levels versus distance.

7.4.6 Nighttime Construction Activities

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

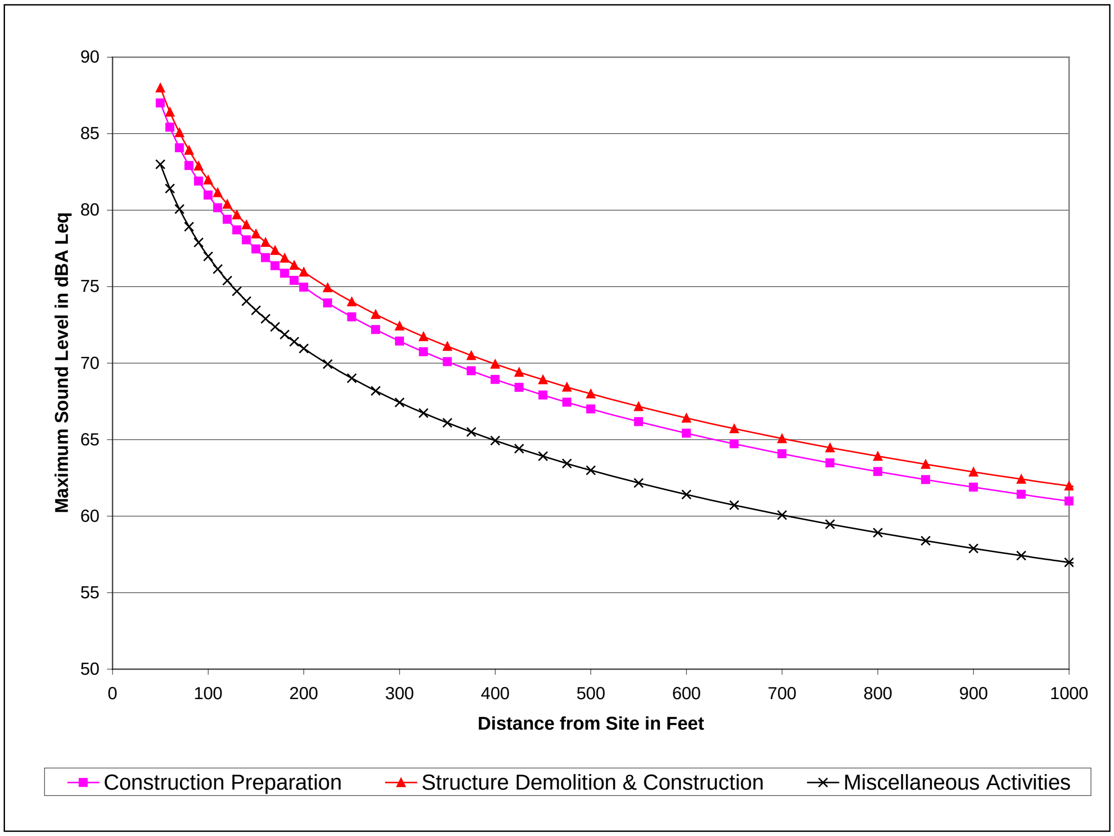

Figure 7-1. Maximum Noise Level versus Distance for Typical Construction Phases

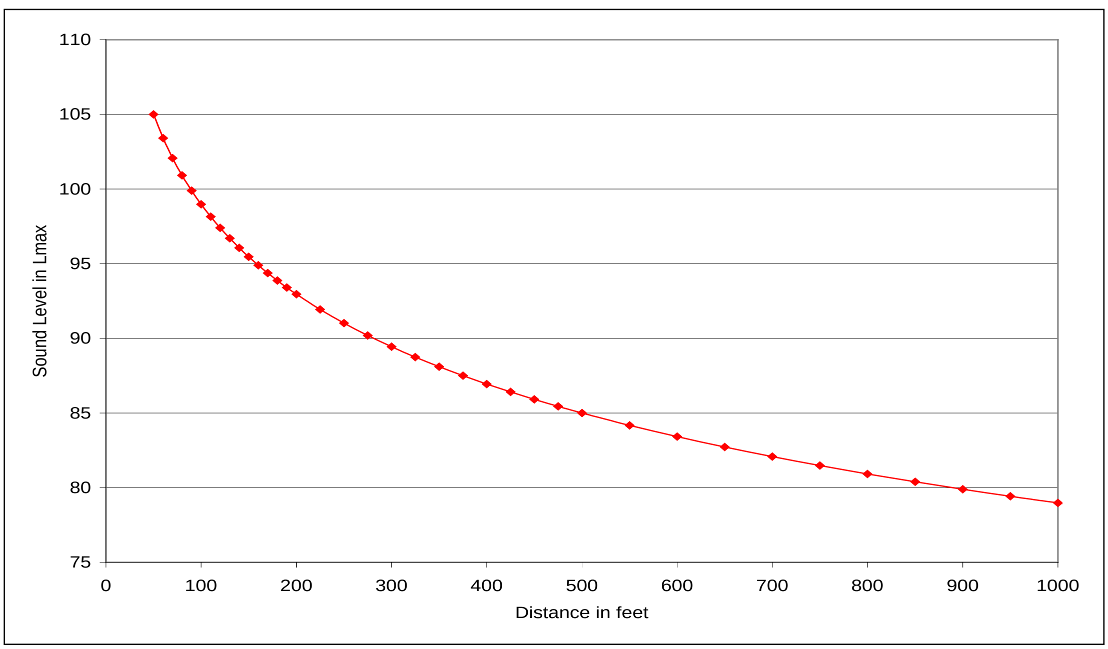

Figure 7-2. Pile-Driving Noise Level versus Distance

7.4.7 Segment A

There are a large number of single-family and multifamily residences along the Segment A alternative alignments. Under all of the Segment A alternatives, noise levels at adjacent residences would have short periods of time with maximum noise levels exceeding 80 dBA Lmax. Major construction noise would occur during demolition of existing structures; relocation of noise walls and utilities; installation of retaining walls (where required); repaving of local access and arterial roadways; and construction of the at-grade, retained cut-and-fill and elevated guideway structures. Pile-driving and sheet-pile installation might also be required. Pile-driving could produce noise levels of 105 dBA Lmax at 50 feet. Although there would be periods of relatively loud construction, noise levels would decrease as tasks are completed and construction activities move to other areas.

Near Northgate, the major noise generator for all light rail alternatives would be construction of the elevated structures connecting the Northgate Station to the guideway along 1st Avenue NE and crossing over Northgate Way. North of Northgate Way, major construction activities could include installation of the elevated guideway under all light rail alternatives and reconstruction of 1st Avenue NE and the North 117th Street overpass under Alternative A1. Several noise walls would also be relocated during the initial phase of the project. Every attempt would be made to replace the noise walls early in the construction process, if possible, which would allow the walls to also assist with mitigating construction noise. Without the noise walls, there would be short periods of time with maximum noise levels exceeding 80 dBA Lmax; when the walls are replaced, the maximum levels should be 10 dB to 12 dB lower than without the walls in place.

Under Alternatives A5, A7, A10, and A11, construction of the NE 130th Street Station would result in additional short-term construction activities in the vicinity of 5th Avenue NE and NE 130th Street. Because this station would not include any parking structures, the main construction activities would be restricted to the west side of 5th Avenue NE for station platforms and associated facilities, including a parking lot under the NE 130th Street Station Option 2. Maximum noise levels during periods of heavy construction would reach up to 75 dBA Lmax, with typical noise levels ranging from 65 dBA to 75 dBA during periods of active construction.

North of NE 130th Street and south of the NE 145th Station options in Segment A, the land use consists mainly of recreational uses that are not noise-sensitive under the FTA regulations. Although construction noise is expected to have some effect on noise levels at the golf course, the added distance and 5th Avenue NE buffer would help to reduce the overall noise effect in this area. With the buffer zone, noise levels should remain below 70 dBA to 75 dBA Lmax in this area.

Noise levels related to the construction of the NE 145th Street Station would be similar under Alternatives A1, A3, A10, and A11. For residences located near the proposed station, short-term maximum noise levels of 70 dBA to 80 dBA could be expected, with typical construction-related noise levels of 65 dBA to 75 dBA.

Several additional noise walls would be relocated under all Segment A alternatives north of the NE 145th Street Station. The noise walls would also be used to provide noise mitigation for light rail operations as well as traffic noise; therefore, these proposed walls might be slightly higher than the existing noise walls. Sound Transit would attempt to relocate the noise walls early in the construction process to assist with construction noise mitigation. During the short periods when the walls would be removed, construction and traffic noise would likely meet or exceed 80 dBA at homes closest to the construction sites.

The NE 155th Street Station under Alternatives A5 and A7 would include the construction of a multistory parking facility. Because of the light rail station and parking structure, noise levels in the vicinity of this station would be elevated longer under Alternatives A7 and A10 than under Alternatives A1, A3, A10, and A11, which would not include the NE 155th Street Station.

North of NE 155th Street to the north end of Segment A, just past 185th Street, construction noise and activities would be similar to those described for the southern part of Segment A, with short periods of time with maximum noise levels exceeding 80 dBA Lmax. In addition, several existing noise walls in this area would also be relocated as part of the project.

Construction noise related to the NE 185th Street Station would vary by design option. Under Alternative A1 with the 185th Street Station Option 1, the parking structure would be on the west side of I-5, and the overpass would be improved for better pedestrian access. Therefore, Option 1 is the only option with which construction noise could affect residences on both sides of I-5. Construction of the parking area along the west side of I-5 would elevate noise levels at residences north of the station along 5th Avenue NE and south of the parking area along NE 185th Street.

Under Alternatives A3, A7, and A11, the 185th Street Station Option 2 would include a three-story parking facility constructed between the station and 8th Avenue NE. Both Alternatives A5 and A10 would include the NE 185th Street Station Option 3, which would have a surface parking lot between the station and 8th Avenue NE, with an option for additional parking farther east. Although both of these station design options would be located entirely on the east side of I-5, construction of the parking garage under Option 2 would be expected to elevate noise levels slightly higher and longer than under Option 3 because of the added construction effort and time required to build the parking structure. Construction of the elevated structures, parking garages, and other major project-related construction activities could result in noise levels of 83 to 87 dBA Leq during periods of heavy construction.

7.4.8 Segment B

Major construction activities in Segment B would include relocating noise walls and utilities; installing retaining walls (where required); repaving local access and arterial roadways; and constructing the at-grade, retained cut-and-fill, and elevated guideway structures. Pile-driving and sheet-pile installation might also be required; pile-driving could produce Lmax noise levels of 105 dBA at 50 feet. Beginning just north of the NE 185th Street Station options, all four Segment B alternative alignments would be along the east side of I-5, and, as with other segments, would require relocating several noise walls. Construction-related noise levels would be highest during the relocation of the walls and installation of the elevated and retained cut-and-fill guideways. During these periods of heavy construction, noise levels would likely exceed 80 dBA Lmax at most front-line residences. When the noise wall relocation is completed, construction noise levels would be reduced because the noise walls would provide shielding from many construction activities.

North of Ballinger Way (SR 104), all four of the Segment B alternatives would be elevated to the Mountlake Terrace Transit Center Station except for Alternative B4, which would move to the I-5 median and return to at-grade near the 236th Street SW overpass. Under all Segment B alternatives, several homes along 60th Avenue NW would experience elevated noise levels from project construction because they would have a direct line-of-sight to the construction areas north of Gateway Place. Because these residences are located approximately 500 feet from most of the construction activities, Sound Transit expects that noise levels during construction would remain below 70 dBA Lmax.

North of the Mountlake Terrace Transit Center Station, Alternatives B1 and B4 would remain in the I-5 median; therefore, most construction would be performed in the center of the freeway, using the express lanes and shoulders. The added buffer of 250 feet to 400 feet and existing noise walls (depending on location) could help to reduce maximum noise levels by 5 dB to 10 dB or more.

Alternatives B2 and B2A would both be located along the west side of I-5, and, as with other Segments A and B alternatives, would require relocating two noise walls. During these periods of heavy construction, Sound Transit expects that noise levels would exceed 80 dBA Lmax. When the noise wall relocation is completed, noise levels would be reduced because of the wall shielding receptors from construction activities.

7.4.9 Segment C

Major construction noise would occur during the demolition of existing structures; relocation of utilities; repaving of local access and arterial roadways; and construction of the at-grade, retained cut-and-fill, and elevated guideway structures. In Segment C, a limited number of residential land uses would be affected by the construction noise. Noise would increase at the homes located in the residential area west of 52nd Avenue West, north of I-5, and south of the Interurban Trail. Under Alternatives C1 and C2, the area of affected homes would continue north along 52nd Avenue West. Businesses along 52nd Avenue West would also be affected. Conversely, under Alternative C3, only the aforementioned residential area and a few businesses would be affected along 52nd Avenue West near the connection between Segments B and C alternatives. Under Alternative C1, numerous apartment and condominium homes along 200th Street SW, which are 70 feet to 100 feet from the project work site, would also experience increased noise levels because of construction activities. Sound Transit projects that maximum noise levels would reach up to 80 dBA Lmax, with typical noise levels ranging from 72 dBA to 80 dBA during periods of active construction.

8 POTENTIAL NOISE MITIGATION MEASURES

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

One of the most effective forms of noise mitigation is to reduce noise at the source. One form of source noise reduction is using low vehicle noise levels. Sound Transit has purchased state-of-the-art, lower-noise vehicles equipped with noise-reducing wheel skirts covering the wheel-rail interface. Several additional operational measures can also be used to reduce noise levels at the source. Table 5-1 lists operational and maintenance measures that Sound Transit performs on a regular basis and the benefits that these measures provide.

Source treatments that Sound Transit is currently using to minimize noise impacts include requiring wheel skirts, maintaining smooth tracks, performing vehicle maintenance and wheel truing, and conducting operator training. The next type of mitigation considered would be applied between the noise source and receiver. Typical noise path mitigation includes noise walls, earth berms, and buffer zones. Constructing noise walls 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, which require more right-of-way than walls and are usually constructed with a 3-to-1 slope. For the Lynnwood Link Extension, berms would not generally be feasible because of topographical conditions and limited right-of-way. Noise walls should be high enough to break the line-of-sight between the noise source and the receiver. The typical height for at-grade noise walls is 6 feet to 8 feet and 4 feet to 6 feet when on elevated structures. Noise walls must also be long enough to prevent flanking of noise around the ends of the walls. Openings in noise 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. However, because the Lynnwood Link Extension would be in an urban setting where land is at a premium, creating buffer zones is not a feasible form of noise mitigation because it would require substantially more project-related displacements.

For situations where noise path mitigation would either be unfeasible or ineffective, Sound Transit would consider building sound insulation. 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 (HUD). Under these guidelines, interior noise levels for residential land uses should not exceed 45 dBA Ldn, and a form of fresh air exchange must be maintained. The air exchange can be achieved by opening a window or using a ventilation system. Sound insulation is normally only used on older dwellings with single-paned windows, or in buildings with double-paned windows that are no longer effective because of leakage. Sound insulation would not reduce exterior noise levels.

When a light rail train travels over a crossover, 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 crossover tracks can include relocating the crossover away from noise-sensitive properties, or the use of special trackwork, such as special frogs that include gap-closing mechanisms, or using movable point frogs. A "frog" in this context 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. A gap is provided on top of the frog so that vehicle wheels can pass regardless of which track is in use. With standard rigid frogs, noise and vibration occurs when the wheels pass over the gap, 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 crossovers include spring-rail or flange-bearing frogs.

Sound Transit's noise mitigation policy is to mitigate both moderate and severe impacts beginning with source treatment, followed by treatments in the noise path. If source and path treatments are not sufficient to mitigate the impact, Sound Transit 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. The following sections provide a summary of the current mitigation strategies proposed for the Lynnwood Link Extension.

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

8.1 Transit Noise Mitigation Analysis

This section generally describes the potential noise mitigation measures that would be used for the light rail alternatives. However, if during final design Sound Transit determines that the relevant noise criterion could be achieved by a less costly means, or that the noise impact at that location would not occur even without mitigation, then the mitigation measure might be eliminated or modified as needed. Conversely, if any additional noise impacts are identified during final design, then Sound Transit would make every attempt to provide mitigation that is consistent with the Sound Transit Noise Mitigation Policy (Sound Transit 2004).

Attachment B provides complete details on mitigation, including projected noise levels with the proposed noise mitigation measures for each receiver. Alternative-specific mitigation measures are presented below, and Table 8-1 provides a complete summary of mitigation measures. Attachment F maps the locations where at-grade noise walls and aerial noise barriers are anticipated to mitigate the noise impacts for each alternative.

Table 8-1. Summary of Potential Noise Impacts and Mitigation Measures

Alternative	Relocation of Noise Walls Required for Project Construction[a]	Light Rail Impacts		Proposed Noise Mitigation Measures for Impacts after Relocating Noise Walls	Locations Considered for Sound Insulation
		Moderate[b]	Severe[c]		
Segment A Alternatives					
A1	sta 38–53: 1,500 feet sta 114–126: 1,200 feet sta 155–189: 3,400 feet sta 197–215: 1,800 feet	134	49	Approximately 11,200 feet of additional noise walls, 2,700 feet at-grade, 4,700 feet on retaining walls, and 3,800 feet along elevated structures	0
A3	sta 155-176: 2,100 feet	146	211	Approximately 17,300 feet of additional noise walls, 500 feet at-grade, 1,600 feet on retaining walls, and 15,200 feet along elevated structures	12
A5	sta 30–52: 2,200 feet sta 115–126: 1,100 feet sta 155–189: 3,400 feet sta 197–202: 500 feet sta 206–216: 1,000 feet	119	107	Approximately 11,000 feet of additional noise walls, 2,600 feet at-grade, 4,500 feet on retaining walls, and 3,900 feet along elevated structures	4
A7	sta 155–176: 2,100 feet	165	202	Approximately 17,400 feet of additional noise walls, 400 feet at-grade, 2,200 feet on retaining walls, and 14,800 feet along elevated structures	13
A10	sta 30–31: 100 feet sta 38–53: 1,500 feet sta 114–126: 1,200 feet sta 155–189: 3,400 feet sta 197–216: 1,900 feet	107	112	Approximately 11,500 feet of additional noise walls, 2,300 feet at-grade, on 5,100 feet on retaining walls, and 4,100 feet along elevated structures	4
A11	sta 155–189: 3,400 feet	146	206	Approximately 17,100 feet of additional noise walls, 300 feet at-grade, 1,600 feet on retaining walls, and 15,200 feet along elevated structures	12
Segment B Alternatives					
B1	None	101	30	Approximately 20,800 feet of additional noise walls, 14,600 feet at-grade or on retaining walls and 6,200 feet along elevated structures	0
B2	sta 394–398: 400 feet sta 410–415: 500 ft	121	52	Approximately 15,000 feet of additional noise walls, 5,600 feet at-grade or on retaining walls and 9,400 feet along elevated structures	5
B2A	sta 394–398: 400 feet sta 410–415: 500 feet	119	52	Approximately 15,000 feet of additional noise walls, 5,600 feet at-grade or on retaining walls and 9,400 feet along elevated structures	6

Table 8-1. Summary of Potential Noise Impacts and Mitigation Measures

Alternative	Relocation of Noise Walls Required for Project Construction[a]	Light Rail Impacts		Proposed Noise Mitigation Measures for Impacts after Relocating Noise Walls	Locations Considered for Sound Insulation
		Moderate[b]	Severe[c]		
B4	None	89	36	Approximately 16,200 feet of additional noise walls, 10,700 feet at-grade or on retaining walls and 5.500 feet along elevated structures	0
Segment C Alternatives					
C1, Option 1	None	125	113	Approximately 7,200 feet of additional noise walls along elevated structures	0
C1, Option 2	None	118	113	Approximately 7,200 feet of additional noise walls along elevated structures	0
C2, Option 1	None	50	62	Approximately 6,600 feet of additional noise walls along elevated structures	0
C2, Option 2	None	41	64	Approximately 6,600 feet of additional noise walls along elevated structures	0
C3, Option 1	None	5	1	Approximately 1,700 feet of additional noise walls, 700 feet on retained fill and 1,000 feet along elevated structures	0
C3, Option 2	None	12	8	Approximately 1,700 feet of additional noise walls, 700 feet on retained fill and 1,000 feet along elevated structures	0

[a] This column shows the location of the start and end points (sta) for relocated noise walls along the light rail route and the corresponding length (feet) of relocated noise walls. The “sta” correlates to the designated station, or location, on the project design drawings, and each consecutive sta marker on the design drawings indicates a distance of 100 feet. For example, from sta 38 to 53 there are 15 sta on the design drawings, which multiplied by 100 for each sta equals a distance of 1,500 feet.

[b] Moderate impact: In this range of noise impact; the change in the cumulative noise level is noticeable to most people but might not be sufficient to cause strong, adverse reactions from the community.

[c] Severe impact: Project-generated noise in the severe impact range can be expected to cause a substantial percentage of people to be highly annoyed by the new noise and represents the most compelling need for mitigation.

8.1.1 Segment A

The main form of noise mitigation in Segment A would be the use of noise walls. Noise walls used in this segment would include short walls, like those used in Tukwila as part of Central Link, which are directly attached to the sides of the elevated guideway. These walls are acoustically absorbent and very effective at reducing noise; typical noise reductions are in excess of 12 dB to 15 dB. Additional at-grade noise walls and walls along retained fills and cuts would also be used, depending on the track type. Because the majority of noise from light rail operations comes from the wheel-rail interface, even relatively short walls can reduce noise levels by 7 dB to 10 dB, depending on topographical conditions and distance. On elevated guideways, short barriers can provide an even greater noise reduction.

Alternative A1: At-grade/Elevated with NE 145th Street and NE 185th Street Stations

Table 8-2 summarizes the potential mitigation noise walls in Segment A for Alternative A1. The proposed noise mitigation would include approximately 11,200 linear feet of noise wall. The majority of noise walls on elevated structures would be 4 feet to 6 feet tall, while noise walls on retaining walls and in cut-and-fill sections would range from 4 feet to 8 feet tall. With the proposed noise walls (see Table 8-2) and the relocation of existing noise walls, Sound Transit would mitigate all predicted noise impacts resulting from Alternative A1. In some areas, relocated walls at their current height might not fully mitigate for light rail noise; these walls could be increased in height or sound insulation may be applied to provide mitigation if needed.

Table 8-2. Summary of Potential Noise Mitigation Measures for Alternative A1

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall on Structure	11	20	900	4
Wall on Retaining Wall	20	26	600	6
Wall At-Grade	36	37	100	4
Wall on Retaining Wall	37	45	800	4
Wall At-Grade	45	53	800	4
Wall on Structure	107	122	1,500	4 to 6
Wall on Retaining Wall	122	133	1,100	4 to 6
Wall on Structure	133	141	800	4 to 6
Wall on Retaining Wall	141	151	1,000	4 to 6
Wall At-Grade	151	156	500	4 to 6
Wall on Structure	190	196	600	4 to 6
Wall on Retaining Wall	196	199	300	4 to 6
Wall At-Grade	199	206	700	4 to 8
Wall on Retaining Wall	206	212	600	4 to 8
Wall on Retaining Wall	228	231	300	4
Wall At-Grade	231	237	600	4
Total linear feet of noise wall			**11,200**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative A3: Mostly Elevated with NE 145th and NE 185th Street Stations

Table 8-3 summarizes the potential mitigation noise walls in Segment A for Alternative A3. The proposed noise mitigation would include approximately 17,300 linear feet of noise wall, with Sound Transit installing most of the walls along the elevated guideway structures. All noise walls would be 4 feet to 6 feet tall. The proposed noise walls (see Table 8-3) and the relocation of existing noise walls would together mitigate most predicted noise impacts. Currently, six single-family homes are immediately adjacent to the proposed light rail alignment on the east side of I-5 between NE 117th Street and NE 123rd Street NE. Also, six single-family homes are immediately adjacent to the alignment on the east side of I-5 between NE 178th Street and NE 180th Street NE that might need sound insulation.

Table 8-3. Summary of Potential Noise Mitigation Measures for Alternative A3

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall on Structure	11	87	7,600	4 to 6
Wall on Structure	108	126	1,800	4 to 6
Wall on Retaining Wall	126	131	500	4 to 6
Wall on Structure	131	141	1,000	4 to 6
Wall on Retaining Wall	141	149	800	4 to 6
Wall At-Grade	149	154	500	4 to 6
Wall on Retaining Wall	154	157	300	4
Wall on Structure	185	233	4,800	4 to 6
Total linear feet of noise wall			**17,300**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative A5: At-grade/Elevated with NE 130th, NE 155th, and NE 185th Street Stations

Table 8-4 summarizes the potential mitigation noise walls in Segment A for Alternative A5. The proposed noise mitigation would include approximately 11,000 linear feet of noise wall, with Sound Transit installing most of the walls along the elevated guideway structures and retaining walls. The majority of noise walls on elevated structures would be 4 feet to 6 feet tall, while noise walls on retaining walls and at-grade would range from 4 feet to 8 feet tall. With the proposed noise walls (see Table 8-4) and the relocation of existing noise walls, Sound Transit would mitigate most predicted noise impacts. Currently, two single-family homes and a duplex are immediately adjacent to the proposed light rail alignment on the east side of I-5 between NE 115th Street and NE 117th Street NE that may need sound insulation.

Table 8-4. Summary of Potential Noise Mitigation Measures for Alternative A5

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall on Structure	11	23	1,200	4 to 6
Wall on Retaining Wall	23	26	300	8
Wall At-Grade	26	33	700	8
Wall on Retaining Wall	33	44	1,100	4
Wall At-Grade	44	45	100	4
Wall on Structure	107	115	800	4 to 6
Wall on Retaining Wall	115	124	900	4 to 6
Wall on Structure	124	134	1,000	4
Wall on Structure	138	141	300	4
Wall on Retaining Wall	141	151	1,000	4 to 6
Wall At-Grade	151	156	500	4 to 6
Wall on Structure	190	196	600	4 to 6
Wall on Retaining Wall	196	199	300	4 to 6
Wall At-Grade	199	204	500	4 to 8
Wall on Retaining Wall	204	209	500	4
Wall At-Grade	223	224	100	4
Wall on Retaining Wall	224	226	200	4
Wall At-Grade	226	230	400	4 to 6
Wall on Retaining Wall	230	231	100	4

Table 8-4. Summary of Potential Noise Mitigation Measures for Alternative A5

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall At-Grade	231	234	300	4 to 6
Wall on Retaining Wall	234	235	100	4
Total linear feet of noise wall			**11,000**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative A7: Mostly Elevated with NE 130th, NE 155th, and NE 185th Street Stations

Table 8-5 summarizes the potential mitigation noise walls in Segment A for Alternative A7. The proposed noise mitigation would include approximately 17,400 linear feet of noise wall, with Sound Transit installing most of the walls along the elevated guideway structures. The majority of noise walls on elevated structures would be 4 feet to 6 feet tall, while noise walls on retaining walls and at-grade would range from 4 feet to 8 feet tall. With the proposed walls (see Table 8-5) and the relocation of existing noise walls, South Transit would mitigate most predicted noise impacts. Currently, 13 residences are on the east side of I-5 that may need sound insulation. Six of these residences are single-family residences immediately adjacent to the proposed light rail alignment between NE 117th Street and NE 123rd Street NE. One of these residences is located just south of the church at the west end of NE 152nd Street. The remaining six of these residences are single-family homes immediately adjacent to the alignment between NE 178th Street and NE 180th Street NE.

Table 8-5. Summary of Potential Noise Mitigation Measures for Alternative A7

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall on Structure	11	87	7,600	4 to 6
Wall on Structure	107	114	700	4
Wall on Retaining Wall	114	125	1,100	4 to 8
Wall on Structure	125	140	1,500	4 to 6
Wall on Retaining Wall	140	150	1,000	4 to 6
Wall At-Grade	150	154	400	4 to 6
Wall on Retaining Wall	155	156	100	4
Wall on Structure	185	235	5,000	4 to 6
Total linear feet of noise wall			**17,400**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative A10: At-grade/Elevated with NE 130th, NE 145th, and NE 185th Street Stations

Table 8-6 summarizes the potential mitigation noise walls in Segment A for Alternative A10. The proposed noise mitigation would include approximately 11,500 linear feet of noise wall, with Sound Transit installing most of the walls along the elevated guideway structures and retaining walls. The majority of noise walls on elevated structures would be 4 feet to 6 feet tall, while noise walls on retaining walls and at-grade would range from 4 feet to 8 feet tall. The proposed walls (see Table 8-6) together with the relocation of existing noise walls would mitigate most predicted noise impacts.

Currently, two single-family homes and a duplex are immediately adjacent to the proposed light rail alignment on the east side of I-5 between NE 115th Street and NE 117th Street NE that may need sound insulation.

Table 8-6. Summary of Potential Noise Mitigation Measures for Alternative A10

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall on Structure	11	23	1,200	4 to 6
Wall on Retaining Wall	23	27	400	8
Wall At-Grade	27	34	700	8
Wall on Retaining Wall	34	44	1,000	4
Wall At-Grade	44	45	100	4
Wall on Structure	107	122	1,500	4 to 6
Wall on Retaining Wall	122	133	1,100	4 to 6
Wall on Structure	133	141	800	6 to 8
Wall on Retaining Wall	141	156	1,500	
Wall on Structure	190	196	600	6
Wall on Retaining Wall	196	199	300	8
Wall At-Grade	199	206	700	8
Wall on Retaining Wall	206	210	400	8
Wall At-Grade	223	224	100	4
Wall on Retaining Wall	224	226	200	4
Wall At-Grade	226	230	400	4 to 6
Wall on Retaining Wall	230	231	100	
Wall At-Grade	231	234	300	
Wall on Retaining Wall	234	235	100	
Total linear feet of noise wall			**11,500**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative A11: Mostly Elevated with NE 130th, NE 145th, and NE 185th Street Stations

Table 8-7 summarizes the potential mitigation noise walls in Segment A for Alternative A11. The proposed noise mitigation would include approximately 17,100 linear feet of noise wall, with Sound Transit installing most of the walls along the elevated guideway structures. All noise walls would be 4 feet to 6 feet tall. The proposed walls (see Table 8-7) together with the relocation of existing noise walls would mitigate most predicted noise impacts. Currently, six single-family homes are immediately adjacent to the proposed light rail alignment on the east side of I-5 between NE 117th Street and NE 123rd Street NE, and six single-family homes are immediately adjacent to the alignment on the east side of I-5 between NE 178th Street and NE 180th Street NE that may need sound insulation.

Table 8-7. Summary of Potential Noise Mitigation Measures for Alternative A11

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall on Structure	11	87	7,600	4 to 6
Wall on Structure	108	126	1800	4 to 6
Wall on Retaining Wall	126	131	500	4 to 6
Wall on Structure	131	141	1000	4 to 6
Wall on Retaining Wall	141	151	1000	4 to 6
Wall At-Grade	151	154	300	4 to 6
Wall on Retaining Wall	154	155	100	4
Wall on Structure	185	233	4,800	4 to 6
Total linear feet of noise wall			**17,100**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

8.1.2 Segment B

The main noise mitigation in Segment B would be the use of noise walls, including short, acoustical absorbent walls directly attached to the sides of the elevated guideway. Sound Transit would also use additional at-grade noise walls and walls along retained fills and cuts, depending on the track type. Because the majority of noise from light rail operations comes from the wheel-rail interface, even relatively short walls can provide noise reductions of 7 dB to 10 dB or more, depending on topographical conditions. However, in Segment B there are several locations where the receivers would be substantially above the grade of the alignment and, therefore, noise walls might not be as effective as when the light rail profile is at the same or higher elevation as the receivers. For those sites, building sound insulation might be the only form of noise mitigation available.

Alternative B1: East side to Mountlake Terrace Transit Center to Median

Table 8-8 summarizes the potential mitigation noise walls in Segment B with Alternative B1. The proposed noise mitigation would include approximately 20,800 linear feet of noise wall, with 12,900 feet of wall on the east side and 7,900 feet of wall on the west side of the alignment. All noise walls would be 4 feet to 8 feet tall, and slightly taller walls could be used if they were found to be effective at mitigating receiver locations higher than the light rail alignment. Also, where the alignment is in the I-5 median, the walls would be maintained continuously as an approximately 3- to 4-foot-tall safety barrier. This would be required regardless of the noise impacts, except along the portion of the alignment where the light rail would be in a retained cut below the grade of the northbound lanes, where a safety barrier already exists. Sound Transit would mitigate all predicted noise impacts through installing the proposed noise walls (see Table 8-8), relocating several noise walls, and adding building sound insulation where required.

Table 8-8. Summary of Potential Noise Mitigation Measures for Alternative B1

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
East Side of Alignment				
Wall on Retaining Wall	305	321	1,600	4 to 6
Wall on Structure	321	338	1,700	4
Wall on Structure	352	364	1,200	4
Wall on Structure	370	388	1,800	4 to 6
Wall At-Grade or Wall on Retaining Wall (includes traffic safety barrier)	388	454	6,600	4 to 6
West Side of Alignment				
Wall on Structure	378	388	1,000	6
Wall on Retaining Wall (includes traffic safety barrier)	388	392	400	8
Wall At-Grade (includes traffic safety barrier)	392	451	5,900	4 to 6
Wall on Retaining Wall	451	452	100	8
Wall on Structure	452	457 (merge with wall in Segment C, which begins at station 500)	500	6
Total linear feet of noise wall and traffic safety barrier			**20,800**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative B2: East Side to Mountlake Terrace Transit Center to West Side

Table 8-9 summarizes the potential mitigation noise walls in Segment B with Alternative B2. The proposed noise mitigation would include approximately 15,000 linear feet of noise wall, with 6,700 feet of wall on the east side and 8,300 feet of wall on the west side of the alignment. All noise walls would be 4 feet to 6 feet tall, and slightly taller walls could be used if they were found to be effective at mitigating receiver locations at a higher elevation than the light rail alignment. With the proposed noise walls (see Table 8-9), relocating several noise walls, and adding building sound insulation where required, Sound Transit would mitigate all predicted noise impacts. Currently, one single-family home along the west side of I-5 between 60th Avenue West and 212th Street SW may need sound insulation. In addition, four homes immediately south of the 220th Street School that have severe noise impacts may also need sound insulation.

Table 8-9. Summary of Potential Noise Mitigation Measures for Alternative B2

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
East Side of Alignment				
Wall on Structure	321	338	1,700	4
Wall on Structure	353	365	1,200	4
Wall on Structure	369	388	1,900	4 to 6
Wall near Track	400	419	1,900	4
West Side of Alignment				
Wall on Structure	377	385	800	4 to 6
Wall on Retaining Wall	385	400	1,500	4 to 6
Wall on Structure	400	438	3,800	4

Table 8-9. Summary of Potential Noise Mitigation Measures for Alternative B2

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall on Fill/Structure	438	460 (merge with wall in Segment C, which begins at station 500)	2,200	4 to 6
Total linear feet of noise wall			**15,000**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative B2A: Optional 220th Street SW Station (Elevated)

Mitigation under Alternative B2A would be the same as discussed previously for Alternative B2, with one additional home that may need sound insulation to mitigate a severe impact.

Alternative B4: East Side to Mountlake Terrace Freeway Station to Median

Table 8-10 summarizes the potential noise walls that Sound Transit would use to mitigate noise in Segment B for Alternative B4. The proposed noise mitigation would include approximately 20,000 linear feet of noise wall, with 12,100 feet of wall on the east side and 7,900 feet of wall on the west side of the alignment. All noise walls would be 4 feet to 8 feet tall, and slightly taller walls could be used if they were found to be effective at mitigating receiver locations at a higher elevation than the light rail alignment. Also, where the light rail alignment is in the I-5 median, the walls would be maintained continuously as a safety barrier approximately 3 feet to 4 feet tall. This would be required regardless of the noise impacts, except along the portion of the alignment where the light rail would be in a retained cut below the grade of the northbound lanes, and where a safety barrier already exists. With the proposed noise walls (see Table 8-10), relocating several noise walls, and adding building sound insulation if needed, Sound Transit would mitigate all predicted noise impacts.

Table 8-10. Summary of Potential Noise Mitigation Measures for Alternative B4

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
East Side of Alignment				
Wall on Retaining Wall	305	321	1,600	4 to 6
Wall on Structure	321	338	1,700	4
Wall on Structure	352	365	1,300	4
Wall on Structure (includes traffic safety barrier)	378	388	1,000	4 to 6
Wall At-Grade or Wall on Retaining Wall (includes traffic safety barrier)	388	453	6,500	4 to 6
West Side of Alignment				
Wall on Structure (includes traffic safety barrier)	378	388	1,000	6
Wall on Retaining Wall (includes traffic safety barrier)	388	392	400	8
Wall At-Grade (includes traffic safety barrier)	392	451	5,900	4 to 6

Table 8-10. Summary of Potential Noise Mitigation Measures for Alternative B4

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall on Retaining Wall (includes traffic safety barrier)	451	452	100	8
Wall on Structure (includes traffic safety barrier)	452	457 (merge with wall in Segment C, which begins at station 500)	500	4 to 6
Total linear feet of noise wall and traffic safety barrier			**20,000**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

8.1.3 Segment C

The light rail alignment in Segment C would be mainly elevated in areas with noise impacts; therefore, noise walls on the elevated guideway structure would be the primary noise mitigation. Additional at-grade noise walls and walls along retained fills and cuts would also be used for the light rail alignments along I-5. For sites with elevations higher than the alignment, Sound Transit might increase noise wall heights or add building sound insulation for noise mitigation when required.

Alternative C1: 52nd Avenue West to 200th Street SW, with Option 1

Table 8-11 summarizes the potential noise walls for noise mitigation in Segment C for Alternative C1 with Option 1. The proposed noise mitigation would include approximately 7,200 linear feet of noise wall, with 2,900 feet of wall on the east side and 4,300 feet of wall on the west side of the light rail alignment. All noise walls would be 4 feet to 6 feet tall, and slightly taller walls could be used if they were found to be effective at mitigating elevated receiver locations. With the proposed noise walls (see Table 8-11) and the addition of building sound insulation if needed, Sound Transit would mitigate all predicted noise impacts.

Table 8-11. Summary of Potential Noise Mitigation Measures for Alternative C1 with Option 1

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
East Side of Alignment				
Wall on Structure	508	512	400	4
Wall on Structure	540	560	2,500	4 to 6
West Side of Alignment				
Wall on Structure	500 (continued from Segment B)	535	3,500	4
Wall on Structure	535	548	800	4 to 6
Total linear feet of noise wall			**7,200**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative C1: 52nd Avenue West to 200th Street SW, with Option 2

Noise mitigation under Alternative C1 with Option 2 would be the same as described above for Alternative C1 with Option 1.

Alternative C2: 52nd Avenue West to Lynnwood Transit Center, with Option 1

Table 8-12 summarizes the potential noise walls to mitigate noise in Segment C for Alternative C2 with Option 1. The proposed noise mitigation would include approximately 6,600 linear feet of noise wall, with 2,200 feet of wall on the east side and 4,400 feet of wall on the west side of the light rail alignment. All noise walls would be 4 feet to 6 feet tall, and slightly taller walls could be used if they were found to be effective at mitigating elevated receiver locations. With the proposed noise walls (see Table 8-12) and the use of building sound insulation if needed, Sound Transit would mitigate all predicted noise impacts.

Table 8-12. Summary of Potential Noise Mitigation Measures for Alternative C2 with Option 1

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
East Side of Alignment				
Wall on Structure	508	512	400	4
Wall on Structure	535	553	1,800	4 to 6
West Side of Alignment				
Wall on Structure	500 (continued from Segment B)	535	3,500	4
Wall on Structure	535	544	900	4
Total linear feet of noise wall			**6,600**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative C2: 52nd Avenue West to Lynnwood Transit Center, with Option 2

Noise mitigation under Alternative C2 with Option 2 would be the same as described for Alternative C2 with Option 1.

Alternative C3: Along I-5 to Lynnwood Park-and-Ride, with Option 1

Table 8-13 summarizes the potential noise walls to mitigate noise in Segment C for Alternative C3 with Option 1. The proposed noise mitigation would include approximately 1,700 linear feet of noise wall. All noise walls would be 4 feet tall. With the proposed walls (see Table 8-13) and use of building sound insulation where required, Sound Transit would mitigate all predicted noise impacts.

Table 8-13. Summary of Potential Noise Mitigation Measures for Alternative C3 with Option 1

Wall Type	Start Station[a]	End Station[a]	Length (linear feet)	Height (feet)
Wall on Retaining Wall	500 (continued from Segment B)	507	700	4
Wall on Structure	507	517	1,000	4
Total linear feet of noise wall			**1,700**	

[a] Station refers to locations on the project design drawings that indicate each 100-foot section of the proposed light rail route.

Alternative C3: Along I-5 to Lynnwood Park-and-Ride, with Option 2

Noise mitigation under Alternative C3 with Option 2 would be the same as discussed for Alternative C3 with Option 1.

8.2 Park-and-Ride Facility Noise Mitigation

8.2.1 Segment A

NE 130th Street Station Option 1

Under Alternatives A5 and A10 with the NE 130th Street Station Option 1, there would be no noise impacts; therefore, no noise mitigation is proposed.

NE 130th Street Station Option 2

Under Alternatives A7 and A11 with the NE 130th Street Station Option 2, there would be no noise impacts; therefore, no noise mitigation is proposed.

NE 145th Street Station Option 1

Under Alternatives A1 and A10 with the NE 145th Street Station Option 1, there would be no noise impacts; therefore, no noise mitigation is proposed.

NE 145th Street Station Option 2

Under Alternatives A3 and A11 with the NE 145th Street Station Option 2, there would be no noise impacts; therefore, no noise mitigation is proposed.

NE 155th Street Station Option 1

Under Alternatives A5 and A7 with the NE 155th Street Station, there would be noise impacts at six properties directly adjacent to the parking garage structure during the early morning hours of 6:00 am to 7:00 am under the assumption that all 500 parking spaces would be filled in 1 hour by 7:00 am. The analysis assumes no additional shielding from the parking structure. Noise mitigation for the parking structure could include modifications to the structure to shield the nearby residence and fire department from traffic noise emitted from the structure or by providing sound insulation as needed to the nearby structures.

NE 185th Street Station Option 1

Under Alternative A1 with the NE 185th Street Station Option 1, Sound Transit identified 15 single-family residences that would experience noise impacts from buses accessing the station drop-off and layover area off 8th Avenue NE, and continuing along the new bus-only route to the elevated station. All impacts would be related to the noise from buses entering and leaving the drop-off and layover area near residences on 8th Avenue NE and near residences on NE 185th Street. Up to six of the affected residences would be mitigated with sound insulation or with a noise wall along the northern and western property lines of the affected residences. These homes are located on 8th Avenue NE directly adjacent to the bus travel routes through the station drop-off and layover area. All other impacts would be mitigated with sound insulation. With the proposed noise mitigation measures, all noise impacts would be mitigated.

NE 185th Street Station Option 2

Under Alternatives A3, A7, and A11 with the NE 185th Street Station Option 2, Sound Transit identified nine single-family residences that would experience noise impacts from the buses accessing the park-and-ride. All noise impacts would be related to noise from buses entering the park-and-ride near residences on 8th Avenue NE and leaving the park-and-ride near residences on NE 185th Street. There are no feasible noise walls that could be used to provide noise mitigation; therefore, all nine single-family residences would be mitigated with sound insulation.

NE 185th Street Station Option 3

Under Alternatives A5 and A10 with the NE 185th Street Station Option 3, Sound Transit identified 12 single-family residences that would experience noise impacts from buses accessing the park-and-ride on NE 8th Avenue. The noise impacts would be related to noise from buses entering and leaving the park-and-ride near residences on 8th Avenue NE. The majority of the impacts would be mitigated with sound insulation. Two affected residences could be mitigated with a noise wall between 8th Avenue NE and the power substation station. With the proposed mitigation, all noise impacts would be mitigated.

8.2.2 Segment B

Mountlake Terrace Transit Center

Under Alternatives B1, B2, and B2A with the Mountlake Terrace Transit Center Station option, Sound Transit identified four single-family residences that would have noise impacts. Mitigation for these impacts would include a sound wall on top of the eastern retaining wall between the park-and-ride facility and the residences. The wall would be effective at mitigating all noise impacts under this station option.

Mountlake Terrace Freeway Station

Under Alternative B4 with the Mountlake Terrace Freeway Station Option, the park-and-ride noise impacts and mitigation would be the same as described above under the Mountlake Terrace Transit Center Station option. With the proposed mitigation, all noise impacts would be mitigated.

220th Street SW Station

Under Alternative B2A with the 220th Street SW Station option, there would be no noise impacts from vehicles accessing the park-and-ride lot; therefore, no noise mitigation is proposed.

8.2.3 Segment C

200th Street SW

Under the 200th Street SW Park-and-Ride Station option, Sound Transit identified noise impacts at several of the multifamily units near the proposed park-and-ride. All impacts would be related to noise from buses accessing the reconfigured bus facility and, to a lesser extent, from vehicles accessing the parking areas off 48th Avenue West. Because of the elevation of the multifamily units, all noise impacts would be mitigated with sound insulation.

Lynnwood Transit Center

Under the Lynnwood Transit Center Station option, Sound Transit identified noise impacts at four of the multifamily units at the Park Five complex. All impacts would be related to noise from buses accessing the reconfigured bus facility. Because of the elevation of the multifamily units, all noise impacts would be mitigated with sound insulation.

Lynnwood Park-and-Ride Station Option 1

Under the Lynnwood Park-and-Ride Station Option 1, no noise impacts were identified; therefore, no noise mitigation is proposed.

Lynnwood Park-and-Ride Station Option 2

Under the Lynnwood Park-and-Ride Station Option 2, no noise impacts were identified; therefore, no noise mitigation is proposed.

8.3 Construction Noise Mitigation Analysis

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

- Install construction site noise barrier or wall by noise-sensitive receivers where appropriate.
- Use smart backup alarms during nighttime work that automatically adjust, or lower the alarm level or tone based on the background noise level, or switch off back-up alarms and replace with spotters.
- Use low-noise emission equipment.
- Implement noise-deadening measures for truck loading and operations.
- Monitor and maintain equipment to meet noise limits.
- Use lined or covered storage bins, conveyors, and chutes with sound-deadening material.
- Use acoustic enclosures, shields, or shrouds for equipment and facilities.
- Install high-grade engine exhaust silencers and engine-casing sound insulation.
- Prohibit aboveground jack hammering and impact pile driving during nighttime hours.

- Minimize the use of generators or use whisper quiet generators to power equipment.
- Limit use of public address systems.
- Use movable noise barriers at the source of the construction activity.
- Limit or avoid certain noisy activities during nighttime hours.

9 REFERENCES AND SUPPORTING DOCUMENTS

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Part 2: Vibration

1 INTRODUCTION AND SUMMARY

1.1 Introduction

This technical report presents a vibration impact assessment for the Lynnwood Link Extension. Section 1 of this report summarizes the results of the vibration assessment. Section 2 discusses the fundamentals of environmental vibration and Section 3 describes the criteria used to assess potential vibration impacts. Section 4 presents the methodology used to predict vibration impacts. Section 5 summarizes the impact assessment and Section 6 outlines potential impact mitigation measures. In addition, Attachment D lists the projected vibration levels and potential vibration impacts by alternative and Attachment E provides detailed vibration measurement data.

1.2 Summary of Vibration Impact Assessment

Based on criteria from the Federal Transit Administration (FTA), the Lynnwood Link Extension would cause 2 to 14 potential vibration impacts without mitigation, depending upon the alignment alternative, at the locations listed in Table 1-1. These potential impacts would be related to annoyance impacts but not to building damage impacts. There will be no impacts related to building damage from future train operations. Section 5.1 includes detailed information regarding the potential vibration impacts from future train operations, and Section 6.1 discusses proposed mitigation measures for those potential impacts.

All of the potential vibration impacts due to future train operations are limited to track segments with at-grade track. All potential vibration impacts can be mitigated with tire-derived aggregate (TDA) as an underlayer beneath the sub-ballast layer of the track. Other mitigation approaches were considered and it was concluded that of the mitigation approaches currently available, a floating slab track (FST) was the only other system, except TDA, that would remove all potential vibration impacts. However, FST costs as much as ten times more than TDA and was, therefore, not developed further as a mitigation approach for the project. Vibration impacts and mitigation options will be reviewed during final design to confirm that appropriate measures are included in the design.

Table 1-1 lists the total length for vibration mitigation recommended for each alternative.

Potential vibration impacts resulting from project construction are summarized in Section 5.2. The potential for cosmetic damage to nearby structures should be closely evaluated if vibratory pile-driving methods are to be used within 80 feet of any receptor or vibratory soil compactor within 40 feet. This task should include documenting the condition of buildings before construction and monitoring vibration during construction. No structural damage will occur to any building adjacent to project construction as long as the vibration does not exceed the threshold levels for causing cosmetic damage.

Potential vibration impacts related to annoyance during construction are projected for sensitive receptors near the stations and are discussed in Section 5.2. Approaches for mitigating potential vibration impacts resulting from construction are discussed in detail in Section 6.2.

Table 1-1. Summary of Potential Vibration Impacts and Mitigation

Segment A Alternatives[a]	Number of Potential Vibration Impacts	Total Mitigation Length (feet)
A1: At-grade/Elevated with NE 145th and NE 185th Street Stations	8	1,600
A3: Mostly Elevated with NE 145th and NE 185th Street Stations	2	275
A5: At-grade/Elevated with NE 130th, NE 155th, and NE 185th Street Stations	14	2,400
A7: Mostly Elevated with NE 130th, NE 155th, and NE 185th Street Stations	3	375
A10: At-grade/Elevated with NE 130th, NE 145th, and NE 185th Street Stations	13	2,300
A11: Mostly Elevated with NE 130th, NE 145th, and NE 185th Street Stations	2	275

[a] No impacts are projected for Segment B or C.

2 ENVIRONMENTAL VIBRATION BASICS

Groundborne vibration is the oscillatory motion of the ground in relation to a static equilibrium position, which can be described in terms of displacement, velocity, or acceleration. Displacement refers to the distance an object moves away from its equilibrium position. Velocity refers to the rate of change in displacement with respect to time or the speed of this motion. Acceleration refers to the time rate of change in the velocity of the object. At any given frequency of oscillation, vibration displacement, velocity, and acceleration are related. However, the relationship between these descriptors is complex and can vary greatly in different situations. Therefore, the relationship between the overall vibration in terms of these descriptors depends on the frequency content of the vibration energy. The overall vibration is the total unfiltered vibration over the entire spectrum.

The response of humans, buildings, and equipment to vibration is usually described using velocity or acceleration. Because human sensitivity to vibration typically corresponds to a constant level of vibration velocity amplitude within the frequency range that is of most concern for environmental vibration (i.e., roughly 8 to 100 Hertz [Hz]), vibration velocity is used in this analysis as the primary measure to evaluate the impacts of vibration.

Several different measures are used to quantify vibration velocity amplitude. One of the most common is the peak particle velocity (PPV), defined as the maximum instantaneous positive or negative peak of the vibration velocity. PPV is used to characterize the threshold of cosmetic damage to building components. The root mean square (rms) velocity is used for evaluating human response. The rms amplitude is defined as the square root of the average of the squared amplitude of the signal over a time interval, typically 1 second. In this report, the averaging time is the train passby duration, usually 4 to 8 seconds. The difference is generally small, but longer averaging times produce less statistical fluctuation when measured.

The vibration velocity is represented by the level in decibels that compresses the range of numbers required to describe vibration. In this report, the vibration is expressed in terms of velocity level in decibels relative to 1 micro-inch per second, defined as follows:

$$L_v = 20\log_{10}(v/v_{ref}), \text{ VdB} \qquad \text{(Equation 2-1)}$$

where:

v = rms velocity, inches/second

v_{ref} = 1×10^{-6} inches/second = 1 micro-inch/second

Figure 2-1 illustrates typical groundborne vibration levels for common sources, and human and structural responses to vibration. As shown, the range of interest is from approximately 50 VdB to 100 VdB (i.e., from imperceptible background vibration to the threshold of building cosmetic damage). Although the threshold of human perception to vibration is approximately 65 VdB, annoyance does not usually occur unless the vibration exceeds 72 VdB.

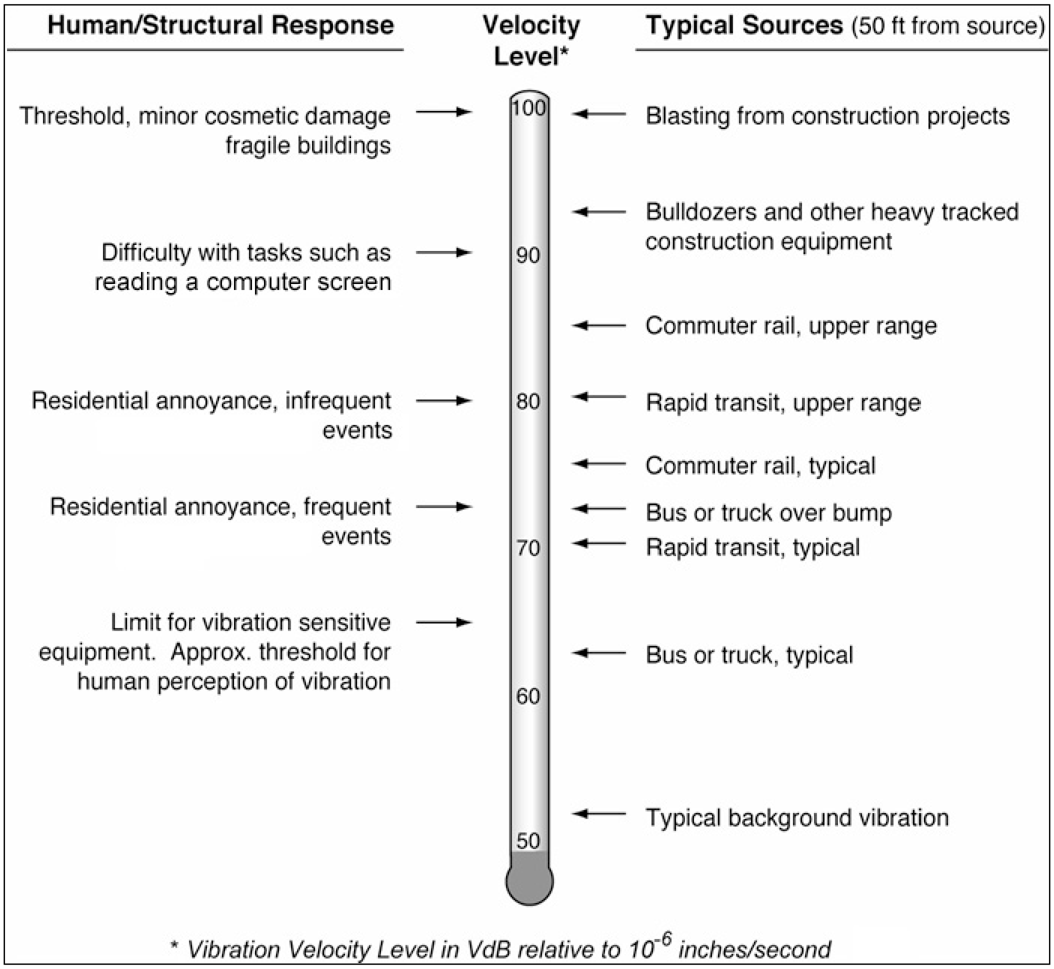

Figure 2-1. Typical Groundborne Vibration Levels and Human/Structural Response

When vibration propagates from transit vehicles to nearby buildings, the floors and walls of the building structure respond to the motion and resonate at natural frequencies. The vibration of the walls and floors may cause perceptible vibration, rattling of items such as windows or dishes on shelves, or a rumbling noise. The rumble is the noise radiated from the motion of the room surfaces; this is called groundborne noise. The potential annoyance of groundborne noise is described in terms of the A-weighted sound level or dBA.

3 VIBRATION IMPACT CRITERIA

This section briefly defines vibration or groundborne noise impacts expected from a transit system; these impacts are then evaluated as they apply to the Lynnwood Link Extension. The criteria that apply to preventing building damage from construction-generated vibration are also discussed.

3.1 Transit Vibration and Groundborne Noise Criteria

3.1.1 Vibration Impact Criteria

The FTA groundborne vibration impact criteria are based on land use and train passage frequency. Table 3-1 lists the criteria for a general assessment of most land uses. The FTA vibration criteria apply primarily to residential (including hotels and other places where people sleep) and institutional land uses. Commercial land uses are only considered when they contain vibration-sensitive uses, such as medical offices or sensitive manufacturing equipment. The criteria applied to these locations depend on the sensitivity of the use. Some buildings, such as concert halls, recording studios, and theaters, can be particularly sensitive to vibration but do not fit into any of the three categories listed in Table 3-1. These buildings usually warrant special attention during the impact assessment. Table 3-2 provides the criteria for acceptable levels of groundborne vibration for special buildings.

If a general assessment of vibration impacts indicates that the project would exceed the criteria in Table 3-1, then a detailed analysis considering the frequency spectra of the vibration is used to provide more information about the effects of the project. In many cases, it is desirable to conduct a detailed analysis without first conducting a general assessment, as was done for the Lynnwood Link Extension.

Table 3-3 provides vibration criteria for the detailed vibration analyses, which were used for the Lynnwood Link Extension. The criteria in Table 3-3 are based on exceedances of the 1/3-octave-band vibration levels over the frequency range 6.3 to 80 Hz. These detailed criteria are also used to assess vibration impacts at highly sensitive locations. However, no such highly sensitive locations have been identified along the project corridor. These criteria are also shown graphically in Figure 3-1.

3.1.2 Groundborne Noise Impact Criteria

Tables 3-1 and 3-2 include separate FTA criteria for groundborne noise—the "rumble" that can be radiated by the motion of room surfaces in buildings caused by groundborne vibration. Because airborne noise often masks groundborne noise for aboveground (i.e., at-grade or elevated) transit systems, groundborne noise criteria are commonly applied only to subway operations where airborne noise is not a factor. For above-grade transit systems, groundborne noise criteria are applied only to special types of buildings that have sensitive interior spaces that are well insulated from exterior noise and are used for noise-sensitive activities, such as sound recording or concert production. There are no special uses that fall into these categories within the project corridor because the entire project is above ground; therefore, a groundborne noise analysis has not been included in this assessment.

Table 3-1. Groundborne Vibration and Noise Impact Criteria for General Assessment

Land Use Category	Groundborne Vibration Impact Levels (VdB re: 1 micro-inch/second)			Groundborne Noise Impact Levels (dB re: 20 micro-Pascals)		
	Frequent Events[a]	Occasional Events[b]	Infrequent Events[c]	Frequent Events[a]	Occasional Events[b]	Infrequent Events[c]
Category 1: Buildings where low ambient vibration is essential for interior operations	65 VdB[d]	65 VdB[d]	65 VdB[d]	N/A[e]	N/A[e]	N/A[e]
Category 2: Residences and buildings where people normally sleep	72 VdB	75 VdB	80 VdB	35 dBA	38 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA

[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] "Occasional Events" are defined as between 30 and 70 vibration events of the same source per day; most commuter trunk lines have this many operations.

[c] "Infrequent Events" are defined as fewer than 30 vibration events of the same kind per day; this category includes most commuter rail branch lines.

[d] This criterion limit is based on levels that are acceptable for most moderately sensitive equipment, such as optical microscopes. Vibration-sensitive manufacturing or research requires detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the heating, ventilation, and air conditioning (HVAC) systems and stiffened floors.

[e] Not applicable. Vibration-sensitive equipment is generally not sensitive to groundborne noise.

Table 3-2. Groundborne Vibration and Noise Impact Criteria for Special Buildings

Type of Building or Room[a]	Groundborne Vibration Impact Levels (VdB re: 1 micro-inch/sec)		Groundborne Noise Impact Levels (dB re: 20 micro Pascals)	
	Frequent Events[b]	Occasional or Infrequent Events[c]	Frequent Events[b]	Occasional or Infrequent Events[c]
Concert Halls	65 VdB	65 VdB	25 dBA	25 dBA
Television Studios	65 VdB	65 VdB	25 dBA	25 dBA
Recording Studios	65 VdB	65 VdB	25 dBA	25 dBA
Auditoriums	72 VdB	80 VdB	30 dBA	38 dBA
Theaters	72 VdB	80 VdB	35 dBA	43 dBA

[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 pm, then trains should 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.

[c] "Occasional or Infrequent Events" are defined as fewer than 70 vibration events per day; this category includes most commuter rail systems.

Table 3-3. Vibration Criteria for Detailed Analysis

Criterion Curve	Maximum L_v (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 20X)
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 (100X) and other equipment of low sensitivity

Table 3-3. Vibration Criteria for Detailed Analysis

Criterion Curve	Maximum L_v (VdB)[a]	Description of Use
VC-A	66	Adequate for medium- to high-power optical microscopes (400X), microbalances, optical balances, and similar specialized equipment
VC-B	60	Adequate for high-power optical microscopes (1,000X) and inspection and lithography equipment up to 3 micron-line widths
VC-C	54	Appropriate for most lithography and inspection equipment to 1 micron detail size
VC-D	48	Suitable in most instances for the most demanding equipment, including electron microscopes operating to the limits of their capability
VC-E	42	The most demanding criterion for extremely vibration-sensitive equipment

[a] As measured in one-third-octave bands of frequency over the frequency range 8 to 80 Hz.

L_v = vibration velocity level; VC = vibration criteria

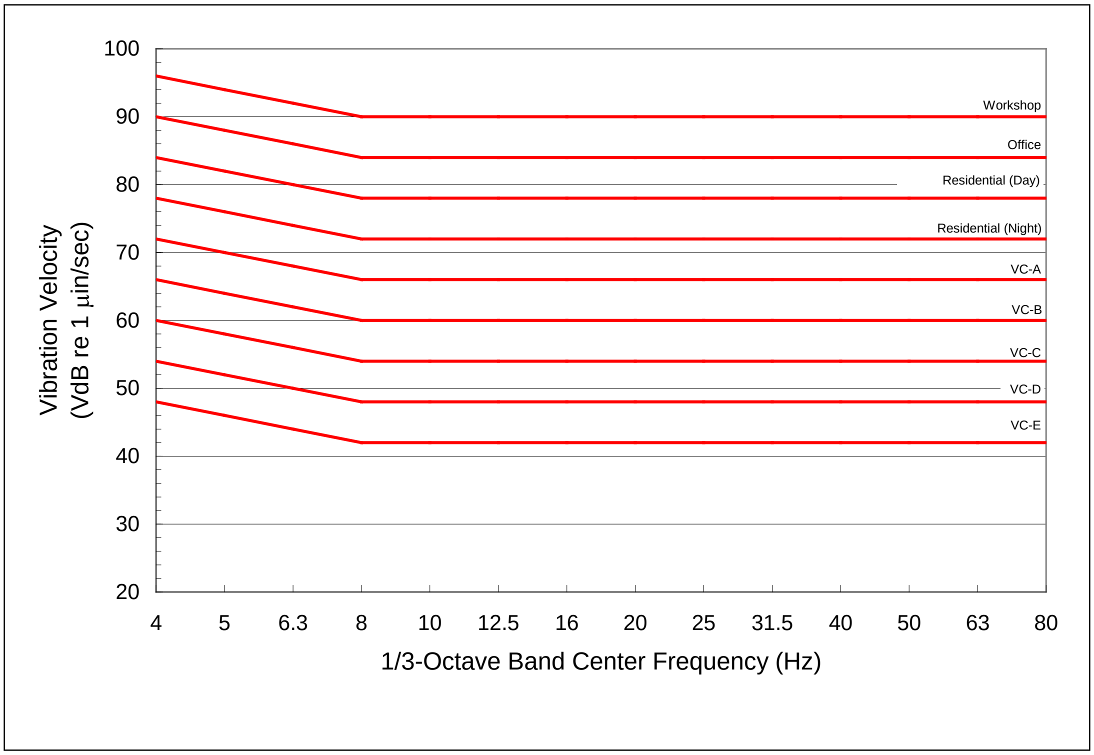

Figure 3-1. Vibration Criteria for Highly Sensitive Locations

3.2 Construction Vibration Criteria

Construction vibration from activities such as blasting and pile-driving, unlike vibration from train operations, has the potential to damage structures at very short distances. Because of this factor, the construction vibration discussion includes both damage criteria and annoyance impact criteria.

Table 3-4 presents threshold cracking criteria for visible cracking in building surfaces for a range of building types, in terms of the PPV. The approximate corresponding rms vibration level is also included in Table 3-4. The majority of the residential receptors in the vicinity of the project guideway will fall into the Category III structure. Vibration that does not exceed threshold cracking criteria for cosmetic damage will not cause structural damage. Thus, threshold cracking criteria are used as the main building damage criteria.

Table 3-4. Cosmetic Structural Damage Criteria

Building Category	PPV (in/sec)	Approximate L_v[a]
I. Reinforced concrete, steel, or timber (no plaster)	0.50	102
II. Engineered concrete and masonry (no plaster)	0.30	98
III. Non-engineered timber and masonry buildings	0.20	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

[a] Root mean square velocity level in decibels (VdB) re 1 micro-inch/second

When vibration and associated groundborne noise are assessed for annoyance due to specific construction activities, the transit vibration impact criteria are used to determine the potential for impact (Table 3-1). Potential impact for damage is considered for all construction activities whereas potential impact for annoyance is considered only for long-term activities.

4 PREDICTION METHODOLOGY

This section summarizes the models, methods, and assumptions used to predict future noise and vibration levels for potential sources of community impact related to the Lynnwood Link Extension. These sources include light rail operation and construction activities. The light rail vehicle wheels and track are assumed to be maintained in good condition with regular wheel truing and rail grinding, in accordance with the Central Puget Sound Regional Transit Authority (Sound Transit) maintenance procedures.

4.1 Light Rail Vibration Projections

The vibration analysis for the Lynnwood Link Extension Environmental Impact Statement (EIS) follows the approach described in the FTA guidance manual, *Transit Noise and Vibration Impact Assessment*, Chapter 11, "Detailed Vibration Analysis" (FTA 2006). The projected vibration level (L_v) at each vibration-sensitive receptor is determined by the dynamic forces generated by the transit vehicle (Force Density Level [FDL]), the line-source transfer mobility from the tracks to the receptor (Line Source Response [LSR]), and the vibration response of the building (Building Vibration Response [BVR]). The BVR accounts for attenuation due to soil/foundation interaction and for amplification due to floor resonance. Additional adjustments were made to account for increased vibration due to special track work such as crossovers and any vibration impact mitigation incorporated into the track design. The above components were used to calculate the 1/3-octave vibration level as follows:

$$L_v \text{ (VdB)} = \text{FDL} + \text{LSR} + \text{BVR} + \text{Adjust.} \qquad \text{(Equation 4-1)}$$

where: L_v = vibration velocity level due to trains (VdB re: 1 micro-inch/second)

FDL = train force density level (L_f) (dB re: 1 lb/ft$^{1/2}$)

LSR = soil line source response (TM_{line}) (dB re: (1 micro-inch/s)/(lb/ft$^{1/2}$))

BVR = building vibration response (C_{build}) (dB)

Adjust. = adjustment to account for crossovers and/or mitigation (dB)

Each of the above factors for the Lynnwood Link Extension is described in the following sections.

In the project area, special purpose receptors with sensitive interior spaces that were well insulated from exterior noise were not found; moreover, the entire project is above ground. Therefore, projections of groundborne noise are not included in this study.

The estimates presented in this analysis do not contain any conservative elements, any added "safety factor," or any adjustment for uncertainty. They are the best estimates or median expected levels based on the best available information.

4.1.1 Force Density Level

The FDL for all at-grade ballast and tie segments on the alignment were based on measurements taken by Wilson Ihrig & Associates on the Sound Transit system near the SODO Station, which was augmented with data from a similar Kinkysharyo vehicle on the Santa Clara Valley Transportation Authority (VTA) system in San Jose, California (Wilson, Ihrig & Associates, Inc. 2007). The track structures for both the SODO Station and VTA measurement locations were at-grade, ballast and tie. Figure 4-1 indicates the above FDL that was used for trains traveling at speeds from 25 to 55 miles per hour (mph), in 5-mph increments, on ballast and tie track. The FDL values plotted in Figure 4-1 are listed in Table 4-1.

The FDLs for aerial structures were based upon measurements taken by Wilson Ihrig & Associates next to the aerial structure leading into the west portal of the Beacon Hill tunnel (at Airport Way) and by ATS Consulting at two locations next to the Tukwila aerial structure, for a total of three measurement locations. The measurements were taken during revenue service, so the FDL for the aerial structure was determined at only one speed at each location, 35 mph west of the Beacon Hill tunnel and an estimated speed of 55 mph at both locations in Tukwila. The Wilson Ihrig & Associates data were adjusted to a speed of 55 mph using the relationship between speed and force density that had been measured while running the trains at different speeds along the ballast and tie track near the SODO Station and at VTA. Next, the energy average was taken of the speed-adjusted Airport Way FDL and the two FDLs measured in Tukwila to develop an FDL at 55 mph for use in the Lynnwood Link Extension vibration analysis for aerial structures. Finally, the differences due to speed that were observed in the previous measurements for Sound Transit and VTA were applied to the energy-averaged FDL to obtain an aerial structure FDL at different speeds. Figure 4-2 and Table 4-2 indicate the FDLs for trains traveling at speeds from 25 to 55 mph, in 5-mph increments, on aerial structures. The FDL applies to a line of vibration forces acting on the ground near the aerial structures and includes the effect of the soil/structure interaction at the foundations of the columns.

Table 4-1. Sound Transit Force Density Levels (dB re: 1 lb/ft1/2) on At-Grade Ballast and Tie Track

	1/3-Octave Band Center Frequency (Hz)																	
Speed	**3.15**	**4**	**5**	**6.3**	**8**	**10**	**12.5**	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**
25 mph	25	20	18	21	22	24	26	24	20	18	21	24	29	34	37	31	31	31
30 mph	25	21	19	23	25	23	24	24	26	21	20	24	30	33	35	33	31	30
35 mph	28	24	21	24	29	28	24	25	26	26	21	24	30	33	36	31	32	30
40 mph	32	26	20	25	31	33	27	24	26	27	25	24	29	34	36	31	32	30
45 mph	31	25	20	25	33	37	34	22	26	26	30	24	28	34	35	31	31	30
50 mph	26	22	11	19	36	36	38	27	24	27	30	28	26	34	34	29	30	25
55 mph	24	29	17	12	31	37	36	26	22	23	24	29	27	38	38	33	32	28

Table 4-2. Sound Transit Force Density Levels (dB re: 1 lb/ft$^{1/2}$) on Aerial Structure

	1/3-Octave Band Center Frequency (Hz)																	
Speed	**3.15**	**4**	**5**	**6.3**	**8**	**10**	**12.5**	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**
25 mph	10	12	23	31	18	23	23	27	15	9	10	15	22	20	22	21	18	22
30 mph	10	17	26	33	20	22	22	25	23	9	9	13	22	19	20	21	18	22
35 mph	13	16	26	35	26	26	22	28	21	17	10	15	22	20	21	21	19	21
40 mph	14	18	24	34	28	31	24	27	20	16	12	15	24	21	21	21	19	21
45 mph	19	24	27	37	31	35	29	27	22	16	17	17	24	20	21	21	20	24
50 mph	14	21	18	30	34	33	33	32	21	17	18	20	22	21	20	20	19	19
55 mph	13	28	25	24	29	34	31	31	18	14	11	22	24	24	24	23	21	22

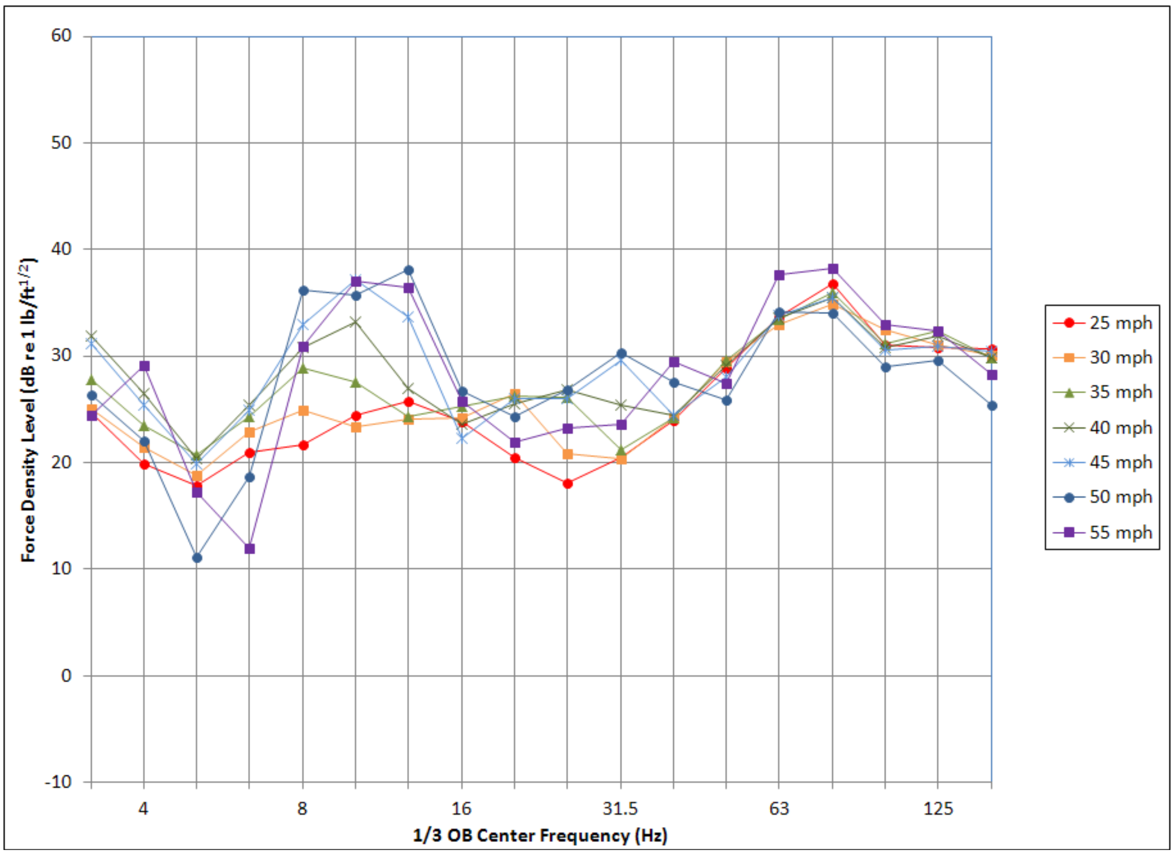

Figure 4-1. Sound Transit Force Density Levels on Ballast and Tie Track

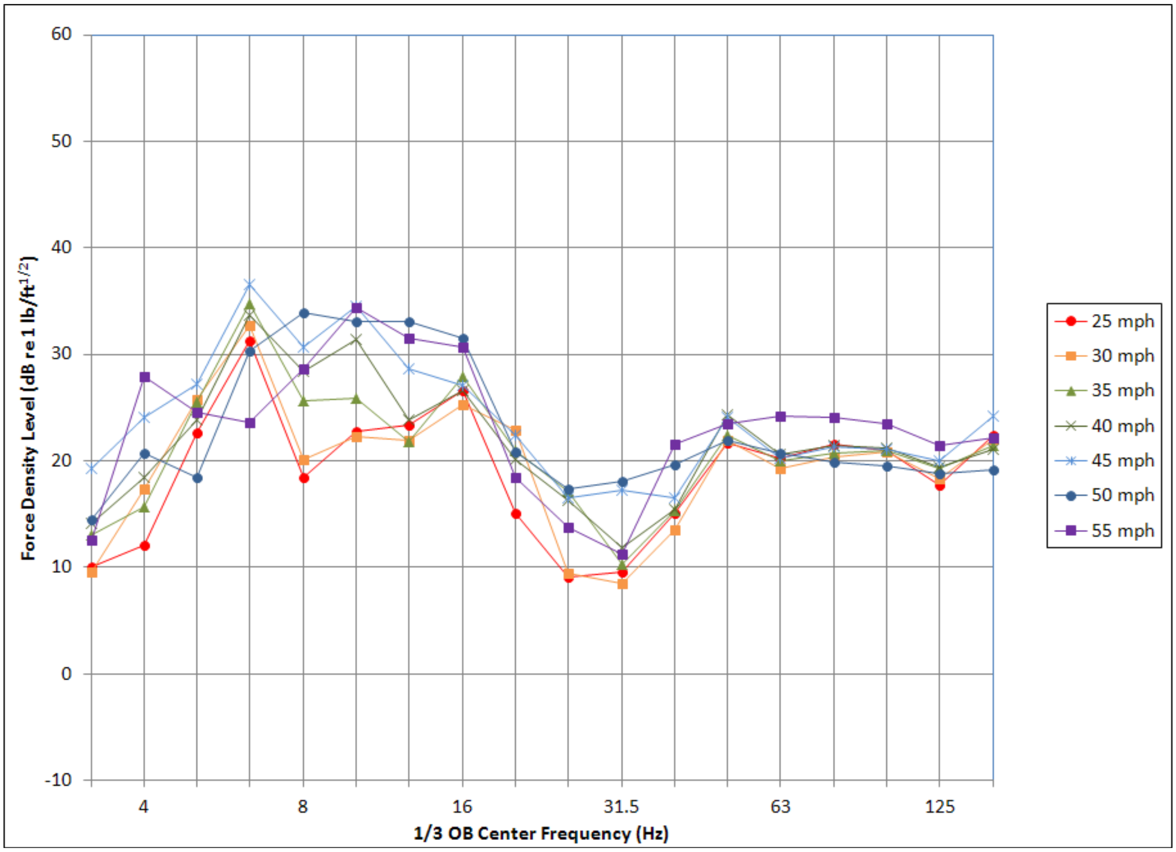

Figure 4-2. Sound Transit Force Density Levels on Aerial Structure

4.1.2 Line Source Response

The LSR represents the response of the ground to vertical forces incoherently distributed over the length of the train (i.e., the force at one location is unrelated to the force at another location). To develop the LSR, the vibration propagation characteristics of the soil are determined by producing an impulsive force on or below the ground surface and measuring the vibration response in each 1/3-octave band (typically from 4 to 160 Hz) at geophones located over a range of distances. The transfer mobilities between each impact and geophone location are calculated from the measured data. The Point Source Response (PSR) is the level in dB of the transfer mobility magnitude. The LSR is calculated by integrating the square of the 1/3-octave transfer mobility at specific distances over the length of the train.

Vibration from aerial structures propagate outward from the foundations of the guideway columns, which act roughly like point sources within the ground. At the time of the vibration analysis, the locations of the columns were not known. Therefore, the LSRs developed for the analysis of the at-grade segments of track were also used to analyze the potential vibration impact next to aerial structures using the FDL developed for aerial structures described in Section 4.1.1. The FDL was based on vibration measurements taken near the columns of existing guideways. Because of this factor, the projected vibration levels for aerial structures represent the worst case condition for receptors close to columns. The vibration at receptors located farther away from columns will be lower than projected.

The LSRs were measured at eight sites near the proposed alignment. Test sites were selected based on a review of aerial photographs, geological information available online from the Washington State Geological Survey, and supplemented by a visual land-use survey. The eight sites, designated as SVT-01 through SVT-08, were selected to represent a range of soil conditions in areas along the project corridor near sensitive land uses. The measurement sites were located in the municipalities of Seattle, Shoreline, Mountlake Terrace, and Lynnwood. The locations of these measurement sites are shown in Figure 4-3 and are described below.

- **Site SVT-01:** This site was located at the intersection of 3rd Avenue NE and NE 117th Street in Seattle. The measurement at this location characterizes the vibration propagation in the south portion of Segment A.
- **Site SVT-02:** This site was located at the intersection of 5th Avenue NE and NE 127th Street in Seattle. The measurement at this location characterizes the vibration propagation in the southern portion of Segment A, south of the Jackson Park Golf Course.
- **Site SVT-03:** This site was located at the intersection of 1st Avenue NE and NE 158th Street in Shoreline. The measurement at this location characterizes the vibration propagation in the middle portion of Segment A, north of the Jackson Park Golf Course.
- **Site SVT-04:** This site was located at the intersection of 8th Avenue NE and NE 189th Street in Shoreline. The measurement at this location characterizes the vibration propagation in the north portion of Segment A.
- **Site SVT-05:** This site was located at the end of NE 200th Street in Shoreline, immediately east of the I-5 corridor. The measurement at this location characterizes the vibration propagation in the south portion of Segment B.
- **Site SVT-06:** This site was located at the intersection of 226th Street SW and 62nd Avenue West in Mountlake Terrace. The measurement at this location characterizes the vibration propagation in the middle portion of Segment B.
- **Site SVT-07:** This site was located in the cul-de-sac at the south end of 53rd Avenue West in Lynnwood, north and west of the Interstate 5 (I-5) corridor. The measurement at this location characterizes the vibration propagation in the north portion of Segment B and the southern half of Segment C.
- **Site SVT-08:** This site was located in the Lynnwood Park-and-Ride parking lot in Lynnwood. The measurement at this location characterizes the vibration propagation in the northern half of Segment C.

The vibration propagation test system for surface alternatives is shown schematically in Figure 4-4. As shown in the cross-section view at the top of Figure 4-4, the surface test consists of dropping a 42-pound weight from a height of 5 to 6 feet onto the ground to generate a dynamic impact force. The measurement equipment includes a load cell to measure the force produced by the weight, high-sensitivity geophones, amplifiers, and a multi-channel digital recorder. Geophones produce an analog electrical signal that is proportional to the vibration velocity of the ground surface to which they are attached. The geophones are located on either paved surfaces, concrete curbs, or on top of steel stakes driven into soil and mounted with a wax compound in the vertical orientation. Where space permitted, impact tests were made along a line parallel with the rail alignment. For these tests, impact forces were at seven points spaced at 0, 25, 50, and 100 feet offset on both sides of a line of ten geophones. The geophones were placed in a line perpendicular to the impact locations at distances between 15 and 400 feet. For locations at the ends of streets, impact forces were at three points at 0 and 25 feet offset to each side of the geophone line. For each impact location, a minimum of 30 impacts were produced and data recorded for averaging the transfer mobility components.

Data recorded in the field were analyzed with digital signal processing software that calculates the transfer mobility and coherence between each impact and geophone location. Coherence is a measure of the signal-to-noise ratio of the test as a function of frequency. The following are the basic analysis steps:

- Narrowband transfer mobilities and coherence functions were computed for each response location from an average of all the impulses at a specific impact location.
- The narrowband transfer mobilities were energy averaged over each 1/3-octave band to obtain the PSR.
- The PSR levels were plotted with respect to the logarithm of distance from the impacts and a polynomial curve was fitted to the data by the method of least squares for each 1/3-octave band using the following formula to obtain the PSR as a function of distance:

$$PSR = A_0 + A_1 \bullet \log_{10}(D) + A_2 \bullet \log_{10}^2(D) + A_3 \bullet \log_{10}^3(D) \qquad \text{(Equation 4-2)}$$

where:

PSR is the Point Source Response; A_0, A_1, A_2 and A_3 are the regression coefficients; and D is the distance (feet) between the source and the receiver.

- The LSR at each test site was calculated by integrating the 1/3-octave PSR energy at specific distances over the length of a four-car train (380 feet) using the regression coefficients determined above.
- Propagation test and analysis procedures are described in more detail in the FTA guidance manual *Transit Noise and Vibration Impact Assessment*.

Detailed vibration propagation data for the project are included in Attachment E of this report.

For all test sites with the exception of SVT-05, there was no observable correlation between the LSR and the geological properties of the soil at those sites. Therefore, a general LSR was developed by applying a polynomial curve fit to the LSRs calculated at multiple distances at each test site (SVT-01 through SVT-04 and SVT-06 through SVT-08). The resulting general LSR is plotted at several distances in Figure 4-5 while the regression coefficients are listed in Table 4-3. The general LSR was applied along the length of the alignment except where noted below.

The LSR calculated from the SVT-05 test site data was applied from Station 347+00 to 354+00. The LSR was calculated by integrating the PSR energy at specific distances over the length of a four-car train (380 feet) using the regression coefficients determined as described above. The PSR regression coefficients used to calculate the LSR at SVT-05 are provided in Attachment E with the vibration data from all test sites.

Table 4-3. Regression Coefficients for the General LSR Applied Along the Length of the Alignment Except Where Noted

Coefficient	1/3-Octave Band Center Frequency (Hz)																	
	3.15	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
A_0	24	10	28	19	18	42	55	87	117	94	101	52	45	30	43	49	26	12
A_1	-21	4	-23	-6	0	-36	-53	-98	-145	-105	-116	-19	2	42	26	11	49	85
A_2	10	-6	9	-1	-4	16	26	49	77	60	71	14	0	-31	-28	-22	-44	-70
A_3	-2	1	-1	0	1	-3	-5	-9	-15	-12	-16	-6	-3	4	4	4	8	13

$LSR = A_0 + A_1 \bullet \log_{10}(D) + A_2 \bullet \log_{10}^2(D) + A_3 \bullet \log_{10}^3(D)$

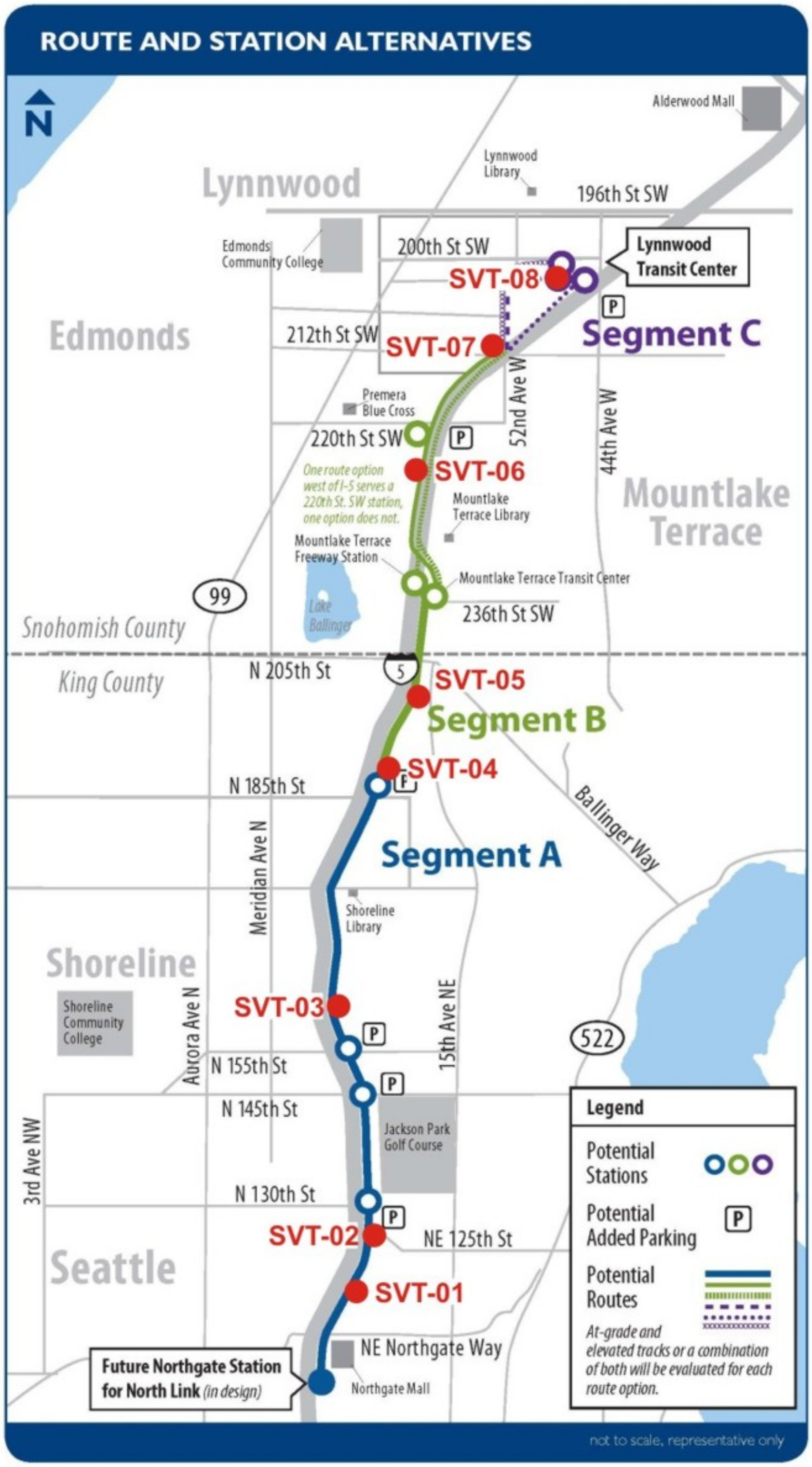

Figure 4-3. Vibration Propagation Test Locations SVT-01 through SVT-08 (locations indicated are approximate)

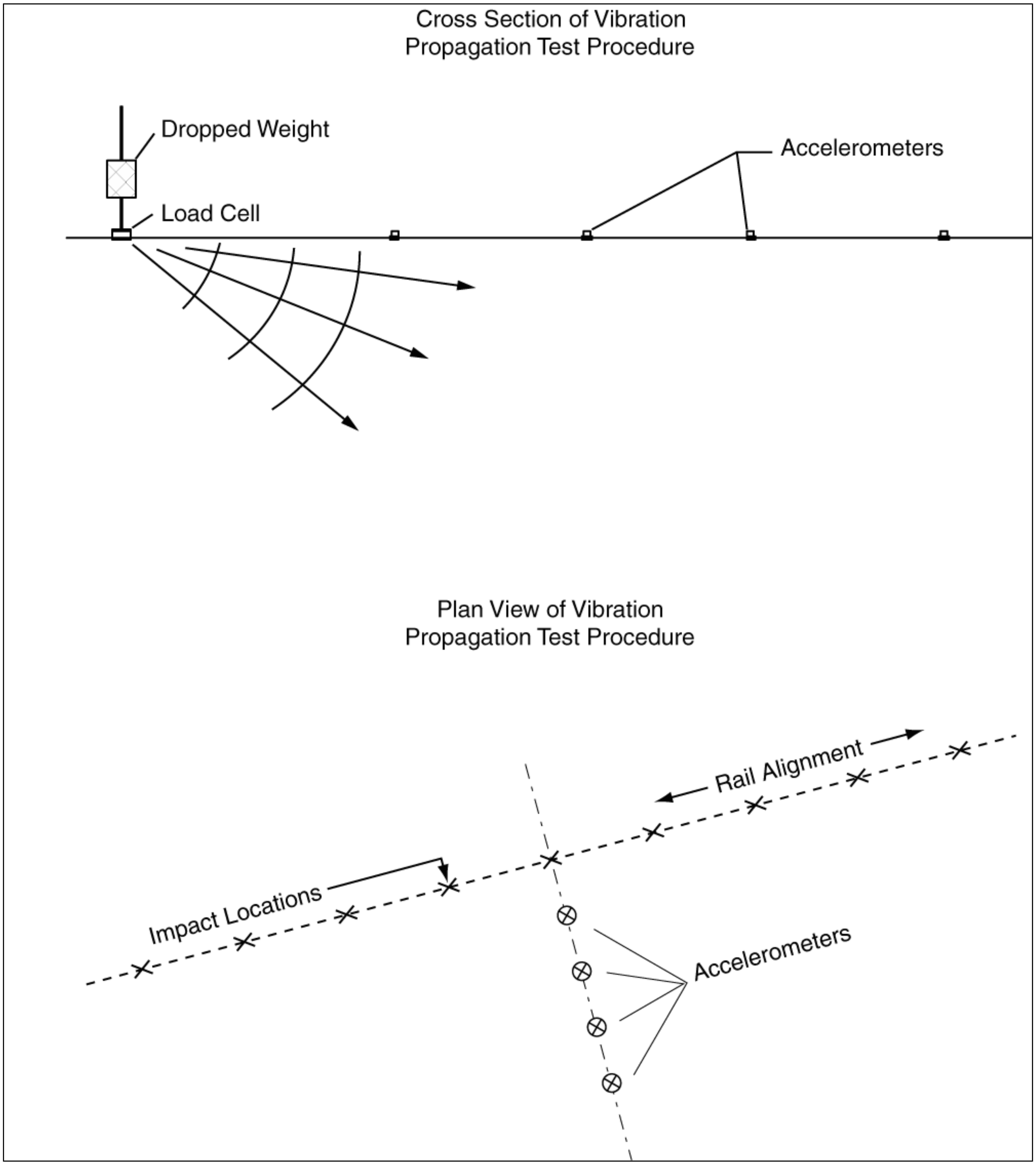

Figure 4-4. Surface Vibration Propagation Test Procedure

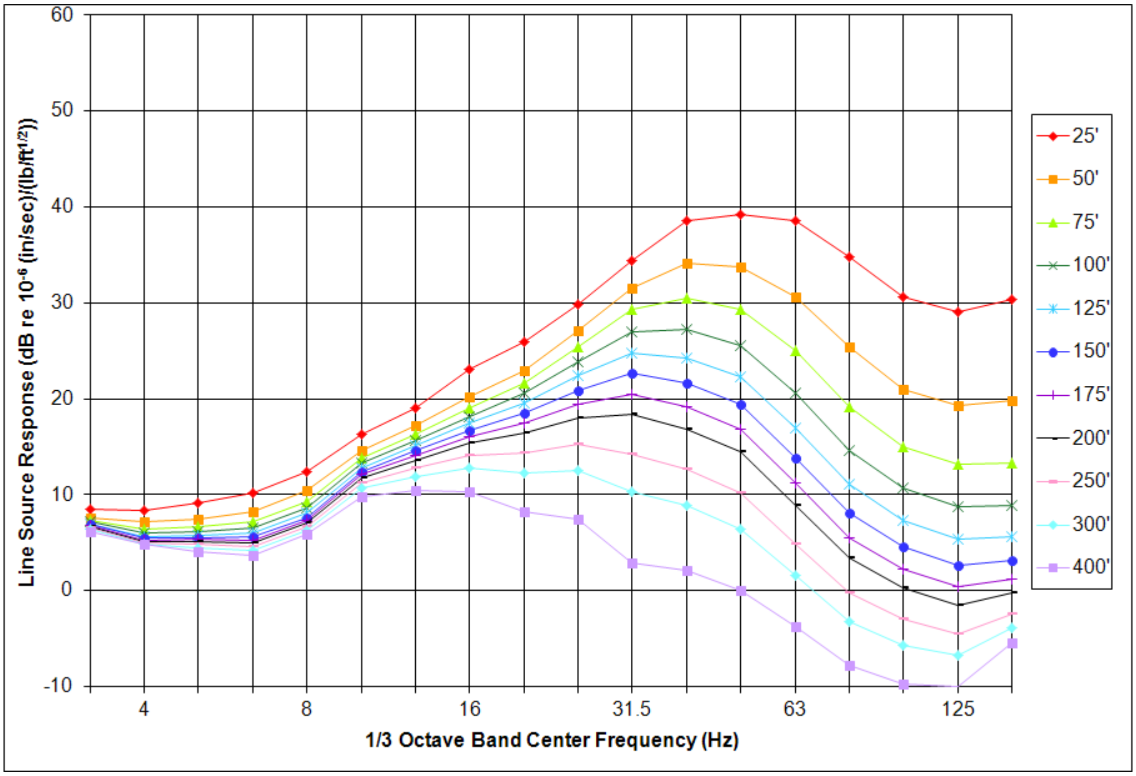

Figure 4-5. General Line Source Transfer Mobilities Based on SVT-01 through SVT-04 and SVT-06 through SVT-08

4.1.3 Building Vibration Response

The mechanical responses of various parts of building structures either reduce or increase the interior vibration levels. Composite building vibration responses were derived to represent the response of the foundation to incident ground vibration, floor-to-floor attenuation, and resonance amplification of floors. These building vibration responses are added to the predicted ground surface vibration levels to arrive at the final predicted indoor floor vibration levels.

Vibration is reduced as it travels from the soil into the building because of the mass of the building, stiffness of the foundation, and reflections of the vibration from the foundation. These combined effects are referred to as the foundation coupling loss. The FTA guidance manual provides foundation coupling losses for a variety of buildings. Because the majority of sensitive land uses along the project corridor are single-family residential structures, the predictions herein are for the first floor, and no floor-to-floor attenuation has been included. As the FTA manual states, the floor resonance amplification varies greatly; therefore, the manual suggests adding +6 dB to floor vibration velocity levels in the frequency range of the fundamental resonance in the floor: from 15 to 20 Hz for wood-frame residential structures and 20 to 30 Hz for a reinforced-concrete slab floor in modern buildings (*Chapter 11: Detailed Vibration Analysis*, page 11-11). The combined frequency range for both types of buildings includes the 1/3-octave bands from 16 to 31.5 Hz. For the

Lynnwood Link Extension vibration analysis, this adjustment was extended to all bands above 31.5 Hz and an adjustment was also added at frequencies below 16Hz. Table 4-4 lists these adjustments.

The resulting BVR levels are identical to those used previously for Sound Transit University Link and Northgate Link Extension, and are listed in Table 4-5. The BVR assigned to each receptor building was based on observation of the buildings along the alignment.

Table 4-4. Adjustment for Floor Resonance Amplification (dB)

	1/3-Octave Band Center Frequency (Hz)														
	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Adjustment	2	3	4	5	6	6	6	6	6	6	6	6	6	6	6

Table 4-5. Building Vibration Response (dB) (Including Adjustment for Floor Resonance Amplification)

	1/3-Octave Band Center Frequency (Hz)														
Structure	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Single Family	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2
1-2 Story Residential	2	1	-1	-1	-1	-2	-2	-2	-3	-3	-3	-3	-2	-2	-1
2-4 Story Masonry on Spread Footings	-1	-2	-3	-4	-4	-5	-6	-7	-8	-8	-8	-6	-6	-5	-4
Large Masonry on Pile Foundation	-2	-2	-1	0	0	-1	-2	-3	-3	-4	-5	-6	-7	-8	-8
Large Masonry on Spread Footings	-6	-7	-6	-6	-6	-7	-8	-8	-8	-8	-8	-8	-8	-7	-6
Slab on Grade Floor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.1.4 Additional Adjustments

Wheel impacts at crossovers increase vibration relative to a tangent track. The vibration generated by special track work tends to propagate as from a point source. Therefore, the adjustment depends strongly upon the proximity of the receptor to the crossover. To account for the increased vibration from crossovers, the following adjustment was applied:

$$+11 \text{ dB for } D < 20 \text{ ft} \qquad \text{(Equation 4-3)}$$

$$11 + 20\log_{10}(20/D) \text{ dB for } 20 \text{ ft} \le D \le 70 \text{ ft}$$

$$0 \text{ dB for } D > 70 \text{ ft}$$

where:

D equals the distance between the receiver and the closest extent of any crossover.

The above adjustment is identical to the adjustment that was applied to the Sound Transit University Link and Northgate Link Extension.

4.2 Construction Vibration Projections

Construction vibration, similar to noise, is highly dependent on the specific equipment and methods employed. Construction vibration can cause a variety of potential effects, including interference with vibration-sensitive equipment, low rumbling or groundborne noise, vibrations perceptible to humans at moderate levels, and cosmetic damage to buildings at the highest levels considered here. Because construction is a short-term, temporary impact, construction vibration was assessed at locations where prolonged annoyance or building cosmetic damage might occur; namely, at the receptors within the vicinity of the passenger stations planned for the project.

Most construction processes do not generate high enough vibration levels to approach threshold cracking damage criteria; moreover, structural damage is highly unlikely for construction vibration. Cosmetic damage from construction vibration is generally limited to pile-driving and vibratory rolling—the only two activities with PPV levels at 25 feet that are higher than the threshold cracking damage criteria discussed in Section 4.5 Construction Vibration Criteria. Because of this reason, care should be taken to limit these activities near structures as much as practicable.

The methodology for assessing construction vibration annoyance includes measuring maximum rms overall vibration levels with an integration time of 1 second for each source at a distance of 25 feet. A summary of expected upper range vibration levels at a reference distance of 25 feet from the vibration source is presented in Table 4-6 (from FTA). For reference, the distance from the vibration source necessary to achieve vibration levels of 72 VdB or below is given in the last column. This level corresponds to the vibration annoyance criteria for frequent events at residential receptors (Table 3-1).

Using the available reference vibration levels at 25 feet, the following general prediction model (from the FTA guidance manual) gives the vibration level as a function of distance:

$$L_v(\text{distance}) = L_v(25\text{ feet}) - 30*\log(\text{distance}/25\text{ feet}) \quad \text{(Equation 4-4)}$$

Table 4-6. Summary of Construction Equipment Vibration

Equipment	PPV at 25 feet (inches/second)	Approx. L_v[a] at 25-foot VdB	Minimum Distance between Equipment and Receptor to Avoid Annoyance Impact (feet)
Vibratory pile or casing	0.734	105	315
Oscillatory pile casing	0.089	87	80
Vibratory soil compactor	0.210	94	120
Auger drilling	0.016	72	25
Hoe ram	0.089	87	80
Excavator/grader/bulldozer	0.089	87	80
Loaded trucks	0.076	86	75

[a] Root mean square velocity level in decibels (VdB) re: 1 micro-inch/second, determined with an integration time of 1 second.

5 VIBRATION IMPACT ASSESSMENT

The detailed vibration impact assessment is based on the criteria discussed in Section 4 and on the projections described in Section 5 of this report. The assessment results are described below.

5.1 Light Rail Vibration Impact Assessment

The vibration impact assessment utilized inputs such as train speed, distance from the receivers to the tracks, guideway configuration, and combined vehicle characteristics with soil propagation properties to estimate vibration levels at sensitive receptors. The locations of sensitive receptors and the distances from the receivers to the tracks were based on geographic information system (GIS) data available in the online document-sharing database for the project. Plan and profile information were based on the Draft EIS – Conceptual Design drawings dated 13 July 2012.

Operating speeds used for the analysis were provided in the *Conceptual Plans for DEIS Evaluation*, Sound Transit Lynnwood Link Extension, June 8, 2012 (Draft EIS Plans, 2012). In accordance with the Sound Transit *Link Design Criteria Manual* (May 2011), maximum design speed for Link light rail corridors is 55 mph, and the maximum acceleration and deceleration rate is 3 mph per second. Using this rate, the design speed may be achieved in less than 20 seconds over a distance of less than 600 feet. As a result, and accounting for 380-foot platforms, the operating speed beyond 200 feet from stations was evaluated at 55 mph, except where limited by track geometry as listed in Table 5-1. Within 200 feet of stations, a conservative average speed of 45 mph was used.

Table 5-1. Areas with Limited Operating Speed

Applicable Alternatives	Begin Track Station	End Track Station	Speed
A1, A3, A10	100+00	117+00	45 mph
A5, A10	212+00	218+00	45 mph
B4	352+00	357+00	40 mph
B4	357+00	367+00	35 mph
B1	360+00	364+00	35 mph
B1	370+00	375+00	35 mph
B1	378+00	384+00	45 mph
B2, B2A	348+00	356+00	45 mph
B2, B2A	360+00	365+00	35 mph
B2, B2A	371+00	376+00	35 mph
B2, B2A	380+00	391+00	45 mph
B2, B2A	407+00	411+00	45 mph
B2, B2A	421+00	428+00	45 mph
B2, B2A	438+00	444+00	45 mph
C1, C2	502+00	513+00	45 mph
C3	516+00	521+00	40 mph
C3	525+00	530+00	40 mph
C1	526+00	534+00	45 mph

Table 5-1. Areas with Limited Operating Speed

Applicable Alternatives	Begin Track Station	End Track Station	Speed
C2	526+00	538+00	35 mph
C1	537+00	546+00	35 mph

Attachment D includes tables that list the vibration-sensitive receptor locations, receiver type, FTA criteria, distance to the nearest track, and the projected maximum 1/3-octave band vibration velocity for each segment, including all alternatives. Receptors with potential vibration impacts are highlighted in the tables.

As discussed in Section 3.1.2, groundborne noise criteria are only applied to buildings that have sensitive interior spaces that are well insulated from exterior noise when assessing potential groundborne noise impacts from at-grade or aerial structure track. No such buildings exist along the project alignment. Therefore, no groundborne noise impacts are reported in this study.

Tables 5-2 through 5-7 summarize the potential vibration impacts, including locations and number of potential impacts at each receptor, for each project segment. Potential vibration impacts would be limited to Segment A. The number of potential impacts at multi-family receptors, if any, is estimated by assuming that the total number of residential units is divided evenly between buildings. The potential impacts reported in this section do not include potential mitigation measures. Mitigation for potential impacts is discussed in Section 6.1.

5.1.1 Segment A: Seattle to Shoreline

The following sections discuss the potential vibration impacts for each of the Segment A alternatives.

Alternative A1: At-grade/Elevated with NE 145th and NE 185th Street Stations

Table 5-2 summarizes the potential vibration impacts for Alternative A1. Potential vibration impacts include eight single-family homes distributed along the alignment. All potential impacts are adjacent to the at-grade track.

Table 5-2. Alternative A1 Potential Vibration Impacts

Station No.	Address	Distance to Near Track (feet)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3-Octave Band (Hz)	Vibration Impact Criterion	No. of Potential Impacts
038+25	327 NE 120th Street, Seattle	37	55	73	63	72	1
155+50	121 NE 163rd Street, Shoreline	27	55	77	63	72	1
169+50	114 NE 167th Street, Shoreline	28	55	76	63	72	1

Table 5-2. Alternative A1 Potential Vibration Impacts

Station No.	Address	Distance to Near Track (feet)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3-Octave Band (Hz)	Vibration Impact Criterion	No. of Potential Impacts
199+75	17821 3rd Avenue NE, Shoreline	35	55	74	63	72	1
203+25	331 NE 180th Street, Shoreline	39	55	78	63	72	1
206+00	18019 5th Avenue NE, Shoreline	37	55	73	63	72	1
209+25	18031 5th Avenue NE, Shoreline	35	55	74	63	72	1
231+00	18921 8th Avenue NE, Shoreline	24	55	78	63	72	1
						Total	**8**

Note: Vibration levels are measured in VdB referenced to 1 micro-inch per second.

Alternative A3: Mostly Elevated with NE 145th and NE 185th Street Stations

Table 5-3 summarizes the potential vibration impacts for Alternative A3. Potential vibration impacts include two single-family homes along the alignment. All impacts are adjacent to the at-grade track.

Table 5-3. Alternative A3 Potential Vibration Impacts

Station No.	Address	Distance to Near Track (feet)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3-Octave Band (Hz)	Vibration Impact Criterion	No. of Potential Impacts
155+50	121 NE 163rd Street, Shoreline	27	55	77	63	72	1
169+50	114 NE 167th Street, Shoreline	28	55	76	63	72	1
						Total	**2**

Note: Vibration levels are measured in VdB referenced to 1 micro-inch per second.

Alternative A5: At-grade/Elevated with NE 130th, NE 155th, and NE 185th Street Stations

Table 5-4 summarizes the potential vibration impacts for Alternative A5. Potential vibration impacts include 12 single-family homes and one duplex distributed along the alignment. All impacts are adjacent to the at-grade track.

Table 5-4. Alternative A5 Potential Vibration Impacts

Station No.	Address	Distance to Near Track (feet)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3-Octave Band (Hz)	Vibration Impact Criterion	No. of Potential Impacts
26+00	136 NE 115th Street, Seattle	32	55	75	63	72	1
26+25	147 NE 116th Street, Seattle	28	55	76	63	72	2
33+00	11708 3rd Avenue NE, Seattle	42	55	72	63	72	1
38+25	327 NE 120th Street, Seattle	36	55	73	63	72	1
116+25	309 NE 149th Street, Shoreline	36	55	73	63	72	1
155+50	121 NE 163rd Street, Shoreline	27	55	77	63	72	1
169+50	114 NE 167th Street, Shoreline	28	55	76	63	72	1
199+75	17821 3rd Avenue NE, Shoreline	35	55	74	63	72	1
203+25	331 NE 180th Street, Shoreline	39	55	78	63	72	1
206+00	18019 5th Avenue NE, Shoreline	37	55	73	63	72	1
209+25	18031 5th Avenue NE, Shoreline	34	55	74	63	72	1
229+00	718 NE 189th Street, Shoreline	30	55	76	63	72	1
230+25	18915 8th Avenue NE, Shoreline	23	55	78	63	72	1
						Total	**14**

Note: Vibration levels are measured in VdB referenced to 1 micro-inch per second.

Alternative A7: Mostly Elevated with NE 130th, NE 155th, and NE 185th Street Stations

Table 5-5 summarizes the potential vibration impacts for Alternative A7. Potential vibration impacts include three single-family homes distributed along the alignment. All impacts are adjacent to the at-grade track.

Table 5-5. Alternative A7 Potential Vibration Impacts

Station No.	Address	Distance to Near Track (feet)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3-Octave Band (Hz)	Vibration Impact Criterion	No. of Potential Impacts
116+25	309 NE 149th Street, Shoreline	36	55	73	63	72	1
155+50	121 NE 163rd Street, Shoreline	27	55	77	63	72	1

Table 5-5. Alternative A7 Potential Vibration Impacts

Station No.	Address	Distance to Near Track (feet)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3-Octave Band (Hz)	Vibration Impact Criterion	No. of Potential Impacts
169+50	114 NE 167th Street, Shoreline	28	55	76	63	72	1
						Total	**3**

Note: Vibration levels are measured in VdB referenced to 1 micro-inch per second.

Alternative A10: At-grade/Elevated with NE 130th, NE 145th, and NE 185th Street Stations

Table 5-6 summarizes the potential vibration impacts for Alternative A10. Potential vibration impacts include 11 single-family homes and one duplex distributed along the alignment. All impacts are adjacent to the at-grade track.

Table 5-6. Alternative A10 Potential Vibration Impacts

Station No.	Address	Distance to Near Track (feet)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3-Octave Band (Hz)	Vibration Impact Criterion	No. of Potential Impacts
26+00	136 NE 115th Street, Seattle	32	55	75	63	72	1
26+25	147 NE 116th Street, Seattle	28	55	76	63	72	2
33+00	11708 3rd Avenue NE, Seattle	42	55	72	63	72	1
38+25	327 NE 120th Street, Seattle	36	55	73	63	72	1
155+50	121 NE 163rd Street, Shoreline	27	55	77	63	72	1
169+50	114 NE 167th Street, Shoreline	28	55	76	63	72	1
199+75	17821 3rd Avenue NE, Shoreline	35	55	74	63	72	1
203+25	331 NE 180th Street, Shoreline	39	55	78	63	72	1
206+00	18019 5th Avenue NE, Shoreline	37	55	73	63	72	1
209+25	18031 5th Avenue NE, Shoreline	34	55	74	63	72	1
229+00	718 NE 189th Street, Shoreline	30	55	76	63	72	1
230+25	18915 8th Avenue NE, Shoreline	23	55	78	63	72	1
						Total	**13**

Note: Vibration levels are measured in VdB referenced to 1 micro-inch per second.

Alternative A11: Mostly Elevated with NE 130th, NE 145th, and NE 185th Street Stations

Table 5-7 summarizes the potential vibration impacts for Alternative A11. Potential vibration impacts include two single-family homes distributed along the alignment. All impacts are adjacent to the at-grade track.

Table 5-7. Alternative A11 Potential Vibration Impacts

Station No.	Address	Distance to Near Track (feet)	Speed (mph)	Maximum 1/3-Octave Vibration Level (VdB)	1/3-Octave Band (Hz)	Vibration Impact Criterion	No. of Potential Impacts
155+50	121 NE 163rd Street, Shoreline	27	55	77	63	72	1
169+50	114 NE 167th Street, Shoreline	28	55	76	63	72	1
						Total	**2**

Note: Vibration levels are measured in VdB referenced to 1 micro-inch per second.

5.1.2 Segment B: Shoreline to Mountlake Terrace

No potential vibration impacts are projected along any of the alternatives or options for Segment B.

5.1.3 Segment C: Mountlake Terrace to Lynnwood

No potential vibration impacts are projected along any of the alternatives or options for Segment C.

5.2 Construction Vibration Impact Assessment

Building damage is the primary concern related to construction vibration. Annoyance is typically a concern only where there is prolonged exposure to construction vibration that would occur during construction of the stations. The following sections discuss potential vibration impacts relative to building damage during construction of the guideway and potential vibration impacts relative to both building damage and annoyance during construction of the passenger stations.

The construction assessment assumes that impact pile-driving will not be used in any construction related to the project. Alternative pile-driving techniques, such as vibratory pile-driving or augered piles, have been considered in this assessment as substitutes for impact pile-driving.

5.2.1 Guideway Construction

Two construction sources that have the potential to cause cosmetic damage to receptors along the alignment during construction of the guideway are vibratory soil compactors and vibratory pile drivers. Vibratory soil compactors might be used during construction of the at-grade segments of the guideway. Vibratory pile-driving might be required during construction of retained cut segments, for excavation, and/or for foundations of retaining walls.

The design of the foundations for aerial structure columns may include large-diameter concrete piles. A common method is to force a large-diameter cylindrical steel casing into the ground to the required depth, excavate the contents of the casing, insert a rebar cage, and then pour concrete into the void. As the concrete is poured in, the casing is extracted for reuse. The casing would be driven into the ground using a vibratory hammer that can produce substantial ground vibration. Constant frequency vibratory pile drivers produce substantially less vibration than vibratory hammers that sweep upwards through the resonance frequency of the pile casing, hammer, and soil. An oscillatory method whereby the temporary casing is rotated back and forth in torsion generates measurably less vibration. The vibration caused by the oscillatory method is similar to other non-pile driving construction activities, and would not represent a substantial source of vibration. These pile casing installation techniques may be used for localized foundations such as guideway columns or for large secant-piled walls.

The potential for cosmetic damage to nearby structures should be closely evaluated if vibratory pile-driving methods would be used within 80 feet of any receptor or vibratory soil compactor within 40 feet. This task should include documenting the condition of buildings prior to construction and monitoring vibration during construction.

No structural damage will occur to any building as long as the vibration does not exceed the threshold cracking criteria, which is the vibration level at which minor cosmetic cracking may occur (Dowding 1996).

5.2.2 Passenger Station Construction

In general, station construction receptors would include primarily single-family residences, a church, a firehouse, and apartment complexes (multi-family residences) adjacent to the Lynnwood Transit Center and Park-and-Ride. All of the stations would be in proximity to I-5.

Station Construction Equipment

The precise means and methods of station construction are not yet known. General construction activities applicable to this project that can produce ground vibration are discussed below.

Demolition of existing structures: Some of the station options would require the demolition (or relocation) of existing buildings. In general, this type of activity would involve the use of hoe rams to break up concrete and large bulldozers for moving materials around the site.

Site excavation and grading: At the station locations and adjacent parking garages as well as surface parking areas, various degrees of excavation and grading of the sites would likely be required. With large excavators and graders, large vibratory soil compactors and compactors could be used to pack down the soil after grading.

Foundations and shoring: Elevated station-platform supporting columns, multi-level parking structures, and retaining walls could require deep pile foundations. Piles could be driven or drilled into the ground using a number of methods.

A common method is to force a large-diameter cylindrical-steel casing into the ground to the required depth, excavate the contents of the casing, insert a rebar cage, and then pour concrete into the void. As the concrete is poured in, the casing is extracted for reuse. The casing can be driven into the ground using a vibratory hammer that can produce substantial ground vibration. Constant frequency vibratory pile drivers produce substantially less vibration than vibratory hammers. An oscillatory method whereby the temporary casing is rotated back and forth generates measurably less vibration. These pile casing techniques may be used for localized foundations such as guideway columns or for large secant-pile walls.

For smaller diameter piles and shallower foundations, pile shafts would typically be drilled with an auger. This would also apply to temporary shoring methods such as soldier pile walls.

Materials transport: For all phases of construction at all of the station sites, truck trips would be needed to transport materials from the construction sites and bring in new materials, especially concrete haul trucks.

Station Construction Vibration Impact Assessment Results

The analysis outlined herein assumes that impact pile-driving will not be used in the station construction. Alternative pile-driving techniques, such as vibratory pile-driving or augered piles, have been considered in the vibration assessment.

Cosmetic Damage Assessment

Based on the available station plans, vibration levels sufficient to cause cosmetic damage to adjacent buildings would not occur, or could be avoided. The potential for cosmetic damage to nearby structures should be more closely evaluated if vibratory pile-driving methods are used within 80 feet of the receptor or vibratory soil compactors within 40 feet. This task could include documenting the condition of buildings prior to construction and monitoring vibration during construction.

Vibration Annoyance Assessment

Construction will continue at the station sites for longer periods than at locations along the guideway. Therefore, nearby residents could be annoyed by vibration. Based on the approximate distances between receptors and the construction site and the distances indicated in the last column of Table 4-6, a summary of potentially affected receptors is presented in Table 5-8. This assessment is based on the assumption that pile foundations would be used only at the station platforms and multi-level parking garages, and that vibratory soil compactors might be used anywhere on the site. All receptors on the perimeter of the construction sites are assumed to be exposed to construction-related truck traffic, regardless of other construction activity.

Potentially affected receptors with respect to vibration annoyance include primarily single-family residences, some apartment complexes, a church, and a fire station. The majority of pile-driving and other construction-related vibration would occur during daytime periods, when most people are least sensitive to vibration.

Table 5-8. Summary of Potential Annoyance Impacts from Station Construction Vibration

	Potential Construction Vibration Annoyance Impacts		
Station	**Vibratory Pile Methods**	**Vibratory Soil Compactor, Non-Vibratory Pile**	**No Vibratory Methods**
NE 130th Street, Option 1	25 SFRs, 1 church	12 SFRs, 1 church	7 SFRs, 1 church
NE 130th Street, Option 2	12 SFRs, 1 church	6 SFRs	6 SFRs
NE 145th Street, Option 1	43 SFRs	20 SFRs	20 SFRs
NE 145th Street, Option 2	46 SFRs	23 SFRs	23 SFRs
NE 155th Street	40 SFRs (including historic log house), fire station	10 SFRs (including historic log house), fire station	4 SFRs, fire station
NE 185th Street, Option 1	21 SFRs	12 SFRs	12 SFRs
NE 185th Street, Option 2	14 SFRs	11 SFRs	11 SFRs
NE 185th Street, Option 3	18 SFRs	14 SFRs	14 SFRs
Mountlake Terrace, Transit Center Option	0	0	0
Mountlake Terrace, Freeway Option	3 SFRs	3 SFRs	3 SFRs
220th Street SW	Melody Hill School, Mountlake Terrace City Hall, 1 office building, 1 apartment complex (Lakeside Apartments)	Mountlake Terrace City Hall	Mountlake Terrace City Hall
Lynnwood, 200th Street SW	3 Apartment Complexes	3 Apartment Complexes	3 Apartment Complexes
Lynnwood Transit Center	1 Apartment Building	0	0
Lynnwood Park-and-Ride, Option 1	1 Apartment Building	0	0
Lynnwood Park-and-Ride, Option 2	1 Apartment Building	0	0

SFR = Single-Family Residence

6 MITIGATION OF POTENTIAL VIBRATION IMPACTS

6.1 Potential Vibration Mitigation Measures

Several mitigation measures were considered during the analysis for mitigating potential vibration impacts. The effects of installing ballast mat under at-grade track were assessed and it was concluded that a ballast mat would not provide enough vibration reduction to mitigate the potential vibration impacts. A slab track with high-resilience rail fasteners would not provide sufficient vibration reduction and would cause an increase in noise relative to the ballasted track. A floating slab track (FST) could be used to mitigate vibration impact, but an FST would provide more vibration reduction than is required and, therefore, may not be cost-effective relative to other vibration mitigation approaches. An FST would also cause an increase in noise relative to a ballasted track. Soil modification beneath the tracks depends upon the relative stiffness of the modified and unmodified soils and may not provide sufficient vibration reduction.

The vibration analysis indicated that all potential vibration impacts could be mitigated with tire derived aggregate (TDA) as an underlayer beneath the sub-ballast layer of the track. TDA is inexpensive compared to other mitigation measures. It has been installed beneath light rail tracks for systems in San Jose, California and Denver, Colorado. To date, there has been no indication of decreased effectiveness of the TDA nor an increase in maintenance costs attributed to the TDA at those light rail systems (Wilson, Ihrig & Associates, Inc. 2009). Vibration impacts and mitigation options will be reviewed during final design to confirm that appropriate measures are included in the design.

TDA is proposed for mitigating potential ground vibration impacts at project ballast and tie track. A typical TDA installation consists of a compacted underlayer of 12 inches of nominally 3-inch tire shreds or chips wrapped with geotextile filter fabric, covered with 12 inches of sub-ballast, and 12 inches of ballast above that to the base of the ties. TDA can only be used on ballast and tie track. Tests indicate that the vibration-attenuation properties of this treatment are midway between that of ballast mats and FST. The adjustments applied in the vibration analysis to account for adding TDA under the tracks were empirically based and are listed in Table 6-1.

Table 6-1. Adjustment (Insertion Gain, dB) for Vibration Mitigation

	1/3-Octave Band Center Frequency (Hz)														
Mitigation	**6.3**	**8**	**10**	**12.5**	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**
Tire-Derived Aggregate	0	0	0	0	-2	-5	-6	-7	-8	-12	-14	-14	-13	-11	-10

Based on the vibration projections conducted for this study, all potential vibration impacts could be eliminated by installing TDA under the tracks or other approach with an identical or better vibration reduction performance than TDA. Table 6-2 outlines the projected extents along the alignment where mitigation for potential vibration impacts is recommended. As indicated in Section 5.1 Light

Rail Vibration Impact Assessment, no potential vibration impacts are projected for any of the alternatives for Segments B and C. Therefore, Table 6-2 only outlines mitigation for the Segment A alternatives.

Table 6-2. Recommended Locations for Vibration Mitigation

Segment Alternative	Mitigation Extents (Station No. – Station No.)	Total Mitigation Length (feet)
A1: At-grade/Elevated with NE 145th and NE 185th Street Stations	037+25 – 038+50 155+25 – 156+50 168+50 – 170+00 199+50 – 210+00 230+75 – 232+25	1,600
A3: Mostly Elevated with NE 145th and NE 185th Street Stations	155+25 – 156+50 168+50 – 170+00	275
A5: At-grade/Elevated with NE 130th, NE 155th, and NE 185th Street Stations	024+75 – 027+75 032+25 – 034+00 037+25 – 038+50 116+50 – 117+50 155+25 – 156+50 168+50 – 170+00 199+50 – 210+00 227+75 – 231+50	2,400
A7: Mostly Elevated with NE 130th, NE 155th, and NE 185th Street Stations	116+50 – 117+50 155+25 – 156+50 168+50 – 170+00	375
A10: At-grade/Elevated with NE 130th, NE 145th, and NE 185th Street Stations	024+75 – 027+75 032+25 – 034+00 037+25 – 038+50 155+25 – 156+50 168+50 – 170+00 199+50 – 210+00 227+75 – 231+50	2,300
A11: Mostly Elevated with NE 130th, NE 145th, and NE 185th Street Stations	155+25 – 156+50 168+50 – 170+00	275

6.2 Construction Vibration Mitigation Control Provisions

Several measures can be implemented to control vibration during construction. The measures require consideration of construction equipment location relative to receptors, as well as construction processes. The basic approach is outlined in the FTA guidance manual. Vibration mitigation measures may include the following:

Project Scheduling:

- Avoid nighttime activities involving major vibration sources. People are generally less aware of vibration during waking hours than when lying in bed. Excessive vibration can disturb sleep.

Alternative Construction Methods:

- Demolish existing structures that are near vibration-sensitive receptors with methods that do not cause impact forces against the buildings or near them. For example, concrete structures can be saw-cut into small sections and loaded onto trucks, rather than breaking large sections and dropping them to the ground.
- Minimize use of vibratory soil compactors or compactors near vibration-sensitive receptors.
- Avoid using variable-frequency vibratory hammers in dense residential areas, such as around the 130th, 145th, 155th, and 185th Street Stations.
- Use of oscillatory pile-casing techniques where appropriate. Oscillatory pile-driving generates significantly lower vibration than impact pile-driving.
- Avoid conventional vibratory hammers. Conventional vibratory hammers that operate from zero to maximum frequency may cause objectionable vibration and risk cosmetic damage as the hammer sweeps through resonance. An alternative to conventional vibratory pile drivers is a resonance-free vibrator or variable eccentric moment vibrator.

7 REFERENCES

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