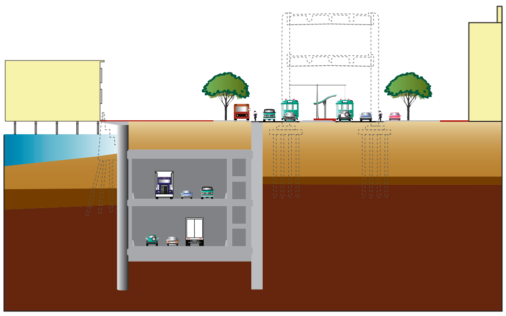
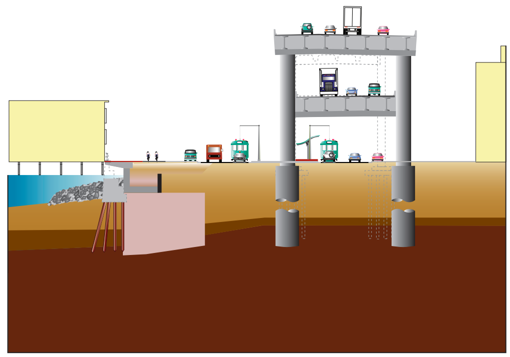
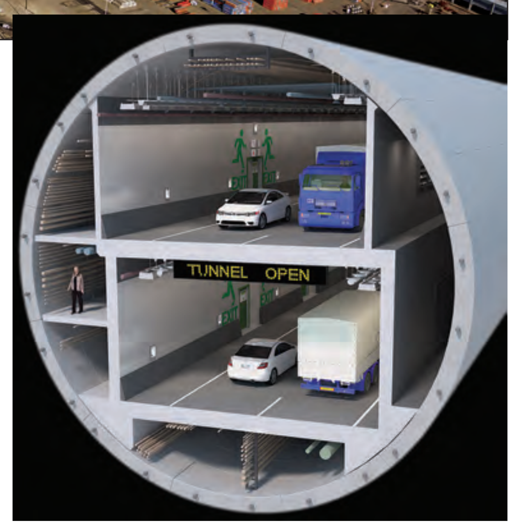
ALASKAN WAY VIADUCT REPLACEMENT PROJECT
Final Environmental Impact Statement

APPENDIX F Noise Discipline Report



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U.S. Department of Transportation
Federal Highway Administration

Washington State Department of Transportation

City of Seattle

JULY 2011

Alaskan Way Viaduct Replacement Project
Final EIS
Noise Discipline Report

The Alaskan Way Viaduct Replacement Project is a joint effort between the Federal Highway Administration (FHWA), the Washington State Department of Transportation (WSDOT), and the City of Seattle. To conduct this project, WSDOT contracted with:

Parsons Brinckerhoff
999 Third Avenue, Suite 3200
Seattle, WA 98104

In association with:
Coughlin Porter Lundeen, Inc.
EnviroIssues, Inc.
GHD, Inc.
HDR Engineering, Inc.
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William P. Ott Construction Consultants

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LIST OF EXHIBITS

ACRONYMS AND ABBREVIATIONS

μPa	micropascals
dB	decibels
dBA	A-weighted decibels for sound energy averages
City	City of Seattle
EIS	Environmental Impact Statement
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
Hz	hertz (cycles per second)
ISO	International Organization for Standardization
L_{dn}	day/night sound level (measure of 24-hour environmental sounds)
L_{eq}	equivalent sound level
$L_{eq}(h)$	hourly equivalent sound level
L_{max}	maximum sound level
L_{min}	minimum sound level
L_n	noise level that is exceeded *n* percent of a specified time
NEPA	National Environmental Policy Act
OSHA	Occupational Safety and Health Administration
Pa	pascals (unit of pressure)
PPV	peak particle velocity
Program	Alaskan Way Viaduct and Seawall Replacement Program
project	Alaskan Way Viaduct Replacement Project
rms	root mean square
SMC	Seattle Municipal Code
SODO	South of Downtown
SR	State Route
TBM	tunnel boring machine
TNM	Traffic Noise Model
VdB	vibration decibels
WAC	Washington Administrative Code
WOSCA	Washington-Oregon Shippers Cooperative Association
WSDOT	Washington State Department of Transportation

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Chapter 1 Introduction and Summary

1.1 Introduction

This discipline report was prepared in support of the Final Environmental Impact Statement (EIS) for the Alaskan Way Viaduct Replacement Project (the project). The Final EIS and all of the supporting discipline reports evaluate the Viaduct Closed (No Build Alternative) in addition to the three build alternatives: the Bored Tunnel Alternative (preferred), the Cut-and-Cover Tunnel Alternative, and the Elevated Structure Alternative. The designs for both the Cut-and-Cover Tunnel and the Elevated Structure Alternatives have been updated since the 2006 Supplemental Draft EIS (WSDOT et al. 2006) to reflect that the section of the viaduct between S. Holgate Street and S. King Street is being replaced by a separate project, and the alignment at S. Washington Street no longer intrudes into Elliott Bay. All three build alternatives are evaluated with tolls and without tolls.

The Federal Highway Administration (FHWA) is the lead federal agency for this project, primarily responsible for compliance with the National Environmental Policy Act (NEPA) and other federal regulations, as well as distributing federal funding. Per the NEPA process, FHWA was responsible for selecting the preferred alternative. FHWA has based its decision on the information evaluated during the environmental review process, including information contained in the 2010 Supplemental Draft EIS (WSDOT et al. 2010) and previous evaluations in 2004 and 2006. After issuance of the Final EIS, FHWA will issue its NEPA decision, called the Record of Decision (ROD).

The 2004 Draft EIS (WSDOT et al. 2004) evaluated five Build Alternatives and a No Build Alternative. In December 2004, the project proponents identified the Cut-and-Cover Tunnel Alternative as the preferred alternative and carried the Rebuild Alternative forward for analysis as well. The 2006 Supplemental Draft EIS (WSDOT et al. 2006) analyzed two alternatives—a refined Cut-and-Cover Tunnel Alternative and a modified rebuild alternative called the Elevated Structure Alternative. After continued public and agency debate, Governor Gregoire called for an advisory vote to be held in Seattle. The March 2007 ballot included an elevated structure alternative (differing in design from the current Elevated Structure Alternative) and a surface-tunnel hybrid alternative. The citizens voted down both alternatives.

After the 2007 election, the lead agencies committed to a collaborative process (referred to as the Partnership Process) to find a solution to replace the viaduct along Seattle's central waterfront. In January 2009, Governor Gregoire, King County Executive Sims, and Seattle Mayor Nickels announced that the agencies had reached a consensus and recommended replacing the aging viaduct with a bored tunnel, which is being evaluated in this Final EIS as the preferred alternative.

1.2 Build Alternatives Overview

The Alaskan Way Viaduct Replacement Project is one of several independent projects developed to improve safety and mobility along SR 99 and the Seattle waterfront from the South of Downtown (SODO) area to Seattle Center. Collectively, these individual projects are referred to as the Alaskan Way Viaduct and Seawall Replacement Program (the Program). See Exhibit 1-1.

Exhibit 1-1. Other Projects Included in the Alaskan Way Viaduct and Seawall Replacement Program

Project	Bored Tunnel Alternative	Cut-and-Cover Tunnel Alternative	Elevated Structure Alternative
Independent Projects That Complement the Bored Tunnel Alternative			
Elliott Bay Seawall Project	X	Included in alternative	Included in alternative
Alaskan Way Surface Street Improvements	X	Included in alternative	Included in alternative
Alaskan Way Promenade/Public Space	X	Included in alternative	Included in alternative
First Avenue Streetcar Evaluation	X	Included in alternative	Included in alternative
Elliott/Western Connector	X	Function provided[1]	Function provided[1]
Transit enhancements	X	Not proposed[2]	Not proposed[2]
Projects That Complement All Build Alternatives			
S. Holgate Street to S. King Street Viaduct Replacement Project	X	X	X
Mercer West Project	X	X	X
Transportation Improvements to Minimize Traffic Effects During Construction	X	X	X
SR 99 Yesler Way Vicinity Foundation Stabilization	X	X	X
S. Massachusetts Street to Railroad Way S. Electrical Line Relocation Project	X	X	X

1. These specific improvements are not proposed with the Cut-and-Cover Tunnel and Elevated Structure Alternatives; however, these alternatives provide a functionally similar connection with ramps to and from SR 99 at Elliott and Western Avenues.
2. Similar improvements included with the Bored Tunnel Alternative could be proposed with this alternative.

This Final EIS (Chapter 7) evaluates the cumulative effects of all the build alternatives; however, direct and indirect environmental effects of these independent projects within the Program will be considered separately in independent environmental documents.

The S. Holgate Street to S. King Street Viaduct Replacement Project, currently under construction as a separate project, was designed to be compatible with any of the three viaduct replacement alternatives analyzed in this Final EIS.

1.2.1 Bored Tunnel Overview

The Bored Tunnel Alternative (preferred alternative) includes replacing State Route (SR) 99 with a bored tunnel and associated improvements, such as relocating utilities located on or under the viaduct, removing the viaduct, decommissioning the Battery Street Tunnel, and making improvements to the surface streets in the tunnel's south and north portal areas.

The Bored Tunnel Alternative would replace SR 99 between S. Royal Brougham Way and Roy Street with two lanes in each direction.

Beginning at S. Royal Brougham Way, SR 99 would be a side-by-side surface roadway that would descend to a cut-and-cover tunnel. At approximately S. King Street, SR 99 would then become a stacked bored tunnel, with two southbound travel lanes on the top and two northbound travel lanes on the bottom.

The bored tunnel would continue under Alaskan Way S. to approximately S. Washington Street, where it would curve slightly away from the waterfront and then travel under First Avenue beginning at approximately University Street. At Stewart Street, it would extend north under Belltown. At Denny Way, the bored tunnel would travel under Sixth Avenue N., where it would transition to a side-by-side surface roadway at about Harrison Street.

Access and exit ramps in the south would include a southbound on-ramp to and northbound off-ramp from SR 99 that would be built in retained cuts and feed directly into a reconfigured Alaskan Way S. with three lanes in each direction. Alaskan Way S. would have one new intersection, with the new east-west cross street at S. Dearborn Street.

The Bored Tunnel Alternative would also reconstruct a portion of the east-west S. King Street and widen the East Frontage Road from S. Atlantic Street to S. Royal Brougham Way to accommodate truck turning movements. Railroad Way S. would be replaced by a new one-lane roadway on which northbound traffic could travel between S. Dearborn Street and Alaskan Way S.

Access from northbound SR 99 and access to southbound SR 99 would be provided via new ramps at Republican Street. The northbound off-ramp to Republican Street would be provided on the east side of SR 99 and routed to an intersection at Dexter Avenue N. Drivers would access the southbound on-ramp via a new connection with Sixth Avenue N. on the west side of SR 99.

Surface streets in the north portal area would be reconfigured and improved. The street grid between Denny Way and Harrison Street would be connected by restoring a section of Aurora Avenue just north of the existing Battery Street Tunnel portal. John, Thomas, and Harrison Streets would be connected as cross streets.

1.2.2 Cut-and-Cover Tunnel Alternative Overview

Under the Cut-and-Cover Tunnel Alternative, a six-lane stacked tunnel would replace the existing viaduct between S. Dearborn Street and Pine Street. At Pine Street, SR 99 would transition out of the tunnel near the Pike Street Hillclimb and cross over the BNSF Railway tracks on a side-by-side aerial roadway. Near Lenora Street, SR 99 would transition to a retained cut extending up to the Battery Street Tunnel portal. SR 99 would travel under Elliott and Western Avenues. The southbound on-ramp from Elliott Avenue and the northbound on-ramp at Western Avenue would be rebuilt. The northbound on-ramp from Bell Street and the southbound off-ramp at Battery Street and Western Avenue would be closed and used for maintenance and emergency access only.

The Battery Street Tunnel would be retrofitted for improved seismic safety. The existing tunnel safety systems would be updated. Improvements would include widening of the south portal, a new fire suppression system, updated ventilation, and new emergency egress structures near Second, Fourth, and Sixth Avenues.

From the north portal of the Battery Street Tunnel, SR 99 would be lowered in a retained cut to about Mercer Street, with improvements and widening north to Aloha Street. Broad Street would be closed between Fifth and Ninth Avenues N., allowing the street grid to be connected. Mercer Street would continue to cross under SR 99 as it does today. However, it would be widened and converted from a one-way to a two-way street, with three lanes in each direction and a center turn lane.

Access to and from SR 99 would be provided at Denny Way and Roy Street. In the northbound direction, drivers could exit at Republican Street.

The Cut-and-Cover Tunnel Alternative would replace the existing seawall with the west wall of the tunnel. Alaskan Way would be rebuilt with this alternative.

1.2.3 Elevated Structure Alternative Overview

The Elevated Structure Alternative would replace the existing viaduct mostly within the existing right-of-way. The Elevated Structure Alternative would replace the seawall between S. Jackson and Broad Streets.

In the central section of Seattle's downtown, the Elevated Structure Alternative would replace the existing viaduct with a stacked aerial structure along the central waterfront. The SR 99 roadway would have three lanes in each direction and wider lanes and shoulders than the existing viaduct.

The existing ramps at Columbia and Seneca Streets would be rebuilt and connected to a new drop lane. This extra lane would improve safety for drivers accessing downtown Seattle on the midtown ramps.

The existing SR 99 roadway would be retrofitted, starting between Virginia and Lenora Streets up to the Battery Street Tunnel's south portal. SR 99 would travel over Elliott and Western Avenues to connect to the Battery Street Tunnel. This aerial structure would transition to two lanes as it enters the Battery Street Tunnel by dropping a northbound lane to Western Avenue. The Battery Street Tunnel would be upgraded with new safety improvements, which include a fire suppression system, seismic retrofitting, and access and egress structures. The vertical clearance would be increased to about 16.5 feet throughout the length of the tunnel.

However, unlike the Battery Street Tunnel improvements with the Cut-and-Cover Tunnel Alternative, the roadway at the south portal would not be widened.

The Elliott and Western Avenue ramps would be rebuilt, and the existing southbound off-ramp at Battery Street and Western Avenue and the northbound on-ramp from Bell Street would be closed and used for maintenance and emergency access only. The southbound on-ramp from Elliott Avenue and the northbound on-ramp at Western Avenue would be rebuilt.

The Alaskan Way surface street would be rebuilt as part of the Elevated Structure Alternative. The southbound lanes would be built in a similar location as the existing roadway, and the northbound lanes would be constructed underneath the viaduct.

At the north portal of the Battery Street Tunnel, Aurora Avenue would be modified from Denny Way to Aloha Street. Aurora Avenue would be lowered in a side-by-side retained cut roadway from the north portal of the Battery Street Tunnel to about Mercer Street and would be at-grade between Mercer and Aloha Streets. Ramps to and from Denny Way would provide access to and from SR 99 similar to today. The street grid would be connected over Aurora Avenue at Thomas and Harrison Streets. Mercer Street would be widened and converted to a two-way street with three lanes in each direction and a center turn lane. It would continue to cross under Aurora Avenue as it does today.

1.3 Summary

The project area is located within the urban core of Seattle. Environmental noise levels from transportation and other sources are typical of an urban environment, and there is a high density of noise-sensitive locations (receptors) in the project vicinity. This report evaluates the noise levels under existing conditions, the 2030 Viaduct Closed (No Build Alternative), and three build alternatives to replace the existing viaduct, each of which is discussed with and without tolls.

The analysis of noise effects in the study area compares predicted (year 2030) noise levels with existing levels (year 2015) and applicable criteria. The effects of construction noise were evaluated on the basis of anticipated construction activities and typical noise levels for construction equipment. Traffic noise levels are predicted at specified receptors using the FHWA Traffic Noise Model (TNM).

Environmental noise is composed of many frequencies, each occurring simultaneously at its own sound pressure level. A common descriptor for environmental noise is the equivalent sound level (L_{eq}), a sound-energy average reported in A-weighted decibels (dBA) to account for how the human ear responds to sound frequencies. To the human ear, a 5-dBA change in noise is readily noticeable. A 10-dBA decrease would sound as if the noise level had been reduced by 50 percent. Section 3.1 of this report describes how the human ear perceives changes in sound levels.

Traffic noise impacts occur when traffic noise levels are within 1 dBA of or exceed the FHWA noise abatement criteria or substantially increase compared to existing levels. Noise from other sources, including construction equipment, is regulated by the City of Seattle (City) property line noise limits as defined in the Seattle Noise Ordinance (Seattle Municipal Code, Section 25.08 [SMC 25.08]).

1.3.1 Operational and Construction Effects

To evaluate traffic noise impacts, 70 sites, representing approximately 4,927 residential units and other noise-sensitive uses, were modeled using TNM. Under existing conditions, traffic noise levels at 54 of the 70 modeled sites approach or exceed the FHWA noise abatement criteria. Noise effects on sensitive receptors were evaluated for the south, central, and north areas of the Bored Tunnel Alternative (preferred), the Cut-and-Cover Tunnel Alternative, and the Elevated Structure Alternative (Exhibit 1-2). A Viaduct Closed (No Build Alternative) considers the Alaskan Way Viaduct being closed in place. Mitigation measures for limiting noise and vibration effects from construction and long-term operation of the facility were also evaluated for all three build alternatives.

Under the non-tolled Bored Tunnel Alternative, expected 2030 peak traffic noise levels near Alaskan Way along the central waterfront would be noticeably lower than those under existing conditions. For example, under 2015 existing conditions, Waterfront Park (receptor 29) would be subjected to a peak traffic noise level of 71 dBA, whereas under the non-tolled Bored Tunnel Alternative, it would be subjected to a peak traffic noise level of 66 dBA. Peak traffic noise levels in the south area would be lower after the elimination of traffic noise from the viaduct. The peak noise levels in the north area would be similar to existing conditions.

Under the non-tolled Cut-and-Cover Tunnel Alternative, expected 2030 peak traffic noise levels along the central waterfront would be noticeably lower than those under the existing conditions. For example, under existing conditions, Waterfront Park is subjected to a peak traffic noise level of 71 dBA, whereas under the non-tolled Cut-and-Cover Tunnel Alternative, it would be subjected to a peak traffic noise level of 65 dBA. Peak traffic noise levels near the viaduct and Alaskan Way in the south area would be noticeably lower than existing conditions. In the north area, peak traffic noise levels would be similar to existing conditions.

Under the non-tolled Elevated Structure Alternative, 2030 peak traffic noise levels along the central waterfront are expected to be similar to existing conditions. For example, Waterfront Park is subjected to a peak traffic noise level of 71 dBA, whereas under the non-tolled Elevated Structure Alternative, it would be subjected to a peak traffic noise level of 71 dBA. Peak traffic noise levels in the south and north areas would be similar to existing conditions.

Exhibit 1-2. Summary of Noise Effects and Mitigation

Alternative	Construction Effects	Operational Effects at Noise-Sensitive Receptors	Mitigation Measures
Existing conditions	None	Traffic noise levels are predicted to approach or exceed the FHWA noise abatement criteria at 53 of the 70 modeled sites, representing approximately 4,578 residential units, 1,612 hotel rooms, 120 shelter beds, 1 church, 1 school, 12 parks or public spaces, and 8 commercial use areas.	None
2030 Viaduct Closed (No Build Alternative)	None	Traffic noise levels in the south area would be somewhat lower than existing conditions. Noise levels along the central waterfront would be noticeably lower than existing conditions, whereas noise levels in the north area would be similar to existing conditions. Year 2030 conditions are predicted to approach or exceed the FHWA noise abatement criteria at 36 of the 70 modeled sites, representing approximately 2,830 residential units, 1,444 hotel rooms, 120 shelter beds, 1 church, 1 school, 8 parks or public spaces, and 3 commercial use areas.	None

Exhibit 1-2. Summary of Noise Effects and Mitigation (continued)

Alternative	Construction Effects	Operational Effects at Noise-Sensitive Receptors	Mitigation Measures
2030 non-tolled Bored Tunnel	During the 65-month construction period, noise would be bothersome to nearby residents and businesses.	Traffic noise levels in the south area would be somewhat lower than existing conditions. Noise levels along the central waterfront would be noticeably lower than existing conditions, whereas noise levels in the north area would be similar to existing conditions. Year 2030 conditions are predicted to approach or exceed the FHWA noise abatement criteria at 40 of the 70 modeled sites, representing approximately 3,705 residential units, 1,286 hotel rooms, 120 shelter beds, 1 church, 1 school, 10 parks or public spaces, and 4 commercial use areas.	A construction noise control program would be implemented to reduce construction noise effects. No mitigation measures for operational effects were found to be feasible and reasonable.
2030 non-tolled Cut-and-Cover Tunnel	During the 105-month construction period, noise would be bothersome to nearby residents and businesses.	Traffic noise levels in the south area would be somewhat lower than existing conditions. Noise levels along the central waterfront would be noticeably lower than existing conditions, whereas noise levels in the north area would be similar to existing conditions. Year 2030 conditions are predicted to approach or exceed the FHWA noise abatement criteria at 40 of the 70 modeled sites, representing approximately 3,541 residential units, 1,257 hotel rooms, 120 shelter beds, 1 church, 1 school, 9 parks or public spaces, and 4 commercial use areas.	A construction noise control program would be implemented to reduce construction noise effects. No mitigation measures for operational effects were found to be feasible and reasonable.
2030 non-tolled Elevated Structure	During the 120-month construction period, noise would be bothersome to nearby residents and businesses.	Traffic noise levels in the south area, central area, and north area would be similar to existing conditions. Year 2030 conditions are predicted to approach or exceed the FHWA noise abatement criteria at 57 of the 70 modeled sites, representing approximately 4,730 residential units, 1,715 hotel rooms, 120 shelter beds, 1 church, 1 school, 13 parks or public spaces, and 8 commercial use areas.	A construction noise control program would be implemented to reduce construction noise effects. No mitigation measures for operational effects were found to be feasible and reasonable.

Note: FHWA = Federal Highway Administration

Vibration is an oscillatory motion that can be described in terms of displacement, velocity, or acceleration. Its effects relate to annoyance and the potential for structural damage. No annoyance effects would occur inside buildings during operation.

The construction activities that would result in the highest levels of ground vibration are the demolition of the existing viaduct and impact pile driving. During viaduct demolition, buildings closer than 100 feet would be subjected to vibration levels in excess of the damage risk criterion for extremely fragile buildings. The risk criterion for newer buildings would not be exceeded at 25 feet. During impact pile driving, buildings closer than 25 feet would be subjected to vibration levels in excess of the damage risk criteria for extremely fragile buildings and newer buildings, depending on the size of the pile driver and the force exerted by it. At distances of 400 feet or greater, impact pile driving is not expected to result in vibration levels that exceed the damage risk criteria for any building. No damage would occur at the seawall.

Noise for certain types of construction activities, such as those that would occur in the south and north areas, is expected to exceed City noise regulations. Exceedances are expected to occur at night and would require a noise variance from the City. A construction noise control program would be implemented to reduce construction noise effects.

1.3.2 Tolling

Under the tolled Bored Tunnel Alternative, expected 2030 peak traffic noise levels along the central waterfront would be similar to those for the non-tolled Bored Tunnel Alternative. Under the tolled Bored Tunnel Alternative, the noise levels would be noticeably lower than existing conditions. For example, under the tolled Bored Tunnel Alternative, Waterfront Park would be subjected to a peak traffic noise level of 66 dBA; under the non-tolled Bored Tunnel Alternative, the peak traffic noise level would be 66 dBA. Under existing conditions, the peak traffic noise level is 71 dBA. Peak traffic noise levels near the south and north areas would be similar to existing conditions. In most locations, traffic noise level changes are predicted to be between a 1-dBA decrease and a 1-dBA increase compared to the non-tolled Bored Tunnel Alternative because of minor changes in traffic patterns compared to existing conditions. A 2-dBA change in noise levels is the smallest change that can be heard by sensitive listeners. In the north area, at receptors 64 and 65, noise levels are predicted to decrease by 2 to 5 dBA because of changes in traffic patterns.

Under the tolled Cut-and-Cover Tunnel Alternative, expected 2030 peak traffic noise levels along the central waterfront would be similar to those for the non-tolled Cut-and-Cover Tunnel Alternative. For example, under the tolled Cut-and-Cover Tunnel Alternative, Waterfront Park would be subjected to a peak traffic noise level of 66 dBA; under the non-tolled Cut-and-Cover Tunnel Alternative, the peak traffic noise level would be 65 dBA. Peak traffic noise levels in the south and north areas would be similar to existing conditions with and without tolling.

Under the tolled Elevated Structure Alternative, expected 2030 peak traffic noise levels along the central waterfront would be similar than those for the non-tolled Elevated Structure Alternative. For example, under the tolled Elevated Structure Alternative, Waterfront Park would be subjected to a peak traffic noise level of 70 dBA; under the non-tolled Elevated Structure Alternative, the peak traffic noise level would be 71 dBA. Peak traffic noise levels in the south and north areas would be similar to existing conditions with and without tolling.

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Chapter 2 METHODOLOGY

2.1 Study Area

The study area for noise and vibration includes areas likely to be affected by changes in traffic or mechanical ventilation noise and areas likely to be affected by construction noise or vibration. As shown in Exhibit 2-1, the study area extends approximately two blocks on either side (east-west) of SR 99 from the area near S. Atlantic Street to Aloha Street.

Land uses in the area range from low-rise light industrial buildings to high-rise office towers. Portions of the study area include residential zoning, such as Belltown and the area west of the Alaskan Way Viaduct along Alaskan Way. Noise-sensitive uses include residences, hotels, motels, parks, social services, educational facilities, and public spaces. There are residential or hotel uses near both the south and north areas of the existing Battery Street Tunnel. Residential uses are also located near Roy Street at the north end of the project area. Several old, vibration-sensitive structures are adjacent to the existing Alaskan Way Viaduct.

A detailed description of the land uses within the study area is provided in Appendix G, Land Use Discipline Report.

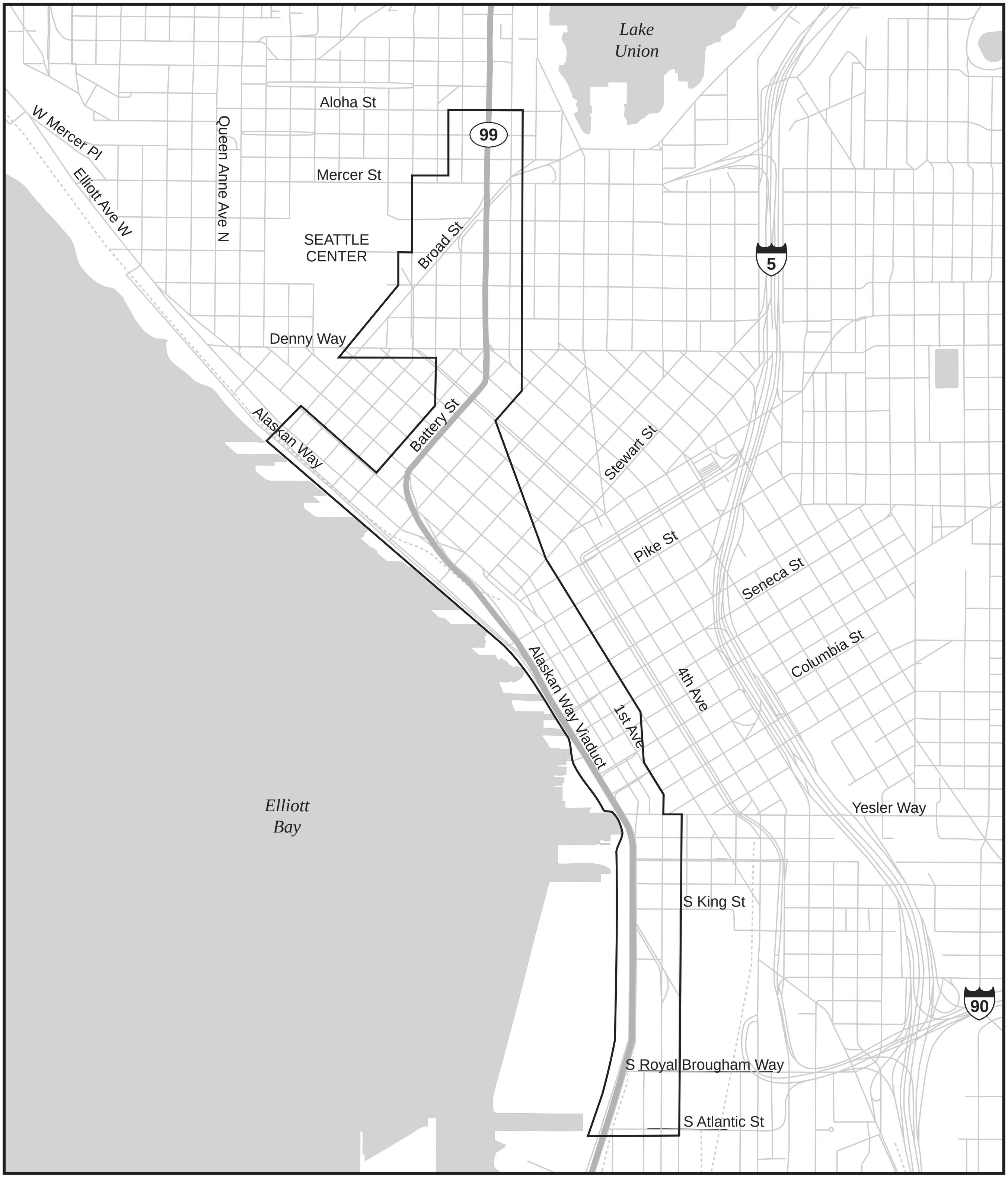
2.2 Data Needs and Sources

2.2.1 Traffic Data

To determine the operational effects of the project, data from the project's traffic analysis were used as input for the noise analysis, including afternoon (PM) peak-hour volume estimates, travel speed estimates, and vehicle mix. For modeling purposes and documentation of the affected environment, the project team used the year 2015 to represent the existing conditions in terms of traffic (see Chapter 4 of Appendix C, Transportation Discipline Report). The operational effects of the build alternatives on traffic are described in Appendix C, Transportation Discipline Report.

2.2.2 Construction Data

The project's design team provided information about the construction methods, including the types of equipment and work durations for each build alternative.



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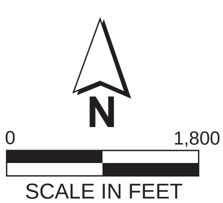

Study Area

Exhibit 2-1
Noise Study Area

2.3 Studies and Coordination

The methods for analyzing noise and vibration were developed for the Program in coordination with the Washington State Department of Transportation (WSDOT), the City, King County, and FHWA. In April 2002, an approach for the noise and vibration analysis was distributed to these agencies for review and comment, and the methodology approach was presented to acoustic staff from WSDOT, the City, and King County for comment and discussion. Input from these agencies was incorporated into the approach used in this study. In March 2009, an updated methodology approach for the noise and vibration analysis was reviewed by WSDOT and City staff. Input from these agencies was incorporated into the study.

2.4 Methods to Assess Existing Conditions

2.4.1 Noise

Ambient noise levels in the project area were measured to describe the existing noise environment, identify major noise sources, and validate TNM. Noise measurements taken as part of past Program efforts (2002 to 2010) are included in the baseline noise measurements (Exhibit 2-2). Ambient noise levels were measured at several locations near the project area to characterize weekday noise levels (USDOT 1996). At most locations, one or more 15-minute measurements were taken with an LD 820 or BK 2231 noise meter to estimate the hourly equivalent sound level, or L_{eq}(h), at various times of day. Fifteen-minute noise measurements were taken at ground level.

FHWA’s TNM Version 2.5 computer model (the most recent version of TNM) (USDOT 2004a, 2004b) was used to predict L_{eq} (h) traffic noise levels. TNM is used to obtain precise noise level estimates at discrete points by considering interactions between different noise sources and the effects of topographical features on the noise propagation. The model estimates the acoustic intensity at a receiver location, calculated from a series of straight-line roadway segments (USDOT 1998). Noise emissions from free-flowing traffic depend on the number of automobiles, medium trucks, and heavy trucks per hour; vehicle speed; and reference noise emission levels of an individual vehicle. TNM also considers the effects of intervening barriers, topography, trees, and atmospheric absorption.

DXF-format computer design files were exported from MicroStation and imported into TNM with major roadways, topographical features, building rows, and sensitive receptors digitized into the model. Elevations were added from the topographic contour data. Elevations for planned improvements were obtained from design profiles. The area covered by the noise model extended approximately two blocks on either side of the existing Alaskan Way Viaduct

Exhibit 2-2. Noise Measurement and TNM Validation Model

Site	Location	Date	Time	Measured L_{eq} (dBA)	Modeled L_{eq} (dBA)
1	Pyramid Brewery	February 7, 2008	12:00 p.m.	69	68
2	Safeco Field sidewalk	February 17,2010	10:10 a.m.	70	69
3	Silver Cloud 10th floor pool	July 7, 2009	1:45 p.m.	74	73
4	Mixed-use building at 1000 First Avenue	July 7, 2009	10:45 a.m.	75	74
5	Triangle sidewalk	February 17, 2010	3:00 p.m.	74	74
6	Palm Court sidewalk	February 17, 2010	2:40 p.m.	71	73
7	Florentine Apartments	September 22, 2010	10:35 a.m.	72	71
8	First Avenue S. and S. King Street	February 18, 2010	11:15 a.m.	73	73
9	Alaskan Way S. and S. Jackson Street	February 18, 2010	11:40 a.m.	75	74
10	300 block of Occidental Avenue	July 31, 2002	1:30 p.m.	63	63
11	First Avenue S. and S. Main Street	September 22, 2010	11:05 a.m.	70	71
12	Occidental Park	July 7, 2009	11:10 a.m.	63	64
13	Washington Street Boat Landing	July 7, 2009	11:50 a.m.	76	74
14	Pioneer Square Hotel street level	July 2, 2009	2:35 p.m.	69	71
15	Pier 50	August 13, 2009	12:25 p.m.	76	75
16	Pioneer Square south side	August 6, 2003	11:30 a.m.	68	68
17	Pioneer Square north side	July 9, 2009	2:10 p.m.	70	69
18	Colman Dock	September 22, 2010	11:55 a.m.	76	75
19	Marion Street pedestrian bridge	September 22, 2010	11:55 a.m.	77	79
20	Spring Street and Alaskan Way	September 22, 2010	2:15 p.m.	77	79

Exhibit 2-2. Noise Measurement and TNM Validation Model (continued)

Site	Location	Date	Time	Measured L_{eq} (dBA)	Modeled L_{eq} (dBA)
21	Western Avenue and Spring Street	September 22, 2010	2:15 p.m.	74	72
22	Spring Street and Post Avenue	September 22, 2010	2:35 p.m.	70	70
23	Elliott's Oyster House	September 22, 2010	12:40 p.m.	72	71
24	Alaskan Way bicycle path at Seneca Street	September 22, 2010	12:40 p.m.	77	76
25	Spring Street and First Avenue	August 13, 2009	12:00 p.m.	73	71
26	Harbor Steps SW Tower (ninth floor)	May 16, 2002	11:50 a.m.	74	73
27	Waterfront Park boardwalk	September 22, 2010	3:00 p.m.	73	71
28	Harbor Steps (plaza level)	June 25, 2009	2:10 p.m.	69	71
29	Waterfront Park	June 25, 2009	1:05 p.m.	72	72
30	Hill Climb Court	September 3, 2010	11:15 a.m.	75	75
31	Pier at Pine Street	July 9, 2009	10:40 a.m.	63	65
32	Waterfront Landing (ground level)	September 28, 2010	10:05 a.m.	75	73
33	Waterfront Landing Condominiums roof	May 22, 2002	10:45 p.m.	80	79
34	Victor Steinbrueck Park (bench area)	September 22, 2010	11:00 a.m.	80	80
35	Elliott Point Apartments Roof	May 29, 2002	10:45 a.m.	78	79
36	Belltown Loft (ground level)	September 22, 2010	4:55 p.m.	68	68
37	Elliott Point (ground level)	September 22, 2010	4:55 p.m.	76	75
38	Belltown Loft Condominiums roof	June 2, 2002	9:00 a.m.	74	75
39	Site 17 (ground level)	August 7, 2003	9:45 a.m.	74	72
40	Site 17 Apartments (ground level)	May 20, 2002	3:00 p.m.	70	70
41	Port of Seattle terrace	July 19, 2002	3:00 p.m.	65	63

Exhibit 2-2. Noise Measurement and TNM Validation Model (continued)

Site	Location	Date	Time	Measured L_{eq} (dBA)	Modeled L_{eq} (dBA)
42	Port of Seattle (ground level)	September 23, 2010	12:15 p.m.	70	68
43	Western Avenue and Cedar Street	September 23, 2010	12:15 p.m.	71	69
44	Fountain Court Apartments	September 23, 2010	11:45 a.m.	72	70
45	Avalon Belltown Apartments	July 17, 2002	3:00 p.m.	68	67
46	Avalon Belltown (ground level)	September 23, 2010	11:20 a.m.	70	68
47	Café Two (street level patio)	September 23, 2010	9:30 a.m.	67	67
48	Tilikum Place Park	June 23, 2009	4:00 p.m.	66	64
49	Pacific Science Center	September 23, 2010	11:00 a.m.	68	67
50	Fisher Plaza	August 27, 2009	3:30 p.m.	67	65
51	Taylor 28	June 25, 2009	11:50 a.m.	58	57
52	Marselle Condominiums sidewalk	August 27, 2009	2:10 p.m.	76	77
53	Parking lot at SR 99 and John Street	August 27, 2009	2:35 p.m.	75	77
54	Denny Park	July 9, 2009	1:30 p.m.	59	59
55	Taylor 28 sidewalk at Sixth Avenue N. and John Street	February 18, 2010	2:10 p.m.	63	64
56	McDonald's sidewalk	August 27, 2009	3:55 p.m.	69	68
57	Quality Inn parking lot	August 27, 2009	1:45 p.m.	76	76
58	Seattle Inn (terrace)	July 9, 2002	4:00 p.m.	78	76
59	Holiday Inn ground level	September 23, 2010	9:55 a.m.	76	75
60	Executive Inn sidewalk	February 18, 2010	2:35 p.m.	64	64
61	Experience Music Project sidewalk	August 27, 2009	4:30 p.m.	69	67
62	Seattle Pacific Hotel north parking lot	March 4, 2010	12:35 p.m.	72	72
63	Sixth Avenue N. and Harrison Street sidewalk	March 4, 2010	1:05 p.m.	68	68

Exhibit 2-2. Noise Measurement and TNM Validation Model (continued)

Site	Location	Date	Time	Measured L_{eq} (dBA)	Modeled L_{eq} (dBA)
64	Broad Street and Aurora Avenue	March 4, 2010	1:40 p.m.	76	75
65	Future Bill and Melinda Gates Foundation Campus[1]	--	--	--	63
66	Comfort Suites Hotel patio	September 23, 2010	10:25 a.m.	63	63
67	Queen Anne Community School south parking lot	March 4, 2010	2:25 p.m.	65	65
68	Lumen Condominiums sidewalk	March 4, 2010	2:55 p.m.	64	64
69	Fulcrum Technologies (outdoor deck)	September 28, 2010	10:35 a.m.	75	74
70	Horizon Church and Residences on Valley Street	September 28, 2010	10:55 a.m.	72	72

Notes: dBA = A-weighted decibel
L_{eq} = equivalent sound level
1. No measurement was taken at the future Bill and Melinda Gates Foundation Campus. The campus is currently under construction. This site was modeled only at an anticipated outdoor area near the center of the campus.

structure (which would predict the noise emissions from the elevated structure), and at the surface street level, above the bored tunnel or cut-and-cover tunnel alignments from near S. Atlantic Street to Aloha Street.

Noise from sources other than traffic is not included in TNM; therefore, it underpredicts actual noise levels when noise from other sources, such as aircraft, is significant in an area. Comparison of measured noise levels to the modeled results demonstrated several important aspects of the sound environment near the Alaskan Way Viaduct. The most important aspects are the following:

- If unadjusted, TNM underpredicts traffic noise from the existing Alaskan Way Viaduct because it does not inherently include the effects of reflected traffic noise from the upper deck of the viaduct.
- Traffic noise is only one aspect of the urban noise environment in downtown Seattle. TNM underpredicts the total sound level in the audible environment.

WSDOT has recognized previously that reflected noise from double-level structures is neglected in noise modeling software (WSDOT 1992). To quantify the effects of noise reflections from the Alaskan Way Viaduct, noise measurements were used to quantify the reflected traffic noise. The measurements were then used to calibrate the model with existing conditions by adding a virtual noise source to represent the reflected noise. WSDOT has previously used this approach to evaluate noise from the viaduct and the Interstate 5 (I-5) Ship Canal Bridge (WSDOT 2005).

The noise measurement locations represent a variety of noise conditions and are typical of other sensitive receptors near the project area. TNM was used to predict L_{eq} (h) traffic noise levels using the traffic data observed during the collection of noise measurements. These modeled noise levels were then compared to the measured noise levels to validate the noise model. The model was considered valid when the difference between the measured and the modeled noise levels was 2 dBA or less (USDOT 1998).

Because TNM neglects all of the noise that is reflected off the bottom of the upper deck and transmitted through the viaduct structure, virtual traffic lanes 1 foot wide were placed at both edges of the upper deck of the Alaskan Way Viaduct. The traffic volumes modeled for the southbound direction were divided by two and split between the two virtual lanes. Within TNM, this approach simulated noise generated by the southbound traffic reflecting off the upper deck and propagating out in both directions from the structure. Once these virtual roadways were applied to the model, additional adjustment factors of 2 to 4 dBA were needed to validate noise level receivers 33, 34, 35, and 37, and adjustment factors of 3 to 6 dBA were needed for receivers 15, 18, and 32 because the difference between the modeled and the measured levels was more than 2 dBA. With the virtual roadways and the adjustment factors, the model produced by TNM was considered valid because the results for existing noise receptors were within 2 dBA of the measured values (Exhibit 2-2).

Noise measurements were taken at receptors 20, 27, 28, 32, and 34 when the Alaskan Way Viaduct was closed to traffic (Exhibit 2-3). A comparison of these measurements shows that the average noise levels near the viaduct are more than 10 dBA greater when the viaduct is open than when it is closed. This is similar to WSDOT's 1992 findings that traffic noise levels were between 6 and 9 dBA greater with the entire viaduct open than with only the northbound lanes open (WSDOT 1992).

Once the model produced by TNM was validated, TNM was used to model the loudest traffic noise hour of the day for 2015 existing conditions. The loudest traffic noise period occurs when traffic volumes are high, but lower than the traffic volume that would cause enough traffic congestion to reduce average speed substantially below the speed limit. The analysis started with the PM peak-hour traffic volumes; where the volumes exceeded roadway capacity, they were adjusted downward to maintain traffic speed. For this study, modeled traffic volumes were provided by the transportation team. The results of the TNM existing conditions model are presented in Section 4.2 of this report.

Exhibit 2-3. Noise Measurement Results With Viaduct Open and Closed

Site	Location	Date	Status	Measured L_{eq} (dBA)	Modeled L_{eq} (dBA)
20	Spring Street and Alaskan Way	March 23, 2002	Closed	71	69
		September 3, 2003	Open	78	79
27	Waterfront Park boardwalk	March 23, 2002	Closed	60	60
		March 22, 2003	Closed	59	60
		March 25, 2003	Open	72	71
28	Harbor Steps	March 23, 2002	Closed	66	65
		May 16, 2002	Open	72	71
32	Waterfront Landing Condominiums	March 23, 2002	Closed	62	60
		May 16, 2002	Open	75	73
34	Victor Steinbrueck Park (at railing that overlooks viaduct)	March 23, 2002	Closed	62	61
		July 31, 2002	Open	81	80

Notes: dBA = A-weighted decibels
Leq = equivalent sound level

Traffic noise is only one aspect of the complex, urban acoustic environment. Noise measurement results were greater than modeled traffic noise levels at many locations within the study area because of various other noise sources, including pedestrian street activity, aircraft, sirens, business and commercial noise, and equipment noise from nearby buildings. Building walls also produced sound reflections in some parts of the study area. Because of these additional noise sources, the measured sound levels averaged 1 or 2 dBA greater than the modeled traffic noise levels.

A building survey was conducted within two blocks of proposed long-term improvements to determine the number of noise-sensitive receptors in the study area. The type of use, number of building floors, presence of balconies or opening windows, and number of residential units or other sensitive uses in the buildings were collected for any buildings that housed sensitive uses (Activity Categories B and E). These data were used to estimate the number of sensitive receptors represented by each modeled noise receptor and are included in Chapter 4, Affected Environment.

2.4.2 Vibration

Vibration measurements taken in 2002 as part of the 2004 Draft EIS (WSDOT et al. 2004) and in 2009 as part of the 2010 Supplemental Draft EIS (WSDOT et al. 2010) were included in the baseline vibration measurements. Vibration measurements were taken in locations at or near the proposed bored tunnel alignment, such as at unrestored areaways in the Pioneer Square area, in spaces beneath the sidewalks of older buildings, and at historic buildings, to determine the level of exposure from bus and truck movements on nearby streets.

Vibration levels were measured at locations near the proposed roadway alignment using the following equipment:

- Larson Davis Model 2900 1/3 Octave Band Real Time Analyzer
- PCB Model 393A03 ICP Accelerometer
- Rion Model ST-78 FFT Analyzer
- Dytran 3056B2 IEPE Accelerometer
- PCB Model 699A02 Hand Held Shaker (Calibrator)

The vibration levels of different heavy trucks passing by were monitored at each of the measurement sites to determine the maximum root mean square (rms) vibration velocity levels generated by these events.

2.5 Methods to Assess Environmental Effects

2.5.1 Noise

FHWA and WSDOT noise abatement criteria were used to assess operational traffic noise impacts. TNM was used to model the loudest traffic noise hour of the day for the Viaduct Closed (No Build Alternative) and the build alternatives in the future design year (2030) using the methods described in Section 2.4.1. The 2030 traffic volumes were provided by the transportation team (see Appendix C, Transportation Discipline Report). No adjustment factors or virtual noise sources were used for the future build and no build noise models.

Construction effects are discussed qualitatively, and the analysis includes information regarding the types and durations of major activities, such as construction of the build alternatives and demolition of the existing viaduct.

City noise level limits were used to establish noise limits for ventilation fans and qualitatively assess the effects of construction noise. Occupational Safety and Health Administration (OSHA) exposure levels were used to establish the in-tunnel noise criterion for this project during emergency and normal operations.

2.5.2 Vibration

The vibration measurements identified in Section 2.4.2 were used as a baseline for evaluating the potential for operational vibration effects. The potential for construction vibration effects was estimated from prior measurements of construction equipment, including any unique characteristics associated with the tunnel boring machine (TBM) (Bored Tunnel Alternative only). The vibration reference data used for this analysis were taken from the available literature and supplemented by measurements collected for other construction projects. The data were used to establish a distance beyond which construction activities would not cause damage to vibration-sensitive structures. A vibration impact criterion that is consistent with Federal Transit Administration (FTA) criteria for buildings and utilities and protective of potentially fragile historic structures was used to assess effects.

2.6 Methods to Determine Mitigation Measures

2.6.1 Noise

A variety of mitigation methods can be effective at reducing operational noise effects. For example, noise effects from the long-term operation of the project could be reduced by implementing traffic management measures, acquiring land as buffer zones or for the construction of noise barriers, realigning the roadway, and installing noise insulation for public use or nonprofit institutional structures. These mitigation measures have been evaluated in accordance with WSDOT and FHWA procedures for their potential to reduce noise effects from the build alternatives. Examples of operational mitigation measures are discussed in Chapter 5, Operational Effects, Mitigation, and Benefits.

To reduce construction noise at nearby receptors, mitigation measures could be incorporated into construction plans, specifications, and variance requirements. Examples of construction mitigation measures are discussed in Chapter 6, Construction Effects and Mitigation.

2.6.2 Vibration

Although FHWA and WSDOT do not have policies that directly address the mitigation of vibration effects, any mitigation recommendations will be consistent with FHWA and WSDOT mitigation policies in terms of feasibility and reasonableness.

Mitigation requirements for construction vibration will be developed in coordination with the City. To reduce vibration at nearby receptors, mitigation measures could be incorporated into construction plans and specifications. Examples of mitigation measures for vibration effects are provided in Chapter 6.

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Chapter 3 STUDIES AND COORDINATION

3.1 Characteristics of Sound

Sound is created when objects vibrate, resulting in a variation in surrounding atmospheric pressure called sound pressure. The human ear's response to sound depends on the magnitude of a sound as a function of its frequency and time pattern (EPA 1974). Magnitude is a measure of the physical sound energy in the air. The human ear detects variations in pressure as small as 20 micropascals (μPa [10^{-6} pascals]). Sound pressure greater than about 100 pascals (Pa) is painfully loud. This range of magnitude, from the faintest to the loudest sound the ear can hear, is so large that sound pressure levels are expressed on a logarithmic scale in units called decibels (dB) that quantify the energy contained in the sound pressure. A sound pressure of 20 μPa is defined as 0 dB (the threshold of hearing for a healthy ear), while a sound pressure of 100 Pa is about 130 dB (the approximate threshold for pain).

Because of the logarithmic dB scale, a doubling of the number of noise sources, such as the number of cars operating on a roadway, increases noise levels by 3 dB. A tenfold increase in the number of noise sources adds 10 dB. As a result, a noise source emitting a noise level of 60 dB combined with another noise source of 60 dB yields a combined noise level of 63 dB, not 120 dB.

Loudness, compared to physical sound measurement, refers to how people subjectively judge a sound. This varies from person to person. The human ear can perceive changes in sound levels better than it can judge the absolute sound level. A 3-dB increase is barely perceptible, while a 5- or 6-dB increase is readily noticeable and sounds as if the noise is about one and one-half times as loud. To most listeners, a 10-dB increase is perceived as a doubling in noise level.

Humans also respond to a sound's frequency or pitch. The human ear can perceive sound frequencies between approximately 20 and 20,000 hertz (Hz, or cycles per second), but it is most effective at perceiving sounds between approximately 1,000 and 5,000 Hz. Environmental sounds are composed of many frequencies, each occurring simultaneously at its own sound pressure level. Frequency weighting, which is applied electronically by a sound level meter, combines the overall sound frequency into one sound level that simulates how an average person hears sounds. The most commonly used frequency weighting for environmental sounds is A-weighting, which is most similar to how humans perceive sounds of low to moderate magnitude. Measures using A-weighting are expressed in dBA.

Sound levels decrease as the distance from the sound source increases. For a line source, such as a roadway, sound levels decrease 3 dBA over hard ground (concrete or pavement) or 4.5 dBA over soft ground (grass) for every doubling of distance between the source and the receptor (individual hearing the noise). For a point source, such as a piece of construction or ventilation equipment, sound levels decrease between 6 and 7.5 dBA for every doubling of distance from the source.

The propagation of sound can be affected greatly by terrain and the elevation of the receiver relative to the sound source. Level ground is the simplest case. Noise travels in a straight line-of-sight path between the source and the receiver. The addition of a berm or other area of high terrain reduces the sound energy arriving at the receiver. Breaking the line of sight between the receiver and the highest sound source results in a sound level reduction of approximately 5 dBA.

If the source is depressed or the receiver is elevated, sound generally travels directly to the receiver. In some situations, sound levels may be reduced because the terrain crests between the source and receiver, resulting in a partial sound barrier. In the case of traffic noise, if the roadway is elevated or the receiver is depressed, noise may be reduced at the receiver because the edge of the roadway can act as a partial noise barrier, blocking some sound transmission between the source and receiver. Exhibit 3-1 shows how the effectiveness of the shielding is a function of the additional length the noise must travel over the barrier compared to a straight path.

Sound may also reflect from buildings and other solid structures. In certain cases when direct sound is blocked by a barrier or other shielding, the reflected sound may be greater than the shielded noise from the traffic source as shown in Exhibit 3-2. This is because the receiver has a line of sight to the reflected surface.

Noise levels from traffic sources depend on volume, vehicle speed, and type of vehicle. In general, an increase in volume, speed, or vehicle size increases the traffic noise level generated by that source. Vehicle noise is a combination of noises from the engine, exhaust, and tires. Other conditions affecting traffic noise include defective mufflers, steep grades, terrain, vegetation, distance from the roadway, and shielding by barriers and buildings.

Exhibit 3-1. Effect of Terrain on Sound Propagation

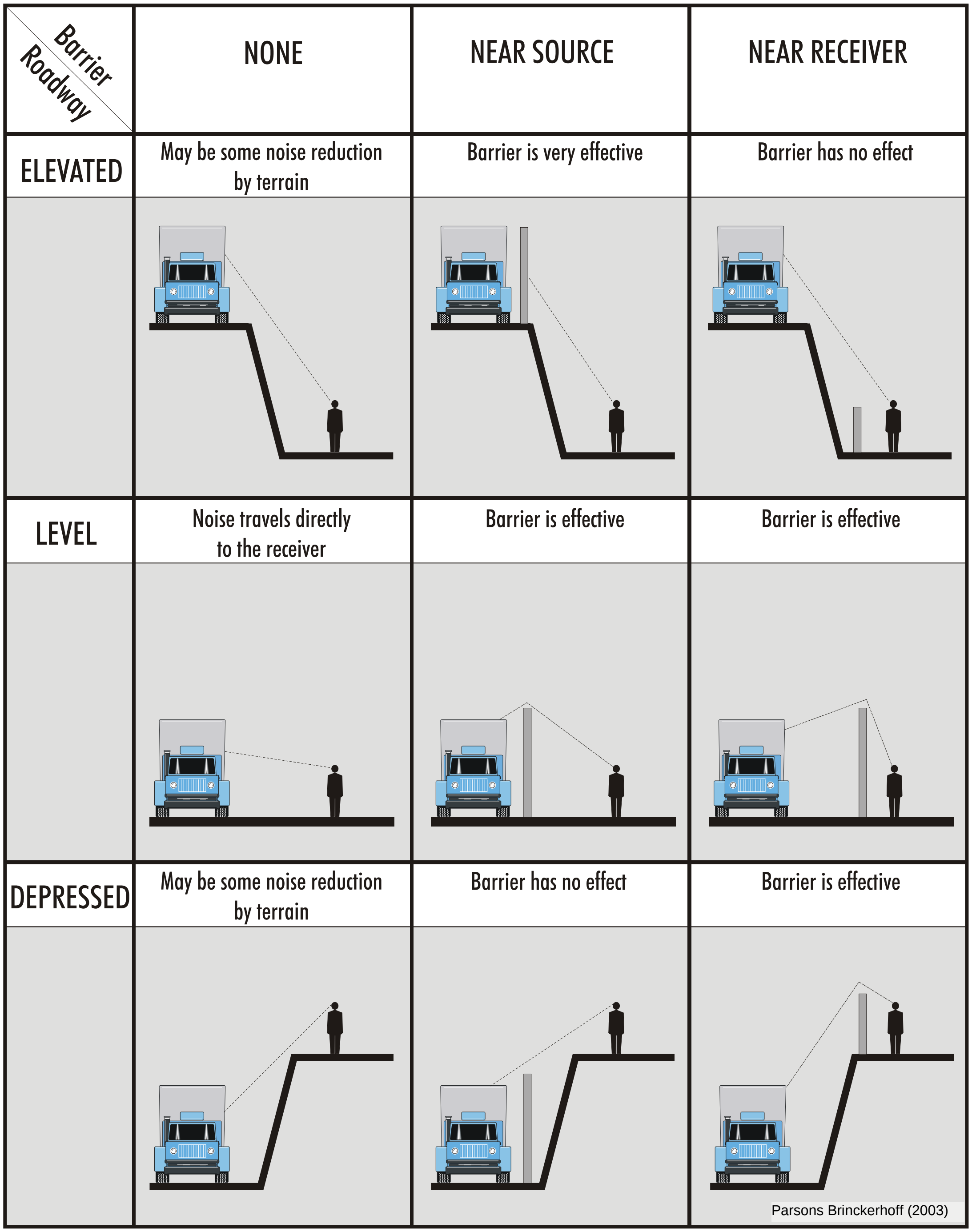
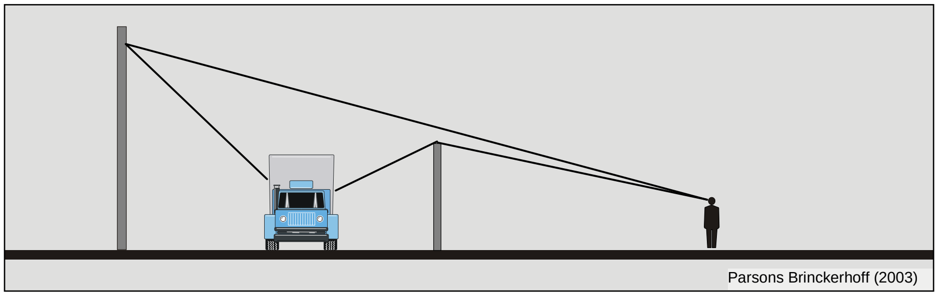


Exhibit 3-2. Effect of Reflected Sound

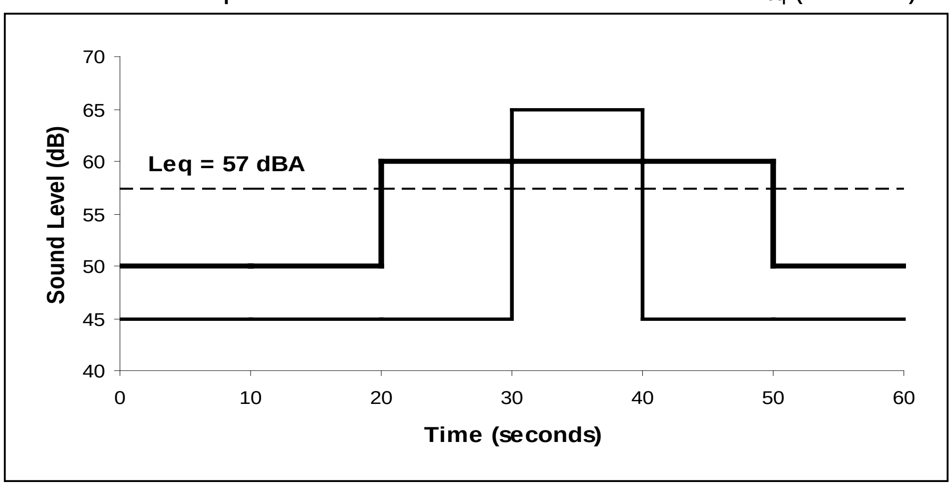


Note: Reflected noise may be greater than the shielded noise.

3.2 Sound Level Descriptors

A widely used descriptor for environmental noise is L_{eq}, which is a measure of the average sound energy during a specified period. L_{eq} is defined as the constant level that, over a given period, transmits the same amount of acoustical energy to the receiver as the actual time-varying sound. Occasional high sound energy levels have more effect on L_{eq} than the general background sound energy level, because the sound level (in dBA) represents sound energy logarithmically. Two sound patterns, one of which has a lower background level but a higher maximum level, can have the same L_{eq}, as shown in Exhibit 3-3.

Exhibit 3-3. Example of Two Sound Patterns With the Same L_{eq} (1 Minute)



Notes: dB = decibels
dBA = A-weighted decibel
Leq = equivalent sound level

L_{eq} is reported for different measurement periods. L_{eq} measured over a 1-hour period is the hourly L_{eq} (L_{eq}[h]), which is often used to analyze highway noise effects and abatement. To analyze traffic noise effects and abatement in residential areas, analysts use a daily averaged noise level that more heavily ranks noise that occurs at night. The day/night level (L_{dn}) adds 10 dBA to noise levels that occur between 10:00 p.m. and 7:00 a.m.

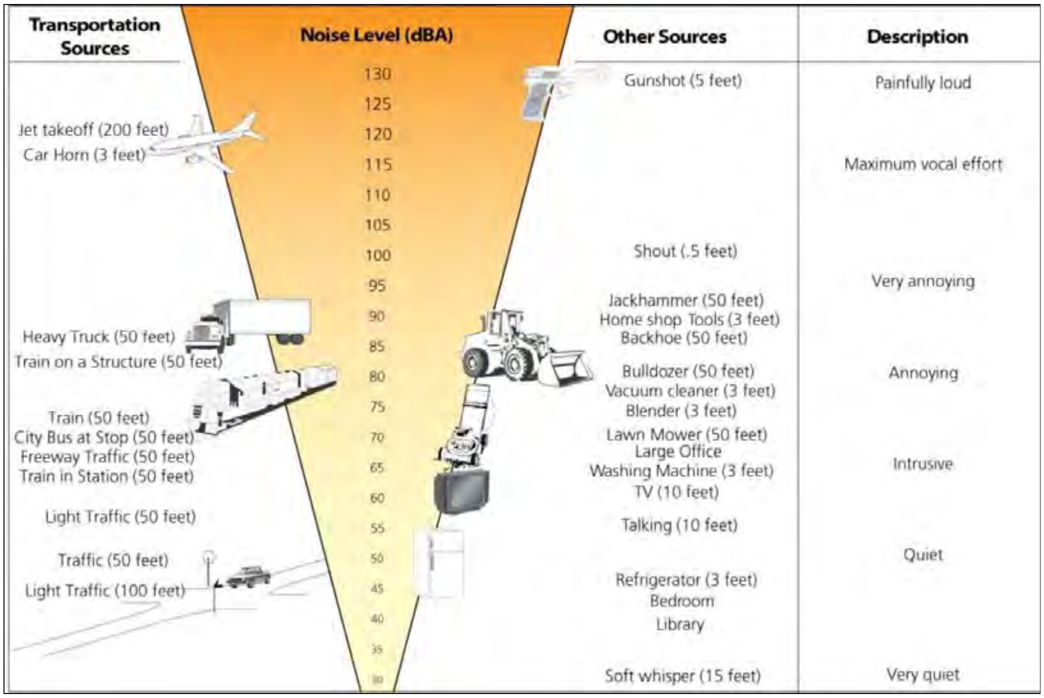
Short-term noise levels, such as those from a single truck passing by, can be described by either the total noise energy or the highest instantaneous noise level that occurs during the event. The sound exposure level is a measure of total sound energy from an event, and it is useful in determining the L_{eq} over a period of time during which several noise events occur. The maximum sound level (L_{max}) is the greatest short-duration sound level that occurs during a single event. L_{max} is related to effects such as speech interference and sleep disruption. By comparison, L_{min} is the minimum sound level during a specific period.

People often find a moderately high, constant sound level easier to tolerate than a quiet background level interrupted by frequent high-level noise intrusions. An individual's response to sound depends on the range in which the sound varies in a given environment. For example, steady traffic noise from a highway is normally less bothersome than occasional aircraft flyovers in a relatively quiet area. In light of this subjective response, it is often useful to look at a statistical distribution of sound levels over a given period in addition to the average sound level. A statistical distribution allows a more thorough description of the range of sound levels during the given measurement period by identifying the sound level exceeded, as well as the percentage of time it was exceeded. These distributions are identified with an L_n where *n* is the percentage of time that the level is exceeded. For example, the L_{10} level is the noise level that is exceeded 10 percent of the time.

3.3 Typical Sound Levels

Typical A-weighted sound levels from various sources are presented in Exhibit 3-4. These sound sources, which range from a quiet whisper or light wind at 30 dBA to a jet takeoff at 120 dBA, demonstrate the great range of the human ear. A typical conversation is in the range of 60 to 70 dBA. Typical outdoor sound levels are shown in Exhibit 3-5.

Exhibit 3-4. Typical Sound Levels



Sources: USDOT 1995; EPA 1971, 1974.
Note: dBA = A-weighted decibel

Exhibit 3-5. Typical Outdoor Sound Levels in Various Environments

Qualitative Description	L_{dn} (dBA)
City noise (downtown major metropolis)	85 80 75
Very noisy urban	70
Noisy urban	65
Urban	60
Suburban	55
Small town and quiet suburban	50 45 40

Source: EPA 1974.
Notes: dBA = A-weighted decibel, L_{dn} = day/night sound level

3.4 Effects of Noise

Environmental noise at high intensities directly affects human health by causing hearing loss. Although scientific evidence currently is not conclusive, noise is suspected of causing or aggravating other diseases. Environmental noise indirectly affects human welfare by interfering with sleep, thought, and conversation. The

FHWA noise abatement criteria are based on speech interference, a well-documented effect that is relatively reproducible in human response studies.

3.5 Noise Regulations and Impact Criteria

3.5.1 Traffic Noise Criteria

Applicable noise regulations and guidelines provide a basis for evaluating potential noise effects. For federally funded highway projects, traffic noise impacts occur when predicted L_{eq} (h) noise levels approach or exceed FHWA's established noise abatement criteria or substantially exceed the existing noise levels (USDOT 1982; Noise Abatement Council). WSDOT noise policy adopts the FHWA criteria (WSDOT 2006). Although "substantially exceed" is not defined in the FHWA criteria, WSDOT's noise policy defines an increase of 10 dBA or more as a substantial increase.

The FHWA noise abatement criteria specify exterior L_{eq} (h) noise levels for various land activity categories (Exhibit 3-6). The noise criterion is 57 dBA for receptors where serenity and quiet are of extraordinary significance (Category A). The noise criteria are 67 dBA for residences, parks, schools, churches, and similar areas (Category B) and 72 dBA for developed lands (Category C). WSDOT considers a noise impact to occur if predicted L_{eq} (h) noise levels approach within 1 dBA of the noise abatement criteria shown in Exhibit 3-6. For example, a noise level of 66 dBA (or greater) would approach (or exceed) the FHWA noise abatement criterion of 67 dBA for residences and, therefore, be considered a noise impact.

Exhibit 3-6. FHWA Noise Abatement Criteria

Activity Category	L_{eq}(h) (dBA)	Description of Activity Category
A	57 (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	67 (exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals
C	72 (exterior)	Developed lands, properties, or activities not included in Categories A or B
D	–	Undeveloped lands
E	52 (interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums

Source: USDOT 1982.

Notes: dBA = A-weighted decibel
FHWA = Federal Highway Administration
L_{eq} (h) = hourly equivalent sound level

WSDOT defines severe noise impacts as traffic noise levels that exceed 80 dBA or that constitute a 30-dBA increase over existing conditions in Category B areas. It is also considered a severe noise impact if predicted future noise levels exceed existing levels by 15 dBA or more in noise-sensitive locations as the result of a project.

3.5.2 Property Line Criteria

The City limits noise levels at property lines of neighboring properties (Seattle Municipal Code, Section 25.08.410 [SMC 25.08.410]). The maximum permissible sound level depends on the land uses of both the noise source and the receiving property (Exhibit 3-7). The maximum permissible sound levels apply to construction activities only if they occur between 10:00 p.m. and 7:00 a.m. on weekdays or 10:00 p.m. and 9:00 a.m. on weekends and legal holidays. Construction activities during nighttime hours that would exceed these levels require a noise variance from the City.

Exhibit 3-7. City of Seattle Maximum Permissible Sound Levels

District of Noise Source	District of Receiving Property			
	Residential[1] (dBA)		Commercial (dBA)	Industrial (dBA)
	Day	Night		
Residential	55	45	57	60
Commercial	57	47	60	65
Industrial	60	50	65	70

Source: Seattle Municipal Code, Section 25.08.410.
Notes: dBA = A-weighted decibel

1. The maximum permissible sound level is reduced by 10 dBA for residential receiving properties between 10:00 p.m. and 7:00 a.m. where the receiving property lies within a residential district of Seattle.

Construction activities from 7:00 a.m. to 10:00 p.m. on weekdays and from 9:00 a.m. to 10:00 p.m. on weekends and legal holidays are allowed to exceed the property line standards per the following limits, measured at 50 feet or the property line, whichever is farther (SMC 25.08.425):

- Earth-moving or other equipment on construction sites may exceed the applicable property line noise limit by 25 dBA.
- Portable powered equipment in temporary locations in support of construction may exceed the limit by 20 dBA.
- Impact equipment, such as jackhammers, may not exceed an L_{eq} (h) of 90 dBA continuously or an L_{eq} (7.5 minutes) of 99 dBA and may be used only from 8:00 a.m. to 5:00 p.m. weekdays and from 9:00 a.m. to 5:00 p.m. on weekends and legal holidays, unless otherwise allowed by a noise variance.

- Temporary ventilation fans are subject to the noise level limits of the Seattle Noise Ordinance (SMC 25.08) and must meet the property line noise limits during nighttime hours. Temporary ventilation fans may exceed the limit by 20 dBA during daytime hours.

Under normal daily operations, a tunnel ventilation system (including but not limited to all ventilation fans and jet fans) is subject to the noise level limits of the Seattle Noise Ordinance and must meet the Seattle property line noise limits. Under emergency operation conditions, ventilation and jet fans are exempt from the ordinance (SMC 25.08.530). Jet fans and ventilation fans must, however, be routinely tested in emergency mode operation, which is subject to the property line noise limits.

3.5.3 Hearing Protection Criteria

To prevent damage to hearing, OSHA recommends a maximum noise level of 85 dBA based on a long-term exposure time of 8 hours during working life. National Fire Protection Association 130, Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 2010) allows an exposure of 115 dBA for a few seconds and 92 dBA for the remainder of the exposure. In accordance with the OSHA criterion, exposures of 115 dBA and 92 dBA are acceptable for 28 seconds and 1 hour 35 minutes, respectively. The in-tunnel noise criterion for the tunnel alternatives during emergency operations is a maximum of 115 dBA for a few seconds and 92 dBA for the remainder of the exposure. The build alternatives would meet the OSHA standards.

3.6 Characteristics of Vibration

Vibration is an oscillatory motion that can be described in terms of displacement, velocity, or acceleration. There is no net movement of the vibration element, and the average of any of the motion descriptors is zero because the motion is oscillatory. Displacement is the easiest descriptor to understand. For a vibrating floor, the displacement is simply the distance that a point on the floor moves away from its static position. The velocity represents the instantaneous speed of the floor movement, and acceleration is the rate of change of the speed. Although displacement is easier to understand than velocity or acceleration, it is rarely used for describing ground-borne vibration. This is because most transducers used for measuring ground-borne vibration use either velocity or acceleration and, more importantly, the response of humans, buildings, and equipment to vibration is more accurately described using velocity or acceleration.

3.7 Vibration Descriptors

One of the several different methods used to quantify vibration amplitude is peak particle velocity (PPV), which is defined as the maximum instantaneous positive or negative peak of the vibration signal. PPV is often used in monitoring blasting vibration because it is related to the stresses that are experienced by buildings. Although PPV is appropriate for evaluating the potential for building damage, it is not suitable for evaluating human response. It takes time for the human body to respond to vibration signals. In a sense, the human body responds to average vibration amplitude. Because the net average of a vibration signal is zero, the rms amplitude is used to describe the "smoothed" vibration amplitude. The rms of a signal is the average of the squared amplitude of the signal. The average is typically calculated over a 1-second period. The rms amplitude is always less than the PPV and is always positive. The PPV and rms velocity are normally described in inches per second in the United States and in meters per second in the rest of the world. Although it is not universally accepted, decibel notation is in common use for vibration. Decibel notation compresses the range of numbers required to describe vibration. The vibration velocity level in decibels is defined in the following equation:

$$L_v = 20\log(V/V_{ref})$$

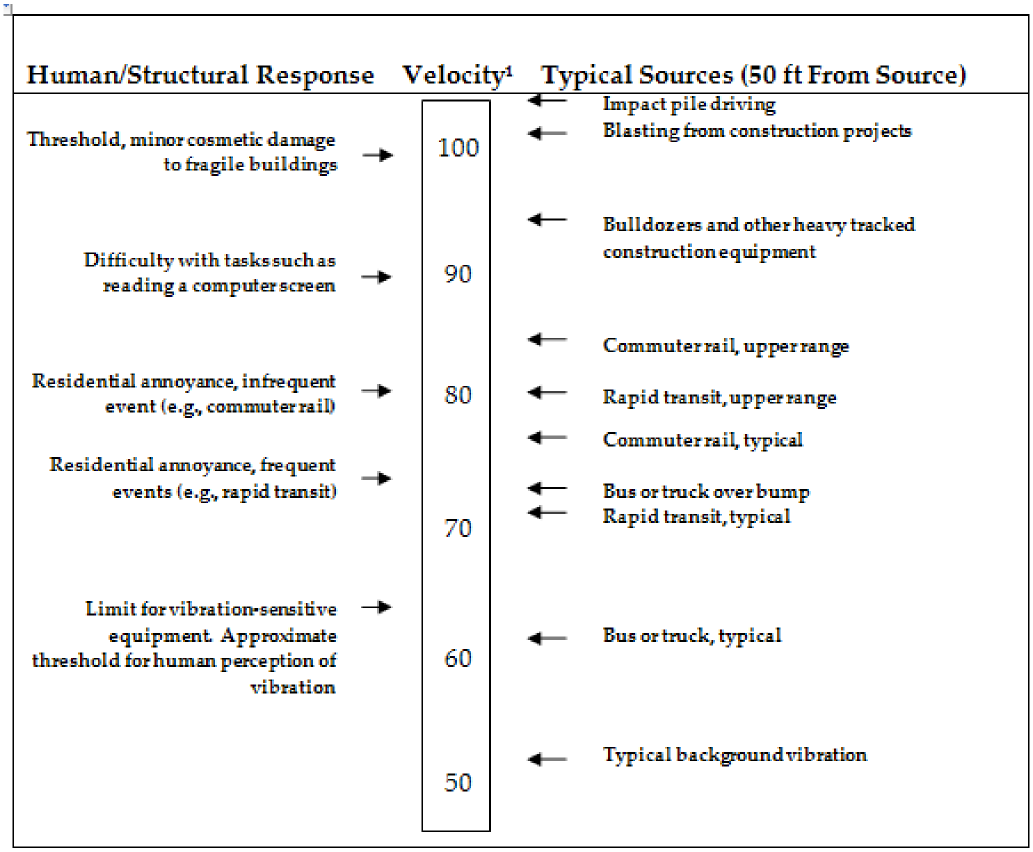
where: L_v is the velocity level in decibels
V is the rms velocity amplitude
V_{ref} is the reference velocity amplitude

A reference must always be specified whenever a quantity is expressed in terms of decibels. All vibration levels in this report are referenced to 1×10^{-6} inch per second. Although not a universally accepted notation, the abbreviation VdB is used in this report to indicate vibration decibels to avoid confusion with sound decibels.

3.8 Typical Vibration Levels

In contrast to airborne noise, ground-borne vibration is not a phenomenon that most people experience every day. The background-vibration velocity level in residential areas is usually 50 VdB or less, well below the threshold of perception for humans, which is around 65 VdB (Exhibit 3-8). Most perceptible indoor vibration is caused by sources within buildings, such as the operation of mechanical equipment, movement of people, or slamming of doors. Typical outdoor sources of perceptible ground-borne vibration are construction equipment, steel-wheeled trains, and traffic on rough roads. Pile driving is a common source of vibration. The vibration from traffic is rarely perceptible if the roadway is smooth. The range of interest is from approximately 50 to 100 VdB.

Exhibit 3-8. Common Vibration Sources and Levels



Source: USDOT 1995.

Notes: VdB = vibration decibel

1. Root mean square vibration velocity level in VdB relative to 10^{-6} inch per second.

Background vibration is usually well below the threshold of human perception and is of concern only when the vibration affects very sensitive manufacturing or research equipment. Electron microscopes and high-resolution lithography equipment are examples of equipment that is highly sensitive to vibration and may be disturbed by vibration levels greater than approximately 65 VdB. Although the perceptibility threshold is about 65 VdB, human response to vibration is not usually substantial unless the vibration exceeds 70 VdB. This is a typical vibration level 50 feet from a rapid transit or light rail system. Buses and trucks rarely create vibration that exceeds 70 VdB unless there are bumps in the road.

3.9 Effects of Vibration

Ground-borne vibration can be a concern for occupants of nearby buildings during construction activities associated with a proposed project. However, it is unusual for vibration from sources such as buses and trucks to be perceptible, even in locations close to major roads. The most common sources of ground-borne vibration are trains, buses on rough roads, and construction activities such as blasting, pile driving, and operation of heavy earth-moving equipment.

The effects of ground-borne vibration include perceptible movement of the building floors, rattling of windows, shaking of items on shelves or hanging on walls, and rumbling sounds. In extreme cases, vibration can cause damage to buildings and utilities. Building damage is not a factor for normal transportation projects, with the occasional exception of blasting, pile driving, and demolition of structures, which may occur during construction.

The rumbling sound caused by the vibration of room surfaces is called ground-borne noise. The annoyance potential of ground-borne noise is usually characterized using the A-weighted sound level. Although the A-weighted level is almost the only metric used to characterize community noise, there are potential problems with characterizing low-frequency noise using A-weighting. This is because of the non-linearity of human hearing, which causes sounds dominated by low-frequency components to seem louder than broadband sounds that have the same A-weighted level. The result is that ground-borne noise with a level of 40 dBA sounds louder than broadband noise with a level of 40 dBA. This is accounted for by setting the limits for ground-borne noise lower than those for broadband noise.

3.10 Vibration Effect Criteria

Criteria for ground vibration resulting from construction must address three types of effects:

- Potential disturbance and annoyance of building occupants
- Potential damage to nearby buildings and other nearby structures
- Potential damage to nearby utilities

During construction, temporary vibration effects may occur in the local area as a result of blasting or the use of pile drivers, jackhammers, hoe rams, soil compactors, and other heavy construction equipment. Buildings near the construction site respond to these vibrations with varying results, ranging from perceptible effects at the lowest levels to low rumbling sounds and noticeable vibrations at moderate levels to slight damage at the highest levels. Ground vibrations from construction activities rarely reach the levels that can damage structures but can reach moderate levels in buildings very close to a site. Impact pile drivers generally cause the highest vibration levels compared to other types of equipment. During the project, mitigation measures would be applied to minimize the potential for harm to nearby structures.

A precise assessment of potential vibration effects requires detailed information on the proposed construction methods, specific construction activity, types of construction equipment, characteristics of the underlying soils, existing conditions, and use of buildings. Field review of building types and construction methods and measurements of existing vibration levels at sensitive sites are also required to determine the potential sensitivity of the buildings near the construction site.

3.10.1 Annoyance Criteria

Annoyance from construction vibration would depend on the magnitude of vibration as well as on the human activity involved. Vibration produced during construction activities becomes a concern when it can be felt. Determining acceptable vibration levels is often problematic because the perception of vibration as a nuisance is subjective. It is the unpredictability and unusual nature of a vibration source, rather than the level itself, that is likely to result in complaints. The effect of intrusion tends to be psychological rather than physiological, and it is more of a problem at night when occupants of buildings do not expect disturbance from external sources. Complaints may occur when vibration levels from an unusual source exceed the human threshold of perception (generally a PPV in the range of 0.008 to 0.012 inch per second), even though these levels are much less than what would result from slamming a door in a modern masonry building. People’s tolerance is typically higher if the origin of the vibrations is known in advance and no damage results.

The criteria used in determining annoyance depend on the type of activities inside the building, as well as the time of day. Conservative design criteria used for assessing human sensitivity during construction have been developed by the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI). These criteria are shown in Exhibit 3-9.

Exhibit 3-9. Criteria for Annoyance Caused by Ground-Borne Vibration

Building Use Category	Maximum Vibration Velocity (inch/second)	Comments
Hospital and critical areas	0.005	–
Residential (nighttime)	0.007	–
Residential (daytime)	0.01	Criterion also applies to churches, schools, hotels, and theaters
Office	0.02	Criterion applies to commercial establishments
Factory	0.03	Criterion applies to industrial establishments

Sources: International Organization for Standardization Standard 2631 (ISO 1974) and American National Standards Institute Standard S3.29-2001 (Acoustical Society of America 2001).

3.10.2 Potential Building Damage Criteria

Building damage is the primary concern related to construction vibration. For this purpose, construction vibration is generally assessed in terms of PPV.

No local, state, or federal agencies require the control of vibration during construction in the way that the Seattle Noise Ordinance addresses noise levels. Assessing the potential for cosmetic or structural damage due to construction activities is based on impact criteria developed by the Acoustical Society of America (2001), ISO (1989), and FTA (2006).

3.10.3 Vibration Criteria to Prevent Structural Damage

Extensive studies conducted by the U.S. Bureau of Mines suggest that a peak vibration velocity of 2.0 inches per second should not be exceeded if major structural damage of buildings is to be prevented. Potential damage to underground and buried utilities could occur at vibration levels greater than 4.0 inches per second (Nicholls et al. 1971). Criteria for sustained construction vibrations, which are normally expected during construction, generally limit vibration velocities to 0.5 to 1.0 inch per second.

Guidelines that are more comprehensive are provided in Swiss Standard SN 640312; they have been checked for conformance with similar vibration criteria established by the American Association of State Highway and Transportation Officials, the U.S. Bureau of Mines, and other relevant standards. Exhibits 3-10 and 3-11 represent the structural categories and vibration criteria for use in selecting appropriate construction vibration limits.

FTA guidance on vibration damage threshold covers "fragile buildings" (0.20 inch per second PPV) and "extremely fragile historic buildings" (0.12 inch per second PPV), which correspond to Building Category IV of the Swiss Standard for buildings of "particularly high sensitivity."

Exhibit 3-10. Structural Categories According to Swiss Standard SN 640312

Structural Category	Definition
I	Reinforced-concrete and steel structures (without plaster), such as industrial buildings, bridges, masts, retaining walls, unburied pipelines; and underground structures such as caverns, tunnels, and galleries, lined and unlined
II	Buildings with concrete floors and basement walls, above-grade walls of concrete, brick, or ashlar masonry; ashlar retaining walls; buried pipelines; and underground structures such as caverns, tunnels, and galleries with masonry lining
III	Buildings with concrete basement floors and walls, above-grade masonry walls, and timber joist floors
IV	Buildings that are particularly vulnerable or worth preserving

Exhibit 3-11. Acceptance Criteria of Swiss Standard SN 640312

Structural Category	Continuous or Steady-State Vibration Sources[1] Frequency (hertz)	Continuous or Steady-State Vibration Sources[1] Maximum Velocity (inch/second)	Transient or Impact Vibration Sources[2] Frequency (hertz)	Transient or Impact Vibration Sources[2] Maximum Velocity (inches/second)
I	10–30 30–60	0.5 0.5–0.7	10–60 60–90	1.2 1.2–1.6
II	10–30 30–60	0.3 0.3–0.5	10–60 60–90	0.7 0.7–1.0
III	10–30 30–60	0.2 0.2–0.3	10–60 60–90	0.5 0.5–0.7
IV	10–30 30–60	0.12 0.12–0.2	10–60 60–90	0.3 0.3–0.5

Notes: [1] Continuous or steady-state vibration consists of vibration from equipment such as vibratory pile drivers, hydromills, large pumps and compressors, bulldozers, trucks, cranes, scrapers and other large machinery, jackhammers and reciprocating pavement breakers, and compactors.

[2] Transient or impact vibration consists of vibration from activities such as blasting with explosives and use of such equipment as drop chisels for rock breaking, buckets, impact pile drivers, wrecking balls and building demolition, gravity drop ground compactors, and pavement breakers.

3.10.4 Vibration Criteria Adopted for This Project

Although FHWA, WSDOT, and the City do not have specific vibration impact criteria, this project has adopted a vibration impact criterion of 0.12 inch per second PPV for extremely fragile structures and 0.50 inch per second for all other occupied buildings. These criteria are consistent with FTA criteria and are protective of potentially fragile historic structures. Structures in the project area that may be extremely fragile include unrestored areaways, the spaces beneath the sidewalks of older buildings, and historic buildings that have not been structurally retrofitted. The damage risk criterion for underground structures is a PPV of 4.0 inches per second. Older cast-iron water mains may be more vibration-sensitive than other utilities; therefore, a protective damage risk criterion of 0.5 inch per second is used for older cast-iron water mains (the Seattle Public Utilities standard).

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Chapter 4 AFFECTED ENVIRONMENT

4.1 Study Area Characteristics

The study area evaluated for noise and vibration effects includes areas likely to be affected by changes in traffic or mechanical ventilation noise under the various alternatives and areas likely to be affected by construction noise or vibration. The study area extends approximately two blocks on either side of SR 99 from near S. Atlantic Street to Aloha Street. For the purpose of discussing the existing conditions and project-related effects on noise, the study area has been divided into three geographic areas: the south area, the central area, and the north area.

The study area runs through the downtown core of Seattle. Land uses range from low-rise light industrial buildings to high-rise office towers and include residential zoning, such as Belltown. Noise-sensitive uses include residences, hotels, motels, parks, social services, daycare providers, one school, and public spaces. Several old, potentially vibration-sensitive structures are adjacent to the existing Alaskan Way Viaduct.

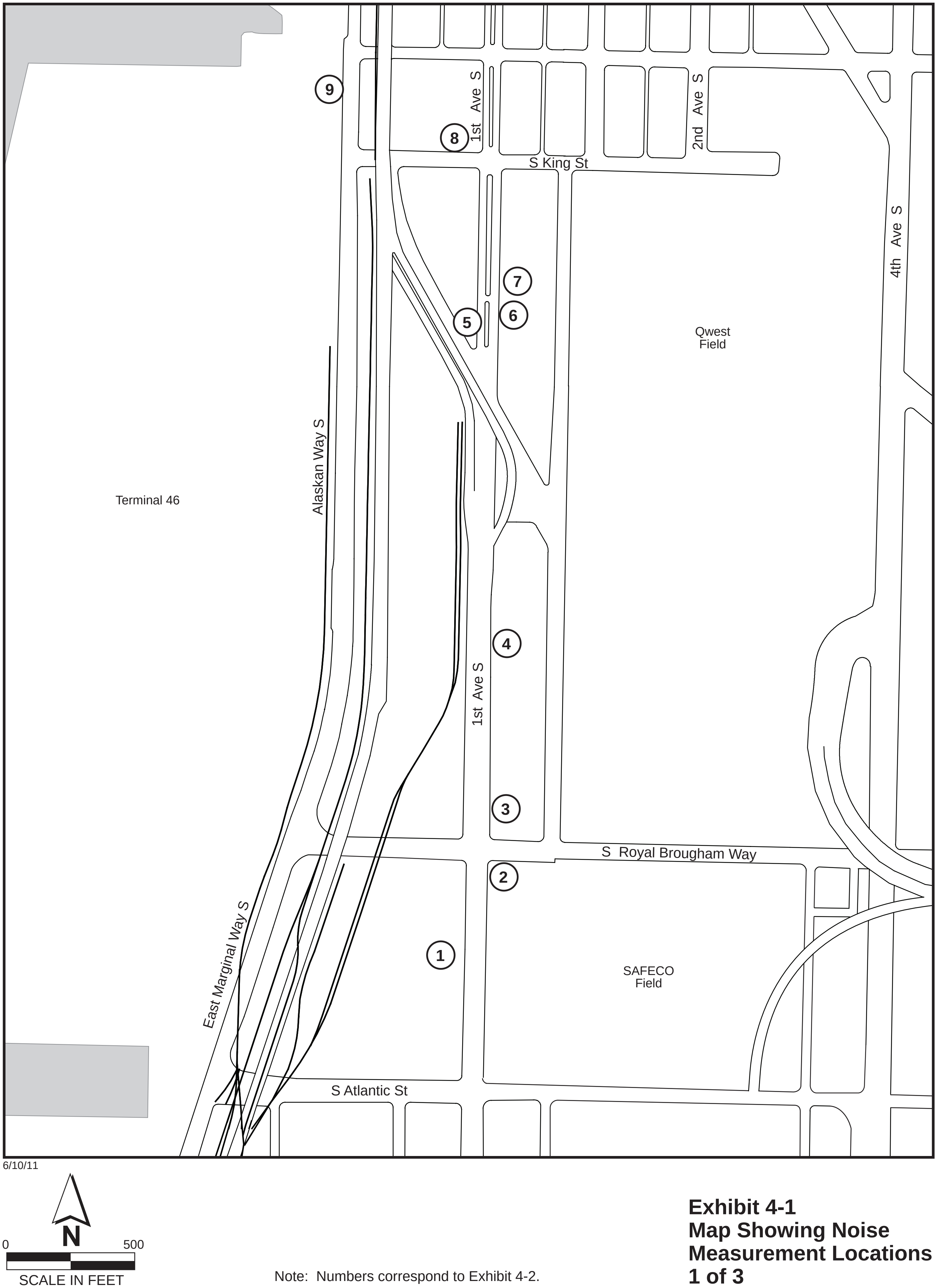
Downtown commercial uses dominate much of the central area. Multi-family residential structures and hotel uses are also present, with higher concentrations in the central and north areas. The south area includes offices, multi-family residential uses, and hotels but is currently zoned primarily as light industrial near SR 99. Many parks and public spaces are located throughout the study area.

In the south and north areas, tunnel operations buildings are planned for the Bored Tunnel Alternative, and tunnel maintenance buildings are planned for the Cut-and-Cover Tunnel Alternative.

See Appendix G, Land Use Discipline Report, for a detailed description of the land uses within the study area.

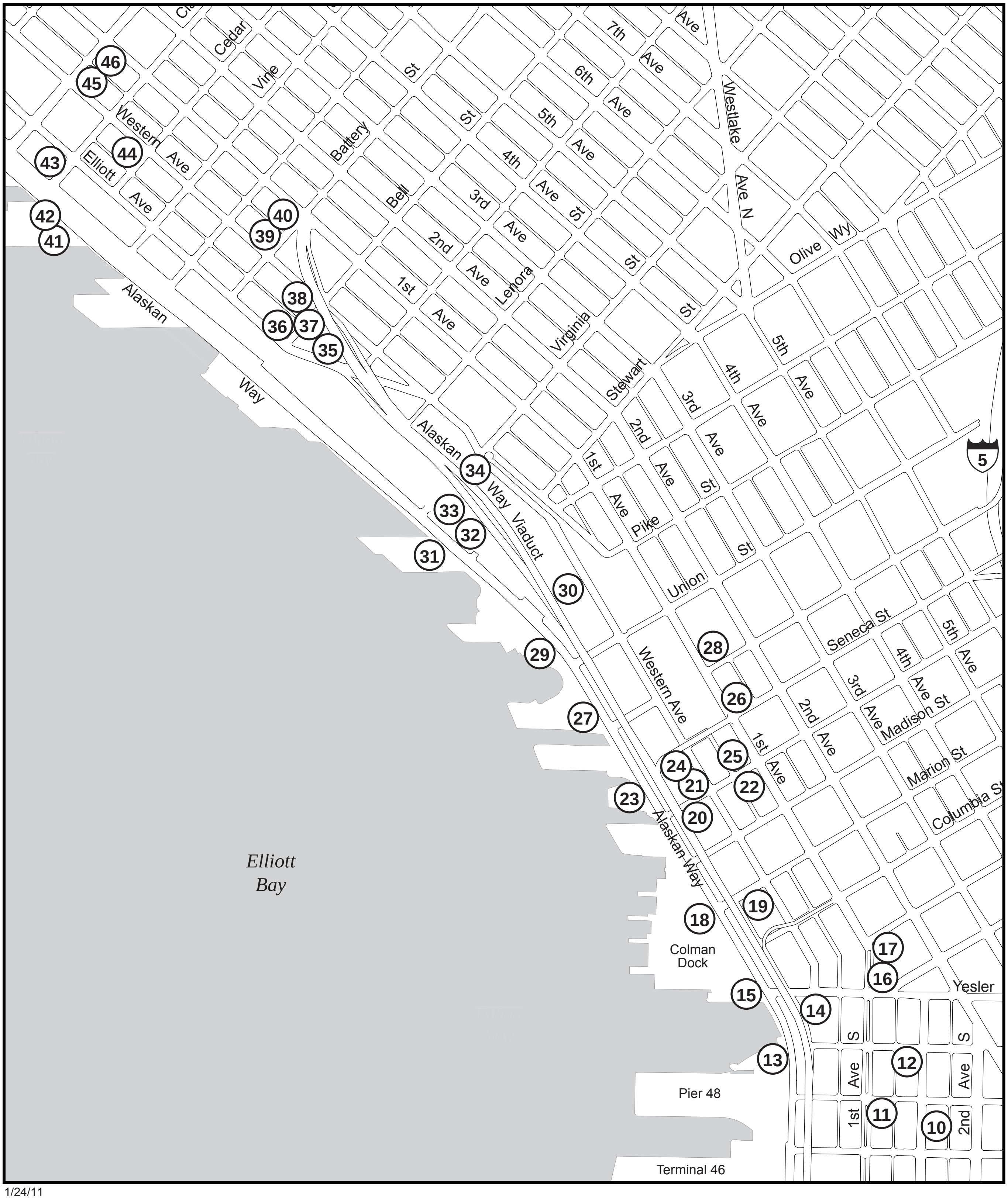
4.2 Existing Noise Environment

Noise levels for the loudest hour of the day were modeled throughout the study area to characterize the existing overall acoustical environment. For modeling purposes and documentation of the affected environment, the project team used the year 2015 to represent existing conditions. For more information on the determination of 2015 as the existing conditions year, please see Appendix C, Transportation Discipline Report, Section 2.3. The noise measurement locations are shown in Exhibit 4-1. The noise levels modeled for 2015 existing conditions are similar to those measured in Chapter 2 of this report.



Note: Numbers correspond to Exhibit 4-2.

Exhibit 4-1
Map Showing Noise Measurement Locations
1 of 3



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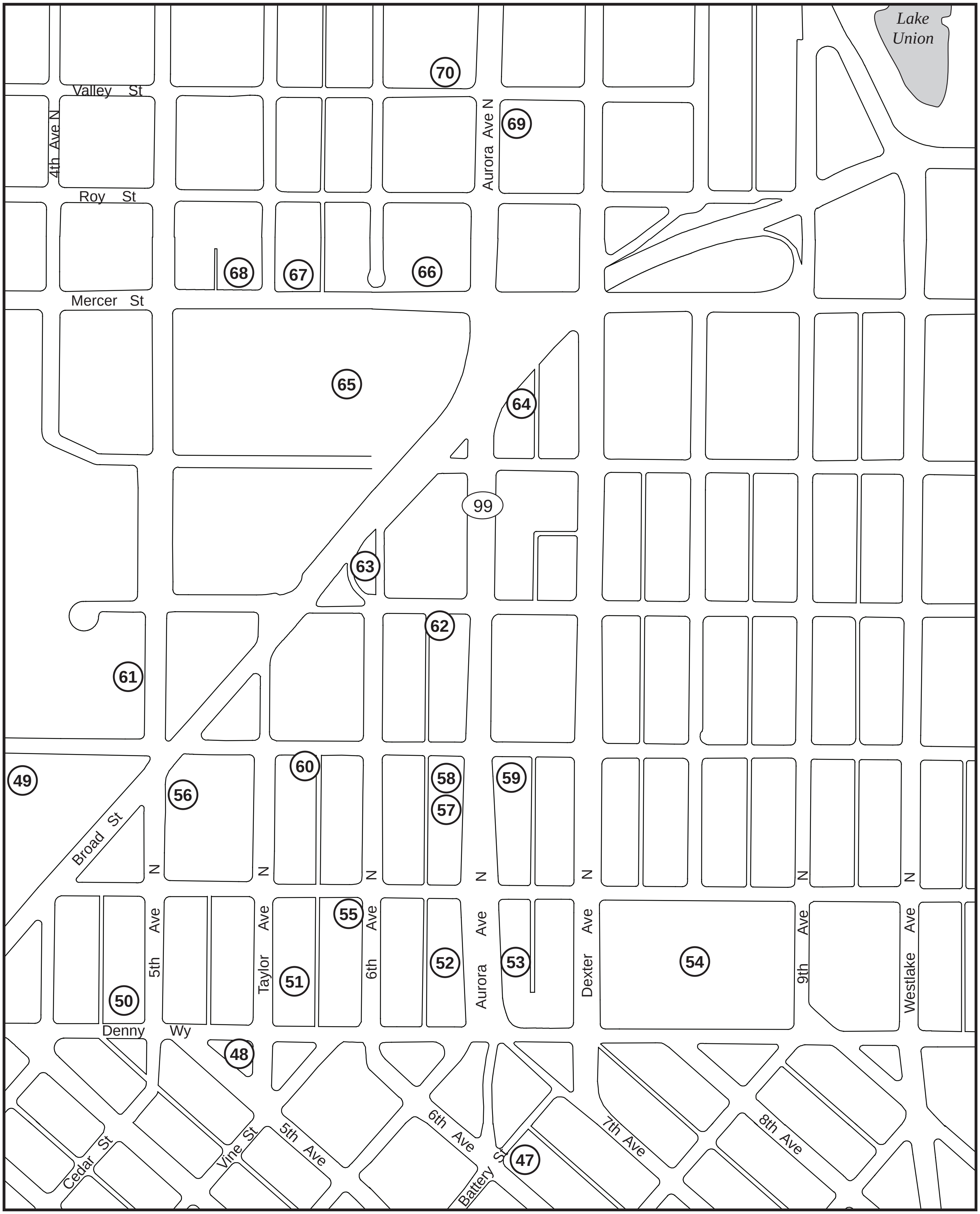
Note: Numbers correspond to Exhibit 4-2.

Exhibit 4-1
Map Showing Noise Measurement Locations
2 of 3



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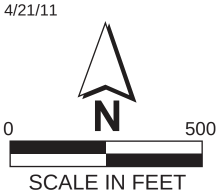


Notes: Numbers correspond to Exhibit 4-2.
Location 65 is under construction and was modeled only.

Exhibit 4-1
Map Showing Noise Measurement Locations
3 of 3

As shown in Exhibit 4-2, the 2015 existing traffic noise levels are predicted to approach or exceed the FHWA noise abatement criteria at 54 of the 70 modeled sites, representing approximately 4,578 residential units, 1,612 hotel rooms, 120 shelter beds, 1 church, 1 school, 12 parks or public spaces, and 8 commercial use areas. The predicted noise level at one site, location 19, currently exceeds the severe noise impact criterion (noise levels exceeding 80 dBA at noise-sensitive land uses).

Exhibit 4-2. Modeled Existing Traffic Noise Levels

Receptor	Noise-Sensitive Land Use	Noise Abatement Criterion (dBA)	2015 Existing Noise Levels (dBA)
1	Commercial	72	67
2	Public space	67	**71**
3	220 hotel rooms	67	**70**
4	Commercial	72	**71**
5	2 residential units	67	**71**
6	25 residential units	67	**68**
7	108 residential units	67	**67**
8	Commercial	72	70
9	Public space	67	**73**
10	Public space and 7 residential units	67	64
11	114 residential units and 120 homeless shelter beds	67	**70**
12	Park	67	64
13	Park	67	**75**
14	115 hotel rooms	67	**72**
15	Commercial	72	**75**
16	Park and 85 residential units	67	**69**
17	Park	67	**70**
18	Commercial use	72	**75**
19	Pedestrian access and 19 residential units	67	**80**
20	Commercial use	72	**79**
21	Commercial use	72	**72**
22	109 hotel rooms	67	**70**
23	Commercial use	72	**72**
24	Commercial use	72	**77**
25	130 residential units	67	**70**
26	169 residential units	67	**72**
27	Park	67	**72**
28	301 residential units	67	**71**

Exhibit 4-2. Modeled Existing Traffic Noise Levels (continued)

Receptor	Noise-Sensitive Land Use	Noise Abatement Criterion (dBA)	2015 Existing Noise Levels (dBA)
29	Park	67	**71**
30	205 residential units	67	**76**
31	Public space	67	**66**
32	115 residential units and 160 hotel rooms	67	**68**
33	115 residential units and 160 hotel rooms	67	**78**
34	Park	67	**77**
35	77 residential units	67	**76**
36	32 residential units	67	**69**
37	77 residential units	67	**73**
38	32 residential units	67	**76**
39	312 residential units	67	**72**
40	312 residential units	67	**71**
41	138 hotel rooms	67	65
42	100 hotel rooms	67	**69**
43	636 residential units	67	**68**
44	695 residential units	67	**70**
45	698 residential units	67	**67**
46	130 residential units	67	**68**
47	Commercial	67	**67**
48	Park	67	**67**
49	Pacific Science Center	67	65
50	Commercial	72	66
51	190 residential units	67	64
52	132 residential units	67	**77**
53	53 residential units	67	**77**
54	Park	67	61
55	60 residential units	67	64
56	Commercial	72	67
57	159 hotel rooms	67	**76**
58	235 hotel rooms	67	**74**
59	196 hotel rooms	67	**77**
60	123 hotel rooms	67	65
61	Experience Music Project	67	64
62	Commercial	72	69
63	Public space	67	**68**
64	Public space	67	**73**
65	Commercial	72	65

Exhibit 4-2. Modeled Existing Traffic Noise Levels (continued)

Receptor	Noise-Sensitive Land Use	Noise Abatement Criterion (dBA)	2015 Existing Noise Levels (dBA)
66	158 hotel rooms	67	**67**
67	School	67	**66**
68	92 residential units	67	65
69	Commercial	72	**71**
70	4 residential units and 1 church	67	**68**

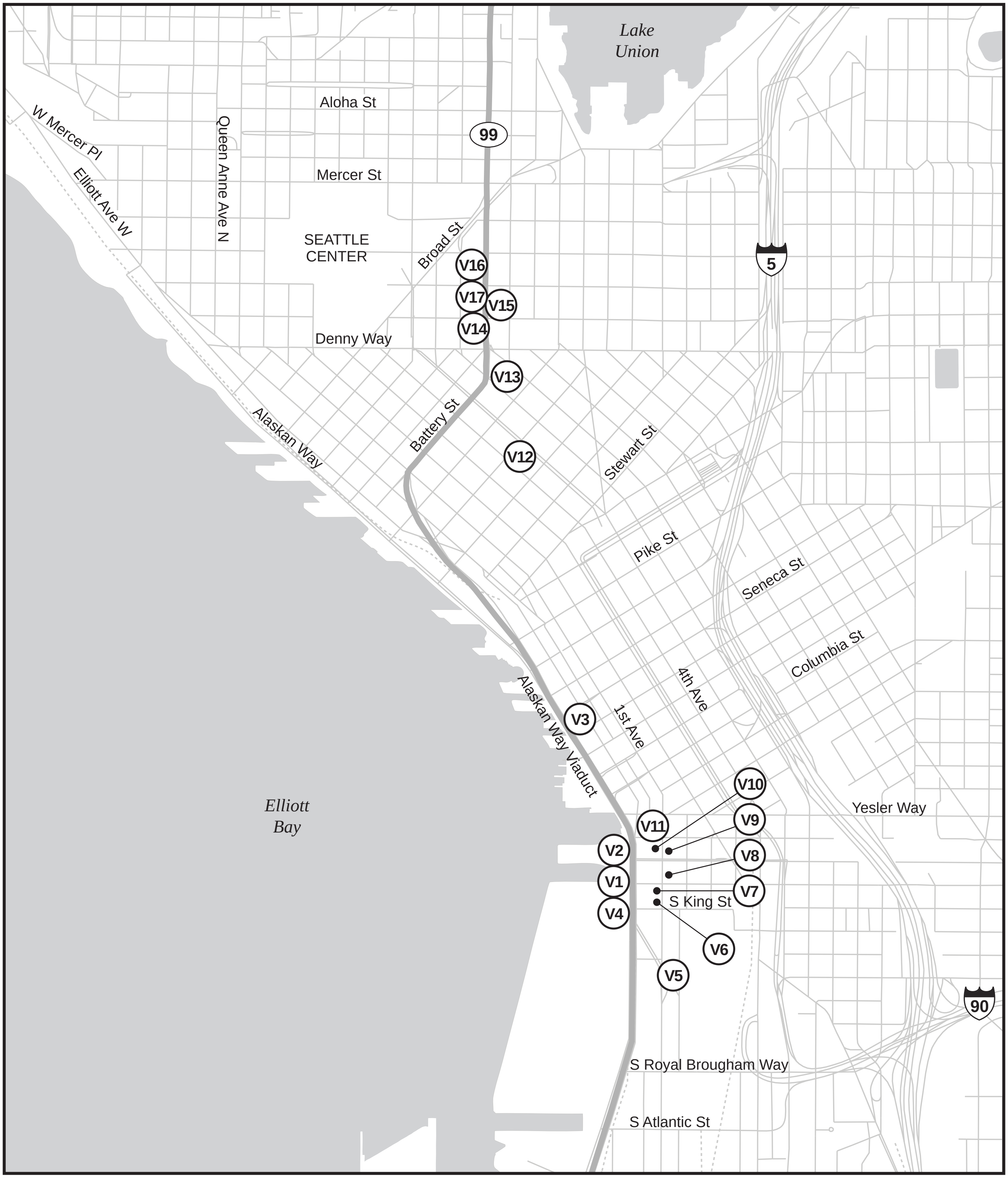
Notes: FHWA's abatement criterion for traffic noise is 67 dBA for most noise-sensitive land uses and 72 dBA for commercial uses.
An impact occurs if the traffic noise level approaches within 1 dBA of the criterion (66 or 71 dBA) or exceeds it.
Noise-sensitive locations that do not include outdoor use areas (FHWA Activity Category E) have an interior noise-level impact criterion of 52 dBA.
Noise levels that approach or exceed the criterion are shown in **bold**.
dBA = A-weighted decibel
FHWA = Federal Highway Administration

4.3 Existing Vibration Environment

Vibration levels generated by rubber-tired vehicles are usually not a concern for existing roadways. However, there are perceptible levels of ground vibration at the base of the vertical steel piers supporting the Alaskan Way Viaduct. This may be due to the mass and roadway span of the structure that, at some locations, amplifies the vibration levels generated by heavy trucks passing by.

The buildings closest to the viaduct are commercial, with occasional residential buildings located farther away. To document the existing vibration environment in these areas, field measurements were taken at representative locations beneath the viaduct and along the alignments of the build alternatives. To establish a baseline, existing vibration levels resulting from heavy vehicles on the viaduct and along First Avenue areaways were measured at 11 locations, along with 6 locations around the north area. These measurement locations are shown in Exhibit 4-3.

The four sites along the viaduct represent the occupied buildings closest to the viaduct. The additional sites represent the buildings closest to the alignments of the build alternatives and surrounding area. The measured levels are presented in Exhibit 4-4 as maximum rms velocity vibration and PPV.



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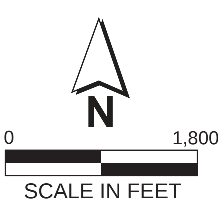

Note: Numbers correspond to Exhibit 4-4.

Exhibit 4-3
Vibration Measurement Locations

Exhibit 4-4. Ambient Vibration Levels Along the Alaskan Way Viaduct

Receiver	Location Description	Maximum Vibration Velocity (VdB)	Peak Particle Velocity (inch/second)
V1	Viaduct at S. Jackson Street	79.5	0.049
V2	76 S. Main Street	78.7	0.043
V3	Antique market	88.2	0.128
V4	Viaduct near S. King Street	77.0	0.035
V5	Triangle Tavern basement	73.5	0.024
V6	Merrill Place – south basement	75.0	0.028
V7	Merrill Place – north basement	77.6	0.038
V8	Northeast corner First Avenue S. and S. Jackson Street – store basement	82.0	0.063
V9	Southeast corner First Avenue S. and S. Main Street – Elliott Bay Bookstore and Café – basement	80.0	0.050
V10	Northwest corner First Avenue S. and S. Main Street – shoe store basement	70.9	0.018
V11	First Avenue S. between S. Main and S. Washington Streets – basement of Grand Central Building	74.6	0.027
V12	Northeast corner of Fourth Avenue and Blanchard Street – street level	71.0	0.017
V13	Antioch University Book Store – street level	72.9	0.029
V14	Fourth floor parking of condominiums on the southwest corner of Aurora Avenue N. and John Street	75.3	0.029
V15	Holiday Inn parking on the northeast corner of Aurora Avenue N. and John Street	77.5	0.038
V16	Seattle Pacific Hotel	75.4	0.028
V17	Quality Inn and Suites	78.5	0.043

VdB = vibration decibel

The following is a description of the vibration measurement sites and the building structures at the locations listed in Exhibit 4-4 and shown in Exhibit 4-3:

- Site V1 – S. Jackson Street. Measurements were taken at an office building located within 5 feet of a viaduct vertical pier. Alaskan Way is located 60 feet west of the building, and S. Jackson Street is located 30 feet north of the building. The area under the viaduct is used for parking.
- Site V2 – 76 S. Main Street. Measurements were taken directly outside the building. The area under the viaduct is used for parking; east of the viaduct are three five-story brick office buildings.
- Site V3 – Antique Market. Measurements were taken in front of the loading dock of the Antique Market.
- Site V4 – S. King Street. Measurements were taken at a building within 30 feet of a viaduct vertical pier.
- Site V5 – Triangle Tavern. Measurements were taken in the basement of the building, west of the First Avenue S. areaway retaining wall.
- Site V6 – Merrill Place, south basement. Measurements were taken in the basement of the building, west of the First Avenue S. areaway retaining wall.
- Site V7 – Merrill Place, north basement. Measurements were taken in the basement of the building, west of the First Avenue S. areaway retaining wall.
- Site V8 – First Avenue S. and S. Jackson Street, basement. Measurements were taken in the basement under 388 First Avenue S., east of the First Avenue S. areaway retaining wall and north of S. Jackson Street.
- Site V9 – First Avenue S. and S. Main Street, basement. Measurements were taken in the basement of the Elliott Bay Book Store and Café, east of the First Avenue S. areaway retaining wall and south of S. Main Street.
- Site V10 – First Avenue S. and S. Main Street, basement. Measurements were taken in the basement level of 217 First Avenue S., west of the First Avenue S. areaway retaining wall and 80 feet north of S. Main Street.
- Site V11 – First Avenue S. between S. Main Street and S. Washington Street, basement. Measurements were taken in the basement level of the Globe Building, 254 First Avenue S., west of the First Avenue S. areaway retaining wall, 109 feet north of S. Main Street, and 150 feet south of S. Washington Street.

- Site V12 – The northeast corner of Fourth Avenue and Blanchard Street. Measurements were taken at street level at a location along the alignments of the build alternatives.
- Site V13 – Antioch University Book Store. Measurements were taken at the street level at the west corner, inside the bookstore, at a location along the alignments of the build alternatives. The site is on Sixth Avenue, 60 feet from Battery Street.
- Site V14 – Condominium parking, 191 Aurora Avenue. Measurements were taken on the fourth level of parking west of Aurora Avenue N. and south of John Street.
- Site V15 – Holiday Inn parking. Measurements were taken at the street level at the southwest corner. The site is east of Aurora Avenue N. and north of John Street.
- Site V16 – Seattle Pacific Hotel parking. Measurements were taken in the street-level parking area on the west side of the hotel. The site is in the middle of the property, halfway between Aurora Avenue N. and Sixth Avenue N. and between Harrison Street and Thomas Street.
- Site V17 – Quality Inn and Suites. Measurements were taken in the street level parking area at the northwest corner. The site is 110 feet west of Aurora Avenue N. and 15 feet south of Thomas Street.

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Chapter 5 Operational Effects, Mitigation, and Benefits

Federal and Washington State environmental regulations require agencies to evaluate a No Build Alternative to provide baseline information about existing conditions in the project area. For this project, the No Build Alternative is not a viable alternative because the existing viaduct is vulnerable to seismic damage and structural failure due to ongoing deterioration. Multiple studies of the viaduct's current structural conditions, including its foundations in liquefiable soils, have determined that retrofitting or rebuilding the existing viaduct is not a reasonable alternative. At some point, the roadway will need to be closed because of safety concerns.

The Viaduct Closed (No Build Alternative) describes the consequences of suddenly losing the function of SR 99 along the central waterfront based on the two scenarios described in Sections 5.1.4 and 5.1.5. These short-term consequences would last until transportation and other agencies could develop and implement a new, permanent solution, which would have its own environmental review.

The build alternatives and the Viaduct Closed (No Build Alternative) are described in more detail in Appendix B, Alternatives Description and Construction Methods Discipline Report. This chapter discusses the operational effects of the non-tolled build alternatives, based on the analyses of potential noise and vibration effects compared with existing conditions. See Chapter 7 of this report for the analysis of the tolled build alternatives.

5.1 Operational Effects of the Viaduct Closed (No Build Alternative)

The modeled loudest-hour traffic noise levels for the Viaduct Closed (No Build Alternative) are described for the south area, the central area, and the north area.

Long-term operational traffic noise levels under the Viaduct Closed (No Build Alternative) were modeled for the year 2030. Under the Viaduct Closed (No Build Alternative), noise levels in the south area and the north area would be lower than existing conditions. Noise levels near Alaskan Way along the central waterfront would be substantially lower than existing conditions.

Under the Viaduct Closed (No Build Alternative), the loudest-hour traffic noise levels would range between 61 and 77 dBA at the modeled sites (see Exhibits 5-1, 5-2, and 5-3). Changes in traffic noise levels are predicted to be between a 16-dBA decrease and a 2-dBA increase relative to existing levels because of changes in traffic patterns. A 2-dBA change in noise level is the smallest change that can be heard by sensitive listeners.

Under the 2030 Viaduct Closed (No Build Alternative), no sites are predicted to exceed the severe noise impact criterion (noise levels exceeding 80 dBA at sensitive land uses). The number of sensitive receptors that meet the noise abatement criteria would be lower than the number under existing conditions, mostly in the central area between S. King Street and Denny Way. Under the Viaduct Closed (No Build Alternative), noise levels are predicted to exceed the noise abatement criteria at 36 of the 70 modeled sites. Many of the residential and hotel sites have no private outdoor use areas. The appropriate criterion at these sites is 52 dBA (Category E) inside the building with the windows closed.

5.1.1 South Area

As shown in Exhibit 5-1, under the modeled 2030 Viaduct Closed (No Build Alternative), traffic noise levels in the south area approach or exceed the FHWA noise abatement criteria at six of the nine modeled sites, representing approximately 135 residential units, 220 hotel rooms, and 2 parks or public spaces.

5.1.2 Central Area

As shown in Exhibit 5-2, under the modeled 2030 Viaduct Closed (No Build Alternative), traffic noise levels in the central area approach or exceed the FHWA noise abatement criteria at 17 of the 37 modeled sites, representing approximately 2,506 residential units, 353 hotel rooms, 120 shelter beds, 3 parks or public spaces, and 2 commercial uses. At most of the modeled sites in the central area, traffic noise levels decrease relative to existing levels.

5.1.3 North Area

As shown in Exhibit 5-3, under the modeled 2030 Viaduct Closed (No Build Alternative), traffic noise levels approach or exceed the FHWA noise abatement criteria at 13 of the 24 modeled sites, representing approximately 189 residential units, 871 hotel rooms, 1 school, 1 church, 3 parks or public spaces, and 1 commercial use.

5.1.4 Scenario 1: Sudden Unplanned Loss of SR 99

With this scenario, there would be a sudden, unplanned closure of SR 99 between S. King Street and Denny Way due to some structural deficiency, weakness, or damage due to a smaller earthquake event. SR 99 would be closed for an unknown period until a viaduct replacement could be built. Severe travel delays would be experienced, and utilities on the viaduct would likely be damaged and require repair. During the closure of SR 99, noise levels along the waterfront would be lower than existing levels.

Exhibit 5-1. Modeled 2030 Noise Levels – South Area

Receptor	Noise-Sensitive Land Use	Noise Abatement Criterion (dBA)	Existing Noise Level (dBA)	2030 Viaduct Closed (No Build Alternative) Noise Level (dBA)	2030 Viaduct Closed (No Build Alternative) Change From Existing (dBA)	2030 Bored Tunnel Alternative Noise Level (dBA)	2030 Bored Tunnel Alternative Change From Existing (dBA)	2030 Cut-and-Cover Tunnel Alternative Noise Levels (dBA)	2030 Cut-and-Cover Tunnel Alternative Change From Existing (dBA)	2030 Elevated Structure Alternative) Noise Level (dBA)	2030 Elevated Structure Alternative) Change From Existing (dBA)
1	Commercial use	72	67	65	-2	66	-1	66	-1	67	0
2	Public space	67	**71**	**69**	-2	**70**	-1	**70**	-1	**69**	-2
3	220 hotel rooms	67	**70**	**67**	-3	**69**	-1	**69**	-1	**69**	-1
4	Commercial use	72	**71**	68	-3	69	-2	70	-1	70	-1
5	2 residential units	67	**71**	**69**	-2	**69**	-2	**68**	-3	**71**	0
6	25 residential units	67	**68**	**69**	1	**70**	2	**69**	1	**70**	2
7	108 residential units	67	**67**	**68**	1	**69**	2	**69**	2	**69**	2
8	Commercial use	72	70	66	-4	67	-3	66	-4	70	0
9	Public space	67	**73**	**70**	-3	**68**	-5	**68**	-5	**74**	1

Notes: FHWA's abatement criterion for traffic noise is 67 dBA for most noise-sensitive land uses and 72 dBA for commercial uses.
An impact occurs if the traffic noise level approaches within 1 dBA of the criterion (66 or 71 dBA) or exceeds it.
Noise-sensitive locations that do not include outdoor use areas (FHWA Activity Category E) have an interior noise-level impact criterion of 52 dBA.
Noise levels that approach or exceed the criterion are shown in **bold**.
dBA = A-weighted decibel
FHWA = Federal Highway Administration

Exhibit 5-2. Modeled 2030 Noise Levels – Central Area

Receptor	Noise-Sensitive Land Use	Noise Abatement Criterion (dBA)	Existing Noise Level (dBA)	2030 Viaduct Closed (No Build Alternative)		2030 Bored Tunnel Alternative		2030 Cut-and-Cover Tunnel Alternative		2030 Elevated Structure Alternative	
				Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)
10	Public space and 7 residential units	67	64	61	-3	61	-3	61	-3	63	-1
11	114 residential units and 120 homeless shelter beds	67	**70**	**68**	-2	**69**	-1	**68**	-2	**70**	0
12	Park	67	64	61	-3	62	-2	61	-3	64	0
13	Park	67	**75**	**73**	-2	**74**	-1	**74**	-1	**78**	3
14	115 hotel rooms	67	**72**	**68**	-4	**68**	-4	**68**	-4	**71**	-1
15	Commercial use	72	**75**	**73**	-2	**73**	-2	**73**	-2	**74**	-1
16	Park and 85 residential units	67	**69**	65	-4	**66**	-3	**66**	-3	**68**	-1
17	Park	67	**70**	**68**	-2	**68**	-2	**68**	-2	**69**	-1
18	Commercial use	72	**75**	**73**	-2	**72**	-3	**72**	-3	**74**	-1
19	Pedestrian access and 19 residential units	67	**80**	**67**	-13	**67**	-13	**66**	-14	**78**	-2
20	Commercial use	72	**79**	70	-9	70	-9	69	-10	**79**	0
21	Commercial use	72	**72**	69	-3	69	-3	69	-3	**72**	0
22	109 hotel rooms	67	**70**	65	-5	65	-5	**66**	-4	**69**	-1
23	Commercial use	72	**72**	67	-5	67	-5	66	-6	**71**	-1
24	Commercial use	72	**77**	70	-7	70	-7	69	-8	**77**	0
25	130 residential units	67	**70**	**67**	-3	**68**	-2	**69**	-1	**70**	0
26	169 residential units	67	**72**	**66**	-6	**66**	-6	**66**	-6	**73**	1
27	Park	67	**72**	65	-7	65	-7	64	-8	**71**	-1

Exhibit 5-2. Modeled 2030 Noise Levels – Central Area (continued)

Receptor	Noise-Sensitive Land Use	Noise Abatement Criterion (dBA)	Existing Noise Level (dBA)	2030 Viaduct Closed (No Build Alternative)		2030 Bored Tunnel Alternative		2030 Cut-and-Cover Tunnel Alternative		2030 Elevated Structure Alternative	
				Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)
28	301 residential units	67	**71**	**66**	-5	**66**	-5	65	-6	**71**	0
29	Park	67	**71**	**66**	-5	**66**	-5	65	-6	**71**	0
30	205 residential units	67	**76**	62	-14	62	-14	61	-15	**74**	-2
31	Public space	67	**66**	62	-4	62	-4	61	-5	**66**	0
32	115 residential units and 160 hotel rooms	67	**68**	63	-5	63	-5	61	-7	**67**	-1
33	115 residential units and 160 hotel rooms	67	**78**	62	-16	62	-16	61	-17	**76**	-2
34	Park	67	**77**	62	-15	62	-15	61	-16	**77**	0
35	77 residential units	67	**76**	64	-12	63	-13	**66**	-10	**77**	1
36	32 residential units	67	**69**	63	-6	63	-6	64	-5	**69**	0
37	77 residential units	67	**73**	63	-10	63	-10	63	-10	**72**	-1
38	32 residential units	67	**76**	64	-12	64	-12	64	-12	**76**	0
39	312 residential units	67	**72**	**66**	-6	**66**	-6	**66**	-6	**71**	-1
40	312 residential units	67	**71**	65	-6	64	-7	64	-7	**71**	0
41	138 hotel rooms	67	65	**66**	1	**66**	1	65	0	**66**	1
42	100 hotel rooms	67	**69**	**71**	2	**71**	2	**70**	1	**70**	1
43	636 residential units	67	**68**	**67**	-1	**66**	-2	**69**	1	**68**	0
44	695 residential units	67	**70**	**68**	-2	**68**	-2	**68**	-2	**67**	-3
45	698 residential units	67	**67**	65	-2	**67**	0	**67**	0	**67**	0
46	130 residential units	67	**68**	**66**	-2	**68**	0	**68**	0	**68**	0

Notes: FHWA's abatement criterion for traffic noise is 67 dBA for most noise-sensitive land uses and 72 dBA for commercial uses.
An impact occurs if the traffic noise level approaches within 1 dBA of the criterion (66 or 71 dBA) or exceeds it.
Noise-sensitive locations that do not include outdoor use areas (FHWA Activity Category E) have an interior noise-level impact criterion of 52 dBA.
Noise levels that approach or exceed the criterion are shown in **bold**.
dBA = A-weighted decibel
FHWA = Federal Highway Administration

Exhibit 5-3. Modeled 2030 Noise Levels – North Area

Receptor	Noise-Sensitive Land Use	Noise Abatement Criterion (dBA)	Existing Noise Level (dBA)	2030 Viaduct Closed (No Build Alternative)		2030 Bored Tunnel Alternative		2030 Cut-and-Cover Tunnel Alternative		2030 Elevated Structure Alternative	
				Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)
47	Commercial use	72	67	66	-1	65	-2	66	-1	66	-1
48	Park	67	**67**	**67**	0	**66**	-1	**66**	-1	**66**	-1
49	Pacific Science Center	67	65	65	0	64	-1	64	-1	64	-1
50	Commercial use	72	66	67	1	65	-1	65	-1	65	-1
51	190 residential units	67	64	64	0	62	-2	61	-3	61	-3
52	132 residential units	67	**77**	**77**	0	**71**	-6	**76**	-1	**76**	-1
53	53 residential units	67	**77**	**77**	0	**73**	-4	**77**	0	**78**	1
54	Park	67	61	61	0	60	-1	62	1	62	1
55	60 residential units	67	64	64	0	65	1	**67**	3	**67**	3
56	Commercial use	72	67	69	2	66	-1	67	0	67	0
57	159 hotel rooms	67	**76**	**77**	1	**73**	-3	**80**	4	**80**	4
58	235 hotel rooms	67	**74**	**75**	1	**72**	-2	**80**	6	**80**	6
59	196 hotel rooms	67	**77**	**77**	0	**71**	-6	**75**	-2	**75**	-2
60	123 hotel rooms	67	65	**66**	1	**66**	1	**67**	2	**68**	3
61	Experience Music Project	67	64	65	1	**66**	2	**67**	3	**67**	3
62	Commercial use	72	69	69	0	**72**	3	**72**	3	**72**	3
63	Public space	67	**68**	**68**	0	**69**	1	**70**	2	**70**	2
64	Public space	67	**73**	**73**	0	**74**	1	**72**	-1	**71**	-2
65	Commercial use	72	65	65	0	60	-5	66	1	66	1
66	158 hotel rooms	67	**67**	**67**	0	65	-2	65	-2	65	-2

Exhibit 5-3. Modeled 2030 Noise Levels – North Area (continued)

Receptor	Noise-Sensitive Land Use	Noise Abatement Criterion (dBA)	Existing Noise Level (dBA)	2030 Viaduct Closed (No Build Alternative)		2030 Bored Tunnel Alternative		2030 Cut-and-Cover Tunnel Alternative		2030 Elevated Structure Alternative	
				Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)	Noise Level (dBA)	Change From Existing (dBA)
67	School	67	**66**	**67**	1	**68**	2	**68**	2	**68**	2
68	92 residential units	67	65	65	0	**68**	3	**68**	3	**68**	3
69	Commercial use	72	**71**	**71**	0	**75**	4	**75**	4	**75**	4
70	4 residential units and 1 church	67	**68**	**68**	0	**72**	4	**72**	4	**72**	4

Notes: FHWA's abatement criterion for traffic noise is 67 dBA for most noise-sensitive land uses and 72 dBA for commercial uses.
An impact occurs if the traffic noise level approaches within 1 dBA of the criterion (66 or 71 dBA) or exceeds it.
Noise-sensitive locations that do not include outdoor use areas (FHWA Activity Category E) have an interior noise-level impact criterion of 52 dBA.
Noise levels that approach or exceed the criterion are shown in **bold**.
dBA = A-weighted decibel
FHWA = Federal Highway Administration

5.1.5 Scenario 2: Catastrophic Collapse of SR 99

This scenario considers the effects of a catastrophic failure and collapse of SR 99. A seismic event of similar or greater magnitude than the 2001 Nisqually earthquake could trigger failure and collapse of portions of the viaduct. This scenario would have the greatest effect on people and the environment. Structural failure of the viaduct could cause injuries and death to people traveling on or near the structure at the time of the seismic event. This type of event could cause buildings to be damaged or collapse and cause extensive damage to utilities. Travel delays would be severe. The environmental effects and length of time it would take to repair the SR 99 corridor are unknown, but the effects would be severe. During the closure of SR 99, noise levels along the waterfront would be lower than existing levels.

5.2 Operational Effects of the Bored Tunnel Alternative

The project area for the Bored Tunnel Alternative includes the south area, the central area where SR 99 would pass under downtown Seattle, and the north area. The modeled traffic noise levels for these areas are described below.

Long-term operational traffic noise levels for the Bored Tunnel Alternative were modeled for the year 2030. With the Bored Tunnel Alternative, noise levels near Alaskan Way in the south area would be noticeably lower than existing conditions, while along the central waterfront, they would be substantially lower than existing conditions. In the north area, future noise levels are predicted to be similar to existing conditions.

The loudest-hour traffic noise levels would range between 60 and 75 dBA at the modeled sites (see Exhibits 5-1, 5-2, and 5-3). Changes in traffic noise levels are predicted to be between a 16-dBA decrease and a 4-dBA increase relative to existing levels because of minor changes in traffic patterns compared to existing traffic patterns. A 2-dBA change in noise level is the smallest change that can be heard by sensitive listeners.

Under the 2030 Bored Tunnel Alternative, no sites are predicted to exceed the severe noise impact criterion (noise levels exceeding 80 dBA at sensitive land uses). The number of sensitive receptors that meet the noise abatement criteria would be higher than the number under existing conditions, mostly in the central area between S. King Street and Denny Way. For example, under existing conditions, Waterfront Park (receptor 29) is subjected to a peak traffic noise level of 71 dBA, whereas under the Bored Tunnel Alternative, it would be subjected to a peak traffic noise level of 66 dBA. Under the Bored Tunnel Alternative, noise levels are predicted to exceed the noise abatement criteria at 40 of the 70 modeled sites.

Many of the residential and hotel sites have no private outdoor use areas. The appropriate criterion at these sites is 52 dBA (Category E) inside the building with the windows closed.

5.2.1 South Area

As shown in Exhibit 5-1, the modeled 2030 Bored Tunnel Alternative traffic noise levels in the south area approach or exceed the FHWA noise abatement criteria at six of the nine modeled sites, representing approximately 135 residential units, 220 hotel rooms, and 2 parks or public spaces.

5.2.2 Central Area

As shown in Exhibit 5-2, the modeled 2030 Bored Tunnel Alternative, traffic noise levels in the central area approach or exceed the FHWA noise abatement criteria at 19 of the 37 modeled sites, representing approximately 3,289 residential units, 353 hotel rooms, 120 shelter beds, 4 parks or public spaces, and 2 commercial uses. At most of the modeled sites in the central area, traffic noise levels decrease relative to existing conditions.

5.2.3 North Area

As shown in Exhibit 5-3, the modeled 2030 Bored Tunnel Alternative traffic noise levels approach or exceed the FHWA noise abatement criteria at 15 of the 24 modeled sites, representing approximately 281 residential units, 713 hotel rooms, 1 school, 1 church, 4 parks or public spaces, and 2 commercial or other less noise-sensitive uses.

5.2.4 Ventilation System Noise

The Bored Tunnel Alternative would require the construction and operation of a mechanical ventilation system. Land use in the south area and near the location of the proposed tunnel operations building is mostly industrial and commercial, with some office buildings, condominiums, and hotels. Several office buildings, condominiums, and hotels are located near the north area and the location of proposed tunnel operations building. The ventilation system would be designed to not exceed the City's maximum permissible sound levels (Exhibit 3-7). The ventilation system (including but not limited to all ventilation fans and jet fans) would not exceed either 60 dBA at the nearest commercial uses or 57 dBA at the property line of the nearest residential use during normal operations, whichever is the most restrictive. Fans that normally operate during nighttime hours (10:00 p.m. to 7:00 a.m. on weekdays and 10:00 p.m. to 9:00 a.m. on weekends and legal holidays) would be designed not to exceed 47 dBA at the property line of the nearest residential use.

With the Bored Tunnel Alternative, the ventilation fans and jet fans would be designed for 92 dBA maximum at 10 feet from either the fan outlet or the jet fans to meet OSHA hearing protection standards.

5.3 Operational Effects of the Cut-and-Cover Tunnel Alternative

The project area for the Cut-and-Cover Tunnel Alternative includes the south area, the central area where SR 99 would pass under downtown Seattle, and the north area. The modeled traffic noise levels for these areas are described below.

Long-term operational traffic noise levels for the Cut-and-Cover Tunnel Alternative were modeled for the year 2030. Noise levels near Alaskan Way in the south area would be noticeably lower than existing conditions, while along the central waterfront, noise levels would be substantially lower than existing conditions. In the north area, future noise levels are predicted to be similar to existing conditions.

The loudest-hour traffic noise levels would range between 61 and 80 dBA at the modeled locations (see Exhibits 5-1, 5-2, and 5-3). Changes in traffic noise levels are predicted to be between a 17-dBA decrease and a 6-dBA increase relative to existing levels because of changes in traffic patterns compared to existing traffic patterns. A 2-dBA change in noise levels is the smallest change that can be heard by sensitive listeners.

Under the 2030 Cut-and-Cover Tunnel Alternative, two sites are predicted to exceed the severe noise impact criterion (noise levels exceeding 80 dBA at sensitive land uses). The number of sensitive receptors that meet the noise abatement criteria would be higher than the number under existing conditions, mostly in the central area between S. King Street and Denny Way. For example, under existing conditions, Waterfront Park is subjected to a peak traffic noise level of 71 dBA, whereas under the Cut-and-Cover Tunnel Alternative, it would be subjected to a peak traffic noise level of 65 dBA. Under the Cut-and-Cover Tunnel Alternative, noise levels are predicted to exceed the noise abatement criteria at 40 of the 70 modeled sites.

Many of the residential and hotel sites have no private outdoor use areas. The appropriate criterion at these sites is 52 dBA (Category E) inside the building with the windows closed.

5.3.1 South Area

As shown in Exhibit 5-1, the modeled 2030 Cut-and-Cover Tunnel Alternative traffic noise levels in the south area approach or exceed the FHWA noise abatement criteria at six of the nine modeled sites, representing approximately 135 residential units, 220 hotel rooms, and 2 parks or public spaces.

5.3.2 Central Area

As shown in Exhibit 5-2, the modeled 2030 Cut-and-Cover Tunnel Alternative traffic noise levels in the central area approach or exceed the FHWA noise abatement criteria at 18 of the 37 modeled sites, representing 3,065 residential units, 324 hotel rooms, 120 shelter beds, 7 parks or public spaces, and 6 commercial or other less noise-sensitive uses. At most of the modeled sites in the central area, traffic noise levels decrease relative to existing conditions.

5.3.3 North Area

As shown in Exhibit 5-3, the modeled 2030 Cut-and-Cover Tunnel Alternative traffic noise levels approach or exceed the FHWA noise abatement criteria at 16 of the 24 modeled sites, representing approximately 341 residential units, 713 hotel rooms, 1 school, 1 church, 4 parks or public spaces, and 2 commercial or other less noise-sensitive uses.

5.3.4 Ventilation System Noise

The Cut-and-Cover Tunnel Alternative would require the construction and operation of a mechanical ventilation system. Mostly industrial and commercial uses are present in the south area and near the location of the proposed tunnel maintenance building, with some office buildings, condominiums, and hotels. Several office buildings, condominiums, and hotels are located in the north area and near the location of the proposed tunnel maintenance building. The ventilation system would be designed to not exceed the City's maximum permissible sound levels (Exhibit 3-7). The ventilation system (including but not limited to all ventilation fans and jet fans) would not exceed either 60 dBA at the nearest commercial uses or 57 dBA at the property line of the nearest residential use during normal operations, whichever is the most restrictive. Fans that normally operated during nighttime hours (10:00 p.m. to 7:00 a.m. on weekdays and 10:00 p.m. to 9:00 a.m. on weekends and legal holidays) would be designed not to exceed 47 dBA at the property line of the nearest residential use.

Within the cut-and-cover tunnel, the ventilation fans and jet fans would be designed for 92 dBA maximum at 10 feet from either the fan outlet or the jet fans to meet OSHA hearing-protection standards.

5.4 Operational Effects of the Elevated Structure Alternative

The project area for the Elevated Structure Alternative includes the south area, the central area, and the north area. The modeled traffic noise levels for these areas are described below.

Long-term operational traffic noise levels for the Elevated Structure Alternative were modeled for the year 2030. Under the Elevated Structure Alternative, noise levels near Alaskan Way near the south area, along the central waterfront, and near the north area are predicted to be similar to existing conditions.

The loudest-hour traffic noise levels would range between 61 and 80 dBA at the modeled locations (see Exhibits 4-1 and 4-2). Changes in traffic noise levels are predicted to be between a 3-dBA decrease and a 6-dBA increase relative to existing levels because of changes in traffic patterns compared to existing traffic patterns. A 2-dBA change in noise levels is the smallest change that can be heard by sensitive listeners.

Under the 2030 Elevated Structure Alternative, two sites are predicted to exceed the severe noise impact criterion (noise levels exceeding 80 dBA at sensitive land uses). The number of sensitive receptors that meet the noise abatement criteria would be similar to the number under existing conditions.

Many of the residential and hotel sites have no private outdoor use areas. The appropriate criterion at these sites is 52 dBA (Category E) inside the building with the windows closed.

5.4.1 South Area

As shown in Exhibit 5-1, the modeled 2030 Elevated Structure Alternative traffic noise levels in the south area approach or exceed the FHWA noise abatement criteria at six of the nine modeled sites, representing approximately 135 residential units, 220 hotel rooms, and 2 parks or public spaces.

5.4.2 Central Area

As shown in Exhibit 5-2, the modeled 2030 Elevated Structure Alternative traffic noise levels in the central area approach or exceed the FHWA noise abatement criteria at 35 of the 37 modeled sites, representing approximately 4,254 residential units, 782 hotel rooms, 120 shelter beds, 7 parks or public spaces, and 6 commercial or other less noise-sensitive uses. At most of the modeled sites in the central area, traffic noise levels decrease relative to existing conditions.

5.4.3 North Area

As shown in Exhibit 5-3, the modeled 2030 Elevated Structure Alternative traffic noise levels approach or exceed the FHWA noise abatement criteria at 16 of the 24 modeled sites, representing approximately 341 residential units, 713 hotel rooms, 1 school, 1 church, 4 parks or public spaces, and 2 commercial or other less noise-sensitive uses.

5.5 Operational Mitigation for All Build Alternatives

Noise can be controlled at three locations: (1) at the source (e.g., with mufflers and quieter engines), (2) along the noise path (e.g., with barriers, shielding, or increased distance), and (3) at the receptor (e.g., with insulation). Noise abatement is necessary only where frequent human use occurs and where a lower noise level would have benefits (USDOT 1982).

A variety of mitigation methods can be effective at reducing traffic noise impacts. For example, noise impacts from the long-term operation of the project could be reduced by implementing traffic management measures, acquiring land as buffer zones or for the construction of noise barriers or berms, realigning the roadway, and installing noise insulation for public use or nonprofit institutional structures (e.g., schools, hospitals, and museums). These mitigation measures were evaluated for their potential to reduce noise impacts from all three build alternatives.

5.5.1 Feasibility and Reasonableness of Mitigation

WSDOT evaluates many factors to determine whether mitigation would be feasible and reasonable. Determination of engineering feasibility includes evaluating whether mitigation could be constructed in a location to achieve a noise reduction of at least 7 dBA at the closest receptors and a reduction of 5 dBA or more at most of the first row of receptors. Determination of reasonableness includes determining the number of sensitive receptors benefited by at least 3 dBA; the cost-effectiveness of the mitigation; and concerns such as aesthetics, safety, and the desires of nearby residents. The reasonableness criteria for cost of noise mitigation provided per benefited receptor are summarized in Exhibit 5-4 (WSDOT 2006). For noise levels above 76 dBA, the allowed cost increases by $3,630 per dBA increase.

Exhibit 5-4. Mitigation Allowance for Noise Impacts

Design Year Traffic Noise Decibel Level (dBA)	Allowed Mitigation Cost per Household	Allowed Wall Surface Area per Household at $53.40 per Square Foot (square feet)
66	$37,380	700
67	$41,110	768
68	$44,640	836
69	$48,270	904
70	$51,900	972
71	$55,530	1,040
72	$59,160	1,108
73	$62,790	1,176
74	$66,420	1,244
75	$70,060	1,312
76	$73,690	1,380

Source: WSDOT 2006.

A final determination of the size and placement of noise barriers or berms and the implementation of other mitigation methods would take place during detailed project design, after an opportunity for public involvement and after approval at the local, state, and federal levels.

5.5.2 Mitigation Options

Traffic Management Measures

Traffic management measures include time restrictions, traffic control devices, signing for prohibition of certain vehicle types (e.g., motorcycles and heavy trucks), modified speed limits, and exclusive lane designations. A transportation-system management plan combined with increased transit facilities to encourage the continued use of carpools and public transit would reduce vehicle trips and, consequently, traffic noise. However, a 3-dBA decrease in traffic noise would require a reduction in traffic volume of approximately 50 percent. Speed limits could be reduced, but a reduction of 10 to 15 miles per hour would be required to decrease traffic noise by 5 dBA. Implementation of these measures would not be reasonable.

Land Acquisition for Noise Buffers or Barriers

The study area is densely developed. Land acquisition for noise buffers or barriers in an urban area such as the study area would require relocating numerous residents and businesses and would not be reasonable for the purpose of noise mitigation.

Realigning the Roadway

The horizontal alignment in the north and south areas is defined by available right-of-way. The vertical alignment is defined by the design features of the project. The cost of realigning the roadway would not be reasonable exclusively as an operational noise mitigation measure.

Sound-Absorptive Materials

The use of sound-absorptive materials can reduce or eliminate reflected noise at the portal of a roadway tunnel, which would reduce the traffic and ventilation fan noise at the tunnel portals. The WSDOT report on the Ship Canal Bridge Noise Study (WSDOT 2005) concluded that perforated metal panels with an interior core of sound-absorptive material are the most effective for reducing reflective noise. With a standard noise wall configuration, noise reductions have been modeled in the range of 1 to 8 dB, depending on the proximity to the noise receiver.

Noise Insulation of Buildings

Insulation of buildings could be feasible, but this remedy applies only to structures with public or nonprofit uses (Code of Federal Regulations, Title 23, Part 772; and Federal Register, Vol. 67, page 13731 [March 26, 2002]). This remedy does not apply to commercial and residential structures, which constitute most uses within the project area. This option also would not reduce exterior noise impacts.

Noise Barriers

Noise barriers include noise walls, berms, and buildings that are not noise sensitive. The effectiveness of a noise barrier is determined by its height, its length, and the project site's topography. To be effective, the barrier must block the line of sight between the highest point of a noise source (e.g., a truck's exhaust stack) and the highest part of a receiver. It must be long enough to prevent sounds from passing around the ends, have no openings such as driveway connections, and be dense enough so that noise would not be transmitted through it. Intervening rows of buildings that are not noise sensitive could also be used as barriers (USDOT 1973).

For a noise barrier to be constructed, it must be determined to be both feasible and reasonable. Exhibit 5-4 summarizes the mitigation allowance for barrier area provided per benefited receptor that is considered reasonable. For all three build alternatives, there are no feasible mitigation measures to further reduce traffic noise levels because the surface streets provide local access to downtown and the waterfront throughout the central waterfront. To be effective, the noise barriers would have to block access to the surface streets.

5.6 Operational Benefits

5.6.1 Bored Tunnel Alternative

Traffic noise levels north of S. King Street, along the central waterfront, and north of Denny Way to Harrison Street would be greatly reduced under the Bored Tunnel Alternative compared to existing levels. Peak traffic noise levels in the central waterfront area for 2030 are expected to be noticeably lower under the Bored Tunnel Alternative as compared to existing conditions. For example, under existing conditions, Waterfront Park is subjected to a peak traffic noise level of 71 dBA, whereas under the Bored Tunnel Alternative, the peak traffic noise level at this site would be 66 dBA.

5.6.2 Cut-and-Cover Tunnel Alternative

Traffic noise levels north of S. King Street, along the central waterfront, and north of Denny Way to Harrison Street would be greatly reduced under the

Cut-and-Cover Tunnel Alternative compared to existing levels. Peak traffic noise levels in the central waterfront area for 2030 are expected to be noticeably lower under the Cut-and-Cover Tunnel Alternative compared to existing conditions. For example, under existing conditions, Waterfront Park is subjected to a peak traffic noise level of 71 dBA, whereas under the Cut-and-Cover Tunnel Alternative, the peak traffic noise level at this site would be 65 dBA.

5.6.3 Elevated Structure Alternative

Under the Elevated Structure Alternative, traffic noise levels in the study area would be similar to the existing levels.

Chapter 6 Construction Effects and Mitigation

Construction noise during project activities is likely to be bothersome to some nearby residents and businesses. Construction workers would also be subjected to noise while working on the site. The noise over the course of project construction would vary spatially and temporally by build alternative. The approximate construction periods for the three build alternatives are as follows:

- Bored Tunnel Alternative – 65 months
- Cut-and-Cover Tunnel Alternative – 105 months
- Elevated Structure Alternative – 120 months

The construction methods are described in detail in Appendix B, Alternatives Descriptions and Construction Methods Discipline Report.

6.1 Common to All Alternatives

6.1.1 Construction Effects

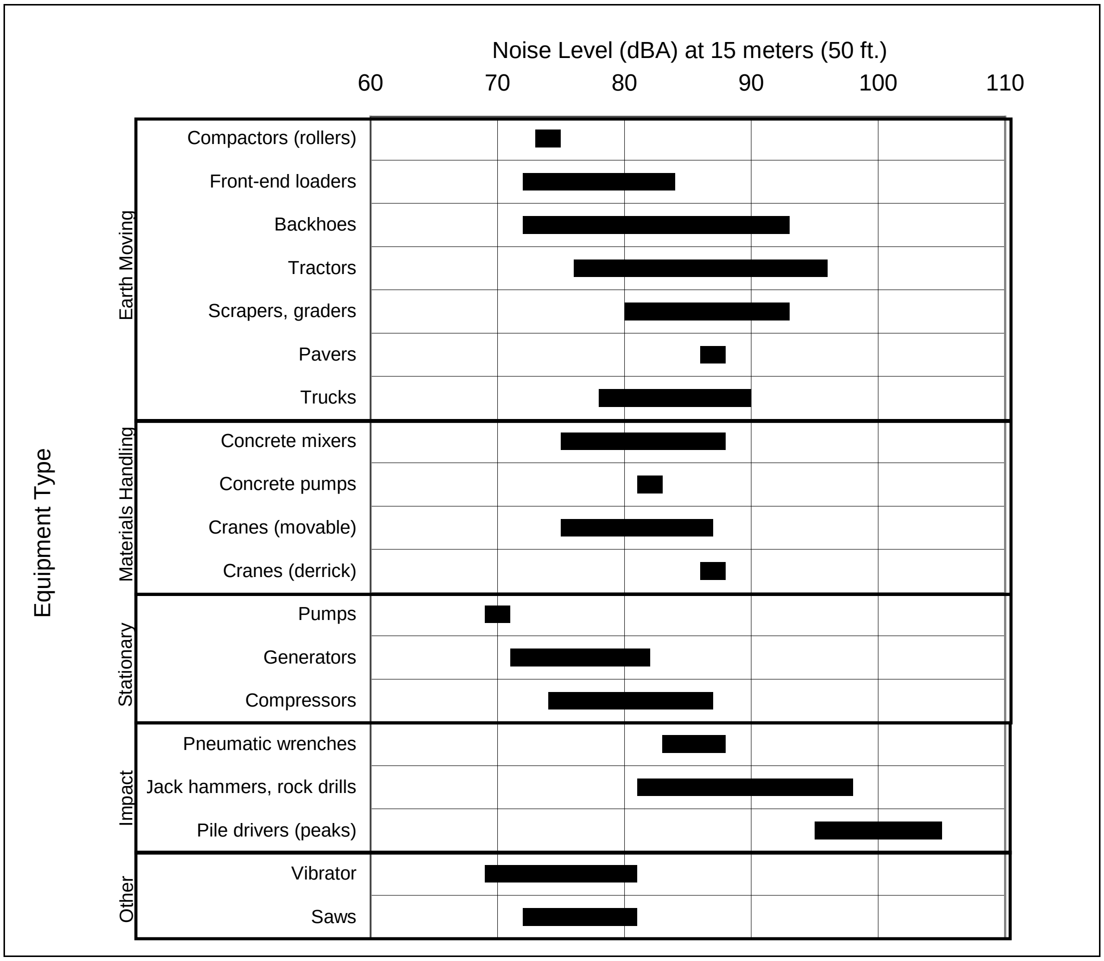
The potential construction effects would consist of noise and vibration. Various periods of disturbance would last for several months in any one area under each build alternative.

Noise

The most prevalent noise source at construction sites would be internal combustion engines. Earth-moving equipment, material-handling equipment, and stationary equipment are all engine-powered. Mobile equipment operates in a cyclic fashion, but stationary equipment (e.g., pumps, generators, and compressors) generates sound levels that are fairly constant. Because trucks would be present during most construction stages and not confined to construction staging areas, noise from trucks could affect more receptors. Other noise sources would include impact equipment and tools such as pile drivers. Impact tools could be pneumatically powered, hydraulic, or electric.

Construction noise would be intermittent, occurring at different times at various locations in the project area. Construction staging and laydown areas could also be located outside the project area (refer to Appendix B, Alternatives Description and Construction Methods Discipline Report). Construction noise levels would depend on the type, amount, and location of construction activities. The type of construction methods determines the maximum noise levels produced by the construction equipment used. The amount of construction activity would quantify how often construction noise would occur throughout the day. The location of the construction equipment relative to adjacent properties would determine any effects of distance in reducing the levels of construction noise. The maximum noise levels of construction equipment under each build alternative would be similar to the typical maximum noise levels from construction equipment presented in Exhibit 6-1.

Exhibit 6-1. Typical Noise Levels From Construction Equipment



Source: EPA 1971.
dBA = A-weighted decibels

As shown in Exhibit 6-1, maximum noise levels from construction equipment would range from 69 to 106 dBA L_{max} at 50 feet. Construction noise at locations farther away would decrease at a rate of 6 to 8 dBA per doubling of distance from the source. The number of occurrences of the L_{max} noise peaks would increase during construction, particularly during pile-driving activities. Because various pieces of equipment would be off, idling, or operating at less than full power at any given time, and because construction machinery is typically used to complete short-term tasks at any given location, average L_{eq} daytime noise levels would be less than the maximum noise levels presented in Exhibit 6-1. Within the Seattle city limits, construction noise levels may not exceed a maximum L_{eq} (7.5 minutes) of 99 dBA at 50 feet or the nearest property line (whichever is farther) (SMC 25.08.425).

Construction noise is allowed to exceed the City property line noise limits by 15 to 25 dBA during the day (7:00 a.m. to 10:00 p.m. on weekdays and 9:00 a.m. to 10:00 p.m. on weekends and legal holidays). Impact equipment such as jackhammers may not exceed an L_{eq} (h) of 90 dBA or an L_{eq} (7.5 minutes) of 99 dBA and may be operated only from 8:00 a.m. to 5:00p.m. on weekdays and from 9:00 a.m. to 5:00 p.m. on weekends and legal holidays, unless otherwise allowed by a noise variance.

The TBM would also produce some ground-borne noise, but due to the depth of the TBM and the ambient noise levels in the area, the noise would not be noticeable at street or building level.

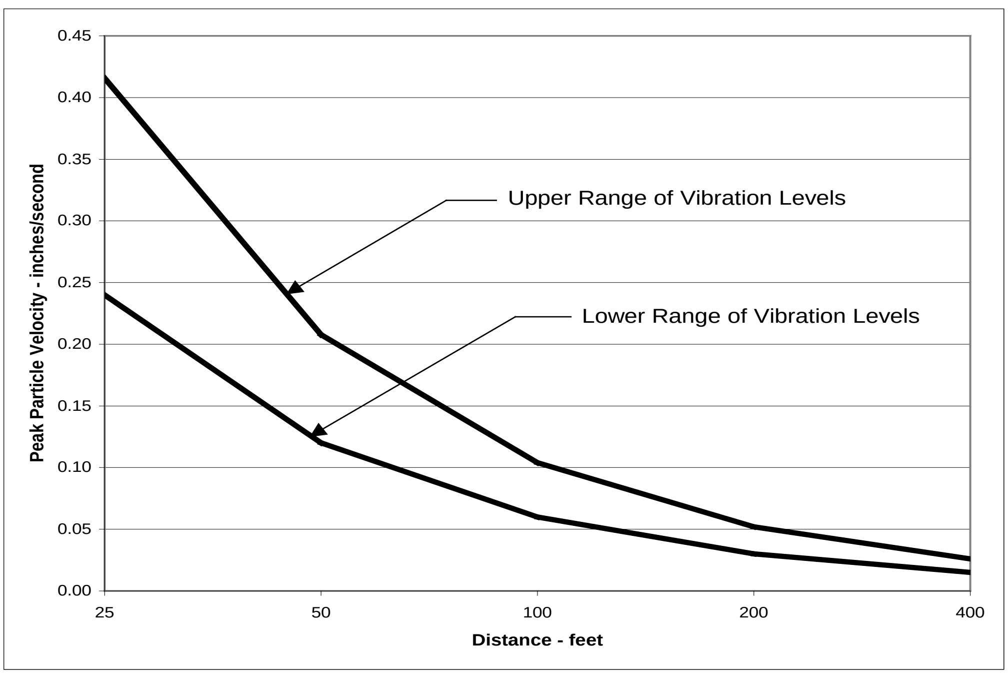
Vibration

Construction activities that would result in the highest levels of ground vibration are demolition of the existing viaduct structure and impact pile driving. For demolition and removal of the viaduct structure between S. King Street and the Battery Street Tunnel, concrete munchers would be used exclusively in locations adjacent to existing businesses to control the size and dispersion of concrete debris. In other areas, the viaduct could be demolished using various methods of concrete removal (including saw cutting and lifting segments out of place); using concrete pulverizers and shears mounted on excavators; or using concrete splitters, jackhammers, hoe rams, or core drilling to break up concrete. The use of jackhammers and hoe rams would result in the highest levels of vibration during the demolition activities. The expected PPV of ground vibration levels at 25 feet from the demolition activities is in the range of 0.24 to 0.42 inch per second (Exhibit 6-2). Hoe rams and jackhammers should not be used within 25 feet of older, extremely fragile buildings. The resulting vibration levels would exceed the damage risk criterion of 0.12 inch per second for older extremely fragile buildings but would not exceed the project's damage risk criterion of 0.50 inch per second for newer buildings. Demolition activities conducted 100 feet or more from existing structures would not result in vibration levels that exceed the damage risk criterion for older extremely fragile buildings. Structures in the project area that may be extremely fragile include unrestored areaways, the spaces beneath the sidewalks of older buildings, and historic buildings that have not been structurally retrofitted.

For impact pile driving, the PPV of ground vibration levels at 25 feet are expected to be in the range of 0.60 to 1.9 inches per second, depending on the size of and force exerted by the pile driver. These levels would substantially exceed the damage risk criteria of 0.12 inch per second for older extremely fragile buildings and 0.50 inch per second for newer buildings. At distances of 400 feet or greater, the damage risk is substantially lower and expected not to exceed 0.10 inch per second.

In general, the potential impact on underground and buried utilities due to construction vibration would be less than the damage risk for buildings. The only construction activity proposed for this project that would generate vibration levels that could damage utilities would be impact pile driving and demolition of the existing viaduct structure. Vibration from pile driving would not exceed the damage risk criteria of 4.0 inches per second PPV at distances greater than 25 feet for most buried utilities or 0.5 inch per second PPV at distances greater than 100 feet for older cast-iron water mains. The damage risk for utilities less than 25 feet from the impact pile driving and older cast-iron water mains less than 100 feet from the impact pile driving should be evaluated further during final design. During demolition of the viaduct, buried utilities would be protected from falling debris either by relocating the utilities or protecting them in place, depending on the feasibility.

Exhibit 6-2. Hoe Ram and Jack Hammer Vibration Levels



Note: Expected peak particle velocity calculated using equipment standards.

6.1.2 Construction Mitigation

Noise

Project construction may require substantial nighttime construction activities; therefore, a nighttime noise variance may be required from the City. Because of the magnitude of the project, Major Public Project Construction Noise Variances would be required. The application for a Major Public Project Construction Noise Variance involves the preparation of a noise management and mitigation plan for the project. Mitigation requirements for construction noise would be developed and specified in the noise variances in coordination with the City.

WSDOT will implement measures to minimize nighttime and weekend construction noise if it exceeds the noise variance levels (except in the case of emergency) during the hours between 10:00 p.m. and 7:00 a.m. on weekdays and between 10:00 p.m. and 9:00 a.m. on weekends and legal holidays. To reduce construction noise at nearby receptors, mitigation measures such as the following would be incorporated into construction plans, specifications, and variance requirements:

- Develop a construction noise management and monitoring plan that establishes specific noise levels for various activities that must not be exceeded during noise-sensitive nighttime hours (between 10:00 p.m. and 7:00 a.m. on weekdays and between 10:00 p.m. and 9:00 a.m. on weekends and legal holidays). This would establish a set of noise limits that could be met during construction while still protecting the public from excessive noise effects.
- Ensure that all equipment used during nighttime hours meets the nighttime noise level limits of the variance.
- Crush and recycle concrete off site, away from noise-sensitive receptors, to decrease construction noise effects. If recycled on site, an operations plan would be required to define the locations and hours of operation.
- Construct temporary noise barrier walls, curtains, or functionally equivalent materials around stationary equipment and long-term work areas located close to residences to decrease noise levels at nearby noise-sensitive receptors. This could reduce equipment noise by 5 to 10 dBA. For the Bored Tunnel Alternative, noise barrier walls are planned at both portal construction areas.
- Construct gates and/or doors in the noise barrier walls for sound containment, with the edges of the gates and doors overlapping the fence to eliminate gaps. Keep the gates and doors closed during nighttime hours, except to allow access to the construction site. Incorporate access doors (or man doors) into the gates to minimize the need to open the large gates during nighttime hours.
- Limit the noisiest construction activities, such as construction of secant piles, during noise-sensitive nighttime hours (between 10:00 p.m. and

7:00 a.m. on weekdays and between 10:00 p.m. and 9:00 a.m. on weekends and legal holidays).

- Prohibit jack hammering and impact pile driving during nighttime hours; impact or impulse tools used between 5 p.m. and 10:00 p.m. would be subject to a noise level limit of 5 dBA above the existing noise level.
- Use generators and compressors between 10:00 p.m. and 7:00 a.m. on weekdays between 10:00 p.m. and 9:00 a.m. on weekends and legal holidays, provided that WSDOT-approved noise mitigation shields are used during this type of work. Specifications for this measure may be modified or changed at the request of the Seattle Department of Planning and Development, depending on the specific location and duration.
- Equip construction equipment engines with adequate mufflers, intake silencers, and engine enclosures, which could reduce noise by 5 to 10 dBA. Out-of-specification mufflers can increase equipment noise by 10 to 20 dBA.
- Use the quietest equipment available, which could reduce noise by 5 to 10 dBA.
- Turn off construction equipment during prolonged periods of non-use, which could eliminate noise from construction equipment during those periods.
- Require maintenance of all equipment and training of equipment operators, which could reduce noise levels and increase operational efficiency.
- Where possible, locate stationary equipment away from noise-sensitive receiving properties.
- Use two-way radios for communication and prohibit the use of public address systems during nighttime hours, except for emergency notifications.
- Grade surface irregularities on construction sites to prevent impact noise and ground vibrations from passing vehicles.
- Provide a 24-hour noise complaint line.
- Notify nearby residents and businesses before periods of intense nighttime construction.
- Where amenable, provide heavy window coverings or other temporary soundproofing material on adjacent buildings for nighttime noise-sensitive locations where prolonged periods of intense nighttime construction would occur.

- Use broadband or strobe backup warning devices or use backup observers in lieu of backup warning devices for all equipment except dump trucks, in compliance with Washington Administrative Code, Sections 296-155-610 and 296-155-615 (WAC 296-155-610; WAC 296-155-615). Backup observers and broadband or strobe backup warning devices must also be used for dump trucks between 10:00 p.m. and 7:00 a.m. on weekdays and between 10:00 p.m. and 9:00 a.m. on weekends and legal holidays (WAC 296-155-610). The use of pure tone backup warning devices is prohibited after 10:00 p.m. and before 7:00 a.m. on weekdays and before 9:00 a.m. on weekends and legal holidays.
- Provide the trucks hauling materials in or out of staging areas and work zones with well-maintained bed liners (as inspected and approved by the WSDOT engineer) to be used between 10:00 p.m. and 7:00 a.m. Sunday night through Friday and between 10:00 p.m. and 9:00 a.m. Friday night through Sunday morning and legal holidays. The bed liners may consist of aluminum, rubber, sand, or dirt.
- During pavement removal, clean up any material that has spilled on the roadway by hand or by sweeping; avoiding the use of scraping equipment.

Vibration

Impact pile driving could be the most prominent source of vibration for this project. The following measures to reduce vibration from impact pile driving could be used, when appropriate for specific site conditions:

- Jetting – The use of a mixture of air and water pumped through a high-pressure nozzle to erode the soil adjacent to the pile to facilitate placement of the pile.
- Predrilling – Predrilling a hole for a pile can be used to place the pile at or near its design depth, eliminating most or all impact driving.
- Cast-in-place or auger piles – These piles would eliminate impact driving and limit vibration to the lower levels generated by drilling.
- Pile cushioning – Pile cushioning is a resilient material that is placed between the driving hammer and the pile.
- Alternative nonimpact drivers – Several types of proprietary pile-driving systems have been designed specifically to reduce the impact-induced vibration by means of torque and down pressure or hydraulic static loading. These methods would be expected to substantially reduce the adverse vibration effects of pile placement.

Vibration from other construction activities can be reduced by either restricting their location to predetermined distances from historic structures or other vibration-sensitive receivers (such as sensitive utilities) or by using alternative equipment or construction methods. An example is the use of saws or rotary rock cutting heads to cut bridge decks or concrete slabs, instead of a hoe ram. During demolition of the viaduct, buried utilities will be protected from falling debris either by relocating the utilities or protecting them in place with construction mats and plating.

Vibration monitoring will be required at the nearest historic structure or vibration-sensitive receiver (such as sensitive utilities) within 300 feet of construction activities. The monitoring data will be compared to the project's vibration criteria to ensure that ground vibration levels do not exceed the damage risk criteria for historic and nonhistoric buildings and sensitive utilities.

6.2 Bored Tunnel Alternative

6.2.1 South Area

The south area design includes the construction of a tunnel operations building for ventilation and operations and maintenance, as well as ramps providing north-and southbound on and off movements for SR 99 between S. Royal Brougham Way and S. King Street. In the south area, access to the bored tunnel would be provided via a side-by-side, retained cut tunnel beginning at S. Royal Brougham Way. The retained cut tunnel would transition to a cut-and-cover tunnel and then to a bored tunnel near S. Dearborn Street. A new southbound on-ramp and northbound off-ramp would connect with Alaskan Way S. near S. King Street.

Construction durations in the south area, such as that for utility relocation activities are based on the assumption of three shifts per day working an average of 6 days per week for tunnel and area construction. The bored tunnel drive would take place 6 days per week with the seventh day used for TBM and auxiliary machinery maintenance.

Temporary, large-scale stationary equipment or structures could be located in the WOSCA south staging area. The WOSCA site is west of First Avenue S., between S. Royal Brougham Way and S. King Street. This site is the likely location of a temporary concrete batch plant for construction work in the south area, if one is deemed necessary. This site would also be used for assembly of the TBM substation and storage and laydown of construction materials. The location of hopper cars or conveyors to move earth spoils has not yet been determined, but the noise associated with these activities could be bothersome to nearby residences.

The tunnel operations building would be located on the block bounded by S. Dearborn Street, Alaskan Way S., and Railroad Way S. Part of the building would be constructed underground.

A four-lane detour route is planned between Railroad Way S. and S. Atlantic Street for maintaining SR 99 traffic during construction, which would increase the traffic noise levels.

Noise associated with construction activities in the south area could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

6.2.2 Central Area

The current plan is to initiate construction of the cut-and-cover tunnel from the south portal access point at Alaskan Way S., between S. Royal Brougham Way and S. King Street. Bored Tunnel construction is planned to begin near S. King Street. The bored tunnel would continue under Alaskan Way S. to approximately S. Washington Street, where it would curve slightly eastward and away from the waterfront and then travel under First Avenue beginning at approximately University Street. At Stewart Street, it would travel in a northerly direction under Belltown. At Denny Way, the bored tunnel would travel under Sixth Avenue N., where it would transition to a side-by-side surface roadway at about Harrison Street. Two roadway decks would be construction within the tunnel, with the southbound roadway on the top and the northbound roadway on the bottom. Each roadway deck would convey two lanes of traffic. Construction durations for this activity are based on the assumption of three shifts working 7 days per week.

The earth pressure balance machine has been selected as the TBM for the bored tunnel construction. This type of TBM can mine below the groundwater table and stabilize the tunnel face, as well as minimize surrounding ground movements and ground subsidence above the tunnel. Compensation grouting for the bored tunnel would occur between S. King and Seneca Streets. The spoils would be removed through the south portal and transported to a staging area (Terminal 46) for stockpiling by means of hoppers and conveyors before they are transported by truck or barge to the Mats Mats quarry in Jefferson County, Washington. Additional noise effects would occur from these ancillary construction activities, although the removal of spoils would take place primarily in a manufacturing/industrial zone with typically high noise levels.

The majority of noise and vibration associated with bored tunnel construction would occur below ground. The maximum noise levels would be similar to the typical maximum construction equipment noise levels presented in Exhibit 6-1. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

Viaduct Removal

Demolition of the existing Alaskan Way Viaduct from S. King Street to Battery Street would take approximately 9 months, assuming two shifts per day working 6 days per week. The viaduct structure between S. King Street and the Battery Street Tunnel would be demolished and removed once the bored tunnel construction is completed and the tunnel is operational. Removal of the existing viaduct would be the loudest activity for residents from S. King Street to the Battery Street Tunnel. The demolition is currently proposed to occur in two locations along the viaduct alignment concurrently. Each of the two demolition crews would work in about two-block segments at a time. This means that up to four blocks along the viaduct alignment would be under demolition at a time.

Noise associated with viaduct removal could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

Battery Street Tunnel Decommissioning

The Battery Street Tunnel would be closed after the bored tunnel is opened to traffic. The cross streets above the tunnel and the utilities would be maintained. According to the current proposal, crushed rubble from the demolition of the existing viaduct would be used to fill the tunnel approximately two-thirds full, and then a low-strength concrete slurry would be pumped in to solidify the rubble. The concrete slurry mix used to fill the remaining clearance space would be poured from openings in the street (Battery Street) above the tunnel. The concrete mix would need to be poured in several locations along the alignment of the Battery Street Tunnel.

Noise generated by the construction activities associated with the Battery Street Tunnel decommissioning could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

6.2.3 North Area

Tunnel boring operations would end just north of Thomas Street, and the TBM would be dismantled and extracted at this location. An open-cut extraction pit would be excavated to remove the TBM. At the end of the bored tunnel, SR 99 would begin to unbraid and transition into a cut-and-cover structure between Thomas and Harrison Streets. The new SR 99 would become a side-by-side roadway at Harrison Street, connecting back to the existing SR 99 just north of Mercer Street.

Construction in the north area would begin with slurry walls constructed along the eastern and western boundaries of the cut-and-cover sections between Thomas and Harrison Streets. The excavation used to extract the TBM would also accommodate the construction of the interior structures housing the north- and southbound roadway decks. A four-lane detour roadway for maintaining SR 99 traffic would be added half a block west of the existing alignment, which would increase the traffic noise levels during construction.

A tunnel operations building would be constructed in the north area between Thomas and Harrison Streets on the east side of Sixth Avenue N. Part of the building would be constructed underground.

Noise associated with construction activities in the north area could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

6.2.4 Mitigation

In addition to the mitigation measures for noise discussed in Section 6.1.2, WSDOT will implement the following mitigation measures for vibration as necessary before construction begins:

- Develop a detailed vibration mitigation and monitoring plan according to WSDOT requirements.
- Identify and categorize potentially affected receptors (building occupants), buildings (especially historic buildings in the Pioneer Square area), and underground utilities.
- Determine appropriate vibration measurement and/or monitoring locations.

- Perform a baseline ambient vibration survey at selected locations.
- Identify expected sources of vibration during construction activities, including the TBM, muck conveyor system, pile driving, and demolition of the existing viaduct.
- Estimate ranges of expected vibration levels at potentially affected receptors, buildings, and underground utilities.

If determined to be necessary and practical for specific receptors, WSDOT will implement the following mitigation measures:

- Develop an empirical site-specific ground vibration propagation model to improve accuracy of predictions as necessary.
- Perform ground vibration propagation tests at selected locations along the tunnel alignment in coordination with a geotechnical consultant.
- Compare predictions with specified criteria, summarize expected impacts, and recommend vibration mitigation measures where needed.

During construction, WSDOT will mitigate ground vibration to acceptable levels and continuously collect comprehensive vibration data. During construction, WSDOT will implement the following measures as necessary:

- Continuously monitor vibration at critical locations.
- Acquire vibration monitors that will be dedicated to the project.
- Daily review vibration data according to the vibration mitigation and monitoring plan.
- Perform ongoing refinement of predictions of building vibration levels as directly measured ground vibration data become available, especially with regard to portal operations.
- Support the public relations effort. Proper education and management of expectations of the public regarding vibration and noise issues are critical.
- Respond to construction vibration issues and/or complaints quickly to reassure the public that their concerns are being heard.

6.3 Cut-and-Cover Tunnel Alternative

6.3.1 South Area

The south area design includes the construction of a tunnel maintenance building and ramps providing north- and southbound on and off movements for SR 99. Construction durations for this activity are based on the assumption of two 8-hour shifts, each working 5 days per week; but the shifts could work up to 24 hours per day 7 days per week if necessary to maintain the schedule.

Other work in the south area includes construction of foundations, grading for roadways, installation of trenches for utilities, ground improvements, placement and compaction of fill, and removal of existing subsurface structures.

Temporary large-scale stationary equipment or structures could be located at the WOSCA south staging area. The WOSCA site is west of First Avenue S., between S. Royal Brougham Way and S. King Street. If a temporary concrete batch plant for construction work in the south area is needed, its likely location would be the WOSCA site. This site would also be used for storage and laydown of construction materials. The noise associated with these activities could be bothersome to nearby residences.

A four-lane detour route is planned between Railroad Way S. and S. Atlantic Street for maintaining SR 99 traffic during construction, which would increase traffic noise levels during construction.

Noise associated with construction activities in the south area could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

6.3.2 Central Area

The cut-and-cover tunnel would transition from a side-by-side, six-lane configuration to a stacked tunnel configuration north of S. Dearborn Street. The tunnel alignment would transition from a stacked double-level configuration to a side-by-side configuration between Spring Street and Union Street and would continue to the north in a side-by-side configuration to the Battery Street Tunnel.

The Cut-and-Cover Tunnel Alternative would replace the Elliott Bay Seawall from S. Jackson Street up to Broad Street. Between S. Jackson Street and S. Washington Street, soil improvements and new face paneling would replace the failing bulkhead at Pier 48. From S. Washington Street to Union Street, the seawall would be replaced with the west wall of the tunnel.

The Elliott Bay Seawall would be constructed in approximately the same location between S. Jackson Street and Yesler Way. North of Yesler Way, the new seawall would gradually move toward the east. Between Yesler Way and Madison Street, the new seawall face would be approximately 10 to 12 feet behind (landward of) the existing seawall.

Between Lenora Street and the Battery Street Tunnel, SR 99 would travel in a new lowered roadway (retained cut) section with overpasses at Elliott and Western Avenues and at the Bell Street intersection. The construction of SR 99 under Elliott and Western Avenues would require a combination of retained cuts and bridges.

Noise associated with construction activities in the central area could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

Viaduct Removal

The viaduct structure between S. King Street and the Battery Street Tunnel would be demolished and removed while the construction of the cut-and-cover tunnel is occurring. Removal of the existing viaduct would be the loudest activity for residents from S. King Street to the Battery Street Tunnel.

Noise associated with viaduct removal could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

Battery Street Tunnel Improvements

The Battery Street Tunnel would be retrofitted for improved seismic safety. The existing tunnel safety systems and facilities would be updated with a fire suppression system, ventilation, and new emergency egress structures near Second, Third, Fourth, and Sixth Avenues.

Noise generated by the construction activities associated with the Battery Street Tunnel improvements could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

6.3.3 North Area

The improvements proposed for SR 99 between the north portal of the Battery Street Tunnel and Aloha Street would lower the roadway profile into a side-by-side retained cut between the north portal and about Mercer Street.

Noise associated with construction activities in the north area could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

6.3.4 Mitigation

Other than the mitigation measures discussed in Section 6.1.2, no additional mitigation measures are proposed.

6.4 Elevated Structure Alternative

Construction of the Elevated Structure Alternative would be similar to that of the Cut-and-Cover Tunnel Alternative in the south and north areas.

6.4.1 South Area

In the south area, the alignment of the Elevated Structure Alternative would be very similar to that of the Cut-and-Cover Tunnel Alternative. The Elevated Structure Alternative would begin near S. Royal Brougham Way with an at-grade SR 99 roadway. Full north- and southbound access to and from SR 99 would be provided at S. Royal Brougham Way.

The southbound on- and off-ramps for SR 99 would feed directly into a reconfigured Alaskan Way S. at S. Dearborn Street, with three lanes in each direction.

Noise associated with construction activities in the south area could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

6.4.2 Central Area

In the central area, the Elevated Structure Alternative would replace the existing viaduct with a stacked aerial structure along the central waterfront. The SR 99 roadway would have three lanes in each direction and wider lanes and shoulders than the existing viaduct.

The existing ramps at Columbia and Seneca Streets would be rebuilt and connected to a fourth lane. This extra lane would improve safety for drivers accessing downtown Seattle on the midtown ramps. Drivers could access downtown Seattle using these reconstructed ramps in either direction:

- Northbound off-ramp to Seneca Street
- Southbound on-ramp from Columbia Street

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

Battery Street Tunnel Improvements

The Battery Street Tunnel would be retrofitted for improved seismic safety. The existing tunnel safety systems and facilities would be updated with a fire suppression system, ventilation, and new emergency egress structures near Second, Third, Fourth, and Sixth Avenues.

Noise generated by construction activities associated with the Battery Street Tunnel improvements could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

6.4.3 North Area

The improvements proposed for SR 99 between the north portal of the Battery Street Tunnel and Aloha Street would lower the roadway profile into a side-by-side retained cut between the north portal and about Mercer Street.

Noise associated with construction activities in the north could be bothersome to nearby residents and businesses. Current estimates indicate that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). A variance would be needed if City noise level limits are exceeded.

The maximum noise levels of construction equipment would be similar to the typical levels presented in Exhibit 6-1.

6.4.4 Mitigation

Other than the mitigation measures discussed in Section 6.1.2, no additional mitigation measures are proposed.

Chapter 7 TOLLING

7.1 General Description of Tolling

A range of tolling proposals was considered and analyzed. The considerations included using low, medium, or high tolls; varying the toll by time of day; applying a peak-only toll; tolling the tunnel segment only; or tolling the tunnel and the SR 99 corridor, by charging drivers who use the corridor to get to or through downtown Seattle from points north and south of the tunnel. The analysis did not assume that transit or carpools would pay a toll.

Further detail on tolling, the variables tested, and the analysis is provided in Appendix C, Transportation Discipline Report.

A major potential effect of tolling at any rate level or location is the diversion of traffic to other routes. People who do not want to pay the toll would choose to travel on a more congested route to save money. The tolling estimates assumed for this report were derived from the traffic modeling analysis. These estimates provided the percentage of drivers who would choose alternate routes. Much of the diverted traffic would use the alternate routes closest to SR 99: Alaskan Way or First Avenue/First Avenue S.

The increased traffic would change noise levels, affecting certain types of businesses, employees, residents, and customers. Appendix C, Transportation Discipline Report, discusses measures that would be implemented to mitigate the effects on traffic. However, the tolled build alternatives are not expected to increase the traffic effects enough to threaten the viability of businesses and other adjacent land uses.

7.2 Tolled Bored Tunnel Alternative

Long-term operational traffic noise levels under the tolled Bored Tunnel Alternative were modeled for the year 2030. Under the tolled Bored Tunnel Alternative, the noise levels would be similar to those of the non-tolled Bored Tunnel Alternative.

The loudest-hour traffic noise levels would range between 60 and 75 dBA at the modeled sites (see Exhibits 7-1, 7-2, and 7-3). The changes in traffic noise levels are predicted to be between a 16-dBA decrease and a 6-dBA increase compared to existing levels because of minor changes in traffic patterns compared to existing traffic patterns. A 2-dBA change in noise levels is the smallest change that can be heard by sensitive listeners.

Exhibit 7-1. Comparison of Modeled 2030 Noise Levels Under Tolled and Non-Tolled Conditions – South Area

			2030 Bored Tunnel Alternative Noise Levels (dBA)				2030 Cut-and-Cover Tunnel Alternative Noise Levels (dBA)				2030 Elevated Structure Alternative Noise Levels (dBA)			
Receptor[1]	Noise Abatement Criterion (dBA)	2015 Baseline Existing Noise Level (dBA)	Tolled Noise Level	Change From Existing	Non-Tolled Noise Level	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled)
1	72	67	66	-1	66	0	66	-1	66	0	66	-1	67	-1
2	67	**71**	**69**	-2	**70**	-1	**70**	-1	**70**	0	**69**	-2	**69**	0
3	67	**70**	**68**	-2	**69**	-1	**69**	-1	**69**	0	**68**	-2	**69**	-1
4	72	**71**	**71**	0	69	2	70	-1	70	0	70	-1	70	0
5	67	**71**	**68**	-3	**69**	-1	**69**	-2	**68**	1	**71**	0	**71**	0
6	67	**68**	**70**	2	**70**	0	**70**	2	**69**	1	**70**	2	**70**	0
7	67	**67**	**69**	2	**69**	0	**70**	3	**69**	1	**69**	2	**69**	0
8	72	70	67	-3	67	0	68	-2	66	2	70	0	70	0
9	67	**73**	**68**	-5	**68**	0	**69**	-4	**68**	1	**74**	1	**74**	0

Notes: FHWA's abatement criterion for traffic noise is 67 dBA for most noise-sensitive land uses and 72 dBA for commercial uses.
An impact occurs if the traffic noise level approaches within 1 dBA of the criterion (66 or 71 dBA) or exceeds it.
Noise-sensitive locations that do not include outdoor use areas (FHWA Activity Category E) have an interior noise-level impact criterion of 52 dBA.
Noise levels that approach or exceed the criterion are shown in **bold**.
dBA = A-weighted decibel
FHWA = Federal Highway Administration
[1] The noise-sensitive land use for these sites is the same as those listed in Exhibit 5-1.

Exhibit 7-2. Comparison of Modeled 2030 Noise Levels Under Tolled and Non-Tolled Conditions – Central Area

			2030 Bored Tunnel Alternative Noise Levels (dBA)				2030 Cut-and-Cover Tunnel Alternative Noise Levels (dBA)				2030 Tolled Elevated Structure Alternative Noise Levels (dBA)			
Receptor[1]	Noise Abatement Criterion (dBA)	2015 Baseline Existing Noise Level (dBA)	Tolled Noise Level	Change From Existing	Non-Tolled Noise Level	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled
10	67	64	61	-3	61	0	61	-3	61	0	64	0	63	1
11	67	**70**	**69**	-1	**69**	0	**69**	-1	**68**	1	**70**	0	**70**	0
12	67	64	62	-2	62	0	62	-2	61	1	64	0	64	0
13	67	**75**	**74**	-1	**74**	0	**75**	0	**74**	1	**77**	2	**78**	-1
14	67	**72**	**69**	-3	**68**	1	**68**	-4	**68**	0	**71**	-1	**71**	0
15	72	**75**	**73**	-2	**73**	0	**74**	-1	**73**	1	**73**	-2	**74**	-1
16	67	**69**	**66**	-3	**66**	0	**66**	-3	**66**	0	**68**	-1	**68**	0
17	67	**70**	**69**	-1	**68**	1	**68**	-2	**68**	0	**70**	0	**69**	1
18	72	**75**	**72**	-3	**72**	0	**73**	-2	**72**	1	**73**	-2	**74**	-1
19	67	**80**	**67**	-13	**67**	0	**67**	-13	**66**	1	**77**	-3	**78**	-1
20	72	**79**	70	-9	70	0	70	-9	69	1	**78**	-1	**79**	-1
21	72	**72**	69	-3	69	0	69	-3	69	0	**72**	0	**72**	0
22	67	**70**	65	-5	65	0	**66**	-4	**66**	0	**68**	-2	**69**	-1
23	72	**72**	67	-5	67	0	67	-5	66	1	**71**	-1	**71**	0
24	72	**77**	70	-7	70	0	**71**	-6	69	2	**76**	-1	**77**	-1
25	67	**70**	**68**	-2	**68**	0	**69**	-1	**69**	0	**71**	1	**70**	1
26	67	**72**	**66**	-6	**66**	0	63	-9	**66**	-3	**73**	1	**73**	0
27	67	**72**	65	-7	65	0	**66**	-6	64	2	**70**	-2	**71**	-1
28	67	**71**	**66**	-5	**66**	0	**66**	-5	65	1	**70**	-1	**71**	-1
29	67	**71**	**66**	-5	**66**	0	**66**	-5	65	1	**70**	-1	**71**	-1

Exhibit 7-2. Comparison of Modeled 2030 Noise Levels Under Tolled and Non-Tolled Conditions – Central Area (continued)

Receptor[1]	Noise Abatement Criterion (dBA)	2015 Baseline Existing Noise Level (dBA)	2030 Bored Tunnel Alternative Noise Levels (dBA)				2030 Cut-and-Cover Tunnel Alternative Noise Levels (dBA)				2030 Tolled Elevated Structure Alternative Noise Levels (dBA)			
			Tolled Noise Level	Change From Existing	Non-Tolled Noise Level	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled
30	67	**76**	62	-14	62	0	63	-13	61	2	**73**	-3	**74**	-1
31	67	**66**	62	-4	62	0	63	-3	61	2	**66**	0	**66**	0
32	67	**68**	63	-5	63	0	63	-5	61	2	**67**	-1	**67**	0
33	67	**78**	62	-16	62	0	63	-15	61	2	**75**	-3	**76**	-1
34	67	**77**	62	-15	62	0	62	-15	61	1	**76**	-1	**77**	-1
35	67	**76**	63	-13	63	0	65	-11	**66**	-1	**76**	0	**77**	-1
36	67	**69**	63	-6	63	0	63	-6	64	-1	**69**	0	**69**	0
37	67	**73**	62	-11	63	-1	63	-10	63	0	**72**	-1	**72**	0
38	67	**76**	63	-13	64	-1	64	-12	64	0	**76**	0	**76**	0
39	67	**72**	65	-7	**66**	-1	**66**	-6	**66**	0	**72**	0	**71**	1
40	67	**71**	64	-7	64	0	65	-6	64	1	**71**	0	**71**	0
41	67	65	**66**	1	**66**	0	**67**	2	65	2	**67**	2	**66**	1
42	67	**69**	**71**	2	**71**	0	**72**	3	**70**	2	**72**	3	**70**	2
43	67	**68**	**66**	-2	**66**	0	**68**	0	**69**	-1	**69**	1	**68**	1
44	67	**70**	**69**	-1	**68**	1	**69**	-1	**68**	1	**69**	-1	**67**	2
45	67	**67**	**67**	0	**67**	0	**68**	1	**67**	1	**68**	1	**67**	1
46	67	**68**	**68**	0	**68**	0	**68**	0	**68**	0	**69**	1	**68**	1

Notes: FHWA's abatement criterion for traffic noise is 67 dBA for most noise-sensitive land uses and 72 dBA for commercial uses.
An impact occurs if the traffic noise level approaches within 1 dBA of the criterion (66 or 71 dBA) or exceeds it.
Noise-sensitive locations that do not include outdoor use areas (FHWA Activity Category E) have an interior noise-level impact criterion of 52 dBA.
Noise levels that approach or exceed the criterion are shown in **bold**.
dBA = A-weighted decibel
FHWA = Federal Highway Administration
[1] The noise-sensitive land use for these sites is the same as those listed in Exhibit 5-2.

Exhibit 7-3. Comparison of Modeled 2030 Noise Levels Under Tolled and Non-Tolled Conditions– North Area

			2030 Bored Tunnel Alternative Noise Levels (dBA)				2030 Cut-and-Cover Tunnel Alternative Noise Levels (dBA)				2030 Elevated Structure Alternative Noise Levels (dBA)			
Receptor[1]	Noise Abatement Criterion (dBA)	2015 Baseline Existing Noise Level (dBA)	Tolled Noise Level	Change From Existing	Non-Tolled Noise Level	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled
47	72	67	66	-1	65	1	67	0	66	1	66	-1	66	0
48	67	**67**	**67**	0	**66**	1	**66**	-1	**66**	0	**66**	-1	**66**	0
49	67	65	65	0	64	1	64	-1	64	0	64	-1	64	0
50	72	66	66	0	65	1	66	0	65	1	66	0	65	1
51	67	64	63	-1	62	1	61	-3	61	0	61	-3	61	0
52	67	**77**	**72**	-5	**71**	1	**76**	-1	**76**	0	**76**	-1	**76**	0
53	67	**77**	**73**	-4	**73**	0	**77**	0	**77**	0	**77**	0	**78**	-1
54	67	61	61	0	60	1	62	1	62	0	62	1	62	0
55	67	64	**66**	2	65	1	**67**	3	**67**	0	**67**	3	**67**	0
56	72	67	67	0	66	1	67	0	67	0	67	0	67	0
57	67	**76**	**73**	-3	**73**	0	**79**	3	**80**	-1	**79**	3	**80**	-1
58	67	**74**	**73**	-1	**72**	1	**78**	4	**80**	-2	**79**	5	**80**	-1
59	67	**77**	**71**	-6	**71**	0	**75**	-2	**75**	0	**75**	-2	**75**	0
60	67	65	**67**	2	**66**	1	**67**	2	**67**	0	**68**	3	**68**	0
61	67	**64**	**68**	4	**66**	2	**67**	3	**67**	0	**67**	3	**67**	0
62	72	69	**72**	3	**72**	0	**71**	2	**72**	-1	**72**	3	**72**	0
63	67	**68**	**69**	1	**69**	0	**70**	2	**70**	0	**70**	2	**70**	0
64	67	**69**	**75**	6	**74**	1	**71**	2	**72**	-1	**71**	2	**71**	0
65	72	65	60	-5	60	0	66	1	66	0	66	1	66	0
66	67	67	65	-2	65	0	65	-2	65	0	65	-2	65	0

Exhibit 7-3. Comparison of Modeled 2030 Noise Levels Under Tolled and Non-Tolled Conditions – North Area (continued)

Receptor[1]	Noise Abatement Criterion (dBA)	2015 Baseline Existing Noise Level (dBA)	2030 Bored Tunnel Alternative Noise Levels (dBA)				2030 Cut-and-Cover Tunnel Alternative Noise Levels (dBA)				2030 Elevated Structure Alternative Noise Levels (dBA)			
			Tolled Noise Level	Change From Existing	Non-Tolled Noise Level	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled	Tolled Noise Levels	Change From Existing	Non-Tolled Noise Levels	Difference Between Non-Tolled and Tolled
67	67	**66**	**68**	2	**68**	0	**68**	2	**68**	0	**68**	2	**68**	0
68	67	65	**68**	3	**68**	0	**68**	3	**68**	0	**68**	3	**68**	0
69	72	**71**	**75**	4	**75**	0	**75**	4	**75**	0	**75**	4	**75**	0
70	67	**68**	**72**	4	**72**	0	**72**	4	**72**	0	**72**	4	**72**	0

Notes: FHWA's abatement criterion for traffic noise is 67 dBA for most noise-sensitive land uses and 72 dBA for commercial uses.
An impact occurs if the traffic noise level approaches within 1 dBA of the criterion (66 or 71 dBA) or exceeds it.
Noise-sensitive locations that do not include outdoor use areas (FHWA Activity Category E) have an interior noise-level impact criterion of 52 dBA.
Noise levels that approach or exceed the criterion are shown in **bold**.
dBA = A-weighted decibel
FHWA = Federal Highway Administration
[1] The noise-sensitive land use for these sites is the same as those listed in Exhibit 5-3.

The differences in traffic noise levels are predicted to be between a 1-dBA decrease and a 2-dBA increase compared to the non-tolled Bored Tunnel Alternative because of minor differences in traffic patterns.

No sites are predicted to exceed the severe noise impact criterion (noise levels exceeding 80 dBA at sensitive land uses with either the tolled or non-tolled Bored Tunnel Alternative. The number of sensitive receptors that meet the noise abatement criteria would be lower than the number under non-tolled conditions, mostly in the central section between S. King Street and Denny Way.

Many of the residential and hotel sites have no private outdoor use areas. The appropriate criterion at these sites is 52 dBA (Category E) inside the building with the windows closed.

7.3 Tolled Cut-and-Cover Tunnel Alternative

Long-term operational traffic noise levels under the tolled Cut-and-Cover Tunnel Alternative were modeled for the year 2030. Under the 2030 tolled Cut-and-Cover Tunnel Alternative, the noise levels near Alaskan Way along the central waterfront would be lower than existing conditions. In the south and north areas future noise levels are predicted to be similar to existing conditions. Under the tolled Cut-and-Cover Tunnel Alternative, the noise levels would be similar to those of the non-tolled Cut-and-Cover Tunnel Alternative.

The loudest-hour traffic noise levels would range between 61 and 79 dBA at the modeled sites (see Exhibits 7-1, 7-2 and 7-3). The changes in traffic noise levels changes are predicted to be between a 15-dBA decrease and a 4-dBA increase compared to existing levels. A 2-dBA change in noise levels is the smallest change that can be heard by sensitive listeners.

The differences in traffic noise levels are predicted to be between a 3-dBA decrease and a 2-dBA increase compared to the non-tolled Cut-and-Cover Tunnel Alternative because of minor differences in traffic patterns.

Under the 2030 non-tolled Cut-and-Cover Tunnel Alternative, two sites are predicted to exceed the severe noise impact criterion (noise levels exceeding 80 dBA at sensitive land uses). Under the 2030 tolled Cut-and-Cover Tunnel Alternative, the number of sensitive receptors that meet the noise abatement criteria would be lower than the number under non-tolled conditions, mostly in the central section between S. King Street and Denny Way.

Many of the residential and hotel sites have no private outdoor use areas. The appropriate criterion at these sites is 52 dBA (Category E) inside the building with the windows closed.

7.4 Tolled Elevated Structure Alternative

Long-term operational traffic noise levels under the tolled Elevated Structure Alternative were modeled for the year 2030. Under the tolled Elevated Structure Alternative, the noise levels near Alaskan Way in the south area, along the central waterfront, and in the north area are predicted to be similar to existing conditions. Under the tolled Elevated Structure Alternative, the noise levels would be similar to those of the non-tolled Elevated Structure Alternative.

The loudest-hour traffic noise levels would range between 61 and 79 dBA at the modeled sites (see Exhibits 7-1, 7-2, and 7-3). The changes in traffic noise levels are predicted to be between a 3-dBA decrease and a 5-dBA increase compared to existing levels because of changes in traffic patterns compared to existing conditions. A 2-dBA change in noise levels is the smallest change that can be heard by sensitive listeners.

The differences in traffic noise levels are predicted to be between a 1-dBA decrease and a 2-dBA increase compared to the non-tolled Elevated Structure Alternative because of minor differences in traffic patterns.

Under the 2030 non-tolled Elevated Structure Alternative, two sites are predicted to exceed the severe noise impact criterion (noise levels exceeding 80 dBA at sensitive land uses). The number of sensitive receptors that meet the noise abatement criteria would be lower than the number under non-tolled conditions, mostly in the central area between S. King Street and Denny Way.

Many of the residential and hotel sites have no private outdoor use areas. The appropriate criterion at these sites is 52 dBA (Category E) inside the building with the windows closed.

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