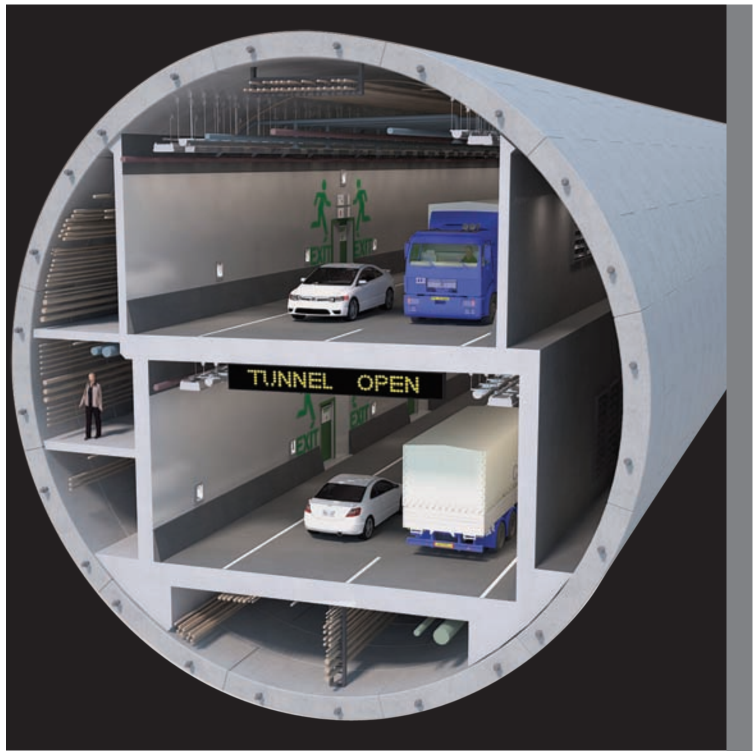
ALASKAN WAY VIADUCT REPLACEMENT PROJECT

2010 Supplemental Draft Environmental Impact Statement

APPENDIX F Noise Discipline Report



Submitted by:
PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC.

Prepared by:
PARAMETRIX

U.S. Department of Transportation
Federal Highway Administration

Washington State Department of Transportation

City of Seattle

OCTOBER 2010

This Page Intentionally Left Blank

Alaskan Way Viaduct Replacement Project

Supplemental Draft 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.
Jacobs Engineering Group Inc.
Magnusson Klemencic Associates, Inc.
Mimi Sheridan, AICP
Parametrix, Inc.
Power Engineers, Inc.
Shannon & Wilson, Inc.
William P. Ott Construction Consultants

This Page Intentionally Left Blank

TABLE OF CONTENTS

List of Attachments

A Cumulative Effects Analysis

List of Exhibits

ACRONYMS AND ABBREVIATIONS

μPa	micropascals
ANSI	American National Standards Institute
dB	decibels
dBA	A-weighted decibels for sound energy averages
CFR	Code of Federal Regulations
City	City of Seattle
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FR	Federal Register
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
Hz	hertz (cycles per second)
I-5	Interstate 5
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

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

This Page Intentionally Left Blank

Chapter 1 INTRODUCTION AND SUMMARY

1.1 Introduction

This discipline report evaluates the Bored Tunnel Alternative, the new alternative under consideration for replacing the Alaskan Way Viaduct. This report and the Alaskan Way Viaduct Replacement Project Supplemental Draft Environmental Impact Statement (EIS) that it supports are intended to provide new information and updated analyses to those presented in the March 2004 Alaskan Way Viaduct and Seawall Replacement Project Draft EIS and the July 2006 Alaskan Way Viaduct and Seawall Replacement Project Supplemental Draft EIS. The discipline reports present the detailed technical analyses of existing conditions and predicted effects of the Bored Tunnel Alternative. The results of these analyses are presented in the main volume of the Supplemental Draft EIS.

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. As part of the NEPA process, FHWA is also responsible for selecting the preferred alternative. FHWA will base their decision on the information evaluated during the environmental review process, including information contained within the Supplemental Draft EIS and the subsequent Final EIS. FHWA can then issue their 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 the city of Seattle. The March 2007 ballot included an elevated alternative and a surface-tunnel hybrid alternative. The citizens voted down both alternatives.

Following this election, the lead agencies committed to a collaborative process to find a solution to replace the viaduct along Seattle's central waterfront. This Partnership Process is described in Appendix S, the Project History Report. 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.

The environmental review process for the Alaskan Way Viaduct Replacement Project (the project) builds on the five Build Alternatives evaluated in the 2004 Draft

EIS and the two Build Alternatives evaluated in the 2006 Supplemental Draft EIS. It also incorporates the work done during the Partnership Process. The bored tunnel was not studied as part of the previous environmental review process, and so it becomes the eighth alternative to be evaluated in detail.

The Bored Tunnel Alternative analyzed in this discipline report and in the Supplemental Draft EIS has been evaluated both quantitatively and qualitatively. The Bored Tunnel 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.

Improvements at the south portal area include full northbound and southbound access to and from SR 99 between S. Royal Brougham Way and S. King Street. Alaskan Way S. would be reconfigured with three lanes in each direction. Two options are being considered for new cross streets that would intersect with Alaskan Way S.:

- New Dearborn Intersection – Alaskan Way S. would have one new intersection and cross street at S. Dearborn Street.
- New Dearborn and Charles Intersections – Alaskan Way S. would have two new intersections and cross streets at S. Charles Street and S. Dearborn Street.

Improvements at the north portal area would include restoring Aurora Avenue and providing full northbound and southbound access to and from SR 99 near Harrison and Republican Streets. Aurora Avenue would be restored to grade level between Denny Way and John Street, and John, Thomas, and Harrison Streets would be connected as cross streets. This rebuilt section of Aurora Avenue would connect to the new SR 99 alignment via the ramps at Harrison Street. Mercer Street would be widened for two-way operation from Fifth Avenue N. to Dexter Avenue N. Broad Street would be filled and closed between Ninth Avenue N. and Taylor Avenue N. Two options are being considered for Sixth Avenue N. and the southbound on-ramp:

- The Curved Sixth Avenue option proposes to build a new roadway that would extend Sixth Avenue N. in a curved formation between Harrison and Mercer Streets. The new roadway would have a signalized intersection at Republican Street.
- The Straight Sixth Avenue option proposes to build a new roadway that would extend Sixth Avenue N. from Harrison Street to Mercer Street in a typical grid formation. The new roadway would have signalized intersections at Republican and Mercer Streets.

For these project elements, the analyses of effects and benefits have been quantified with supporting studies, and the resulting data are found in the discipline reports (Appendices A through R). These analyses focus on assessing the Bored Tunnel Alternative's potential effects for both construction and operation, and consider appropriate mitigation measures that could be employed. The Viaduct Closed (No Build Alternative) is also analyzed.

The Alaskan Way Viaduct Replacement Project is one of several independent projects that 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 often referred to as the Alaskan Way Viaduct and Seawall Replacement Program (the Program). This Supplemental Draft EIS evaluates the cumulative effects of all projects in the Program; however, direct and indirect environmental effects of these independent projects will be considered separately in independent environmental documents. This collection of independent projects is categorized into four groups: roadway elements, non-roadway elements, projects under construction, and completed projects.

Roadway Elements

- Alaskan Way Surface Street Improvements
- Elliott/Western Connector
- Mercer West Project (Mercer Street improvements from Fifth Avenue N. to Elliott Avenue)

Non-Roadway Elements

- First Avenue Streetcar Evaluation
- Transit Enhancements
- Elliott Bay Seawall Project
- Alaskan Way Promenade/Public Space

Projects Under Construction

- S. Holgate Street to S. King Street Viaduct Replacement
- Transportation Improvements to Minimize Traffic Effects During Construction

Completed Projects

- SR 99 Yesler Way Vicinity Foundation Stabilization (Column Safety Repairs)
- S. Massachusetts Street to Railroad Way S. Electrical Line Relocation Project (Electrical Line Relocation Along the Viaduct's South End)

1.2 Summary

The project 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 receptors in the project vicinity. This report evaluates the Bored Tunnel Alternative for replacement of the existing viaduct.

The analysis of noise effects in the study area compares predicted future (year 2030) noise levels with existing levels and applicable criteria. Construction noise effects are described based on anticipated construction activities and typical noise levels for construction equipment. Traffic noise levels are predicted at specified noise-sensitive locations (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 like the noise level has been reduced by 50 percent.

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 City of Seattle (City) property-line noise limits as defined in the Seattle Noise Ordinance.

To evaluate traffic noise impacts, 68 sites, representing approximately 4,894 residential units and other noise-sensitive uses, were modeled using TNM. Under existing conditions, traffic noise levels at 48 of the 68 modeled sites approach or exceed the FHWA noise abatement criteria. Under the Bored Tunnel Alternative, the noise effects on sensitive receptors were evaluated for three areas: the south portal area, the central project area, and the north portal area (Exhibit 1-1). Mitigation measures for limiting noise and vibration effects from construction and long-term operation were also evaluated.

Expected 2030 peak traffic noise levels in the central waterfront area would be noticeably lower under the Bored Tunnel Alternative compared to the existing conditions. For example, under existing conditions, the Waterfront Park would have a peak traffic noise level of 71 dBA, while the Bored Tunnel Alternative peak traffic noise level would be 64 dBA. Peak traffic noise levels near the south and north portals would be similar to existing conditions.

Exhibit 1-1. Summary of Noise and Vibration Effects and Mitigation

Construction Effects	Operation Effects	Mitigation Measures
	Existing Viaduct (2015)	
There would be no construction effects associated with the 2015 Existing Viaduct.	2015 Existing Viaduct noise levels would be similar to existing conditions. Under existing conditions, traffic noise levels were predicted to approach or exceed the FHWA noise abatement criteria at 48 of the 68 modeled sites, representing approximately 3,746 residential units, 1,612 hotel rooms, 120 shelter beds, 1 church, 12 parks or public spaces, and 7 commercial use areas. 2015 Existing Viaduct traffic noise levels near south portal area for both options were predicted to approach or exceed the FHWA noise abatement criteria at 7 of the 9 modeled sites, representing approximately 135 residential units, 220 hotel rooms, 2 parks or public spaces, and 1 commercial use area. 2015 Existing Viaduct traffic noise levels near the central project area were predicted to approach or exceed the FHWA noise abatement criteria at 28 of the 37 modeled sites, representing approximately 3,426 residential units, 644 hotel rooms, 120 shelter beds, 6 parks or public spaces, 2 schools, and 4 commercial use areas. 2015 Existing Viaduct traffic noise levels near the north portal area for both options were predicted to approach or exceed the FHWA noise abatement criteria at 12 of the 22 modeled sites, representing approximately 748 hotel rooms, 1 church, 4 parks or public spaces, and 2 commercial use areas.	No mitigation measures would be implemented.

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

Construction Effects	Operation Effects	Mitigation Measures
	Bored Tunnel Alternative	
During the 66-month (5.5-year) construction period, noise would be bothersome to nearby residents and businesses.	For the design year (2030), traffic noise levels in the central waterfront would be noticeably lower than existing conditions, whereas noise levels at the north portal would be similar to existing conditions. The south portal traffic noise levels would be somewhat lower than existing conditions. 2030 condition were predicted to approach or exceed the FHWA noise abatement criteria at 40 of the 68 modeled sites, representing approximately 3,449 residential units, 1,444 hotel rooms, 120 shelter beds, 1 church, 2 schools, 10 parks or public spaces, and 3 commercial use areas. For the design year (2030), traffic noise levels near the south portal area for both options were predicted to approach or exceed the FHWA noise abatement criteria at 6 of the 9 modeled sites, representing approximately 135 residential units, 220 hotel rooms, and 2 parks or public spaces. For the design year (2030), traffic noise levels near the central project area were predicted to approach or exceed the FHWA noise abatement criteria at 18 of the 37 modeled sites, representing approximately 2,977 residential units, 353 hotel rooms, 120 shelter beds, 4 parks or public spaces, and 2 commercial use areas. For the design year (2030), traffic noise levels near the north portal area for both options were predicted to approach or exceed the FHWA noise abatement criteria at 16 of the 22 modeled sites, representing approximately 337 residential units, 871 hotel rooms, 1 church, 2 schools, 4 parks or public spaces, and 1 commercial use area.	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.

Vibration is an oscillatory motion, which can be described in terms of displacement, velocity, or acceleration. Vibration 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 and force exerted by the pile driver. 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 portal 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.

This Page Intentionally Left Blank

Chapter 2 BACKGROUND, REGULATIONS, AND GUIDELINES

2.1 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 measures 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 will add 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 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 A-weighted decibels (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 greatly affected 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 will travel 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 2-1 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 on Exhibit 2-2. This is because the receiver has a line of sight to the reflected surface.

Noise levels from traffic sources depend on volume, speed, and the type of vehicle. Generally, an increase in volume, speed, or vehicle size increases the traffic noise level generated by that source. Vehicular 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 2-1. Effect of Terrain on Sound Propagation

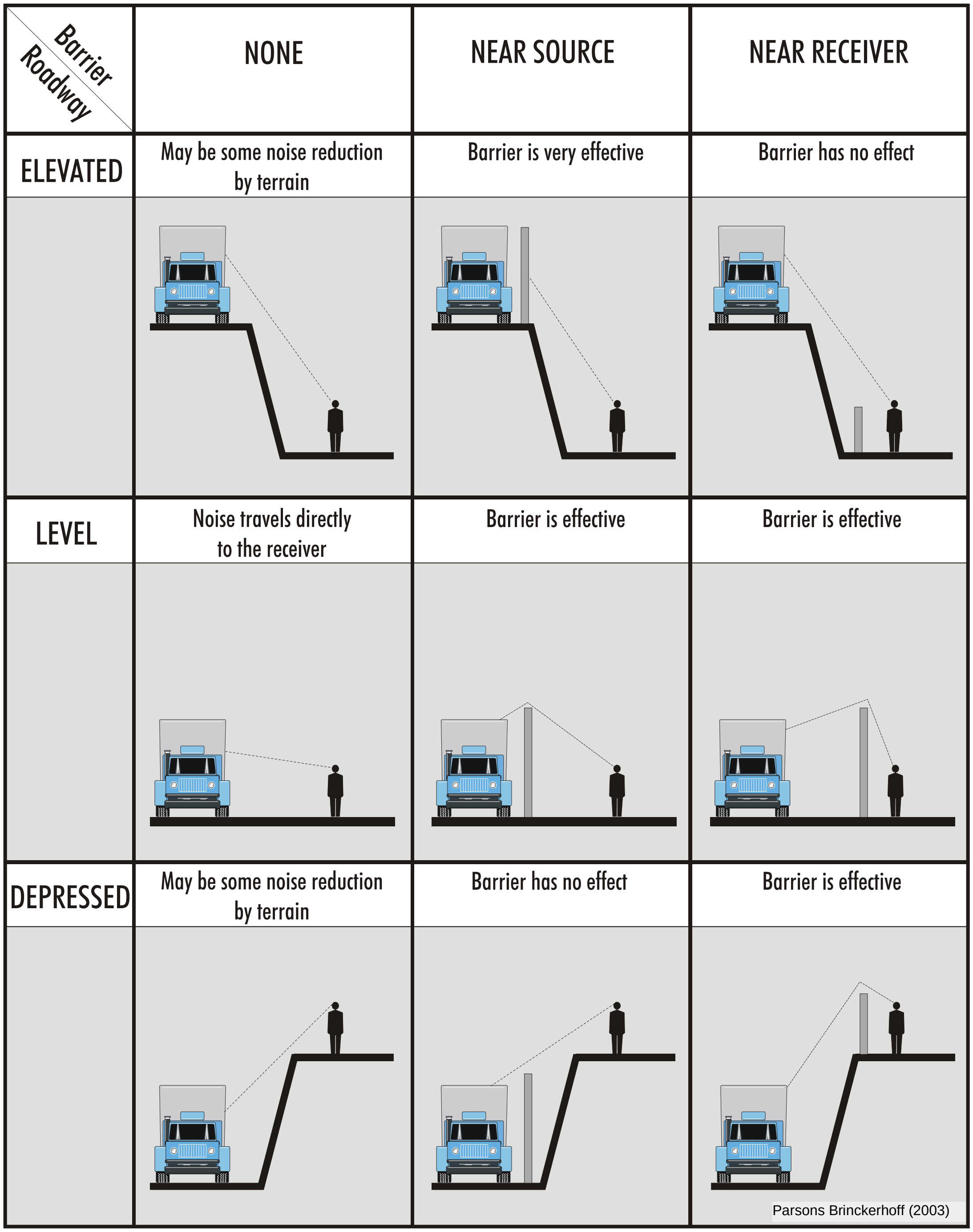
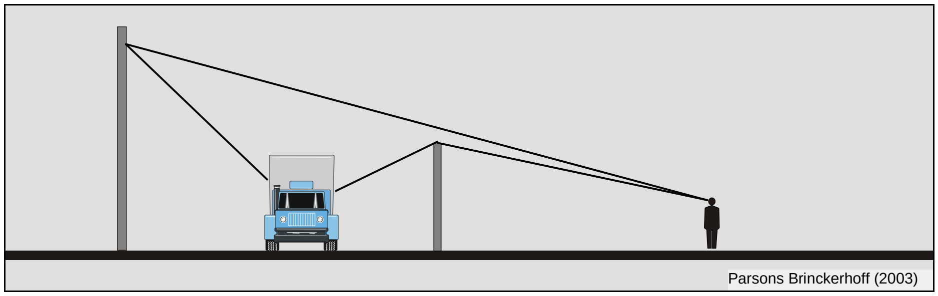


Exhibit 2-2. Effect of Reflected Sound

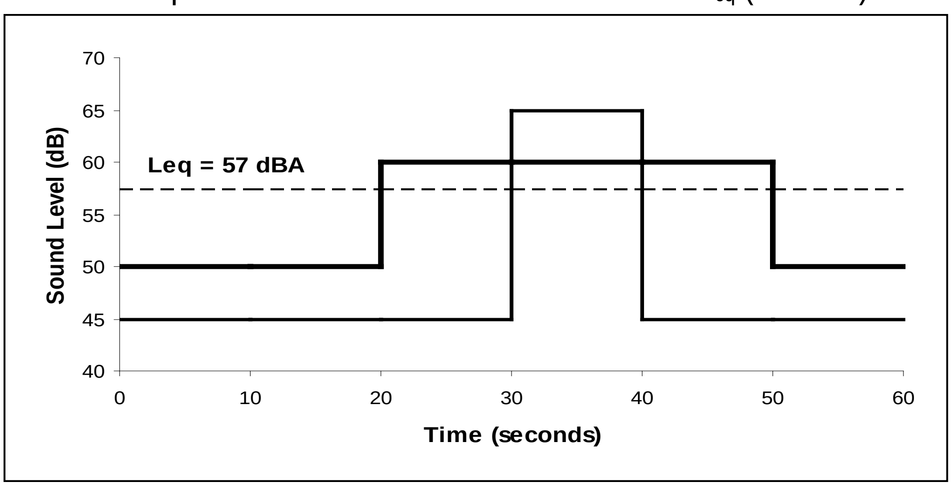


Note: Reflected noise may be greater than the shielded noise.

2.2 Sound Level Descriptors

A widely used descriptor for environmental noise is the equivalent sound level (L_{eq}). L_{eq} 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 2-3.

Exhibit 2-3. Example of Two Sound Patterns With the Same L_{eq} (1 Minute)



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 p.m. and 7 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 what the L_{eq} would be over a period in time when 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 on speech interference and sleep disruption. In comparison, L_{min} is the minimum sound level during a specific period.

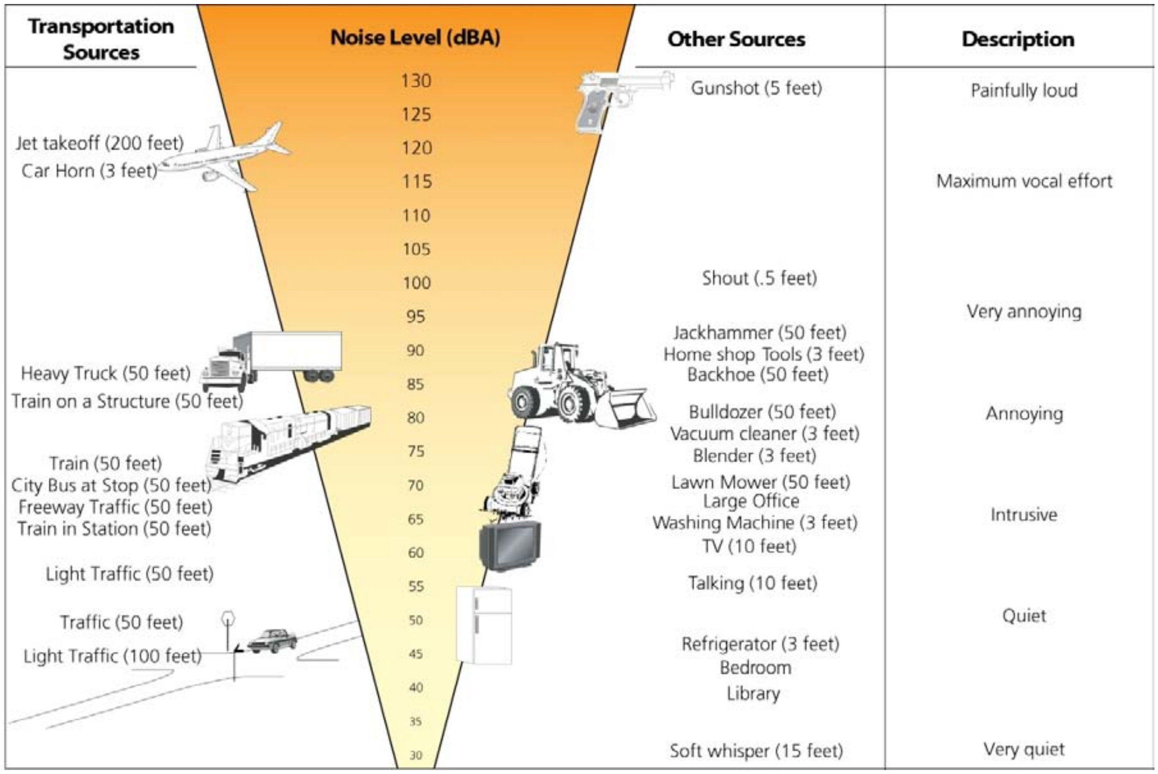
People will often find a moderately high, constant sound level more tolerable than a quiet background level interrupted by frequent high-level noise intrusions. An individual's response to sound depends on the range in which the sound varies in a given environment. For example, steady traffic noise from 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 for 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.

2.3 Typical Sound Levels

Typical A-weighted sound levels from various sources are presented in Exhibit 2-4. 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.

Background environmental sound levels vary widely in different environments. The U.S. Environmental Protection Agency (EPA) evaluated L_{dn} sound levels at various locations and has developed qualitative descriptions of the sound environments that experience various sound levels (Exhibit 2-5). The L_{dn} level is a measure of 24-hour environmental sounds and is often lower than the peak 1-hour sound levels.

Exhibit 2-4. Typical Sound Levels



Sources: USDOT 1995; EPA 1971, 1974.

Exhibit 2-5. 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.

2.4 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.

2.5 Noise Regulations and Impact Criteria

2.5.1 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 existing noise levels (USDOT 1982; Noise Abatement Council). Washington State Department of Transportation (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 to be a substantial increase.

The FHWA noise abatement criteria specify exterior L_{eq}(h) noise levels for various land activity categories (Exhibit 2-6). The noise criterion is 57 dBA for receptors where serenity and quiet are of extraordinary significance (Category A). The noise criterion is 67 dBA for residences, parks, schools, churches, and similar areas (Category B); the noise criterion is 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 2-6. For example, a noise level of 66 dBA or greater would approach or exceed the FHWA noise abatement criterion of 67 dBA for residences.

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. Severe noise impacts also occur if predicted future noise levels exceed existing levels by 15 dBA or more in noise-sensitive locations as the result of a project.

Exhibit 2-6. 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 Category A or B above.
D	-	Undeveloped lands.
E	52 (interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

Source: USDOT 1982.

2.5.2 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 2-7). The maximum permissible sound levels apply to construction activities only if they occur between 10 p.m. and 7 a.m. on weekdays or 10 p.m. and 9 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 2-7. City of Seattle Maximum Permissible Sound Levels (dBA)

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

Source: Seattle Municipal Code, Section 25.08.410.

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

Construction activities between 7 a.m. and 10 p.m. on weekdays and between 9 a.m. and 10 p.m. on weekends 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 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 between 8 a.m. and 5 p.m. on weekdays and between 9 a.m. and 5 p.m. on weekends, 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 Seattle property line noise limits during nighttime hours. Temporary ventilation fans may exceed the limit by 20 dBA during daytime hours.

Under normal daily operations, tunnel ventilation fans are subject to the noise level limits of the Seattle Noise Ordinance and must meet Seattle property line noise limits. Under emergency operation conditions, ventilation and jet fans are exempt from the ordinance. Jet fans and ventilation fans must, however, be routinely tested in emergency mode operation, which is subject to the property line noise limits.

2.5.3 Hearing Protection Criteria

To prevent damage to hearing, the Occupational Safety and Health Administration (OSHA) recommends a maximum noise level of 85 dBA based upon a long-term exposure time of 8 hours during working life. National Fire Protection Association (NFPA) 130: Standard for Fixed Guideway Transit and Passenger Rail Systems (2000) allows an exposure of 115 dBA for a few seconds and 92 dBA for the remainder of the exposure. In accordance with the OSHA criteria, exposures of 115 dBA and 92 dBA are acceptable for 28 seconds and 1 hour 35 minutes, respectively. The in-tunnel noise criterion for this project during emergency operations is a maximum of 115 dBA for a few seconds and 92 dBA for the remainder of the exposure. The Bored Tunnel Alternative would meet OSHA standards.

2.6 Characteristics of Vibration

Vibration is an oscillatory motion, which 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.

2.7 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 of 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 root mean square (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:

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

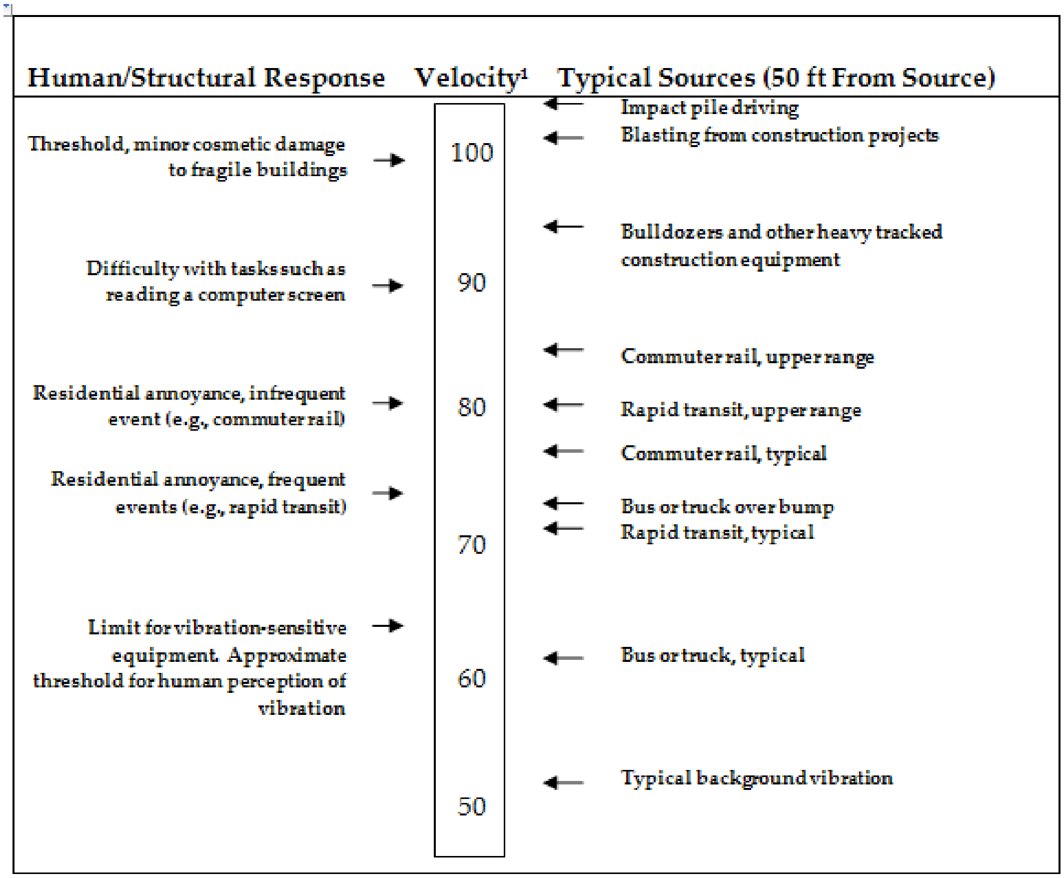
where: L_v is the velocity level in decibels
V is the rms velocity amplitude
V_{ref} is the reference velocity amplitude

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} inches 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.

2.8 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 lower, well below the threshold of perception for humans, which is around 65 VdB (Exhibit 2-8). Most perceptible indoor vibration is caused by sources within buildings, such as 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 2-8. Common Vibration Sources and Levels



Source: USDOT 1995.
[1] Root mean square vibration velocity level in VdB relative to 10^{-6} inches 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.

2.9 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. 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.

2.10 Vibration Effect Criteria

Criteria for construction ground vibration must address two types of effects:

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

Temporary vibration effects may occur in the local area during construction as a consequence 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, low rumbling sounds and noticeable vibrations at moderate levels, and 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 should 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, the specific construction activity, the types of construction equipment, the characteristics of underlying soils, and the existing conditions and the 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.

2.10.1 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 operations becomes a concern when it can be felt. Determining acceptable vibration levels is often problematic because ascertaining whether vibration is 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 expect no unusual 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 will be improved 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 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 2-9.

Exhibit 2-9. Criteria for Annoyance Caused by Ground-Borne Vibration

Building Use Category	Maximum Vibration Velocity (inches/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: ISO Standard 2631 (1974) and ANSI Standard S3.29-2001 (Acoustical Society of America 2001).

2.10.2 Potential Building Damage Criteria

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

No local, state, or federal agencies require control of vibration during construction in the way that the Seattle Noise Ordinance addresses noise levels, although the EPA has established noise emission standards. The potential for cosmetic or structural damage due to construction activities is assessed on the basis of impact criteria developed by the Acoustical Society of America (2001), ISO (1989), and the Federal Transit Administration (FTA 2006).

2.10.3 Vibration Criteria to Prevent Structural Damage

Extensive studies conducted by the U.S. Bureau of Mines suggest that a peak vibration velocity of 2 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.

More comprehensive guidelines are provided in Swiss Standard SN 640312 and 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 2-10 and 2-11 represent the structural categories and vibration criteria for use in selecting appropriate construction vibration limits.

The Federal Transit Administration (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 2-10. 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; underground structures such as caverns, tunnels, 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; underground structures such as caverns, tunnels, 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 2-11. Acceptance Criteria of Swiss Standard SN 640312

	Continuous or Steady-State Vibration Sources[1]		Transient or Impact Vibration Sources[2]	
Structural Category	Frequency (Hz)	Maximum Velocity (inches/second)	Frequency (Hz)	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: Hz = hertz

[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.

2.10.4 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 buried structures is a PPV of 4.0 inches per second. Older cast-iron water mains may be more 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).

Chapter 3 METHODOLOGY

3.1 Study Area

The study area for noise and vibration includes areas likely to be affected by changes in traffic or mechanical ventilation noise under the Bored Tunnel Alternative and areas likely to be affected by construction noise or vibration. As shown on Exhibit 3-1, the study area extends approximately two blocks on either side of SR 99 from the vicinity of S. Royal Brougham Way to Roy Street and at the surface, above the bored tunnel.

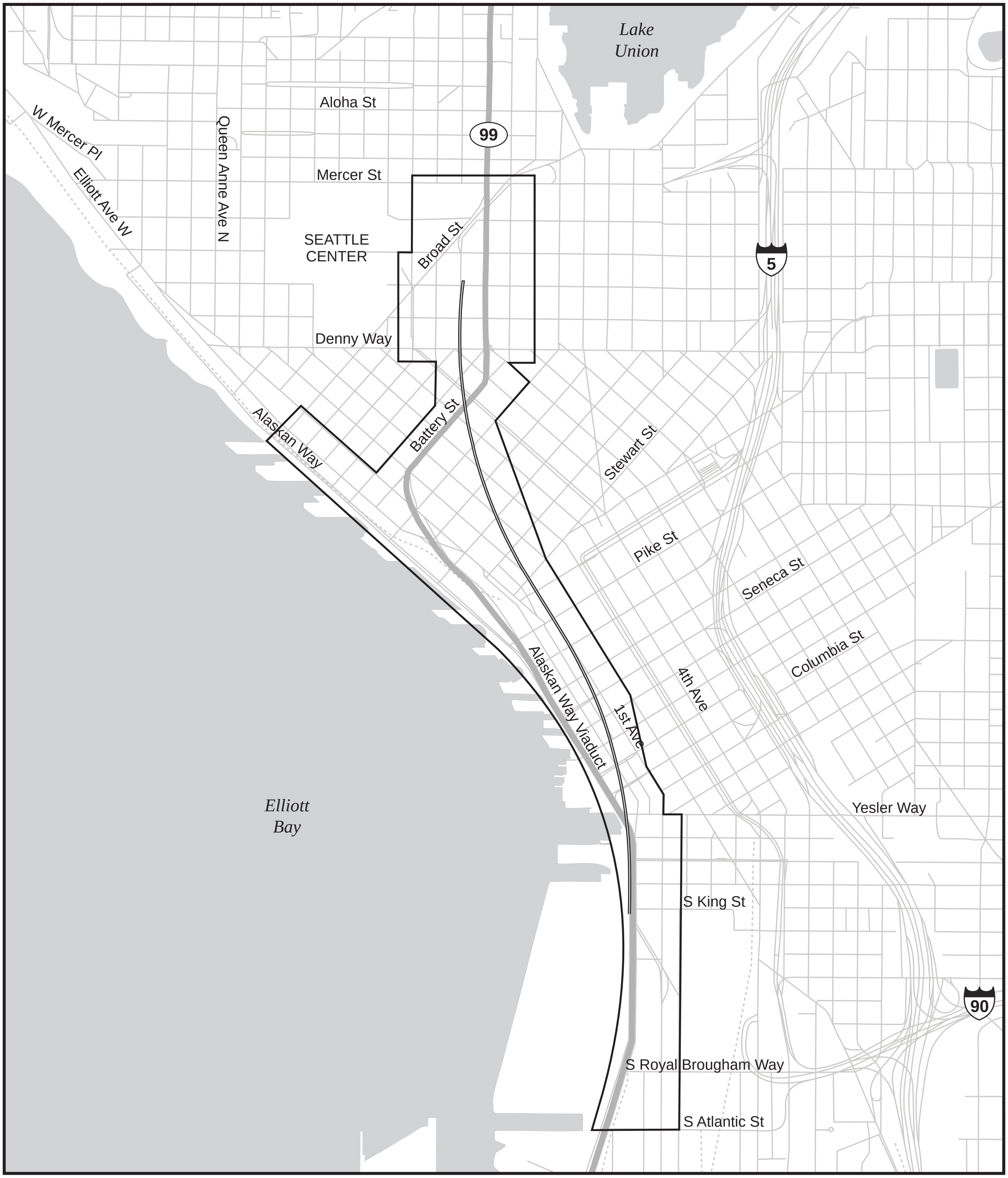
The study area runs through the downtown core of Seattle. Land use in the area ranges from low-rise light industrial buildings to high-rise office towers. Portions of the study area include residential zoning, such as Belltown and the area west of the Alaskan Way Viaduct along Alaskan Way. There are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

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

3.2 Data Needs and Sources

3.2.1 Traffic Data

To determine the operational effects of the project, data from the project's traffic analysis were used as input for this analysis, including PM peak-hour volume estimates, travel speed estimates, and vehicle mix. For more detailed discussion of the operational effects of the Bored Tunnel are described in Appendix C, Transportation Discipline Report. Estimates of the existing conditions were derived from traffic counts conducted by WSDOT and the City from 2004 through 2006. Traffic volumes on SR 99 within the study area have generally remained stable in recent years, so these volume estimates can still be considered current. Additional traffic count data were collected within the corridor in 2007 and 2008 by the City and in 2009 by the project team. Analysts evaluated these data and updated existing traffic volume estimates as necessary to reflect changes, if any, that were evident in these latest counts. For modeling purposes and documentation of the affected environment, the project team used the year 2005 as the existing conditions year.



554-1585-030/CC(07) 3/31/10

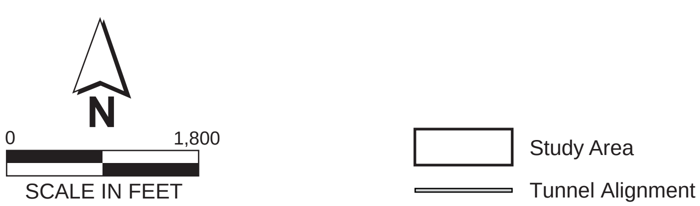


Exhibit 3-1
Noise Study Area

3.2.2 Construction Data

The construction team supplied the construction methods, including type of equipment and duration of work.

3.3 Studies and Coordination

Noise and vibration methods and analysis were developed for the Program in coordination with WSDOT, the City, King County, and FHWA. In April 2002, a an approach for the noise and vibration analysis was distributed to these agencies for review and comment, and the approach methodology 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 for the study was presented to WSDOT and City staff, and input from these agencies was incorporated into the study.

3.4 Methods to Assess Existing Conditions

3.4.1 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 2008) are included in the baseline noise measurements. 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 L_{eq}(h) at various times of day. At several additional locations, 24-hour noise measurements were taken with LD 720 logging noise meters to characterize the daily sound environment. Fifteen-minute noise measurements were taken at ground level, while 24-hour measurements were taken on either balconies or building roofs, depending on availability of access.

FHWA's TNM Version 2.5 computer model (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; vehicular 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 noise model extended approximately two blocks on either side of the existing SR 99 and at the surface, above the bored tunnel, from near S. Royal Brougham Way to Roy 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 considerable 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 previously recognized 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.

The measurement locations represent a variety of noise conditions and are representative 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.

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 3-2).

Exhibit 3-2. Noise Measurement and TNM Validation Model

Location		Date	Time	Measured L_{eq}	Modeled L_{eq}
1	Pyramid Brewery	7-Feb-08	12:00 p.m.	69	68
2	Safeco Field sidewalk	17-Feb-10	10:10 a.m.	70	69
3	Silver Cloud 10th floor pool	7-Jul-09	1:45 p.m.	74	73
4	Mixed-use building at 1000 First Avenue	7-Jul-09	10:45 a.m.	75	74
5	Triangle sidewalk	17-Feb-10	3:00 p.m.	74	74
6	Palm Court sidewalk	17-Feb-10	2:40 p.m.	71	73
7	Florentine Apts. (5th floor)	5-Jun-02	2:00 p.m.	73	71
8	First Avenue and S. King Street	18-Feb-10	11:15 a.m.	73	73
9	Alaskan Way and S. Jackson Street	18-Feb-10	11:40 a.m.	75	74
10	300 block of Occidental Avenue	31-Jul-02	1:30 p.m.	63	63
11	First Avenue and S. Main Street	6-Aug-03	1:15 p.m.	72	71
12	Occidental Park	31-Jul-02	1:30 p.m.	63	64
		6-Aug-03	12:15 p.m.	63	64
		7-Jul-09	11:10 a.m.	63	64
13	Washington Street Boat Landing	31-Jul-02	11:55 a.m.	76	74
		7-Jul-09	11:50 a.m.	76	74
14	Pioneer Square Hotel street level	2-Jul-09	2:35 p.m.	69	71
15	Pier 50	31-Jul-02	11:30 a.m.	77	75
		13-Aug-09	12:25 p.m.	76	
16	Pioneer Square south side	31-Jul-02	3:30 p.m.	68	68
		6-Aug-03	11:30 a.m.	68	
17	Pioneer Square north side	31-Jul-02	3:40 p.m.	71	69
		6-Aug-03	11:15 a.m.	71	
		9-Jul-09	2:10 p.m.	70	

Exhibit 3-2. Noise Measurement and TNM Validation Model (continued)

Location		Date	Time	Measured L_{eq}	Modeled L_{eq}
18	Colman Dock	31-Jul-02	11:10 a.m.	77	75
19	Marion Street Pedestrian Bridge	31-Jul-02	11:05 a.m.	77	79
20	Spring Street and Alaskan Way	3-Sep-03	1:00 p.m.	78	79
21	Western Avenue and Spring Street	31-Jul-02	10:10 a.m.	74	72
		6-Aug-03	10:15 a.m.	73	
22	Spring Street and Post Avenue	31-Jul-02	10:35 a.m.	72	70
23	Elliott's Oyster House	31-Jul-02	9:45 a.m.	71	71
24	Alaskan Way bike path at Seneca Street	31-Jul-02	9:45 a.m.	78	76
25	Spring Street and First Avenue	31-Jul-02	10:35 a.m.	72	70
		13-Aug-09	12:00 p.m.	73	71
26	Harbor Steps SW Tower (9th floor)	16-May-02	11:50 a.m.	74	73
27	Waterfront Park boardwalk	25-Mar-03	2:00 p.m.	71	71
28	Harbor Steps (plaza level)	16-May-02	2:00 p.m.	71	71
		25-Jun-09	2:10 p.m.	69	71
29	Waterfront Park	31-Jul-02	9:15 a.m.	72	70
		25-Jun-09	1:05 p.m.	72	72
30	Hill Climb Court	31-Jul-02	8:50 a.m.	74	75
		3-Sep-03	11:15 a.m.	75	75
31	Pier at Pine Street	9-Jul-09	10:40 a.m.	63	65
32	Waterfront Landing (ground level)	22-May-02	11:15 a.m.	75	73
33	Waterfront Landing Condos roof	22-May-02	10:45 p.m.	80	79
34	Victor Steinbrueck Park	31-Jul-02	8:20 a.m.	81	80
35	Elliott Point Apts. roof	29-May-02	10:45 a.m.	78	79
36	Belltown Loft (ground level)	4-Jun-02	9:45 a.m.	68	68
37	Elliott Point (ground level)	7-Aug-03	9:15 a.m.	76	75
38	Belltown Loft Condos roof	2-Jun-02	9:00 a.m.	74	75
39	Site 17 (ground level)	7-Aug-03	9:45 a.m.	74	72
40	Site 17 Apartment (ground level)	20-May-02	3:00 p.m.	70	70
41	Port of Seattle terrace	19-Jul-02	3:00 p.m.	65	63
42	Port of Seattle (ground level)	19-Jul-02	2:00 p.m.	70	68
43	Western Avenue and Cedar Street	7-Aug-03	10:30 a.m.	71	69
44	Fountain Court Apartments	8-Aug-03	10:15 a.m.	72	70

Exhibit 3-2. Noise Measurement and TNM Validation Model (continued)

Location		Date	Time	Measured L_{eq}	Modeled L_{eq}
45	Avalon Belltown Apartments	17-Jul-02	3:00 p.m.	68	67
46	Avalon Belltown (ground level)	17-Jul-02	3:00 p.m.	70	68
47	Antioch University	27-Jun-02	1:45 p.m.	64	64
48	Tilikum Place Park	23-Jun-09	4:00 p.m.	66	64
49	Pacific Science Center	20-Jun-02	1:40 p.m.	69	67
50	Fisher Plaza	27-Aug-09	3:30 p.m.	67	65
51	Taylor 28	25-Jun-09	11:50 a.m.	58	57
52	Marselle Condos sidewalk	27-Aug-09	2:10 p.m.	76	77
53	Parking lot at SR 99 and John Street	27-Aug-09	2:35 p.m.	75	77
54	Denny Park	3-Sep-03	10:34 a.m.	60	59
		9-Jul-09	1:30 p.m.	59	59
55	Taylor 28 sidewalk at Sixth Avenue and John Street	18-Feb-10	2:10 p.m.	63	64
56	McDonald's sidewalk	27-Aug-09	3:55 p.m.	69	68
57	Quality Inn parking lot	27-Aug-09	1:45 p.m.	76	76
58	Seattle Inn (terrace)	9-Jul-02	4:00 p.m.	78	76
59	Holiday Inn	17-Jul-03	10:50 a.m.	76	75
60	Executive Inn sidewalk	18-Feb-10	2:35 p.m.	64	64
61	Experience Music Project sidewalk	27-Aug-09	4:30 p.m.	69	67
62	Seattle Pacific Hotel north parking lot	4-Mar-10	12:35 p.m.	72	72
63	Sixth Avenue and Harrison Street sidewalk	4-Mar-10	1:05 p.m.	68	68
64	Broad Street and Aurora Avenue	4-Mar-10	1:40 p.m.	76	75
65	Future Bill and Melinda Gates Foundation Campus[1]	--	--	--	63
66	Hotel at Aurora Avenue and Mercer Street	17-Jul-03	2:30 p.m.	75	73
67	Queen Anne Community School south parking lot	4-Mar-10	2:25 p.m.	65	65
68	Lumen Condos sidewalk	4-Mar-10	2:55 p.m.	64	64

[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 located near the center of the campus.

Noise measurements were taken at receptors 20, 27, 28, 32, and 34 when the Alaskan Way Viaduct was closed to traffic (Exhibit 3-3). 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 existing conditions. The loudest traffic noise period occurs when traffic volumes are high, but lower than the traffic volume that would cause 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. Results of the TNM existing conditions model are presented in Section 4.2 of this report.

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

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

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.

3.4.2 Vibration

Vibration measurements taken in 2002 as part of the 2004 Draft EIS and areaway monitoring data were included in the baseline vibration measurements. Additional vibration measurements were taken for areas potentially affected by the Bored Tunnel Alternative at unrestored areaways, the spaces beneath the sidewalks of older buildings, and historic buildings to determine the level of exposure from bus and truck movements on nearby streets.

Additional 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 rms vibration velocity levels generated by these events.

3.5 Methods to Assess Environmental Effects

3.5.1 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 Bored Tunnel Alternative in the future design year (2030) using the methods described in Section 3.4.1. The 2030 traffic volumes were provided by the transportation team (the actual volumes data can be found in Appendix C, Transportation Discipline Report). No adjustment factors or virtual noise sources were used for the Bored Tunnel Alternative future noise model.

Federal and Washington State regulations require agencies to evaluate a No Build Alternative. For this project, the Viaduct Closed (No Build Alternative) is not a viable alternative because the existing viaduct is vulnerable to earthquakes and failure due to ongoing deterioration. At some point, the roadway will need to be closed. For these reasons, this report qualitatively discusses the effects of two scenarios for the Viaduct Closed (No Build Alternative).

Construction effects are discussed qualitatively, and the analysis includes information regarding the types and durations of major operations, such as construction of the bored tunnel and demolition of the existing viaduct.

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

3.5.2 Vibration

The vibration measurements were used as a baseline for evaluation of the future 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). The reference vibration 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 sensitive structures. A vibration impact criterion that is consistent with FTA criteria for buildings and utilities and protective of potentially fragile historic structures was used to assess effects.

3.6 Methods to Determine Mitigation Measures

3.6.1 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 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 Bored Tunnel Alternative. 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.

3.6.2 Vibration

While FHWA and WSDOT do not have policies that directly address vibration mitigation, any mitigation recommendations will be consistent with FHWA and WSDOT mitigation policies in regards to feasibility and reasonableness.

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

3.7 Methodology for Cumulative Effects

Cumulative effects are effects on the environment that result from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions. The cumulative effects analysis focused on the combined effect of the Bored Tunnel Alternative and other roadway and non-roadway elements included in the Program. In addition, other projects that are anticipated to add to effects on noise in the study area were evaluated.

These other roadway and non-roadway elements of the Program were qualitatively assessed for operational and construction effects on noise. The roadway Program elements included in this qualitative analysis are the Alaskan Way Surface Street Improvements (on the location of the former viaduct) from S. King Street to Pike Street, the Elliott/Western Connector from Pike Street to Battery Street, and the Mercer West Project (Mercer Street improvements from Fifth Avenue N. to Elliott Avenue). The non-roadway Program elements include the Elliott Bay Seawall Project, the Alaskan Way Promenade/Public Space to be built in the location of the existing Alaskan Way surface street, the First Avenue Streetcar Evaluation, and Transit Enhancements.

Other planned projects and developments in Seattle may add to the effects on noise in the study area. The following projects were included in the cumulative effects analysis:

- Alaskan Way Viaduct and Seawall Replacement Moving Forward projects
- Sound Transit North Link Light Rail
- Sound Transit East Link Light Rail
- Sound Transit University Link Light Rail Project
- S. Spokane Street Viaduct Widening
- SR 519 Intermodal Access Project, Phase 2
- SR 520 Bridge Replacement and HOV Program
- I-5 Improvements
- South Lake Union Redevelopment

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 Bored Tunnel Alternative 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. Royal Brougham Way to Roy Street and at the surface, above the bored tunnel.

The study area runs through the downtown core of Seattle. Land use in the area ranges from low-rise light industrial buildings to high-rise office towers. Portions of the study area 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.

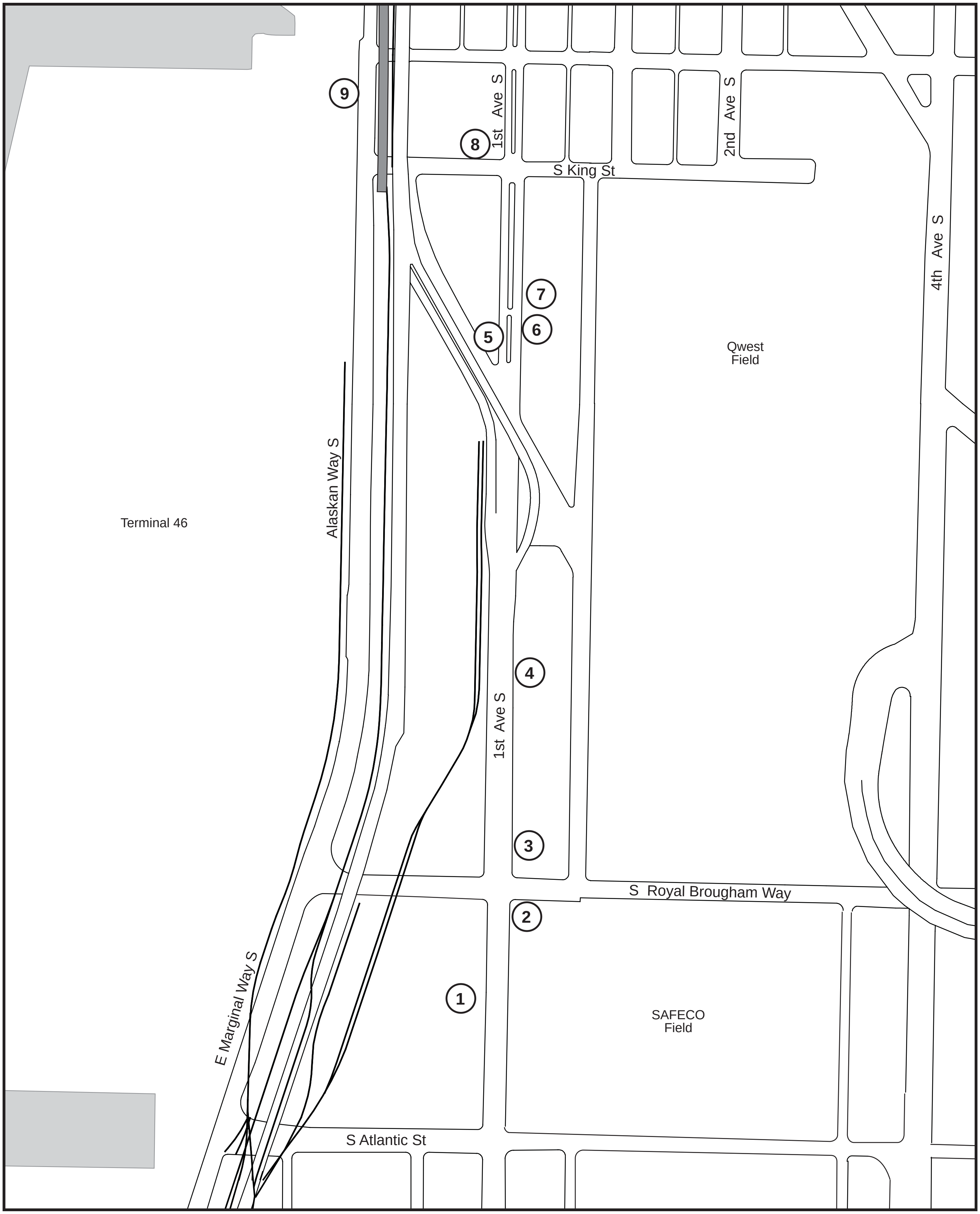
There are residential or hotel uses near both of the portal areas and the tunnel operations buildings for the bored tunnel. Land uses near the south portal and south tunnel operations building that could occur under the Bored Tunnel Alternative would be commercial and industrial, as zoned.

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

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. The noise measurement locations are shown in Exhibit 4-1.

As shown in Exhibit 4-2, existing traffic noise levels were predicted to approach or exceed the FHWA noise abatement criteria at 48 of the 68 modeled sites, representing approximately 3,746 residential units, 1,612 hotel rooms, 120 shelter beds, 1 church, 12 parks or public spaces, and 7 commercial use areas. The predicted noise level at one site, location 35, currently exceeds the severe noise impact criterion (noise levels exceeding 80 dBA at sensitive land uses).



554-1585-030/CC(07) 6/24/10

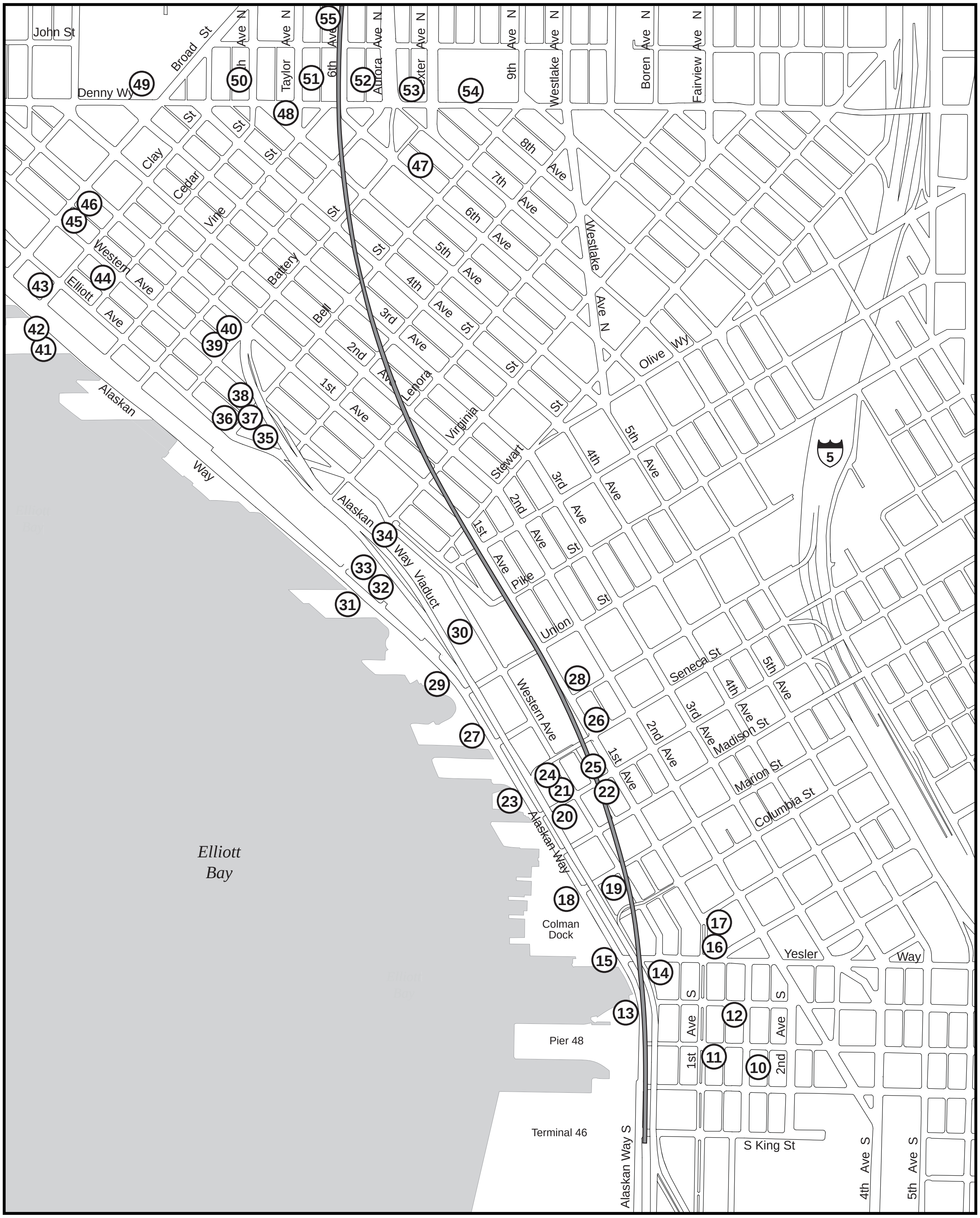
N

0 500

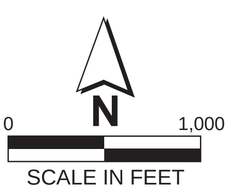
SCALE IN FEET

Note: Numbers correspond to Exhibit 4-2.

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

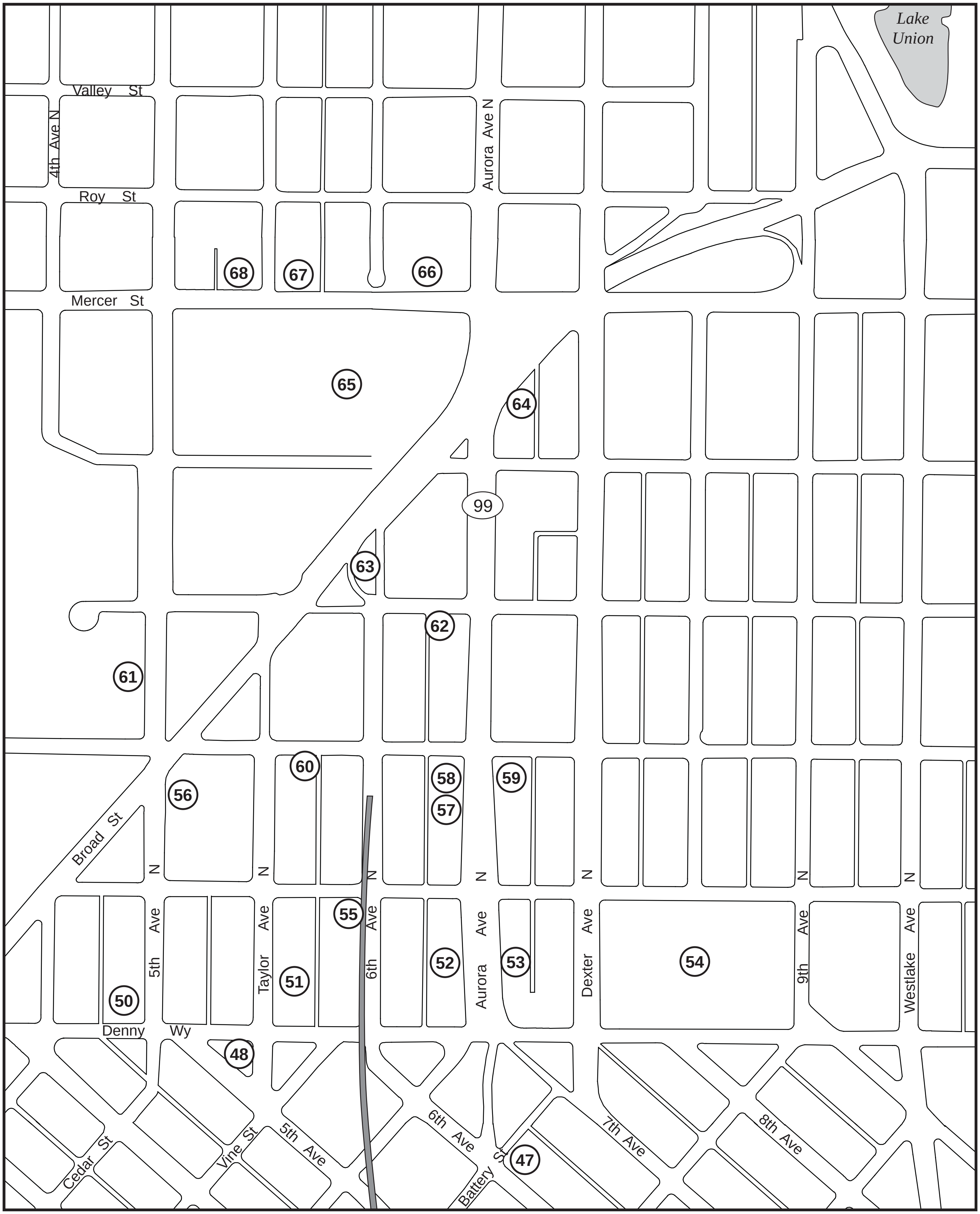


554-1585-030/CC(07) 3/31/10



Note: Numbers correspond to Table 4-2.

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



554-1585-030/CC(07) 3/31/10

N
0 500
SCALE IN FEET

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

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

Exhibit 4-2. Modeled Existing Noise Levels

Receptor	Noise-Sensitive Use	Noise Abatement Criterion (dBA)	Existing Noise Levels (dBA)
1	Commercial	72	68
2	Public space	67	**69**
3	220 hotel rooms	67	**73**
4	Commercial	72	**74**
5	2 residential units	67	**73**
6	25 residential units	67	**72**
7	108 residential units	67	**70**
8	Commercial	72	70
9	Public space	67	**72**
10	Public space and 7 units	67	63
11	114 residential units and 120 homeless shelter beds	67	**69**
12	Park	67	63
13	Park	67	**74**
14	115 hotel units	67	**71**
15	Commercial	72	**75**
16	Park and 85 units	67	**67**
17	Park	67	**68**
18	Commercial use	72	**75**
19	Pedestrian access and 19 residential units	67	**79**
20	Commercial use	72	**78**
21	Commercial use	72	71
22	109 hotel rooms	67	**69**
23	Commercial use	72	71
24	Commercial use	72	**76**
25	130 residential units	67	**69**
26	169 residential units	67	**72**
27	Park	67	**71**
28	301 residential units	67	**71**
29	Park	67	**71**
30	205 residential units	67	**75**
31	Public space	67	65
32	115 residential units and 160 hotel rooms	67	**68**
33	115 residential units and 160 hotel rooms	67	**79**
34	Park	67	**79**
35	77 residential units	67	**80**
36	32 residential units	67	**68**
37	77 residential units	67	**75**

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

Receptor	Noise-Sensitive Use	Noise Abatement Criterion (dBA)	Existing Noise Levels (dBA)
38	32 residential units	67	**76**
39	312 residential units	67	**71**
40	312 residential units	67	**71**
41	138 hotel rooms	67	64
42	100 hotel rooms	67	**68**
43	636 residential units	67	**67**
44	695 residential units	67	**70**
45	698 residential units	67	64
46	130 residential units	67	65
47	Antioch University	67	65
48	Park	67	**67**
49	Pacific Science Center	67	65
50	Commercial	72	69
51	190 residential units	67	62
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	**72**
57	159 hotel rooms	67	**71**
58	235 hotel rooms	67	**77**
59	196 hotel rooms	67	**71**
60	123 hotel rooms	67	64
61	Experience Music Project	67	**67**
62	Commercial	72	**72**
63	Public space	67	**68**
64	Public space	67	**75**
65	Commercial	72	63
66	158 hotel rooms and church	67	**73**
67	School	67	65
68	92 residential units	67	64

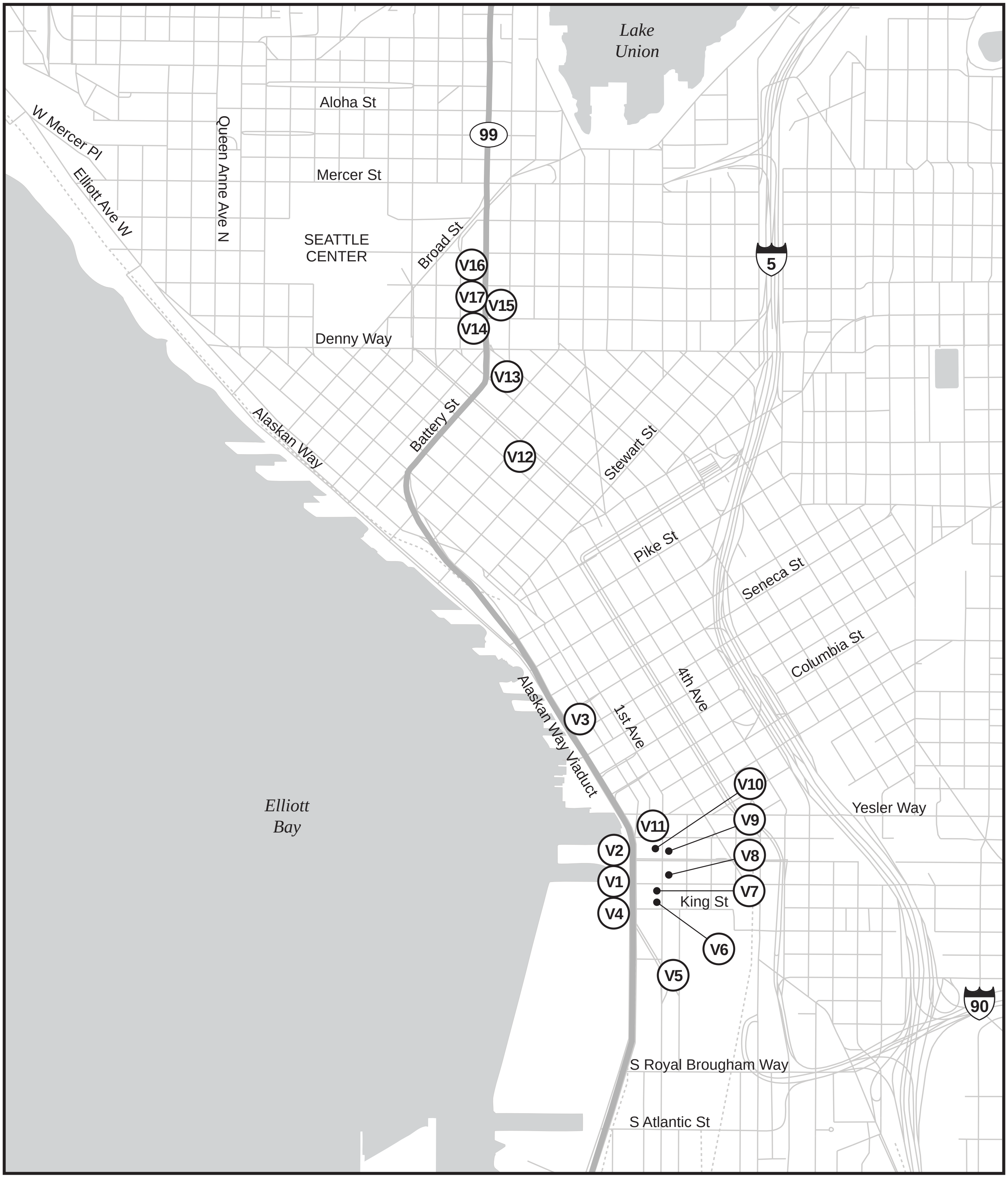
Notes: The FHWA traffic noise abatement criterion is 67 dBA for most noise-sensitive land uses and 72 dBA for commercial uses. An impact occurs if the traffic noise level approaches within 1 dBA of the criterion (66 or 71 dBA). Noise-sensitive locations that do not include outdoor use areas (FHWA Activity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

4.3 Existing Vibration Environment

Vibration levels generated by rubber-tired vehicles are usually not of 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 above the proposed tunnel alignment. 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 proposed north portal, to establish a baseline. 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 proposed bored tunnel and portal areas. The measured levels are presented in Exhibit 4-4 as maximum rms velocity vibration and PPV.



554-1585-030/CC(07) 4/6/10

N

0 1,800

SCALE IN FEET

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 ID	Location Description	Maximum Vibration Velocity (VdB)	Peak Particle Velocity (inches/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 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 condos on the southwest corner of Aurora Avenue and John Street	75.3	0.029
V15	Holiday Inn parking on the northeast corner of Aurora Avenue and John Street	77.5	0.038
V16	Seattle Pacific Hotel	75.4	0.028
V17	Quality Inn and Suites	78.5	0.043

The following is a description of the vibration measurement sites and the building structures at these locations. Refer to Exhibit 4-3 for a map of the locations.

- 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 to the west of the building, and S. Jackson Street is located 30 feet to the north. The area under the viaduct is used for parking.

- Site V2 – 76 S. Main Street. Measurements were taken directly outside of 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 areaway retaining wall.
- Site V6 – Merrill Place, south basement. Measurements were taken in the basement of the building, west of the First Avenue areaway retaining wall.
- Site V7 – Merrill Place, north basement. Measurements were taken in the basement of the building, west of the First Avenue areaway retaining wall.
- Site V8 – First Avenue S. and S. Jackson Street, basement. Measurements were taken in the basement under 388 First Avenue, east of the First Avenue 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 Cafe, east of the First Avenue 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, west of the First Avenue 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 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 in the street level at a location above the proposed bored tunnel alignment.
- Site V13 – Antioch University Book Store. Measurements were taken in the street level at the west corner, inside the book store, at a location above the proposed bored tunnel alignment. The site is on Sixth Avenue, 60 feet from Battery Street.
- Site V14 – Condominium parking, 191 Aurora Avenue. Measurements were taken in the fourth level of parking west of Aurora Avenue and south of John Street.

- Site V15 – Holiday Inn parking. Measurements were taken in the street level at the southwest corner. The site is east of Aurora Avenue and north of John Street.
- Site V16 – Seattle Pacific Hotel parking. Measurements were taken in the street level parking on the west side of the hotel. The site is in the middle of the property, halfway between Aurora Avenue 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 at the northwest corner. The site is 110 feet west of Aurora Avenue and 15 feet south of Thomas Street.

This Page Intentionally Left Blank

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 earthquakes 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 No Build Alternative describes what would happen if the bored tunnel or another build alternative is not implemented. If the existing viaduct is not replaced, it will be closed, but it is unknown when that would happen. However, it is highly unlikely that the existing structure could still be in use in 2030. For these reasons, this Supplemental Draft EIS compares the effects of the proposed build alternatives to a 2015 Existing Viaduct.

The 2015 Existing Viaduct assumes that the existing viaduct will continue to be part of the transportation network between S. King Street and Denny Way in the year 2015. For this environmental analysis, the focus is on comparing the proposed Bored Tunnel Alternative with the 2015 Existing Viaduct; however, we also make comparisons to potential post-earthquake condition to understand what could happen at some unknown time in the future.

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 Section 5.2. 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 Bored Tunnel Alternative and the Viaduct Closed (No Build Alternative) evaluated for noise and vibration are described in more detail in Appendix B, Alternatives Description and Construction Methods Discipline Report.

5.1 Operational Effects of the 2015 Existing Viaduct Condition

Traffic noise levels for the 2015 Existing Viaduct would be similar to current levels because (1) traffic patterns would not substantially change, and (2) peak traffic volumes would increase only slightly because current peak-period traffic volumes are near the capacity of the roadway system in much of the study area.

Traffic noise levels would continue to approach or exceed the FHWA noise abatement criteria throughout much of the study area.

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

5.2.1 Scenario 1: Sudden Unplanned Loss of SR 99

Under 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. Under this scenario, 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 would require repair. During the closure of SR 99, noise levels along the waterfront would be lower than those experienced today; increased congestion and decreased travel speeds would also result in lower noise levels in the rest of the project area.

5.2.2 Scenario 2: Catastrophic Collapse of SR 99

This scenario considers the effects of a catastrophic failure and collapse of SR 99. Under this scenario, 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 those experienced today; increased congestion and decreased travel speeds would also result in lower noise levels in the rest of the project area.

5.3 Operational Effects of the Bored Tunnel Alternative

The Bored Tunnel Alternative includes two options in the south portal area and two options in the north portal area. The modeled Bored Tunnel Alternative traffic noise levels are described for the south portal area, the central project area, and the north portal area, including both options in the north and south portal areas.

Long-term operational traffic noise levels under the Bored Tunnel Alternative were modeled for the year 2030. Under the Bored Tunnel Alternative, noise levels near Alaskan Way along the central waterfront and near the south portal would be lower than existing conditions. At the north portal and in all other areas, future noise levels were predicted to be similar to existing conditions.

Loudest hour traffic noise levels would range between 61 and 74 dBA at the modeled locations (see Exhibits 4-1 and 4-2). Traffic noise level changes are predicted to be between a 17-dBA decrease and a 4-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.

No sites were predicted to exceed the severe noise impact criterion (noise levels exceeding 80 dBA at sensitive land uses) under the 2030 Bored Tunnel Alternative. The number of sensitive receptors that meet the noise abatement criteria would be lower than the number under existing conditions, mostly in the central project area between S. King Street and Denny Way, where existing noise levels were predicted to approach or exceed the FHWA noise abatement criteria at 22 of the 45 modeled sites.

Many of the residential and hotel sites do not have 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 Portal Area including Options

Two options are being considered for new cross streets that would be built to intersect with Alaskan Way S.:

- New Dearborn Intersection – Alaskan Way S. would have one new intersection and cross street at S. Dearborn Street. The cross street would have sidewalks on both sides.
- New Dearborn and Charles Intersections – Alaskan Way S. would have two new intersections and cross streets at S. Charles Street and S. Dearborn Street. The cross streets would have sidewalks on both sides.

As shown in Exhibit 5-1, the modeled 2030 Bored Tunnel Alternative, traffic noise levels in the south portal 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 open space uses, regardless of the option selected. Traffic noise levels decrease at eight of nine modeled locations for both south portal area options.

Exhibit 5-1. Modeled 2030 Bored Tunnel Alternative Noise Levels – South Portal Area

Receptor	Noise-Sensitive Use	Noise Abatement Criterion	Existing Noise Levels (dBA)	2030 Bored Tunnel Alternative Noise Levels (dBA)	Change from Existing Noise Levels (dBA)
1	Commercial	72	68	66	-2
2	Public space	67	**69**	**70**	1
3	220 hotel rooms	67	**73**	**69**	-4
4	Commercial	72	**74**	71	-3
5	2 residential units	67	**73**	**69**	-4
6	25 residential units	67	**72**	**70**	-2
7	108 residential units	67	**70**	**69**	-1
8	Commercial	72	70	67	-3
9	Public space	67	**72**	**68**	-4

Notes: The FHWA traffic noise abatement criterion 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). 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**.

5.3.2 Central Project Area

As shown in Exhibit 5-2, the modeled 2030 Bored Tunnel Alternative, traffic noise levels in the central project area approach or exceed the FHWA noise abatement criteria at 18 of the 37 modeled sites, representing approximately 2,977 residential units, 353 hotel rooms, 120 shelter beds, 4 parks or public open space uses, and 2 commercial or other less noise-sensitive uses. Traffic noise levels decrease at most of the modeled locations in the central project area.

Exhibit 5-2. Modeled 2030 Bored Tunnel Alternative Noise Levels – Central Project Area

Receptor	Noise-Sensitive Use	Noise Abatement Criterion	Existing Noise Levels (dBA)	2030 Bored Tunnel Alternative Noise Levels (dBA)	Change from Existing Noise Levels (dBA)
10	Public space and 7 units	67	63	61	-2
11	114 residential units and 120 homeless shelter beds	67	**69**	**69**	0
12	Park	67	63	62	-1
13	Park	67	**74**	**74**	0
14	115 hotel units	67	**71**	**69**	-2
15	Commercial	72	**75**	**73**	-2
16	Park and 85 units	67	**67**	**66**	-1
17	Park	67	**68**	**69**	1
18	Commercial use	72	**75**	**72**	-3

Exhibit 5-2. Modeled 2030 Bored Tunnel Alternative Noise Levels – Central Project Area (continued)

Receptor	Noise-Sensitive Use	Noise Abatement Criterion	Existing Noise Levels (dBA)	2030 Bored Tunnel Alternative Noise Levels (dBA)	Change from Existing Noise Levels (dBA)
19	Pedestrian access and 19 residential units	67	**79**	**67**	-12
20	Commercial use	72	**78**	70	-8
21	Commercial use	72	71	69	-2
22	109 hotel rooms	67	**69**	65	-4
23	Commercial use	72	71	67	-4
24	Commercial use	72	**76**	70	-6
25	130 residential units	67	**69**	**68**	-1
26	169 residential units	67	**72**	**66**	-6
27	Park	67	**71**	65	-6
28	301 residential units	67	**71**	**66**	-5
29	Park	67	**71**	**66**	-5
30	205 residential units	67	**75**	62	-13
31	Public space	67	65	62	-3
32	115 residential units and 160 hotel rooms	67	**68**	63	-5
33	115 residential units and 160 hotel rooms	67	**79**	62	-17
34	Park	67	**79**	62	-17
35	77 residential units	67	**80**	63	-17
36	32 residential units	67	**68**	63	-5
37	77 residential units	67	**75**	62	-13
38	32 residential units	67	**76**	63	-13
39	312 residential units	67	**71**	65	-6
40	312 residential units	67	**71**	64	-7
41	138 hotel rooms	67	64	**66**	2
42	100 hotel rooms	67	**68**	**71**	3
43	636 residential units	67	**67**	**66**	-1
44	695 residential units	67	**70**	**69**	-1
45	698 residential units	67	64	**67**	3
46	130 residential units	67	65	**68**	3

Notes: The FHWA traffic noise abatement criterion 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). 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**.

5.3.3 North Portal Area, Including Options

Two options are being considered in the north portal area for Sixth Avenue N. and the southbound on-ramp:

- The Curved Sixth Avenue option proposes to build a new roadway that would extend Sixth Avenue N. in a curved formation between Harrison and Mercer Streets. The new roadway would have a signalized intersection at Republican Street.
- The Straight Sixth Avenue option proposes to build a new roadway that would extend Sixth Avenue N. from Harrison Street to Mercer Street in a typical grid formation. The new roadway would have signalized intersections at Republican and Mercer Streets.

As shown in Exhibit 5-3, with either Sixth Avenue option, the modeled 2030 Bored Tunnel Alternative traffic noise levels approach or exceed the FHWA noise abatement criteria at 16 of the 22 modeled sites, representing approximately 337 residential units, 871 hotel rooms, 2 schools, 1 church, 4 parks or public open space uses, and 1 commercial or other less noise-sensitive use. There are only small differences in noise levels between the two options.

Exhibit 5-3. Modeled 2030 Bored Tunnel Alternative Noise Levels – North Portal Area

Receptor	Noise-Sensitive Use	Noise Abatement Criterion	Existing Noise Levels (dBA)	2030 Bored Tunnel Curved Sixth Avenue Option Noise Levels (dBA)	Change from Existing Noise Levels (dBA)	2030 Bored Tunnel Straight Sixth Avenue Option Noise Levels (dBA)	Change from Existing Noise Levels (dBA)
47	Antioch University	67	65	**66**	1	**66**	1
48	Park	67	**67**	**67**	0	**67**	0
49	Pacific Science Center	67	65	65	0	65	0
50	Commercial	72	69	66	-3	66	-3
51	190 residential units	67	62	63	1	63	1
52	132 residential units	67	**77**	**72**	-5	**72**	-5
53	53 residential units	67	**77**	**74**	-3	**74**	-3
54	Park	67	61	61	0	61	0
55	60 residential units	67	64	**66**	2	**66**	2
56	Commercial	72	**72**	67	-5	67	-5
57	159 hotel rooms	67	**71**	**73**	2	**73**	2

Exhibit 5-3. Modeled 2030 Bored Tunnel Alternative Noise Levels – North Portal Area (continued)

Receptor	Noise-Sensitive Use	Noise Abatement Criterion	Existing Noise Levels (dBA)	2030 Bored Tunnel Curved Sixth Avenue Option Noise Levels (dBA)	Change from Existing Noise Levels (dBA)	2030 Bored Tunnel Straight Sixth Avenue Option Noise Levels (dBA)	Change from Existing Noise Levels (dBA)
58	235 hotel rooms	67	**77**	**73**	-4	**73**	-4
59	196 hotel rooms	67	**71**	**71**	0	**71**	0
60	123 hotel rooms	67	64	**67**	3	**67**	3
61	Experience Music Project	67	**67**	**68**	1	**68**	1
62	Commercial	72	**72**	**72**	0	**72**	0
63	Public space	67	**68**	**68**	0	**69**	1
64	Public space	67	**75**	**75**	0	**75**	0
65	Commercial	72	63	65	2	65	2
66	158 hotel rooms and church	67	**73**	**73**	0	**73**	0
67	School	67	65	**68**	3	**68**	3
68	92 residential units	67	64	**68**	4	**68**	4

Notes: The FHWA traffic noise abatement criterion 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). 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**.

5.3.4 Ventilation System Noise

The Bored Tunnel Alternative would require the construction and operation of a mechanical ventilation system with several ventilation stacks. At the south portal area and near the proposed tunnel operations building, there are mostly industrial and commercial uses. At the north portal area and near the proposed tunnel operations building, there are several nearby condominiums and hotels. The ventilation fans would be designed not to 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. If the fans normally would be operated during nighttime hours (10 p.m. to 7 a.m. on weekdays and 10 p.m. to 9 a.m. on weekends), they would be designed not to exceed 47 dBA at the property line of the nearest residential use during nighttime hours.

Within the bored tunnel, the ventilation fans and jet fans would be designed for 92 dBA at 10 feet from either the fan outlet or the jet fans.

5.4 Operational Mitigation

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 construction of noise barriers or berms, realigning the roadway, and installing noise insulation for public use or nonprofit institutional structures. These mitigation measures were evaluated for their potential to reduce noise impacts from the Bored Tunnel Alternative.

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

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.

5.4.2 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 between 10 and 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 at the north and south portals 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 consideration.

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 [23 CFR 772] and Federal Register, Vol. 67, page 13731 (March 26, 2002) (67 FR 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, 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. Under the Bored Tunnel Alternative, including the south and north portal area options, 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, noise barriers would have to block access to the surface streets.

5.5 Operational Benefits

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. Expected 2030 peak traffic noise levels in the central waterfront area would be noticeably lower under the Bored Tunnel Alternative compared to existing conditions. For example, under existing conditions, Waterfront Park would have a peak traffic noise level of 71 dBA, while the Bored Tunnel Alternative peak traffic noise level would be 64 dBA.

Chapter 6 CONSTRUCTION EFFECTS AND MITIGATION

Noise during the construction period would be bothersome to nearby residents and businesses. Construction workers would also be subjected to construction noise while working on the site. Construction noise would vary spatially and temporally over the course of the project. The construction period for the Bored Tunnel Alternative is anticipated to last approximately 66 months (5.5 years). Various periods of disturbance would last for several months in any one area.

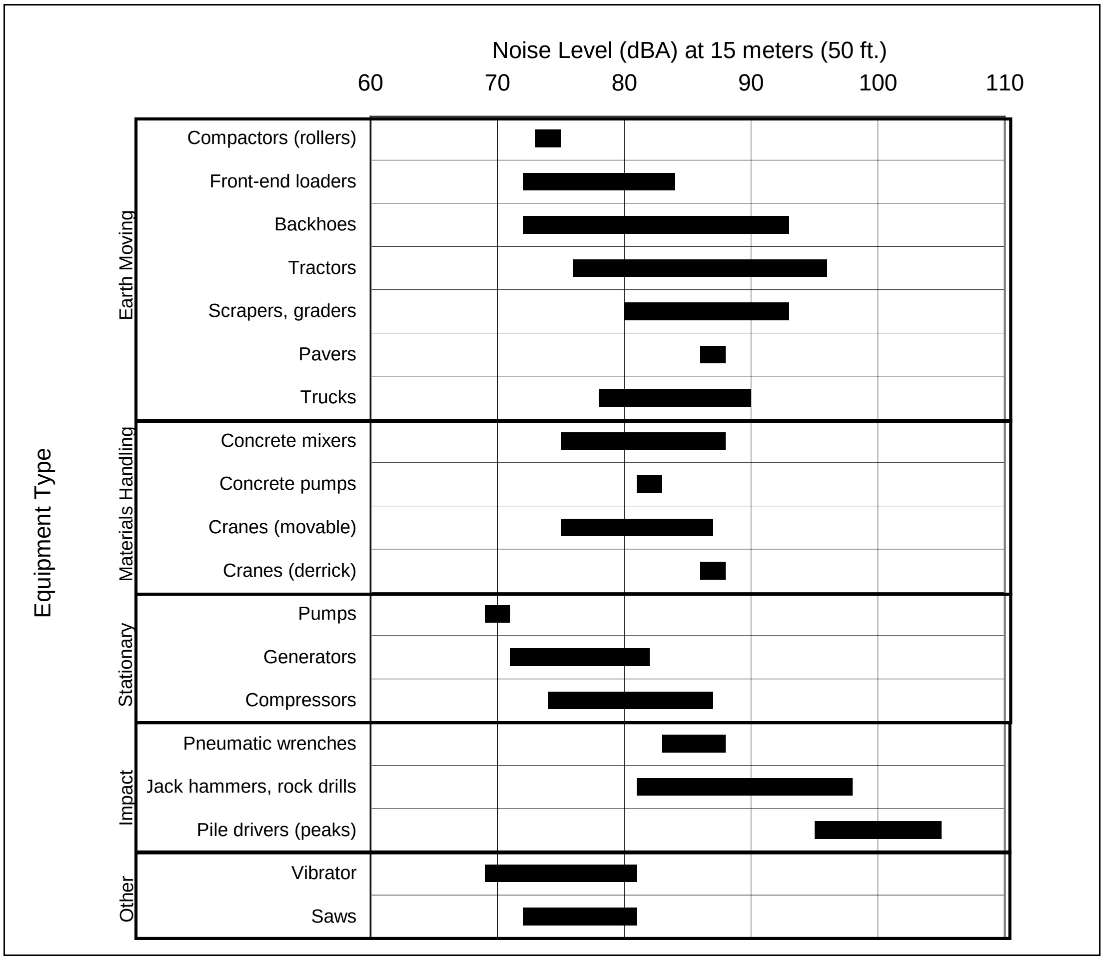
The most prevalent noise source at construction sites would be internal combustion engines. Earth-moving equipment, material-handling equipment, and stationary equipment are all engine-powered. Mobile equipment operates in a cyclic fashion, but stationary equipment (e.g., pumps, generators, and compressors) generates sound levels that are fairly constant over time. Because trucks would be present during most phases and would not be confined to the project site, 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 over an approximately 66-month construction period 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 establish the maximum noise levels of construction equipment used. The amount of construction activity would quantify how often construction noise would occur throughout the day. The location of construction equipment relative to adjacent properties would determine any effects of distance in reducing construction noise levels. The maximum noise levels of construction equipment under the Bored Tunnel Alternative would be similar to the typical maximum construction equipment noise levels presented in Exhibit 6-1.

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 turned 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).

Exhibit 6-1. Typical Construction Equipment Noise Levels



Source: EPA (1971).

Construction noise is allowed to exceed City property-line noise limits by 20 to 25 dBA during daytime hours (7 a.m. to 10 p.m. on weekdays, 9 a.m. to 10 p.m. on weekends). 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 between 8 a.m. and 5 p.m. on weekdays and between 9 a.m. and 5 p.m. on weekends, unless otherwise allowed by a noise variance.

Noise from TBM operations would occur at the staging areas where the muck and slurry could be treated, stored, and removed. Noise at the staging areas could also potentially include effects from a temporary concrete batch plant and a temporary slurry treatment plant. As stated above, the noise may be bothersome to nearby residents and businesses. 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 building level.

Vibration

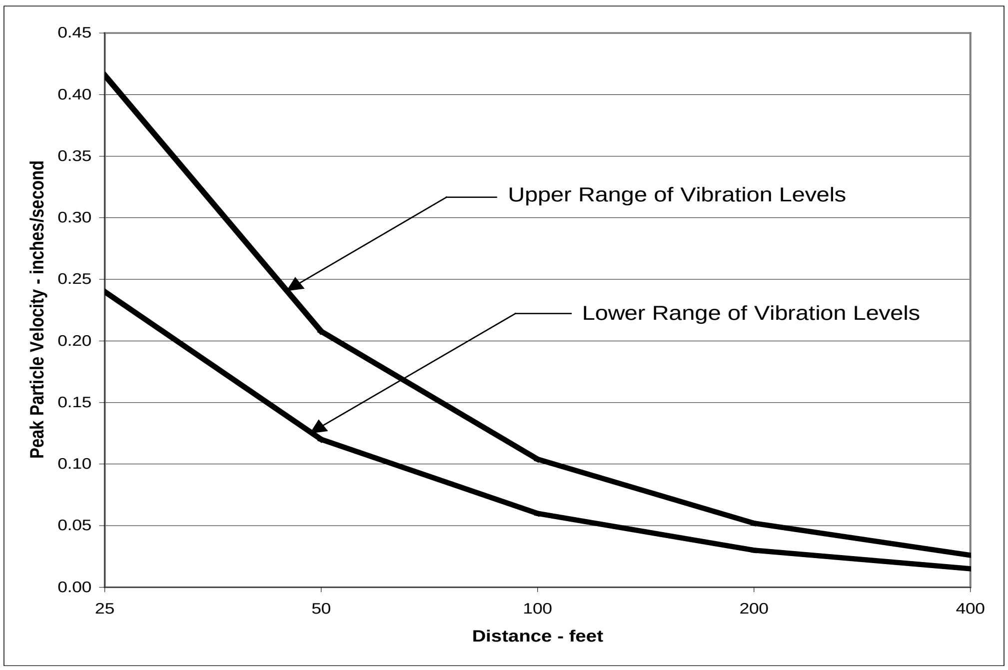
The construction activities that would result in the highest levels of ground vibration are the demolition of the existing viaduct structure and impact pile driving. For the demolition and removal of the viaduct structure between S. King Street and the Battery Street Tunnel, concrete munchers would be 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 for newer buildings of 0.50 inch per second. 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.

The TBM would also produce some ground vibration; however, because of the depth of the TBM and the ambient noise levels along First Avenue, the vibration levels would not be noticeable at building level and would not pose a damage risk to buildings.

In general, the potential impact on underground and buried utilities from 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. Vibration from pile driving would not exceed the damage risk criteria for most buried utilities of 4.0 inches per second PPV at distances greater than 25 feet or for older cast-iron water mains of 0.5 inch per second PPV at distances greater than 100 feet. The damage risk for utilities less than 25 feet and older cast-iron water mains less than 100 feet from impact pile-driving locations should be further evaluated during final design.

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



6.1 Construction Effects

6.1.1 South Portal

The south portal design includes the construction of a tunnel operations building for ventilation and operations and maintenance, as well as ramps providing northbound on, northbound off, southbound on, and southbound off movements to and from SR 99 between S. Royal Brougham Way and S. King Street. In the south, 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. Charles Street for both south portal area options. New southbound on- and northbound off-ramps would connect with Alaskan Way S. near S. King Street.

Construction durations for south portal construction, such as utility support and replacement work, are based on the assumption of three shifts per day for 6 days per week for tunnel and portal area construction.

Temporary large-scale stationary equipment or structures could be located at the Washington-Oregon Shippers Cooperative Association (WOSCA) south portal staging area. The WOSCA site is west of First Avenue S., between S. Royal Brougham Way and S. King Street. Part of the site would be used for a slurry separation plant, if needed. This site is the likely location of a temporary concrete batch plant for the south portal area construction work, if one is deemed necessary. This site would also be used for the assembly of the TBM substation, as well as for 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. The remaining portion of the building is expected to be approximately 60 feet tall with vent stacks extending up to 30 feet above the roof.

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 during construction.

At this time, it is anticipated that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). Should noise levels exceed City noise level limits, a noise variance would be needed.

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

6.1.2 Bored Tunnel

The current plan is to initiate cut-and-cover construction from the south portal access point at Alaskan Way S., near the middle point between S. Royal Brougham Way and S. King Street. 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 northern 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 installed, with the southbound roadway above the northbound roadway in the tunnel. Each roadway deck would support two lanes of traffic. Construction durations for this activity are based on the assumption of three shifts 6 days per week.

For deep bore tunnel construction, three types of pressurized-face tunneling machines are in use today. These machines 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. Spoils would be removed through the south portal using hoppers and conveyors to transport spoils to a staging area (potentially off site) for stockpiling before trucking or barging to a disposal site. Additional noise and vibration effects would occur from these ancillary construction activities, although as previously noted, removal of spoils would primarily take place in a manufacturing/industrial zone with typically high noise levels.

The majority of the noise and vibration associated with the bored tunnel would occur below ground. The maximum noise levels of construction equipment would be similar to the typical maximum construction equipment noise levels presented in Exhibit 6-1. At this time, it is anticipated that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). Should noise levels exceed City noise level limits, a noise variance would be needed.

6.1.3 North Portal

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 of the north portal 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 would be used to facilitate the extraction of the TBM. It would also accommodate the construction of the interior structures housing the northbound 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.

As part of the north portal, a tunnel operations building would be constructed between Thomas and Harrison Streets on the east side of Sixth Avenue N. Part of the building would be constructed underground. The remaining portion of the building is expected to be approximately 65 feet tall with vent stacks extending up to 30 feet above the roof.

Noise associated with construction activities in the north portal area could be bothersome to nearby residents and businesses. At this time, it is anticipated that construction noise levels may exceed City noise level limits at 50 feet or the nearest property line (whichever is farther). Should noise levels exceed City noise level limits, a noise variance would be needed.

6.1.4 Viaduct Removal

The demolition of the existing Alaskan Way Viaduct, from S. King Street to Battery Street, would take approximately 10 months, assuming two shifts per day, 6 days per week. A 1-month stage is planned for the portion of the viaduct between the middle of the WOSCA site and S. King Street, and a separate 9-month stage is planned for removal of the much larger remaining portion of the viaduct.

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 four blocks along the viaduct alignment would be under demolition each week.

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

6.1.5 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.

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

6.2 Construction Mitigation

6.2.1 Noise

Construction of the Bored Tunnel Alternative may require substantial nighttime construction activities; therefore, a nighttime noise variance may be required from the City. Because of the magnitude of the project, a Major Public Project Construction Noise Variance would most likely be required. In coordination with the City, construction noise mitigation requirements would be developed and specified in the noise variance. To reduce construction noise at nearby receptors, mitigation measures such as the following could be incorporated into construction plans, specifications, and variance requirements:

- Develop a construction noise management and monitoring plan that establishes specific noise levels that may not be exceeded for various activities during specific times. This would establish a set of noise limits that could be met during construction while still protecting the public from excessive noise effects.
- Crush and recycle concrete off site, away from noise-sensitive uses, 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 barriers or curtains around stationary equipment and long-term work areas located close to residences to decrease noise levels at nearby sensitive receptors. This could reduce equipment noise by 5 to 10 dBA.
- Limit the noisiest construction activities to between 7 a.m. and 10 p.m. on weekdays and between 9 a.m. and 10 p.m. on weekends and legal holidays to reduce construction noise levels during sensitive nighttime hours. A noise variance would be required from the City for construction between 10 p.m. and 7 a.m. on weekdays and between 10 p.m. and 9 a.m. on weekends and legal holidays.
- Limit use of impact equipment to between 8 a.m. and 5 p.m. on weekdays and between 9 a.m. and 5 p.m. on weekends and legal holidays. A noise variance from the City would also be required for impact equipment used for construction between 5 p.m. and 8 a.m. on weekdays and between 5 p.m. and 9 a.m. on weekends and legal holidays.
- Use generators and compressors between 10:00 p.m. and 7:00 a.m. Monday through Friday and between 10:00 p.m. and 9:00 a.m. Saturday, Sunday, and legal holidays provided that WSDOT-approved noise mitigation shields are used during this type of work. Specifications for this measure may by modified or changed at the request of the Seattle

Department of Planning and Development, depending on specific location and duration.

- Equip construction equipment engines with adequate mufflers, intake silencers, and engine enclosures; this could reduce noise by 5 to 10 dBA.
- Use the quietest equipment available; this could reduce noise by 5 to 10 dBA.
- Turn off construction equipment during prolonged periods of non-use; this could eliminate noise from construction equipment during those periods.
- Require maintenance of all equipment and training of equipment operators; this could reduce noise levels and increase operational efficiency. Out-of-specification mufflers can increase equipment noise by 10 to 20 dBA.
- Where possible, locate stationary equipment away from sensitive receiving properties.
- Provide a 24-hour noise complaint line.
- Notify nearby residents and businesses prior to 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, ambient-sensitive, 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 and 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. Monday through Friday, and between 10:00 p.m. and 9:00 a.m. on Saturday, Sunday, 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, or 9:00 a.m. on weekends.
- Trucks performing export hauling must use rubber bed liners 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. from Friday night through Sunday morning.

- During pavement removal, material spilled on the roadway could be removed by hand or by sweeping, avoiding the use of scraping equipment.

6.2.2 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 – A resilient material placed between the driving hammer and the pile.
- Alternative non-impact drivers – Several types of proprietary pile-driving systems have been designed specifically to reduce the impact-induced vibration by using torque and down-pressure or hydraulic static loading. These methods would be expected to substantially reduce adverse vibration effects of pile placement.

Vibration from other construction activities can be reduced by either restricting their operation to predetermined distances from historic structures or other sensitive receivers (such as sensitive utilities), or the use of alternative equipment or construction methods. An example would be the use of saws or rotary rock cutting heads to cut bridge decks or concrete slabs, instead of a hoe ram.

Vibration monitoring will be required at the nearest historic structure or sensitive receiver (such as sensitive utilities) within 300 feet of construction activities. The monitored 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.

Chapter 7 CUMULATIVE EFFECTS

Cumulative effects are effects on the environmental that result from the incremental impact of the proposed action when added to other past, present, or reasonably foreseeable future actions. Attachment A, Cumulative Effects Analysis, provides a more detailed analysis of cumulative effects. It describes the specific geographic area evaluated for cumulative effects and the period considered, and provides a list of past, present, and reasonably foreseeable future projects used to evaluate these effects.

7.1 Trends Leading to Present Noise Conditions

The city of Seattle was first settled in 1851 in the Yesler area near Pioneer Square. The city has developed steadily as an urban center since that time, with large-scale commercial and industrial development including rail and working wharves in the downtown core area in the south portal area, retail with residential mix to the north, and residential with retail mix in the north portal area. The construction and operational activities created noisy conditions that likely grew to considerable levels and likely was one of the factors that lead to decreased livability. Noise sources would have included construction activities, various transportation modes, such as the noises associated with train whistles ship's horns, and wheels on cobblestone-paved streets. Progressive levels of congestion from car and truck traffic after the 1930s until the present day also affect people working and living in the Program area. In addition, many of the buildings in the Program area were built in the early 20th century and are considered fragile. These buildings and their occupants may be more sensitive to nuisance noise and the potential for building damage due to vibration.

7.2 Effects From Other Roadway Elements of the Program

7.2.1 Alaskan Way Surface Street Improvements – S. King to Pike Streets

The Alaskan Way surface street would be six lanes wide between S. King and Columbia Streets (not including turn lanes), transitioning to four lanes between Marion and Pike Streets. Generally, the new Alaskan Way surface street would be located on the east side of the right-of-way where the viaduct is located today. The new street would include new sidewalks, bicycle lanes, parking and loading zones, and signalized pedestrian crossings at cross streets.

Changes in the alignment of the Alaskan Way surface street would lead to Alaskan Way operating much like many other downtown streets. An increase in noise levels would occur at areas that would be closer to the existing alignment, and a decrease in noise levels would occur for areas that would be farther from the existing alignment. Increased traffic volumes along Alaskan Way could lead to an increase in noise levels. Without the viaduct, operational noise levels along the waterfront would still be lower than existing levels.

These improvements are expected to add to the noise and vibration effects in the study area during project construction.

7.2.2 Elliott/Western Connector – Pike Street to Battery Street

The new roadway connecting Alaskan Way to Elliott and Western Avenues (in the area between Pike and Battery Streets) would be four lanes wide and would provide a grade-separated crossing of the BNSF mainline railroad tracks. The new roadway would include bicycle and pedestrian facilities. The Lenora Street pedestrian bridge is expected to remain as it is today, except that where the bridge terminates on its east side, modifications would be made to provide an at-grade pedestrian crossing on Elliott Avenue.

An increase in traffic volumes along the connecting structure from Pike Street to Battery Street could lead to an increase in noise levels. Without the viaduct, operational noise levels along the connecting structure would still be lower than existing levels with the viaduct. Construction noise from these improvements would be bothersome to nearby noise-sensitive uses, such as Victor Steinbrueck Park located at Western Avenue and Virginia Street.

7.2.3 Mercer West Project – Fifth Avenue N. to Elliott Avenue

Mercer Street would be restriped and signalized between Fifth Avenue N. and Second Avenue W. to create a two-way street with turn pockets. These improvements also include the restriping and resignalization necessary to convert Roy Street to two-way operations from Fifth Avenue N. to Queen Anne Avenue N.

An increase in traffic volumes and speeds along the Mercer Street west corridor could lead to an increase in operational noise levels compared to existing conditions. Construction noise from these improvements would be bothersome to nearby noise-sensitive uses.

7.3 Effects from Non-Roadway Elements of the Program

7.3.1 Elliott Bay Seawall Project

The Elliott Bay Seawall needs to be replaced to protect the shoreline along Elliott Bay, including Alaskan Way. It is at risk of failure due to seismic and storm events. The seawall currently extends from S. Washington Street in the south to Bay Street in the north, a distance of about 8,000 feet. The Elliott Bay Seawall

Project limits extend from S. Washington Street in the south to Pine Street in the north (also known as the central seawall).

The seawall replacement is not anticipated to affect operational noise levels. Construction noise from these improvements would be bothersome to nearby noise-sensitive uses.

7.3.2 Alaskan Way Promenade/Public Space

A new expanded waterfront promenade and public space would be provided to the west of the new Alaskan Way surface street between S. King Street and Pike Street. Between Marion and Pike Streets, this space would be approximately 70 to 80 feet wide. This public space will be designed at a later date. Access to the piers would be provided by service driveways. Other potential open-space sites include a triangular space north of Pike Street and east of Alaskan Way and parcels created by the removal of the viaduct between Lenora and Battery Streets.

Noise levels experienced on the Alaskan Way Promenade/Public Space would be substantially lower than existing conditions. Noise levels would be lower the farther the receiver is from the alignment of Alaskan Way. Construction noise from these improvements would be bothersome to nearby noise-sensitive uses.

7.3.3 First Avenue Streetcar Evaluation

The First Avenue streetcar is planned to run between S. Jackson Street and Republican Street along First Avenue and would include an extension to the South Lake Union streetcar line. The maintenance base would likely be either at the extension of the South Lake Union line or at a new maintenance base that would be built as part of the First Hill streetcar line.

First Avenue could experience a decrease in traffic volume, and the streetcar noise would be added to the existing noise environment. Noise levels would be similar to existing conditions. Construction noise from these improvements would be bothersome to nearby noise-sensitive uses.

7.3.4 Transit Enhancements

A variety of transit enhancements would be provided to support planned transportation improvements associated with the Program and to accommodate future demand. These enhancements include (1) the Delridge RapidRide line, (2) additional service hours on the West Seattle and Ballard RapidRide lines, (3) peak-hour express routes added to South Lake Union and Uptown, (4) local bus changes (such as realignments and a few additions) to several West Seattle and northwest Seattle routes, (5) transit priority on S. Main and/or S. Washington Streets between Alaskan Way and Third Avenue, and (6) simplification of the electric trolley system. RapidRide transit along the Aurora Avenue corridor would also be provided.

Enhanced transit service could lead to an increase in the volume of buses and a decrease in traffic volume. Noise levels would be similar to existing conditions. No construction noise is anticipated to affect nearby noise-sensitive uses.

7.4 Cumulative Effects of the Project and Other Program Elements

Traffic noise levels between S. Royal Brougham Way and S. King Street, along the central waterfront, and north of Denny Way to Harrison Street would already be reduced as a result of the Program. In other areas, traffic noise levels would be similar to current levels because (1) traffic patterns would not substantially change, and (2) peak traffic volumes would increase only slightly because current peak-period traffic volumes are near the capacity of the roadway system in much of the study area. Traffic noise levels would continue to approach or exceed the FHWA noise abatement criteria throughout much of the study area. For additional discussion of these transportation changes, see Appendix C, Transportation Discipline Report.

7.5 Cumulative Effects of the Project, Other Program Elements, and Other Actions

This section describes the cumulative effects of the Bored Tunnel Alternative and the other Program elements when combined with those of past, present, and reasonably foreseeable future projects.

The Bored Tunnel Alternative would contribute to effects on adjacent businesses in addition to effects from other projects that may occur along, or near, the proposed project alignment. Other key development projects located within the study area include the following:

- Alaskan Way Viaduct and Seawall Replacement Moving Forward projects
- Sound Transit projects
- S. Spokane Street Viaduct Widening
- SR 519 Intermodal Access Project, Phase 2
- SR 520 Bridge Replacement and HOV Program
- I-5 Improvements
- South Lake Union Redevelopment

These key development projects are expected to add to the noise and vibration effects in the study area that would occur during project construction. In addition, other smaller private projects along the project alignment, such as Belltown/Queen Anne Proposed Development, and Seattle Downtown Proposed

Development, , are expected to be developed during the construction period of the Bored Tunnel Alternative. Although the timelines for these projects would be staggered, taken together, they would be expected to cause adjacent noise-sensitive uses to experience higher noise levels.

Under the Bored Tunnel Alternative, traffic noise levels south of S. King Street, along the central waterfront, and north of Denny Way to Harrison Street would already be greatly reduced compared to existing levels. In other areas, traffic noise levels would be similar to current levels because (1) traffic patterns would not substantially change, and (2) peak traffic volumes would increase only slightly because current peak-period traffic volumes are near the capacity of the roadway system in much of the study area. Traffic noise levels would continue to approach or exceed the FHWA noise abatement criteria throughout much of the study area. For additional discussion of these transportation changes, see Appendix C, Transportation Discipline Report.

This Page Intentionally Left Blank

Chapter 8 REFERENCES

Acoustical Society of America. 2001. American National Standard: Guide to Evaluation of Human Exposure to Vibration in Buildings. Revised. ANSI S3.29-2001.

EPA (U.S. Environmental Protection Agency). 1971. Noise From Construction Equipment and Operations, Building Equipment, and Home Appliances. Washington, D.C.

EPA. 1974. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety. Report Number 550/9-74-004. Washington, D.C.

FTA (Federal Transit Administration). 2006. Transit noise and vibration impact assessment. May 2006.

ISO (International Organization for Standardization). 1989. Evaluation of Human Exposure to Whole-Body Vibration in Buildings (1–80 Hz). ISO-2631-2.

Nicholls, H.R., C.F. Johnson, and W.I. Duvall. 1971. Blasting Vibrations and Their Effect on Structures. U.S. Bureau of Mines Bulletin #656.

USDOT (U.S. Department of Transportation). 1973. Fundamentals and Abatement of Highway Traffic Noise. Federal Highway Administration, Washington, D.C.

USDOT. 1982. Highway Construction Noise – Environmental Assessment and Abatement. Federal Highway Administration, Washington, D.C.

USDOT. 1995. Transit Noise and Vibration Impact Assessment. Federal Transit Administration, Washington, D.C.

USDOT. 1996. Measurement of Highway-Related Noise. Federal Highway Administration, Washington, D.C.

USDOT. 1998. FHWA Traffic Noise Model User's Guide. Federal Highway Administration, Washington, D.C.

USDOT. 2004a. FHWA Traffic Noise Model (TNM) Version 2.5 User's Guide. Federal Highway Administration, Washington, D.C.

USDOT. 2004b. Federal Highway Administration's Traffic Noise Model (FHWA TNM®) User's Guide (Version 2.5 Addendum). Final Report April 2004. Federal Highway Administration, Washington, D.C.

WSDOT (Washington State Department of Transportation). 1992. Multi-Level Roadway Noise Abatement. Report WA-RD 266.1.

WSDOT. 2005. Ship Canal Bridge Noise Study. [Cited in new Sound-Absorptive Materials section in Section 5.4.2].

WSDOT. 2006. Traffic Noise Analysis and Abatement Policy and Procedures. Olympia, Washington.

WSDOT, City of Seattle, and U.S. Department of Transportation, Federal Highway Administration. 2004. SR 99: Alaskan Way Viaduct & Seawall Replacement Project Draft Environmental Impact Statement. Washington State Department of Transportation, Urban Corridors Office, Seattle, Washington.

WSDOT, City of Seattle, and U.S. Department of Transportation, Federal Highway Administration. 2006. SR 99: Alaskan Way Viaduct & Seawall Replacement Project Supplemental Draft Environmental Impact Statement and Section 4(f) Evaluation. Washington State Department of Transportation, Urban Corridors Office, Seattle, Washington.

ATTACHMENT A

Cumulative Effects Analysis

This Page Intentionally Left Blank

Cumulative Effects Analysis

This cumulative effects analysis follows *Guidance on Preparing Cumulative Impact Analyses*, published by Washington State Department of Transportation (WSDOT) in February 2008. The guidance document was developed jointly by WSDOT, Federal Highway Administration (FHWA) – Washington Division, and U.S. Environmental Protection Agency – Region 10. The guidance can be used for FHWA's National Environmental Policy Act (NEPA) compliance (Code of Federal Regulations, Title 23, Part 771) and fulfillment of Washington State Environmental Policy Act (SEPA) requirements for evaluation of cumulative effects (Washington Administrative Code, Section 197-11-792).

The approach provided in the WSDOT guidance calls for early consideration of cumulative impacts while direct and indirect effects are being identified, preferably as part of the scoping process. For analysis, the guidance recommends the use of environmental documents such as discipline reports, as well as other relevant information such as local comprehensive plans, zoning, recent building permits, and interviews with local government. The guidance also advocates a partnership approach among agencies that includes early collaboration and integrated planning activities.

The guidance established eight steps to serve as guidelines for identifying and assessing cumulative impacts. These eight steps have been used in the following cumulative effects evaluation for the Bored Tunnel Alternative of the Alaskan Way Viaduct Replacement Project (the project). A matrix that identifies projects with the potential for cumulative effects with this project and an assessment of likely contributions to cumulative effects is also included.

Step 1. Identify the resource that may have cumulative impacts to consider in the analysis

Noise and vibration

Step 2. Define the study area and timeframe for the affected resource

The study area for the assessment of potential cumulative effects is the same as for the assessment of direct and indirect effects.

- The study area for operational benefits and effects extends approximately two blocks on either side of SR 99 from the vicinity of S. Royal Brougham Way to Roy Street.
- The study area for the assessment of temporary construction effects extends approximately two blocks from the construction zone. Nighttime construction noises would be disturbing for residents trying to sleep within two blocks of construction activities.

The timeframe for the assessment of potential cumulative effects includes construction and operation of the proposed project.

- The timeframe for construction-related (temporary) effects is the approximately 66-month construction duration for the Bored Tunnel Alternative (2011 through 2017).
- Operational effects were assessed for the design year of the project (2030).

Step 3. Describe the current health and historical context for each affected resource

Most of the project area is located within a highly developed urban city established in the mid-1850s. Extensive development includes a commercial and industrial center in the south portal area, a bustling retail district through the core area, and retail and residential uses in the north portal area. These areas are linked by roadways. Many of the buildings in the historic districts and along the project corridor were constructed from the late 1880s to the 1920s, making them more susceptible to nuisance noise and damage due to vibration. Rises in noise levels throughout the city were likely due to the transportation corridors for cars and rail. It is likely that Seattle's historical and current noise levels are comparable to other similarly sized cities.

Construction in the Seattle downtown area is an ongoing activity, and construction noise occurs frequently. The study area for noise runs through the downtown core of Seattle; it includes the two portal areas where vehicles would enter and exit the bored tunnel. Land use in the area ranges from low-rise light-industrial buildings to high-rise office towers. Portions of the study area, such as Belltown, include residential zoning. Noise-sensitive uses include residences, hotels, motels, parks, social services, daycare providers, and public spaces. There are several old, potentially vibration-sensitive structures adjacent to the existing Alaskan Way Viaduct.

The primary area for potential vibration effects includes commercial buildings close to the viaduct, with some residential buildings located farther away.

Step 4. Identify the direct and indirect impacts that may contribute to a cumulative impact

Construction effects of other projects were assessed qualitatively in terms of how their construction noise from equipment use and construction activities would contribute to the cumulative noise environment. Operational benefits and effects of other projects were assessed qualitatively in terms of how they would affect traffic patterns, congestion, and travel speeds, which would then affect the total noise environment.

Noise levels for the loudest hour of the day were modeled throughout the study area to characterize the existing overall acoustical environment (see Exhibit 4-1 of the Noise Discipline Report for noise measurement locations). Existing traffic noise levels were predicted to approach or exceed the FHWA noise abatement criteria at 48 of the 68 modeled sites (see Exhibit 4-2 of the Noise Discipline Report for modeled existing noise levels). The modeled traffic-only noise level at seven sites currently exceeds the severe noise impact criterion. The sites where existing severe traffic noise impacts (noise levels exceeding 75 A-weighted decibels (dBA) at sensitive land uses) were modeled are receptors 10, 14, 15, 19, 25, 28, 29, 30, 32, 33, 35, 47, 48, and 52.

To document the existing vibration environment in these areas, field measurements were taken at representative locations beneath the viaduct and above the proposed tunnel alignment. Existing vibration levels resulting from heavy vehicles on the viaduct and along First Avenue areaways were measured in 11 locations, along with 6 locations around the proposed north portal, to establish a baseline (see Exhibit 4-3 of the Noise Discipline Report). The four sites along the viaduct represent the occupied buildings closest to the viaduct. The additional sites represent the buildings closest to the proposed tunnel. No vibration effects were identified.

Step 5. Identify other historic, current, or reasonably foreseeable actions that may affect resources

The project team considered 39 projects (shown in the matrix at the end of this attachment) for potential activities that could have a cumulative effect on noise within the study area. The projects likely to have some cumulative noise effects are identified below. No projects were identified to contribute to cumulative vibration effects.

The three projects below would have cumulative effects during construction and could lead to an increase in noise levels during operation of the Bored Tunnel Alternative.

- **A.1.** Alaskan Way Surface Street Improvements – S. King Street to Pike Street
- **A.2.** Elliott/Western Connector – Pike Street to Battery Street
- **A.3.** Mercer West Project – Mercer Street from Fifth Avenue N. to Elliott Avenue and Roy Street from Aurora Avenue to Queen Anne Avenue N. become two-way

The three projects below would have temporary cumulative effects during construction that could be bothersome to nearby noise-sensitive uses. These projects would not lead to an increase in noise levels during operation of the project.

- **B.1.** Elliott Bay Seawall Project
- **B.2.** Alaskan Way Promenade/Public Space
- **B.4.** First Avenue Streetcar Evaluation

The 12 projects below would contribute to minor temporary cumulative effects during construction that could be bothersome to nearby noise-sensitive uses. These projects would not lead to an increase in noise levels during operation of the project.

- **E.1.** Gull Industries on First Avenue S.
- **E.2.** North Parking Lot Development at Qwest Field
- **E.3.** Seattle Center Master Plan (EIS) (Century 21 Master Plan)
- **E.4.** Bill and Melinda Gates Foundation Campus Master Plan
- **E.5.** South Lake Union Redevelopment
- **E.6.** U.S. Coast Guard Integrated Support Command
- **E.7.** Seattle Aquarium and Waterfront Park
- **E.8.** Seattle Combined Sewer System Upgrades
- **F.1.** Bridging the Gap Projects
- **F.2.** S. Spokane Street Viaduct Widening
- **F.3.** SR 99/East Marginal Way Grade Separation
- **F.4.** Mercer East Project from Dexter Avenue N. to I-5

<u>Step 6</u>. Assess potential cumulative impacts to the resource; determine the magnitude and significance

Construction effects of the projects would include the following temporary effects:

- Increased noise in the general areas where construction would occur simultaneously with the construction activity associated with other nearby projects.

Simultaneous construction activity is likely to occur in the same areas as construction of the Bored Tunnel Alternative. Temporary traffic detours would further affect traffic that cannot use the new SR 99 bored tunnel and would be reliant upon the surface street network along the waterfront and through downtown. These impacts would be highly localized and would not likely affect most of the surrounding area.

Changes in the alignment of surface streets would lead to an increase in noise levels for receptors that would be closer and a decrease in noise levels for receptors that would be farther from the new alignment. Generally, an increase in traffic volumes along the surface streets could lead to an increase in noise levels. Without the viaduct, operational noise levels along the waterfront would still be lower compared to existing levels, and noise levels would be similar to existing levels elsewhere.

Because there would be no direct vibration impacts from the operation of the project, no cumulative vibration impacts are predicted.

<u>Step 7</u>. Report the results

The cumulative effects would be highly localized around the area of immediate impact during construction but there would be no significant cumulative effects on the larger area that includes nearby projects (see the matrix below). Without the viaduct, operational noise levels along the waterfront would still be lower compared to existing levels, and noise levels would be similar to existing levels elsewhere.

<u>Step 8</u>. Assess and discuss potential mitigation issues for all adverse impacts

No mitigation for cumulative noise effects is proposed.

The following matrix identifies project-specific potential cumulative effects.

PROJECT-SPECIFIC CUMULATIVE EFFECTS MATRIX

PROJECT	POTENTIAL CUMULATIVE EFFECTS
A. Roadway Elements	
A1. Alaskan Way Surface Street Improvements – S. King Street to Pike Street	Construction of these improvements would result in a temporary increase in noise from construction equipment and construction activities. Changes in the alignment of the Alaskan Way surface street would lead to an increase in noise levels for receptors that would be closer and a decrease in noise levels for receptors that would be farther from the new alignment. An increase in traffic volumes along the Alaskan Way surface street could lead to an increase in noise and vibration levels. Without the viaduct, operational noise levels along the waterfront would still be lower compared to existing levels.
A2. Elliott/Western Connector – Pike Street to Battery Street	Construction of these improvements would result in a temporary increase in noise from construction equipment and construction activities. An increase in traffic volumes along the connecting structure from Pike Street to Battery Street could lead to an increase in noise levels. Without the viaduct, operational noise levels along the connecting structure would still be lower compared to existing levels.
A3. Mercer West Project – Mercer Street from Fifth Avenue N. to Elliott Avenue and Roy Street from Aurora Avenue to Queen Anne Avenue N. become two-way	Construction of these improvements would result in a temporary increase in noise from construction equipment and construction activities. An increase in traffic volumes and speeds along the Mercer Street west corridor could lead to an increase in operational noise levels compared to existing conditions.
B. Non-Roadway Elements	
B1. Elliott Bay Seawall Project	Construction of these improvements would result in a temporary increase in noise from construction equipment and construction activities. The operation and maintenance of the facility would not affect noise.
B2. Alaskan Way Promenade/Public Space	Construction of these improvements would result in a temporary increase in noise from construction equipment and construction activities. The operation and maintenance of the facility would not affect traffic noise.

PROJECT	POTENTIAL CUMULATIVE EFFECTS
B3. Transit Enhancements – 1) Delridge RapidRide 2) Additional service hours on West Seattle and Ballard RapidRide lines 3) Peak hour express routes added to South Lake Union and Uptown 4) Local bus changes to several West Seattle and northwest Seattle routes 5)Transit priority on S. Main and/or S. Washington Streets between Alaskan Way and Third Avenue 6) Simplification of the electric trolley system	Due to the increase in transit and decrease in automobile use, traffic-related noise levels would be similar to those modeled.
B4. First Avenue Streetcar Evaluation	Construction of these improvements would result in a temporary increase in noise from construction equipment and construction activities. Due to the increase in transit and decrease in automotive use, traffic-related noise levels would be similar to those modeled.
C. Projects Under Construction	
C1. S. Holgate Street to S. King Street Viaduct Replacement Project	Construction of these improvements would result in a temporary increase in noise from construction equipment and construction activities. The operation and maintenance of the facility would not affect noise.
C2. Transportation Improvements to Minimize Traffic Effects During Construction	Construction of these improvements would result in a temporary increase in noise from construction equipment and construction activities. The operation and maintenance of the facility would not affect traffic noise.
D. Completed Projects	
D1. SR 99 Yesler Way Vicinity Foundation Stabilization (Column Safety Repairs)	No cumulative effects on noise are anticipated during construction or operation. Construction of this project is already completed.
D2. S. Massachusetts Street to Railroad Way S. Electrical Line Relocation Project (Electrical Line Relocation Along the Viaduct's South End)	No cumulative effects on noise are anticipated during construction or operation. Construction of this project is already completed.
E. Seattle Planned Urban Development	
E1. Gull Industries on First Avenue S.	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation.
E2. North Parking Lot Development at Qwest Field	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation.
E3. Seattle Center Master Plan (EIS) (Century 21 Master Plan)	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation.
E4. Bill and Melinda Gates Foundation Campus Master Plan	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation.

PROJECT-SPECIFIC CUMULATIVE EFFECTS MATRIX (CONTINUED)

PROJECT	POTENTIAL CUMULATIVE EFFECTS
E5. South Lake Union Redevelopment	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation.
E6. U.S. Coast Guard Integrated Support Command	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation.
E7. Seattle Aquarium and Waterfront Park	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation.
E8. Seattle Combined Sewer System Upgrades	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation.
F. Local Roadway Improvements	
F1. Bridging the Gap Projects	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation because operational effects of the improvements were included in the 2030 Bored Tunnel Alternative noise analysis.
F2. S. Spokane Street Viaduct Widening	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation because operational effects of the improvements were included in the 2030 Bored Tunnel Alternative noise analysis.
F3. SR 99/East Marginal Way Grade Separation	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation because operational effects of the improvements were included in the 2030 Bored Tunnel Alternative noise analysis.
F4. Mercer East Project from Dexter Avenue N. to I-5	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are expected during operation because operational effects of the improvements were included in the 2030 Bored Tunnel Alternative noise analysis.
G. Regional Roadway Improvements	
G1. I-5 Improvements	No cumulative effects on noise are anticipated during construction or operation. Construction will be outside the study area. Operational effects were included in the 2030 Bored Tunnel Alternative noise analysis.
G2. SR 520 Bridge Replacement and HOV Program	No cumulative effects on noise are anticipated during construction or operation. Construction will be outside the study area. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.
G3. I-405 Corridor Program	No cumulative effects on noise are anticipated during construction or operation. Construction will be outside the study area. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.

PROJECT-SPECIFIC CUMULATIVE EFFECTS MATRIX (CONTINUED)

PROJECT	POTENTIAL CUMULATIVE EFFECTS
G4. I-90 Two-Way Transit and HOV Operations, Stages 1 and 2	No cumulative effects on noise are anticipated during construction or operation. Construction will be outside the study area. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.
H. Transit Improvements	
H1. First Hill Streetcar	Possible minor cumulative effects on noise during construction. No cumulative effects on noise are anticipated during operation because operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.
H2. Sound Transit University Link Light Rail Project	No cumulative effects on noise are anticipated during construction or operation. Construction will be outside the study area. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.
H3. RapidRide	No cumulative effects on noise are anticipated during construction or operation. Any necessary construction will be outside the study area. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.
H4. Sound Transit North Link Light Rail	No cumulative effects on noise are anticipated during construction or operation. Construction will be outside the study area. Operational effects were included in the 2030 Bored Tunnel Alternative noise analysis.
H5. Sound Transit East Link Light Rail	No cumulative effects on noise are anticipated during construction or operation. Construction will be outside the study area. Operational effects were included in the 2030 Bored Tunnel Alternative noise analysis.
H6. Washington State Ferries Seattle Terminal Improvements	No cumulative effects on noise are anticipated.
I. Transportation Network Assumptions	
I1. HOV Definition Changes to 3+ Throughout the Puget Sound Region	No cumulative effects on noise are anticipated during construction or operation. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.
I2. Sound Transit Phases 1 and 2	No cumulative effects on noise are anticipated during construction or operation. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.
I3. Other Transit Improvements	No cumulative effects on noise are anticipated during construction or operation. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.

PROJECT-SPECIFIC CUMULATIVE EFFECTS MATRIX (CONTINUED)

PROJECT	POTENTIAL CUMULATIVE EFFECTS
J. Completed but Relevant Projects	
J1. Sound Transit Central Link Light Rail (including the Sea-Tac Airport extension)	No cumulative effects on noise are anticipated during construction or operation. Construction of this project is already completed. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.
J2. South Lake Union Streetcar	No cumulative effects on noise are anticipated during construction or operation. Construction of this project is already completed. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.
J3. SR 519 Intermodal Access Project, Phase 2	Construction of this project is already completed; therefore no adverse effects are expected. Operational effects were included in the 2015 and 2030 Bored Tunnel Alternative noise analysis.