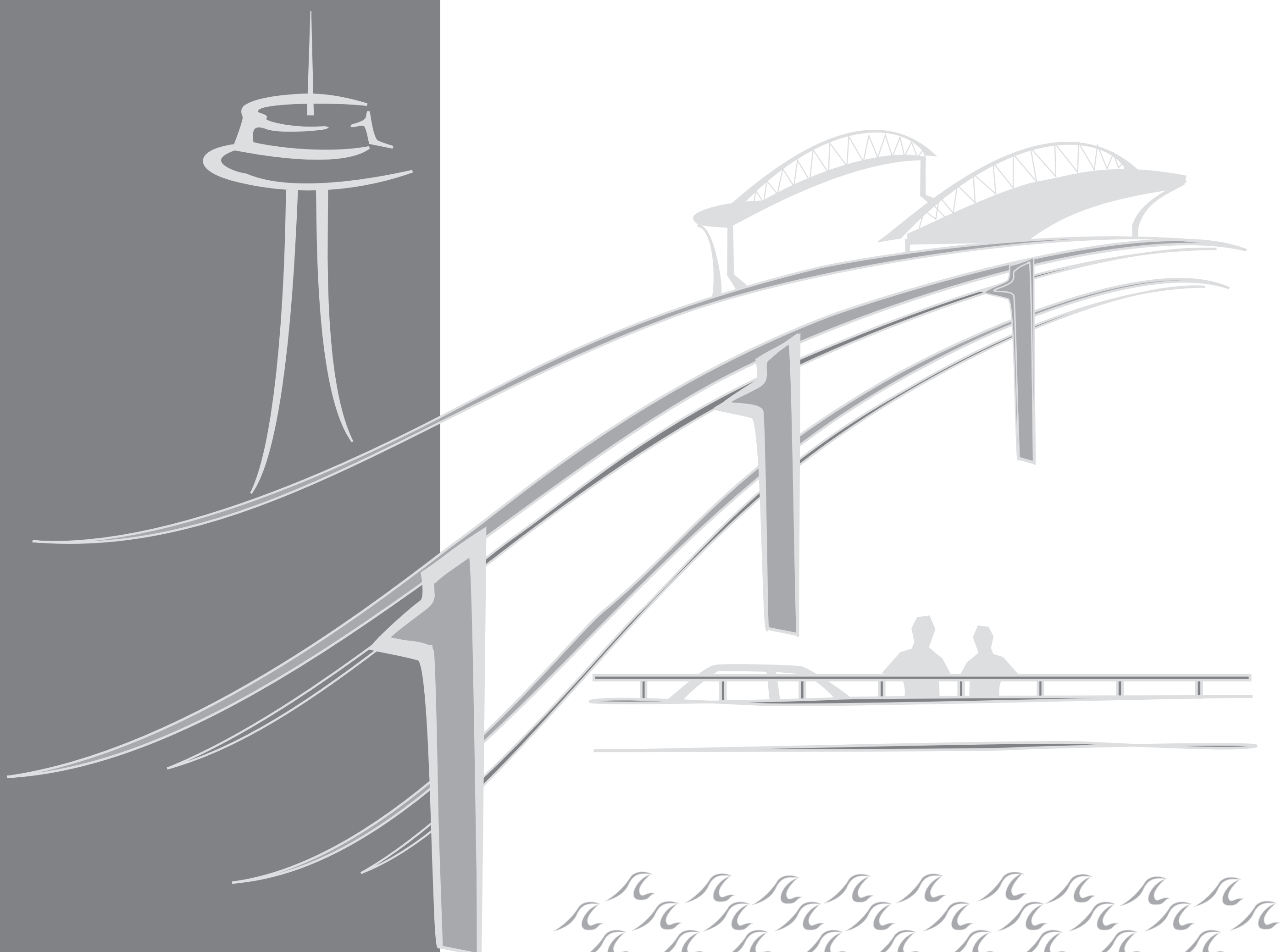
SR 99: ALASKAN WAY VIADUCT & SEAWALL REPLACEMENT PROJECT

Draft Environmental Impact Statement
Appendix F
Noise and Vibration Discipline Report



MARCH 2004

Submitted by:
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U.S. Department of Transportation Federal Highway Administration

Washington State Department of Transportation

City of Seattle

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SR 99: ALASKAN WAY VIADUCT & SEAWALL REPLACEMENT PROJECT

Draft EIS
Noise and Vibration Discipline Report

AGREEMENT NO. Y-7888

FHWA-WA-EIS-04-01-D

Submitted to:

Washington State Department of Transportation
Alaskan Way Viaduct and Seawall Replacement Project Office
999 Third Avenue, Suite 2424
Seattle, WA 98104

The SR 99: Alaskan Way Viaduct & Seawall Replacement Project is a joint effort between the Washington State Department of Transportation (WSDOT), the City of Seattle, and the Federal Highway Administration (FHWA). To conduct this project, WSDOT contracted with:

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In association with:

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TABLE OF CONTENTS

LIST OF EXHIBITS

ATTACHMENTS

ACRONYMS

ANSI	American National Standards Institute
dB	decibels
dBA	A-weighted decibels
EPA	United States Environmental Protection Agency
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
Hz	hertz (cycles per second)
ISO	International Organization for Standardization
L_{dn}	day/night sound level
L_{eq}	equivalent sound level
L_{max}	maximum sound level
L_{min}	minimum sound level
OSHA	Occupational Safety and Health Administration
Pa	Pascal
PPV	peak particle velocity
rms	root mean square
SMC	Seattle Municipal Code
SR	State Route
TNM	Traffic Noise Model
VdB	vibration decibels
WAC	Washington Administrative Code

Chapter 1 SUMMARY

The State Route (SR) 99 Alaskan Way Viaduct and Seawall Replacement Project is located within the urban core of Seattle. Environmental noise levels from both transportation and other sources are typical of an urban environment, and there is a high density of noise-sensitive receptors in the project vicinity. Five Build Alternatives and several options for replacement of the viaduct and seawall were evaluated.

Analysis of noise impacts in the study area compares predicted future noise levels with existing levels and applicable criteria. Construction noise impacts are described based on anticipated construction activities and typical noise levels for construction equipment. Traffic noise levels are predicted at specific noise-sensitive locations (receptors) using the Federal Highway Administration (FHWA) Traffic Noise Model (TNM). Mitigation measures that may be taken to avoid or reduce potential noise impacts are discussed where appropriate.

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 cut in half.

Traffic noise impacts occur when traffic noise levels approach 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 property-line noise limits.

To evaluate traffic noise impacts, 48 sites, representing approximately 4,600 residential units and other noise-sensitive uses, were modeled using TNM. Traffic noise levels at 43 of the 48 modeled sites currently approach or exceed the FHWA noise abatement criteria. The number of sensitive receptors that would be affected by noise under each of the alternatives is summarized in Exhibit 1-1. Mitigation measures were evaluated to limit noise and vibration impacts from both construction and long-term operation.

Expected 2030 peak traffic noise levels in the central waterfront area would be noticeably lower for the Tunnel and Bypass Tunnel Alternatives. For example, at the Colman Dock, the 2030 baseline, Rebuild, Aerial, and Surface

Alternatives would be 74 to 75 dBA, while the Tunnel and Bypass Tunnel Alternative noise levels would be 63 to 65 dBA.

The 2030 peak traffic noise levels at Waterfront Park and the Seattle Aquarium are 70 to 71 dBA and 73 to 74 dBA, respectively, for the 2030 No Build, Rebuild, and Aerial Alternatives. At these same locations, the Surface Alternative would lower noise levels by approximately 3 dBA, and the noise level would drop noticeably by 9 to 10 dBA for the Tunnel and Bypass Tunnel Alternatives.

At the Harbor Steps, the Tunnel and Bypass Tunnel Alternatives would lower noise levels by about 5 dBA compared to the 2030 No Build, Rebuild, Aerial, and Surface Alternatives. All of the alternatives may cause noise levels at Victor Steinbrueck Park to fluctuate by 1 dBA from the 2030 No Build, but this change would not be noticeable to people. Overall, the Tunnel and Bypass Tunnel Alternatives would reduce noise levels along the central waterfront area, which would make the area more pleasant for pedestrians, residents, and nearby businesses compared to the other alternatives.

Vibration is an oscillatory motion, which can be described in terms of the displacement, velocity, or acceleration. Vibration impacts relate to annoyance and the potential for structural damage. No annoyance impacts would occur inside buildings during operation. During viaduct demolition, buildings closer than 100 feet would exceed the damage risk criteria for extremely fragile buildings. The criteria for newer buildings would not be exceeded at 25 feet. For pile driving, buildings closer than 400 feet would exceed the damage risk criteria for extremely fragile buildings, while at 50 feet they would not exceed the criteria for newer buildings.

Under all of the alternatives, noise for certain types of construction activities, like pile driving and viaduct demolition, is expected to exceed City of Seattle noise regulations. Exceedances are expected to occur in the daytime and nighttime, which would require a noise variance from the City of Seattle. The Rebuild and Aerial Alternatives would have greater noise and vibration impacts compared to the other alternatives because construction of their structures through the central project area would require a considerable amount of pile driving. The Rebuild Alternative would have the greatest amount of noise and vibration impacts because it requires more pile driving than the other alternatives.

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

Alternative	Construction Impacts	Operation Impacts	Mitigation Measures
No Build	None	Traffic noise levels were modeled to approach or exceed the FHWA noise abatement criteria at 42 modeled sites representing approximately 4,490 residential units, 1,290 hotel rooms, and 120 shelter beds.	None required
Rebuild	During the 7.5-year construction period, noise would be bothersome to nearby residents and businesses.	Traffic noise levels were modeled to approach or exceed the FHWA noise abatement criteria at 43 modeled sites representing approximately 4,490 residential units, 1,290 hotel rooms, and 120 shelter beds.	A construction noise control program would be implemented to reduce construction noise impacts. Sound absorptive materials may be used on the bottom of the upper deck of the rebuilt viaduct to reduce traffic noise levels along the central waterfront.
Aerial	During the 11-year construction period, noise would be bothersome to nearby residents and businesses.	Traffic noise levels were modeled to approach or exceed the FHWA noise abatement criteria at 43 modeled sites representing approximately 4,490 residential units, 1,290 hotel rooms, and 120 shelter beds.	A construction noise control program would be implemented to reduce construction noise impacts. Sound absorptive materials may be used on the bottom of the upper deck of the new viaduct to reduce traffic noise levels along the central waterfront.
Tunnel	During the 9-year construction period, noise would be bothersome to nearby residents and businesses.	Traffic noise levels were modeled to approach or exceed the FHWA noise abatement criteria at 29 modeled sites representing approximately 4,250 residential units, 1,290 hotel rooms, and 120 shelter beds.	A construction noise control program would be implemented to reduce construction noise impacts.
Bypass Tunnel	During the 8.5-year construction period, noise would be bothersome to nearby residents and businesses.	Traffic noise levels were modeled to approach or exceed the FHWA noise abatement criteria at 31 modeled sites representing approximately 4,360 residential units, 1,290 hotel rooms, and 120 shelter beds.	A construction noise control program would be implemented to reduce construction noise impacts.

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

Alternative	Construction Impacts	Operation Impacts	Mitigation Measures
Surface	During the 8-year construction period, noise would be bothersome to nearby residents and businesses.	Traffic noise levels were modeled to approach or exceed the FHWA noise abatement criteria at 38 modeled sites representing approximately 4,490 residential units, 1,290 hotel rooms, and 120 shelter beds.	A construction noise control program would be implemented to reduce construction noise impacts.

Chapter 2 BACKGROUND, STUDIES, AND COORDINATION

2.1 Characteristics of Sound

Sound is created when objects vibrate, resulting in a minute 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 µPascals (10^{-6} Pascals). Sound pressure greater than about 100 Pascal (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 decibel 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 dBA 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 and varies from person to person. The human ear can better perceive changes in sound levels 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. A 10 dB increase appears to be a doubling in noise level to most listeners.

Humans also respond to a sound's frequency or pitch. The human ear can perceive sounds with a frequency between approximately 20 and 20,000 hertz (Hz), 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 commonly used frequency weighting for environmental sounds is A-weighting (dBA), which is most similar to how humans perceive sounds of low to moderate magnitude.

Sound levels decrease as the distance increases from the sound source. For a line source such as a roadway, sound levels decrease 3 dBA over hard ground (concrete, 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 near the receiver. 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). 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 be reflected 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 sound arriving directly at the receiver (Exhibit 2-2).

Noise levels from traffic sources depend on volume, speed, and the type of vehicle. Generally, an increase in volume, speed, or vehicle size increases traffic noise levels. 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.

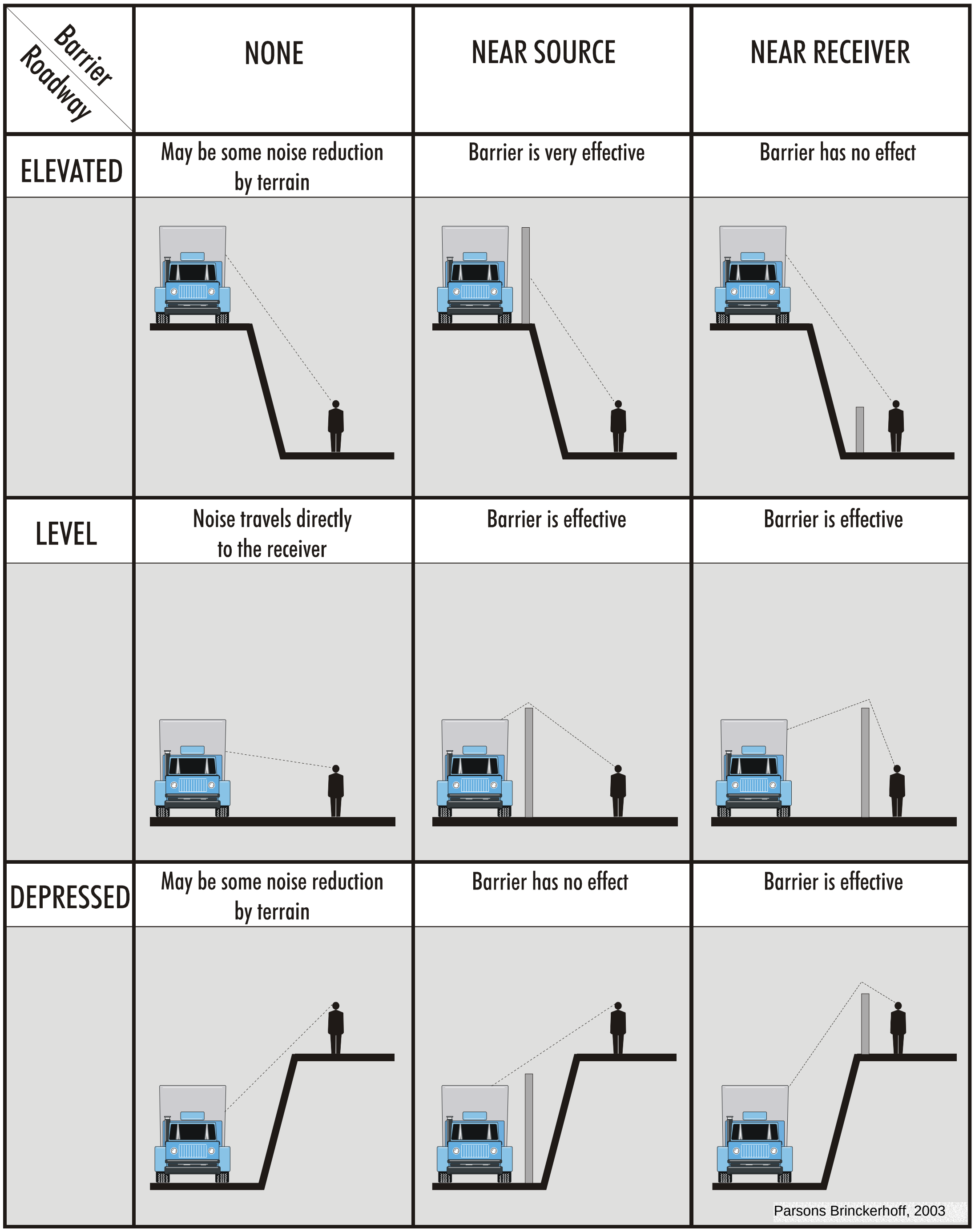


Exhibit 2-1. Effect of Terrain on Sound Propagation

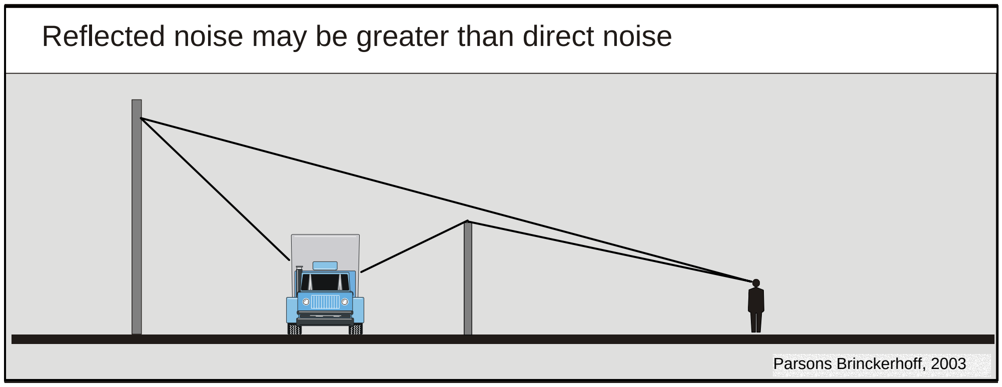


Exhibit 2-2. Effect of Reflected Sound

2.2 Sound Level Descriptors

A widely used descriptor for environmental noise is the equivalent sound level (L_{eq}). The L_{eq} is a measure of the average sound energy during a specified period of time. L_{eq} is defined as the constant level that, over a given period of time, transmits to the receiver the same amount of acoustical energy as the actual time-varying sound. Because the sound level, in dBA, represents sound energy logarithmically, occasional high sound energy levels have more effect on L_{eq} than does the general background sound energy level. Two sound patterns, one of which has a lower background level but a higher maximum level, can have the same L_{eq} (Exhibit 2-3).

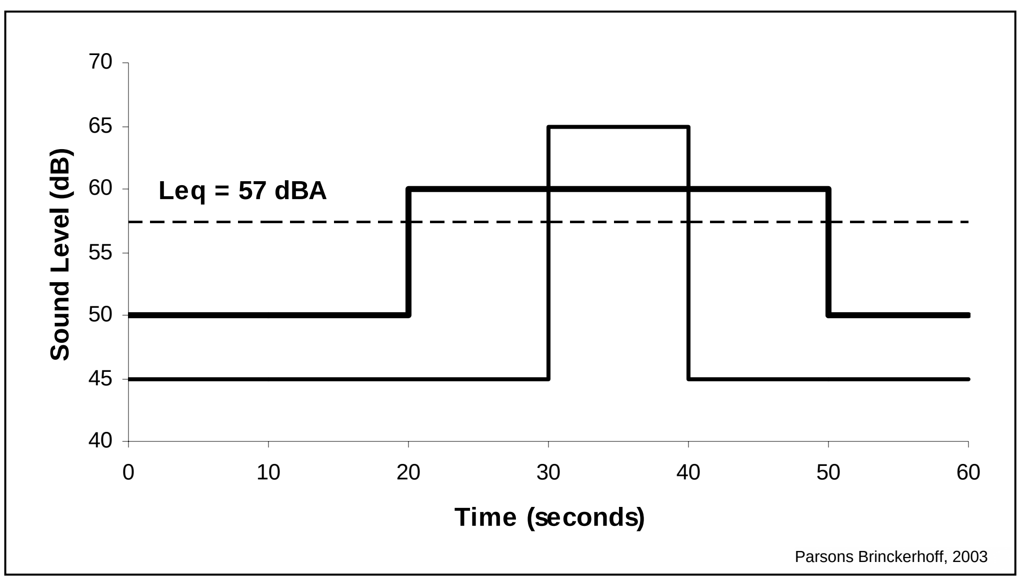


Exhibit 2-3. Example of Two Sound Patterns with the Same L_{eq} (1 minute)

L_{eq} measured over a 1-hour period is the hourly L_{eq} [L_{eq}(h)], which is used for highway noise impact and abatement analyses. The day/night level (L_{dn}), a daily averaged noise level that ranks noise that occurs during the evening or night more heavily, is often reported. The L_{dn} adds 10 dBA to noise levels that occur between 10 p.m. and 7 a.m. L_{dn} is used for transit noise impact and abatement analyses to residential areas.

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 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 impacts on speech interference and sleep disruption. In comparison, L_{min} is the minimum sound level during a period of time.

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 greatly upon the range that 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 time period in addition to the average sound level. Such distributions identify the sound level exceeded and the percentage of time exceeded; therefore, a statistical distribution allows for a more thorough description of the range of sound levels during the given measurement period. These distributions are identified with an L_n where n is the percentage of time that the levels are 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. The sound environments described between 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.

Exhibit 2-4. Typical Sound Levels

Transportation Sources	Sound Level (dBA)	Other Sources	Description
	130		Painfully loud
Jet takeoff (200 feet)	120		
Car horn (3 feet)			Maximum vocal effort
	110		
	100	Shout (0.5 feet)	
			Very annoying
Heavy truck (50 feet)	90	Jack hammer (50 feet)	Loss of hearing with prolonged exposure
		Home shop tools (3 feet)	
Train on a structure (50 feet)	85	Backhoe (50 feet)	
City bus (50 feet)	80	Bulldozer (50 feet)	Annoying
		Vacuum cleaner (3 feet)	
Train (50 feet)	75	Blender (3 feet)	
City bus at stop (50 feet)			
Freeway traffic (50 feet)	70	Lawn mower (50 feet)	
		Large office	
Train in station (50 feet)	65	Washing machine (3 feet)	Intrusive
	60	TV (10 feet)	
Light traffic (50 feet)		Talking (10 feet)	
Light traffic (100 feet)	50		Quiet
		Refrigerator (3 feet)	
	40	Library	
	30	Soft whisper (15 feet)	Very quiet

Sources: USDOT (1995); EPA (1971, 1974).

Background environmental sound levels vary widely in different environments. The United States 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 that are evaluated in this report.

Exhibit 2-5. Typical Outdoor Sound Levels in Various Environments

Qualitative Description	L_{dn} (dBA)
	85
City Noise (Downtown Major Metropolis)	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, which is a well documented impact 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 impacts. For federally funded highway projects, traffic noise impacts occur when predicted L_{eq}(h) noise levels approach or exceed the FHWA's established noise abatement criteria or substantially exceed existing noise levels (USDOT 1982; Noise Abatement Council). WSDOT noise policy adopts the FHWA criteria (WSDOT 2003). Although "substantially exceed" is not defined, WSDOT considers 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). For receptors where serenity and quiet are of extraordinary significance, the noise criterion is 57 dBA. For residences, parks, schools, churches, and similar areas, the noise criterion is 67 dBA. For developed lands, the noise criterion is 72 dBA. WSDOT considers a noise impact to occur if predicted L_{eq}(h) noise levels approach within 1 dBA of the noise abatement criteria in Exhibit 2-6. Thus, if a noise level were 66 dBA or higher, it would approach or exceed the FHWA noise abatement criterion of 67 dBA for residences.

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 Categories 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).

WSDOT defines severe noise impacts as traffic noise levels that exceed 75 dBA outdoors in Category B areas or 60 dBA indoors at Category E uses. 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.

2.5.2 Property Line Criteria

The City of Seattle limits noise levels at property lines of neighboring properties (SMC 25.08.410). The maximum permissible sound level depends on the land uses of both the source noise and 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 and 10 p.m. and 9 a.m. on weekends. Performance of construction activities during nighttime hours that would exceed these levels requires a noise variance from the City of Seattle.

Exhibit 2-7. City of Seattle Maximum Permissible Sound Levels (dBA)

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

[a] The maximum permissible sound level is reduced by 10 dBA for residential receiving properties between 10 p.m. and 7 a.m.
Source: Seattle Municipal Code 25.08.410.

Short-term exceedances above the permissible sound level are allowed for any noise source. The maximum level may be exceeded by 5 dBA for a total of 15 minutes, by 10 dBA for a total of 5 minutes, or by 15 dBA for a total of 1.5 minutes during any 1-hour period. These allowed exceptions are referred to in terms of the percentage of time a certain level is exceeded; an L_{25} is the noise level that is exceeded 15 minutes during an hour. Therefore, the permissible L_{25} would be 5 dBA greater than the values in Exhibit 2-7, provided that the noise level is below the permissible level in Exhibit 2-7 for the rest of the hour and never exceeds the permissible level by more than 5 dBA. An hourly L_{eq} of approximately 2 dBA higher than the values in Exhibit 2-7 is an equivalent sound level to the permissible levels, including the allowed short-term excursions. Using this example, an L_{eq}(h) of 59 dBA corresponds approximately to a noise level of 57 dBA for 45 minutes and 62 dBA for 15 minutes, which is the maximum permissible noise level created by a source in a commercial zone and received by a property in a residential zone.

Construction activities carried out 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 further (SMC 25.08.425):

- Earthmoving or other large construction equipment may exceed the applicable property line limit by 25 dBA.
- Portable powered equipment may exceed the limit by 20 dBA.
- Impact equipment, such as jackhammers, may not exceed an L_{eq}(h) of 90 dBA or an L_{eq}(7.5 min) of 99 dBA.

Under normal operations, tunnel ventilation fans are subject to the noise level limits of the Seattle Noise Ordinance. Under emergency operation conditions, the ventilation and jet fans are exempt from the Ordinance. Jet fans and ventilation fans do, however, have to 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. Standard NFPA 130 (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.

2.6 Characteristics of Vibration

Vibration is an oscillatory motion, which can be described in terms of the displacement, velocity, or acceleration. Because the motion is oscillatory, there is no net movement of the vibration element, and the average of any of the motion descriptors is zero. 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, even more important, 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 that are 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 of blasting vibration since it is related to the stresses that are experienced by buildings. Although peak particle velocity is appropriate for evaluating the potential of building damage, it is not suitable for evaluating human response. It takes some time for the human body to respond to vibration signals. In a sense, the human body responds to an 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 root mean square 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 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 acts to compress the range of numbers required to describe vibration. Vibration velocity level in decibels is defined as:

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

where "L_v" is the velocity level in decibels,
"V" is the rms velocity amplitude, and
"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 document for vibration decibels to reduce the potential for confusion with sound decibels.

2.8 Typical Vibration Levels

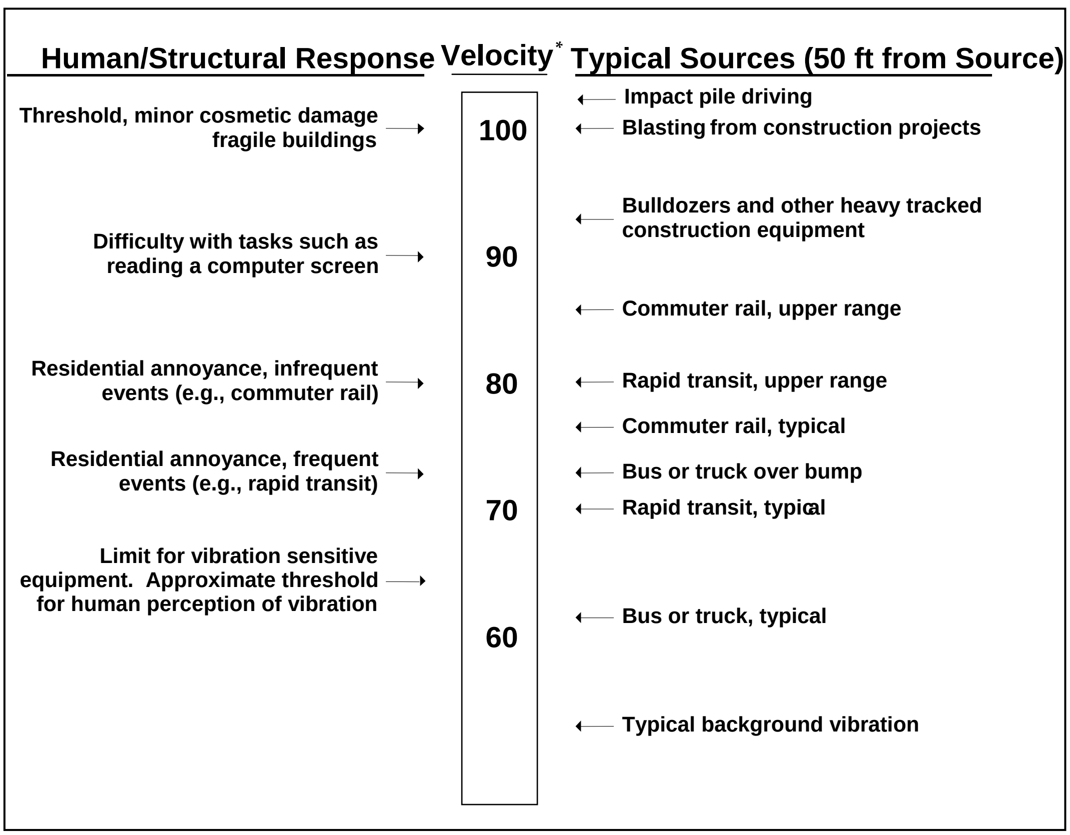
In contrast to airborne noise, ground-borne vibration is not a phenomenon that most people experience every day. The background vibration velocity level in residential areas is usually 50 VdB or lower, well below the threshold of perception for humans, which is around 65 VdB (Exhibit 2-8). Most perceptible 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 one of the greatest common sources of vibration. If the roadway is smooth, the vibration from traffic is rarely perceptible. The range of interest is from approximately 50 VdB to 100 VdB.

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 typical 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 significant unless the vibration exceeds 70 VdB. This is a typical 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 the 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. Most common sources of ground-borne vibration are trains, buses on rough roads, and construction activities such as blasting, pile driving, and operating heavy earth-moving equipment.

The effects of ground-borne vibration include feelable movement of the building floors, rattling of windows, shaking of items on shelves or hanging on walls, and rumbling sounds. In extreme cases, the 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.



Note: *RMS Vibration Velocity Level in VdB relative to 10^{-6} inches per second.
Source: USDOT (1995).

Exhibit 2-8. Common Vibration Sources and Levels

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 with the A-weighted sound level. Although the A-weighted level is almost the only metric used to characterize community noise, there are potential problems when 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 40 dBA broadband noise. This is accounted for by setting the limits for ground-borne noise lower than for broadband noise.

2.10 Vibration Impact Criteria

Criteria for construction ground vibration must address both:

- The potential for disturbance and annoyance to building occupants.
- The potential for damage to nearby buildings and other nearby structures.

Temporary vibration impacts may occur in the local area during the construction period as a consequence of the use of blasting, pile drivers, jackhammers, hoe rams, soil compactors, and other heavy construction equipment. Buildings in the vicinity of 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 achieve the noticeable range in buildings very close to a site. Impact pile drivers generally cause the highest vibration levels compared to other types of equipment. Measures should be applied to minimize the potential for harm to nearby structures. 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 is required for a precise assessment of potential effects. Measurement of existing vibration levels at sensitive sites also is required to determine the potential sensitivity of people living in the vicinity of 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 of concern when it can be felt.

Determining acceptable vibration levels is often problematic because of its subjective nature with respect to being a nuisance. 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 is more of a problem at night, when occupants of buildings expect no unusual disturbance from external sources. When vibration levels from an unusual source exceed the human threshold of perception (generally in the range of PPV 0.008 to 0.012 inches/second) complaints may occur, 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 provided that 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 are those that have been developed by the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI). These criteria levels 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

Source: ISO Standard 2631 (1974) and ANSI Standard S3.29-2001.

2.10.2 Potential Building Damage Criteria

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

There are no local, state, or federal requirements similar to the Seattle Noise Ordinance; noise emission standards developed by the EPA; or other federal, state, and local agencies for the control of vibration during construction. 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 ("American National Standard: Guide to Evaluation of Human Exposure to Vibration in Buildings," ANSI S3.29-2001), the International Standards of Organization ("Evaluation of Human Exposure to Whole-Body Vibration in Buildings (1-80 Hz)", ISO-2361-2, 1989), and the Federal Transit Administration (FTA) ("Transit Noise and Vibration Impact Assessment", April 1995).

2.10.3 Vibration Criteria to Prevent Structural Damage

Extensive studies conducted by the United States 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 above 4.0 inches/second (U.S. Bureau of Mines, 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 (AASHTO), United States 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.

Exhibit 2-10. Structural Categories According to 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, timber joist floors
IV	Buildings that are particularly vulnerable or worth preserving

Exhibit 2-11. Acceptance Criteria of SN 640312

Structural Category	Continuous or Steady State Vibration Sources[a]		Transient or Impact vibration Sources[b]	
	Frequency (Hz)	Max Velocity (In/s)	Frequency (Hz)	Max Velocity (In/s)
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

Hz = hertz; In/s = inches per second

[a] Continuous or steady state vibration consists of equipment such as vibratory pile drivers, hydromills, large pumps and compressors, bull dozers, trucks, cranes, scrapers and other large machinery, jackhammers and reciprocating pavement breakers, and compactors.

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

The FTA guidance on vibration damage threshold covers 'fragile buildings' (0.20 inches/second PPV) and 'extremely fragile historic buildings' (0.12 inches/second PPV), which relate to building category IV of the Swiss Standard for 'particularly high sensitivity' buildings. The majority of buildings along the proposed alignment, which are non-fragile, are covered by building categories II or III, for low or average sensitivity.

2.10.4 Vibration Criteria Adopted for this Project

Because FHWA, WSDOT, and the City of Seattle do not have specific vibration impact criteria, a vibration impact criterion of 0.12 inches/second PPV has been adopted for extremely fragile structures and 0.50 inches/second for all other occupied buildings. These criteria are consistent with FTA criteria and is 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 criterion for underground buried structures is a PPV of 4.0 inches/second. Older cast-iron water mains may be more sensitive than other utilities; therefore, a protective damage risk criteria of 0.5 inches/second is being used for older cast-iron water mains (Seattle Public Utilities standard).

2.11 Coordination With Agencies and Jurisdictions

Noise and vibration methods and analysis were developed for the Alaskan Way Viaduct and Seawall Replacement Project in coordination with WSDOT, the City of Seattle, King County, and FHWA. During April of 2002, a noise and vibration analysis approach was distributed to these agencies for review and comment. On April 17, 2002, the approach was presented to acoustic staff from WSDOT, the City of Seattle, and King County for comment and discussion. Input from these agencies was incorporated into the approach used in this study. On July 23, 2003, an update was presented to WSDOT and City of Seattle staff. Monitoring results were distributed to WSDOT and city of Seattle staff on August 26, 2003 to solicit any comments on field data prior to completion of the noise technical analysis. Inputs from these agencies were incorporated into the study.

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Chapter 3 METHODOLOGY

3.1 Noise

Ambient noise levels in the project area were measured to describe the existing noise environment, identify major noise sources, and validate the traffic noise model. 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. Twenty-four-hour noise measurements were taken with LD 720 logging noise meters at several additional locations to characterize the daily sound environment. Fifteen-minute noise measurements were taken at ground level, while 24-hour measurements were taken either on balconies or building roofs, depending on availability of access.

The measurement locations represent a variety of noise conditions and are representative of other sensitive receptors near the proposed project. Existing and future noise levels for the various Build and No Build Alternatives were modeled at the monitoring locations.

The FHWA's Traffic Noise Model (TNM) Version 2.1 computer model (FHWA 2003) was used to predict L_{eq}(h) traffic noise levels. The 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. Modeled traffic volumes used in TNM are included in Attachment C. TNM also considers the effects of intervening barriers, topography, trees, and atmospheric absorption.

TNM was used to model the loudest traffic noise hour of the day. 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 p.m. peak hour traffic volumes; where the volumes exceeded roadway capacity, they were adjusted downward to maintain traffic speed.

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 taken from design profiles. The noise model extended approximately three blocks either side of SR 99 from the vicinity of S. Royal Brougham Way to Ward Street.

The roadway, transit, and pedestrian configuration along Seattle's central waterfront would change considerably under some of the alternatives.

Noise from sources other than traffic is not included in TNM; therefore, when non-traffic noise such as aircraft is considerable in an area, TNM will under-predict the actual noise level. Comparison of measured noise levels to the modeled results demonstrated several important aspects of the sound environment in the vicinity of 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 noise. The measurements were then used to calibrate the model 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 I-5 Ship Canal Bridge (WSDOT 1992).

A series of noise measurements were taken in close proximity to the Alaskan Way Viaduct when it was open to traffic in both directions, when only the northbound lanes (upper deck) were open, and when it was closed to traffic (Exhibit 3-1). Comparison of these measurements shows that the average noise levels in the vicinity of the viaduct are more than 10 dBA greater when the viaduct is open than when it is closed, and approximately 5 to 7 dBA greater when both directions of travel are open compared to only the northbound direction being open. The measurements taken with the viaduct closed represent the background ambient sound level, including both traffic and other sound sources, that would occur if the viaduct did not exist.

The results presented in Exhibit 3-1 are similar to WSDOT's 1992 findings that traffic noise levels were between 6 and 9 dBA greater with the entire viaduct open than only the northbound lanes, but the levels with only the southbound lanes open were within 2 dBA of both directions open (WSDOT 1992).

Exhibit 3-1. Noise Measurement Results with Viaduct Open and Closed

Location	Date	Status	L_{eq}
C1. Bike path under Viaduct at Fire Station Number 5	March 23, 2003	Northbound only	74 dBA
	March 25, 2003	Northbound and southbound open	79 dBA
C2. Sidewalk at Fire Station Number 5	March 23, 2003	Northbound only	73 dBA
	March 25, 2003	Northbound and southbound open	77 dBA
C3. Corner of Spring Street and Alaskan Way	March 23, 2002	Closed	71 dBA
	September 3, 2003	Northbound and southbound open	78 dBA
C4. Sidewalk east side of Viaduct between Seneca and Spring Streets	March 22, 2003	Closed	60 dBA
	March 23, 2003	Northbound only	74 dBA
	March 25, 2003	Northbound and southbound open	77 dBA
C5. Seneca Street, between Western Avenue and the Viaduct	March 22, 2003	Closed	65 dBA
	March 23, 2003	Northbound only	74 dBA
	March 25, 2003	Northbound and southbound open	77 dBA
C6. Waterfront Park boardwalk	March 23, 2002	Closed	60 dBA
	March 22, 2003	Closed	59 dBA
	March 23, 2003	Northbound only	68 dBA
	March 25, 2003	Northbound and southbound open	72 dBA
C7. Waterfront Park sidewalk	March 22, 2003	Closed	70 dBA
	March 23, 2003	Northbound only	74 dBA
	March 25, 2003	Northbound and southbound open	76 dBA
C8. Harbor Steps	March 23, 2002	Closed	66 dBA
	May 16, 2002	Northbound and southbound open	72 dBA
C9. Waterfront Landing Condos	March 23, 2002	Closed	62 dBA
	May 16, 2002	Northbound and southbound open	75 dBA

Exhibit 3-1. Noise Measurement Results with Viaduct Open and Closed (continued)

Location	Date	Status	L_{eq}
C10. Victor Steinbrueck Park	March 23, 2002	Closed	62 dBA
	July 31, 2002	Northbound and southbound open	81 dBA

When initially modeled in TNM, the effects of Alaskan Way Viaduct were underpredicted by 3 to 8 dBA because the model neglects all of the noise that is reflected off the bottom of the upper deck and that is transmitted through the viaduct structure. To account for this additional noise that is neglected in the model, 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 the TNM model, this approach simulated noise generated by the southbound traffic reflecting off of the upper deck and propagating out in both directions from the structure. Once these virtual roadways were applied to the model, the TNM model results for noise receptors in close proximity to the Alaskan Way Viaduct were within 2 dBA of measured values when the field traffic counts were used in the model.

Traffic noise is only one aspect of the complex, urban acoustic environment. Noise measurement results were greater than modeled traffic noise levels at every location within the project 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 more than one to two blocks away from the Alaskan Way Viaduct averaged 1 or 2 dBA greater than the modeled traffic noise levels.

To determine the number of noise-sensitive receptors, a building survey was conducted of buildings within two blocks of proposed long-term improvements. For any buildings that housed sensitive uses (Activity Categories B and E), 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 was collected. This data was used to estimate the number of sensitive receptors represented by each modeled noise receptor. This data is included in Chapter 4, Affected Environment.

3.2 Vibration

Existing vibration levels were measured at four locations near the existing viaduct using the following equipment:

- Larson Davis Model 2900 1/3 Octave Band Real Time Analyzer
- PCB Model 393A03 ICP Accelerometer
- PCB Model 699A02 Hand Held Shaker (Calibrator)

At each of the measurement sites the vibration levels of different heavy truck passbys were monitored to determine the maximum rms vibration velocity levels generated by these events. These measurements were used as a baseline for evaluation of the future potential for operational vibration impacts.

The potential for construction vibration impacts was estimated from prior measurements of construction equipment. The reference vibration data used for this analysis was taken from the available literature (see Chapter 9 for references) and supplemented by measurements conducted by Parsons Brinckerhoff on other construction projects. The data was used to establish a distance beyond which construction activities would not cause damage to sensitive structures.

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Chapter 4 AFFECTED ENVIRONMENT

4.1 Study Area Characteristics

The project study area evaluated for noise and vibration impacts includes areas likely to be affected by changes in traffic or mechanical ventilation noise under the various alternatives and areas likely to be affected by construction noise or vibration during construction. The study area extends approximately three blocks either side of SR 99 from the vicinity of S. Royal Brougham Way to Ward Street.

The study area runs through the downtown core of Seattle and several sub-areas (Exhibit 4-1). Land use in the area ranges from low-rise light industrial to high-rise office towers. Portions of the study area include residential zoning, such as Belltown and west of the Alaskan Way Viaduct in the vicinity of Ward Street. Noise-sensitive uses include residences, hotels, motels, parks, social services, and daycare providers. There are several old, vibration-sensitive structures adjacent to the existing Alaskan Way Viaduct.

There are residential or hotel uses near both the south and north portals of the existing Battery Street Tunnel. Land uses near the south portal and King Street ventilation building that would be constructed under the Tunnel and Bypass Tunnel Alternatives are commercial and industrial. Land uses near the north portal and Yesler Way, Spring Street, and Pike Street ventilation buildings include residential uses.

A detailed description of the land use within the study area is provided in Appendix G, Land Use and Shorelines Technical Memorandum.

4.2 Existing Noise Environment

Both short-term and 24-hour noise measurements were taken throughout the project area to describe the existing acoustical environment. Measured outdoor L_{dn} sound levels (Exhibit 4-2) generally ranged between those typical of urban to downtown major metropolitan areas (see Exhibit 2-5). Both short-term and 24-hour noise measurements were taken in the study area to characterize the overall acoustic environment, evaluate the transportation noise component of the environment, and validate the Traffic Noise Model. Monitoring sites are shown in Exhibits 4-3 and 4-4.

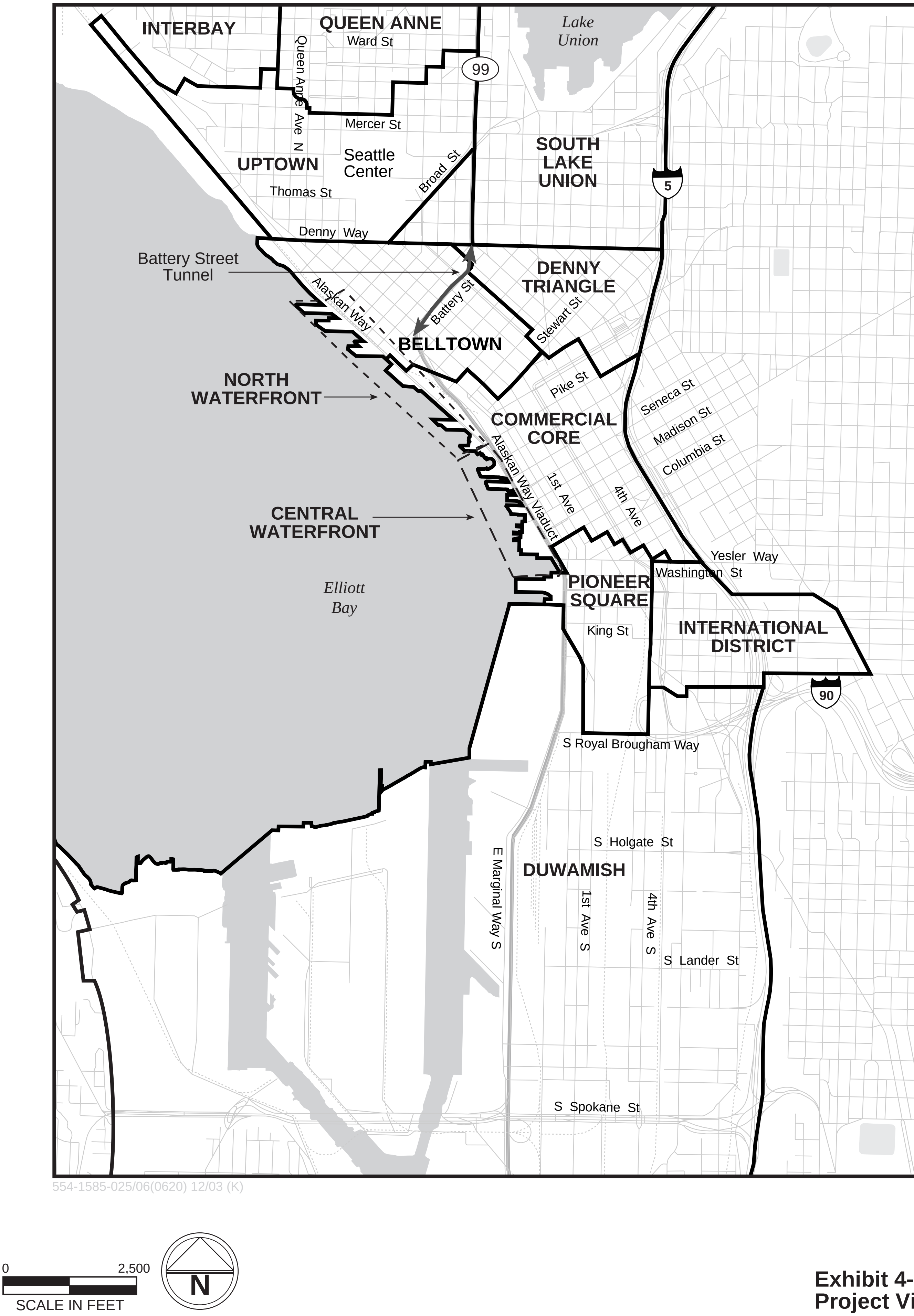


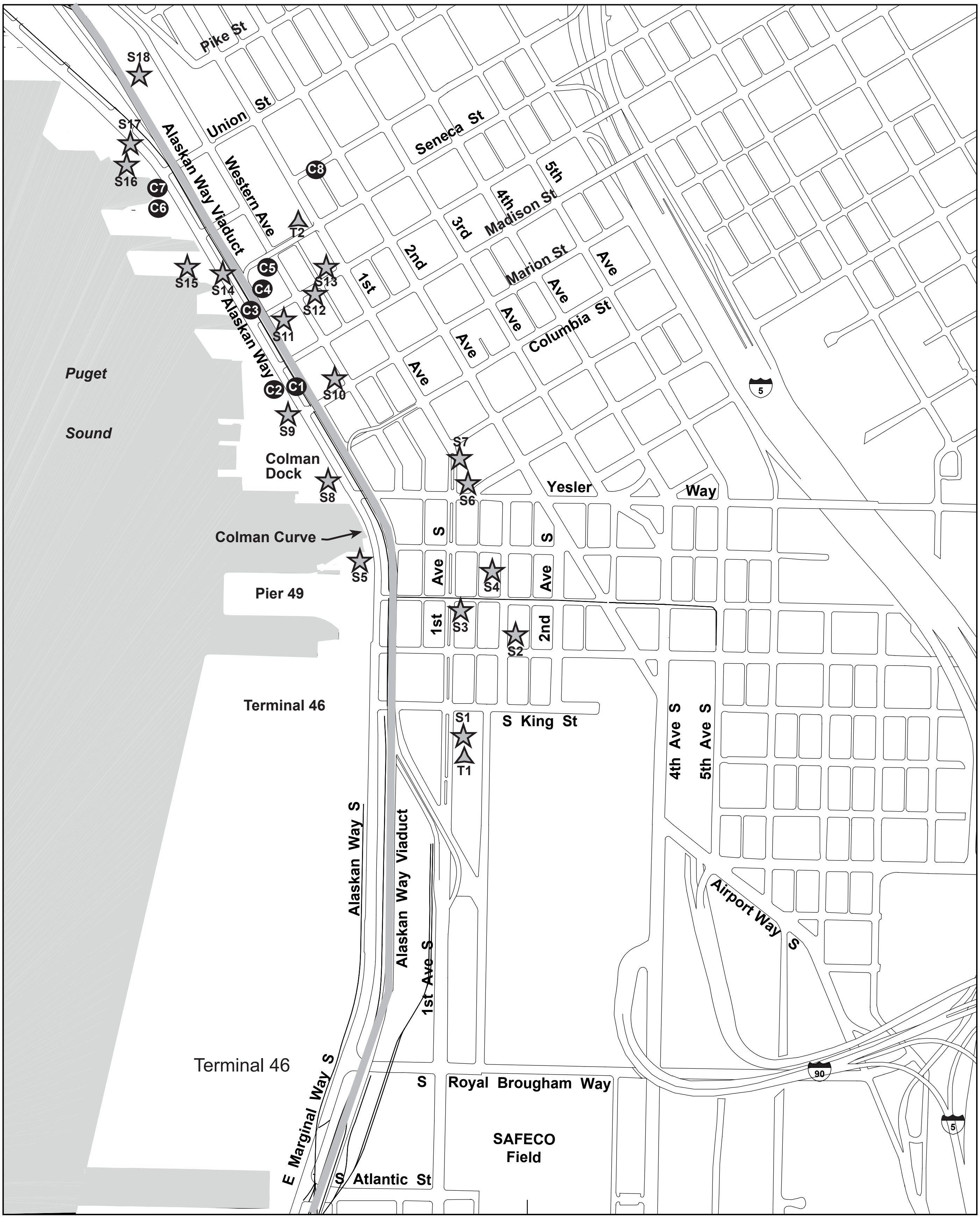
Exhibit 4-1
Project Vicinity

Exhibit 4-2. Twenty-four Hour Noise Measurement Results

	Location	L_{dn}	Loudest Hour $L_{eq}(h)$	Time of Day
T1	Florentine Condominiums	78	85	4 p.m.
T2	Harbor Steps Apartments	78	84	7 p.m.
T3	Waterfront Landing Condominiums	80	80	7 a.m.
T4	Elliott Point Apartments	83	83	8 a.m.
T5	Belltown Loft Condominiums	75	80	10 a.m.
T6	Site 17 Apartments	72	73	5 p.m.
T7	Port of Seattle	75	76	6 p.m.
T8	Avalon Belltown Apartments	71	76	7 a.m.
T9	Group Health at Battery Street	72	77	11 a.m.
T10	Group Health at Wall Street	72	77	11 a.m.
T11	Antioch University	75	75	7 p.m.
T12	Pacific Science Center	75	75	3 p.m.
T13	Seattle Inn	77	78	11 a.m.

Noise receptor designations reflect the type and purpose of the noise measurement taken at the location. Receptors with a "T" denote 24-hour measurement locations, with an "S" denote short-term measurement locations, and with a "C" denote locations where measurements were taken with the viaduct closed. Some locations (S1 and T1 for example) represent two measurement types taken in close proximity.

The daily noise profiles for several representative sites in the study are shown in Exhibit 4-5. In general, the study area has a relatively high overall noise level that tends to be about 10 dBA quieter during nighttime and early morning hours (midnight to 6 a.m.) than during the rest of the day. Measured daily L_{dn} sound levels ranged between 71 and 83 dBA at the 13 receptors where 24-hour noise measurements were taken (see Exhibit 4-2).



Alaskan Way Viaduct 554-1585-025/06(0620) 9/03 (K)

SCALE IN FEET

0 400 800

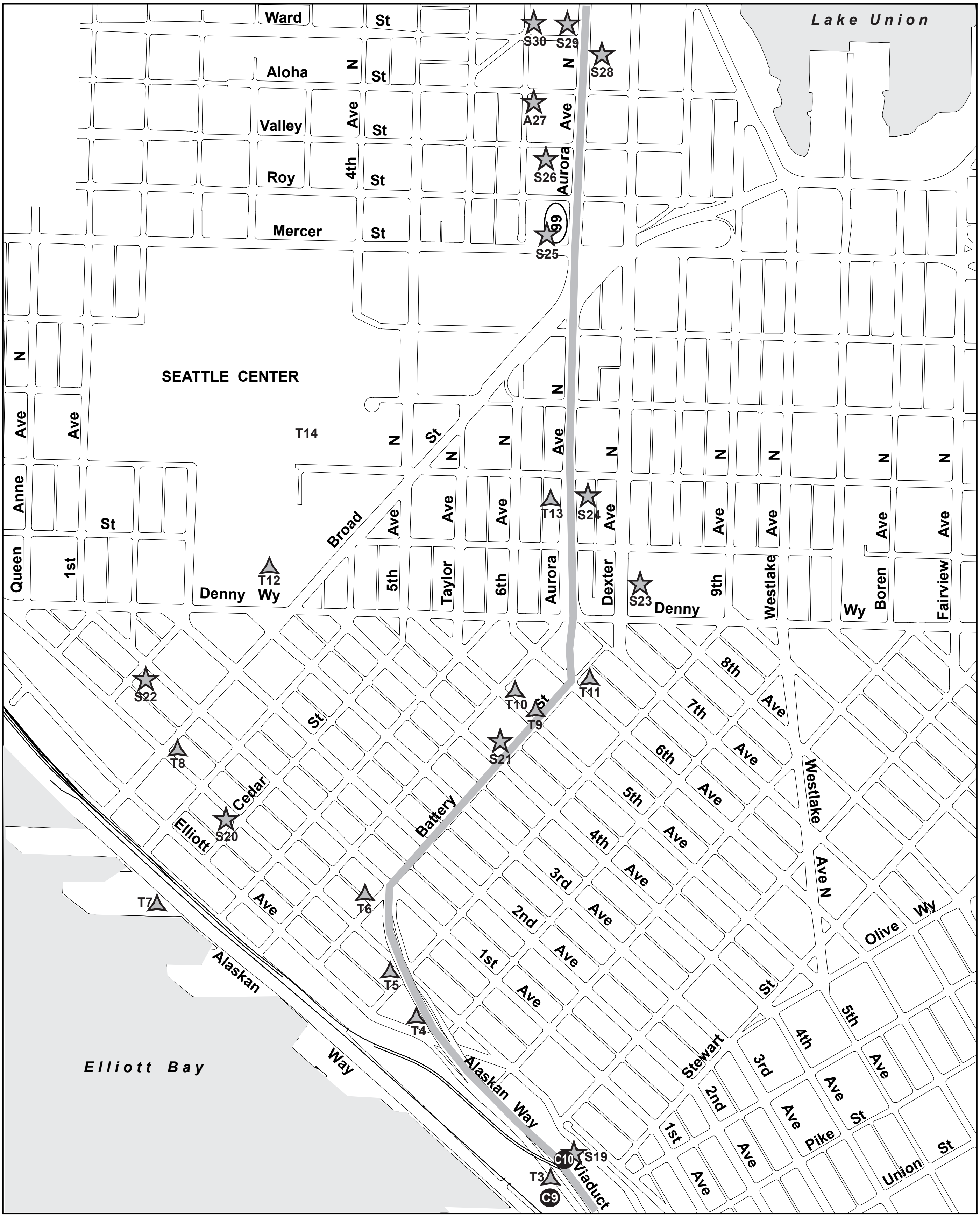
N

S14 Short Term Measurement

T2 Twenty-four Hour Measurement

C5 Closed Viaduct Measurement

Exhibit 4-3
Noise Measurement Locations - Central



Alaskan Way Viaduct 554-1585-025/06(0620) 8/03 (K)

SCALE IN FEET
0 400 800

N

S14 Short Term Measurement
T2 Twenty-four Hour Measurement
C5 Closed Viaduct Measurement

Exhibit 4-4
Noise Measurement Locations - North

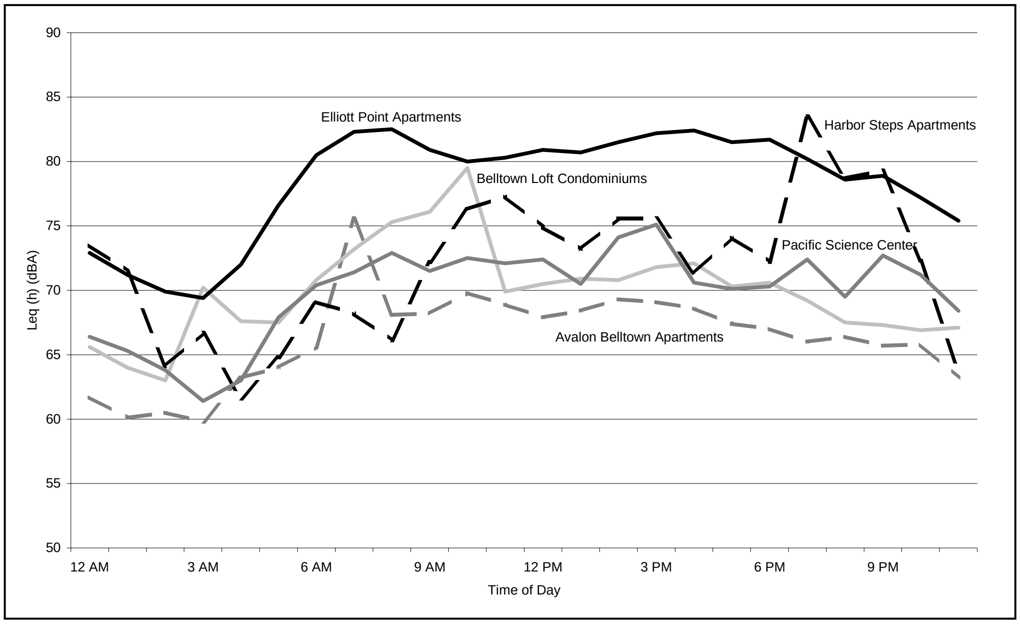


Exhibit 4-5. Daily Noise Patterns at Select Study Area Sites

Daytime L_{eq} sound levels measured in the project area ranged between 57 and 81 dBA (Exhibits 4-6 and 4-7). At several locations, the measured total noise level exceeded WSDOT's severe impact criteria of 75 dBA for traffic noise at noise-sensitive receptors. The Washington Street Boat Landing (S5), Seattle Aquarium (S17), and Victor Steinbrueck Park (S19) are three such locations.

The TNM was used to evaluate the roadway noise portion of the acoustic environment. The p.m. peak traffic volumes were entered into the existing conditions noise model, along with transit bus and truck percentages appropriate to each of the downtown streets. Modeled existing loudest hour L_{eq}(h) traffic noise levels varied between 59 and 79 dBA (Exhibits 4-8 and 4-9). Existing traffic noise levels were modeled to approach or exceed the FHWA noise abatement criteria at 43 of the 48 modeled sites. The modeled traffic-only noise level at four sites currently exceeds the severe noise impact criteria. The sites where existing severe traffic noise impacts (noise levels exceeding 75 dBA at sensitive land uses) are modeled are S18, S19, S29, and T13, representing 248 residential units, 159 hotel rooms, and one park.

Exhibit 4-6. Short-Term Noise Measurement Results

Location		Date	Time	L_{eq}
S1/ T1	Florentine Apts (ground level)	July 31, 2002	2:00 p.m.	72
		August 6, 2003	2:15 p.m.	72
S2	300 block Occidental Ave.	July 31, 2002	1:30 p.m.	63
S3	First & Main	August 6, 2003	1:15 p.m.	72

Exhibit 4-6. Short-Term Noise Measurement Results (continued)

Location		Date	Time	L_{eq}
S4	Occidental Park	July 31, 2002	1:30 p.m.	63
		August 6, 2003	12:15 p.m.	63
S5	Washington Street Boat Landing	July 31, 2002	11:55 a.m.	76
		July 31, 2002	2:40 p.m.	77
		August 6, 2003	10:45 a.m.	78
S6	Pioneer Square south side	July 31, 2002	3:30 p.m.	68
		August 6, 2003	11:30 a.m.	68
S7	Pioneer Square north side	July 31, 2002	3:40 p.m.	71
		August 6, 2003	11:15 a.m.	71
S8	Pier 50	July 31, 2002	11:30 a.m.	77
S9	Ferry Dock	July 31, 2002	11:10 a.m.	77
S10	Ferry Pedestrian Crossing	July 31, 2002	11:05 a.m.	77
S11	Western and Spring	July 31, 2002	10:10 a.m.	74
		August 6, 2003	10:15 a.m.	73
S12	Spring and Post	July 31, 2002	10:35 a.m.	72
S13	Spring and First	July 31, 2002	10:35 a.m.	72
S14	Alaskan Way bike path at Seneca	July 31, 2002	9:45 a.m.	78
S15	Elliott's Oyster House	July 31, 2002	9:45 a.m.	71
S16	Waterfront Park	July 31, 2002	9:15 a.m.	72
S17	Seattle Aquarium	July 31, 2002	9:15 a.m.	76
S18	Hill Climb Court	July 31, 2002	8:50 a.m.	74
		September 3, 2003	11:15 a.m.	75
S19/C10	Victor Steinbrueck Park	July 31, 2002	8:20 a.m.	81
S20	Western and Cedar	August 7, 2003	10:30 a.m.	71
S21	Fountain Court Apartments	August 8, 2003	10:15 a.m.	72
S22	First and Eagle	August 7, 2003	10:10 a.m.	69
S23	Denny Park	September 3, 2003	10:34 a.m.	60
S24	Holiday Inn	July 17, 2003	10:50 a.m.	76
S25	Hotel at Aurora and Mercer	July 17, 2003	2:30 p.m.	75
S26	615 Valley	July 17, 2003	1:00 p.m.	73
S27	Sixth and Aloha	July 17, 2003	2:20 p.m.	57
S28	1000 Aurora	July 17, 2003	11:45 a.m.	78
S29	Ward and Aurora	July 17, 2003	1:50 p.m.	79
S30	Ward and Sixth	July 17, 2003	2:10 p.m.	58

Exhibit 4-7. Additional Short-term Noise Measurement Results

Location		Date	Time	L_{eq}
T2/C8	Harbor Steps (plaza level)	May 16, 2002	2:00 p.m.	71
T3/C9	Waterfront Landing (ground level)	May 22, 2002	11:15 a.m.	75
T4	Elliott Point (ground level)	August 7, 2003	9:15 a.m.	76
T5	Belltown Loft (ground level)	June 4, 2002	9:45 a.m.	68
T6	Site 17 (ground level)	August 7, 2003	9:45 a.m.	74
T7	Port of Seattle (ground level)	July 19, 2002	2:00 p.m.	70
T8	Avalon Belltown (ground level)	July 17, 2002	3:00 p.m.	70
T9/T10	Group Health (ground level)	August 8, 2003	10:00 a.m.	72
T11	Antioch University (ground level)	August 7, 2003	1:20 p.m.	70
T12	Pacific Science Center (ground level)	August 7, 2003	11:30 a.m.	73
T13	Seattle Inn (terrace)	July 9, 2002	4:00 p.m.	78

Exhibit 4-8. Modeled Existing Traffic L_{eq}(h) Noise Levels

Receptor	Noise Sensitive Use	Noise Abatement Criteria	Measured Sound Level (dBA)	Modeled Existing Peak Traffic Noise (dBA)
S1/T1	**163 residential units**	**67**	**72**	**70**
S2	**Public space and 7 units**	**67**	63	62
S3	**77 residential units and 120 homeless shelter beds**	**67**	**72**	**71**
S4	**Park**	**67**	63	63
S5	**Park and 20 units**	**67**	**76**	**74**
S6	**Park and 85 units**	**67**	**68**	**66**
S7	**Park**	**67**	**71**	**69**
S8	**25 residential units and 75 hotel rooms**	**67**	**77**	**74**
S9	Commercial use	**72**	**77**	**74**
S10	Pedestrian access	**72**	**77**	**79**
S11	Commercial use	**72**	**74**	**72**
S12	**109 hotel rooms**	**67**	**72**	**70**
S13	**257 residential units**	**67**	**72**	**71**
S14	Commercial use	**72**	**78**	**77**
S15	Commercial use	**72**	**71**	**72**

Exhibit 4-8. Modeled Existing Traffic L_{eq} (h) Noise Levels (continued)

Receptor	Noise Sensitive Use	Noise Abatement Criteria	Measured Sound Level (dBA)	Modeled Existing Peak Traffic Noise (dBA)
S16	**Park**	**67**	**72**	**70**
S17	**Park**	**67**	**76**	**73**
S18	**190 residential units**	**67**	**75**	**77**
S19/C10	**Park**	**67**	**81**	**79**
S20	**636 residential units**	**67**	**71**	**69**
S21	**695 residential units**	**67**	**72**	**70**
S22	**192 residential units**	**67**	**69**	**70**
S23	**Park**	**67**	60	59
S24	**235 hotel rooms**	**67**	**76**	**75**
S25	**158 hotel rooms**	**67**	**75**	**73**
S26	**21 residential units**	**67**	**73**	**70**
S27	**62 residential units**	**67**	57	61
S28	**78 residential units**	**67**	**78**	**75**
S29	**58 residential units**	**67**	**79**	**77**
S30	**41 residential units**	**67**	58	59

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 the criterion within 1 dBA (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**.
Noise-sensitive land uses are shown in **BOLD**. If there is no noise-sensitive use (FHWA Activity Category B) at a receptor location, the general use in that vicinity is described. For uses that are not noise sensitive, the noise abatement criterion is 72 dBA.

Exhibit 4-9. Additional Modeled Existing Traffic L_{eq}(h) Noise Levels

Receptor	Noise Sensitive Use	Noise Abatement Criteria	Measured Sound Level (dBA)	Modeled Existing Peak Traffic Noise (dBA)
T2/C8	**126 residential units**	**67**	**71**	**70**
T3/C9	**235 residential units and 320 hotel rooms**	**67**	**75**	**66**
T4	**64 residential units**	**67**	**76**	**72**
T5	**131 residential units**	**67**	**68**	**68**
T6	**617 residential units**	**67**	**74**	**73**
T7	**238 hotel rooms**	**67**	**70**	**69**

Exhibit 4-9. Additional Modeled Existing Traffic Leq(h) Noise Levels (continued)

Receptor	Noise Sensitive Use	Noise Abatement Criteria	Measured Sound Level (dBA)	Modeled Existing Peak Traffic Noise (dBA)
T8	**798 residential units**	**67**	**70**	**70**
T9/T10	**Childcare facility**	**67**	**72**	**68**
T11	**Antioch University**	**67**	**70**	**66**
T12	**Seattle Center**	**67**	**73**	**71**
T13	**159 hotel rooms**	**67**	**78**	**76**
C1	Pedestrian and bicycle use	**72**	**79**	**78**
C2	Commercial use	**72**	**77**	**74**
C3	Commercial use	**72**	**78**	**78**
C4	Commercial use	**72**	**77**	**75**
C5	Commercial use	**72**	**77**	**73**
C6	**Park**	**67**	**72**	**70**
C7	**Park**	**67**	**76**	**73**

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 the criterion within 1 dBA (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**.
Noise-sensitive land uses are shown in **BOLD**. If there is no noise-sensitive use (FHWA Activity Category B) at a receptor location, the general use in that vicinity is described. For uses that are not noise sensitive, the noise abatement criterion is 72 dBA.

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, which at some locations is amplifying the vibration levels generated by heavy trucks passing by.

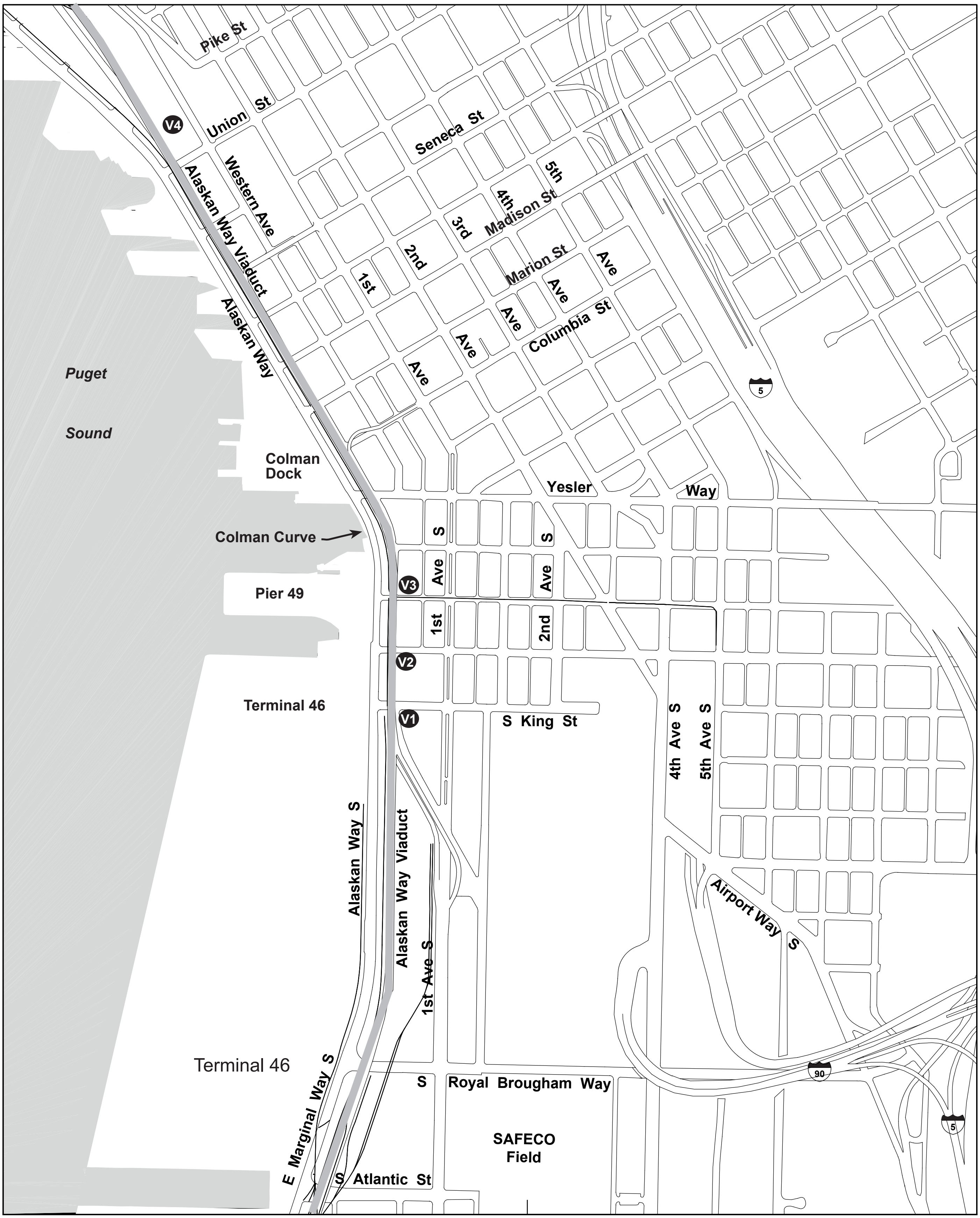
The closest buildings to the viaduct structure are commercial, with occasional residential buildings located further away. To document the existing vibration environment in these areas, field measurements were carried out at representative locations beneath the viaduct structure. Existing vibration levels resulting from heavy vehicles on the Alaskan Way Viaduct were measured in four locations to establish a baseline (Exhibit 4-11). The four sites along the AWV represent the closest occupied buildings to the viaduct structure. The measured levels are presented in Exhibit 4-10 as maximum rms velocity vibration and PPV.

Exhibit 4-10. Ambient Vibration Levels Along Alaskan Way Viaduct

Receiver ID	Location Description	Maximum Vibration Velocity Level Lv, VdB	Peak Particle Velocity Level, in/s
V1	AWV at Jackson Street	78.5	0.042
V2	76 S. Main Street	66.3	0.010
V3	Antique Market	88.2	0.128
V4	AWV near King Street	77.0	0.035

The following is a description of the vibration measurement sites and the building structures at these locations.

- Site V1 – Jackson Street. Measurements conducted 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 Jackson Street 30 feet to the north. This area under the viaduct is used for parking.
- Site V2 – 76 S. Main Street. Measurements were conducted directly outside of the building. This area under the viaduct is used for parking and to the east of the viaduct are three 5-story brick office buildings.
- Site V3 – Antique Market. Measurements were conducted in front of the loading dock of the Antique Market.
- Site V4 – King Street. Measurements were conducted at a building within 30 feet of a viaduct vertical pier.



Alaskan Way Viaduct 554-1585-025/06(0620) 9/03 (K)

V1 Vibration Measurement Location

SCALE IN FEET

0 400 800

N

Exhibit 4-11
Vibration Measurement Locations

Chapter 5 Operational Impacts and Benefits

Long-term operational traffic noise levels under all of the alternatives were modeled for the year 2030. In most areas, future noise levels were similar between all of the alternatives and existing conditions. In the vicinity of Alaskan Way along the central Seattle waterfront, noise levels would be lower under the alternatives that do not include an elevated structure.

The alternatives evaluated for noise and vibration are described in Appendix B, Alternatives Description and Construction Methods Technical Memorandum.

5.1 No Build Alternative

Traffic noise levels in 2030 under the No Build Alternative would continue to be similar to current levels because traffic patterns would not substantially change and peak traffic volumes would increase only slightly because current peak period traffic volumes are near roadway system capacity 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.

Loudest hour traffic noise levels would range between 60 and 79 dBA at the modeled locations (Exhibits 5-1 and 5-2). Traffic noise levels are predicted to change between a 2-dBA decrease and a 2-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. The modeled traffic noise levels approach or exceed the FHWA noise abatement criteria at 42 of the 48 modeled sites representing approximately 4,490 residential units, 1,290 hotel rooms, and 120 shelter beds. Nine of the sites represent park or public open space uses, one represents a childcare facility, and ten sites represent commercial or other less noise-sensitive uses only (Exhibit 5-3). 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.

To better demonstrate the effects of the various alternatives on the acoustic environment, the noise profile was modeled at a typical location along the central waterfront (Exhibit 5-4). The location was selected to demonstrate the traffic noise pattern in relation to surface, elevated, and depressed roadway sources for the proposed roadway and sidewalk configurations along the waterfront.

Exhibit 5-1. Modeled 2030 Peak Traffic L_{eq}(h) Noise Levels

Receptor	Noise-Sensitive Use	2002 Existing	No Build	Rebuild	Aerial	Tunnel	Bypass Tunnel	Surface
S1/T1	163 residential units	**70**	**70**	**71**	**71**	**70**	**70**	**71**
S2	Public space and 7 units	62	62	61	62	59	59	61
S3	77 residential units and 120 homeless shelter beds	**71**	**71**	**72**	**71**	**70**	**71**	**73**
S4	Park	63	62	62	62	60	60	62
S5	Park and 20 units	**74**	**74**	**72**	**75**	**66**	65	**72**
S6	Park and 85 units	**66**	**67**	**66**	**67**	64	64	**67**
S7	Park	**69**	**70**	**69**	**70**	**68**	**69**	**70**
S8	25 residential units and 75 hotel rooms	**74**	**75**	**74**	**75**	65	65	**71**
S9	Commercial use	**74**	**75**	**74**	**74**	63	65	**71**
S10	Pedestrian access	**79**	**79**	**79**	**79**	**71**	N/A	N/A
S11	Commercial use	**72**	**72**	**72**	**72**	69	68	70
S12	109 hotel rooms	**70**	**70**	**70**	**70**	**68**	**68**	**70**
S13	257 residential units	**71**	**71**	**71**	**71**	**69**	**70**	**71**
S14	Commercial use	**77**	**77**	**77**	**77**	71	**73**	**79**
S15	Commercial use	**72**	**72**	**72**	**72**	60	62	68
S16	Park	**70**	**70**	**71**	**70**	61	61	**67**
S17	Park	**73**	**74**	**74**	**73**	64	64	**70**
S18	190 residential units	**77**	**77**	**77**	**77**	**70**	**69**	**76**
S19/C10	Park	**79**	**79**	**79**	**79**	**80**	**79**	**78**
S20	636 residential units	**69**	**71**	**71**	**70**	**70**	**69**	**69**
S21	695 residential units	**70**	**72**	**72**	**71**	**70**	**69**	**71**
S22	192 residential units	**70**	**69**	**69**	**69**	**69**	**69**	**69**
S23	Park	59	60	60	60	60	60	60
S24	235 hotel rooms	**75**	**76**	**76**	**76**	**76**	**76**	**76**
S25	158 hotel rooms	**73**	**74**	**74**	**74**	**74**	**73**	**74**
S26	21 residential units	**70**	**71**	**71**	**71**	**71**	**71**	**71**
S27	62 residential units	61	62	62	62	62	62	62
S28	78 residential units	**75**	**76**	**76**	**76**	**76**	**76**	**76**
S29	58 residential units	**77**	**78**	**78**	**78**	**78**	**78**	**78**
S30	41 residential units	59	61	61	61	61	61	61

Note: Values in **BOLD** approach or exceed the FHWA noise abatement criteria for traffic noise.
N/A = Not applicable; this receiver would be within the roadway under this alternative.

Exhibit 5-2. Additional Modeled 2030 Peak Traffic L_{eq}(h) Noise Levels

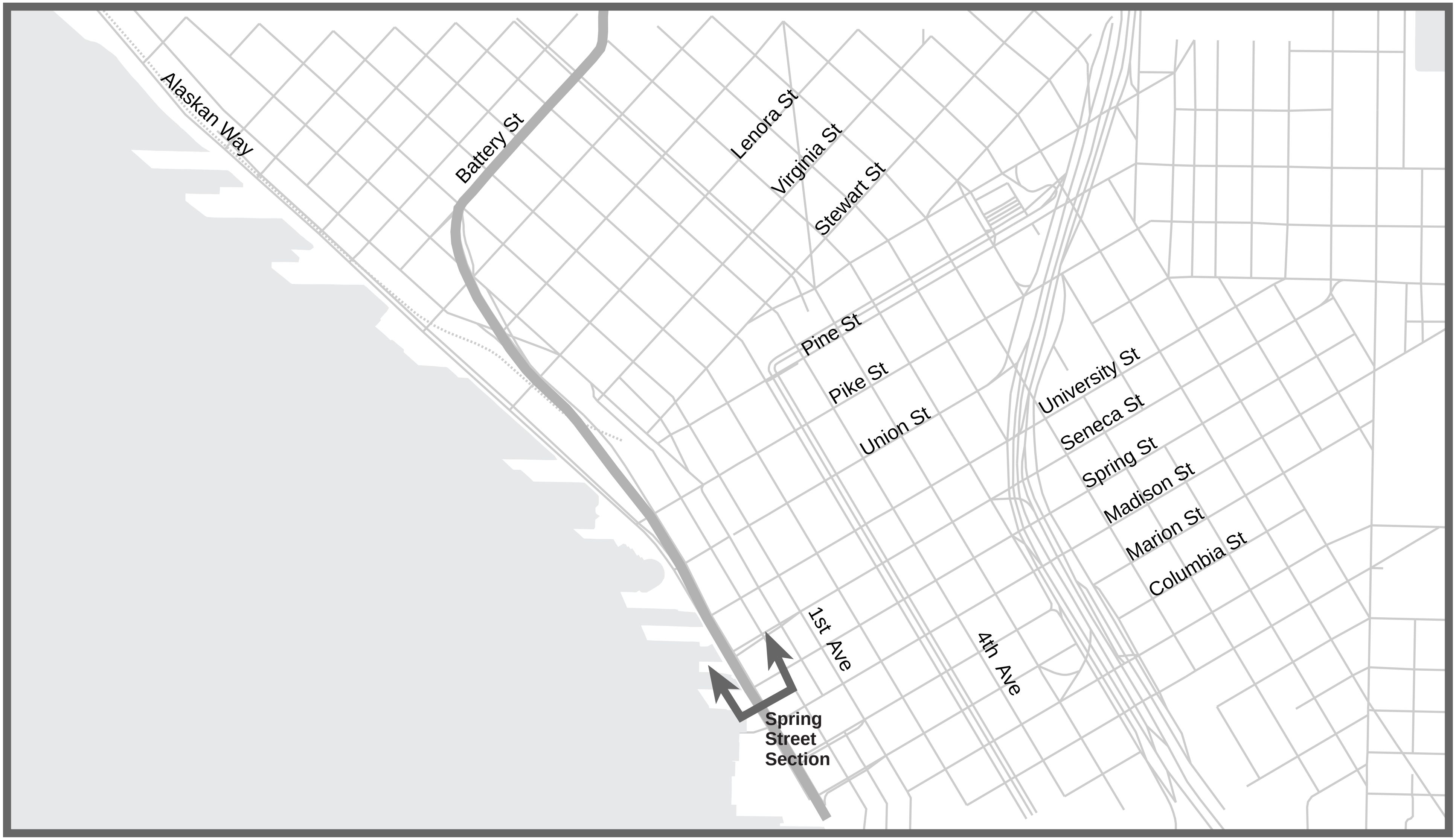
Receptor	Noise-Sensitive Use	2002 Existing	No Build	Rebuild	Aerial	Tunnel	Bypass Tunnel	Surface
T2/C8	126 residential units	**70**	**71**	**71**	**71**	66	**66**	**70**
T3/C9	235 residential units and 320 hotel rooms	**66**	**67**	**68**	**67**	**72**	**69**	**68**
T4	64 residential units	**72**	**73**	**73**	**72**	**73**	**72**	**72**
T5	131 residential units	**68**	**69**	**69**	**69**	**69**	**68**	**68**
T6	617 residential units	**73**	**74**	**73**	**73**	**72**	**71**	**73**
T7	238 hotel rooms	**69**	**69**	**69**	**69**	**75**	**72**	**74**
T8	798 residential units	**70**	**72**	**72**	**71**	**71**	**71**	**70**
T9 /T10	Childcare facility	**68**	**67**	**68**	**69**	**69**	**69**	**69**
T11	Antioch University	**66**	64	**67**	**67**	**67**	**67**	**67**
T12	Seattle Center	**71**	**72**	**72**	**72**	**72**	**72**	**72**
T13	159 hotel rooms	**76**	**78**	**78**	**78**	**78**	**78**	**78**
C1	Pedestrian and bicycle use	**78**	**78**	**79**	**79**	N/A	N/A	N/A
C2	Commercial use	**74**	**75**	**74**	**74**	63	65	**71**
C3	Commercial use	**78**	**78**	**79**	**79**	N/A	N/A	N/A
C4	Commercial use	**75**	**75**	**75**	**75**	**68**	N/A	N/A
C5	Commercial use	**73**	**73**	**73**	**74**	66	70	**77**
C6	Park	**70**	**70**	**70**	**70**	60	62	**68**
C7	Park	**73**	**73**	**74**	**74**	62	64	**71**

Note: Values in **BOLD** approach or exceed the FHWA noise abatement criteria for traffic noise.
N/A = Not applicable; this receiver would be within the roadway under this alternative.

Exhibit 5-3. Number of Receptors Experiencing Noise Impacts

	Land Use Impacted					
Alternative	Residential Units	Hotel Rooms	Shelter Beds	Parks	Childcare/ Education Facilities	Commercial Use Only Receptors
2002 Existing	4,490	1,290	120	9	2	10
No Build	4,490	1,290	120	9	1	10
Rebuild	4,490	1,290	120	9	2	10
Aerial	4,490	1,290	120	9	2	10
Tunnel	4,250	1,290	120	4	2	3
Bypass Tunnel	4,360	1,290	120	3	2	5
Surface	4,490	1,290	120	9	2	5

Note: Residential Units, Hotel Rooms, and shelter Beds are the number of individual units. Parks, Childcare/Education Facilities, and Commercial Use Only Receptors are the number of modeled sites that represent these uses.



Alaska Way Viaduct/554-1585-025/06(0620) 12/03 (K)

Exhibit 5-4
Noise Profile Evaluation Location

The traffic noise profile was calculated as a typical cross section through the roadway and adjacent piers and buildings. Exhibit 5-5 presents the traffic noise profile for the No Build Alternative. Traffic noise levels are greatest near the existing viaduct and decrease with distance from the structure. Surface street traffic also contributes to the noise levels near the surface roadways. The modeled traffic noise level is greater than the FHWA noise abatement criteria for the entire area included in the noise profile calculation.

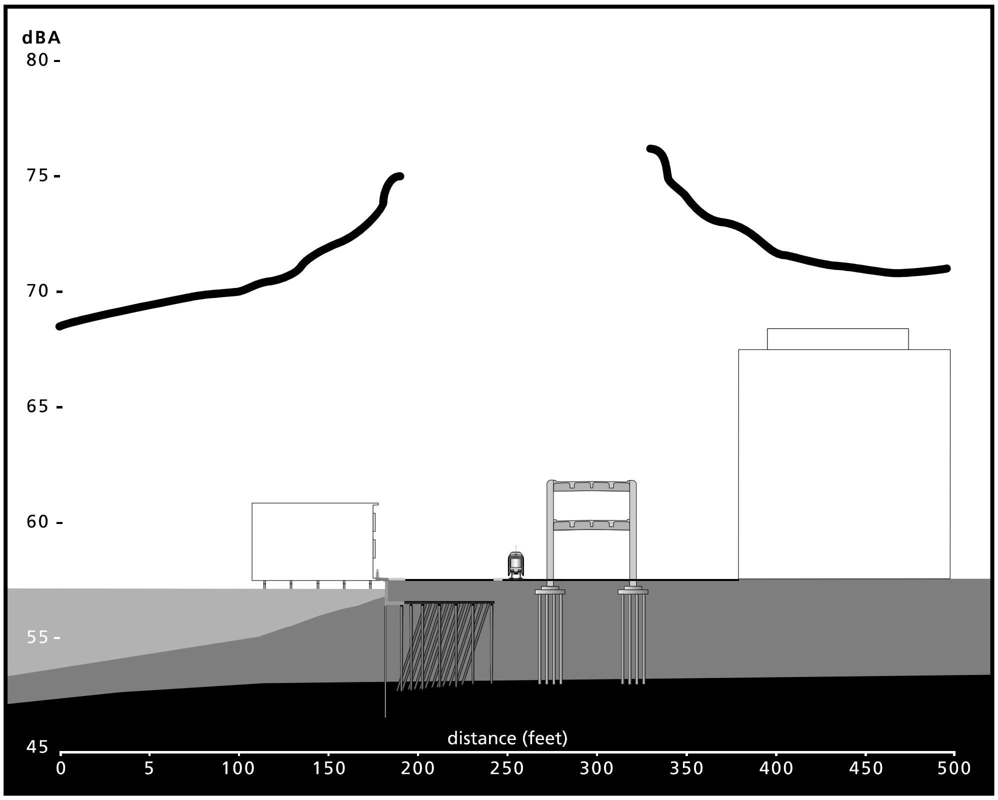


Exhibit 5-5. No Build Alternative Noise Profile at Spring Street

Note: FHWA traffic noise abatement criterion is 67 dBA.

If the surface roadway, trolley tracks, and bicycle and pedestrian facility locations are shifted, the noise levels that would result from the revised configuration can be estimated by selecting an appropriate offset distance on the noise profiles and reading the noise level at that location off of the chart.

In addition to the four sites modeled to experience severe noise impacts under existing conditions, two additional sites would experience severe noise impacts in 2030 under the No Build Alternative. The sites where severe noise impacts (sound levels exceeding 75 dBA at sensitive land uses) are expected are S18, S19, S24, S28, S29, and T13, representing 326 residential units, 394 hotel rooms, and one park.

Total noise levels at many of the sites would be greater than the predicted traffic noise level because non-traffic sound sources contribute substantially to the total environmental noise level in much of the study area. Non-traffic noise sources at the various sites included aircraft, sounds from restaurants and other businesses, sidewalk noise, construction noise, building mechanical noise, alarms, and sirens.

In the event that the Alaskan Way Viaduct would have to be closed in the future, either through collapse or seismic damage, peak traffic noise levels in the study area would be somewhat less than the modeled results because there would be reduced roadway capacity resulting in lower traffic volumes and lower average speeds. With loss or closure of the existing Alaskan Way Viaduct, traffic noise levels would likely be similar to those presented for the Surface Alternative.

The No Build Alternative does not include modifications and upgrades to the Battery Street Tunnel ventilation system; therefore, there would not be a substantial change in mechanical system noise under the No Build Alternative.

Vibration levels under the No Build Alternative would continue to be similar to those currently experienced near the Alaskan Way Viaduct.

5.2 Rebuild Alternative

Traffic noise levels in 2030 under the Rebuild Alternative would continue to be similar to current levels and those under the No Build Alternative in most of the study area because traffic patterns would be similar to current patterns. Peak traffic volumes would increase only slightly because current peak period traffic volumes are already near roadway system capacity in much of the study area.

Under the Rebuild Alternative, loudest hour traffic noise levels would range between 60 and 79 dBA at the modeled location (see Exhibits 5-1 and 5-2). Traffic noise levels are predicted to change between a 2-dBA decrease and a 2-dBA increase compared to existing levels. These small changes would occur because of changes in traffic patterns largely resulting from changes to on- and off-ramp locations.

The modeled traffic noise levels approach or exceed the FHWA noise abatement criteria at 43 of the 48 modeled sites. The sites modeled to approach or exceed the FHWA noise abatement criteria represent approximately 4,490 residential units, 1,290 hotel rooms, and 120 shelter beds.

Nine of the sites represent park or public open space uses, two represent educational or childcare facilities, and ten sites represent commercial or other less noise-sensitive uses only (see Exhibit 5-3). Many of the residential and hotel sites do not have private outdoor use areas, but most have windows that open. The same six sites modeled to experience severe noise impacts under the No Build Alternative would also experience severe noise impacts in 2030 under the Rebuild Alternative. The sites where severe noise impacts are expected are S18, S19, S24, S28, S29, and T13, representing 326 residential units, 394 hotel rooms, and one park.

Total noise levels at many of the sites would be greater than the predicted traffic noise level because non-traffic sound sources contribute substantially to the total environmental noise level in much of the study area. Non-traffic noise sources at the various sites included aircraft, sounds from restaurants and other businesses, sidewalk noise, construction noise, building mechanical noise, alarms, and sirens.

5.2.1 Traffic Noise South of the Battery Street Tunnel

In the area south of the Battery Street Tunnel (Receptors S1 to S19, T1 to T5, T7, and C1 to C9), traffic noise levels would vary by up to 2 dBA compared to existing conditions. At the Washington Street Boat Landing, traffic noise levels are predicted to decrease by 2 dBA as a result of changed alignment of the structure in that area, which would eliminate the stacked design (the roadway for one direction of travel located above the roadway for the other direction of travel) in that vicinity. A 1-dBA increase is predicted at Receptor C1, the bicycle and pedestrian trail along the Alaskan Way surface street, as a result of small changes to alignment and increased traffic volume by 2030.

A traffic noise profile was developed at the same location for the Rebuild Alternative as for the No Build Alternative (Exhibit 5-6).

5.2.2 Traffic Noise in Belltown and the North Waterfront

In the Belltown and North Waterfront area (Receptors S20 to S22 and T6, T8 to T12), traffic noise levels would vary by up to 2 dBA compared to existing conditions as a result of changes in traffic patterns in the Belltown area.

Broad Street Underpass not Constructed

In the event that the Broad Street underpass is not constructed, traffic to and from Magnolia and the Ballard Bridge would continue to be routed primarily along Elliott and Western Avenues via reconstructed ramps south of the Battery Street Tunnel. Compared to the analyzed alternative, this option could shift a small volume of traffic off of the Alaskan Way surface street onto the rebuilt viaduct south of the Battery Street Tunnel and onto Elliott and

Western Avenues through Belltown. This option is expected to change traffic volumes during the loudest hour by less than 25 percent; therefore, noise levels would change by less than 1 dBA. Along the northern waterfront, the traffic and associated noise would decrease slightly, while along Elliott and Western Avenues it would increase slightly.

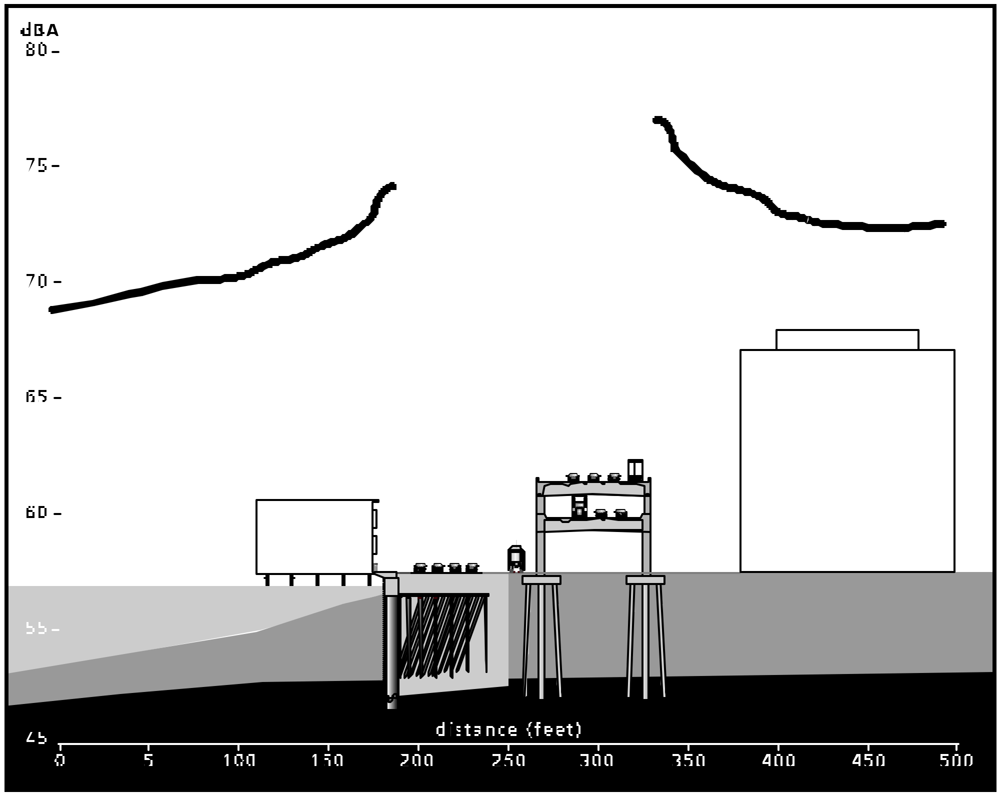


Exhibit 5-6. Rebuild Alternative Noise Profile at Spring Street

Note: FHWA traffic noise abatement criterion is 67 dBA.

5.2.3 Traffic Noise North of the Battery Street Tunnel

In the area north of the Battery Street Tunnel (Receptors S23 to S30 and T13), traffic noise levels would increase by up to 2 dBA compared to existing conditions as a result of changes in traffic in the area (see Exhibits 5-1 and 5-2).

5.2.4 Vibration Impacts

Long-term vibration impacts under the Rebuild Alternative would be similar to existing levels because the rebuilt viaduct structure would be in a similar location and would have a similarly configured but strengthened support structure compared to the existing viaduct.

5.3 Aerial Alternative

The configuration and traffic operations of the Aerial Alternative are very similar to the Rebuild Alternative; therefore, traffic noise levels in 2030 under the Aerial Alternative would be nearly identical to the Rebuild Alternative. Like the Rebuild Alternative, loudest hour traffic noise levels under the Aerial Alternative would range between 59 and 79 dBA at modeled locations (see Exhibits 5-1 and 5-2). Traffic noise levels are predicted to change between a 2-dBA decrease and a 2-dBA increase compared to existing levels.

The modeled traffic noise levels approach or exceed the FHWA noise abatement criteria at 43 of the 48 modeled sites. The sites modeled to approach or exceed the FHWA noise abatement criteria represent approximately 4,490 residential units, 1,290 hotel rooms, and 120 shelter beds. Nine of the sites represent park or public open space uses, two represent educational or childcare facilities, and ten sites represent commercial or other less noise-sensitive uses only (see Exhibit 5-3). Many of the residential and hotel sites do not have private outdoor use areas, but most have windows that open. The same six sites modeled to experience severe noise impacts under the No Build and Rebuild Alternatives would also experience severe noise impacts in 2030 under the Aerial Alternative. The sites where severe noise impacts are expected are S18, S19, S24, S28, S29, and T13, representing 326 residential units, 394 hotel rooms, and one park.

Total noise levels at many of the sites would be greater than the predicted traffic noise level because non-traffic sound sources contribute substantially to the total environmental noise level in much of the study area. Non-traffic noise sources at the various sites included aircraft, sounds from restaurants and other businesses, sidewalk noise, construction noise, building mechanical noise, alarms, and sirens.

5.3.1 Traffic Noise South of the Battery Street Tunnel

In the area south of the Battery Street Tunnel (Receptors S1 to S19, T1 to T5, T7, and C1 to C9), traffic noise levels would vary by up to 1 dBA compared to existing conditions as a result of small changes in traffic patterns and volumes. These changes in traffic noise levels would not be audible.

The traffic noise profile was developed at the same location for the Aerial Alternative as for the other alternatives (Exhibit 5-7).

Option: SR 99 At-Grade With SR 519 Elevated Interchange

The area south of S. King Street was not considered in this analysis because there are no noise-sensitive land uses south of S. Royal Brougham Way.

5.3.2 Traffic Noise in Belltown and the North Waterfront

In the Belltown and North Waterfront area (Receptors S20 to S22 and T6, T8 to T12), traffic noise levels would vary by up to 1 dBA compared to existing conditions as a result of changes in traffic patterns in the Belltown area. These changes in traffic noise levels would not be audible.

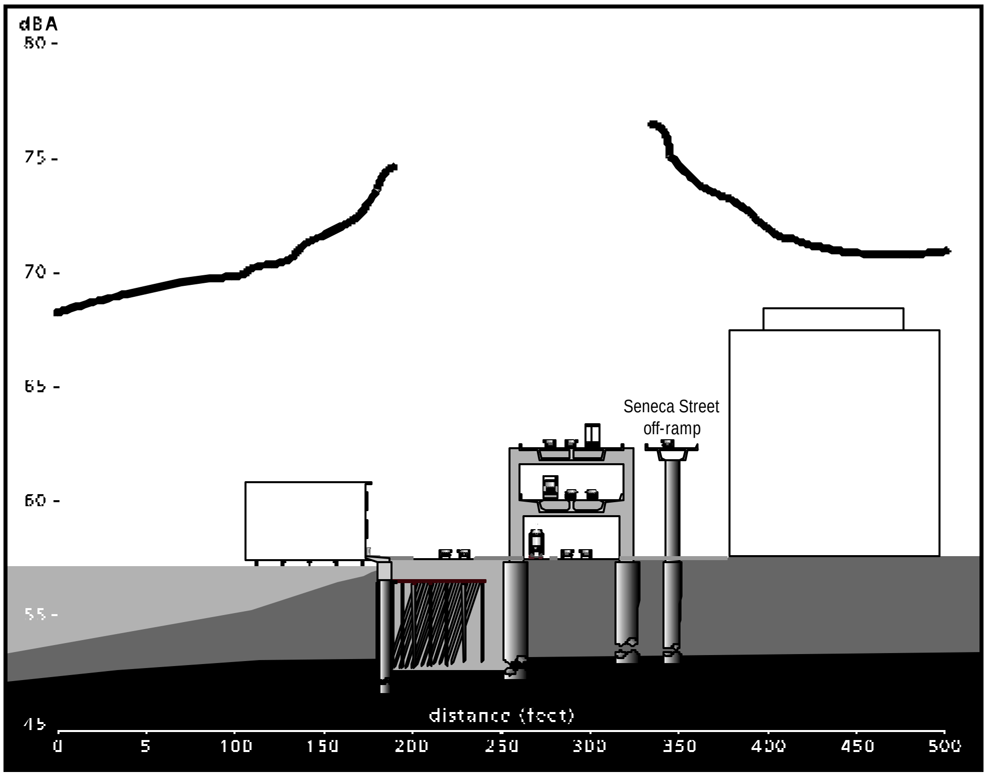


Exhibit 5-7. Aerial Alternative Noise Profile at Spring Street

Note: FHWA traffic noise abatement criterion is 67 dBA.

Broad Street Underpass not Constructed

In the event that the Broad Street underpass is not constructed, traffic to and from Magnolia and the Ballard Bridge would continue to be routed primarily along Elliott and Western Avenues via reconstructed ramps south of the Battery Street Tunnel. Compared to the analyzed alternative, this option could shift a small volume of traffic off of the Alaskan Way surface street onto the rebuilt viaduct south of the Battery Street Tunnel and onto Elliott and Western Avenues through Belltown. This option is expected to change traffic noise levels by less than 1 dBA as a result of shifting the traffic from the waterfront to Belltown.

5.3.3 Traffic Noise North of the Battery Street Tunnel

In the area north of the Battery Street Tunnel (Receptors S23 to S30 and T13), traffic noise levels would vary by up to 2 dBA compared to existing conditions as a result of widening of Mercer Street and changes in traffic in the area. These changes in traffic noise levels would not be audible.

Option: Lowered Aurora/SR 99

The option to lower Aurora Avenue north of the Battery Street Tunnel would reduce traffic noise levels somewhat at receptors north of the tunnel (Receptors S24 to S30) because the retaining walls along the lowered section would shield adjacent areas from noise. Traffic noise levels would likely be reduced by between 1 and 5 dBA in this area, depending on the location of the receptor.

5.3.4 Ventilation System Noise

Improvements to the Battery Street Tunnel would include the extension of the tunnel portals and installation of jet fans to provide emergency and supplemental ventilation. Within the tunnel, the ventilation fans and jet fans would be designed for 92 dBA at 10 feet from either the fan outlet or jet fans. There are several residential uses near the south portal: Elliott Point Apartments, Belltown Loft Condominiums, and 2300 Elliott Apartments. The Holiday Inn and Seattle Inn hotels are within one block of the north portal. The jet fans are expected to operate during peak-traffic periods and in emergencies. During normal operations, the fans would operate at reduced output. The jet fans would be designed not to exceed 57 dBA at the nearest residential property line during normal daytime operations. If they 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 during those hours.

5.3.5 Vibration Impacts

Long-term vibration impacts under the Aerial Alternative would be similar to existing levels, because the new viaduct structure would be in a similar location to the existing viaduct. Vibration energy would continue to be transferred from the structure to the ground via the columns.

5.4 Tunnel Alternative

Traffic operations with the Tunnel Alternative are similar to the Aerial and Rebuild Alternatives; however, SR 99 traffic along the central waterfront would be routed underground, substantially reducing traffic noise in that area. Loudest hour traffic noise levels under the Tunnel Alternative would range between 58 and 80 dBA at modeled locations (see Exhibits 5-1 and 5-2). Traffic noise levels are predicted to change between a 12-dBA decrease and a 6-dBA increase compared to existing levels. A 12-dBA decrease in traffic noise levels sounds approximately like a halving of the noise level.

The modeled traffic noise levels approach or exceed the FHWA noise abatement criteria at 30 of the 48 modeled sites. The sites modeled to approach or exceed the FHWA noise abatement criteria represent approximately 4,250 residential units, 1,290 hotel rooms, and 120 shelter beds. Four of the sites represent park or public open space uses, two represent educational or childcare facilities, and three sites represent commercial or other less noise-sensitive uses only (Exhibit 5-3). Many of the residential and hotel sites do not have private outdoor use areas and have only indoor noise-sensitive uses (Activity Category E).

The same six sites modeled to experience severe noise impacts under the previous alternatives would also experience severe noise impacts in 2030 under the Tunnel Alternative. The sites where severe noise impacts are expected are S18, S19, S24, S28, S29, and T13, representing 326 residential units, 394 hotel rooms, and one park.

Total noise levels at many of the sites would be greater than the predicted traffic noise level because non-traffic sound sources contribute substantially to the total environmental noise level in much of the study area. Non-traffic noise sources at the various sites included aircraft, sounds from restaurants and other businesses, sidewalk noise, construction noise, building mechanical noise, alarms, and sirens.

At-grade Design Option South of South King Street

The area south of S. King Street was not considered in this analysis because there are no noise-sensitive land uses south of S. Royal Brougham Way.

5.4.1 Traffic Noise South of the Battery Street Tunnel

In the area south of the Battery Street Tunnel (Receptors S1 to S19, T1 to T5, T7, and C1 to C9), traffic noise levels would vary between a 12-dBA decrease and a 6-dBA increase compared to existing conditions. At the south end of the Waterfront Landing Condominiums, traffic noise levels are predicted to increase by 6 dBA where the waterfront tunnel would transition into an aerial structure to connect to the existing Battery Street Tunnel. At this location, SR 99 is currently overhead, but would be near ground level and climbing towards the Battery Street Tunnel under the Tunnel Alternative; therefore, there would be a direct line of sight to traffic from this location.

Receptors south of Pike Street along the waterfront and within one to two blocks east of Alaskan Way (Receptors S5, S8, S15, S16, S17, and C2) would experience decreases in traffic noise levels compared to existing levels of between 8 and 12 dBA as a result of eliminating traffic on the Alaskan Way Viaduct as a noise source. Traffic noise in this area would subjectively be between noticeably quieter and one-half as loud as existing traffic noise levels in this area.

A traffic noise profile was developed at the same location for the Tunnel Alternative as for the other alternatives (Exhibit 5-8). The noise profile for the Tunnel Alternative is approximately 10 dBA lower than the alternatives with only aboveground traffic. This can be observed by comparing the scale along the left of the exhibits.

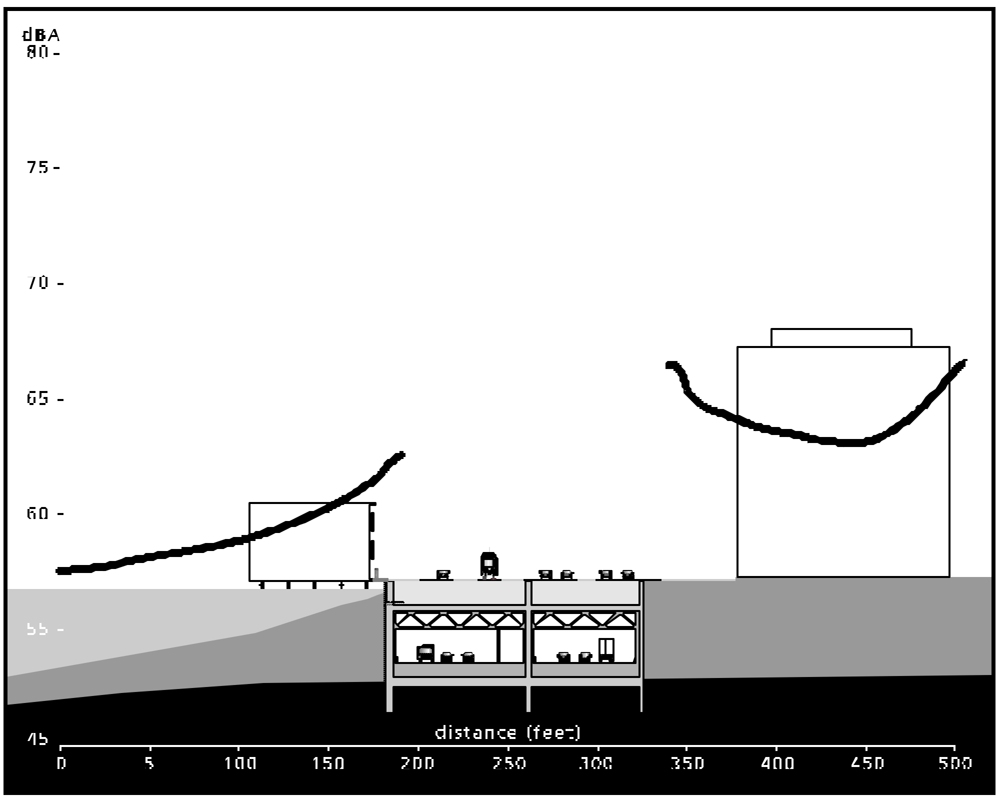


Exhibit 5-8. Tunnel Alternative Noise Profile at Spring Street

Note: FHWA traffic noise abatement criterion is 67 dBA.

5.4.2 Traffic Noise in Belltown and the North Waterfront

In the Belltown and North Waterfront area (Receptors S20 to S22 and T6, T8 to T12), traffic noise levels would vary by up to 2 dBA compared to existing conditions as a result of changes in traffic patterns in the Belltown area. These changes in traffic noise levels would not be audible.

Broad Street Underpass not Constructed

In the event that the Broad Street underpass is not constructed, ramps would need to be constructed from Alaskan Way north of the central waterfront tunnel to Elliott and/or Western Avenues to replace the existing connections to the Alaskan Way Viaduct in that area. This option would shift traffic off of the Alaskan Way surface street into the central waterfront tunnel and onto Elliott and Western Avenues through Belltown. This option could reduce traffic noise levels along the north waterfront and increase them along Elliott and Western Avenues by 1 to 2 dBA compared to the traffic noise analysis results for the Tunnel Alternative.

5.4.3 Traffic Noise North of the Battery Street Tunnel

In the area north of the Battery Street Tunnel (Receptors S23 to S30 and T13), traffic noise levels would vary by up to 2 dBA compared to existing conditions as a result of widening of Mercer Street and changes in traffic in the area. These changes in traffic noise levels would not be audible.

5.4.4 Ventilation System Noise

The central waterfront tunnel would require the construction and operation of a mechanical ventilation system with several ventilation stacks. At the south portal and King Street vent building, there are mostly industrial and commercial uses. The ventilation fans would be designed not to exceed 60 dBA at the nearest commercial property line during normal operations.

There are two residential receivers near the Yesler Way vent building, the Travelers Hotel and Pioneer Square Hotel. The closest receivers to the Spring Street vent building are commercial uses. However, Harbor Steps Apartments and Grand Pacific Condominiums, located approximately one block from the vent building, are the closest residential uses. There are several residential uses near the Pike Street vent building: Market Square, Hillclimb Court, and Ross Manor. The closest residential receivers to the north portal of the waterfront tunnel are the Waterfront Landings Condominiums and Marriott Hotel. 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 they 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.

Improvements to the Battery Street Tunnel would include the extension of the tunnel portals and installation of jet fans to provide emergency and supplemental ventilation. Within the tunnel, the ventilation fans and jet fans would be designed for 92 dBA at 10 feet from either the fan outlet or jet fans. There are several residential uses near the south portal: Elliott Point Apartments, Belltown Loft Condominiums, and 2300 Elliott Apartments. The Holiday Inn and Seattle Inn hotels are within one block of the north portal. The jet fans would be designed not to exceed 57 dBA at the nearest residential property line during normal daytime operations. If they normally would be operated during nighttime hours they would be designed not to exceed 47 dBA during nighttime hours.

5.4.5 Vibration Impacts

Long-term peak vibration levels under the Tunnel Alternative would be less than existing levels because vibration energy from traffic traveling in the tunnel or on the surface would not be concentrated in the vicinity of piers.

5.5 Bypass Tunnel Alternative

Traffic operations with the Bypass Tunnel Alternative are similar to the Tunnel Alternative, but traffic traveling between south and west Seattle and Interbay, Magnolia, and Queen Anne would travel along the central waterfront on the Alaskan Way surface street. As a result, traffic volumes and noise levels along the central waterfront would be slightly higher than under the Tunnel Alternative, but still lower than under the other alternatives. Loudest hour traffic noise levels under the Bypass Tunnel Alternative would range between 59 and 79 dBA at modeled locations (see Exhibits 5-1 and 5-2). Traffic noise levels are predicted to change between a 10-dBA decrease and a 3-dBA increase compared to existing levels. A 10-dBA decrease in traffic noise levels sounds approximately like a halving of the noise level.

The modeled traffic noise levels approach or exceed the FHWA noise abatement criteria at 30 of the 48 modeled sites. The sites modeled to approach or exceed the FHWA noise abatement criteria represent approximately 4,360 residential units, 1,290 hotel rooms, and 120 shelter beds. Three of the sites represent park or public open space uses, two represent educational or childcare facilities, and five sites represent commercial or other less noise-sensitive uses only (see Exhibit 5-3). Many of the residential and hotel sites do not have private outdoor use areas, but most have windows that open.

The same six sites modeled to experience severe noise impacts under the previous alternatives would also experience severe noise impacts in 2030 under the Bypass Tunnel Alternative. The sites where severe noise impacts are expected are S18, S19, S24, S28, S29, and T13, representing 326 residential units, 394 hotel rooms, and one park.

Total noise levels at many of the sites would be greater than the predicted traffic noise level because non-traffic sound sources contribute substantially to the total environmental noise level in much of the study area. Non-traffic noise sources at the various sites included aircraft, sounds from restaurants and other businesses, sidewalk noise, construction noise, building mechanical noise, alarms, and sirens.

5.5.1 Traffic Noise South of the Battery Street Tunnel

In the area south of the Battery Street Tunnel (Receptors S1 to S19, T1 to T5, T7, and C1 to C7), traffic noise levels would vary between a 10-dBA decrease and an 3-dBA increase compared to existing conditions. The traffic noise level in the original locations would be similar to the noise levels modeled under the Tunnel Alternative. At the south end of the Waterfront Landing Condominiums, traffic noise levels are predicted to increase by 3 dBA where the waterfront tunnel would transition into an aerial structure to connect to the existing Battery Street Tunnel.

Receptors south of Pike Street along the waterfront and within one to two blocks east of Alaskan Way (Receptors S5, S8, S15, S16, S17, and C2) would experience decreases in traffic noise levels compared to existing levels of between 9 and 10 dBA as a result of eliminating traffic on the Alaskan Way Viaduct as a noise source. Traffic noise in this area would subjectively be between noticeably quieter and one-half as loud as existing traffic noise levels in this area.

The traffic noise profile was developed at the same location for the Bypass Tunnel Alternative as for the other alternatives (Exhibit 5-9). The Bypass Tunnel Alternative has a similar profile to the Tunnel Alternative.

5.5.2 Traffic Noise in Belltown and the North Waterfront

In the Belltown and North Waterfront area (Receptors S20 to S22 and T6, T8 to T12), traffic noise levels would vary by up to 3 dBA compared to existing conditions as a result of changes in traffic patterns in the Belltown area. These changes in traffic noise levels would not be audible.

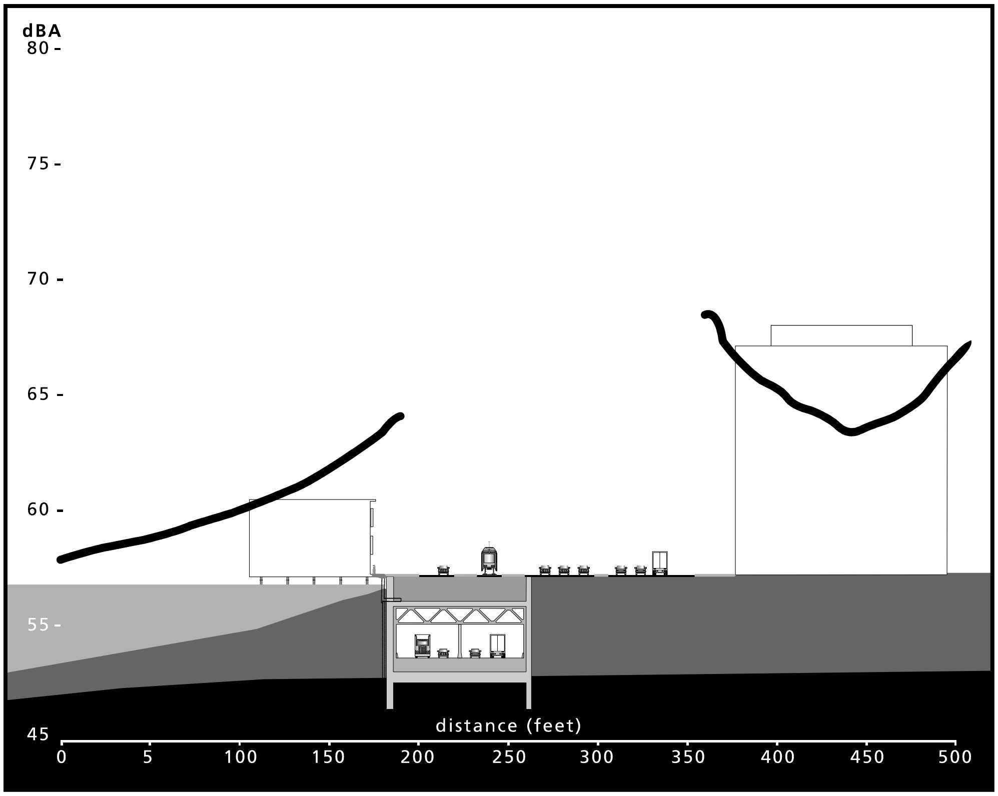


Exhibit 5-9. Bypass Tunnel Alternative Noise Profile at Spring Street

Note: FHWA traffic noise abatement criterion is 67 dBA.

Broad Street Underpass not Constructed

In the event that the Broad Street underpass is not constructed, Alaskan Way surface street would need to be connected to Elliott and/or Western Avenues to replace the existing connections to the Alaskan Way Viaduct in that area. This option would shift traffic off of the Alaskan Way surface street along the north waterfront and onto Elliott and Western Avenues through Belltown. This option could reduce traffic noise levels along the north waterfront and increase them along Elliott and Western Avenues by 1 to 2 dBA compared to the traffic noise analysis results for the Bypass Tunnel Alternative.

5.5.3 Traffic Noise North of the Battery Street Tunnel

In the area north of the Battery Street Tunnel (Receptors S23 to S30 and T13), traffic noise levels would vary by up to 2 dBA compared to existing conditions as a result of widening of Mercer Street and changes in traffic in the area. These changes in traffic noise levels would not be audible.

5.5.4 Ventilation System Noise

The central waterfront tunnel would require the construction and operation of a mechanical ventilation system with several ventilation stacks. At the south portal and King Street vent building, there are mostly industrial and commercial uses. The ventilation fans would be designed not to exceed 60 dBA at the nearest commercial property line during normal operations.

There are two residential receivers near the Yesler Way vent building, the Travelers Hotel and Pioneer Square Hotel. The closest receivers to the Spring Street vent building are commercial uses. However, Harbor Steps Apartments and Grand Pacific Condominiums, located approximately one block from the vent building, are the closest residential uses. There are several residential uses near the Pike Street vent building: Market Square, Hillclimb Court, and Ross Manor. The closest residential receivers to the north portal of the waterfront tunnel are the Waterfront Landings Condominiums and Marriott Hotel. The ventilation fans would be designed for normal operational noise levels not to exceed either 60 dBA at the nearest commercial uses or 57 dBA at the property line of the nearest residential use, whichever is the most restrictive. If they 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.

Improvements to the Battery Street Tunnel would include the extension of the tunnel portals and installation of jet fans to provide emergency and supplemental ventilation. Within the tunnel, the ventilation fans and jet fans would be designed for 92 dBA at 10 feet from either the fan outlet or jet fans. There are several residential uses near the south portal: Elliott Point Apartments, Belltown Loft Condominiums, and 2300 Elliott Apartments. The Holiday Inn and Seattle Inn hotels are within one block of the north portal. The jet fans would be designed not to exceed 57 dBA at the nearest residential property line during normal daytime operations. If they normally would be operated during nighttime hours they would be designed not to exceed 47 dBA during nighttime hours.

5.5.5 Vibration Impacts

Long-term peak vibration levels under the Bypass Tunnel Alternative would be less than existing levels because vibration energy from traffic traveling in the tunnel or on the surface would not be concentrated in the vicinity of piers.

5.6 Surface Alternative

Traffic operations with the Surface Alternative differ from the other alternatives by routing both local access and through traffic to the arterial street grid. This alternative has lower capacity, resulting in lower traffic volumes; however, the volumes are distributed onto the surface streets adjacent to many of the noise-sensitive receptors in the project area. The loudest traffic hour would not be the peak hour under the Surface Alternative, because average speeds would be substantially lowered by traffic congestion. Early-morning, midday, and evening periods with high traffic volumes still able to travel near the speed limit would result in the highest traffic noise conditions.

Loudest hour traffic noise levels under the Surface Alternative would range between 60 and 79 dBA at modeled locations (see Exhibits 5-1 and 5-2). Traffic noise levels are predicted to change between a 4-dBA decrease and a 5-dBA increase compared to existing levels. A 5-dBA increase in traffic noise is readily noticeable.

The modeled traffic noise levels approach or exceed the FHWA noise abatement criteria at 42 of the 48 modeled sites. The sites modeled to approach or exceed the FHWA noise abatement criteria represent approximately 4,490 residential units, 1,290 hotel rooms, and 120 shelter beds. Nine of the sites represent park or public open space uses, two represent educational or childcare facilities, and five sites represent commercial or other less noise-sensitive uses only (see Exhibit 5-3). Many of the residential and hotel sites do not have private outdoor use areas, but most have windows that open.

The same six sites modeled to experience severe noise impacts under the previous alternatives would also experience severe noise impacts in 2030 under the Surface Alternative. The sites where severe noise impacts are expected are S18, S19, S24, S28, S29, and T13, representing 326 residential units, 394 hotel rooms, and one park.

Total noise levels at many of the sites would be greater than the predicted traffic noise level because non-traffic sound sources contribute substantially to the total environmental noise level in much of the study area. Non-traffic noise sources at the various sites included aircraft, sounds from restaurants and other businesses, sidewalk noise, construction noise, building mechanical noise, alarms, and sirens.

5.6.1 Traffic Noise South of the Battery Street Tunnel

In the area south of the Battery Street Tunnel (Receptors S1 to S19, T1 to T5, T7, and C1 to C9), traffic noise levels would vary between a 4-dBA decrease and a 2-dBA increase compared to existing conditions. Traffic noise levels along the bicycle and pedestrian facilities along the Alaskan Way surface street would increase by up to 3 dBA compared to existing levels as a result of increased surface traffic immediately adjacent to the bicycle and pedestrian facilities.

The traffic noise profile was developed at the same location for the Surface Alternative as for the other alternatives (Exhibit 5-10). The scale on the Surface Alternative exhibit is the same as on the No Build, Rebuild, and Aerial Alternatives.

At-grade Design Option

The area south of S. King Street was not considered in this analysis because there are no noise-sensitive land uses south of S. Royal Brougham Way.

5.6.2 Traffic Noise in Belltown and the North Waterfront

In the Belltown and North Waterfront area (Receptors S20 to S22 and T6, T8 to T12), traffic noise levels would vary by up to 1 dBA compared to existing conditions as a result of changes in traffic patterns in the Belltown area. These changes in traffic noise levels would not be audible.

Broad Street Underpass not Constructed

In the event that the Broad Street underpass is not constructed, access would need to be provided from Alaskan Way to Elliott and/or Western Avenues to replace the existing connections to the Alaskan Way Viaduct in that area. This option would shift traffic off of the Alaskan Way surface street into the central waterfront tunnel and onto Elliott and Western Avenues through Belltown. This option could reduce traffic noise levels along the north waterfront and increase them along Elliott and Western Avenues by 1 to 2 dBA compared to the traffic noise analysis results for the Surface Alternative.

5.6.3 Traffic Noise North of the Battery Street Tunnel

In the area north of the Battery Street Tunnel (Receptors S23 to S30 and T13), traffic noise levels would vary by up to 2 dBA compared to existing conditions as a result of widening of Mercer Street and changes in traffic in the area. These changes in traffic noise levels would not be audible.

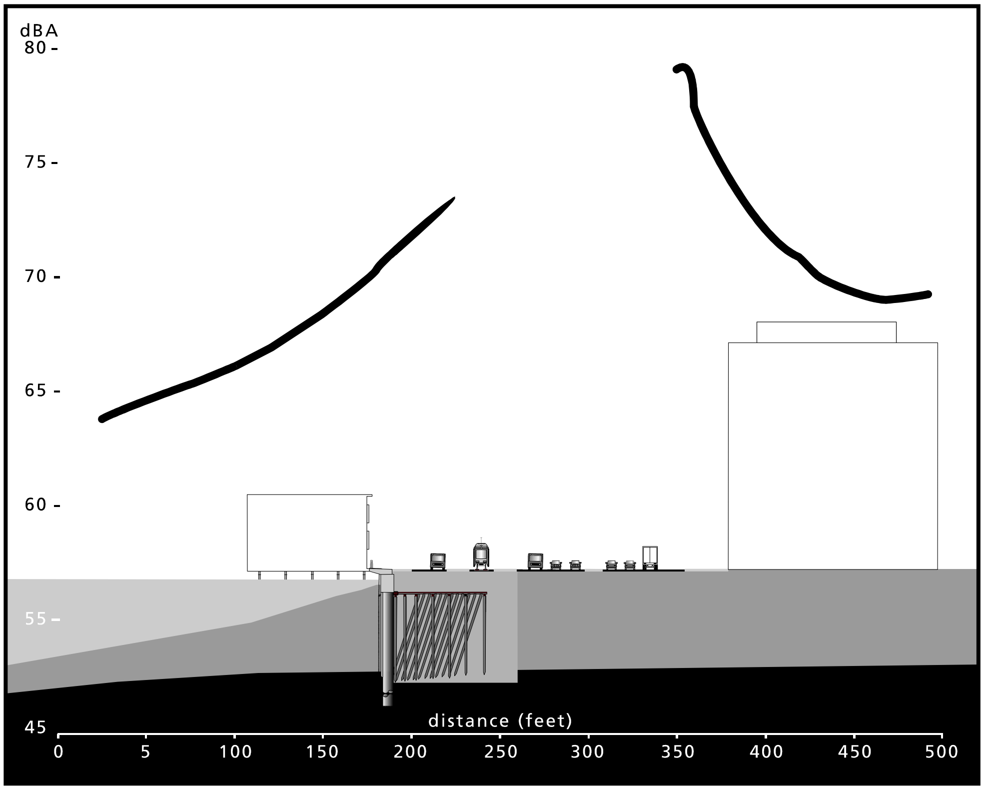


Exhibit 5-10. Surface Alternative Noise Profile at Spring Street

Note: FHWA traffic noise abatement criterion is 67 dBA.

Option: Existing SR 99 With Added Signals at Roy, Republican, and Harrison Streets

Reconnecting the roadway grid at-grade with Aurora Avenue and including a signal at Mercer Street would lower speeds on Aurora Avenue. The noise reduction as a result of decreased speed would be partially offset by vehicles accelerating away from the signal. Traffic noise levels at adjacent receptors could be 1 to 3 dBA lower as a result of the reduced speed.

5.6.4 Ventilation System Noise

Improvements to the Battery Street Tunnel would include the extension of the tunnel portals and installation of jet fans to provide emergency and supplemental ventilation. Within the tunnel, the ventilation fans and jet fans would be designed for 92 dBA at 10 feet from either the fan outlet or jet fans. There are several residential uses near the south portal: Elliott Point Apartments, Belltown Loft Condominiums, and 2300 Elliott Apartments. The Holiday Inn and Seattle Inn hotels are within one block of the north portal. The jet fans would be designed not to exceed 57 dBA at the nearest residential property line during normal daytime operations. If they 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 during those hours.

5.6.5 Vibration Impacts

Long-term peak vibration levels under the Surface Alternative would be less than existing levels, because vibration energy from traffic traveling on the surface would not be concentrated in the vicinity of piers.

Chapter 6 CONSTRUCTION IMPACTS

Construction of the SR 99 Alaskan Way Viaduct and Seawall Replacement Project would occur over an 8- to 11-year period depending on the alternative. Construction under any of the alternatives would occur in several stages, each stage including various construction activities of different durations at various locations within the study area. All of the Build Alternatives assume that construction would continue 24 hours per day.

While most construction projects with nighttime work activities are completed under a temporary noise variance from the City of Seattle Department of Planning and Development, the long duration and unique nature of this project would likely require a technical variance. Technical variances are granted when there are no practical means to work within the City noise ordinance. Obtaining a technical variance includes a public hearing process and requires the applicant to abide by noise mitigation measures set forth by the City.

The construction approaches evaluated for noise and vibration are described in Chapters 3 and 4 of Appendix B, Alternatives Description and Construction Methods Technical Memorandum. The construction activities evaluated in this study represent one possible construction sequence for each alternative. The actual construction sequence could differ substantially from this evaluation; however, the locations and types of activities would be similar under the final sequence.

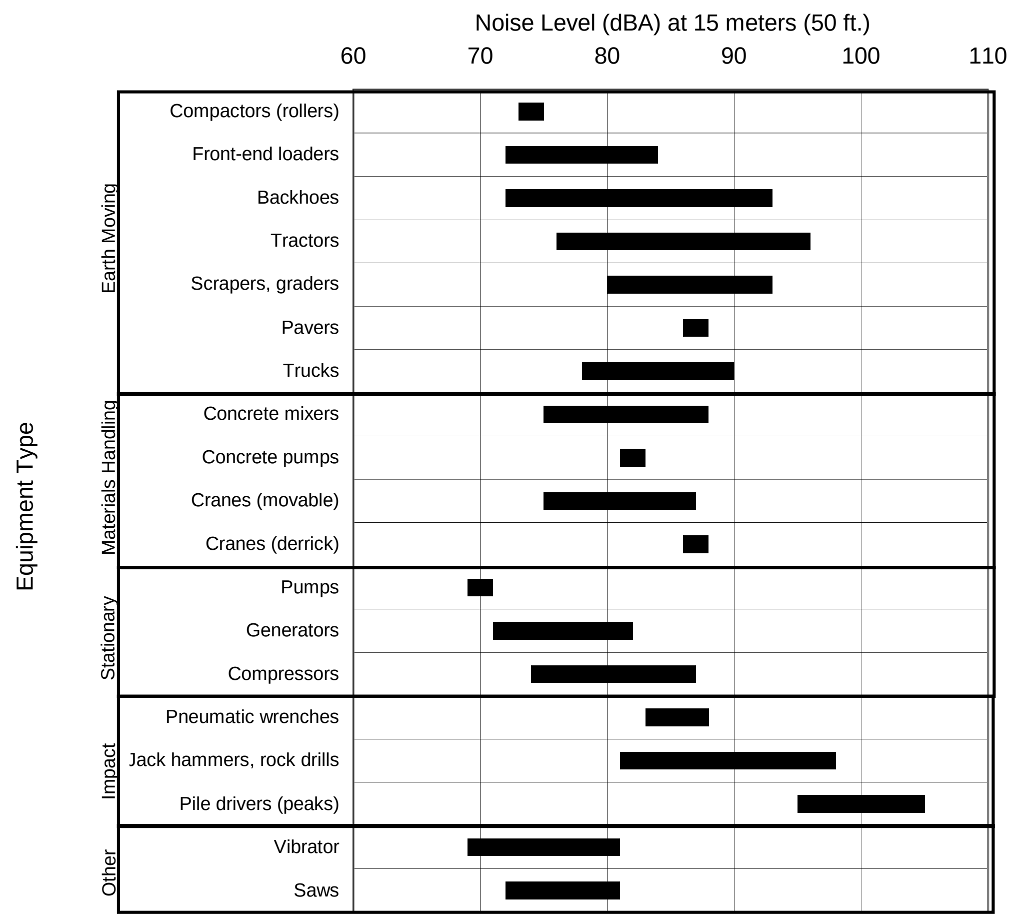
6.1 Noise

Noise during the construction period would be bothersome to nearby residents and businesses. Construction workers also would be subject to construction noise while working on the site. Construction noise would vary widely both spatially and time-wise over the course of the project. For the Alaskan Way Viaduct and Seawall Replacement Project, the construction period is anticipated to last between 8 and 11 years, with various periods of disturbance that would last for several weeks 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) operates at 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 approximate 8- to 11-year construction period at various locations in the project area. 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 all Build Alternatives would be similar to the typical maximum construction equipment noise levels presented in Exhibit 6-1.



Source: EPA, 1971 and WSDOT, 1991.

Exhibit 6-1. Typical Construction Equipment Noise Levels

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. Construction noise levels may not exceed a maximum $L_{eq(7.5 \text{ minute})}$ of 99 dBA at 50 feet or the nearest property line (whichever is further) within the city of Seattle (SMC 25.08.425).

Construction noise is allowed to exceed City of Seattle property-line noise limits by 20 to 25 dBA during daytime hours (7 a.m. to 10 p.m. on weekdays and 9 a.m. to 10 p.m. on weekends). Under all of the Build Alternatives, noise from certain activities is likely to exceed the higher daytime limits during some construction stages. Substantial nighttime construction that would exceed nighttime noise limits would also be required under each of the Build Alternatives. If concrete is crushed and recycled on-site, a noise control plan would be required to address the associated activities. To accommodate these exceedances of the City of Seattle noise regulations, a nighttime noise variance would be required from the City.

Reconstruction of the seawall, whether stand-alone or as part of a tunnel wall, could generate in-water noise and vibration levels that are disturbing to fish and marine mammals. Construction behind a coffer dam, or other methods to reduce in-water pile driving, would reduce the potential for impact.

6.1.1 No Build Alternative

Construction noise under the No Build Alternative would be limited to noise associated with ongoing maintenance activities to the existing viaduct. Should the existing viaduct be damaged and need to be closed, there would be noise created by activities to close or remove the structure.

6.1.2 Rebuild Alternative

The Rebuild Alternative is anticipated to be constructed in four general stages: Site Preparation, Construction of Seawall, Rebuild of Alaskan Way, and Project Closeout. The construction would take approximately 7.5 years.

The Site Preparation stage is anticipated to require approximately 18 months and would include noise from various activities throughout the corridor at various times. Most construction activities during the first stage would be of limited duration in any single location. Noise levels would be typical of excavation and paving activities as utilities and rail lines are relocated and access roads and staging areas are constructed (see Exhibit 6-1). Some activities during the first stage would occur during nighttime hours, particularly activities that would require traffic lane closures.

Construction of the seawall is anticipated to require approximately 24 months. During that period, several work crews would be rebuilding the existing seawall progressively along the waterfront between S. Washington Street and Broad Street. Construction activities would be occurring at several locations along the waterfront at any point in time during this stage. Seawall construction would require stabilization of existing soils, likely by jet grouting. Drilled shaft piles would be placed where needed, and a new face would be attached. Completion of the seawall replacement on schedule would require nighttime work during much of this stage. Recent noise measurements of jet grouting operations by the City of Seattle exhibited noise levels of 85 dBA at 50 feet. Jet grouting equipment used for complete seawall replacement would be larger than the measured equipment and could range 1 to 5 dBA louder. Substantial noise could occur for several weeks at a time in any one area. Other activities during the second stage would include limited roadway reconstruction or retrofit.

Stage three would include rebuilding most of the existing viaduct over an approximately 54-month period. At times, traffic would be detoured in various locations along the project corridor. Rebuilding the viaduct would include various activities that would be occurring in localized work areas that would move over the period of reconstruction. Activities would include placement of new piles and footings, replacement of structural supports, and replacement of the roadway decks. Piles could be driven, bored, or vibrated into place. If driven piles are used, peak noise levels during pile driving would likely be the loudest noises during reconstruction of the viaduct. Noise levels during pile driving typically approach 100 dBA at 50 feet (93 dBA at 100 feet) from the pile being driven (Exhibit 6-2). Noise levels from bored piles are typically 15 to 20 dBA less than from driven piles. Vibrated piles likely could not be used in much of the project area because soils are not suitably stable. The Rebuild Alternative is expected to require more driven piles than any of the other alternatives. Other activities, including excavation, pavement breaking, and concrete pumping, would generate substantial noise during this phase; however, they would generally be less loud than pile driving. Substantial noise levels could occur for several weeks at a time in any one area.

The fourth stage would require approximately 8 months and would include various activities to finalize construction, replace the waterfront trolley tracks, and complete street restoration. Most construction activities during the fourth stage would be of limited duration in any single location.

Exhibit 6-2. Noise Levels Typical of Pile Placement

Activity	Noise Level (L_{eq}) and Distance
Driven piles[a]	95-99 dBA (50 feet)
Driven sheet pile[b]	115 dBA (15 feet)
Bauer bg22 pile bore rig[b]	90 dBA (15 feet)
Impact pile driver[c]	98 dBA (operator location)
Drilled pile[c]	83 dBA (operator location)

[a] FHWA (1982).

[b] WACEP (1998).

[c] WCBBC (2000).

6.1.3 Aerial Alternative

Construction activities for the Aerial Alternative would be similar to the Rebuild Alternative. It is anticipated to be constructed in five general stages: Site Preparation, Construction of Seawall, Southbound Battery Street Tunnel and Broad Street Detour, Removal and Construction of the Aerial Viaduct, and Project Closeout. The construction would take approximately 11 years.

The first two construction stages would be similar in activities and duration to the Rebuild Alternative. The seawall construction stage would take approximately 36 months because it would also include the construction of temporary aerial structures above a portion of the seawall. The temporary aerial structure would be supported on drilled shaft piers. Other aspects of temporary viaduct construction would generate noise levels similar to the construction of the final aerial structure.

Stage three would take approximately 30 months and would include removal and replacement of the viaduct north of Pike Street, improvements to the southbound Battery Street Tunnel, and configuration of local streets to accommodate detour traffic. During this period, construction activities and noise levels similar to those described for stage three of the Rebuild Alternative construction would occur between Pike Street and the Battery Street Tunnel. Demolition of the existing viaduct would include saw cutting and removal by crane, pulverizing, shearing, jack hammering, hoe ramming, and drilling. Demolition activities could include crushing and recycling of concrete on-site. Improvements to the Battery Street Tunnel would include lengthening the tunnel slightly and installing emergency ventilation equipment. Construction activities are expected to take place during both daytime and nighttime hours.

Stage four would include removal and replacement of the viaduct south of Pike Street over approximately 48 months. It would also include improvements to the northbound Battery Street Tunnel and configuration of local streets to accommodate detour traffic. During this period, construction activities and noise levels would be similar to those during stage three, but would largely occur south of Pike Street. Improvements to the Battery Street Tunnel would include lengthening the tunnel slightly and installing emergency ventilation equipment. Construction activities are expected to take place during both daytime and nighttime hours.

Stage five would require approximately 15 months. In addition to the noise generated by activities described for stage four of the Rebuild Alternative, temporary aerial structures along the waterfront would need to be removed under the Aerial Alternative.

6.1.4 Tunnel Alternative

The Tunnel Alternative is anticipated to be constructed in five general stages: Site Preparation, Construction of Seawall and Southbound Tunnel, Southbound Aerial and Battery Street Tunnel Construction, Removal of Viaduct and Northbound Tunnel, Aerial and Battery Street Tunnel Construction, and Project Closeout. The construction would take approximately 9 years. The first construction stage would be similar in activities and duration to the Rebuild and Aerial Alternatives.

The second stage would take approximately 24 months and would include construction of a secant pile wall to replace the existing seawall between approximately King and Pike Streets. In the vicinity of the Colman Dock Ferry Terminal, the pile wall would extend into Elliott Bay. The secant pile wall would be constructed of a series of large-diameter drilled shafts placed adjacent to each other. Noise levels from this activity are expected to be 5 to 10 dBA less than the jet grouting that would be required during seawall construction under the Rebuild and Aerial Alternatives.

A permanent excavation support wall would then be constructed to form the center wall of the final tunnel. The wall construction would utilize excavation and concrete pumping equipment. Finally, the area between the two walls would be excavated and the roadway and roof slab constructed. Noise levels would be typical of earthmoving activities. At any one time during this stage, these various activities would be occurring in limited areas along the waterfront south of approximately Pike Street. Construction activities are expected to take place during both daytime and nighttime hours.

The third stage would be similar to stage three under the Aerial Alternative and would take approximately 36 months. In addition to the activities north of Pike Street described under the Aerial Alternative, final utility relocations would be occurring along the corridor, which would be of limited duration in any single location.

Stage four would include removal of the viaduct south of Pike Street and excavation and construction of the northbound half of the waterfront tunnel over an approximately 36-month period. Demolition of the existing viaduct would include saw cutting and removal by crane, pulverizing, shearing, jack hammering, hoe ramming, and drilling. Demolition activities could include crushing and recycling of concrete on-site. Removal of the existing viaduct would be the loudest activity during this stage of work. Construction of the southbound tunnel would include construction of the eastern tunnel wall, excavation of the final northbound section, and roadway and roof slab placement. Battery Street Tunnel improvements would be similar to the Aerial Alternative. Noise from these activities would be similar to the wall construction and excavation noise levels during stage two.

Stage five would require approximately 13 months and would generate noise levels similar to stage four of the Rebuild Alternative.

6.1.5 Bypass Tunnel Alternative

The Bypass Tunnel Alternative is anticipated to be constructed in five general stages: Site Preparation, Construction of Seawall and Tunnel, Southbound Aerial and Battery Street Tunnel Construction, Removal of Viaduct and Northbound Aerial and Battery Street Tunnel Construction, and Project Closeout. The construction would take approximately 8.5 years.

The first two construction stages would be similar in activities and duration to the Tunnel Alternative.

The third stage would be similar to stage three under the Aerial Alternative and would take approximately 30 months.

Stage four would include removal of the viaduct south of Pike Street and rehabilitation of the northbound Battery Street Tunnel over an approximately 30-month period. Unlike the Tunnel Alternative, this stage would not include construction of a second parallel tunnel section along the waterfront. Demolition of the existing viaduct would include saw cutting and removal by crane, pulverizing, shearing, jack hammering, hoe ramming, and drilling. Battery Street Tunnel improvements would be similar to the Aerial and

Tunnel Alternatives. Demolition activities could include crushing and recycling of concrete on-site. Removal of the existing viaduct would be the loudest activity during this stage of work.

Stage five would require approximately 18 months and would generate noise levels similar to stage five of the Tunnel Alternative.

6.1.6 Surface Alternative

The Surface Alternative is anticipated to be constructed in five general stages: Site Preparation, Construction of Seawall, Southbound Aerial and Battery Street Tunnel Construction, Removal of Viaduct and Northbound Aerial and Battery Street Tunnel Construction, and Project Closeout. The construction would take approximately 8 years. The first construction stage would be similar in activities and duration to the other Build Alternatives.

Stage two, construction of the seawall, is anticipated to require approximately 30 months and would include similar activities and noise levels to the second stage of the Rebuild Alternative. The third stage would be similar to stage three under the Aerial and Bypass Tunnel Alternatives and would take approximately 30 months. The fourth stage would be similar in activity and duration to stage four of the Bypass Tunnel Alternative. Stage five would require approximately 8 months and would generate noise levels similar to stage four of the Rebuild Alternative.

6.2 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. Under all of the proposed Build Alternatives, the viaduct would be removed and demolished. The timing for removing the viaduct and the amount of material removed varies between plans; however, similar removal methods are anticipated. In general, the viaduct would 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, and/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 inches/second (Exhibit 6-3). This would exceed the damage risk criteria of 0.12 inches/second for older extremely fragile buildings but would not exceed the project's damage risk criteria for newer buildings of 0.50 inches/second. Demolition activities conducted 100 feet or more from existing structures would not exceed the damage risk criteria 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.

During impact pile driving, the PPV of ground vibration levels at 25 feet is expected to be in the range of 0.60 to 1.9 inches/second depending on the size and force exerted by the pile driver (Exhibit 6-4). These levels would substantially exceed the damage risk criteria of 0.12 inches/second for older extremely fragile buildings and 0.50 inches/second for newer buildings. At distances of 400 feet or greater, the damage risk is significantly lower and is expected not to exceed 0.10 inches/second.

In general, the potential impact to underground and buried utilities from construction vibration would be less than the damage risk to 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/second PPV at distances greater than 25 feet or 0.5 inches/second PPV damage risk criteria for older cast-iron water mains at distances greater than 100 feet. The damage risk to 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.

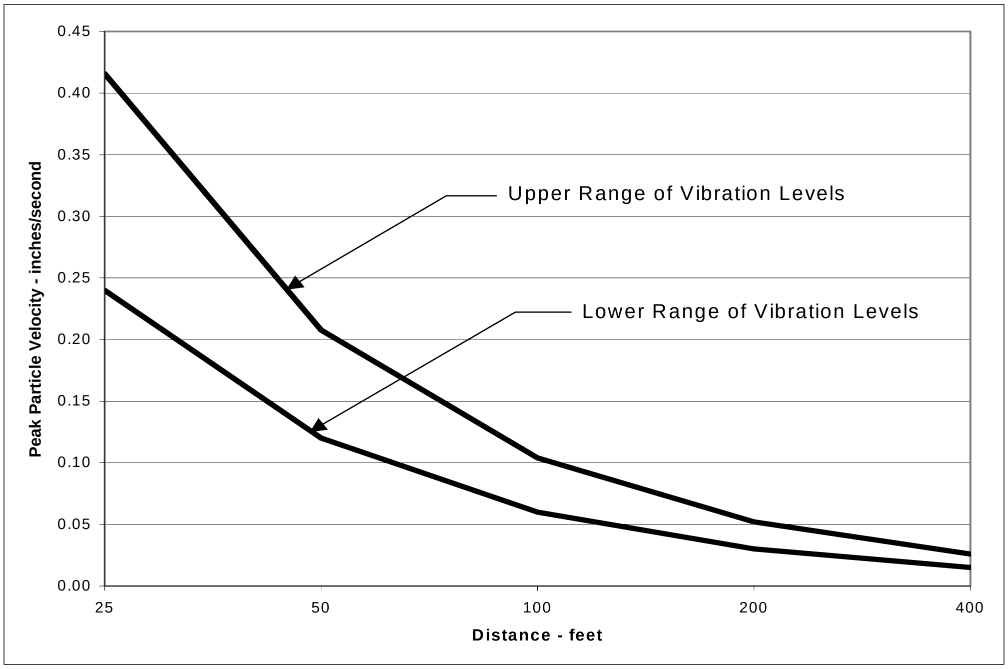


Exhibit 6-3. Hoe Ram and Jack Hammer Vibration Levels

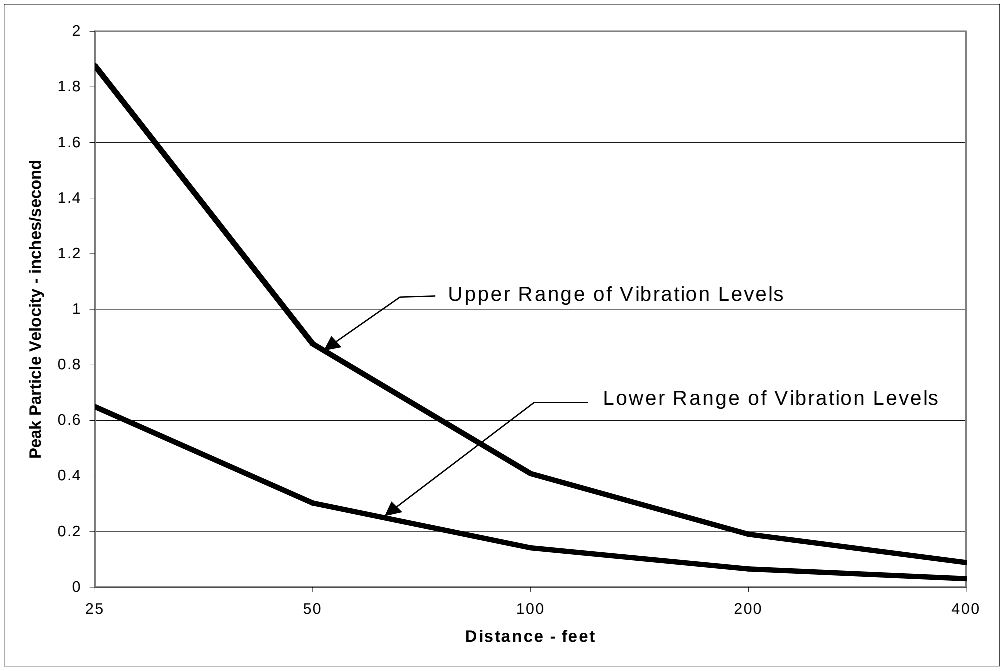


Exhibit 6-4. Impact Pile Driving Vibration Levels

Chapter 7 SECONDARY AND CUMULATIVE IMPACTS

Secondary impacts are reasonably foreseeable effects of an action that occur later in time or are further removed in distance from the direct effects of the project. Generally, these effects are induced by the initial action. Secondary impacts to the audible environment are expected to be limited and unlikely because none of the alternatives would increase existing capacity and connections.

Cumulative impacts are additive effects of the project with other reasonably foreseeable developments or actions in the future. The traffic noise analysis for the Alaskan Way Viaduct and Seawall Replacement Project considers the long-term cumulative traffic noise from Alaskan Way and future traffic on the Seattle street grid. Because traffic noise is the dominant noise source in the project area, considering the cumulative noise effect of all traffic noise in the study area reasonably evaluates the cumulative future noise environment, including the various Alaskan Way Viaduct and Seawall Replacement alternatives.

During the construction phase, several other projects are expected to be under construction in the downtown Seattle area, including Central Link Light Rail, Mercer Street Corridor, Seattle Monorail Project, and several other smaller or less well defined projects. If construction of other projects is within the immediate vicinity (less than approximately 1,000 feet) of the Alaskan Way Viaduct and Seawall Replacement Project construction areas and occurring at the same time, the cumulative noise impacts on nearby residents could increase in the vicinity of those activities.

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Chapter 8 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, with insulation. Noise abatement is necessary only where frequent human use occurs and where a lower noise level would have benefits (USDOT 1982).

8.1 Operational Noise

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 proposed action.

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 reasonability 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 8-1 (WSDOT 1999). For noise levels above 74 dBA, the allowed cost increases by $1,500 per dBA increase.

Exhibit 8-1. Mitigation Allowance for Noise Impacts

Design Year Traffic Noise Decibel Level	Allowed Mitigation Cost Per Household	Allowed Wall Surface Area Per Household (at $22.10 / ft^2)
66 dBA	$15,500	700 sq. ft.
67 dBA	$17,000	770 sq. ft.
68 dBA	$18,500	837 sq. ft.
69 dBA	$20,000	905 sq. ft.
70 dBA	$21,500	973 sq. ft
71 dBA	$23,000	1,041 sq. ft.
72 dBA	$24,500	1,109 sq. ft.
73 dBA	$26,000	1,176 sq. ft.
74 dBA	$27,500	1,244 sq. ft

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.

8.1.2 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. Noise impacts could be reduced by land use controls throughout the Puget Sound region; however, the area is largely built out. 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, subsequently, 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; however, a reduction of between 10 and 15 miles per hour would be required to decrease traffic noise by 5 dBA.

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 project study area would require relocating numerous residents and businesses and would be irrational for noise mitigation purposes.

Realigning the Roadway

The horizontal alignment is defined by available right-of-way and the existing Alaskan Way Viaduct Corridor. The various alternatives evaluate several vertical alignments, including elevated, at-grade, and belowground. The effects of changing the vertical alignment of Alaskan Way can be seen by comparing the peak hour noise levels of the various alternatives in Exhibits 5-1 and 5-2. Traffic noise levels under the Tunnel Alternative would decrease by up to 10 dBA compared to existing noise levels along the central waterfront. Traffic noise impacts would be eliminated at 210 residential units as a result of depressing and covering SR 99 (Exhibit 5-3). The incremental cost of tunnel construction would not be reasonable exclusively as a noise mitigation consideration.

Noise Insulation of Buildings

Insulation of buildings could be feasible, but this remedy only applies to structures with public or non-profit uses (23 CFR 772 and v67 n58 FR p13731, March 26, 2002.). 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 and 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). Clear barrier materials of either glass or plastic have been used on some projects. They have been successfully used along freeways in the San Diego, California area, where they could be placed near the affected residences and away from traffic. Their use immediately adjacent to roadways has been less successful because they require frequent cleaning and periodic replacement of etched, cracked, graffitied, or yellowed panels.

For a noise barrier to be constructed, it must be determined to be both feasible and reasonable. Exhibit 8-1 summarizes the mitigation allowance for barrier area provided per benefited receptor that is considered reasonable.

Sound-Absorptive Materials

The use of sound-absorptive materials can reduce or eliminate reflected noise. Incorporation or retrofit of sound-absorptive materials onto the bottom of elevated structures can reduce noise reflected off of the structure. Similarly, the use of absorptive materials near the mouth of roadway tunnels can reduce the traffic and ventilation system noise emanating from the tunnel.

8.1.3 Mitigation of Traffic Noise Impacted Receivers

Because the project corridor lies within a highly dense urban core, traffic noise levels already approach or exceed noise abatement criteria in much of the study area. In many locations, the levels approach or exceed the criteria as a result of general traffic on the urban arterial grid independent of traffic noise generated by Alaskan Way.

Mitigation of Traffic Noise South of the Battery Street Tunnel

Traffic noise levels near the elevated Alaskan Way structure under the Rebuild and Aerial Alternatives would be substantially higher as a result of the facilities. Comparing these alternatives to the Tunnel Alternative in Exhibits 5-1 and 5-2 demonstrates that the elevated structure can account for an increase in traffic noise levels of up to 10 dBA in this area. Two mitigation measures could be feasible for the Rebuild and Aerial Alternatives: sound-absorptive materials and barriers.

The use of sound-absorptive materials on the bottom of the upper deck of the Alaskan Way Viaduct was evaluated by eliminating the virtual roadway that represents the reflected sound from the traffic noise model for existing conditions. Eliminating the noise reflection source in the noise model reduced traffic noise levels between 1 and 10 dBA at several locations in the central waterfront. Exhibit 8-2 summarizes the results for all receptors that would experience a 3-dBA or greater reduction as a result of eliminating the reflection using sound-absorptive materials. The 3-dBA or greater benefits were only experienced at areas of public open space along the central waterfront and areas with commercial use. This mitigation measure would not reduce any of the severe impacts because they all occur north of the central waterfront. The installed cost of sound-absorptive materials is approximately $10 per square foot. Sound-absorptive materials can increase maintenance requirements.

Exhibit 8-2. Effectiveness of Eliminating Noise Reflections

Receptor	Represented Receptors	Traffic Noise Reduction (dBA)
S10	Pedestrian access	6
S14	Commercial use	6
S15	Commercial use	3
C1	Pedestrian and bicycle use	10
C3	Commercial use	9
C4	Commercial use	9
C5	Commercial use	4
C6	Park	3
C7	Park	3

It could also be possible to enclose the lower deck of the Alaskan Way Viaduct under the Rebuild and Aerial Alternatives by constructing a noise barrier between the lower and upper decks. A shorter barrier would not be effective unless upper deck reflections were also eliminated using sound-absorptive materials. This mitigation option would require mechanical ventilation of the enclosed vehicular space. Fire suppression and emergency egress systems would also have to be provided. Unless clear materials were used, the sound barrier walls would block views both from the viaduct and through the viaduct structure. The use of clear materials would substantially increase maintenance by requiring frequent cleaning of the walls and also periodic replacement of etched, cracked, or yellowed panels. This option may not be feasible because of the safety and engineering requirements associated with enclosure of the lower deck.

The effect of enclosing the lower deck was analyzed by removing from the noise model the traffic on the lower deck as a noise source. The sound-level benefits of enclosing the lower deck are summarized in Exhibit 8-3 for all receptors that would experience a 3-dBA or greater reduction. Comparing the results of Exhibit 8-3 to those of Exhibit 8-2 shows that completely enclosing the lower deck of the viaduct structure would provide only moderate additional traffic noise reductions compared to treating the lower side of the top deck with sound-absorptive materials.

Exhibit 8-3. Effectiveness of Enclosing the Lower Deck of the Viaduct

Receptor	Represented Receptors	Traffic Noise Reduction (dBA)
S8	25 Residential units and 75 hotel rooms	3
S9	Commercial use	3
S10	Pedestrian access	11
S14	Commercial use	6
S15	Commercial use	3
C1	Pedestrian and bicycle use	11
C2	Commercial use	3
C3	Commercial use	9
C4	Commercial use	10
C5	Commercial use	5
C6	Park	3
C7	Park	3

Under the Tunnel and Tunnel Bypass Alternatives, there are no feasible mitigation measures to further reduce traffic noise levels from Alaskan Way because the Alaskan Way surface street provides local access to downtown and the waterfront throughout the central waterfront. Traffic noise levels along the central waterfront would already be greatly reduced under those alternatives compared to existing levels.

It may be possible to reduce traffic noise levels under the Tunnel and Bypass Tunnel Alternatives at Receptor C9 (the south end of the Waterfront Landing Condominiums) by constructing a noise wall in the vicinity of the north portal of the Waterfront tunnel as SR 99 transitions onto an aerial structure. Extending a noise wall on the western roadway shoulder from the north tunnel portal for 200 feet would reduce ground-level noise at the southeast corner of the condominiums by 8 dBA with an 8 foot wall or 11 dBA with a 16 foot wall (Exhibit 8-4). At the southwest corner of the building, traffic noise levels would be much lower, at 61 dBA without a wall. At this location the evaluated walls would only further reduce the noise level by 2 dBA. While there are windows along the south wall of the condominium building, outdoor use areas are on the west side of the building and shielded from SR 99; therefore, they would experience noise levels more similar to the southwest corner of the building.

Exhibit 8-4. Evaluation of Noise Wall at Tunnel Transition for the Tunnel Alternative

Modeled Receptor Location	Wall Height	Traffic Noise Leq (h) (dBA)	Traffic Noise Reduction (dBA)
C9 Southeast corner of Waterfront Landing Condominium Complex	No wall	74	0
	8 feet	66	8
	16 feet	63	11
Southwest corner of Waterfront Landing Condominium Complex	No wall	61	0
	8 feet	59	2
	16 feet	59	2

Under the Surface Alternative, all traffic noise originates from local surface arterials with closely spaced at-grade connections. It is not feasible to mitigate traffic noise impacts under this alternative.

Mitigation of Traffic Noise in Belltown and the North Waterfront

Traffic noise impacts in Belltown and the North Waterfront occur as a result of high traffic volumes on the urban arterial grid. Traffic speeds are already low, and transit ridership is high. Future traffic levels are not predicted to change substantially in this area as a result of any of the proposed alternatives. Mitigation of traffic noise levels is not feasible in this area because the majority of the traffic noise is generated by arterial traffic on the city street grid.

Mitigation of Traffic Noise North of the Battery Street Tunnel

North of the Battery Street Tunnel, several arterials intersect Aurora Avenue (SR 99) at-grade in right-turn-only intersections. Several buildings with both noise-sensitive and commercial uses also directly face onto Aurora Avenue.

8.1.4 Mitigation of Ventilation Noise

Several methods may be used to control ventilation fan noise and meet design goals. These methods may include:

- Sound attenuators at the fan outlets,
- Sound attenuators at the fan inlets,
- Plenums and shafts treated with a sound absorptive materials,
- Treatment of the underside of the tunnel ceiling with sound absorptive materials for a minimum of 100 feet each side of jet fan outlets, and
- Sound absorptive treatment of tunnel walls and ceiling near tunnel openings.

8.2 Construction Noise

Construction of any of the Build Alternatives would require substantial nighttime construction activities; therefore, a nighttime noise variance would be required from the City of Seattle. Because of the magnitude of the project, a technical noise variance would most likely be required as described in Chapter 6, Construction Impacts. Construction noise mitigation requirements would be developed in coordination with the City 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, contractor specifications, and variance requirements:

- Develop a construction noise management and monitoring plan that establishes specific noise levels that may not be exceeded by the contractor for various activities during specific time periods. This would establish a set of noise limits that could be met by the contractor while still protecting the public from excessive noise impacts.
- Crushing and recycling of concrete off-site, away from noise sensitive uses, would decrease construction noise impacts. If recycled on-site, an operations plan would be required to define the locations and hours of operations.

- Construct temporary noise barriers or curtains around stationary equipment and long-term work areas that must be located close to residences would 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 would reduce construction noise levels during sensitive nighttime hours. A noise variance would be required from the City of Seattle for construction between 10 p.m. and 7 a.m. on weekdays and between 10 p.m. and 9 a.m. on weekends.
- Equip construction equipment engines with adequate mufflers, intake silencers, and engine enclosures; this could reduce their noise by 5 to 10 dBA (USEPA 1971).
- Use the quietest equipment available; this could reduce noise by 5 to 10 dBA.
- Require contractors to use OSHA-approved ambient sound-level sensing backup alarms; this could reduce disturbances to nearby residents from backup alarms during quieter periods.
- Turn off construction equipment during prolonged periods of non-use; this could eliminate noise from construction equipment during those periods.
- Require contractors to maintain all equipment and train their 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 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 occurs.

8.3 Construction Vibration

Impact pile driving would be the most significant source of vibration for this project. Potential measures to reduce vibration from impact pile driving that can be used by the Contractor, when appropriate for specific site conditions, are:

- Jetting – The use of a mixture of air and water pumper 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 – Eliminates impact driving and limits vibration to the lower levels generated by drilling.
- Pile cushioning – A resilient material placed between the driving hammer and the pile.
- Alternative nonimpact drivers – Several types of proprietary pile-driving systems have been designed specifically to reduce the impact-induced vibration by using torque and down-pressure or hydraulic static loading. These methods would be expected to significantly reduce adverse vibration effects from pile placement.

Vibration from other construction activities can be reduced by either restricting their operation to pre-determined distances from historic structures or other sensitive receivers, 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.

The Contractor would be required to monitor vibration at the nearest historic structure or sensitive receiver to the 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 non-historic buildings.

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Chapter 9 REFERENCES

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ATTACHMENT A

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