APPENDIX D

NOISE AND VIBRATION DISCIPLINE REPORT

First Hill Streetcar
Noise and Vibration Discipline Report

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1 Introduction

This report describes the noise and vibration impact analyses conducted by ENVIRON International Corporation (ENVIRON) in support of the environmental studies for the First Hill Streetcar Project. The project would introduce a new streetcar line and maintenance facility to portions of south downtown Seattle, First Hill, and Capitol Hill.

2 Noise and Vibration Terminology

2.1 Noise

The human ear responds to a very wide range of sound intensities. The decibel scale (dB) used to describe sound is a logarithmic rating system that accounts for the large differences in audible sound intensities. This scale accounts for the human perception of a doubling of loudness as an increase of 10 dB. Therefore, a 70-dB sound level will sound about twice as loud as a 60-dB sound level. People generally cannot detect differences of 1 dB; in ideal laboratory situations, people can detect differences of 2 or 3 dB, but such a change probably would not be detectable in an average outdoor environment. A 5-dB change is likely to be perceived under normal listening conditions.

When addressing the effects of noise on people, it is useful to consider the "frequency response" of the human ear, or those frequencies that people hear most effectively. Sound measurement instruments are therefore often programmed to consider or "weight" the data based on the frequencies of the sound. The frequency weighting system used is A-weighting because it approximates the frequency response of human hearing and is highly correlated to the potential effects of noise on people. Measurements from instruments using this system are reported in "A-weighted decibels" or dBA. All sound levels in this evaluation are reported in A-weighted decibels.

Distance from the source, the frequency of the sound, the absorbency of the intervening ground, obstructions, and duration of the noise-producing event all affect the transmission and perception of noise. The degree of this effect also depends on who is listening and on existing ambient or background sound levels.

2.2 Vibration

Vibration is an oscillatory motion that can be measured and characterized by the frequency and amplitude of waves of motion. Ground-borne vibration (GBV) consists of oscillatory waves that propagate from a source through the ground to adjacent buildings. Vibration amplitude (i.e., the size of the wave of motion) can be measured as displacement, velocity, or acceleration. Displacement is a measure of the distance a point moves away from its resting position. Velocity represents the instantaneous speed and direction of the movement, and acceleration is the rate of change of the velocity. Although displacement is easier to understand than velocity or acceleration, this measure is rarely used for describing ground-borne vibration.

While it is conceivable that ground-borne vibration from rail rapid transit vehicles could cause building damage, the vibration from train movements is almost never of sufficient amplitude to cause even minor cosmetic damage to buildings. The real concern is that the vibration and radiated noise can be intrusive and annoying to building occupants. Any such building vibration caused by ground-borne vibration (GBV) could be perceived as either (1) motion of building surfaces such as rattling of windows, items on shelves or pictures hanging on walls, or (2) as a low-frequency rumbling noise, which is referred to as ground-borne noise.

3 Regulatory Overview

The streetcar line and maintenance facility would be located in the City of Seattle. In addition, the city requested review in accordance with criteria applied by the Federal Transit Administration (FTA) to inform the SEPA process. Therefore, applicable noise review criteria include noise limits established by the City of Seattle and the FTA noise and vibration impact criteria.

3.1 Seattle Municipal Code

The project site is within the City of Seattle, Washington. Therefore, the noise limits included in the Seattle noise ordinance (Seattle Municipal Code Chapter 25.08) are applicable to the construction and operation of the proposed facility. This ordinance sets levels and durations of allowable daytime/nighttime operational noise (upper portion of **Table 1**) and daytime construction noise (lower portion of **Table 1**). These limits are based on the zoning of the source and receiving properties.

The Seattle noise limits are based on the hourly equivalent sound level (L_{eq}) and a short-term maximum sound level (L_{max}) attributable to a sound source. The L_{eq} is a noise metric representing a *constant* sound level containing the same sound energy as the actual *fluctuating* sound over the same time period. As such, the L_{eq} can be considered an energy-average sound level. All the sound level limits displayed in **Table 1** are expressed in terms of an hourly L_{eq} except as specifically noted. There are also corresponding L_{max} limits that allow short-term peak noise levels up to 15 dBA higher than the L_{eq} levels displayed in **Table 1**.

The Seattle noise code exempts noise from traffic on public roadways from the noise limits. Thus, the Seattle operational noise limits would not apply to sound levels produced by operation of the streetcar by virtue of it being located in public streets. However, the Seattle noise limits will apply to sounds produced during construction of the various facility components and to noise from the streetcar maintenance facility.

Table 1. Seattle Exterior Sound Level and Construction Noise Limits (dBA)

Zoning District of Noise Source [25.08.410 & 420 & 425]	Zoning District of Receiving Property		
	Residential Day / Night [a]	Commercial	Industrial
Operational Noise Limits			
Residential	55 / 45	57	60
Commercial	57 / 47	60	65
Industrial	60 / 50	65	70
Daytime Construction Noise Limits [b]			
On-site sources like dozers, loaders, power shovels, cranes, derricks, graders, off-highway trucks, ditchers, and pneumatic equip (maximum+25) [25.08.425 A.1]			
Residential	80	82	85
Commercial	82	85	90
Industrial	85	90	95
Portable equip used in temporary locations in support of construction like chain saws, log chippers, and powered hand tools (maximum+20) [25.08.425 A.2]			
Residential	75	77	80
Commercial	77	80	85
Industrial	80	85	90
Impact types of equipment like pavement breakers, pile drivers, jackhammers, sand-blasting tools, or other impulse noise sources - may exceed maximum permissible limits between 8 a.m. and 5 p.m. weekdays and 9 a.m. and 5 p.m. weekends, but may not exceed the following limits [25.08.425 B]: L_{eq} (1 hr) 90 dBA; L_{eq} (30 minutes) 93 dBA; L_{eq} (15 minutes) 96 dBA; L_{eq} (7.5 minutes) 99 dBA			

[a] The operational noise limits for residential receivers are reduced by 10 dBA during nighttime hours (i.e., 10 p.m. to 7 a.m. weekdays, 10 p.m. to 9 a.m. weekends) and are displayed for daytime/nighttime hours.

[b] Construction noise limits apply at 50' or a real property line, whichever is greater. Construction noise is limited to the higher levels listed in the lower portion of the table during "daytime" hours only. For purposes of limiting construction noise received in certain zones, daytime hours are defined as 7 a.m. to 7 p.m. weekdays and 9 a.m. to 7 p.m. weekends for noise received in Lowrise, Midrise, Highrise, Residential-Commercial, or Neighborhood-Commercial zones. For construction projects in all other zones, and for public projects or locations where there are no residential uses within 100 feet, daytime construction hours are defined as 7 a.m. to 10 p.m. weekdays and 9 a.m. to 10 p.m. weekends.

Source: Seattle Municipal Code - 25.08

3.2 Federal Transit Administration (FTA) Noise Impact Criteria

The FTA describes its noise impact criteria in the manual entitled *Transit Noise and Vibration Impact Assessment* (FTA 2006). These criteria apply to rail projects, fixed facilities such as transit stations, maintenance facilities, and park and ride lots; buses in bus-only highway lanes; ferry terminals; and motor vehicles in route to and from transit facilities.

FTA noise impact criteria are based on the land use category of the receiving properties (**Table 2**). Criteria for lands with uses confined primarily to daytime activities (e.g., schools, churches, offices, etc.) are based on the hourly equivalent sound level (L_{eq}) of the noisiest hour of transit-related activity, especially during periods of increased sensitivity to noise. In contrast, FTA criteria apply the day-night sound level, or L_{dn}, at residences and other locations used for habitation/sleep (e.g., hospitals and hotels) because of the potential for sleep disturbance. The L_{dn} is like a 24-hour L_{eq}, except that the metric includes an additional 10 dBA added to sound levels in each hour between 10 p.m. and 7 a.m. to account for increased sensitivity to noise during times when people are typically trying to sleep.

Table 2. Land Use Categories and Metrics for Transit Noise Impact Criteria

Land Use Category	Noise Metric (dBA)	Description of Land Use Category
1	Outdoor $L_{eq(1)}$ [a]	Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use.
2	Outdoor L_{dn}	Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels, where a nighttime sensitivity to noise is assumed to be of utmost importance.
3	Outdoor $L_{eq(1)}$ [a]	Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches, where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material. Buildings with interior spaces where quiet is important, such as medical offices, conference rooms, recording studios, and concert halls fall into this category, as do places for meditation or study associated with cemeteries, monuments, and museums. Certain historical sites, parks, and recreational facilities are also included.

[a] Equivalent sound level of the noisiest hour of transit-related activity during period of noise sensitivity.

Source: FTA *Transit Noise and Vibration Impact Assessment*, May 2006. FTA-VA-90-1003-06.

The FTA noise impact criteria apply a sliding scale of impact levels for project-related noise based on the existing sound levels and the amount of noise a project would contribute (**Figure 1**). Based on these criteria, receiving locations with low existing sound levels can be exposed to greater increases in overall noise, after the addition of project noise, before an impact occurs. Conversely, locations with higher existing sound levels can be exposed to smaller increases in overall noise before an impact occurs. The FTA impact criteria are to be used only when considering exterior use locations such as patios, decks, pools, and play areas. When there are no exterior uses near a sensitive receiver, the impact criteria are applied near building doors and windows. FTA guidance assumes a typical building will provide an outdoor-to-indoor noise reduction of about 25 dBA, which

may result in interior sound levels that do not warrant additional noise mitigation even if impacts are predicted at the exterior of the building (FTA 2006).

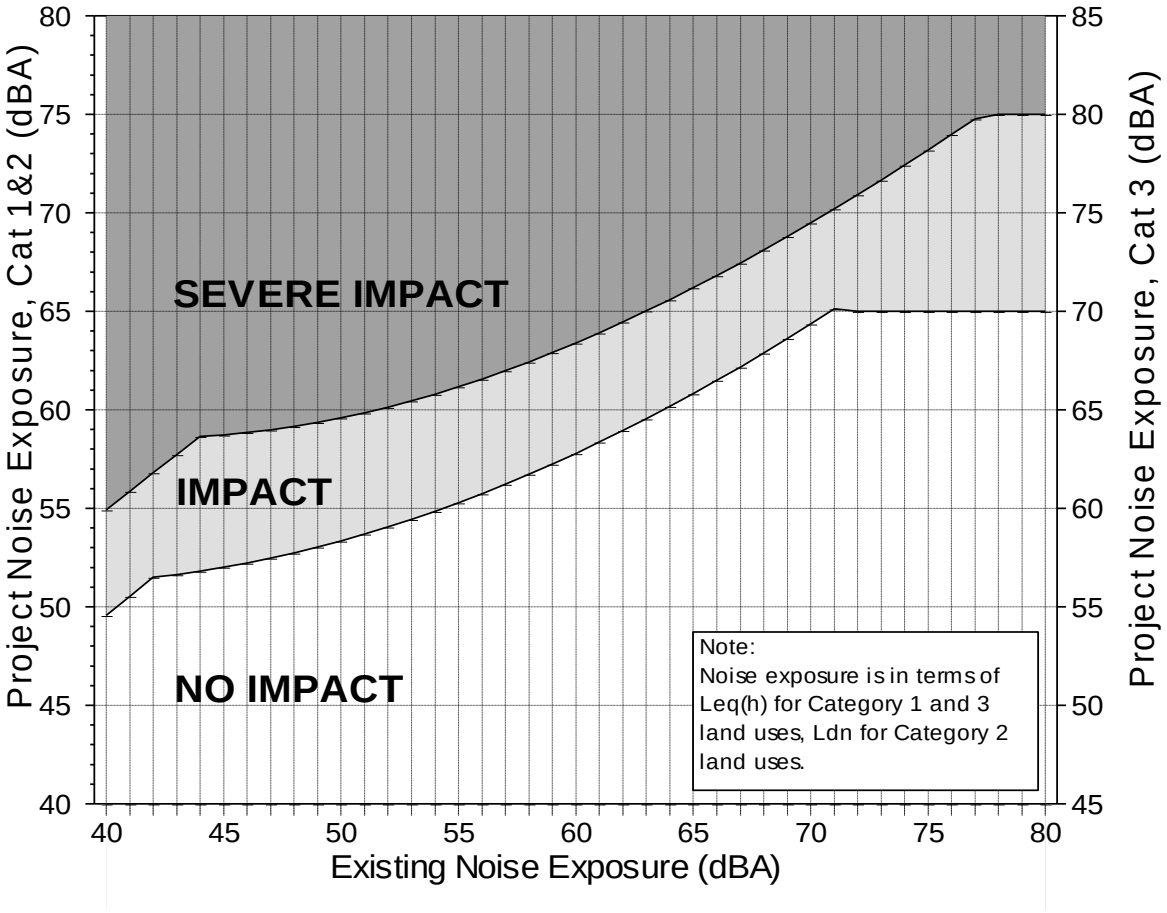


Figure 1. FTA Noise Impact Criteria

3.3 FTA Vibration Impact Criteria

The FTA characterizes the potential for impacts from ground-borne vibration (GBV) and ground-borne noise based on three categories of land uses with varying sensitivity to interference or annoyance from vibration. FTA further delineates the potential for such impacts based on how often GBV or ground-borne noise events would be expected to occur. The FTA impact criteria for GBV are summarized in **Table 3**. FTA methodology for assessing potential impacts from vibration from transit facility operations considers vibration amplitude in terms of vibration decibel levels (VdB).These criteria are considered in relation to potentially sensitive receiving locations within the FTA impact screening distances.

Note that the FTA vibration impact criteria do not use a scale that includes "moderate" and "severe" impacts as are applied to noise. Instead, the criteria are used to determine the presence or absence

of vibration-related impacts, and any such identified impacts are intended to be considered for possible mitigation.

Table 3. FTA Ground-Borne Vibration Impact Criteria

Land Use Category	Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec) [a]		
	Frequent Events [b]	Occasional Events [c]	Infrequent Events [d]
Category 1 [e] Buildings where vibration would interfere with sensitive interior operations (e.g., sensitive equipment)	65 VdB [f]	65 VdB [f]	65 VdB [f]
Category 2 Residences and buildings where people normally sleep	72 VdB	75 VdB	80 VdB
Category 3 Institutional land uses with primarily daytime use (e.g., quiet offices)	75 VdB	78 VdB	83 VdB

[a] VdB means vibration decibel levels

[b] "Frequent Events" are more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category, and the First Hill Streetcar project is in this category.

[c] "Occasional Events" are between 30 and 70 vibration events of the same source per day. Most commuter rail trunk lines are in this category.

[d] "Infrequent Events" are fewer than 30 vibration events of the same kind per day. Most commuter rail branch lines are in this category.

[e] Although not specifically identified as "Category 1" uses, concert halls, TV studios, and recording studios have the same ground-borne vibration and ground-borne noise level criteria as Category 1 uses.

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

Source: FTA 2006

3.3.1 Vibration Damage Criteria Applied to Construction

In contrast with the FTA vibration impact criteria for transit facility operations that are based on the potential for GBV to annoy people or to interfere with the operation of sensitive equipment, FTA vibration impact criteria for construction are based on the potential for the vibration to result in physical damage to buildings. In this instance, the criteria consider potential vibration levels from a variety of construction equipment (**Table 4**) in conjunction with classes of buildings and their potential to be adversely affected by GBV (**Table 5**). The combination of these factors is considered in the construction vibration impact assessment later in this report.

Table 4. Vibration Source Levels for Construction Equipment

Equipment		PPV at 25 ft (in/sec) [a]
Pile Driver (Impact)	Upper Range	1.515
	Typical	0.644
Pile Driver (Sonic)	Upper Range	0.734
	Typical	0.170
Vibratory Roller		0.210
Hoe Ram		0.089
Large Bulldozer		0.089
Caisson drilling		0.089
Loaded trucks		0.076
Jackhammer		0.035
Small bulldozer		0.003

[a] PPV means peak particle velocity

Source: FTA 2006

Table 5. FTA Construction Vibration Damage Criteria

Building Category and Description	PPV (in/sec)	Approximate Level (VdB) [a]
I. Reinforced-concrete, steel, or timber (no plaster)	0.5	102
II. Engineered concrete and masonry (no plaster)	0.3	98
III. Non-engineered timber and masonry buildings	0.2	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

[a] Note that the levels of all criteria related to potential damage to buildings are much higher than even the highest level of FTA vibration impact criteria associated with potential adverse effects on people (**Table 3**).

Source: FTA 2006

4 Affected Environment

This section describes the general project setting and existing noise sources in the project vicinity. Area-specific estimates of existing sound levels are discussed in the impacts section of this memo.

4.1 Existing Land Uses and Zoning

Because the Seattle noise limits are based on the zoning of the noise source and the receiving properties, and because the FTA noise standards are based on the land use of the receiving property, it is important to identify both the zoning and land uses of the noise source properties and the potentially affected receiving properties.

The entirety of the project setting is a heavily developed urban environment with numerous existing sound sources that contribute to a typical urban soundscape. Major noise sources include two major freeways, numerous major surface streets, plane and helicopter over flights, and a variety of commercial and residential neighborhood uses. Property uses adjacent to the proposed streetcar rail line are varied. Downtown, west of I-5, the uses are primarily commercial/retail but include residences and hotels. None of the downtown properties have exterior use areas facing the proposed streetcar line. East of I-5 existing uses include commercial/retail, residences, schools, churches, and medical clinics/hospitals. Most of these properties do not have exterior use areas facing the streetcar line; notable exceptions include residences in Yesler Terrace and a few additional single-family residences and apartments along the proposed project alignment.

As mentioned previously, because the streetcar line would operate on public roadways its operational noise would not be subject to Seattle noise limits. Therefore, the zoning identification used to apply the Seattle noise limits is discussed here only with reference to the potential maintenance facilities.

Two alternative sites for the streetcar maintenance facility sites are being considered. The Charles Street site is between Charles and Dearborn Streets and between 7th and 8th Avenues. This property is zoned C2, a commercial zone according to the Seattle zoning code. This area is currently adjacent to an SDOT maintenance yard. The surrounding properties are zoned either IG2 (an industrial district) or C2. No noise sensitive receivers have been identified in the vicinity of this site, so construction or operation of the maintenance facility at this site would result in no noise impacts. Consequently, this site was not considered further in the noise impact assessment.

An alternative maintenance facility site, the Boren site, is located between Yesler Way and East Fir Street and between Boren and 12th Avenues. This property includes portions with three zoning designations, MR, NC3P, and NC3. MR is a residential district while NC3 and NC3P are commercial districts. The sensitive receivers nearest the Boren site are single family and apartment residences along the north side of East Fir Street (zoned MR), and residences in Yesler Terrace

west of Boren Avenue on property zoned L3 (residential district). The assessment of maintenance facility noise on the Boren site focused on these residential-use properties.

5 Impact Assessment

5.1 Operational Noise

Operational noise from the streetcar line is being reviewed under FTA impact criteria to inform the SEPA process using objective measures typically applied to transit sources. ENVIRON completed this review based on a screening level survey of uses and possible sensitive receivers along the project alignment along with estimates of existing sound levels in the project study area.

Normal operation of a streetcar typically results in low levels of noise from sources including steel wheels rolling on steel rails, the minor "whoosh" of passbys as the vehicle displaces air, and occasional brake noise. The vehicles proposed for use in Seattle are electrically powered, so there is no diesel engine noise. Streetcars are equipped with warning bells and a horn for use at the operator's discretion to indicate to other drivers or pedestrians that the streetcar is approaching. The horn is used infrequently, typically to alert another vehicle's driver who is making an illegal movement that could cause an accident. Bells are used primarily to signal pedestrians at streetcar platforms of streetcar arrival or departure. Each streetcar will be equipped with a two-volume setting warning bell; the lower volume bell setting would be used where ambient noise levels are lower.

5.1.1 FTA Noise Impact Assessment

The review of the facility noise included an initial screening review to assess the presence of sensitive receivers that could be affected by streetcar noise followed by a general impact review using FTA methods. Both aspects of the noise review are described below along with other issues pertaining to potential noise associated with operation of the streetcar.

Facility Operation Noise Receptor Screening Review

The FTA *Transit Noise and Vibration Impact Assessment* guideline includes a screening procedure to identify locations where there is little possibility of noise impacts based on defined screening distances for a variety of transit sources. The screening review process applies the principle that if there are no sensitive receivers within the specified screening distance, then no noise impacts would be expected and no further assessment is necessary. The screening distance identified in the FTA manual for "low or intermediate capacity transit with steel wheels" for receivers with an unobstructed sound path to the transit facility is 125 feet. During the screening survey of the proposed streetcar line ENVIRON identified approximately 35 sensitive-use buildings (e.g., residences, hotels, hospitals) within the screening distance, ranging from 25 to 120 feet from the nearest line. ENVIRON therefore conducted a general noise impact assessment for these receivers to more specifically consider potential impacts from operation of the streetcar line.

In addition, several residences were identified in the vicinity of the alternative maintenance facility site between Boren and 12th Avenues, and potential noise impacts were considered in more detail for these residences. **Figure** 2 depicts the project alignment and the potentially noise-sensitive receivers identified and considered in the noise impact assessment. Note that this figure includes some sensitive-use buildings beyond the screening distance as well as some that would be displaced by the Boren Street maintenance facility alternative.

Streetcar Operation General Noise Impact Review

Because numerous sensitive receivers were identified within the 125-foot FTA screening distance of the proposed streetcar line, ENVIRON conducted a general noise assessment consistent in FTA policy (FTA 2006).

The first step of a general noise assessment is to identify the existing sound levels at potentially affected properties. In addition to one ambient sound level measurement, ENVIRON used several published documents and recent or ongoing noise studies to estimate sound levels at locations adjacent to the rail line. For the most part, except for central interior areas in the Yesler Terrace development that are well isolated from the nearest roads, sound levels in the project vicinity tend to be 65 dBA L_{dn} or higher. Estimated and measured existing sound levels in the project vicinity are summarized in **Table 6**.

Using these estimated and measured existing sound levels and project specific streetcar operational data (i.e., frequency of streetcar passbys and speeds of weekday periods), ENVIRON estimated a secondary "screening" distance beyond which no noise impacts would be expected to occur due to streetcar operation. This process is described following the table.

The streetcar is expected to have 10-minute headways during the peak hours (i.e., 6 trains/hour) and 15-minute headways during off-peak hours (i.e., 4 trains/hour). ENVIRON assumed peak-hour operations would occur between 6 and 9 a.m. and again between 4 and 7 p.m. Off-peak hours would include all other hours from 5 a.m. to 1 a.m. This schedule results in a total of 70 streetcar trips in each direction during daytime hours (7 a.m. to 10 p.m.) and 22 trips in each direction at night (10 p.m. to 7 a.m.).

As a conservative method of estimating operational noise ENVIRON assumed a travel speed of 30 mph would occur along the entire First Hill streetcar alignment. This assumed speed is 5 mph faster than the expected *maximum* travel speed of 25 mph, and much faster than typical operational speed along many portions of the line. So this is a conservative assumption that overstates actual noise likely to be associated with the streetcar. Based on this assumption ENVIRON used the FTA spreadsheet calculation tool to determine the distance at which the streetcar sound levels would be 60 dBA or less, thus avoiding a noise impact under FTA policy. **(1)**

(1) ENVIRON also measured operational noise near a single track section of the South Lake Union (SLU) streetcar to assess whether noise from this operational streetcar complies with the noise limits in the equipment specifications that apply to both the SLU and the First Hill streetcars. These measurements, which are summarized in **Appendix A** and discussed in relation to the applicable noise specification, suggest the SLU streetcar is operating within the equipment noise specification.

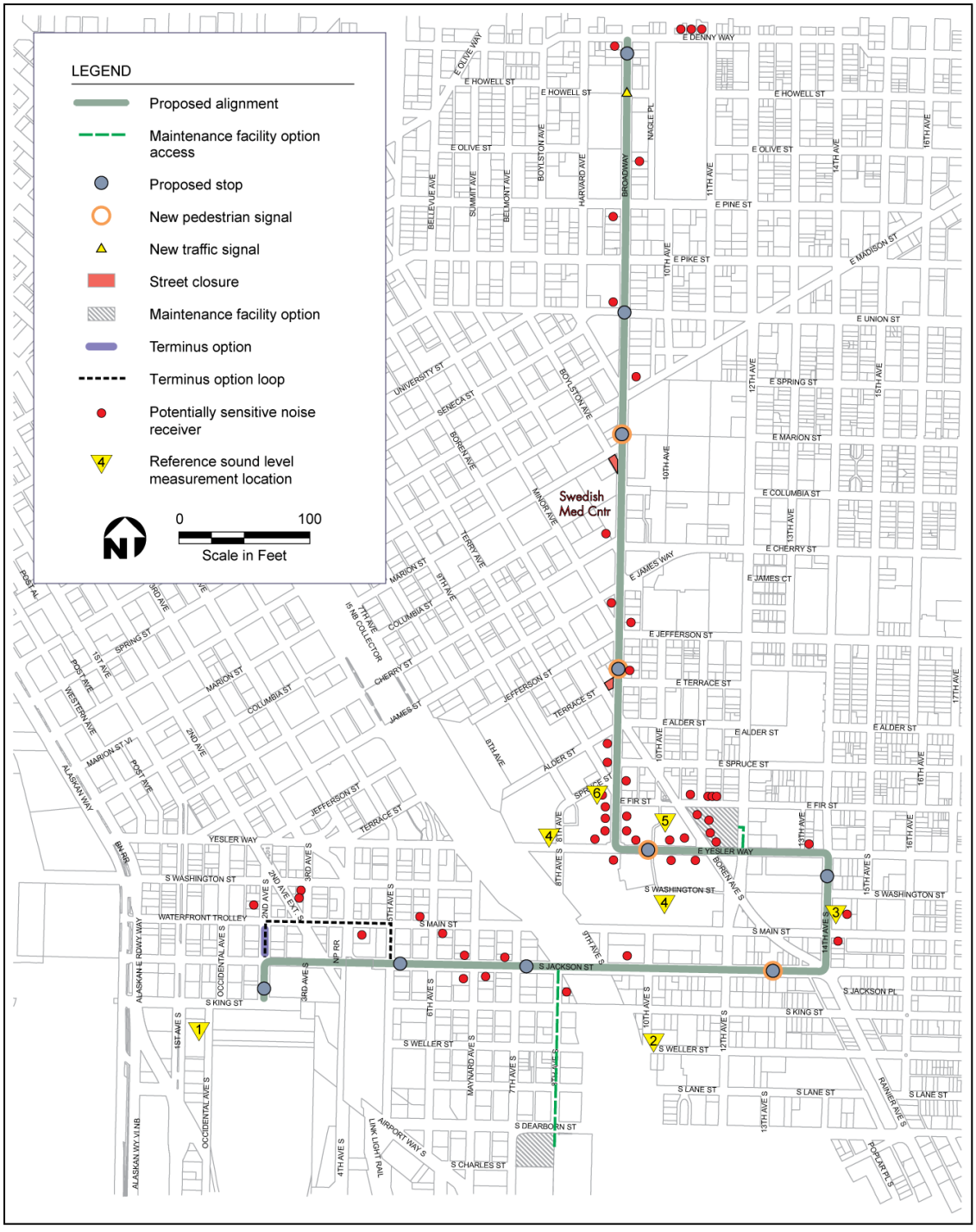


Figure 2. Proposed Project Alignment, Identified Potentially Noise-Sensitive Receivers, and Reference Sound Level Measurement Locations

Estimates of streetcar operational noise based on the conservative assumption that the travel speed at all locations would be 30 mph indicate streetcar noise would not exceed 59 dBA L_{dn} except at locations where the nearer of the two streetcar tracks would be within 20 feet and the farther track would be within 30 feet. Beyond these distances, streetcar noise would be lower and would not rise to the level of comprising even a moderate noise impact under FTA policy. Because there are no sensitive receivers within these distances of the proposed streetcar line, no noise impacts are anticipated from operation of the streetcar.

Table 6. Estimated and Measured Existing Sound Levels (L_{dn}, dBA)

Area	Estimated L_{dn}	Moderate Impact Level [a]	Severe Impact Level [a]	Source of Sound Measurements that were basis of Estimated Existing Sound Levels [b]
(1) Downtown, west of I-5	67	63	68	North Lot Development Addendum to South Downtown Planning Study FEIS, 2009
(2) Adjacent to S Jackson St, east of I-5	77	66	75	Livable South Downtown FEIS, 2008
(3) Adjacent to 14th Avenue S [c]	67	63	68	ENVIRON SLM 2010
(4) Yesler Way, distant from Boren Ave	65	61	67	Seattle Housing Authority, Yesler Terrace Redevelopment Project, Draft EIS not yet published (ENVIRON SLMs)
(5) Yesler Way, adjacent to Boren Ave	73	66	72	
(6) Adjacent to Broadway	65	61	67	

[a] Level of a project-related day-night sound level that would, based on the existing sound level, be considered a moderate or severe impact as defined in FTA *Transit Noise and Vibration Impact Assessment*, 2006.

[b] With one exception, ENVIRON estimated existing sound levels along the project alignment based on day-night sound level measurements taken in other studies, as indicated. The locations of these reference sound level measurements (i.e., *not* the specific locations listed above) are shown in **Figure** 2 (page 11), labeled with the same numbers shown above. These sound level measurement data provide representative information on which to base the noise impact assessment against FTA policy.

[c] A sound level measurement at the Wisteria View Manor on 14th Avenue S documented existing sound levels over a 24-hour period. The measured day-night sound level (L_{dn}) was 67.2 dBA. This measurement representing sound levels in the area that includes the Bailey Gatzert Elementary School is reported more completely in **Appendix B**.

Source: Compiled by ENVIRON International Corporation

Operational Wheel Squeal

While streetcars are generally less susceptible to wheel squeal than longer-wheelbase train cars, wheel squeal can occur where turn radii are less than 1,000 feet. Wheel squeal can be irritating to people nearby because it includes high-frequency noise, and squeal can generate L_{max} noise levels up to about 100 dBA 50 feet from the tracks. Such squeal can be reduced by traveling at slow speeds around tight turns – as is proposed with this project, and eliminated by increasing curve radius, or reduced with several measures discussed under mitigation. With incorporation of appropriate mitigation measures, substantial wheel squeal is not anticipated from the streetcar.

To confirm this supposition ENVIRON measured sound levels near the operating South Lake Union (SLU) streetcar line at a 90° turn in the northbound rail at the intersection of Terry Avenue N and Thomas Street. Observations and data collected during six streetcar passbys found no wheel squeal and documented operational sound levels similar to or less than other vehicles in the area. For example, noise 25 feet from the passing streetcar was about the same as noise from a bus passing one block (about 270') away, and much less than noise from a passing semi-truck about 30 feet away. These measurements are summarized in **Appendix C**. Note that these measurements do *not* provide definitive sound levels representing normal streetcar operation due to the presence of high background levels from nearby construction activities during all of the observed and measured streetcar passbys; streetcar noise levels may be somewhat lower than suggested by these data.

The First Hill streetcar line would include four 90° turns, with two additional turns possible as part of the terminus option loop, and one additional turn to allow access to one of the two alternative maintenance facility sites. As shown in **Figure** 2 (page 11), the primary turns would occur at the following locations: the South Jackson Street intersections with 2nd Avenue South and Boren-Rainier-14th Avenue, and the East Yesler Way intersections with 14th Avenue South and Broadway. These turns would occur entirely within the existing roadway rights-of-way, and there are no residential receivers within 50 feet of any of these locations.

The average measured L_{eq} sound level 25 feet from a right-angle turn on the SLU line was 66.5 dBA for six passby events lasting 112 seconds. This equates to an hourly L_{eq} of 51 dBA, which is 10 dBA less than the FTA impact level for the quietest locations along the proposed project alignment. Therefore in the absence of substantial wheel squeal through such turns, the First Hill streetcar would not result in any noise impacts as defined under FTA policy.

Operational Track Switch Noise

Streetcar track junctions and switches require rails to intersect such that wheels can move from one track system to another. These sorts of connections can create relatively uneven rail surfaces where the tracks meet that cause wheels to "thump" as they traverse these surfaces. Such thumps are very short term (i.e., <1 second), but may be loud in comparison with normal streetcar passby noise. ENVIRON measured sound levels near one switch location on the SLU streetcar line to document wheel thumping noise at a track junction. The collected sound data are summarized in **Appendix D**.

Sound measurements of wheel thump noise documented an average L_{max} sound level of about 71 dBA and a maximum L_{max} of about 76 dBA 50 feet from (perpendicular to) the rail junction. As shown in **Appendix D**, this sound level is less than common vehicle-related sound levels like medium truck and motorcycle passbys. Given this sort of sound level and the fact that there are no residential uses near any of the planned or potential switch locations along the proposed First Hill streetcar alignment, noise from switching locations would be unlikely to result in significant noise impacts. See **Appendix E** for additional information regarding potential rail switch locations.

Maintenance Facility Noise Impact Assessment

As discussed previously, two alternative maintenance facility sites designated as the Charles Street site and the Boren site are being considered as part of the streetcar line expansion. Please refer to Figure 2 in the *Proposed Project in the First Hill Streetcar SEPA Checklist* for additional information regarding the locations of the two maintenance facility sites. Because there are no sensitive receivers near the Charles Street site, the noise analysis considered potential noise impacts only for the Boren maintenance facility site.

ENVIRON considered the maintenance facility at the Boren alternative site as a maximum 8-car facility with entry from 12th Avenue (a site layout formerly designated as "K"). This maintenance facility would have the potential to result in noise impacts at the nearest sensitive receivers, including residences north of East Fir Street and residence in Yesler Terrace west of Boren Avenue. The estimated existing sound level at the residences on East Fir Street is 65 dBA L_{dn} (**Table 6**). At these residences, FTA noise impact criteria indicate a noise impact would occur with a project-related noise level of 61 dBA L_{dn} or more. Severe impacts would be expected with project noise levels of 67-dBA L_{dn} or more. For residences adjacent to Boren Avenue the existing sound level is 73 dBA Ldn, for which FTA defines a moderate noise impact as being a project-related noise level of 66 dBA L_{dn} or more and a severe noise impact as a level of 72 dBA or more.

Much of the maintenance activity would likely involve relatively little noise. Some of the louder activities, however, would include the use of pneumatic tools and banging on metal, which could result in temporary increases in noise. Streetcar movements into and out of the facility would have minimal effect on the overall sound levels because of very slow travel speeds and limited arrivals and departures across the day. The maintenance facility noise impact analysis therefore focused on the loudest maintenance activities having the greatest potential to result in noise impacts.

For this assessment ENVIRON applied measured sound levels of pneumatic tools and banging on metal taken from previous noise analyses and calculated cumulative noise levels based on the assumptions described in later text. Pneumatic tool (i.e., an air wrench) noise included a measured sound level of about 74 dBA at 100 feet from an open maintenance bay door. Banging on metal was approximately 76 dBA at 100 feet with direct line of site to the activity. At an oblique angle to an open doorway, the sound levels of such activities would be reduced by approximately 16 dBA to 58 to 60 dBA at 100 feet for the pneumatic tool and metal banging, respectively, due to the partial obstruction of the sound path by the building wall. Without openings (i.e., if all such activities are conducted with all doors and windows closed), a typical wall would reduce the noise by at least 25 dBA, resulting in levels of 49 to 51 dBA at 100 feet for the pneumatic tool and metal banging, respectively. Note that these are all short-term sound levels that do not consider the duration of the noise-making events. Time-weighted levels are discussed below.

There are five single and multi-family residential use buildings that would be within about 200 feet of the maintenance facility at the Boren location alternative site (see **Figure 3** containing identifying numeric labels corresponding to the highlighted numbers shown in the following text). The westernmost single-family residence on East Fir Street north of the facility [1] would have a wall providing at least 25 dBA of noise reduction from interior maintenance activities. The remaining

easternmost two single-family residences [2 & 3] could be subjected to noise from interior activities occurring at an oblique angle (i.e., with a 16-dBA reduction). These residences would all be approximately 100 feet or farther from the nearest activities. For the westernmost residence of these three [1], with a solid intervening wall, the calculated sound level of all activities is 53 dBA. Assuming activities including pneumatic tools and/or metal banging occur 25% of the time, 24 hours a day (a conservative estimate), the resulting calculated day-night sound level (L_{dn}) is 54 dBA. Because project-related noise is estimated to be less than 61 dBA, no noise impacts would be expected at this residence. Using similar assumptions for the other two residences at an oblique angle to maintenance facility activities [2 & 3], the calculated L_{dn} is 63 dBA, resulting in potential moderate noise impacts.

Figure 3. Boren Alternative Site for Maintenance Facility – and Nearby Residential Uses (marked receivers described in text)

The next nearest residences to the Boren site maintenance facility are in the apartment building on the northeast corner of East Fir Street and Boren Avenue [4] and the residences in Yesler Terrace on the west side of Boren Avenue [5], approximately 120 and 190 feet or more from the nearest maintenance activities, respectively. The existing sound level at these residences is 73 dBA L_{dn}, indicating that no impact would occur with project-related levels of 65 dBA L_{dn} or less. There would

be a solid wall between maintenance activities inside the building and these residences. Using the same approach as described above, the estimated L_{dn} levels are 52 and 48 dBA at the apartments and Yesler Terrace residences, respectively. Thus, no noise impacts would be expected at these residences due to the maintenance facility.

5.1.2 Seattle Noise Limits Compliance Assessment

In addition to assessing potential noise impacts from the streetcar operation and maintenance facility activities as impacts are defined by FTA, compliance with the Seattle noise limits also needs to be considered. Noise from operation of the streetcar in public roadways is exempt from the noise limits. However, noise from the maintenance facility must be compared to the Seattle noise limits to assess the potential for compliance. As with the previous discussion of maintenance facility noise impacts, ENVIRON focused the noise compliance assessment on the Boren site.

The Seattle noise limits are based on the zoning of both the noise source and the receiving properties. While approximately one-third of the proposed Boren site is zoned NC3P or NC3 (a commercial source), the majority of the site is zoned MR. For purposes of the compliance assessment, ENVIRON considered the facility site a residentially zoned noise source. The nearest potentially affected residences north of East Fir Street are zoned MR and the residences west of Boren Avenue are zoned L3; all are residential receiving properties. The daytime and nighttime noise limits for residential sources affecting residential receivers are 55 and 45 dBA (hourly L_{eq}), respectively.

Unlike the noise impact assessment described previously, Seattle's noise limits are based on the hourly equivalent sound level (L_{eq}), not the L_{dn}. Similar to the impact assessment, the hourly L_{eq} was calculated assuming that use of pneumatic tools and banging of metal would occur for 25% of an hour.

Residences on the west half of the Fir Street block north of the facility would have a wall providing at least 25 dBA of noise reduction from maintenance activities inside the building. Residences on the eastern half of the block would be subjected to noise from interior activities occurring at an oblique angle (i.e., with a 16-dBA reduction). The residences would be approximately 100 feet or more from the nearest activities. The calculated hourly sound level of maintenance activities at 100 feet through a solid wall or at an oblique angle are 53 and 62 dBA, respectively. These calculated levels do *not* comply with the nighttime noise limit of 45 dBA at either location, and the level at locations at an oblique angle to an open door also would not meet the 55-dBA daytime limit. Calculated sound levels at locations with an intervening solid wall comply with the Seattle daytime noise limit.

The apartments on the northeast corner of East Fir Street and Boren Avenue and the Yesler Terrace residences are both protected by an intervening wall and are approximately 120 and 190 feet or more from the nearest maintenance activities, respectively. At these locations, the calculated sound levels of 52 and 48 dBA comply with the daytime noise limit but do *not* comply with the nighttime limit.

5.2 Operational Vibration

The review of potential impacts related to vibration from operation of the proposed facility was based on a screening-level review that considered the proximity of residential uses to the streetcar rail lines. The review compared estimated maximum operational levels of vibration with the FTA 72-VdB impact criterion for residential uses (**Table 3**, page 6). To estimate levels of operational vibration ENVIRON began by assuming streetcars would travel at the actual projected maximum speed of 25 mph and calculated the level of vibration at this speed using information extracted from FTA guidance (2006, Figure 10-1 page 10-3). This calculation indicated that at a travel speed of 25 mph, residential receivers within about 26 feet of the nearest streetcar rail would have the potential to be affected by operational vibration. At lower speeds or at greater distances, vibration levels would be less, and there would be no potential for impacts under FTA criteria.

Based on the field survey of buildings along the facility alignment, there are three buildings within the 26-foot screening distance. After making this determination, ENVIRON applied segment-specific projected travel speeds (from the project speed profile) for the sections of the streetcar line in the vicinity of these three buildings within the screening distance. After the adjustment to represent the anticipated maximum travel speeds near the three buildings within the screening distance, maximum projected levels of ground-borne vibration were found to be less than the FTA specific impact level. At all other locations, screening based on the maximum travel speed (instead of the actual expected travel speed) indicated operational levels of vibration would be less than the FTA 72-VdB impact threshold. Thus, no vibration impacts would be expected due to operation of the proposed streetcar. A summary tabulation of the operational vibration screening review is shown in **Table 7**.

Because the thresholds for impacts related to perception of vibration (**Table 3**, page 6) are much lower than the damage thresholds for buildings (**Table 5**, page 7), if there are no impacts related to perception, there also would be no impacts due to potential damage to buildings. Therefore operation of the streetcar would not be expected to result in any damage to any buildings along the project alignment, including any of the identified historical buildings.

Table 7. Operational Vibration Screening Review Summary

Building Description/ Name	Distance from Line	Address (if determined)	Within 26' Screening Distance	Max Speed (mph)	Operational Vibration Level (VdB)
Downtowner Apts	33 ft	308 4th S		25	70
Commercial/Apts	40 ft	319 Maynard		25	69
Bush Hotel	32 ft	409 Maynard		25	70
Commercial/Apts	37 ft			25	69
Commercial/Apts	40 ft	670 S Jackson		25	69
Pac Rim Ctr, Comm/Apts	36 ft	900 S Jackson		25	69
Operation Nightwatch w/Res	30 ft	300 14th Ave		25	71
Ritz Residential	30 ft	1302 E Yesler Way		25	71
YWCA Housing	20 ft	1104 Yesler Way	Yes	14	68
Yesler Terrace	40 ft	1023-1033 E Yesler Way		25	69
Yesler Terrace	40 ft	1003-1019 E Yesler Way		25	69
Yesler Terrace	50 ft	1022 E Yesler Way		25	67
Yesler Terrace	30 ft	102 10th Ave		25	71
Yesler Terrace	30 ft	102 Broadway		25	71
Yesler Terrace	35 ft	105-111 Broadway		25	70
Yesler Terrace	35 ft	117-125Broadway		25	70
Yesler Terrace	40 ft	118-126 Broadway		25	69
Yesler Terrace	40 ft	133 Broadway		25	69
Yesler Terrace	45 ft	919 Spruce		25	68
Japanese Baptist Church	40 ft	160 Broadway		25	69
Apts	40 ft	210 Terry		25	69
Apts	41 ft	1009 Alder		25	69
Childhaven	60 ft	316 Broadway		25	66
Residence	41 ft	400 Broadway		25	69
Broadway Apts	25ft	1203 James	Yes	14	67
Commercial/Apts	33 ft	502-5 Broadways		25	70
Commercial/Apts	33 ft	508 Broadway (corner)		25	70
Silver Cloud	35 ft	1100 Broadway		25	70
Commercial/Apts	35 ft	1620 Broadway		25	70
Commercial/Apts	25ft	SW Corner Broadway/Denny	Yes	14	67
Commercial/Apts	30 ft	SW Corner Broadway/Pine		25	71
QFC/Bartells/Apts	46 ft	Rooftop Area, NW Corner Broadway/Union		25	68
Residence	45 ft	E Denny		25	68

Note that highlighted cells signify the locations for which maximum speed of 25 mph was adjusted to reflect the speed profile of actual travel speed of the streetcar in these areas. As is standard in a screening review, all other locations are shown with the operational vibration levels that would result from the maximum corridor speed instead of the expected actual speed, and because all are less than the 72-VdB FTA impact criterion, no impacts would be expected.

Source: ENVIRON International Corporation

5.3 Facility Construction

5.3.1 Noise

Noise from construction activities for the streetcar line or the new maintenance facility have the potential to impact nearby receivers, particularly sensitive uses such as residences, schools, or hospitals. For daytime construction activities, the Seattle Noise Code allows temporary construction to exceed the noise limits applied to long-term operations by set amounts (see **Table 1**). This allows for noisier construction activities to occur while still controlling the potential for significant noise impacts to nearby receivers. During nighttime hours as defined in the rule, however, allowed increases are not applied to construction activities, and the stricter nighttime noise limits (e.g., 45 dBA for sources in residential zones affecting receivers in residential zones) would apply. Because it is difficult for construction activities to meet these stricter nighttime noise limits, construction activities are generally limited to daytime hours unless a noise variance is obtained from the City. The temporary nature of construction reduces the potential for significant impacts from construction activities and equipment.

The variations in zoning throughout the project area result in varying construction noise limits and timing restrictions. The daytime noise limits shown in the middle and lower portions of **Table 1** apply to the most common construction equipment of concern (i.e., diesel-powered mobile equipment and pneumatic equipment), resulting in limits ranging from 80 to 85 dBA depending on the specific source and receiver combination. As can be seen in the upper portion of **Table 8**, construction activities within 100 feet of sensitive receivers have the potential to exceed 80 to 85 dBA, and care should be taken to choose equipment and construction techniques that can comply with the City limits.

In addition to showing overall hourly noise levels from various construction activities, the lower portion of **Table 8** shows the ranges of sound levels (i.e., minimum to maximum levels) emitted by individual pieces of equipment. Because this equipment would not necessarily operate for an entire hour, it is not appropriate to compare these levels with the Seattle noise limits. However, these levels give an idea of the relative sound levels that can be expected from different kinds of equipment. In the absence of intervening terrain or structures, sounds from construction equipment and activities (usually point sources) decrease about 6 dBA for each doubling in distance from the source.

Overall project construction is projected to last up to two years, but construction would be completed in small segments and staged so that any given area would have up to about five weeks of construction for each direction of track. The streetcar rail line would be installed in major streets and through major intersections, and require work involving in-place utilities. Thus, some nighttime construction activities are anticipated to be necessary. Nighttime construction work would be minimized to the extent practical, and nighttime construction activities would require a noise variance issued by the City. Depending on the type of variance pursued, the City would ensure that the construction activities did not endanger public health or safety and/or would require noise controls to reduce potential noise impacts. Because the installation of streetcar infrastructure is a

fairly quick process, nighttime construction activities are expected to be limited in duration near any single affected location.

Table 8. Typical Noise Levels from Construction Activities Equipment (dBA)

Activity	Range of Hourly L_{eqs}		
	At 25'	At 50'	At 100'
Clearing	89	83	77
Grading	81-94	75-88	69-82
Paving	77-94	71-88	66-82
Erection	78-90	72-84	66-78
Types of Equipment	**Range of Noise Levels**		
	At 25'	At 50'	At 100'
Bulldozer	83-88	77-82	71-76
Dump Truck	83	77	71
Scraper	86-90	80-84	74-78
Paver	83	77	71
Generators	77-87	71-81	65-75
Compressors	80-84	74-78	68-72
Pneumatic Wrenches	89-91	83-86	77-80
Jackhammers	87-95	81-89	75-83

Sources: U.S. Environmental Protection Agency, 1971. *Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances*, Technical Report NTID300.1; Federal Highway Administration, 2006, *Roadway Construction Noise Model Users Guide*, FHWA-HEP-05-054; DOT-VNTSC-FHWA-05-01

5.3.2 Construction Vibration

Construction and street repairs are a common occurrence in these neighborhoods and vibration during construction is not anticipated to be sufficiently severe to damage either buildings or areaways, including historic buildings. Before construction begins, SDOT will review available information on the areaways adjacent to the construction area and will inspect the areaways as needed. If features are identified that would be vulnerable to damage from streetcar line construction or operation, additional steps would be taken to ensure protection of any such sensitive buildings. It will be incumbent on the project designers to factor in potential effects of construction vibration during both the design and the actual construction of the facility.

To illustrate the issue, the typical construction equipment vibration levels (**Table 4**, page 7) and the FTA building type construction vibration damage thresholds (**Table 5**, page 7) presented previously are combined in **Table 9** to provide a listing of "no-impact" distances for a variety of construction equipment. The information presented provides reasonable estimates for distances beyond which normal vibration associated with typical construction equipment and activities would not be

expected to damage buildings within the respective type categories. For example, impact pile driving (upper range) needs to be at least 55 feet from Category I buildings and at least 140 feet from Category IV buildings to reasonably expect to avoid possible damage from the associated ground-borne vibration. At the low end of vibration-generating equipment, some tasks can be conducted within about 5 to 15 feet of even the most sensitive building type without risk of damage. Construction activities requiring vibration-generating equipment occurring at distances less than the specified no-impact levels should be avoided if possible or should be closely monitored to prevent damage.

Table 9. FTA Construction Vibration Damage Thresholds and No-Impact Distances

Equipment [a]	PPV at 25 ft [a] (in/sec)	Building Categories and FTA Damage Thresholds [b]			
		Category I (0.5 PPV)	Category II (0.3 PPV)	Category III (0.2 PPV)	Category IV (0.12 PPV)
		No-Impact Distance (feet) [c]			
Pile Driver (Impact) Upper Range	1.518	55	75	100	140
PD (sonic) Upper Range	0.734	35	50	60	85
Pile Driver (Impact) Typical Range	0.644	30	45	55	80
Vibratory Roller	0.210	15	20	30	40
Clam Shovel Drop	0.202	15	20	30	40
Pile Driver (Sonic) Typical Range	0.170	15	20	25	35
Hoe Ram	0.089	10	15	15	25
Large bulldozer	0.089	10	15	15	25
Caisson drilling	0.089	10	15	15	25
Loaded trucks	0.076	10	15	15	20
Jackhammer	0.035	5	10	10	15
Hydromill in rock	0.017	5	5	5	10
Hydromill in soil	0.008	5	5	5	5
Small bulldozer	0.003	5	5	5	5

[a] See **Table 4**. Note that equipment types have been resorted based on PPV levels
[b] See **Table 5** regarding building type definitions.
[c] The estimated minimum distance required to avoid potential damage to the specified categories of buildings from construction equipment vibration, assuming typical methods of building construction and normal vibration transmission through the soil. All values have been rounded up to the nearest multiple of 5 feet

Source: ENVIRON International Corporation based on information in FTA 2006

6 Mitigation

6.1 Operation

6.1.1 Streetcar

No noise impacts from general operation of the streetcar line were identified. Therefore, no specific noise mitigation measures are required or recommended.

If final track design includes curves with radii less than 1,000 feet, measures would be implemented to reduce wheel squeal. Vehicle specifications and discussions with the vehicle manufacturer should evaluate options to accommodate the anticipated curve radii and to reduce or eliminate squeal. In addition, use of resilient, damped, or profiled wheels can substantially reduce squeal, and the rail material used in tight curve areas also could be changed to reduce or eliminate squeal. If there is wheel squeal after the facility begins operation, rail lubrication would be implemented on the curves where wheels squeal.

6.1.2 Maintenance Facility

The proposed Charles Street maintenance facility would not be proximate to any sensitive receivers and is not expected to result in noise impacts or to require any specific mitigation.

The proposed Boren maintenance facility plan considered in this analysis could potentially result in moderate noise impacts (under FTA criteria) to residences near the facility. This conclusion is based on very conservative estimates of maintenance activity frequency and duration. Reduced duration of the use of pneumatic tools and metal banging and/or closing maintenance bay doors could help to eliminate even moderate noise impacts.

Although any noise impacts identified are expected to be moderate and not severe under FTA policy, noise from the maintenance facility also could potentially exceed the Seattle daytime and/or nighttime noise limits at nearby residences, based on the conservative assumptions discussed above. To eliminate the potential to exceed the noise limits, several mitigation measures could be employed including the following:

- Ensure that the maintenance building exterior walls or building interior configurations (e.g., the placement of interior offices) provide a minimum of 30 dBA of reduction for interior to exterior noise (based on the obstructions provided by the partitions)
- Close the maintenance bay doors during the operation of pneumatic tools or during metal banging, especially during nighttime hours

More specific consideration of maintenance facility noise levels and the effectiveness of mitigation measures should be included in the final facility design if the Boren site is selected.

6.2 Construction

6.2.1 Noise

Some relatively simple and inexpensive practices can reduce the extent to which people are affected by construction noise and ensure that construction noise levels stay within the applicable daytime sound level limits. Examples include using properly sized and maintained mufflers, engine intake silencers, engine enclosures, and turning off idle equipment. Construction contracts can specify that mufflers be in good working order and that engine enclosures be used on equipment when the engine is the dominant source of noise.

Stationary equipment could be placed as far away from sensitive receiving locations as possible. Where this is infeasible, or where noise impacts are still significant, portable noise barriers could be placed around the equipment with the opening directed away from the sensitive receiving property. These measures are especially effective for engines used in pumps, compressors, welding machines, and similar equipment that operate continuously and contribute to high, steady background noise levels. In addition to providing about a 10-dBA reduction in equivalent sound levels, the portable barriers demonstrate to the public the contractor's commitment to minimizing noise impacts during construction.

Substituting hydraulic or electric models for impact tools such as jack hammers, rock drills and pavement breakers could reduce construction and demolition noise. Electric pumps could be specified if pumps are required. In addition, particularly loud activities such as pavement breaking within about 300 feet of any residences should be restricted to the hours before 10 p.m.

Although as safety warning devices back-up alarms are exempt from noise ordinances, these devices emit some of the most annoying sounds from a construction site. One potential mitigation measure would be to ensure that all equipment required to use backup alarms utilize ambient-sensing alarms that broadcast a warning sound loud enough to be heard over background noise but without having to use a preset, maximum volume. An even better alternative would be to use broadband backup alarms instead of typical pure tone alarms. And the best alternative would be to fit all large equipment that requires backup alarms with ambient-sensing broadband alarms. Such devices have been found to be very effective in reducing annoying noise from construction sites. Requiring operators to lift rather than drag materials wherever feasible can also minimize noise from material handling.

Note that in the event a nighttime noise variance is required, that process would require coordination with Seattle DPD Noise Abatement and the development of a Noise Management and Mitigation Plan per SMC 25.08.590.

6.2.2 Vibration

Mitigation of construction vibration will entail careful consideration of the use of large equipment near existing buildings, and especially near older buildings. For example, the use of impact equipment for pavement removal or placement of piles should be avoided within about 100 feet of known fragile cast-iron water mains or within about 25 feet of other fragile underground utilities or historic buildings.

Appendix A – Measured Operational Lmax Noise Levels near South Lake Union Streetcar (dBA)

Event 1		Event 2		Event 3		Event 4		Event 5		Event 6	
Time	Lmax	Time	Lmax	Time	Lmax	Time	Lmax	Time	Lmax	Time	Lmax
12:35:52	63.8	12:46:47	62.8	12:56:23	63.9	13:06:49	64.7	13:16:26	66.3	13:26:55	64.1
12:35:53	65.3	12:46:48	66.1	12:56:24	64.5	13:06:50	64.2	13:16:27	67.0	13:26:56	65.1
12:35:54	67.3	12:46:49	69.4	12:56:25	66.5	13:06:51	65.5	13:16:28	66.9	13:26:57	64.6
12:35:55	68.9	12:46:50	69.2	12:56:26	69.0	13:06:52	66.6	13:16:29	66.3	13:26:58	65.2
12:35:56	72.8	12:46:51	71.7	12:56:27	74.7	13:06:53	68.1	13:16:30	65.6	13:26:59	67.2
12:35:57	74.8	12:46:52	72.8	12:56:28	87.1	13:06:54	71.5	13:16:31	67.5	13:27:00	70.4
12:35:58	75.4	12:46:53	73.8	12:56:29	82.5	13:06:55	72.6	13:16:32	69.1	13:27:01	74.7
12:35:59	74.9	12:46:54	73.7	12:56:30	75.1	13:06:56	72.7	13:16:33	74.1	13:27:02	76.4
12:36:00	73.3	12:46:55	72.8	12:56:31	77.6	13:06:57	71.9	13:16:34	73.5	13:27:03	77.6
12:36:01	71.8	12:46:56	73.7	12:56:32	71.9	13:06:58	71.4	13:16:35	75.3	13:27:04	78.4
12:36:02	70.4	12:46:57	71.1	12:56:33	66.5	13:06:59	70.7	13:16:36	74.6	13:27:05	77.4
12:36:03	67.3	12:46:58	67.8	12:56:34	64.9	13:07:00	68.6	13:16:37	74.8	13:27:06	72.1
12:36:04	66.5	12:46:59	66.6	12:56:35	64.1	13:07:01	66.9	13:16:38	73.0	13:27:07	69.1
12:36:05	66.3	12:47:00	66.0	12:56:36	64.1	13:07:02	66.4	13:16:39	69.8	13:27:08	67.5
		12:47:01	67.1	12:56:37	64.6	13:07:03	65.1	13:16:40	66.8	13:27:09	64.4
		12:47:02	67.2	12:56:38	64.0	13:07:04	64.5	13:16:41	65.5		
		12:47:03	65.1					13:16:42	64.3		
Speed (mph)	11.2		9.0		9.0		9.0		9.0		11.2
Max	75.4		73.8		77.6		72.7		75.3		78.4
Average	75.5										

Bell noise in close proximity (highlighted) not included in calculation of Lmax.
SLMs taken 9/25/2010 on east side of Terry Street between Harrison and Republican Streets, 25 feet from centerline of track.

Source: Sound level measurements by ENVIRON International Corporation

The noise specification for the First Hill Streetcar is the same as the specification for the South Lake Union Streetcar. This specification indicates assessments of compliance with the noise specs are to be conducted in accord with International Standards Organization (ISO) 3095. The latest adopted version of this standard is ISO 3095:2005, which says sound level measurements of mobile rail sources should be taken in fast mode, and that results of at least three measurements should be arithmetically averaged and rounded to the nearest whole decibel. This standard also specifies that sound level measurements for this spec be taken with equipment allowing a maximum of ±2 dBA variability in recorded sound levels, so this same variation applies to the standard.

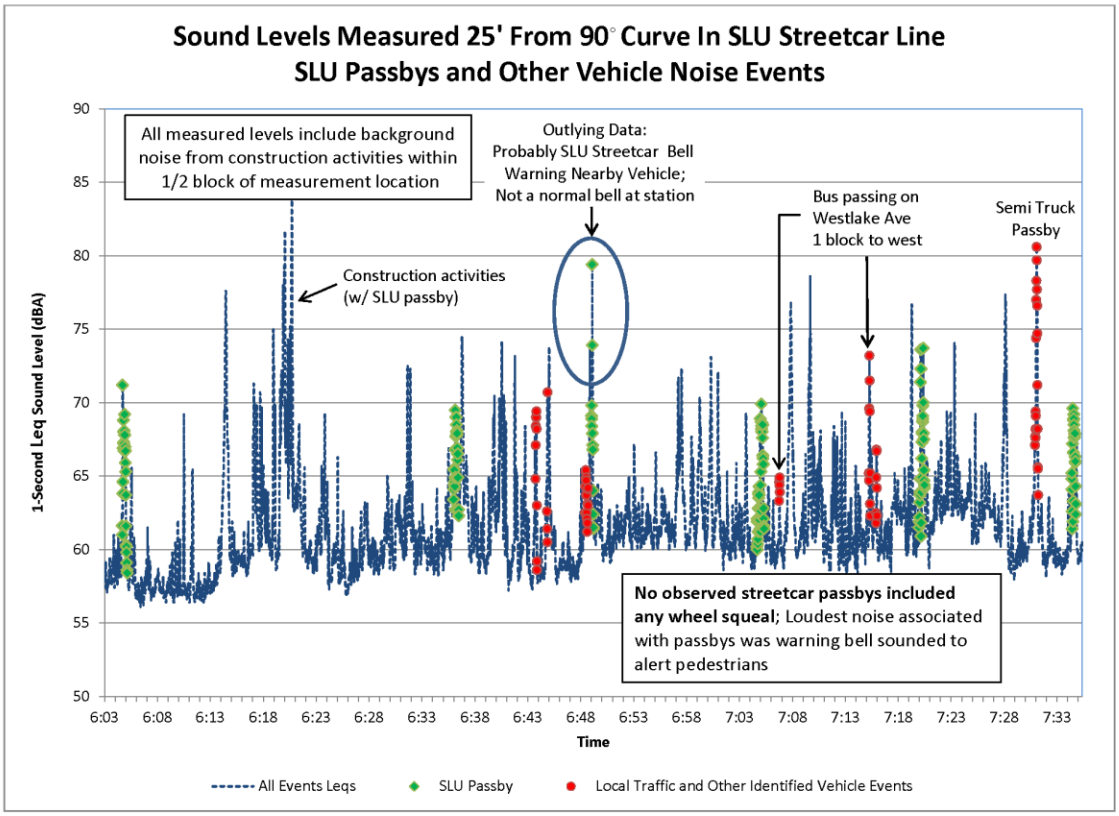
The average of measured Lmax sound levels from the operational SLU streetcar was 75.5 dBA 25 feet from the centerline of the track, which is within 2 dBA of the specification level 75 dBA. The measured operational noise therefore complies with the noise specification for this equipment.

Appendix B – Measured Existing Sound Levels at Wisteria View Manor

Date	Time	Duration	Leq	Lmax	Lmin	L02	L08	L25	L90
08-Sep-10	16:00:00	3600	64.1	78.0	54.2	70.0	67.8	65.2	57.7
08-Sep-10	17:00:00	3600	64.3	77.5	54.2	70.5	68.3	65.5	57.2
08-Sep-10	18:00:00	3600	64.8	77.5	55.5	70.6	68.3	65.9	58.8
08-Sep-10	19:00:00	3600	64.3	79.6	55.7	70.0	68.2	65.3	58.6
08-Sep-10	20:00:00	3600	63.1	81.0	52.3	69.8	67.4	63.8	56.2
08-Sep-10	21:00:00	3600	62.4	82.2	51.7	69.0	66.4	62.7	54.9
08-Sep-10	22:00:00	3600	61.7	75.9	51.7	69.7	66.5	61.8	54.3
08-Sep-10	23:00:00	3600	59.8	75.8	48.7	68.6	64.9	58.6	51.6
09-Sep-10	0:00:00	3600	56.8	73.8	46.3	66.9	61.2	53.4	48.8
09-Sep-10	1:00:00	3600	55.6	76.2	46.2	64.8	58.9	52.7	48.6
09-Sep-10	2:00:00	3600	57.0	83.9	45.7	64.3	56.4	52.2	48.1
09-Sep-10	3:00:00	3600	54.0	71.7	45.5	63.5	56.9	51.6	48.0
09-Sep-10	4:00:00	3600	59.3	80.9	47.5	68.3	63.7	56.1	50.3
09-Sep-10	5:00:00	3600	60.8	74.4	52.0	69.4	65.8	59.4	54.2
09-Sep-10	6:00:00	3600	64.2	84.3	53.5	71.1	68.6	64.8	56.1
09-Sep-10	7:00:00	3600	64.5	85.0	53.2	70.9	68.6	65.6	56.5
09-Sep-10	8:00:00	3600	64.4	82.0	56.3	70.4	67.6	65.2	58.8
09-Sep-10	9:00:00	3600	64.7	89.1	54.4	69.6	67.3	65.0	58.1
09-Sep-10	10:00:00	3600	64.1	82.8	53.8	70.2	67.7	64.9	56.5
09-Sep-10	11:00:00	3600	63.9	79.5	55.4	70.3	67.3	64.4	58.1
09-Sep-10	12:00:00	3600	63.9	83.1	54.9	69.7	67.3	64.8	58.5
09-Sep-10	13:00:00	3600	63.7	76.4	55.8	69.4	67.0	64.7	58.6
09-Sep-10	14:00:00	3600	64.1	77.2	56.4	69.9	67.4	65.0	59.2
09-Sep-10	15:00:00	3600	64.2	78.8	55.2	70.1	67.6	65.0	59.0
09-Sep-10	16:00:00	3600	64.4	91.3	54.7	70.2	67.7	65.1	58.1
09-Sep-10	17:00:00	3600	68.6	96.4	56.8	71.3	68.4	65.7	59.3
09-Sep-10	18:00:00	3600	69.5	98.1	56.9	70.8	68.6	66.2	59.6

All sound levels expressed as dBA.
Source: ENVIRON International Corporation

Appendix C – Measured Sound Levels near South Lake Union Streetcar Line Turn



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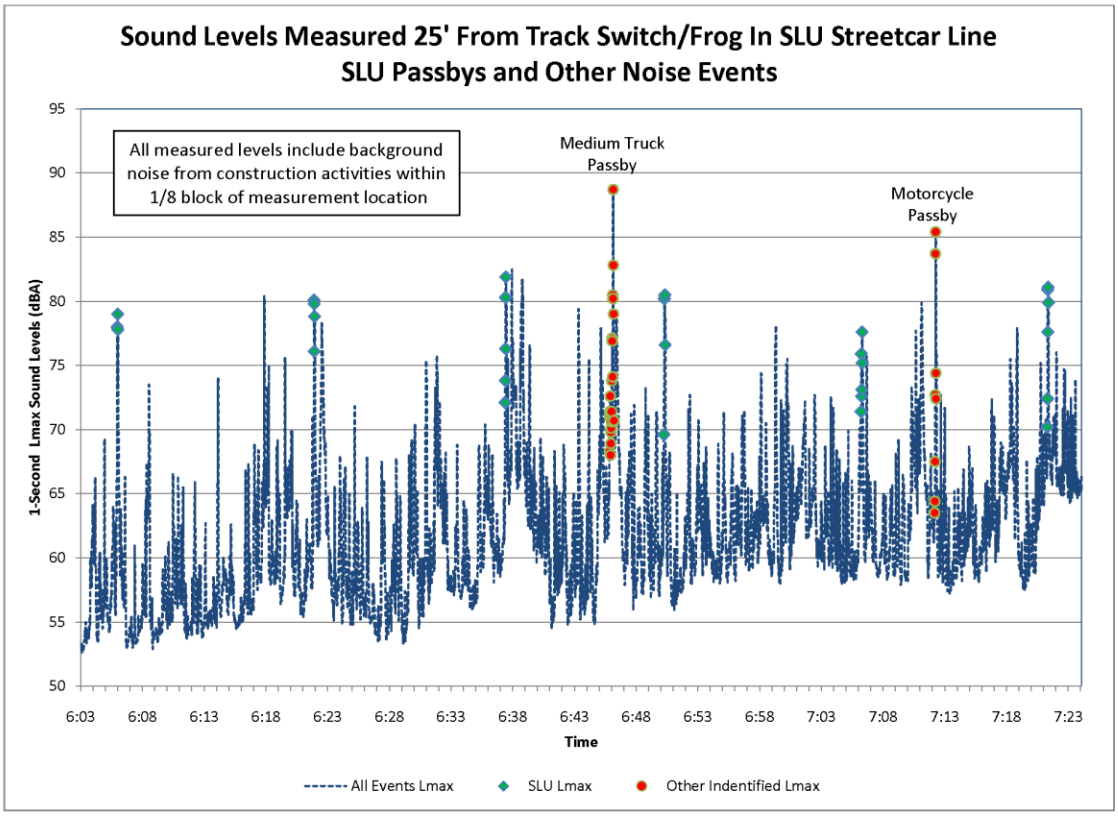
Appendix D - Measured Sound Levels near South Lake Union Streetcar Line Switch



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Appendix E – First Hill Streetcar Planned and Potential Track Switching Locations

The following locations have been identified as planned or potential track switch locations. There are no residential receivers within about 100 feet of any of these locations.

1. Turnout on Jackson St. just east of 5th Ave in the middle of the road.

2. Jackson Street at 8th Ave. This switch has not yet been designed but is associated with the Charles Street alternative Maintenance Facility access. It could include one turnout in each direction and potentially a diamond crossing of the eastbound tracks on Jackson.

3. Yesler at 12th Avenue. This switch has not yet been designed but is associated with the Boren Street alternative Maintenance Facility access. It could include one turnout in each direction and potentially a diamond crossing of the EB tracks on Yesler.

4. One cross-over on Broadway between Columbia and Marion. This requires one turnout for each direction.

5. Turnout at just north of Howell along the west side of Broadway.

The proposed project would include either (but not both) #2 or #3.

Source: URS, Inc., 2010