Attachment C
Noise and Vibration Technical Memorandum

Sounder Yard and Shops Facility Project

Noise and Vibration Technical Memorandum

March 25, 2016

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ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
APTA	American Public Transit Association
BNSF	Burlington Northern Santa Fe Railroad
dBA	A-weighted decibels
EIS	Environmental Impact Statement
EPA	United State Environmental Protection Agency
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
ips	inches per second
L_{eq}	equivalent sound level
L_{dn}	day/night sound level
L_{max}	maximum noise levels
mph	miles per hour
NEPA	National Environmental Policy Act
RMS	root mean square
SEPA	State Environmental Policy Act
SW	southwest
VdB	vibration velocity expressed in decibel units
WAC	Washington Administrative Code

1.0 BACKGROUND AND OVERVIEW

This memorandum summarizes the assessment of potential noise and vibration impacts associated with the Sounder Yard and Shops Facility Project and builds on earlier noise and vibration analysis work completed for the Sounder Yard Expansion phase. The Sounder Yard and Shops Facility Project involves construction of a maintenance building to accommodate back shops and other critical uses.

The analysis of noise impacts in the Sounder Yard and Shops Facility Project is based on a comparison of noise caused by the project with existing noise levels and Federal Transit Administration (FTA) impact levels to determine if noise levels would exceed FTA Criteria. Construction noise impacts are described based on maximum noise levels of construction equipment published by the U.S. Environmental Protection Agency (EPA). Train noise exposure is predicted at sensitive receptors based on projected operations using the FTA noise assessment spreadsheet model. Mitigation measures are discussed, where appropriate, to avoid or reduce potential noise impacts.

Sound Transit is proposing to build a new maintenance building on site and supporting facilities, such as roadway, site lighting, drainage facilities, and required utility infrastructure, are included in the project. Additional project elements are described in Chapter 2.0.

The noise impact analysis for the proposed project considered all project improvements for construction and operations at the new maintenance building and associated improvements described in Chapter 2.0. All Sounder revenue service trips from Seattle to Lakewood and all non-revenue trips between Lakewood and the Sounder Century Yard were evaluated in previous environmental assessments and are not part of the Sounder Yard and Shops Facility Project (Sound Transit, 2002, 2005, 2009, 2011). The addition of a third storage track at the site was evaluated in 2013 (Sound Transit, 2013).

Potentially noise-sensitive land uses and vibration-sensitive buildings were identified by reviewing previous noise and vibration studies that included the Century Yard and a field survey of the study area. Noise levels were measured at multiple locations near the proposed yard improvements to establish the existing noise environment. Predicted future noise levels in the study area are based on measured levels conducted as a part of this study and approved future daily rail operations.

Noise levels in the project area are typical of an urban area located near an existing rail corridor. Project noise exposures that would result from the project were modeled at noise-sensitive uses closest to the project alignment using FTA methods. Vibration levels from the project area were determined using Chapter 10: General Vibration Assessment information and procedures contained in the FTA's guidance manual, *Transit Noise and Vibration Impact Assessment* (FTA, 2006).

Substantial transportation-related noise already exists in the project area, including noise from train and vehicular traffic, as well as aircraft flying to and from Joint Base Lewis-McCord and the Clover Park Vocational Technical School Airport. Noise exposure from the project would range between 50 and 59 dBA day-night sound level (L_{dn}) at the modeled noise-sensitive land uses. As a result of the project, noise levels are predicted to increase by 1 to 2 dBA (L_{dn}) at nearby residences. Project noise levels are predicted to result in no change in noise levels at Southgate Elementary School and increase by 1 dBA (L_{eq}) at Clover Park Technical College. Moderate noise impacts are under the FTA criteria are predicted to occur at 12 multi-family units located along Lakewood Avenue South and four single family homes located along Kline Street SW. Predicted future noise level increases would occur between 8 p.m. and 4 a.m. based on the anticipated Sounder yard and shop operation schedule. The frequency of noise peaks (L_{max} noise levels) could increase as transit maintenance operations increase in the project area.

Construction activities would generate temporary noise and vibration during the construction period. Maximum (peak) noise levels from construction equipment would range from 69 to 93 dBA 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. Because construction equipment would be turned off, idling, or operating at less-than-full power at any time and because construction machinery is typically used to complete short-term tasks at any given location, the average L_{eq} noise levels during the day would be less than the maximum noise levels.

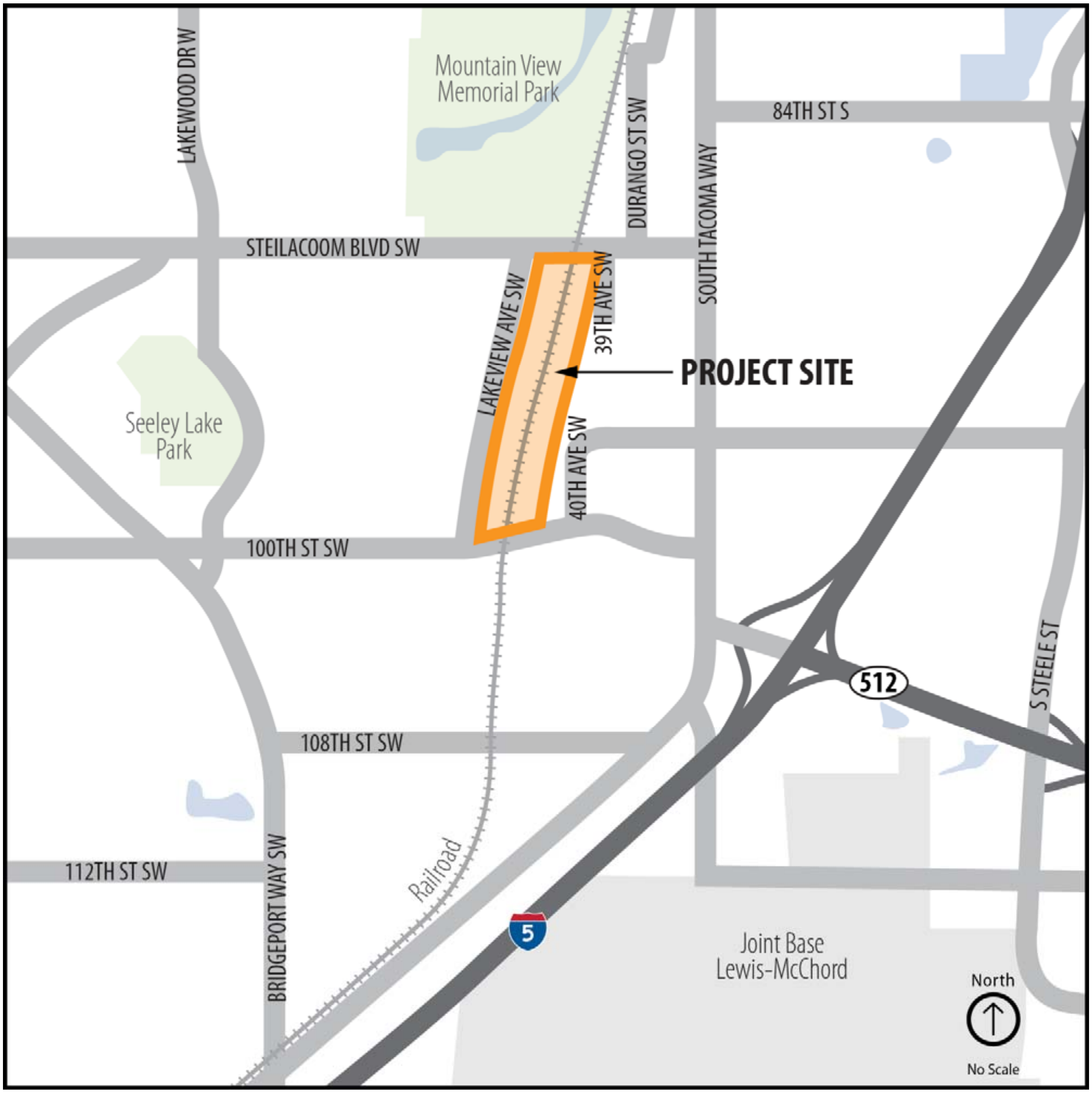
Construction would occur predominantly during daytime hours, however some nighttime construction may occur. Construction noise is exempt from regulations during daytime hours. Nighttime construction may require coordination with the City of Lakewood and the Contractor. Construction noise levels could be reduced by implementing the construction practices identified in Chapter 7.0.

No substantial construction vibration impacts and no building damage are expected to occur as a result of the project because no vibration-sensitive uses and vibration-sensitive structures were identified within the immediate project area.

This technical memo describes the outcome of the analysis beginning with a project description (Chapter 2.0) and description of the study methods and assumptions (Chapter 3.0). Chapter 4.0 provides a background on noise and vibration fundamentals and regulations. Future site-generated noise levels in comparison to impact thresholds are described in Chapter 5.0, while potential mitigation considerations are described in Chapter 6.0.

The study area for the noise and vibration analysis includes noise-sensitive land uses located up to a half a mile from the project site, shown in Figure 1-1.

Figure 1-1. Vicinity Map



2.0 INTRODUCTION AND PROJECT DESCRIPTION

2.1 Introduction

The Federal Transit Administration (FTA) is the federal project lead and the Central Puget Sound Regional Transit Authority (Sound Transit) is the state lead agency for the project.

This technical report has been prepared in support of the Sounder Yard and Shops Facility Project Documented Categorical Exclusion (DCE) in accordance with the National Environmental Policy Act (NEPA), State Environmental Policy Act (SEPA), and the Federal Transit Administration (FTA) guidance manual, *Transit Noise and Vibration Impact Assessment, Final Report* (FTA, 2006).

2.2 Existing Improvements

Sound Transit has undertaken a series of improvements to the Century Yard site including:

- M-to-Lakewood Track and Signal Project (completed in 2010)
- Sounder Lakewood Layover Improvement Project (completed 2013)
- Sounder Yard Expansion Project (scheduled completion late 2017)

Two layover tracks (LT1 and LT2) for train storage were constructed as part of the M-to-Lakewood Track and Signal Project, in the rail right-of-way adjacent to the existing tracks at the Century Yard site in 2010.

The subsequent Sounder Lakewood Layover Improvement Project included perimeter fencing, yard lighting, gravel access roads, a dry fire line, and wayside power units.

The current planned improvements of the Sounder Yard Expansion Project consist of the addition of a third layover track (LT3) and a new train and engine crew building (T & E Building) with an associated 45-stall parking lot, a storage building, and a stand-alone compressed air unit. In addition, Sound Transit will pave existing gravel access roads, add an additional East Access Road, and install underground utilities, site lighting, and two new bullet-proof guard booths. Drainage facilities will be provided and/or updated accordingly. The Sounder Yard Expansion Project improvements will be in place by late 2017, well in advance of the proposed Sounder Yard and Shops Facility Project described below.

2.3 Sounder Yard and Shops Facility Project Proposed Improvements

The existing Sounder Century Yard is located between Steilacoom Boulevard SW and 100th Street SW (Figure 1-1). The majority of the improvements associated with the Sounder Yard and Shops Facility

Project are located on the northern end of the existing yard, south of Steilacoom Boulevard SW. Sound Transit plans to purchase two additional parcels at the northern end of the existing yard and to the east of the existing site to accommodate the new shop building, vehicle parking, and access (Figure 2-1).

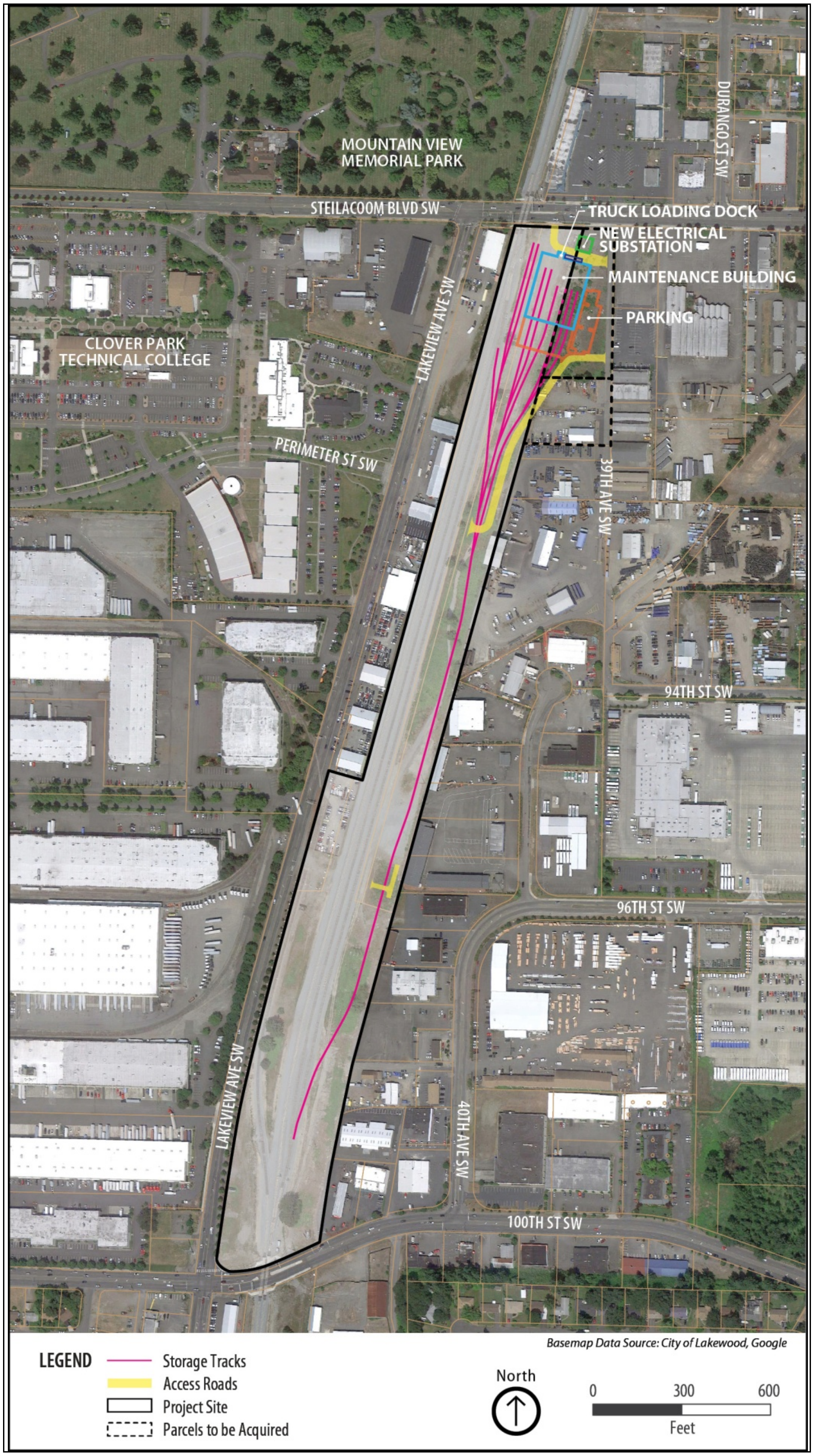
Sound Transit is proposing construction of a new, approximately 40,000-square-foot maintenance building on the Sounder Century Yard site. The single-story building would contain back shops, material storage areas, offices, a conference room, welfare facilities for workers, including restrooms, locker rooms, a lunchroom kitchenette, and other ancillary uses. Posted rail, hoisting equipment, cranes, and other machinery required to support the inspection and maintenance of the fleet would be included. The improvements would allow for daily Federal Railroad Administration-required inspection of the fleet. Some of the maintenance activities performed at the Seattle Amtrak Yard would be relocated to the proposed shop; however the Amtrak facility would continue to provide car wash and fueling services.

The proposed project provides no new train service. Up to approximately 24 nighttime crossings of 100th Street SW per week (or up to approximately 12 per night) to and from the site would be required for train switching to move trains between the yard and shop areas (see Appendix A). This would block 100th Street SW for approximately 3 minutes for each crossing. To minimize the duration of the blockage, the train sets will move all the way through the intersection, allowing the railroad gate arm to rise and the queue of vehicles to pass before the gates lower again to allow the train to move north across the intersection back into the train yard. Appendix A provides additional train operations assumptions that were used to support project-related noise modeling.

In addition, load testing, which assesses the performance of locomotives, will occur at the site and generate noise. This activity would generally occur approximately 170 times per year during daytime hours. The load testing would occur over one hour to cover either: 1) pre-load testing when the locomotive arrives for inspections; or 2) a final load test when the inspection is completed. Load testing would only occur at night in an emergency situation.

An estimated 31 staff would be employed at the maintenance building (27 day shift and 4 night shift employees). Primary night shift activities consist of moving the train cars into the maintenance building and staging the remaining cars that require work so they are in position for easy access to the maintenance building.

Figure 2-1. Project Site Plan



In addition to the maintenance building, approximately 40 vehicle parking spaces would be provided east of the maintenance building. The existing north access road from Steilacoom Boulevard SW would be reconfigured into a paved access drive for truck deliveries to the loading dock behind the maintenance building. The main entrance to the site would be relocated from Steilacoom Boulevard SW to the new access drive off of 39th Avenue SW, a private roadway that would be improved.

The Tacoma Public Utilities 115kV transmission line, currently located parallel to the rail alignment, would be relocated on-site to avoid conflicts with the planned maintenance facility.

Supporting facilities, such as roadway, site lighting, drainage facilities, and required utility infrastructure, are included in the project. Additional key project elements are as follows:

- Construct a new shop lead on the eastern side of the site
- Construct shop tracks to provide train access to the new maintenance building
- Relocate the existing north guard booth to the new site entrance off 39th Avenue SW
- Construct a new electrical substation
- Modify or partially relocate existing on-site fiber optic lines crossed by new track

2.4 Construction

Construction of the Sounder Yard and Shops Facility Project is expected to occur over a two-year period with the assumption that the preceding yard expansion elements are already in place. The yard expansion work is expected to be completed by fall 2017 while completion of the Sounder Yard and Shops Facility Project is anticipated in 2021. Temporary noise and vibration would be generated during construction periods.

3.0 METHODOLOGY

3.1 Background

The methodology associated with this noise and vibration analysis was summarized in a formal methods-and-assumptions memo, which included descriptions of the analysis, monitoring updates, and project elements. Please refer to the Sounder Yard and Shops Facility Project *Noise and Vibration Assumptions and Methodology Memorandum* (Sound Transit, 2015) for the final document regarding the analysis methodology.

The following section describes the methods and approach followed for this study per the FTA guidance manual, *Transit Noise and Vibration Impact Assessment, Final Report* (FTA, 2006). which procedures for assessing improvements to conventional passenger rail lines and stationary rail facilities and horn noise assessment.

3.2 Noise Assessment Methodology

3.2.1 Methodology Overview

Predicted noise levels in the area surrounding the project were modeled with the current (2007 version) FTA noise spreadsheet model. Predicted future noise levels in the project area were based on measured sound levels and future daily rail operations outlined in Chapter 1.0. The spreadsheet was developed by FTA and uses the methods and formulas described in Chapter 6: Detailed Noise Analysis of the FTA guidance manual, *Transit Noise and Vibration Impact Assessment, Final Report* (FTA, 2006).

Noise impacts from rail operations are generated from the interaction of wheels on track and motive power. The interaction of steel wheels on rails generates four different types of noise, depending on track work:

- Noise generated by passing trains operating on tangent track sections
- Noise generated from wheel squeal on tightly curved track
- Noise generated on special track work sections, such as at crossovers or turnouts
- Noise generated at grade crossings, including warning bells, horns on the locomotive, or wayside horns

The noise impact analysis for the project considered all project improvements with focus on the construction and operation of the new maintenance building and supporting facilities, such as roadway, site lighting, drainage facilities, and required utility infrastructure. Analysis of operation of the maintenance facility included load testing of locomotives. Load testing would occur approximately 170 times per year during daytime hours, with a typical duration of one-hour for annual inspection. The highest noise level resulting from load testing would be approximately 62 dBA (L_{eq}) at 100 feet. All load testing would occur during daytime hours except in an emergency.

All revenue service trips from Seattle to Lakewood (9 daily roundtrips with the future implementation of Easements 1 through 4) and all non-revenue trips between Lakewood and Century Yard were evaluated in previous assessments in the study area (Sound Transit, 2002, 2005, 2009, 2011). The addition of a third storage track was evaluated in 2013 (Sound Transit, 2013).

Potentially noise-sensitive land uses and vibration-sensitive buildings were identified by reviewing previous noise and vibration studies that included the project study area and site observations from public view points. Noise levels were measured at multiple locations near the proposed yard improvements to establish the existing noise environment (Figure 3-1). All noise measurements followed FTA guidance and were made in accordance with American National Standards Institute (ANSI) procedures for community noise measurements. Larson Davis Model 720 or Model 820 sound level meters were used for all noise measurements.

Predicted future noise levels in the study area are based on measured levels conducted as a part of this study and future daily rail operations. To provide a baseline for the analysis of potential noise impacts of the rail operations, long-term (24-hour) measurements were conducted at three residential areas. Two short-term (1-hour) noise measurements were conducted at areas nearby playfield at Southgate Elementary School and outdoor use areas at Clover Park Technical School with daytime use only. Monitoring locations are shown on Figure 3-1.

Two sets of short-term noise measurements were conducted to record sound levels when a train passes by on mainline tracks and storage tracks to compare to reference levels. These simultaneous measurements were conducted 15 feet and 30 feet from the centerline of the near track and also recorded sound levels generated during train idling and on-board horn blows. The measurements within the Century Yard are also shown on Figure 3-1 and are labeled SYS1 and SYS2. Table 3-1 provides details of each noise measurement and measurement location.

Figure 3-1. Noise Monitoring Locations

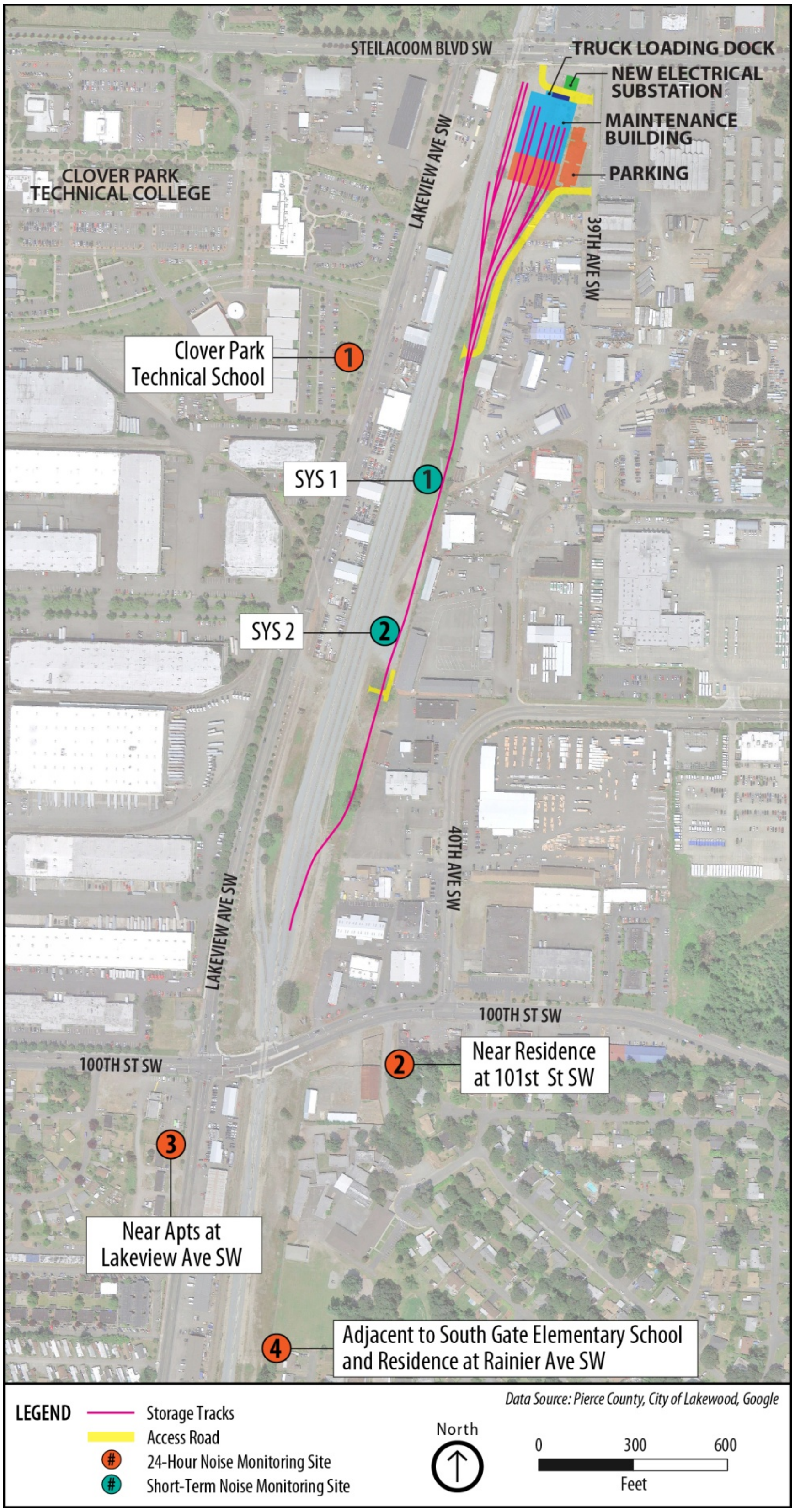


Table 3-1. Noise Measurement Locations and Distances to Key Noise Sources (dBA)

Site # / Name	FTA Land Use Category[1]	Measurement Start Time	Measured Existing Noise Levels[2]	Distance to Near Track Centerline	Distance to Nearest Crossing	Distance to Planned Maintenance Improvements at Century Yard
Site 1: Clover Park Technical College	3	11:10 a.m.[3]	60 Leq	250 feet	1,600 feet	625 feet
Site 2: Residences at 101st Street SW	2	10:05 a.m.[4]	60 Ldn	450 feet	544 feet	3,050 feet
Site 3: Residences at Lakeview Avenue SW	2	10:35 a.m.[4]	62 Ldn	250 feet	550 feet	3,485 feet
Site 4: Residences at Rainier Ave S and Southgate Elementary School[5]	2 / 3	9:20 a.m.[4]	60 Ldn / 61 Leq	130 feet	1,000 feet	4,150 feet

Notes:
[1] FTA Land Use Categories are described in Chapter 4.
[2] Measured noise levels were collected as part of this study on July 29th and 30th, 2015.
[3] 30-minute measurement.
[4] 24-hour measurement.
[5] Site 4 represents the .LDN level at the residence and the peak hour noise level for the school.

Follow-up measurements were conducted at the grade crossing at 100th Street SW to characterize the sound levels of warning devices used at the crossing. The noise levels for the warning devices at 50 feet are shown in Table 3-2, the noise levels at Site 1, 2, 3 and 4 already included the noise from the warning devices, and the measurements at 50 feet were taken to be used as a reference level in the prediction model. The data collected from these measurements is included in Appendix B of this technical memo.

Table 3-2. Modeled Project Elements and Reference Noise Levels

Modeled Project Elements	Reference Noise Level (1-hour Leq) at 50 feet	Reference SEL Level at 50 feet
1 Locomotive at 5 mph	66.4	98
8 Train Cars at 5 mph	35.4	79
Crossing Signals – 20 seconds	50.8	109
Layover Tracks – 1 Train per hour	73.4	109
Crossover Tracks – 1 Train per hour	37.8	100
Locomotive Warning Horns – 1 per hour	74.4	110

Sounder Yard and Shops Facility Project

Noise resulting from the Sounder Yard and Shops Facility Project includes the prediction of rail storage line and storage yard noise levels over the course of a typical weekday of operation using the FTA spreadsheet model from all individual noise sources. Traffic noise from additional vehicle travel to the shop was not modeled, because the increase in traffic would not be high enough to increase the existing noise levels.

Noise sources within the facility would be inside the building and over 1,000 feet from any noise sensitive land uses, so they were not considered a primary noise source. The primary noise sources associated with the project are as follows:

- Train movements on sidings tracks
- Wayside horn
- Crossing bells at 100th Street SW
- Track work at each of the sidings

Noise exposure (future noise that would be generated by the project) was forecast using the FTA 2011 noise model. The FTA model includes default reference noise levels for 23 different noise sources that could be part of a rail project. The default noise reference levels for train types are based on measurements taken from different vehicle types. They are conservative because the reference levels represent the worst-case noise from the vehicle types. The noise model spreadsheet considers the speed of the train, the number of engines and number of cars per train set, and the number of trains per hour during daytime and nighttime hours. Other inputs included the type of track, if a track is on aerial structures, if a barrier is present, and if there are buildings between the rail and the receiver. This document uses the default reference noise levels provided by FTA and confirmed on measurements of Sounder commuter rail trains.

The predicted noise levels are compared to the site-specific criteria to determine if there is "No Impact," a "Moderate Impact," or a "Severe Impact" at each site according to the FTA criteria.

3.2.2 Modeled Project Elements and Assumptions

The current FTA *Transit Noise Assessment Spreadsheet Model* (HMMH, 2007) was used to calculate noise levels generated by train operations and supporting operations that would occur as a result of the project. Nighttime activities include moving the train cars into the maintenance building and staging the remaining cars that require work in position for easy access to the maintenance building. These train movements would require up to approximately 12 nighttime (8 p.m. to 4 a.m.) crossings of 100th Street SW, resulting in roadway blockages of approximately 3 minutes for each crossing. The nighttime crossings would include the use of wayside horns and crossing bells for safety reasons. Load testing of the train cars would occur during the daytime shift. Project elements and assumptions used in the FTA spreadsheet model are provided in Table 3-3. When calculating the sound exposure level for a 24-hour day for residences or other land uses that include 24-hour use, the L_{eq} from 7 a.m. to 10 p.m. is added to 10 times the sound exposure level (SEL) from 10 p.m. to 7 a.m.

Table 3-3. Modeled Project Elements and Assumptions

Project Elements	Assumption
Daily Train Storage Movements (on layover/storage tracks only)	12 (2.5 per hour) nighttime crossings
Hours of Operation	12 one-way crossings between 8 p.m. and 4 a.m.
Average / Maximum Speed (mph)	5
Diesel Electric Locomotives/ Train	1
Rail Cars / Train	8
Project Added Turnouts	0
Fixed Guideway (Track)	Welded track, at grade, without intervening buildings
Stationary Noise Sources	One layover track, two turnouts
Wayside Horns	15 to 20 Seconds , 2.5 soundings per hour
Crossing Bells	3 minutes per crossing
Load Testing	Average 1 hour per day during daytime hours only

Reference noise levels for each noise source are provided in Table 3-2.

3.3 Rail Vibration Assessment Methodology

Vibration impacts from rail operations are generated through the wheel/rail interface. The smoothness of these motions/actions are influenced by wheel and rail roughness, rail vehicle suspension, train speed, track construction (including types of fixation and ballast), the location of switches and crossovers, and the geologic strata (layers of rock and soil) underlying the track. Vibration from a passing train has the potential to move through the geologic strata, resulting in building vibration transferred through the building foundation. The principal concern is annoyance to building occupants.

Vibration assessment for the project area followed Chapter 10: General Vibration Assessment information and procedures contained in the FTA's guidance manual (FTA, 2006). FTA vibration reference levels for rail vehicles were used to represent the train's force density level function. Transfer mobility functions used to determine ground attenuation were based on vibration reference data. The combination of force density and transfer mobility functions provide an estimate of ground vibration as it relates to distance from the fixed guideway.

The vibration reference levels are based on FTA reference levels, which use base curves that are representative of the upper range of well-maintained North America systems. The vibration model uses the method and formulas in Chapter 10 of the FTA guidance manual to determine if there are possible vibration impacts. The model also considers the speed of the train and distance from the nearest track to the receiver, and then calculates the predicted vibration levels by adjusting the speed and distance of the reference base curves. A number of adjustment factors can be added, including the type of track joint, the type of wheels on the car, the type of track bed, whether special track work is in place, and whether vibration control track treatments are in use. Vibration levels are compared to Table 8-1 in Chapter 8 of the FTA guidance manual to determine possible vibration impacts. Results from this general assessment will provide information to determine the need for and extent of detailed vibration assessment.

Predicted future vibration levels in the study area are based on the previous assessment in the study area (Sound Transit, 2002) which is consistent with the most recent 2006 FTA guidance. No vibration monitoring was performed for this assessment as the survey of nearby land uses did not include any vibration-sensitive uses within 50 feet of the tracks.

3.4 Construction Noise and Vibration Methodology

Because the means and methods of construction will not be known until a contractor is selected for the project, the analysis of construction noise and vibration was based on typical activities and equipment used for demolition, excavation, and erection work. Both daytime and nighttime construction activities were analyzed since it is possible that construction work could occur during nighttime hours.

Construction noise experienced by nearby sensitive receptors is qualitatively discussed and evaluated based on EPA estimates of maximum noise levels of typical construction equipment.

4.0 NOISE AND VIBRATION FUNDAMENTALS AND CRITERIA

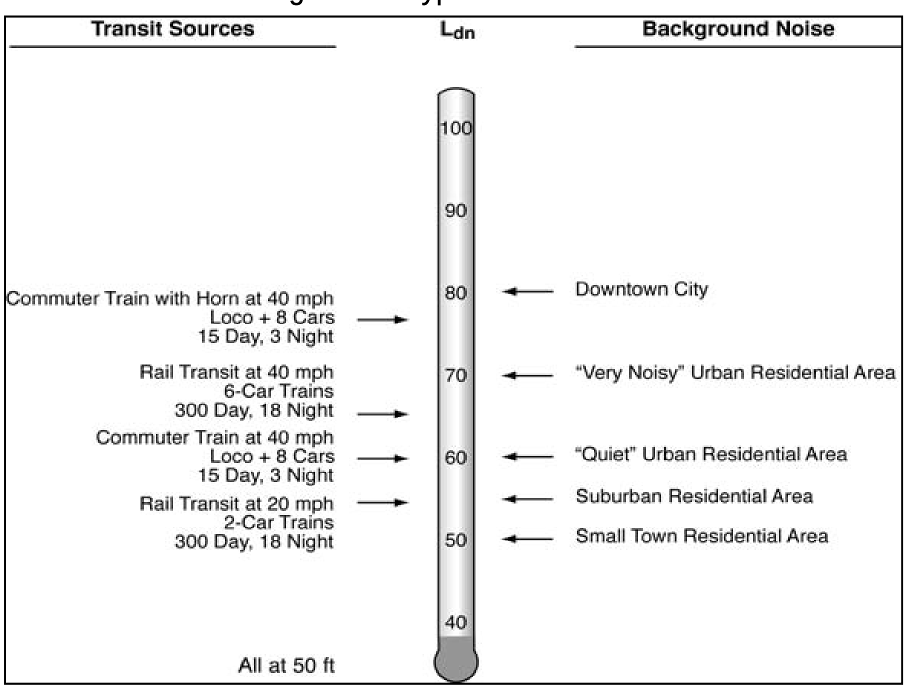
4.1 Noise

The basic unit of measurement for noise is the decibel (dB), which is a logarithmic measure of sound energy that tracks closely with human perception of loudness. To better account for human hearing sensitivity to different frequencies contained in sound (or “unwanted sound” called noise), noise is quantified in units of decibels on an "A-weighted scale" (dBA). The "A" scale approximates the average human ear's sensitivity to sounds comprised of many different frequencies. The terms "sound" and "noise" are used interchangeably in this report.

The most commonly used noise metric (also called a "noise descriptor") is the Equivalent Noise Level (L_{eq}), which is the energy sum of all the sound that occurs during a measurement period. Another descriptor known as Average Day-Night Noise Level (L_{dn}) is nearly universally used to evaluate noise in areas with noise-sensitive uses that include sleeping quarters such as residential areas. The L_{dn} is a 24-hour L_{eq} with a 10-dB penalty added to noise occurring from 10 p.m. to 7 a.m. The effect of this penalty is that, in the calculation of L_{dn}, any sound (or noise event) during nighttime hours is equivalent to 10 identical events occurring during daytime hours. This strongly weights L_{dn} toward nighttime noise to reflect that most people are more easily annoyed by noise during nighttime hours when background sounds may be lower and most people are sleeping.

A rural area with no major roads nearby would have a typical L_{dn} of around 40 dBA; a noisy urban residential area close to a major arterial highway would average around 70 dBA L_{dn}. Most residential areas in the study corridor fall within the range of 60 to 75 dBA L_{dn}. Figure 4-1 provides typical L_{dn} values experienced in a range of residential and urban areas.

Figure 4-1. Typical Ldn Values



Source: FTA, 2006

4.2 Ground-borne Vibration

Ground-borne vibration differs from airborne noise in that it consists of energy transmitted through the earth rather than the air. Ground-borne vibration is not a widespread environmental problem, and is generally limited to localized areas very near roadways, rail systems, construction sites, and some industrial operations. Automobile, bus, and truck traffic rarely create perceptible ground-borne vibration, except where bumps, potholes, or other discontinuities in the roadway surface exist.

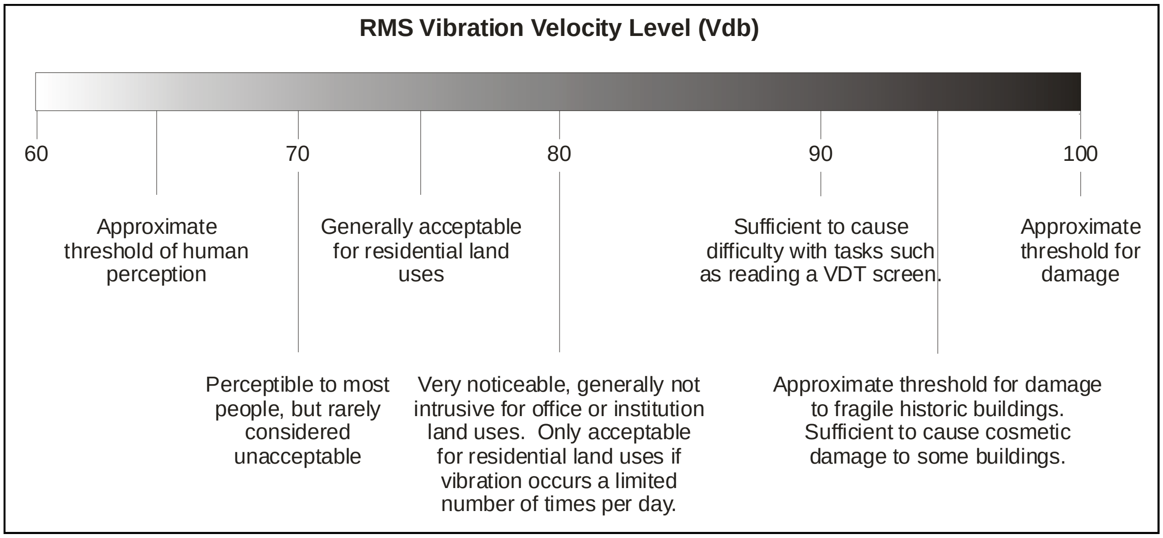
When traffic causes phenomena such as rattling windows, the cause is more likely to be acoustic (airborne) excitation rather than ground-borne vibration. The unusual situations where traffic or other existing sources cause intrusive vibration can be an indication of geologic conditions that could also result in higher-than-normal levels of train vibration.

Vibration is an oscillatory (back-and-forth) motion that can be described in terms of the displacement, velocity, or acceleration of the oscillations. Vibration velocity has been standardized as the metric for evaluating environmental vibration effects on humans. Therefore, vibration in this context usually is expressed in units of inches per second (ips). However, because of the very large velocity range over which typical environmental vibration energy can occur (below .001 to above 1.0 ips), a more convenient decibel scale has been adopted that allows for compression of this large range into a more practical scale. The velocity of vibration is expressed in units of decibels relative to 1 micro-inch per second, and the abbreviation VdB is used for vibration decibels to avoid confusion with sound decibels. The vibration level in most urban areas ranges typically from about 40 to 100 VdB.

Train vibration is almost always characterized in terms of the root-mean-square (RMS) amplitude of the velocity. RMS is a widely used method of characterizing vibration and other oscillating phenomena. It represents the average energy over a short time interval; typically, a one-second interval is used to evaluate human response to vibration. RMS vibration velocity is considered to be the best available measure of potential human annoyance from ground-borne vibration because it is highly correlated with the human body’s response to vibration.

Existing background building vibration usually ranges from 40 to 50 VdB, which is well below the range of human perception. Although the perceptibility threshold is about 65 to 70 VdB, human response to vibration is usually not substantial unless the RMS vibration velocity level exceeds 70 VdB (Figure 4-2). This is a typical level of vibration experienced 50 feet from railroad tracks. Buses and trucks rarely create vibration that exceeds 70 VdB, unless there are large bumps or potholes in the road.

Figure 4-2. Typical Levels of Ground-Borne Vibration



Source: FTA, 2006

4.3 Impact Criteria

There are federal but no state or local noise impact criteria in use for operation of the project. There are several state, county, and local noise regulations and ordinances applicable to construction noise. In general, construction noise is exempt from these standards between 7:00 a.m. and 10:00 p.m.

4.3.1 Federal Noise Impact Criteria

FTA has developed standards and criteria for assessing noise impacts related to transit projects. The standards outlined in the FTA guidance manual *Transit Noise and Vibration Impact Assessment* (FTA, 2006) are based on community reaction to noise.

These standards evaluate changes in existing noise conditions using a sliding scale. The higher the level of existing noise, the less room there is for a project to contribute additional noise.

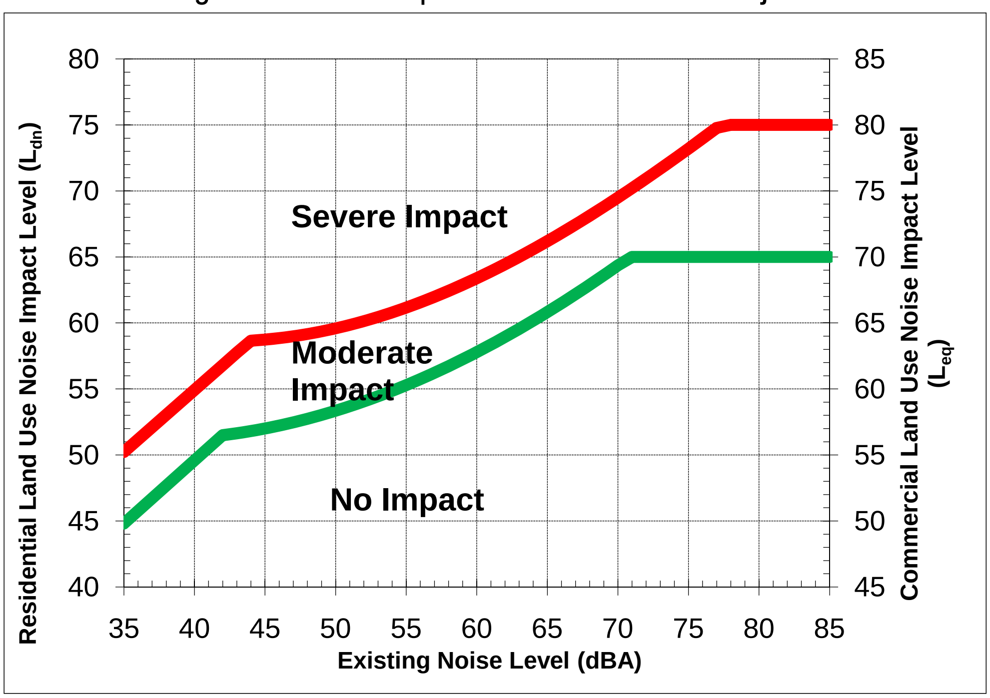
Some land use activities are more sensitive to noise than others; for example, churches, and residences are more noise-sensitive than industrial and commercial areas. The Noise Impact Criteria group sensitive land uses into the following three categories:

- **Category 1**: Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavilions, as well as national historic landmarks with significant outdoor use. Also included are recording studios and concert halls.
- **Category 2**: Residences and buildings where people normally sleep. This includes residences, hospitals, and hotels, where nighttime sensitivity is assumed to be of utmost importance.
- **Category 3:** Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, theaters, and churches where it is important to avoid interference with activities such as speech, meditation, and concentration on reading material. Places for meditation or study associated with cemeteries, monuments, museums, campgrounds, and recreational facilities can also be considered to be in this category. Certain historical sites and parks are also included.

L_{dn} is used to characterize noise exposure for residential areas (Category 2), and maximum one-hour L_{eq} (during the period that the facility is in use) is used for other noise-sensitive land uses such as school buildings (Categories 1 and 3).

Figure 4-3 shows the levels of impact from project noise exposure included in the noise impact criteria.

Figure 4-3. Noise Impact Criteria for Transit Projects



Source: FTA, 2006

The level of impact also affects potential mitigation requirements for a project. Sound Transit follows this policy for determination of impacts on transit and inter-city rail projects for which it is the local lead agency for purposes of environmental review.

- Severe Impact: Project-generated noise can be expected to cause a larger percentage of people to be highly annoyed by the new noise and represents the most compelling need for mitigation. Noise mitigation will normally be incorporated into the project unless there are truly extenuating circumstances that prevent it.
- Moderate Impact: Moderate impacts are associated with changes in the cumulative noise level that are noticeable to most people but may not be sufficient to cause strong, adverse reactions from the community. Project noise levels in the Moderate Impact range will also require consideration and adoption of mitigation measures when it is considered reasonable. While impacts in this range are not of the same magnitude as Severe Impacts, there can be circumstances regarding the factors outlined below that make a compelling argument for mitigation. These other factors can include the predicted increase over existing noise levels, the type and number of noise-sensitive land uses affected, existing outdoor/indoor sound insulation, community views, special protection provided by law, and the cost-effectiveness of mitigating noise to more acceptable levels.

Table 4-1 summarizes the noise impact criteria for commuter and intercity rail operations. The first column of Table 4-1 shows the existing noise exposure, and the remaining columns show the level of impact (Moderate Impact or Severe Impact) for future noise exposure. There would be No Impact if noise levels are below the Moderate Impact noise levels. The future noise exposure is the combination of the existing noise exposure and the additional noise exposure caused by the rail project. As the existing noise exposure increases, the amount of the allowable increase decreases in the overall noise exposure caused by the project.

Table 4-1. Noise Impact Criteria

Existing Noise Exposure Leq or Ldn1	Project Noise Exposure Impact Thresholds: Ldn or Leq1 (all noise levels in dBA)			
	Category 1 or 2 Sites		Category 3 Sites	
	Moderate Impact	Severe Impact	Moderate Impact	Severe Impact
<43	Amb.+10	Amb.+15	Amb.+15	Amb.+20
43-44	52	58	57	63
45	52	58	57	63
46-47	53	59	58	64
48	53	59	58	64
49-50	54	59	59	64
51	54	60	59	65
52-53	55	60	60	65
54	55	61	50	66
55	56	61	61	66
56	56	62	61	67
57-58	57	62	62	67
59-60	58	63	63	68
61-62	59	64	64	69
63	60	65	65	70
64	61	65	66	70
65	61	66	66	71
66	62	67	67	72
67	63	67	68	72
68	63	68	68	73
69	64	69	70	74
70	65	69	70	74
71	66	70	71	75
72-73	66	71	71	76
74	66	72	71	77
75	66	73	71	78
76-77	66	74	71	79
>77	66	75	71	80

Source: FTA, 2006
Notes:
[1]Ldn is used for land uses where nighttime sensitivity is a factor; Daytime Leq is used for land uses involving only daytime activities.
Category Definitions:
Category 1: Buildings or parks where quiet is an essential element of their purpose.
Category 2: Residences and buildings where people normally sleep. This includes residences, hospitals, and hotels where nighttime sensitivity is assumed to be of utmost importance.
Category 3: Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches.

For example, Figure 4-4 and Figure 4-5 show the impact levels for future project noise exposure if the existing noise exposure is 53 dBA. As shown, for residential land use (Category 1 or 2), a Moderate Impact would occur at 55 dBA and a Severe Impact would occur at 60 dBA. For commercial land use (Category 3) a Moderate Impact would occur at 60 dBA and a Severe Impact would occur at 65 dBA.

Figure 4-4. Example Impact Levels with an Existing Noise Exposure Level of 53 dBA

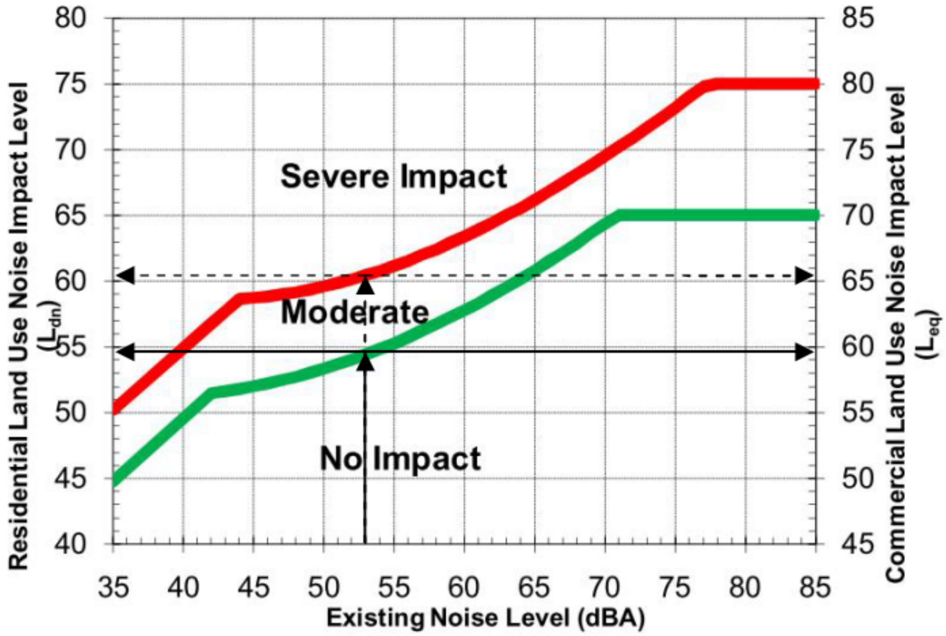
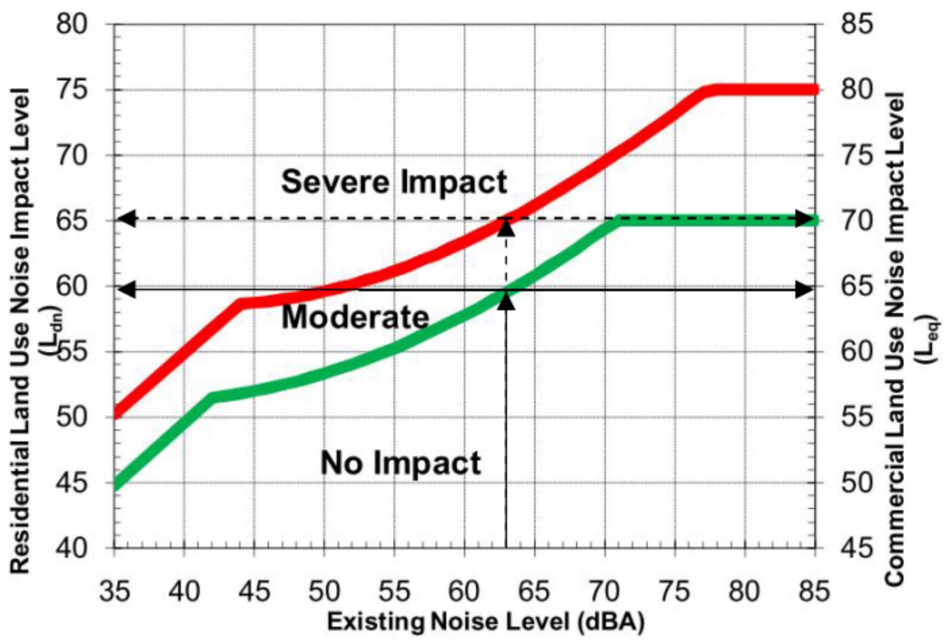


Figure 4-5. Example Impact Levels with an Existing Noise Exposure Level of 63 dBA



4.3.2 State of Washington Noise Criteria

In Chapter 173-60 of the Washington Administrative Code (WAC), the Department of Ecology has adopted Maximum Environmental Noise Levels for residential, commercial, industrial, and construction areas. However, WAC 173-60 states that: “The department conceives the function of noise abatement and control to be primarily the role of local government and intends actively to encourage local government to adopt measures for noise abatement and control. Wherever such measures are made effective and are being actively enforced, the department does not intend to engage directly in enforcement activities.”

4.3.3 City of Lakewood Noise Limits

The City of Lakewood treats noise as a public disturbance and limits sounds originating from construction sites, including, but not limited to, sounds from construction equipment, power tools, and hammering between the hours of 10 p.m. and 7 a.m. on weekdays and 10 p.m. to 9 a.m. on weekends (Lakewood Municipal Code 08.36.010—Noise Control). The City does not have a noise variance process.

4.3.4 Federal Vibration Impact Criteria

FTA has developed impact criteria for acceptable levels of ground-borne noise and vibration (FTA, 2006).

Ground-borne vibration from rail vehicles is characterized in terms of the RMS vibration velocity amplitude, which is a good indicator for the potential for human disturbance. A one-second RMS time constant is assumed. This is in contrast to vibration from blasting and other construction procedures that could cause building damage. When assessing the potential for building damage, ground-borne vibration is usually expressed in terms of the peak particle velocity.

The threshold of vibration perception for most humans is around 65 to70 VdB; levels from 70 to 75 VdB are often noticeable but acceptable; and levels greater than 80 VdB are usually considered unacceptable.

For human annoyance, there is a relationship between the number of events and the degree of annoyance caused by the vibration. It is intuitive to expect that more frequent or longer duration vibration events are more annoying to building occupants. To account for the fact that most commuter rail systems have fewer daily operations than the typical urban transit line, the criteria in *Transit Noise and Vibration Assessment* (FTA, 2006) include an 8-VdB higher impact threshold if there are fewer than 30 events of the same source type per day, regardless of the number of cars per train. Thus, for rail systems with fewer than 30 trains per day, the limit for an acceptable level of residential ground-borne vibration is 80 VdB.

Ground-borne vibration from any type of train operation will rarely be high enough to cause building damage, even minor cosmetic damage. The only real concern is that the vibration will be intrusive to building occupants or interfere with vibration-sensitive equipment.

The vibration of floors and walls may cause a rumble noise within a building. This rumble is the noise radiated from the motion of the room surfaces. In essence, the room surfaces act like a giant loudspeaker. This is called ground-borne noise. Ground-borne noise could result in an impact for underground rail operations. It is not considered for at-grade or above-ground rail operations because the level of airborne noise transmitted through windows or walls would exceed the ground-borne levels.

Table 4-2 summarizes the impact criteria for ground-borne vibration. These criteria are based on previous standards, criteria, and design goals, including the ANSI S3.29 (Acoustical Society of America, 1983) and the noise and vibration guidelines of the American Public Transit Association (APTA, 1981). Some buildings, such as concert halls, television and recording studios, and theaters, can be very sensitive to vibration but do not fit into any of the three categories. Because of the sensitivity of these buildings, they usually warrant special attention during the environmental review of a transit project.

Table 4-2. Ground-Borne Vibration Impact Criteria

Land Use Category	Ground-Borne Vibration Impact Levels (VdB re: 1 micro-inch/sec)		
	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
Category 1: Buildings where low ambient vibration is essential for interior operations	65 VdB[4]	65 VdB[4]	65 VdB[4]
Category 2: Residences and buildings where people normally sleep	72 VdB	75 VdB	80 VdB
Category 3: Institutional land uses with primarily daytime use	75 VdB	78 VdB	83 VdB

Source: FTA, 2006

Notes:

[1] "Frequent Events" are defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
[2] "Occasional Events" are defined as between 30 and 70 vibration events of the same sources per day. Most commuter trunk lines have this many operations.
[3] "Infrequent Events" are defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.
[4] This criterion is based on levels that are acceptable for most moderately sensitive equipment, such as optical microscopes. Vibration-sensitive manufacturing or research uses will require detailed evaluation to define acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC system and stiffened floors.

The vibration impact criteria are a function of the existing conditions within the corridor. For rail corridors that carry more than 12 trains per day, if maximum vibration levels from the project would be no greater than those already experienced, then the project would not cause a vibration impact unless it doubles the number of vibration events (FTA, 2006, Section 8.1.2).

Chapter 9 of the FTA manual provides screening procedures for transit projects, which were used to consider activites in the maintenace shops. A screening distance of 50 feet was selected as appropriate for maintenance shop activities.

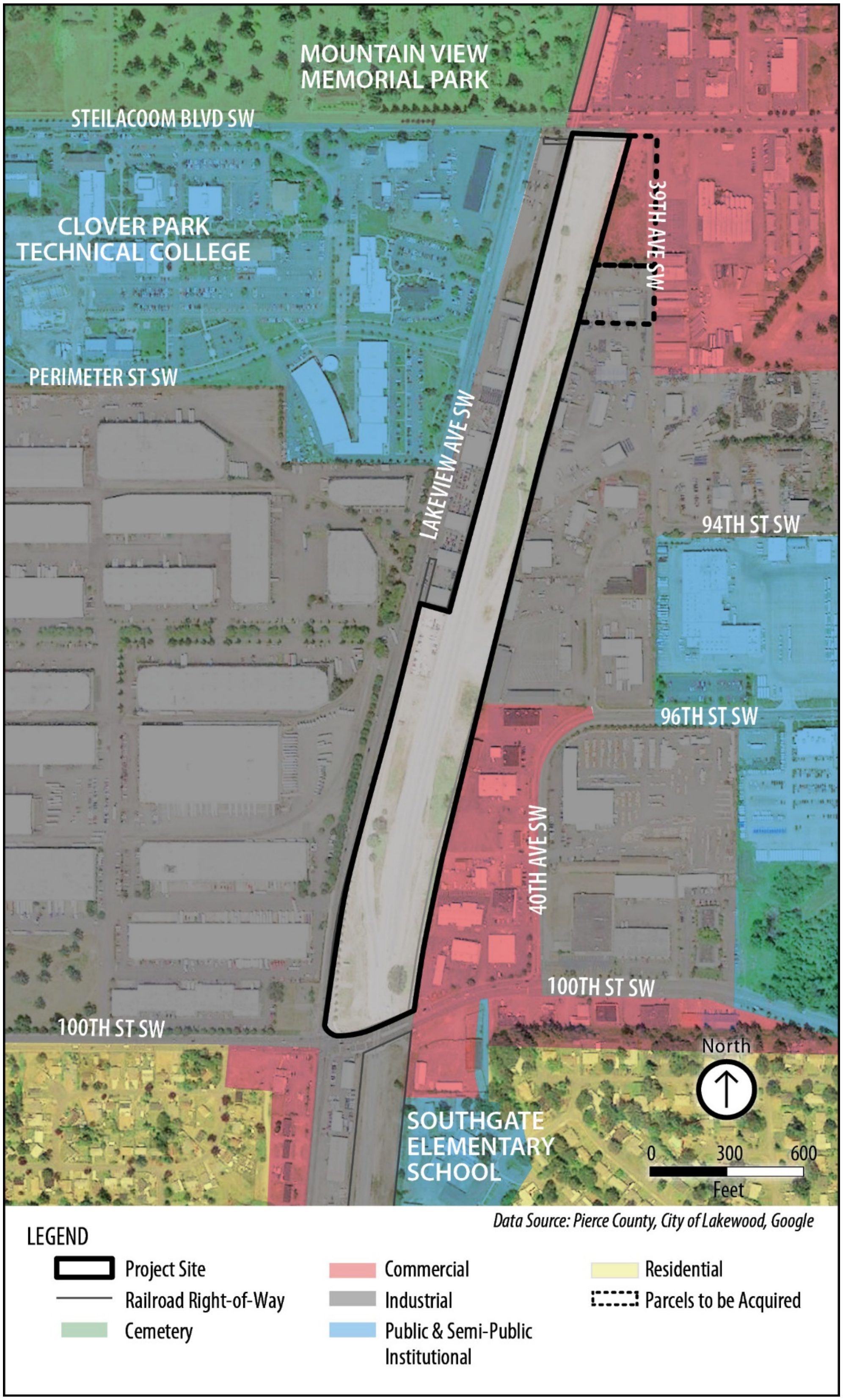
5.0 AFFECTED ENVIRONMENT

5.1 Noise

Potentially noise-sensitive land uses and vibration-sensitive buildings were identified by reviewing previous noise and vibration studies that included the Sounder Yard and Shops Facility Project study area. Field review did not identify any newly constructed land uses. Noise measurements and calculated sound levels using the FTA model were performed for the project and were used to provide a baseline for the analysis of potential noise impacts of the project improvements. Predicted future noise levels in the study area are based on measured and calculated sound levels and future daily rail operations.

The project study area is primarily characterized by adjacent industrial and commercial land uses along with residential and institutional land farther from the project site (Figure 5-1). As shown on Figure 5-1, residences (a FTA Category 2 land use as described in Chapter 4) are located to the south of the project area, south of 100th Street SW and to the east and west of Lakeview Avenue SW. Southgate Elementary School is also located south of the project area and south of 100th Street SW. Clover Park Technical College is located to the west of the project site and Mountain View Memorial Cemetery Park is located to the northwest. The primary daytime uses at both of the schools and the cemetery are included in FTA Category 3 land uses. The measurement and modeling locations include the residences closest to the

Figure 5-1. Land Use Map



Sounder Century Yard and the nearest noise sensitive outdoor uses at Southgate Elementary School and Clover Park Technical College.

The project would use an existing Sound Transit rail corridor currently in use. Ambient conditions in the project area are characteristic of an urban area with nearby train service, local roadway noise, and aircraft noise from nearby Joint Base Lewis-McCord.

5.2 Vibration

The survey of nearby land uses did not identify any vibration-sensitive uses within 50 feet of the tracks. Existing rail operations generate vibration in the corridor, but there is no record of vibration impacts or complaints in the project vicinity.

6.0 PROJECT IMPACTS

6.1 Operation

6.1.1 Noise

Noise exposure levels (the noise level that would be generated by the project, not including other noise sources) were predicted for the three modeled locations. The noise exposure calculations for the hours of 8 p.m. to 4 a.m. included railroad crossing bells and wayside horns operating at 100th Street SW and train movement through yard switches for each of the 12 train movements. The crossing bells were modeled to sound for 8 minutes per hour and the wayside horns to sound for 15 to 20 seconds 2.5 times per hour on average during this time period. As a result of the project, future noise levels are predicted to result in at most a 2 dBA L_{dn} increase compared to existing noise levels at residences south of 100th Street SW. The proposed project is predicted to result in no change in noise levels at Southgate Elementary School and an increase of 1 dBA L_{eq} at Clover Park Technical School.

Multiple transportation-related noise sources and other urban noise sources already exist in the project area. Noise exposure from the project would range between 50 and 59 dBA L_{dn}/ L_{eq} at the modeled noise-sensitive land uses compared to the 60 to 62 dBA L_{dn} existing (Table 6-1).

Table 6-1. Modeled Sound Levels of Project-Related Noise (dBA)

Site # / Name	FTA Land Use Category[1]	Measured Noise Levels 2015[2] (Existing[3])	FTA Thresholds for Moderate/ Severe Impact[4]	Sounder Yard & Shops Facility Project Noise Exposure[5]	Future/ Total Noise Exposure[6]	Calculated Total Noise Increase	FTA Impact with Project? (Moderate or Severe)
Site 1: Clover Park Technical College	3	60 Leq	63-68/ >68	53 Leq	61 Leq	1	None
Site 2: Residences at 101st Street SW	2	60 Ldn	58-63 >63	56 Ldn	61 Ldn	1	None
Site 3: Residences at Lakewood Avenue SW	2	62 Ldn	59-64/ >64	59 Ldn	64 Ldn	2	Moderate
Site 4A: Residences at Rainier Ave S	2	60 Ldn	58-63 >63	55 Ldn	61 Ldn	1	None
Site 4 B: Southgate Elementary School	3	61 Leq	64-69 >69	50 Leq	61 Leq	0	None

Notes:

1 FTA Land Use Categories are described in Chapter 4.

2 Measured noise levels were collected as part of this study.

3 Existing L_{dn} is reported for residential areas; L_{eq} is reported for other noise-sensitive areas.

4 FTA Noise Impact Criteria are L_{dn} or L_{eq} values as appropriate, calculated from Figure 4-3 in Chapter 4.0.

5 Sounder Yard & Shops Facility Project noise exposure includes noise from the increased future transit noise associated with project operations; non-project-related noise sources are not included.

6 Future noise exposure includes noise from the increased future transit noise associated with project operations and non-project-related noise sources.

As shown in Table 6-1, project-generated noise levels are projected to be between 3 and 11 dBA less than measured existing noise levels, which would result in increases of 0 to 2 dBA in total noise levels. Moderate noise impacts under the FTA criteria are predicted to occur at one of the four locations evaluated for the Sounder Yard and Shops Facility Project. This site represents 12 multi-family units located along Lakewood Avenue South and four single family homes located along Kline Street SW. There would be an increase in the frequency of nighttime noise peaks caused by train operations and project-related facilities at the project site. The highest noise levels associated with this project would occur between 8 p.m. and 4 a.m. at Site 3 at residences located south of the crossing at 100th Street SW west of Lakeview Avenue SW, because of the project's maintenance schedule and this site's proximity to the at-grade crossing of 100th Street SW and associated bell and horn noise. FTA moderate noise impact locations are shown in Appendix C.

Future total noise levels near the project site are predicted to increase from existing noise levels of 60 to 62 dBA L_{dn} at the nearest residential locations to 61 to 64 dBA L_{dn}. Noise levels at Clover Park Technical College would increase from 60 to 61 dBA L_{eq}, while the levels at Southgate Elementary School would be unchanged when compared to existing noise levels. Wheel squeal is another potential noise source. Wheel squeal is caused when wheels slip or stick to rails as vehicles negotiate tight radius curves. The low train speed (5 mph in the yard and entering and exiting the yard) and turning radii for train movements entering and exiting the third layover/storage track (1,011 feet, greater than FTA recommended 1,000 feet to avoid wheel squeal) would avoid wheel squeal at the project site.

Load testing would occur approximately 170 times per year during daytime hours except in an emergency, with a typical duration of one-hour for annual inspection. The highest noise level resulting from load testing would be approximately 62 dBA (L_{eq}) at 100 feet which would not result in an impact under FTA criteria.

6.1.2 Vibration

Vibration resulting from the new maintenance building and supporting facilities included in the proposed project was evaluated using Chapter 9: Vibration Screening Procedures contained in the FTA's guidance manual. Vibration impacts from maintenance activities would only occur if vibration-sensitive land uses are located in the immediate vicinity of the project. Operations at the maintenance building and supporting facilities would not generate high vibration levels. There are no vibration-sensitive uses within the 50 foot survey screening distance to project improvements. As discussed in Section 4.3.4, the rail operations would only cause a vibration impact if they doubled existing operations in the vicinity of the yard. The number of daily operations would not double as a result of the project. Therefore, no vibration impacts are predicted to occur as a result of operation of this project.

6.2 Construction

Nearby receptors would experience temporary noise impacts during project construction. No vibration impacts are expected.

6.2.1 Noise

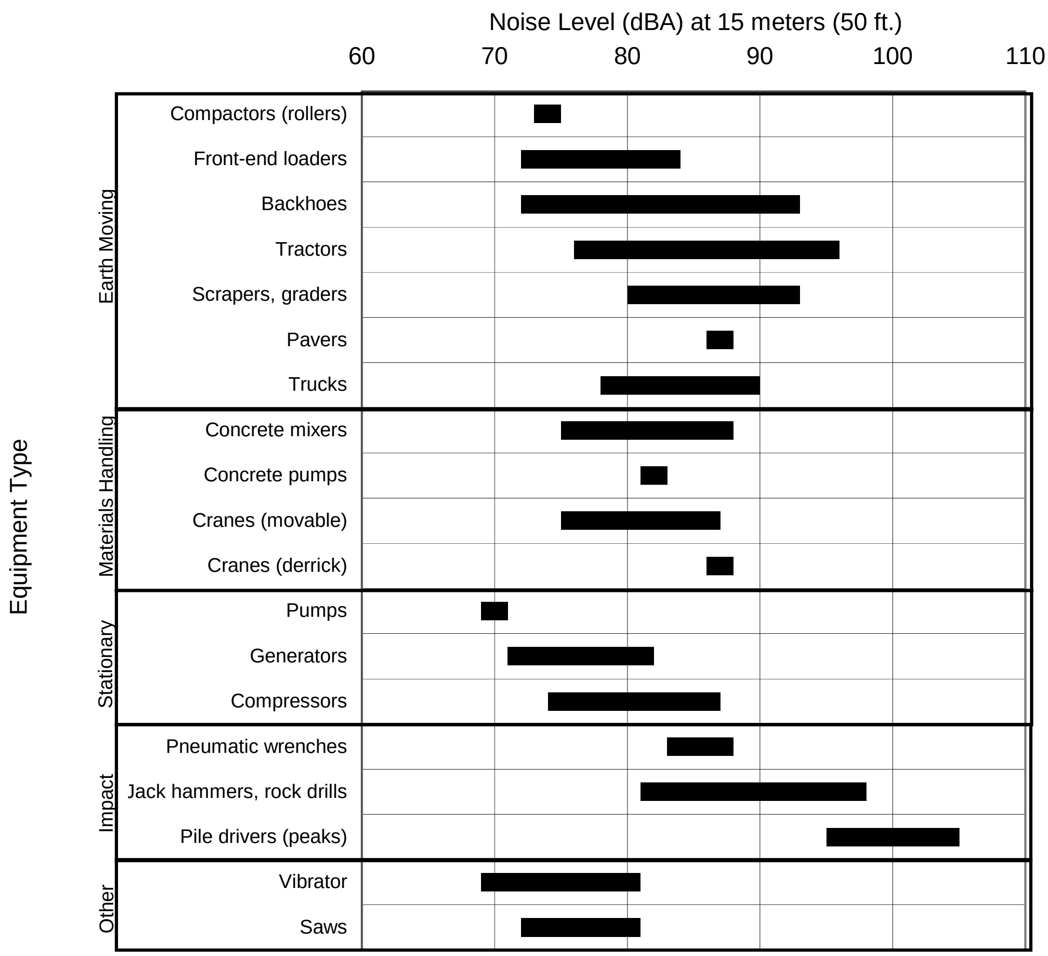
Noise during the construction period could be bothersome to nearby residences. Construction would be carried out in several discrete steps, each with its own mix of equipment and, consequently, its own noise characteristics. Railroad and access road construction would involve clearing, cut-and-fill activities, placing ballast, and installing new track or retrofitting existing track and paving. For the project, the highest construction noise levels would likely be associated with earthmoving typically associated with building and roadway construction. Construction noise is temporary and would vary widely both spatially and time-wise over the course of the project's construction.

The most prevalent noise source at project 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 cyclical fashion, but stationary equipment (e.g., generators and compressors) operates at sound levels that are fairly constant over time. Because trucks would be present during most construction phases and would not be confined to the project site, noise from trucks could affect more receptors.

Construction noise would be intermittent, occurring at various locations on the project site. Construction noise levels would depend on the type, amount, and location of construction activities. The type of construction methods would establish the maximum noise levels of construction equipment used. The location of construction equipment relative to adjacent properties would determine any effects of distance in reducing construction noise levels. The maximum noise levels of construction equipment under the project would be similar to the typical maximum construction equipment noise levels presented in Figure 6-1.

As shown in Figure 6-1, maximum noise levels (L_{max}) from construction equipment would range from 69 to 93 dBA at 50 feet. The closest noise sensitive receiver to project construction is Clover Park Technical School. Construction noise at residences farther away would decrease at a rate of 6 to 8 dBA per doubling of distance from the source. Outdoor areas at the Clover Park Technical School, Southgate Elementary, and the nearest homes south of 100th Street SW are estimated to experience temporary maximum construction equipment noise from the 50's dBA to 80's dBA depending on the types of equipment in use. 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 Figure 6-1.

Figure 6-1. Construction Noise Levels



Source: EPA, 1971; WSDOT, 1991

Construction would occur predominantly during daytime hours, however some nighttime construction may occur. Construction noise is exempt from regulations during daytime hours. Nighttime construction may require coordination with the City of Lakewood and the Contractor. Construction noise levels could be reduced by implementing the construction practices identified in Chapter 7.

6.2.2 Vibration

Common vibration-producing equipment used during above-ground construction activities includes bulldozers, backhoes, and ballast tampers. Pavement breaking and soil compaction would probably produce the highest levels of vibration. Table 6-2 shows types of construction equipment measured under a variety of construction activities, and includes an average of source levels reported in terms of velocity levels. Although the table lists one velocity level for each piece of equipment, considerable variation exists in reported ground-vibration levels from construction activities. The data provide a reasonable estimate for a wide range of soil conditions.

Table 6-2. Vibration Source Levels for Construction Equipment

Equipment		Peak Particle Velocity at 25 feet (in/sec)	Approximate Lv at 25 feet (VdB)
Clam shovel drop (slurry wall)		0.202	94
Hydromill (slurry wall)	In soil	0.008	66
	In rock	0.017	75
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58

Source: FTA, 2006
Notes:
Lv = RMS velocity in decibels (VdB) re 1 micro-inch/sec
RMS = The square root of the mean-square value of an oscillation waveform.

Vibration is usually measured as a root-mean-square velocity level L_v, which is reported in velocity decibels (VdB) referenced to a vibration level of 1 micro inch/second. Humans can perceive vibration levels above approximately 65 VdB. Heavy construction equipment such as large bulldozers and loaded trucks frequently generates between 85 and 87 VdB at 25 feet. The threshold for minor damage to fragile buildings is approximately 100 VdB. Buses and trucks frequently generate approximately 65 VdB at 25 feet.

No potentially fragile buildings are located within 25 feet of proposed construction activities; therefore, no vibration damage is expected to buildings during construction.

Limits on construction activities discussed in Chapter 7 would minimize the risk of vibration impacts during construction.

6.3 Cumulative

Multiple transportation-related noise sources and other urban noise sources already exist in the project area, generating an existing 60 to 62 dBA L_{dn} (Table 6-1). Independent of the Sounder Yard and Shops Facility Project, noise levels would increase compared to existing conditions between 4 a.m. and 7 a.m. and between 5 p.m. and 8 p.m. based on the future operation schedule. Cumulative noise levels would range between 61 and 64 dBA L_{dn} including both the effects of the project and other noise sources (Table 6-1). The project would not have a cumulative effect on vibration levels at any vibration-sensitive locations.

7.0 MITIGATION

7.1 Operation

7.1.1 Noise

Moderate noise impacts under the FTA criteria are predicted to occur at one of the four locations (Site 3 of Figure 3-1) evaluated for the project. This site represents 12 multi-family residences and 4 single-family homes. The impacts would result from warning devices sounded at the 100th Street SW crossing during nighttime hours. Because the impacts would result from safety devices located at a roadway crossing, constructing barriers to shield residences from noise is not possible while maintaining access to the crossing and continuing to provide an audible warning to approaching traffic. Instead, residential sound insulation would be evaluated for the 12 apartment units and 4 single-family homes that would experience moderate impacts and offered at properties where the existing building does not already achieve a sufficient exterior-to-interior reduction of noise levels. During final design, all predicted noise levels and mitigation measures would be reviewed. If equivalent mitigation can be achieved by a less costly means, such as operational changes, or if the final design analysis shows no impact, then the mitigation measure may be modified or eliminated.

7.1.2 Vibration

No mitigation is proposed because no impacts are expected.

7.2 Construction

7.2.1 Noise

The contractor would be required to comply with local noise regulation. Nighttime work (10:00 p.m. to 7:00 a.m. weekdays and 10:00 p.m. to 9:00 a.m. weekends) is regulated by the City of Lakewood as a public disturbance (City of Lakewood Noise Control Ordinance 08.36.010). The City of Lakewood does not have a noise variance process. If construction occurred during nighttime hours, noise control measures could be implemented as necessary to reduce potential effects of construction noise.

- Construction hours could be set, and construction activity noise level emission criteria could be determined and compliance required during construction.
- Natural and artificial barriers (e.g., ground elevation changes and existing buildings) could be considered for use as shielding against construction noise.
- Noisier activities involving large machinery could be limited to daytime hours as practical.
- Stationary construction equipment should be placed as far away from sensitive receiving locations as possible.

7.2.2 Vibration

No mitigation is proposed because no vibration damage is expected to buildings during construction.

8.0 REFERENCES

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Appendix A

Sounder Century Yard Train Operations

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APPENDIX A

Sounder Century Yard Train Operations

Yard-to-Shop Train Movement for Maintenance

Sounder trains are stored at the Century Yard in Lakewood overnight for cleaning and light maintenance and redeployment the following morning; or they are staged for movement into the shop for preventive or unscheduled maintenance. Performing maintenance at the shop would require the equipment (passenger cars and locomotives, referred to as units here) to move from the storage tracks to the shop and, once having completed maintenance, to move from the shop back to the storage tracks in the yard. With newly maintained equipment, the trains would be put on the storage tracks for the next day's service.

Figure 1 depicts the movements required for the units from one train. Moving from the storage tracks in the yard to the shop, the train would head south on the mainline track and onto the island circuit, causing the signal and gates at 100th Street SW to activate. The train would cross 100th Street SW and travel beyond the island circuit to deactivate the signal and gates, then pause to allow any traffic queued on 100th Street SW to clear. Once the queue is clear, the train would head north reactivating the island circuit causing the gates to descend. The train would re-cross 100th Street SW and enter the shop on the shop lead track. This operation would be reversed to move the train from the shop to the storage tracks in the yard. Each maintenance train movement would require four crossings of 100th Street SW, stopping traffic for approximately 3 minutes each time.

Maintenance Types and Frequency

The Sounder shop would handle two types of maintenance: preventive maintenance and unscheduled maintenance. Preventive maintenance is maintenance regularly scheduled in accordance with the Federal Railroad Administration mandates. Sound Transit anticipates six units would require preventive maintenance each week, with three units taken out of service on one day of the week and three more taken out of service on a second day of the week.

Unscheduled maintenance consists of unanticipated repairs to cars or locomotives. The scope and number of units requiring unscheduled maintenance would vary. Historical data indicates an average of two units per week would require movement into the shop for unanticipated repairs. The worst case to date has been four units in one week.

Number of Maintenance Train Crossings at 100th Street SW

Preventive maintenance of the six units per week would occur in groupings of three units that have been assembled into one train in the south Seattle yard prior to reaching Century Yard. Moving each preventive maintenance train would require four crossings of 100th Street SW. Two preventive maintenance trains each week would require eight crossings of 100th Street SW each week.

Units needing unscheduled maintenance would generally not be within the same train. Therefore, the units would be moved between the storage tracks in the yard and the shop in separate movements, which equates to four crossings of 100th Street SW for each unit needing repair. With a maximum of four units needing repair per week, that equates to 16 crossings per week. The maximum number of crossings of 100th Street SW in one week would therefore be 24, as shown in Table 1.

Figure 1: Site Plan of Crossings at 100th Street SW

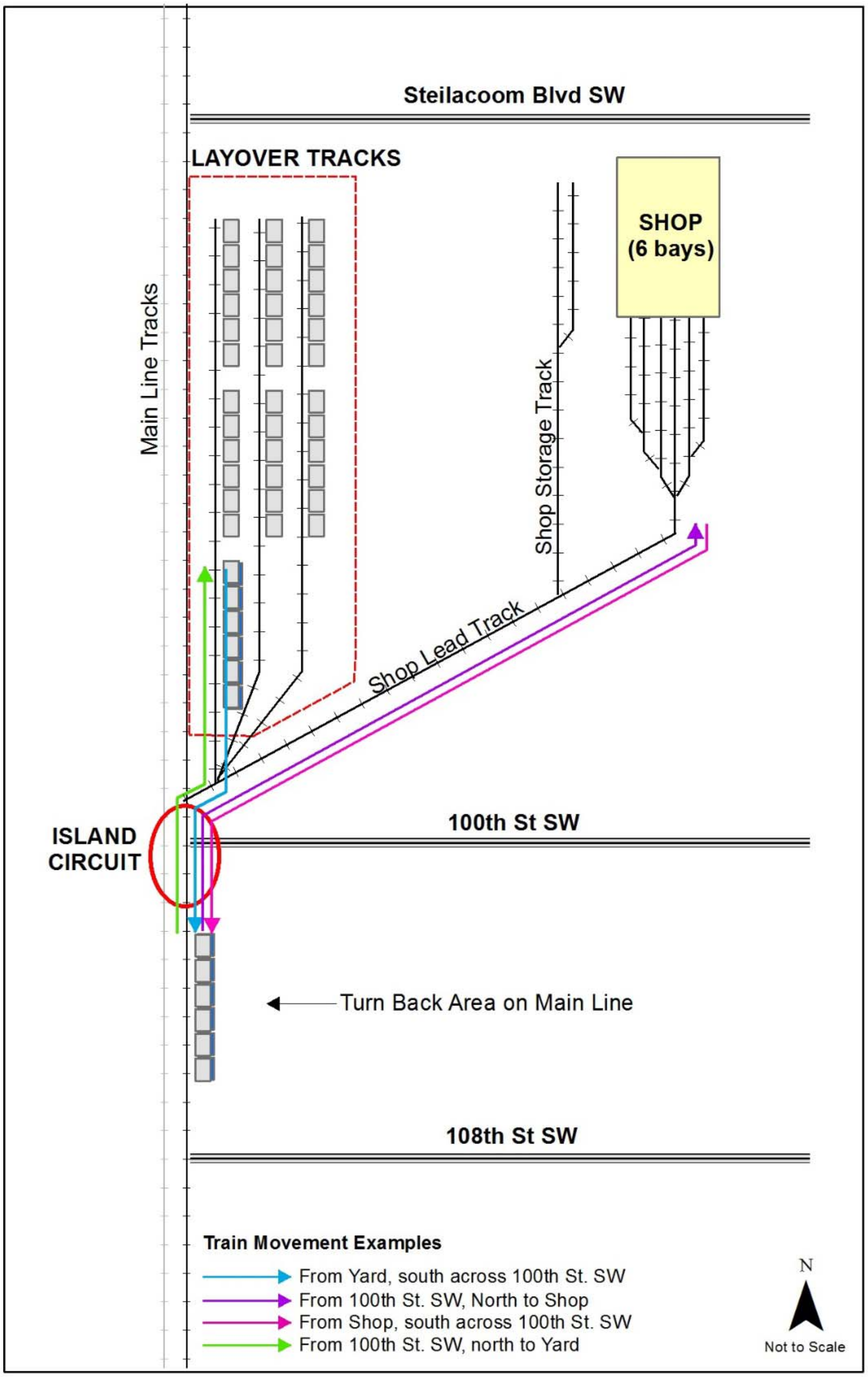

Table 1: Number of Maintenance Train Crossings at 100th Street SW

Per Week		**Per Night**	
No. of Units	**Total Crossings** (4 per train)	**No. of Units**	**Total Crossings** (4 per train)
2 (PM)[1]	8	1 (PM)	4
4 (UM)	16	2 (UM)[2]	8
Total: 6	**Total: 24 max.**	**Total: 3**	**Total: 12 max.**
KEY PM= Preventative Maintenance UM= Unscheduled Maintenance for repairs			
Notes: 1) 3 units requiring PM on one train 2) Assumed the average of 2 UM per week occur on 1 night.			

Because potential traffic and noise impacts require assessment on a daily rather than weekly basis, Sound Transit estimated the maximum number of crossings of 100th Street SW per night assuming that train movements included one preventive maintenance train and the week's average unscheduled maintenance. This assumption provides a conservative worst-case scenario for impact analysis of up to 12 crossings of 100th Street SW per night as depicted in Table 1. In actual operations, preventative maintenance and unscheduled maintenance would most likely occur on different nights, resulting in a lower number of crossings per night on average.

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Appendix B

Century Yard—Sounder Yard and 100th Street SW Crossing Sound Levels

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MEMO

TO:	Shankar Rajaram, Sound Transit
FROM:	Patrick Romero and Lawrence Spurgeon, Parsons Brinckerhoff
SUBJECT:	Century Yard - Sounder Yard and 100th Street SW Crossing Sound Levels
DATE:	October 22, 2015

In support of the Sounder Commuter Rail Yard and Shops Facilities Project, noise measurements of Sounder train yard operations and crossings of 100th Street SW were conducted to characterize sound levels of Sound Transit's existing operations.

Century Yard Operational Sound Measurements

On July 30, 2015, sound level measurements were conducted of train operations within Century Yard. A Type I sound level meter was located 15 feet from the centerline of the tracks (Figure 1). Measurements were taken of the train horn of a stationary train before it moved, then of a train pulling in, idling, and shutting down. The measurement results are summarized in Table 1.

Figure 1. Sound Level Measurement Location in Century Yard

Table 1. Century Yard Sound Level Measurements

Time	Duration	Activity	Lmax	Leq
5:39 P.M.	0:00:11	Train horn sounded	120.9*	97.9
6:45 P.M.	0:01:58	Train movement on storage track	96.9	72.3
6:50 P.M.	0:01:32	Train idiling on storage track	97.4	79.8
6:53 P.M.	0:03:48	Train stopped, brake release, shutdown cycle	106.9	75.0

* Train horn sounding was measured from 15 feet to the side of the locomotive.

Grade Crossing Sound Measurements

On September 3, 2015, sound level measurements were conducted of grade crossings at 100th Street SW. Type I sound level meters were located on the sidewalk 50 feet east and west of the crossing gates and wayside horns (Figure 2). Measurements were taken to characterize the sound levels of the crossing bells, wayside horns, and the train crossing through the grade. The measurement results are summarized in Table 2. At 100th Street SW, the crossing warning devices, including bells, gates, and wayside horn, were observed to activate twice with each mainline train pass, activating 20 seconds prior to the train reaching the crossing, gate and bells continuing to operate until the train cleared the crossing, gate opening after the train cleared the crossing, then activating a second time after the train moved away from the crossing.

Figure 2. Sound Level Measurement Locations at 100th Street SW

Table 2. 100th Street SW Sound Level Measurements

Time	Duration	Activity	Lmax dBA	Leq dBA
Measurement 50 feet east of wayside horns				
6:59 P.M	0:00:02	Crossing bells	87	70.9
6:59 P.M	0:00:33	Wayside horns	101.1	97.4
7:00 P.M.	0:00:55	Train crossing through grade crossing[1]	90.3	69.3

[1]Measurement did not include train horn because wayside horns were in use.

Appendix C

FTA Moderate Noise Impact Locations

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APPENDIX C

Figure C-1. FTA Moderate Noise Impact Locations

Table C-1. Noise Evaluation and Impact Summary Table

Modeled Site / Location	Impact Summary		
	Moderate Impacts	Severe Impacts	Description of Moderate Impact Location
Site 1: Clover Park Technical College	0	0	None
Site 2: Residences at 101st St SW	0	0	None
Site 3: Residences at Lakeview Ave SW	7	0	3 MF (4-unit buildings) on Lakeview Ave SW 4 SFRs on Kline St SW
Site 4A: Residences at Rainier Ave S	0	0	None
Site 4B: Southgate Elementary School	0	0	None

Notes:
SFR – single-family residential building
MF – multi-family residential building