Exhibit ST-15

Lynnwood Link Extension | Northgate Station to Lynnwood Transit Center
Contract No. RTA/AE 0010-15

Contract L300M
Construction Noise, Vibration and Groundborne Noise Report
100pct Submittal

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Prepared for:

SOUNDTRANSIT

Prepared by:

HNTB Jacobs trusted design partners

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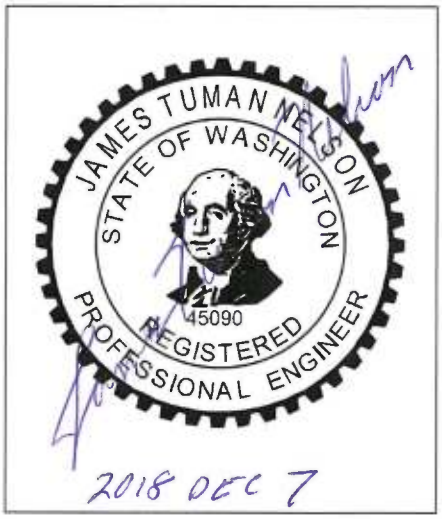

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1.0 INTRODUCTION

This report outlines the existing construction noise criteria for the various jurisdictions along the Lynnwood Link Extension corridor, briefly describes the existing sound environment along the alignment, and summarizes potential construction noise sources and mitigation options. This report provides guidelines for the GC/CM to assess, monitor, and control construction noise and vibration to meet the stated criteria. The sound and vibration levels for equipment typically used for the construction of heavy civil projects are provided.

Criteria or regulations that may apply to construction noise and vibration were taken from published information provided by Sound Transit, the FTA, the State of Washington, the City of Shoreline, the City of Mountlake Terrace, and the City of Lynnwood. The Washington State code serves as the basis for the ordinances adopted by the local jurisdictions. All three cities generally apply the state noise code and the City of Shoreline has recently added a specified variance process. Existing noise levels in the corridor are summarized, though none of the state and local criteria are based on ambient noise levels. FTA states that construction noise should not exceed the existing ambient by more than ten decibels.

In general, construction noise control requirements are established by the local Authority Having Jurisdiction (AHJ), and only apply during non-exempt hours (i.e., nighttime) defined in the ordinances and permits issued for the project. High-energy construction vibration activity such as pile-driving and vibratory soil compaction must be monitored and controlled at all times where there is the potential for damage to nearby structures. Requirements for the monitoring and control of construction noise and vibration are included in Contract Specification 01 57 15.

In this discussion, the Equivalent Level (L_{eq}) metric is the time-averaged A-weighted noise level computed over the specified time period, and the Day Night Level (L_{dn}) is the day-night average noise level computed over a 24-hour period with a +10 decibel "penalty" added to noise levels occurring between 10 pm and 7 am. A-weighting is a standard frequency filter applied to the noise spectrum to approximate the typical response of people.

2.0 SOUND TRANSIT DESIGN CRITERIA

The Sound Transit Link Design Criteria Manual, March 2016, Revision 4 – Chapter 3 Noise and Vibration states the following regarding noise and vibration during construction:

"For noise and vibration generated during construction, local codes should be followed where applicable. The FTA 2006 Manual (VA-90-1003-06) Chapter 12 provides guidance for assessment, criteria, and mitigation development where local codes do not exist or apply."

Section 12.1.3 of the referenced 2006 FTA Transit Noise and Vibration Impact Assessment manual addresses Construction Noise Criteria. No standardized criteria are put forth and the manual states that, when no local ordinances apply, criteria should be project-specific and "should take into account the existing noise environment, the absolute noise levels of the construction activities, the duration of the construction, and the adjacent land use." FTA proposes construction noise criteria for residential land use of 80 dBA 8-hour L_{eq} for daytime, 70

dBA 8-hour L_{eq} for nighttime hours, and a 30-day average of 75 dBA L_{dn}. Furthermore, for areas with high ambient noise levels (L_{dn} > 65 dBA), which is true of many of the residential areas adjacent to I-5, the L_{dn} from construction operations should not exceed the existing ambient level by more than 10 dBA. Noise measurements in the corridor indicate that the first and second row of homes adjacent to I-5 currently experience an ambient noise environment in excess of 70 dBA L_{dn}.

For the Lynnwood Link Extension, project-specific criteria are established by the AHJs in their ordinances, permits, and variances, if needed.

2.1 Washington Administrative Code

The Washington Administrative Code (WAC) Chapter 173-60-40 provides maximum permissible environmental noise levels for different land usage, called Environmental Designation for Noise Abatement (EDNA). Construction noise is generally exempt from the WAC for work performed during daytime hours. The WAC limits are shown in Table 1.

Table 1: Washington State Noise Control Regulation

EDNA OF NOISE SOURCE	EDNA OF RECEIVING PROPERTY (Maximum allowable noise level)		
	Class A: Residential	Class B: Commercial	Class C: Industrial
Class A: Residential	55 dBA	57 dBA	60 dBA
Class B: Commercial	57 dBA	60 dBA	65 dBA
Class C: Industrial	60 dBA	65 dBA	70 dBA

Between 10 pm and 7 am, the levels given above are reduced by 10 dBA in Class A EDNAs.

The WAC contains short-term exemptions to the property line noise standards based on the minutes per hour that the noise limit is exceeded, as indicated in Table 2.

Table 2: WAC Short-Term Noise Exemptions for Property Line Noise Levels

Minutes per hour	Adjustment to Maximum Sound Level
15	+ 5 dBA
5	+10 dBA
1.5	+15 dBA

2.1.1 WAC Construction Noise Criteria

Sounds received in Class A EDNAs that originate from construction sites are exempt from the limits of the WAC regulations during normal daytime hours (7:00 am to 10:00 pm). If construction is performed during the nighttime, the contractor must still meet the WAC noise-level requirements for sounds received in Class A EDNAs, as presented in Tables 1 and 2, or obtain a noise variance from the governing jurisdiction. The WAC also contains a set of construction-specific allowable noise-level limits. These construction noise regulations are organized by type of noise and, among other things, include haul trucks and back-up safety alarm criteria.

A) Haul Truck Noise Criteria

Maximum permissible sound levels for haul trucks on public roadways are limited to 86 dBA for speeds of 35 miles per hour (mph) or less, and 90 dBA for speeds over 35 mph when measured at 50 feet (Chapter 173-62, WAC). For trucks operating within staging areas, the general construction equipment noise criteria would be used to determine compliance during nighttime hours in Class A EDNAs.

B) Noise Related to Back-up Alarms

Tonal sounds created by back-up alarms are prohibited by the WAC during nighttime hours (10:00 pm and 7:00 am) in Class A EDNAs. Other forms of back-up safety measures may be used, such as broadband alarms (as opposed to tonal), or switching off back-up alarms and using human spotters.

2.2 City of Shoreline

The City of Shoreline recently passed Ordinance No. 818 which repeals the Municipal Code Chapter 9.05 Public Disturbance Noise in its entirety and replaces it with Chapter 9.05 Noise Control. The Ordinance was passed by the City Council on April 16, 2018 and went into effect on August 1, 2018, and will therefore apply to the Lynnwood Link Extension Project.

The new ordinance establishes maximum permissible noise levels consistent with the WAC criteria (Table 1), and allows short term deviations of higher noise levels (Table 2). The ordinance indicates that “sounds created by construction and emanating from construction sites” are exempt from the provisions of the ordinance when generated between the hours of 7:00 am and 10:00 pm on weekdays, and between 9:00 am and 10:00 pm on weekends. However, construction noise produced outside of these hours are considered unlawful “public nuisance noise”.

The ordinance also includes a provision for granting noise variances if compliance cannot be achieved due to economic or physical factors. The variance can be related to permitted activity such as the Special Use Permit. For the Lynnwood Link project, the variance application shall include descriptions of the construction activity to be performed and expected noise levels, the reason for the variance request, and proposed interim noise control measures.

2.3 City of Mountlake Terrace

The City of Mountlake Terrace regulates noise pursuant to Chapter 8.20 of its Municipal Code, Regulation of Noise and Sound that primarily addresses public nuisance. The City of Mountlake Terrace does not have any quantified noise level limits that are similar to those contained in the WAC. Elements of the code that would apply to construction noise are addressed below.

2.3.1 Construction Noise Criteria

Sounds originating from construction sites as a result of construction activity are considered a nuisance when performed between 10:00 pm and 7:00 am (City of Mountlake Terrace Municipal Code Section 8.20.010(D)(2) and (D)(3)). Hence, sounds from construction activities are exempt every day of the week between 7:00 am and 10:00 pm. In addition, *"loud and frequent, repetitive or intermittently continuous sounds made in connection with the starting, operation, repair, rebuilding or testing of any motor vehicle"* are considered a nuisance. The City of Mountlake Terrace regulates Essential Public Facilities pursuant to Chapter 18.15 of the City of Mountlake Terrace's Municipal Code, and one of the purposes of this chapter is to ensure that such facilities are subject to reasonable conditions for noise (City of Mountlake Terrace Municipal Code Section 18.15.010). The City of Mountlake Terrace does not have any laws or regulations that address construction noise variances.

2.4 City of Lynnwood

The City of Lynnwood primarily regulates noise pursuant to Chapter 10.12 of its Code, Noise, which states maximum permissible environmental noise levels requirements that are similar to those contained in the WAC (City of Lynnwood Municipal Code Section 10.12.500). In addition, City of Lynnwood Municipal Code Section 17.05.070, Environmental Health, authorizes a responsible official to *"require applicants for city permits to provide documentation by a qualified consultant that the project will not exceed noise standards or violate nuisance regulations pertaining to noise, and provide recommendations from such a consultant as to how noise can be minimized. The responsible official is authorized to condition or deny projects which would violate state and local standards."* Sounds that are exempt at all times from the maximum permissible sound levels include *"Sounds created by warning devices not operating continuously for more than 5 minutes, or bells, chimes, and carillons,"* (City of Lynnwood Municipal Code Section 10.12.500(F)(4)).

2.4.1 Construction Noise Criteria

Sounds originating from construction sites as a result of construction activity are exempt on every day of the week from the City of Lynnwood environmental noise level requirements at all times in Class B and C EDNAs, and between 7:00 am and 10:00 pm in Class A EDNAs (Lynnwood Municipal Code Section 10.12.500(E)).

In addition, section 10.12.500(G) states *"Nothing in these exemptions is intended to preclude the community development director from requiring installation of the best available noise abatement technology consistent with economic feasibility."*

The City of Lynnwood does not have any laws or regulations that specifically address construction noise variances.

3.0 EXISTING ENVIRONMENTAL NOISE LEVELS

During the environmental phase of this project, a total of 59 noise measurements were made throughout the corridor to characterize the existing noise environment. These included 45 long-term measurements (more than 24 hours) and 14 short-term measurements (15 minute samples). The existing environmental noise levels measured in the project corridor, as measured and reported in the Lynnwood Link Extension Final Environmental Impact Statement (FEIS) Noise and Vibration Technical Report dated April 2015, were in the range of 56 to 81 dBA L_{dn} with peak-hour levels of 51 to 78 dBA L_{eq}.

Additional noise measurements were conducted to supplement the data gathered during the environmental phase. A total of 6 long-term and 11 short-term measurements were made. Measured noise levels ranged from 63 to 80 dBA L_{dn} with peak-hour levels of 59 to 78 dBA L_{eq}. Hourly noise levels during nighttime hours were typically in the range of 55 to 65 L_{eq} depending on location. The minimum nighttime noise levels were generally greater than 50 dBA.

The noise levels at the first and second row of homes adjacent to I-5, where most of the construction activity will take place, are generally in excess of 70 dBA L_{dn}. As such, the ambient noise levels at the residences closest to the construction activity will in many cases be significantly greater than the baseline noise criteria put forth in the WAC. None of the noise ordinances described above take into account the existing noise environment and present only absolute noise level limits.

4.0 CONSTRUCTION NOISE LEVELS

Construction will occur on a 24-hour basis, with most work being performed during exempt daytime hours. Grading along the alignment and station construction will be performed during the day, along with the drilled shafts to prepare the foundations along elevated sections. The delivery and installation of the guideway girders will be performed at night, and the necessary equipment may be limited to cranes and generators to power lighting. In general, construction activities will be scheduled so that quieter activities will be reserved for nighttime hours.

Construction will require the temporary use of noise-generating equipment. The equipment to be utilized during construction is still under consideration, but is assumed to be similar to that typically used for heavy civil projects. The expected equipment noise levels listed in the FHWA *Roadway Construction Noise Model User's Guide* (FHWA 2006) are provided here for reference. Table 3 provides the reference maximum (L_{max}) noise level at a distance of 50 feet. The L_{max} is the highest noise level, averaged over 1 second, detected within the duration of measurement.

Table 3: Maximum Construction Noise Levels (FHWA)

Construction Equipment	Reference L_{max} at 50 feet (dBA)
All Other Equipment > 5 horsepower	85
Air Compressor	80
Backhoe	80
Compactor	80
Crane	85
Dozer	85
Drill Rig	84
Dump Truck	84
Excavator	85
Generator (>25 kVA)	82
Grader	85
Jackhammer	85
Paver	85
Pile Driver	101
Pneumatic Tools	85
Roller	85
Vacuum Excavator	85
Welder	73

The equipment presented in Table 3 will not be operated continuously, nor will the equipment always operate simultaneously. Usage factors account for the fact that equipment is not always operated at full throttle conditions, and are applied irrespective of workday duration. Typical usage factors for construction equipment were obtained from the FHWA user's guide and applied to the equipment sound levels. This provides an average sound level that would occur during a typical workday. Table 4 provides the construction sound levels adjusted to reflect a typical workday calculated at various distances out to 1,000 feet, and expressed in terms in the equivalent noise level (L_{eq}) averaged over the course of a shift or duration of a specific activity.

Table 4: Typical Construction Noise Levels (L_{eq})

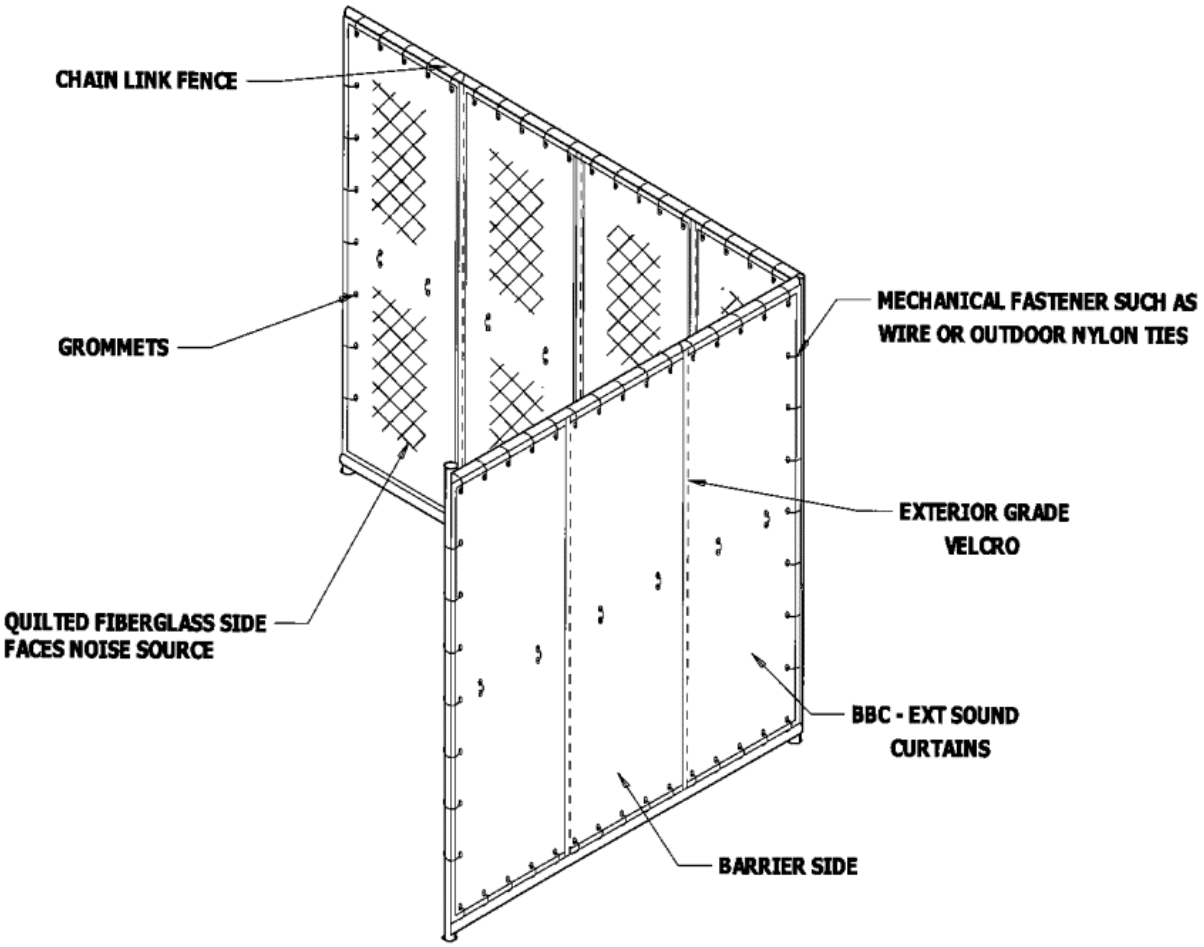
Construction Equipment	50 feet	100 feet	200 feet	500 feet	1000 feet
All Other Equipment > 5 horsepower	82	76	70	62	56
Air Compressor	76	70	64	56	50
Backhoe	76	70	64	56	50
Compactor	73	67	61	53	47
Crane	77	71	65	57	51
Dozer	81	75	69	61	55
Drill Rig	77	71	65	57	51
Dump Truck	80	74	68	60	54
Excavator	81	75	69	61	55
Generator (>25 kVA)	79	73	67	59	53
Grader	81	75	69	61	55
Jackhammer	78	72	66	58	52
Paver	82	76	70	62	56
Pile Driver	94	88	82	74	68
Pneumatic Tools	82	76	70	62	56
Roller	78	72	66	58	52
Vacuum Excavator	81	75	69	61	55
Welder	69	63	57	49	43

5.0 CONSTRUCTION NOISE BARRIERS

For construction activity at a fixed location expected to occur for longer periods, or where existing highway noise walls will be temporarily removed for construction, a temporary noise barrier would be appropriate. One common method is to suspend acoustical curtains on portable sections of chain link fence or pipe frame. The blankets must have significant mass in order to block sound effectively. The curtains should include a layer of limp dense material, typically mass-loaded vinyl of at least 1 lb per square foot, and a layer of sound-absorbing material such as open-cell foam or 1.5 lb per cubic foot glass fiber. The absorptive side of the curtains should face the noise source. The curtains should be sealed in a thin, weatherproof cover material and incorporate grommets for attachment to the fence. Sheets of ¾ inch thick plywood may be used in place of the acoustical curtains. Barriers should be assembled so that gaps are minimized. Below are links for example acoustical curtains. An example mobile fence/curtain assembly is shown in Figure 1.

- http://www.acousticalsurfaces.com/curtan_stop/sound_blanket.htm
- https://acousticalsolutions.com/product/abbc-13-ext-audioseal-exterior-sound-blanket/
- http://www.construction-noise.com/BBC-ext-n.html

Figure 1: Example of Temporary Construction Noise Barrier Assembly



DETAIL: SOUND CURTAINS ATTACHED TO CHAIN LINK FENCE

5.1 Existing Highway Noise Wall Demolition

Three sections of existing highway noise walls in Mountlake Terrace conflict with the future alignment or construction access requirements and will be removed during construction. These highway traffic walls will be replaced within three years of removal. Removing these walls would expose receptors to increased sound levels from traffic on I-5. Long term temporary sound barriers are proposed to protect those receptors. The proposed long term temporary sound barriers may partially mitigate both traffic noise and construction noise impacts, and are proposed in addition to the aforementioned construction barriers. Descriptions and graphics depicting the proposed temporary barriers are provided in the L300E IFC Construction Noise Vibration and Groundborne Noise Report.

In some cases, the proposed temporary noise barrier approach may be ineffective, especially for receptors with upper story bedrooms. These receptors will be identified prior to demolition of the existing highway noise walls, and will be considered for receiver-based treatment. This typically involves covering exposed windows and doors with acoustic blankets and providing a ventilation system.

6.0 CONSTRUCTION VIBRATION

6.1 Construction Vibration Criteria

Construction vibration from activities such as pile-driving and vibratory soil compaction, unlike vibration from train operations, has the potential to damage nearby structures. Because of this factor, the construction vibration discussion includes both damage criteria and annoyance impact criteria.

Damage Criteria: Table 5 presents threshold cracking damage criteria for visible cracking in building surfaces for a range of building types. Threshold cracking is also known as cosmetic cracking to emphasize that it refers to non-structural damage. Cosmetic cracking commonly occurs in homes due to sources other than construction such as the heating expansion and cooling contraction that occurs over the course of 24 hours, minor foundation shifting, settlement, etc. Vibration measurements for damage assessment are cast in terms of the peak particle velocity (PPV) of the ground. The approximate corresponding root-mean-squared (rms) vibration level expressed in decibels is also included in Table 5. The majority of the residential receptors in the vicinity of the project guideway will fall into the Building Category III structure. Vibration that does not exceed the threshold cracking criteria for cosmetic damage does not cause structural damage. Thus, threshold cracking criteria will be used as the main building damage criteria.

Table 5: Threshold Cracking Damage Criteria

Building Category	PPV (in/sec)	Approximate L_v[a]
I. Reinforced concrete, steel, or timber (no plaster)	0.50	102
II. Engineered concrete and masonry (no plaster)	0.30	98
III. Non-engineered timber and masonry buildings	0.20	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

Root mean square velocity level in decibels (VdB) re 1 micro-inch/second measured in any one second time period

Annoyance Criteria: Unlike the potential impact for damage, which will be considered for all construction activities, potential impact for annoyance will be considered only for long-term activities occurring during non-exempt hours. When vibration is assessed for annoyance due to specific construction activities, the transit vibration impact criteria will be used to determine the potential for impact (per FTA). These impact criteria are defined in Table 6. For a high level vibration source like impact pile driving, each hammer blow would be considered an "event". However, for vibratory pile driving, each pile might be considered an "event". Similarly, for vibratory soil compaction, each time a vibratory roller passes by a receptor would count as an "event". Any activity localized near a receptor for the duration of a shift would certainly be considered "frequent".

Table 6: FTA 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 vibration would interfere with 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

[1]"Frequent Events" is defined as more than 70 vibration events of the same source per day.

[2]"Occasional Events" is defined as between 30 and 70 vibration events of the same source per day.

[3]"Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day

[4]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.

6.2 Construction Vibration Analysis

Construction vibration, similar to noise, is highly dependent on the specific equipment and methods employed. Construction vibration can cause a variety of potential effects, including interference with vibration-sensitive equipment, low rumbling or groundborne noise, vibrations perceptible to people at moderate levels, and cosmetic damage to buildings at the highest levels. Because construction is a short-term, temporary impact, construction vibration will be assessed at locations where prolonged annoyance or building cosmetic damage might occur; namely, at the receptors within the vicinity of excavation, pile driving, and vibratory soil compaction activities.

Most construction processes do not generate high enough vibration levels to approach the threshold for cracking damage; therefore, structural damage, which requires very high levels, is highly unlikely for construction vibration. Cosmetic damage from construction vibration is generally limited to pile-driving and vibratory rolling: these two activities have the potential to produce vibration magnitudes that exceed the threshold for cracking damage. Care should be taken to avoid or limit these activities near structures as much as practicable.

Vibratory pile drivers that use a vibrating mass with variable rotating speed may generate very high short duration transient vibration due to resonance of the pile in the ground. Vibratory pile drivers that employ constant frequency sinusoidal forces to the pile produce less vibration, especially those that employ a downward static force and clamp the pile during the driving process.

The methodology for assessing construction vibration annoyance includes measuring maximum rms overall vibration levels with an integration time of 1 second for each source at a distance of 25 feet. A summary of expected upper-range vibration levels at a reference distance of 25 feet from various vibration sources are presented in Table 7 (from FTA).

Table 7: Summary of Construction Equipment Vibration

Equipment	PPV at 25 feet (inches/second)	Approximate L_v at 25-foot VdB	Minimum Distance between Equipment and Receptor to Avoid Annoyance Impact (feet)
Vibratory pile or casing	0.734	105	315
Impact pile driving	1.158	112	540
Oscillatory pile casing	0.089	87	80
Vibratory soil compactor	0.210	94	120
Auger drilling	0.016	72	25
Hoe ram	0.089	87	80
Excavator/grader/bulldozer	0.089	87	80
Loaded trucks	0.076	86	75

Using the available reference vibration levels at 25 feet, the following general prediction model (from the FTA guidance manual) gives the vibration level as a function of distance:

Damage Assessment: $PPV_{equip} = PPV_{ref} \times (25/\text{distance})^{1.5}$

Annoyance Assessment: $L_v(\text{distance}) = L_v(25 \text{ feet}) - 30 \cdot \log(\text{distance}/25 \text{ feet})$

A vibration level of 72 VdB corresponds to the vibration annoyance criteria for frequent events at residential receptors (Table 6). The minimum distance from the vibration source necessary to achieve vibration levels of 72 VdB or below is given in the last column of Table 7. Any residences located further than the distances provided are unlikely to experience an impact.

7.0 CONSTRUCTION MONITORING

Monitoring of the construction noise and vibration levels is necessary to ensure that any unacceptable impacts are readily detected. The construction A-weighted equivalent noise levels (L_{eq}) and peak particle velocity (PPV in inches/second), will be measured continuously or on a regular basis. General guidelines for construction monitoring are outlined below with details to be developed by the GC/CM in the Construction Noise and Vibration Mitigation and Monitoring Plan.

7.1 Construction Noise Monitoring

Preconstruction ambient sound levels shall be measured to accurately quantify existing noise levels along the alignment and in any area identified for construction noise monitoring.

Long-term noise monitoring shall be conducted near residences that will be exposed to construction noise over an extended period during non-exempt hours. This includes station construction sites and several staging areas for equipment and supplies.

Some sections of highway noise wall will be removed during construction. In these sections, a temporary noise barrier consisting of chain link fencing with acoustical blankets will be installed during Early Work. Temporary noise barriers will also be installed in locations where construction activities may occur in close proximity to receptors. Short-term monitoring should be completed at these locations to ensure that the temporary barriers sufficiently reduce noise from the I-5 roadway and the construction equipment.

Noise monitoring should also be in place at nearby representative receptors during high level activity such as pile driving.

7.2 Construction Vibration Monitoring

Construction activities will be performed with means and methods designed to avoid vibration damage to structures. Pile driving likely will be required at a few locations; vibration monitoring will be conducted at any location where pile driving would occur within 200 feet of any structure. Vibration monitoring also should be in place at sensitive receptors during demolition, excavation, or when vibratory equipment is in use (such as vibratory pile driving or soil compaction) in close proximity to structures (within 100 feet). Potential sensitive receptors include residential and business structures, as well as existing utilities (such as gas regulator vaults and gas transmission lines). Vibration should be monitored in real time and construction halted for assessment if the levels approach or exceed damage criteria. Levels that approach or exceed annoyance criteria may be addressed without halting construction immediately. In either case, appropriate mitigation measures should be enacted if a criterion is exceeded.