LIGHT RAIL PERMITTING ADVISORY COMMITTEE MEETING

Date: June 27, 2014

To: Light Rail Permitting Advisory Committee

From: Matthews Jackson (425-452-2729, mjackson@bellevuewa.gov)
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Liaisons to the Advisory Committee
Development Services Department

Subject: July 2nd, 2014 Advisory Committee Meeting

Enclosed you will find an agenda packet for your fifteenth Advisory Committee meeting next Wednesday, July 2nd. We will begin at 3:00 p.m. in Room 1E-113 at Bellevue City Hall. The meeting will be chaired by Doug Mathews and Marcelle Lynde.

This packet includes:

1. Agenda
2. June 18th Meeting Minutes (Desk copy will be provided at the meeting due to schedule)
3. Bel Red Noise and Vibration Reports
4. Bel Red Ancillary Structure Drawings

We will have hard copies of all electronic packet materials for you on July 2nd. Materials will also be posted on the City's project web site at http://www.bellevuewa.gov/light-rail-permitting-cac.htm.

Please let us know if you have any questions prior to our meeting. We look forward to seeing you next week.

LIGHT RAIL PERMITTING ADVISORY COMMITTEE MEETING

Wednesday, July 2, 2014
3:00 p.m. – 5:00 pm • Room 1E-113
Bellevue City Hall • 450 110th Ave NE

AGENDA

3:00 p.m.	1.	Call to Order, Approval of Agenda, Approval of June 18th Meeting Minutes *Committee Co-Chairs Mathews and Lynde*
3:10 p.m.	2.	Public Comment *Limit to 3 minutes per person*
3:20 p.m.	3.	City of Bellevue Noise Code *Kate Berens-City of Bellevue*
3:50 p.m.	4.	Review and Discussion of Bel Red Tree Mitigation *Sound Transit*
4:20 p.m.	5.	Review and Discussion of Bel Red Ancillary Structures *Sound Transit*
4:50 p.m.	6.	Public Comment *Limit to 3 minutes per person*
5:00 p.m.	7.	Adjourn

Project web site located at: http://www.bellevuewa.gov/light-rail-permitting-cac.htm . For additional information, please contact the Light Rail Permitting Liaisons: Matthews Jackson (425-452-2729, mjackson@bellevuewa.gov) or Carol Helland (425-452-2724, chelland@bellevuewa.gov). Meeting room is wheelchair accessible. American Sign Language (ASL) interpretation available upon request. Please call at least 48 hours in advance. Assistance for the hearing impaired: dial 711 (TR).

East Link | South Bellevue to Overlake Transit Center
Contract No. RTA/AE 0143-11

Package E340
Construction Noise and Vibration Study
60% Submittal

August 12, 2013

Prepared for:

SOUNDTRANSIT

Prepared by:

HJH FINAL DESIGN PARTNERS.

Package E340
Construction Noise and Vibration Study

ATS Consulting
acoustics, transportation + strategy

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Tables

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Acronyms and Abbreviations

dBA	A-weighted decibel
DF	Direct Fixation
EIS	Environmental Impact Statement
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
Ldn	24-hr day-night sound level
Leq	Equivalent sound level
LRT	Light Rail Transit
LRV	Light Rail Vehicle
LSTM	Line Source Transfer Mobility
PNB	Pacific Northwest Ballet
PPV	Peak Particle Velocity
ST	Sound Transit
TPSS	Traction Power Substation
VdB	Vibration decibel with reference to 1 µin/sec
WSDOT	Washington Department of Transportation

1.0 Introduction

The E340 Contract of the East Link Light Rail Project involves construction activities which generate high noise and vibration levels. This Construction Noise and Vibration Plan (the Plan) discloses the predicted noise and vibration effects of construction activities related to the E340 Contract Package of the Project. The Plan was prepared to meet the criteria, standards, and mitigation commitments in the East Link Project Final Environmental Impact Statement (EIS), July 2011. The Plan identifies receivers where noise or vibration impact may occur as a result of construction activities, provides additional information on the noise and vibration limits for the planned means and methods of construction, and recommends mitigation measures and monitoring locations where necessary.

The Plan includes noise and vibration predictions for the major noise and vibration generating activities that will take place during different phases of construction. Background information on noise and vibration including definitions and key concepts that may be useful for interpreting the predictions and recommendations in the Plan are included in Appendix A.

2.0 Construction Activities

The E 340 Contract consists of a trackway from approximately 124th Avenue NE, where the E 335 Contract ends, to NE 20th Street where the E 360 Contract begins. This contract has two primary elements in addition to the trackwork itself: an Elevated Guideway from 124th Avenue. NE to 130th Avenue NE. and an at grade section that passes through existing light industrial area along NE 16th Street and 136th Place NE ending at the north side of NE 20th Street. The 130th Avenue Station is an at-grade station and will include a 300 stall Park and Ride surface lot.

For purposes of this analysis it is assumed that the E360 Contractor will demolish the building along the alignment north of NE 20TH Street, but that the E340 Contractor will be granted a portion of that area for staging their work. This arrangement may be reversed should the E340 Contract start first.
Also included in this section of the alignment is an Elevated Guideway that is currently planned as a pre-cast girder bridge with direct fixation rail. The girders will be lifted into place by cranes from access on the south side of the guideway.

<u>Phases of Construction:</u> For purposes of this analysis the phases of work on this section of trackway was based on a preliminary schedule developed during a study on contract packaging performed during the summer of 2012. The schedule created at that time assumed a different contracting strategy than is currently being used, but since scheduling has not been advanced in any substantive way since that time, the activities used in last summer's schedule were combined to provide a the attached sequence of work and phases of construction. The phases of construction are reflected in both the attached equipment list and schedule, and are generally described as follows:

- Building Demolition
- At-grade work
- 130th Avenue Station
- Elevated Guideway
- Track installation

<u>Hours of Construction</u>: Daytime work only (7:00 am to 6:00pm as defined by City of Bellevue Noise Ordinance). No night work, except as may be necessary to complete concrete pours or bridge girder delivery and erection.

3.0 Construction Noise Limits

3.1 State and Local Noise Regulations Relating to Project Construction

The FTA does not provide standardized criteria for assessing construction noise impacts and recommends applying local ordinances or, if none can be found to apply, developing criteria on a project-specific basis. Project construction would take place in the city of Bellevue, Washington and would be subject to the City's noise ordinance.

Washington Administrative Code

Most cities in Washington rely, at least in part, on the Washington Administrative Code (WAC), Chapter 173-60, Maximum Environmental Noise Levels (the Washington State Noise Control Ordinance), for residential, commercial, and industrial noise limits, as well as construction noise limits. The Washington State Noise Control Ordinance exempts from regulation sounds originating from temporary construction sites as a result of construction activity.

For stationary land uses with noises originating from outside public roadways and rights-of-way, the Washington State Noise Control Ordinance defines three classes of property usage, called Environmental Designation for Noise Abatement (EDNA), and maximum allowable noise levels for each, as shown in Table 3-1. For example, the noise caused by a commercial property must be less than 57 dBA at the closest residential property line. From 10:00 pm to 7:00 am, the allowable maximum sound levels shown in Table 3-1 are reduced by 10 dBA.

The WAC contains short-term exemptions to the property line noise standards in Table 3-2 based on the minutes per hour that the noise limit is exceeded. The allowable exceedances presented in Table 3-2 are commonly measured using the statistical distribution measurement metrics, with the L25 equal to the 15 minute exccedance, the L8.3 for the 5 minute exceedance, and the L2.5 for the 1.5 minute exceedance.

Table 3-1. Washington State Noise Control Regulation

EDNA Source of Noise	EDNA Receiver of Noise Maximum Allowable Sound Level in dBA[a])		
	Residential	Commercial	Industrial
Residential	55	57	60
Commercial	57	60	65
Industrial	60	65	70

[a] Between 10:00 pm and 7:00 am, the levels given above are reduced by 10 dBA for residential receiving property.
dBA = decibel with A-weighting

Table 3-2. Washington State Exemptions for Short-Term Noise Exceedances

Minutes Per Hour	Adjustments to Maximum Sound Level
15	+5 dBA
5	+10 dBA
1.5	+15 dBA

dBA = decibel with A-weighting

Although construction noise is exempt from the limits in the WAC Noise Ordinance, those limits may be adopted with any necessary adjustments for construction noise for the Project. Most project construction can be performed within the limits of the Washington State Noise Control Ordinance if the work is conducted 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 presented in Table 3-1 and Table 3-2 or get a noise variance from the governing jurisdiction.

3.2 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 at staging areas, the general construction equipment would be used to determine compliance.

3.3 Noise Related to Back-Up Alarms

Sounds created by backup alarms are exempt, except between 10 p.m. and 7 a.m. when "beep-beep" backup alarms are essentially prohibited by the WAC in urban areas and would be replaced with smart back-up alarms, which automatically adjust the alarm level based on the background level or switch off back-up alarms and replace with spotters. This criterion is included because, just like noise from construction activities, noise from back-up beepers would exceed the WAC nighttime criteria, even with the allowable exceedance, at distances up to 800 feet, or more, from the construction site.

3.4 City of Bellevue

Under the Bellevue City Code (BCC), noise emanating from construction sites is prohibited outside of the hours of 7 a.m. to 6 p.m. Monday through Friday, and 9 a.m. to 6 p.m. on Saturdays. No construction site noise is permitted on Sundays and legal holidays. Note that the daytime hours in the BCC are more stringent than the hours defined in the WAC. If after-hours sounds from a construction site are clearly audible across a real property boundary or at least 75 feet from their source, it will be considered a noise disturbance (BCC 9.18.040.A.4). A noise variance from the city of Bellevue is required for any after-hours work.

4.0 Construction Vibration Criteria

The primary concern regarding construction vibration relates to risk of damage. Vibration is generally assessed in terms of peak particle velocity (PPV) for risk of building damage. PPV is the appropriate metric for evaluating the potential of building damage and is often used when monitoring blasting and construction vibration because it relates to the stresses that are experienced by the buildings. Vibration damage risk thresholds were used to assess potential for damage from construction in the East Link Final EIS/EIR and are based on criteria from Swiss Consultants for Road Construction Association, 1992. There is no state or local ordinances concerning construction vibration limits. The vibration damage risk thresholds for different building categories are:

- ☐ Reinforced concrete, steel, or timber: 0.5 PPV
- ☐ Engineered concrete and masonry: 0.3 PPV
- ☐ Nonengineered timber and masonry buildings: 0.2 PPV
- ☐ Buildings extremely susceptible to vibration damage: 0.12 VdB

Construction vibration, unlike vibration from operations, has the potential to cause damage to structures at very close distances, from activities such as impact hammering and pile-driving. Generally, because of the short duration of construction vibration activities, annoyance is usually not an issue. The thresholds for damage for even the most sensitive buildings are 1 to 2 orders of magnitude higher than the criteria for annoyance from vibration.

5.0 Sensitive Receivers

The primary land uses along E340 Contract alignment is commercial and light industrial. There is one location, the Pacific Northwest Ballet (PNB) School at the Francia Russell Center that is considered a noise sensitive receiver. Noise sensitive receivers were determined using the land use category definitions in the FTA guidance manual for operational noise impact assessment which does not include commercial, office space, or industrial land uses as noise sensitive. Note that construction noise limits for many jurisdictions include limits for these "non-noise sensitive" land uses.

The predicted construction noise and vibration levels at the PNB School are presented in this report. There are no historic buildings or buildings that are extremely susceptible to vibration damage within the package limits.

6.0 Construction Noise Predictions

6.1 Noise Prediction Methodology

The projected daytime construction noise levels were modeled using CadnaA version 4.0, a three dimensional graphics oriented noise modeling program that uses the International Standards Organization (ISO)9613, a general purpose standard for outdoor noise propagation. CadnaA incorporates the following elements:

- The noise generated by the equipment at a reference distance.
- A propagation model that calculates how the noise level varies with distance.
- A prediction model that sums the noise of each source at sensitive locations.

The noise modeling includes the effects of ground cover, the shielding of building structures, and the reduction provided by a noise barrier fence (if one is specified in the construction plans). The construction noise levels were estimated at each of the receivers within close proximity to the construction sites. The source noise levels used in the model for different pieces of construction equipment are based on the actual measured noise level data presented in Table 6-1. This data is from the Federal Highway Administration (FHWA) Roadway Construction Noise Model and compares the actual measured noise level (shown in the third column) with the limits typically specified for construction projects (shown in the second column). The measured noise level data was used for the noise modeling when it was higher than the specified noise level limits.

6.2 Noise Prediction Results and Impact Assessment

Noise prediction models were developed for each construction site based on the project plan drawings and the current means and methods planned for the construction phases. The following section presents predictions of noise levels at the Pacific Northwest Ballet School.

Table 6-1: Construction Equipment Noise Emission Levels

Equipment Description	Lmax Noise Limit at 50 ft, dB Slow	Measured Lmax at 50 ft, dB Slow	Is Equipment an Impact Device?
Auger Drill Rig	85 dBA	84 dBA	No
Backhoe	80 dBA	78 dBA	No
Chain Saw	85 dBA	84 dBA	No
Clam Shovel	93 dBA	87 dBA	Yes
Compactor (ground)	80 dBA	83 dBA	No
Compressor (air)	80 dBA	78 dBA	No
Concrete Mixer Truck	85 dBA	79 dBA	No
Concrete Pump Truck	82 dBA	81 dBA	No
Concrete Saw	90 dBA	90 dBA	No
Crane (mobile or stationary)	85 dBA	81 dBA	No
Dozer	85 dBA	82 dBA	No
Dump Truck	84 dBA	76 dBA	No
Excavator	85 dBA	81 dBA	No
Flat Bed Truck	84 dBA	74 dBA	No
Front End Loader	80 dBA	79 dBA	No
Generator (25 KVA or less)	70 dBA	81 dBA	No
Generator (more than 25 KVA)	82 dBA	73 dBA	No
Gradall	85 dBA	83 dBA	No
Horizontal Boring Hydraulic Jack	80 dBA	82 dBA	No
Impact Pile Driver (diesel or drop)	95 dBA	101 dBA	Yes
Jackhammer	85 dBA	89 dBA	Yes
Mounted Impact Hammer	90 dBA	90 dBA	Yes
Paver	85 dBA	77 dBA	No
Pickup Truck	55 dBA	75 dBA	No
Pneumatic Tools	85 dBA	85 dBA	No
Pumps	77 dBA	81 dBA	No
Rock Drill	85 dBA	81 dBA	No
Scraper	85 dBA	84 dBA	No
Slurry Plant	78 dBA	78 dBA	No
Slurry Trenching Machine	82 dBA	80 dBA	No
Tractor	84 dBA	82 dBA	No
Vacuum Excavator (Vac-Truck)	85 dBA	85 dBA	No
Vacuum Street Sweeper	80 dBA	82 dBA	No
Vibratory Concrete Mixer	80 dBA	80 dBA	No
Welder	73 dBA	74 dBA	No

Source: FHWA Roadway Construction Noise Model, January 2006

Pacific Northwest Ballet School

The activities for the construction of the embedded trackway at the Pacific Northwest Ballet School consist of trackway preparation, demolition of existing roadways, and installation of embedded rail. The equipment expected to be used for these different construction activities are presented in Table 6-2. The construction noise predictions represent a worst-case noise level in which all of the pieces of equipment in Table 6-2 for the different phases of construction are operating simultaneously in the area closest to the sensitive receiver.

Predicted noise levels for each of the construction phases are presented in Table 6-3 and are graphically presented as noise contours on Figure 6-1 through Figure 6-4. These activities are assumed to occur weekdays during the daytime hours of 9 a.m. to 6 p.m. If these activities occur during the week after 6 p.m. or before 9 a.m. or anytime on Saturday or Sunday a noise variance will be needed from the City of Bellevue.

Table 6-2. Construction Equipment for At-Grade Trackway at Pacific Northwest Ballet

Equipment	Trackway Preparation	Demolition of Existing Roadway	Construction of New Roadway	Embedded Rail Installation
Backhoe Loader (w/ attachments - breaker/ compactor/etc)	X	X	X	X
Boom Truck			X	
Dump truck	X	X	X	
Excavator	X	X	X	
Flatrack Truck				X
Forklift (Gradall)			X	X
Front End Loader	X			X
Generator Diesel set				X
General Utility Truck	X	X	X	
Grader			X	
Misc. Hand held power tools (cut off saw/ chain saw/ Rotohammer/ Pneumatic spade/, etc.		X	X	X
Pickup truck	X	X	X	X
Portable Generators		X		X
Ready Mix Concrete Trucks			X	
Rough Terrain Crane			X	
Street Sweeper	X	X		
Track Dozer (w/ winch)	X		X	
Water Truck		X	X	
Welding Machine				X
Vacuum Truck			X	
Vibratory Roller - 84"			X	

Table 6-3: Construction Noise Predictions at Pacific Northwest Ballet – Lmax (dBA)

Construction Activity	Receiver 1 (Studio A)	Receiver 2 (Studio C)
Trackway Preparation	85	77
Roadway Demolition	86	77
New Roadway Construction	88	84
Rail Installation	85	79

Figure 6-1. Trackway Construction Noise: Pacific Northwest Ballet

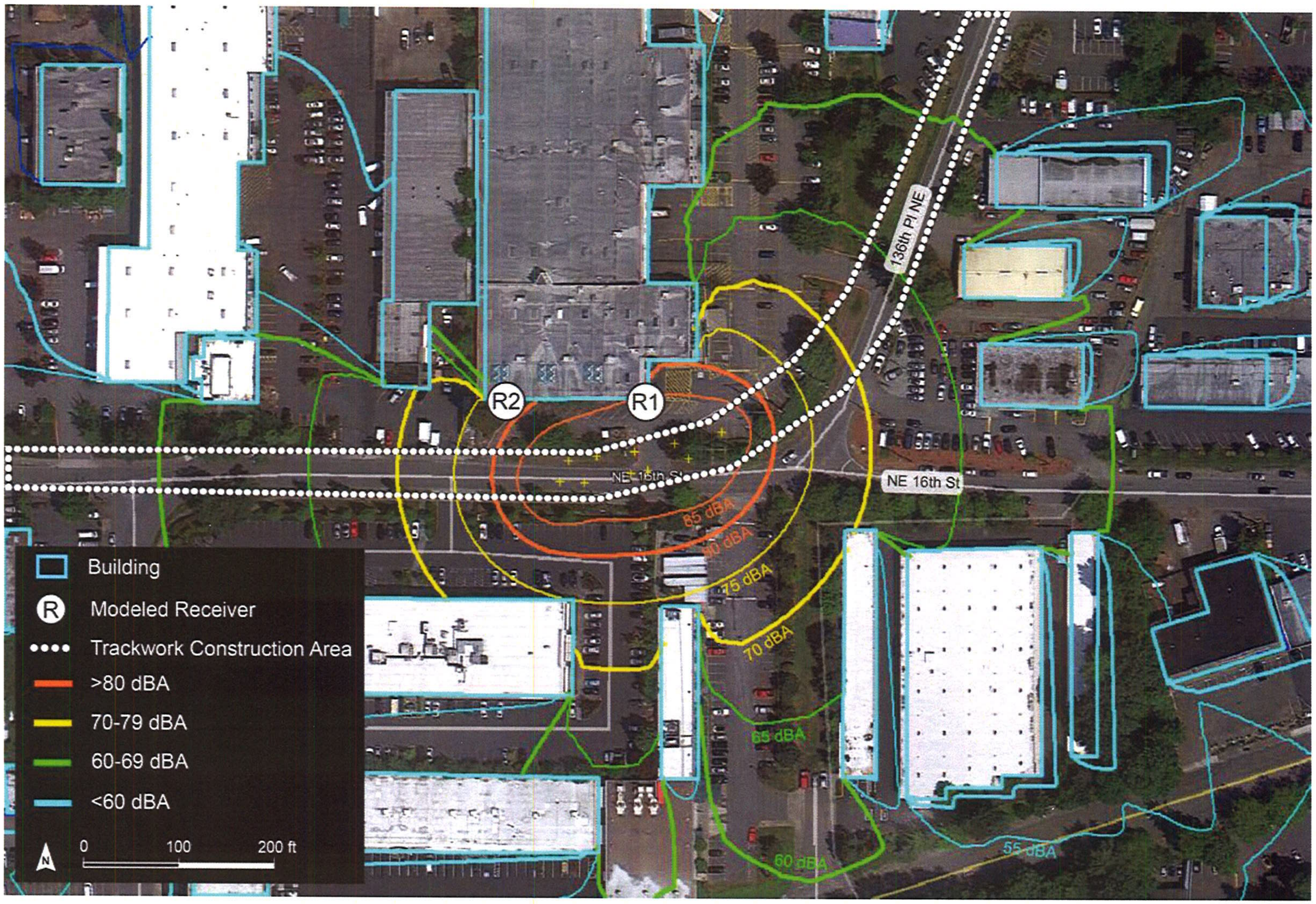


Figure 6-2. Roadway Demolition Construction Noise: Pacific Northwest Ballet

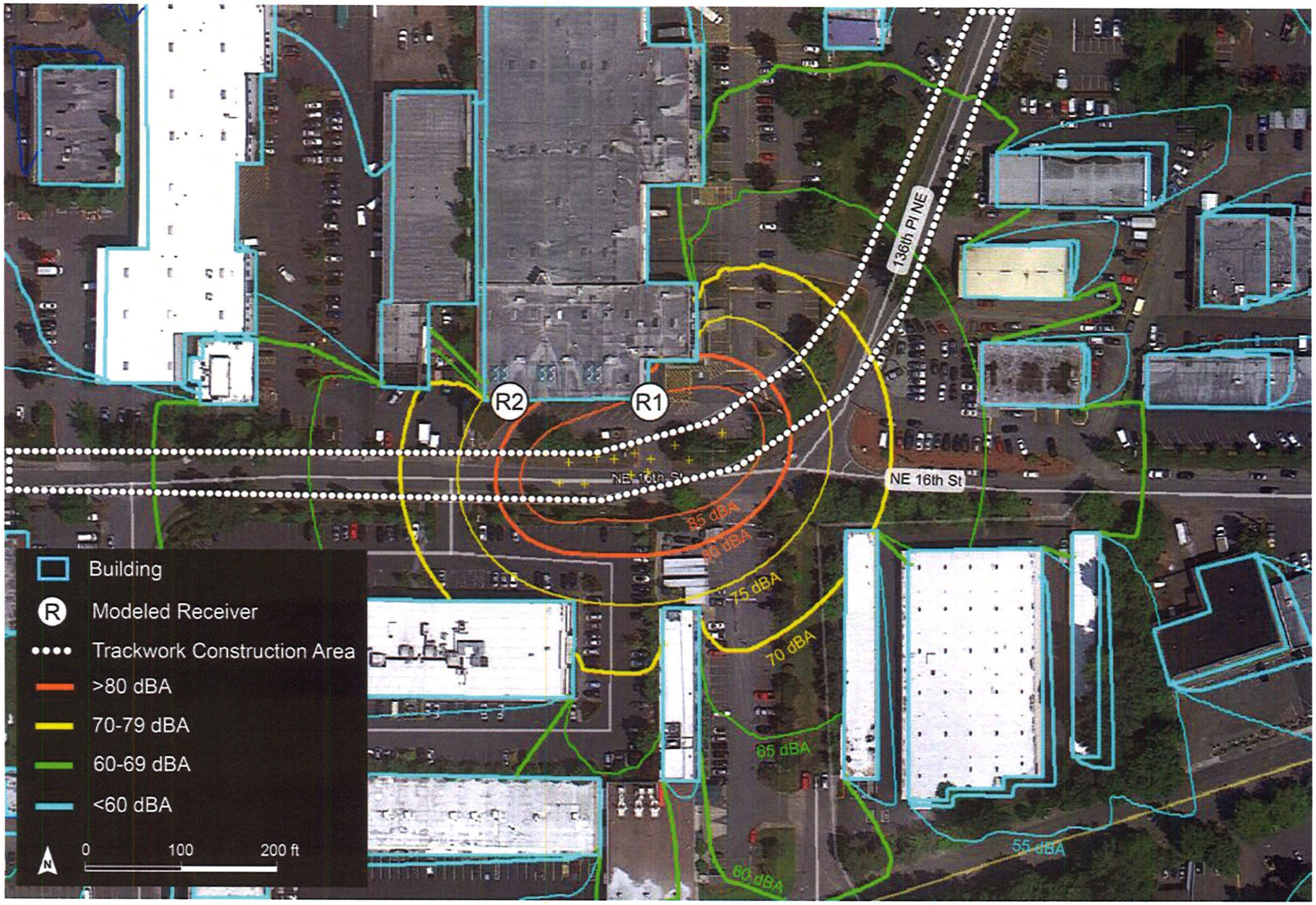


Figure 6-3. New Roadway Construction Noise: Pacific Northwest Ballet

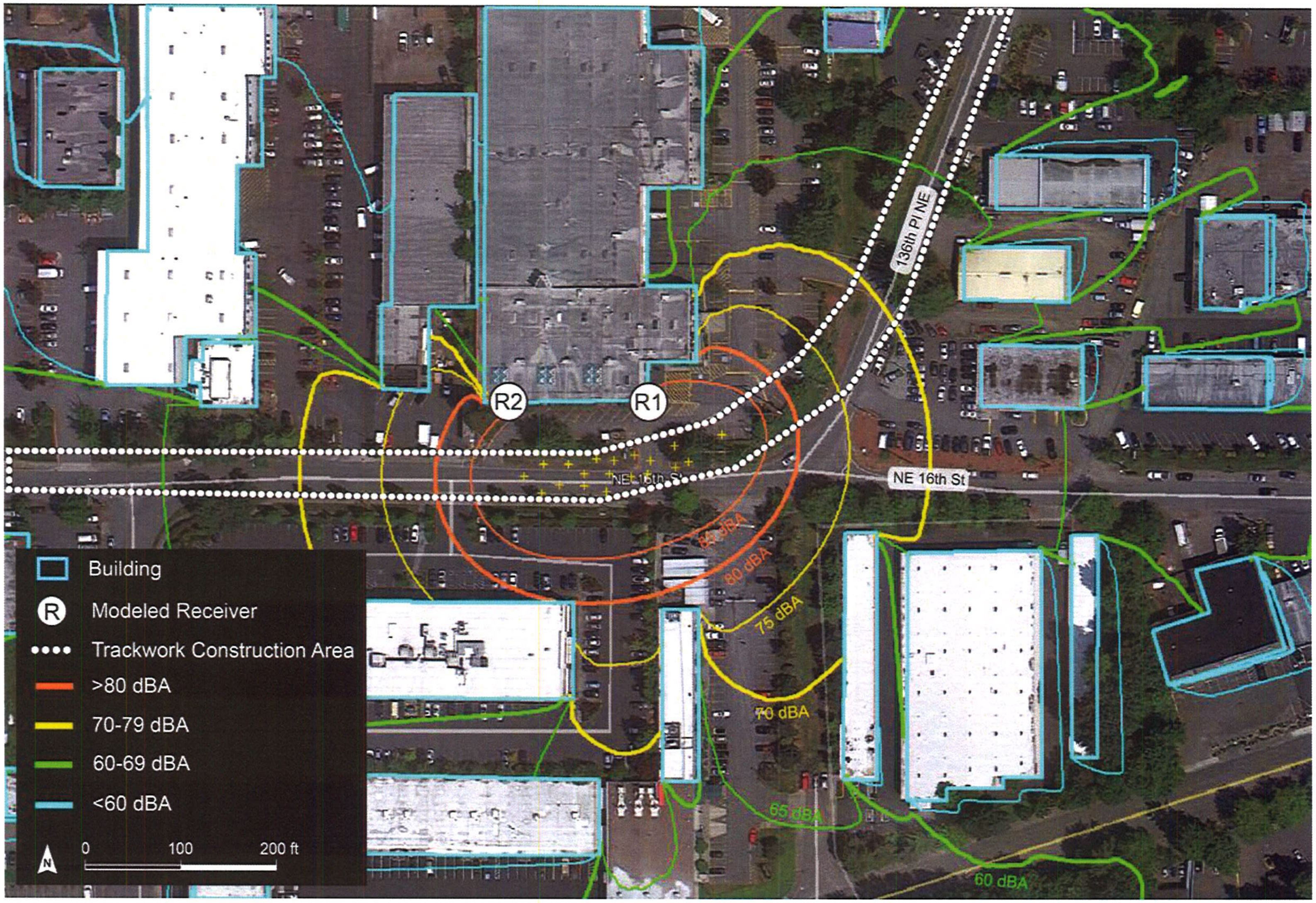
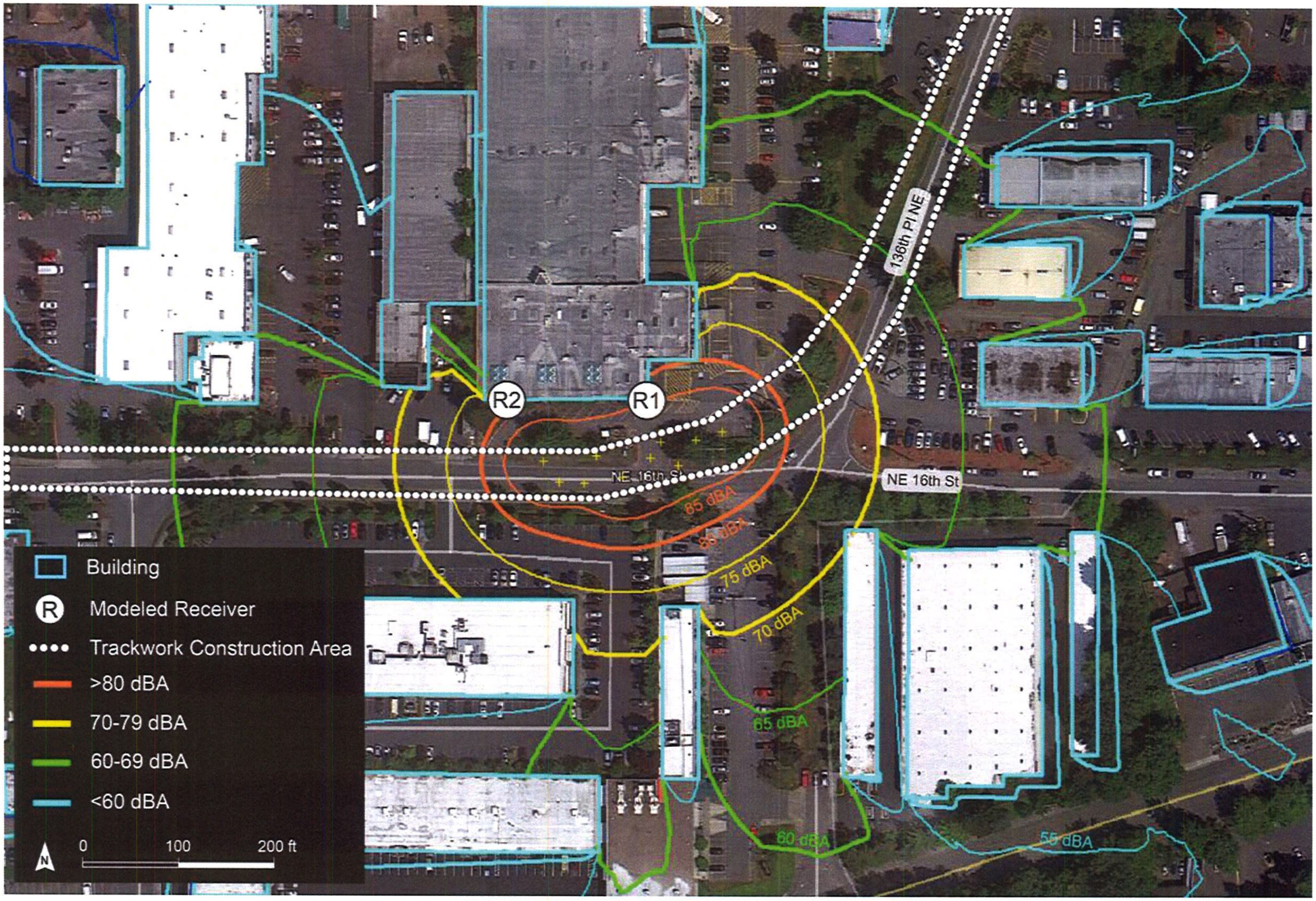


Figure 6-4. Rail Installation Construction Noise: Pacific Northwest Ballet



7.0 Construction Vibration Predictions

7.1 Prediction Methodology

For this study, the FTA analytical/empirical construction vibration prediction model was used to estimate vibration levels propagate from construction equipment to vibration sensitive locations. The vibration model is based on a combination of previous works including measured equipment vibration emission data from the FTA and the Central Artery/Tunnel project in Boston, and ground transmissibility relationships found in Charles Dowding's reference textbook Construction Vibrations[1]. The fundamental equation used in the model is based on propagation relationships of vibration through average soil conditions and distance, as follows:

$$PPV_{receiver} = PPV_{ref} * \left({}^{100}\!/_{Dist_{receiver}} \right)^n ,$$

where:

PPVreceiver = predicted PPV at the receiver,

PPVref = reference PPV of equipment at 100 feet,

Distreceiver = distance from the receiver to the equipment in feet, and

n = 1.1 (the vibration attenuation rate through the soil).

The value for n can lie between 1.0 and 2.0 and a value of 1.5 is commonly used in general models. The suggested value for n in the FTA Manual is 1.5 which is used when receivers are over 100 feet from the construction activities. The value of 1.1 is considered appropriate for this model because the potential receivers are within 100 feet of the construction activities.

Equipment vibration emission levels used for the predictions are shown in Table 7-1. The levels were gathered from measurements performed and published from several projects including the FTA Manual, Central Artery/Tunnel Project in Boston, and Dowding's textbook[1]. The equipment with a reference PPV of N/A implies the equipment does not generate vibration levels significantly above normal ambient levels. Therefore, equipment such as generators and compressors that may require noise modeling and assessment are not assessed for vibration impact. The vibration generating equipment that is likely to be used during the Project is shown as highlighted in Table 7-1.

Table 7-1: Equipment Vibration Emission Levels

Equipment Description	Vibration Type (Steady or Transient)	Ref PPV at 100 ft
Auger Drill Rig	Steady	0.011125
Backhoe	Steady	0.011
Compactor	Steady	0.03
Concrete Mixer	Steady	0.01
Concrete Pump	Steady	0.01
Crane	Steady	0.001
Dozer	Steady	0.011

[1] Dowding, Charles, Construction Vibrations, Prentice Hall, Upper Saddle River, NJ, 1996.

Equipment Description	Vibration Type (Steady or Transient)	Ref PPV at 100 ft
Dump Truck	Steady	0.01
Excavator	Steady	0.011
Flat Bed Truck	Steady	0.01
Front End Loader	Steady	0.011
Gradall	Steady	0.011
Grader	Steady	0.011
Horizontal Boring Hydraulic Jack	Steady	0.003
Hydra Break Ram	Transient	0.05
Impact Pile Driver	Transient	0.2
Insitu Soil Sampling Rig	Steady	0.011125
Jackhammer	Steady	0.003
Mounted Hammer hoe ram	Transient	0.18975
Paver	Steady	0.01
Pickup Truck	Steady	0.01
Scraper	Steady	0.000375
Slurry Trenching Machine	Steady	0.002125
Soil Mix Drill Rig	Steady	0.011125
Tractor	Steady	0.01
Tunnel Boring Machine (rock)	Steady	0.0058
Tunnel Boring Machine (soil)	Steady	0.003
Vibratory Pile Driver	Steady	0.15
Vibratory Roller (large)	Steady	0.059
Vibratory Roller (small)	Steady	0.022
Blasting	Transient	0.75
Clam Shovel	Transient	0.02525
Rock Drill	Steady	0.011125
3-ton truck at 35 mph	Steady	0.0002

7.2 Prediction Results and Impact Assessment

Table 7-2 presents the distance beyond which the damage risk criteria would not be exceeded for the major vibration-generating pieces of equipment likely to be used for the construction activities at the PNB School. Most of the equipment can be operated without risk of damage near the PNB School. The exception is the mounted hammer hoe ram, which generally should only be operated at a distance of 45 feet or greater from the PNB School.

Table 7-2: Distance to Construction Vibration Impact Thresholds

Equipment	PPV Ref Level at 100 ft (in/sec)	Distance to Impact Threshold of 0.5 in/sec PPV
Backhoe	0.011 in/sec	8 ft
Excavator	0.011 in/sec	8 ft
Grader	0.011 in/sec	8 ft
Vibratory Roller	0.059 in/sec	15 ft
Front End Loader	0.011 in/sec	8 ft
Mounted Hammer Hoe Ram	0.190 in/sec	45 ft

Pacific Northwest Ballet School

The range of predicted vibration levels for the different phases of construction activities are presented in Table 7-3. The worst-case predicted vibration levels are expected to occur from the operation of the mounted hammer hoe rams used during track preparation and roadway demolition. The predicted vibration level of the mounted hammer hoe ram does exceed the damage risk threshold at the PNB school. All other equipment operations are not expected to exceed the damage risk criteria.

Table 7-3: Construction Vibration Predictions: Pacific Northwest Ballet, PPV (in/sec)

Construction Activity	Receiver 1 (Studio A)	Receiver 2 (Studio C)	Damage Risk Threshold
Trackway Preparation	0.030 to 0.520	0.026 to 0.457	0.5
Roadway Demolition	0.030 to 0.520	0.026 to 0.457	0.5
New Roadway Construction	0.030 to 0.162	0.026 to 0.142	0.5
Rail Installation	0.030	0.026	0.5

8.0 Mitigation

General noise mitigation measures that can be used at this location are specified in Section 01 57 15, Temporary Construction Noise and Vibration Control of the E340 Contract Specifications. These mitigation measures are consistent with the FEIS Record of Decision Environmental Commitments and include the following:

- Where possible, use concrete crushers or pavement saws rather than hoe rams for tasks such as concrete deck removal and retaining wall demolition.
- Ensure that pneumatic impact tools and equipment used at the construction site have intake and exhaust mufflers recommended by the manufacturers thereof, to meet relevant noise ordinance limitations.
- Construction equipment, both stationary and mobile, should be of recent manufacture and incorporate effective noise-suppression design, including features such as shrouds, baffles, and mufflers or as recommended by the manufacturers. Locate stationary equipment that generates noise away from sensitive receptors and shield with a noise-attenuating barrier or shroud.
- Line or cover storage bins and chutes with sound-deadening material. Ensure all vehicles engaged in loading on-site have lined truck beds.
- Provide mufflers or shield paneling for other equipment, including internal combustion engines, recommended by manufacturers thereof.
- Use alternative procedures of construction and selection of proper combination of techniques that generate least overall noise and vibration. Such alternative procedures include the following:
- Use electric welders powered from utility main lines instead of internal combustion powered generators/welders.
- Mix concrete off-site instead of on-site.
- Employ prefabricated structures instead of assembling on-site.
- Drilled pile installation methods.
- Use construction equipment manufactured or modified to dampen noise and vibration emissions, such as:
    - Use electric instead of diesel-powered equipment.
    - Use hydraulic tools instead of pneumatic impact tools.
    - Use electric instead of air- or gasoline-driven saws.
- Operate equipment so as to minimize banging, clattering, buzzing, and other annoying types of noises, especially near residential areas.
- To the extent feasible, configure the construction site in a manner that keeps noisier equipment and activities as far as possible from noise sensitive locations and nearby buildings.
- Maximize physical separation, as far as practicable, between noise generators and noise receptors. Separation includes following measures:
    - Provide enclosures for stationary items of equipment and barriers around particularly noisy areas on site.

  - Locate stationary equipment to minimize noise and vibration impact on community, subject to verification by the Resident Engineer.
- Minimize noise-intrusive impacts during most noise sensitive hours.
  - Plan noisier operations during times of highest ambient noise levels.
  - Keep noise levels relatively uniform; avoid excessive and impulse noises.
  - Turn off idling equipment and vehicles.
  - Phase in start-up and shut-down of site equipment.
  - Avoid simultaneous activities that both generate high noise levels.
  - Conduct truck loading, unloading and hauling operations so noise and vibration are kept to a minimum.
  - Do not operate trucks on streets that pass by schools during school hours.
  - Limit the time that steel decking or plates for street decking or covering excavated areas are in use.
  - Grade surface irregularities on construction sites to minimize the generation of impact noise and ground vibrations by passing vehicles.
- Use warning broadband backup alarms on all equipment in operation at the site, at all times.
- Limit the use of annunciators or public address systems, except for emergency notifications.

9.0 Monitoring

The Contractor is required to submit a Noise and Vibration Monitoring Plan prepared, stamped, and administered by the Contractor's Acoustical Engineer. Noise and vibration monitoring should be performed at the PNB during the phases of construction that generate substantial noise and vibration.

9.1 Noise Monitoring

Short-term noise monitoring, which consists of measurements conducted for 1 hour or less are required to verify that noise levels during construction do not exceed the relevant impact criteria . Short-term noise measurements should be performed weekly using a sound level meter and associated ancillary equipment. Short-term measurements should be conducted at the building façade at a height of approximately 5 feet above ground level.

9.2 Vibration Monitoring

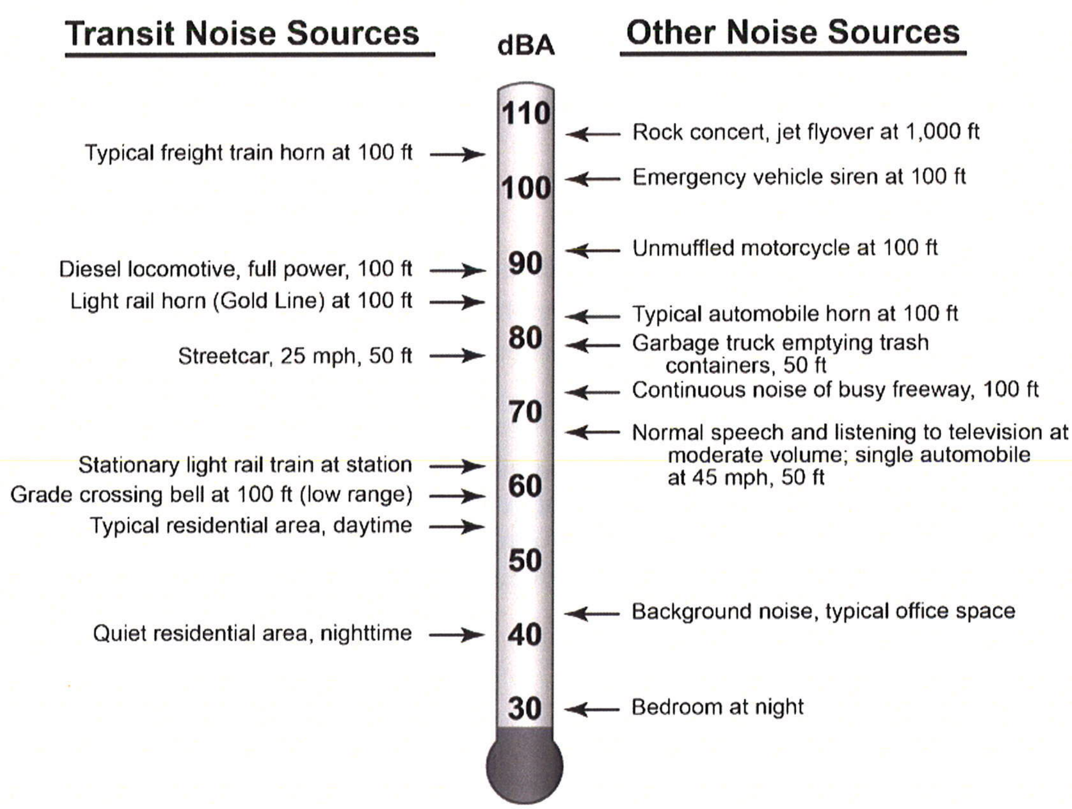
Vibration monitoring for this project should consist of measurements of vibration at the closest PNB School building façade to the construction activities when equipment that generate a substantial amount of ground-borne vibration, such as mounted hammer hoe rams, are in use. Vibration monitors should be equipped with an “alarm” feature to provide notification that vibration impact criteria have been approached or exceeded.

APPENDIX A: NOISE AND VIBRATION BACKGROUND INFORMATION

Sound is mechanical energy transmitted by pressure waves in a compressible medium such as air. Noise is generally defined as unwanted or excessive sound. Sound can vary in intensity by over one million times within the range of human hearing. Therefore, a logarithmic scale, known as the decibel scale (dB), is used to quantify sound intensity and compress the scale to a more manageable range.

Sound is characterized by both its amplitude and frequency (or pitch). The human ear does not hear all frequencies equally. In particular, the ear deemphasizes low and very high frequencies. To better approximate the sensitivity of human hearing, the A-weighted decibel scale has been developed. A-weighted decibels are abbreviated as "dBA." On this scale, the human range of hearing extends from approximately 3 dBA to around 140 dBA. As a point of reference, Figure A-1 includes examples of A-weighted sound levels from common indoor and outdoor sounds.

Figure A-1: Typical Outdoor and Indoor Noise Levels



Using the decibel scale, sound levels from two or more sources cannot be directly added together to determine the overall sound level. Rather, the combination of two sounds at the same level yields an increase of 3 dBA. The smallest recognizable change in sound level is approximately 1 dBA. A 3-dBA increase is generally considered perceptible, whereas a 5-dBA increase is readily perceptible. A 10-dBA increase is judged by most people as an approximate doubling of the perceived loudness.

Two of the primary factors that reduce levels of environmental sounds are increasing the distance between the sound source and the receiver and having intervening obstacles, such as walls, buildings, or terrain features that block the direct path between the sound source and the receiver. Factors that act to increase the loudness of environmental sounds include the proximity of the sound source to the receiver, sound enhancements caused by reflections, and focusing caused by various meteorological conditions.

Brief definitions of the measures of environmental noise used in this report are:

- **Equivalent Sound Level (Leq)**: Environmental sound fluctuates constantly. The equivalent sound level (Leq), sometimes referred to as the energy-average sound level, is the most common means of characterizing community noise. Leq represents a constant sound that, over the specified period, has the same sound energy as the time-varying sound.
- **Day-Night Sound Level (Ldn)**: Ldn is basically a 24-hour Leq with an adjustment to reflect the greater sensitivity of most people to nighttime noise. The adjustment is a 10-dB penalty for all sound that occurs between the hours of 10 P.M. and 7 A.M. The effect of the penalty is that, when calculating Ldn, any event that occurs during the nighttime is equivalent to 10 of the same event during the daytime. Ldn is the most common measure of total community noise over a 24-hour period.
- **Maximum Sound Level (Lmax)**: The maximum sound level over a period of time or for a specific event can also be a useful parameter for characterizing specific noise sources. Standard sound level meters have two settings, fast and slow, which represent different time constants. Lmax using the fast setting will typically be 1 to 3 dB greater than Lmax using the slow setting.
- **Percent Exceedance Level (Lxx)**: This is the sound level that is exceeded for xx percent of the measurement period. For example, L99 is the sound level exceeded 99 percent of the measurement period. For a one hour period, the sound level is less than L99 for 36 seconds of the hour and the sound level is greater than L1 for 36 seconds of the hour. L1 represents typical maximum sound levels, L33 is approximately equal to Leq when free-flowing traffic is the dominant noise source, L50 is the median sound level, and L99 is close to the minimum sound level.
- **Sound Exposure Level (SEL)**: SEL is a measure of the total sound energy of an event. In essence, all sound from the event is compressed into a one-second period. This means that SEL increases as the event duration increases and as the event sound level increases. SEL is useful for estimating the Ldn that would be caused by individual events such as train passbys.

Vibration is an oscillatory motion that can be described in terms of the displacement, velocity, or acceleration of the motion. One potential effect from the proposed project is an increase in vibration that is transmitted from the tracks through the ground into adjacent houses. When evaluating human response, groundborne vibration is usually expressed in terms of decibels using the RMS vibration velocity. RMS is defined as the average of the squared amplitude of the vibration signal. To avoid confusion with sound decibels, the abbreviation VdB is used for vibration decibels. All vibration decibels in this report use a decibel reference of 1 μin/sec. Vibration can also be expressed as the peak particle velocity (PPV), which is generally used to evaluate whether vibration has potential to cause damage to fragile building structures. Peak particle velocity is normally expressed in inches per second.

East Link | South Bellevue to Overlake Transit Center
Contract No. RTA/AE 0143-11

Contract E340
Noise and Vibration Report
90% Submittal

OPERATIONS

April 2, 2014

Prepared for:

SOUNDTRANSIT

Prepared by:

HJH FINAL DESIGN PARTNERS.

Contract E340
Noise and Vibration Report

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Acronyms and Abbreviations

AWD	Audible Warning Device
BCC	Bellevue City Code
dBA	A-weighted decibel
DF	Direct Fixation
EDNA	Environmental designation for noise abatement
EIS	Environmental Impact Statement
FDL	Force Density Level
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
Ldn	24-hour day-night sound level
Leq	Equivalent sound level
LRT	Light Rail Transit
LRV	Light Rail Vehicle
LSTM	Line Source Transfer Mobility
PA	Public Address
PNB	Pacific Northwest Ballet
ROD	Record of Decision
SEL	Sound Exposure Level
ST	Sound Transit
TNM	Traffic Noise Model
TPSS	Traction Power Substation
VdB	Vibration decibel with reference to 1 µin/sec

1.0 Introduction

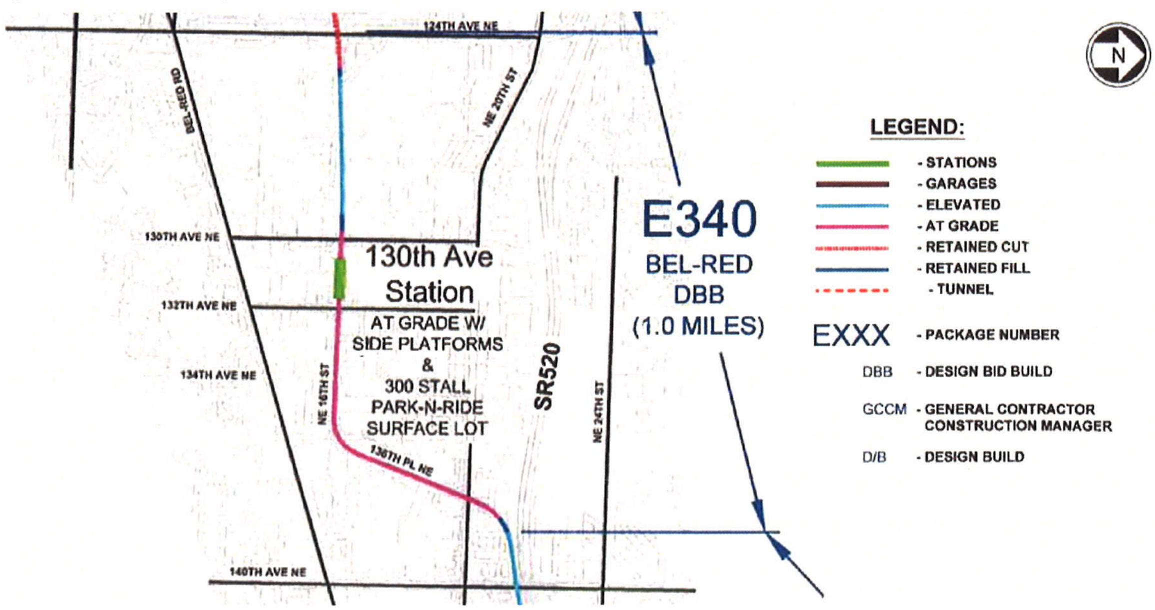
This draft Noise and Vibration Report presents the results of the noise and vibration impact assessment and the recommended mitigation measures for the E340 package. The predicted noise levels demonstrate compliance with both the Federal Transit Administration (FTA) impact criteria and the Bellevue City Code (BCC) Chapter 9.18 noise limits. Package E340 extends from the intersection of the ROW and 124th Ave NE at Station 635+00 to the intersection of 136th Place NE and NE 20th Street near SR-520 at Station 688+00. The package includes track that is in a retained cut, on elevated structure, and at-grade. The 130th Avenue Station with a 300 stall park-n-ride surface lot is located within the package. Figure 1-1 shows a site map of the East Link E340 package.

This report includes a noise impact assessment of operations of light-rail transit including noise from light-rail vehicles (LRVs), bell noise from trains and crossings, noise from the park-and-ride facility, and an assessment of station acoustics. Also included is a detailed vibration impact assessment of light-rail operations. The information in this report is an update to the noise and vibration impact assessment presented in the East Link Project Final Environmental Impact Statement (EIS), Appendix H2: Noise and Vibration Technical Report (July 2011). The recommendations in this report are based on the additional measurements and analysis performed by ATS Consulting in March through October of 2013.

The noise and vibration impact assessment presented in this report is consistent with the guidelines and methodology presented in the following documents:

- FTA's Transit Noise and Vibration Impact Assessment guidance manual (referred to in this report as the FTA guidance manual);
- Sound Transit's Link Noise Mitigation Policy, February 2004;
- Record of Decision (ROD) issued November 2011;
- the East Link Final Environmental Impact Statement, July 2011; and
- City's Noise Control Code, Chapter 9.18 Bellevue City Code

Figure 1-1: Site Map of East Link Package E340



2.0 Executive Summary

The FTA noise and vibration impact thresholds apply only to land uses defined as noise or vibration sensitive receivers in the FTA guidance manual. There is one parcel classified as a noise and vibration sensitive receiver located near the LRT tracks within the package E340 limits using the FTA land use definitions. The sensitive receiver is parcel EL310, the Francia Russell Center, a Pacific Northwest Ballet (PNB) School (an institutional land use). The location of the PNB School is shown in Figure 5-1. The PNB facility is being relocated to a new structure within the same parcel as part of the Project; the noise and vibration analysis in this report is for the new building location. This report includes a detailed noise and vibration impact assessment of LRT operations for this sensitive receiver using the FTA impact thresholds. There is also a sensitive receiver, the Blue Sky Church, located north of the park-and-ride facility at the 130th Avenue Station. The church is over 500 feet from the LRT tracks which is beyond the screening distance requiring an operational noise and vibration impact assessment; however, the church is assessed for noise impact from the park-and-ride facility using the FTA impact thresholds.

This report also assesses noise impact using the City of Bellevue's noise code, which applies to the Project's stationary noise sources such as park-and-ride facilities and stations. Traction power substation (TPSS) units are another stationary noise source associated with the Project; however, there are no TPSS sites within the package E340 limits.

This report includes a detailed noise and vibration impact assessment of LRT operations and park-and-ride noise for sensitive receivers using the FTA impact thresholds, as well as an assessment of park-and-ride noise and station noise using the noise limits defined in the City's noise code.

The conclusions of the noise and vibration impact assessment are:

- The predicted noise level at the PNB School is one decibel below the FTA noise impact threshold, so no noise mitigation measures are recommended. The predicted noise level at the PNB School is a one-hour equivalent sound level (Leq) of 62 dBA. The FTA moderate noise impact threshold at the PNB School is 63 dBA Leq(1-hour).
- The Project design includes the installation of lubricators on the curve adjacent to the PNB School to minimize wheel squeal and flanging. Noise from wheel squeal was not included in the noise predictions for the school because lubricators are included in the design.
- The predicted groundborne vibration and groundborne noise levels are below the FTA impact thresholds for the PNB School. No vibration mitigation is recommended.
- There is one crossover located within the package limits beginning at station 644+30. The crossover is located on the elevated structure between 124th Avenue NE and 130th Avenue NE. There are no noise or vibration sensitive land uses near the crossover using the FTA land use definitions. Therefore, no low-impact frog is recommended for the crossover to minimize noise and vibration levels from the special trackwork.
- The 130th Avenue Station is an at-grade station that is not fully enclosed but is open to the outside area. Due to the large area of the station ceiling and side walls that are open to the outside area, no acoustical treatment or other noise mitigation is required for the station.

- The predicted noise from the park-and-ride facility at 130th Avenue Station is below the FTA noise impact thresholds and below the limits in the City's noise code. No mitigation is recommended.
- Station noise from electrical transformers and public address announcements (PA) will not exceed the noise limits in the City's code.

3.0 ROD Commitments and EIS Mitigation Recommendations

The impact analysis and mitigation recommendations presented in this report are consistent with the ROD commitments. The noise and vibration ROD commitments applicable to the 60% design are:

1. Noise mitigation measures would be provided that are consistent with Sound Transit's Light Rail Noise Mitigation Policy (Motion No. M2004-08). The FTA manual also defines when mitigation is needed and bases this on the impact's severity, with severe impacts requiring the most consideration. During final design, all predicted impacts and mitigation measures will be reviewed for verification. During final design, if it is discovered that equivalent mitigation can be achieved by a less costly means or if the detailed analysis show no impact, then the mitigation measure may be eliminated or modified. Prior FTA approval is required for any elimination or substantial modification to mitigation measures. The potential mitigation options available for noise from transit operations on the East Link Project are primarily sound walls, special trackwork, lubricated curves, and residential building sound insulation. Sound walls are proposed where feasible and reasonable, as determined by Sound Transit (and the Federal Transit Administration, at its discretion) based on specific site conditions. Sound walls would be located on the ground for at-grade profiles and on the guideway structure for elevated profiles. Sound walls are preferred because they are effective at reducing noise. For locations where there is a potential for traffic noise to be reflected off the sound walls, Sound Transit will include where feasible the use of absorptive treatments to remedy this issue. A crossover track uses a frog (a rail-crossing structure) to allow the train to either cross over to another track or continue moving on the same track. A gap is provided on top of the frog so that vehicle wheels can pass regardless of which track is in use. With typical frogs, noise and vibration are generated when the wheels pass over the gap. Special trackwork, such as movable point or spring rail frogs, eliminates the gap between tracks at crossovers that causes noise and vibration at these locations and will be used where feasible. Sound Transit is currently investigating the use of non-audible warnings for gated and ungated at-grade crossings. If non-audible warning devices are found to be viable, this option could be used to reduce or eliminate bell noise at specific crossings. Where practical, grade separation of at-grade light rail crossings would also be considered to eliminate the need for bells or other audible warning devices. If bells are used at gated crossings, the bells would be set at the minimum noise level that maintains a safe crossing. Finally, the use of acoustic bell shrouds would be examined during final design; the shrouds would direct the bell noise at gated crossings to the intersection. When source mitigation measures or sound walls are infeasible or not entirely effective at reducing noise levels below the FTA impact criteria, then residential sound insulation would be evaluated and implemented at impacted properties where the existing building does not already achieve a sufficient exterior-to-interior reduction of noise levels. Many newer buildings, particularly in Downtown Bellevue, have good interior noise reduction and additional sound insulation may not be necessary. While the mitigation provided herein is based on predicted impacts, noise mitigation shall be provided if, after operations commence, noise impacts occur for which mitigation is deemed necessary and appropriate under FTA noise standards.
2. Traffic noise impacts will be mitigated by sound walls, where determined to be reasonable. For locations with residual traffic noise impacts caused by the project, residential sound insulation might also be considered by Sound Transit.

3. Wheel Squeal: For curves of 600-foot radius or less, a trackside or vehicle-mounted lubrication system will be used to mitigate wheel squeal noise. For curves of 600- to 1,250[1]-foot radius, the project will be designed to accommodate a lubrication system if wheel squeal occurs during operations.
4. Vibration and groundborne noise impacts that exceed FTA criteria warrant and will receive from Sound Transit effective mitigation measures, as described below, when determined to be reasonable and feasible. The locations requiring mitigation will be refined during final design and will be included, where needed, in the project's final design specifications. At some locations, however, light rail trackways or guideways could be within 20 feet of buildings and vibration mitigation may not be effective at reducing the vibration level to below the FTA criteria. At these locations, project design modification and additional information on affected buildings could eliminate these impacts. For instance, the type of building foundation might reduce vibration impacts and therefore, these residual impacts might be eliminated. In addition, each building will need to be examined in detail to determine where the vibration-sensitive uses are located. For example, the side of a building nearest the proposed alternative might be a vibration-sensitive use. Buildings that are mixed use might not have sensitive uses on lower floors where impacts are predicted to occur, and the vibration is not predicted to be noticeable by the time it reached higher floors with sensitive uses, such as sleeping quarters. Outdoor-to-indoor vibration testing, which tests how the vibration changes from the soil outside to a sensitive space inside a building, would also help to refine the vibration projections at these locations. Vibration mitigation measures will be employed at those areas where vibration impacts have not been anticipated but are shown evident after operations commence. Options for mitigating vibration impacts include the following: 1) Ballast mats, which consist of a pad made of rubber or rubberlike material placed on an asphalt or concrete base with the normal ballast, ties, and rail on top. The reduction in groundborne vibration provided by a ballast mat is strongly dependent on the vibration frequency content and the design and support of the mat. 2) Resilient fasteners to provide vibration isolation between rails and concrete slabs for direct fixation track, typically on elevated structures or in tunnels. These fasteners include a soft, resilient element between the rail and concrete to provide greater vibration isolation than standard rail fasteners. 3) Tire-derived aggregate (TDA), which consists of shredded tires wrapped with filter fabric that is added to the base below the track ties. 4) Special trackwork, such as movable point or spring rail frogs, to eliminate the gap between tracks at crossovers that causes noise and vibration at these locations. 5) Floating slabs, which consist of thick concrete slabs supported by resilient pads on a concrete foundation; the tracks are mounted on top of the floating slab. Although floating slabs are designed to reduce vibration at lower frequencies than ballast mats, they are extremely expensive and are rarely used, except in the most extreme situations. Most successful floating slab installations are in subways, and their use for at-grade track is less common and often not reasonable.

The noise and vibration impact analysis performed for the Final EIS did not find any impact within the Contract E340 project limits, and therefore no mitigation measures were recommended in the Final EIS and no mitigation measures were required in the ROD.

[1] The ROD says curves of 600 ft to 1,000 ft should be designed to accommodate a lubrication system, but the Design Criteria Manual (DCM V-3) states lubrication systems shall be accounted within the track design on all curves less than 1250' expect bored tunnels. The ROD text in this section has been modified to be consistent with the DCM.

4.0 Impact Assessment Methodology

4.1 Impact Thresholds and Noise Limits

FTA Impact Thresholds

This report includes a noise and vibration impact assessment using the using the prediction methodology and impact thresholds set forth in the FTA guidance manual. The FTA noise and vibration impact thresholds apply only to land uses defined as noise and vibration sensitive in the FTA guidance manual. The FTA guidance manual defines three categories of noise sensitive land uses:

- 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. Included are outdoor amphitheaters, recording studios, and concert halls.
- Category 2: Residences and buildings where people normally sleep. This category includes homes, hospitals and hotels where nighttime sensitivity to noise 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 such activities as speech, meditation, and concentration on reading material.

There is one parcel classified as a noise and vibration sensitive receiver near the LRT tracks within the package E340 limits using the FTA land use definitions. The sensitive receiver is parcel EL310, the Francia Russel Center, a Pacific Northwest Ballet (PNB) school and is classified as a Category 3 land use. There is another sensitive receiver, the Blue Sky Church, which is adjacent to the park-and-ride facility at 130th Avenue Station. The Church is over 500 ft north of the LRT tracks which is beyond the screening distance requiring an operational noise and vibration assessment; however, it is assessed for noise impact from the park-and-ride facility. Therefore, the PNB School is assessed for operational noise and vibration impact using the FTA impact thresholds and the Blue Sky Church is assessed for noise impact from the park-and-ride facility using the FTA impact thresholds.

Bellevue City Code Noise Limits

Chapter 9.18 of the Bellevue City Code (BCC) addresses noise control. The chapter includes maximum permissible noise levels and exemptions to those noise limits. The BCC applies to stationary noise sources associated with the Project. The stationary noise sources within the E340 package are the park-and-ride facility and the station. Noise from stationary sources are assessed for impact using the maximum permissible noise levels presented in BCC 9.18.030.B. Those maximum permissible noise levels are summarized in Table 4-1.

Table 4-1: Applicable Maximum Permissible Sound Levels, Bellevue City Code

EDNA of Noise Source	EDNA Of Receiving Property	
	Class B	Class C
Class B	60 dBA	65 dBA
Class C	65 dBA	70 dBA

Source: Bellevue City Code Chapter 9.18

4.2 Airborne Noise

Light-Rail Vehicle Operations

The noise from the operation of LRT vehicles includes noise from the steel wheels rolling on steel rails (wheel/rail noise) and noise from propulsion motors, air conditioning, and any other auxiliary equipment on the vehicles. Operational LRT noise at sensitive receivers is predicted using the FTA detailed noise analysis procedure which is a spreadsheet model using formulas presented in the FTA guidance manual. The formulas take into account the following specific operating characteristics of the Sound Transit system:

- Measured reference sound level of existing Sound Transit LRVs,
- the train operating schedule,
- train speed, and
- track structure.

ATS Consulting took reference sound level measurements on the existing ST Central Link light-rail system in April 2013[2]. Measurements were taken on at-grade track and aerial structure track. The measurements were made using a 3-car train consist travelling at controlled speeds during non-revenue service hours and measurements of 2-car train consists during regular revenue service hours. The results of the noise measurements show that the noise levels on the Central Link system are about 2 decibels higher than the FTA reference noise level for LRVs. The reference sound exposure level (SEL) used for the predictions in this analysis is 84 dBA at 50 ft for a one-car train traveling at 50 mph on ballast-and-tie track (2 decibels higher than the FTA reference level of 82 dBA) and is based on the results of the measurements. The reference sound level measured for direct-fixation track is 4 dB higher than for ballast-and-tie track (the same +4 dB adjustment is recommended in the FTA guidance manual for direct fixation track).

The train schedule from Sound Transit's Revised 2035 Light Rail Operation Plan, shown in Table 4-2, was used for the noise predictions. Note that the revised 2035 operating schedule is different from the assumptions used in the Final EIS predictions. The revised operating schedule assumes 8 minute peak headways and 4-car train consists, while the Final EIS schedule assumed 7-minute peak headways and 3-car train consists. The operating speeds and track structure type assumed in the predictions are based on the information in the 90% design drawings.

Table 4-2: East Link Operating Plan

Hours	Headway (minutes)	Total train cars (assuming 4-car trains)
5-6am	15	16
6-7am	8	30
7-8:30am	8	45
8:30am-3:00pm	10	156
3-6:30pm	8	105
6:30-10pm	10	84

[2] The sound level measurements of the existing ST Central Link light-rail system are documented in the report: *Noise Measurements of Existing Sound Transit Trains* dated October 16, 2013.

Hours	Headway (minutes)	Total train cars (assuming 4-car trains)
10pm-1:00am	15	48
1-5am	0	0

In addition to the operating characteristics of the system, the noise formulas also account for distance from the sensitive receiver, ground absorption effects, and noise from bells. The methodology for the analysis in this report follows the procedures in the FTA guidance manual and the Final EIS.

Bell noise is also included in operational LRT noise for the FTA analysis. The assumptions used for bell predictions are based on the Sound Transit bell policy. Included in the predictions are noise from the warning bells on the light-rail vehicles and audible warning devices at crossings. The assumptions for the different types of bells are:

- Trains will have a high bell, low bell, and horn. The horn is for emergency situations only and is not used in the noise analysis. Consistent with the practice on the Central Link line, the train-mounted bell will be sounded two to three times as a train approaches and passes through an at-grade crossing and for arrivals and departures at a station. The high bell has a sound pressure level of 80 dBA at 50 feet and is used during the daytime hours from 6 a.m. to 10 p.m. The low bell has a sound pressure level of 72 dBA at 50 feet and is used during the nighttime hours from 10 p.m. to 6 a.m.

- Wayside pedestrian audible warning devices (AWDs) located at the at-grade crossings will operate at 10 decibels above the ambient noise levels. The predictions assume the AWDs have an Lmax of 77 dBA at 15 feet and will sound for approximately 40 seconds per train. The noise analysis does not assume that the noise levels of the audible warning devices would be reduced during nighttime hours (a worst case assumption).

AWDs are stationary noise sources; however, they are not included in the impact assessment using the City's noise code. There are two exemptions in section 9.18.020 of the BCC that apply to AWDs. The first exemption is in subsection A.10 and is for "Sounds created by safety and protective warning devices where noise suppression would render the device ineffective". The second exemption is in subsection B.1 and is for "Sounds created by bells, chimes and carillons not operating continuously for more than five minutes in any one hour." Therefore, bell noise is only included in the impact assessment using the FTA noise impact thresholds.

Noise from Park-and-Ride Facilities

Noise from park-and-ride facilities is assessed using both the FTA impact thresholds and the limits in the City's noise code. The methodology for predicting noise levels at receiving properties follows the FTA guidance manual procedures. (The City's noise code does not address prediction methodology).

The noise level at the nearest receiving property or sensitive receiver is predicted using the following equation:

$$Leq(1hr) = SEL_{ref} + 10\log(N_a/2000) - 20*\log(dist/50) - 35.6$$

where SEL_{ref} is the reference SEL at 50 ft, N_a is the number of automobiles per hour, and *dist* is the distance from the facility to the property line of the receiving property (for the analysis using the City's nosie limits) or the distance from the facility to the nearest sensitive receiver (for the FTA analysis). The reference sound exposure level (SEL) at 50 feet for 1000 cars in the peak activity hour is 101 dBA at 50 feet. The predicted noise level from the park-and-ride facility is compared to the impact thresholds to identify potential impacts.

Station Noise

Stationary noise sources associated with the LRT stations are the operation of electrical transformers and PA announcements. Noise from these sources are subject to the limits in the City's noise code.

A 156 KVA transformer will be used at the 130th Avenue NE station. Manufacturer's sound level data of a transformer between 150 KVA and 300 KVA is less than 55 dBA at 3 feet. The noise level at the nearest receiving property is predicted using the following equation:

$$Leq(1hr) = Leq_{ref} - 20*\log(dist/3)$$

where Leq_{ref} is the reference noise level of 55 dBA at 3 feet and *dist* is the distance from the transformer to the property line of the receiving property. Note that this prediction methodology assumes the transformer operates continuously.

The PA speakers at the station will operate at 10 dB above the ambient noise level at a distance of 10 feet from the speaker. The noise level from the PA announcements at the nearest receiving property is predicted using the following equation:

$$Leq(1hr) = L_{ref} + 10*\log(duration) - 20*\log(dist/10) - 10*\log(60*60)$$

where L_{ref} is the reference noise level of 10 dB above the ambient, *duration* is the total duration in seconds of announcements over one hour, and *dist* is the distance from the speaker to the property line of the receiving property.

There is one station located within the E340 package limits - the 130th Avenue NE station. The ambient noise level at the station is assumed to be equal to the ambient noise level measured at the PNB school: Leq(1hr) = 59 dBA. Based on this ambient noise level, the PA announcements will be 69 dBA at 10 feet from the PA speaker on the station platform.

Station Acoustics

In an enclosed environment such as a transit station sound can continue to reflect for a period of time after a source has stopped emitting sound. This prolongation of the sound is called reverberation. Reverberation time (TR60) is defined as the time required, in seconds, for the average sound in a room to decrease by 60 decibels after a source stops generating sound. Reverberation time is the primary descriptor of an acoustic environment and minimizing reverberation time in a transit station helps to ensure intelligibility of announcements and speech within the station.

Reverberation time is affected by the size of the space and the amount of reflective or absorptive surfaces within the space. A space with highly absorptive surfaces will absorb the sound and stop it from reflecting back into the space. This would yield a space with a short reverberation time. In general, larger spaces have longer reverberation times than smaller spaces. Therefore, a large space will require more absorption to achieve the same reverberation time as a smaller space.

Reverberation time for the transit stations are calculated using the Sabine Formula:

$$RT_{60}= 0.049*V/a$$

where V is the volume of the space (ft^3) and a is the total room absorption at a given frequency in sabins. It is important to note that the absorption and surface area must be considered for every material within a space in order to calculate sabins. The number of sabins is determined by multiplying the noise reduction coefficients of different surfaces within the station by the surface area of that material.

This calculation method is used to determine if the design of a transit station will achieve the Sound Transit Design Criteria of a maximum reverberation time of 1.5 seconds or less in station platform areas, enclosed public spaces, and other areas where the transit patrons rely on the PA system for information and directions. The FTA and BCC do not have a criteria relating to station reverberation time. The Sound Transit Design Criteria is the only criteria that apply to the acoustical design of the stations.

4.3 Groundborne Vibration and Groundborne Noise

The FTA detailed vibration analysis procedure is an empirical method based on testing of the vibration propagation characteristics of the soil near sensitive receivers and measurements of the vibration characteristics of a similar LRV. The vibration propagation test is used to determine the line source transfer mobility (LSTM). The LSTM quantifies how easily vibration travels through the earth (high transfer mobility indicates that there is relatively little attenuation as vibration travels through the earth). The vibration characteristics of the LRV are quantified by the force density level (FDL). The basic relationship used for the vibration predictions is:

Lv = LSTM + FDL + Train Length Adjustment +Safety Factor
where:

Lv	Predicted train vibration velocity
LSTM	Measured line source transfer mobility that characterizes the vibration propagation through the soil
FDL	Measured force density level that characterizes the vibration forces generated by the train and the track
Train Length Adjustment	A+0.5 dB adjustment to account for a 4-car train consist
Safety Factor	+3 dB adjustment to account for uncertainty in the measurement results

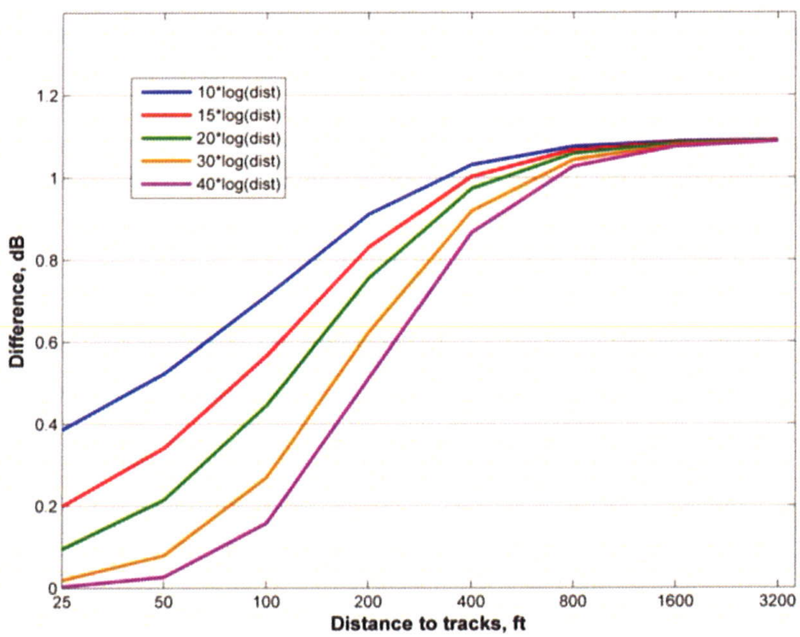
Vibration propagation tests were conducted near the vibration sensitive receiver in the E340 package. The results from the test are presented in Section 5.1.

ATS Consulting measured the FDL on the existing ST Central Link light-rail system in April 2013. Measurements were taken on at-grade track, direct fixation track in a retained cut, and on an aerial structure to determine the FDL for different track types. The FDL measurements were made using a 3-car train consist. The results of the FDL measurements are documented in the report: Vibration Measurements of Existing Sound Transit Trains, July 14, 2013. A plot of the FDL used for the analysis in this report is included in Section 5.1.

The current East Link operating plan calls for four-car trains. A train length adjustment is included in the predictions to account for the fact that the FDL measurement test was conducted with a three-car train. The train length adjustment was derived using a spreadsheet model. The effect of train length on vibration levels at a sensitive receiver will depend on the vibration propagation characteristics of the soil at the receiver and the distance from the tracks to the receiver. Therefore, the effect of train length varies depending on site specific conditions. Figure 4-1 shows the expected vibration difference for four car trains compared to three car trains. The horizontal axis is the distance from the tracks and the vertical axis is the expected increase in vibration levels for a four-car train compared to a three-car train. The different lines on the plot represent different soil propagation characteristics. For example, the blue line represents soil where vibration travels very efficiently and the pink line represents soil where vibration does not travel very efficiently.

The train length adjustment used for the predictions is a +0.5 dB adjustment applied to all frequency bands and to receivers at all distances. This adjustment was chosen because the +0.5 dB adjustment is conservative (most likely an overestimate) for receivers closer than 100 ft to the tracks and all sensitive receivers identified with potential for impact in the Final EIS are located closer than 100 ft to the tracks.

Figure 4-1: Expected Vibration Difference for a 4-Car Train Compared to a 3-Car Train



The relationship between the predicted groundborne vibration, Lv, and the predicted groundborne noise, La, is:

$$La = Lv + Ka\text{-}wt + Krad,$$

where Ka-wt is the A-weighting adjustment at the 1/3 octave band center frequency and Krad is an adjustment to account for the conversion from vibration velocity level to sound pressure level such as any acoustical absorption in the room. The FTA guidance manual recommends a Krad value of zero for typical residential rooms although recent research indicates the average Krad for residential construction is closer to -5 dBA. The analysis in this report assumes a Krad of 0, which is a conservative assumption to ensure groundborne noise predictions are not underestimated.

Noise Impact Assessment for PNB School

The PNB School is assessed for noise impact using the FTA impact thresholds for an institutional land use. A one hour noise measurement was conducted at the PNB School on May 14, 2013. Determining the existing noise levels at a sensitive receiver is an important step in the noise impact assessment because the FTA thresholds for noise impact are based on existing noise. The noise impact thresholds are higher for areas with high existing noise levels and lower for areas with low existing noise levels.

The noise measurement location at the PNB School is shown in Figure 5-2. The microphone was at the setback distance of the building, 60 feet from NE 16th Street. The primary noise source was traffic from NE 16th Street and activity in the parking lot. The measured 1-hour Leq (equivalent noise level) at the PNB School was 59 dBA. The moderate impact threshold for a Category 3 land use with an existing noise level of 59 dBA is a 1-hour Leq of 63 dBA. The severe impact threshold is a 1-hour Leq of 68 dBA.

Figure 5-2: Aerial Photograph of the PNB School Noise Measurement Location

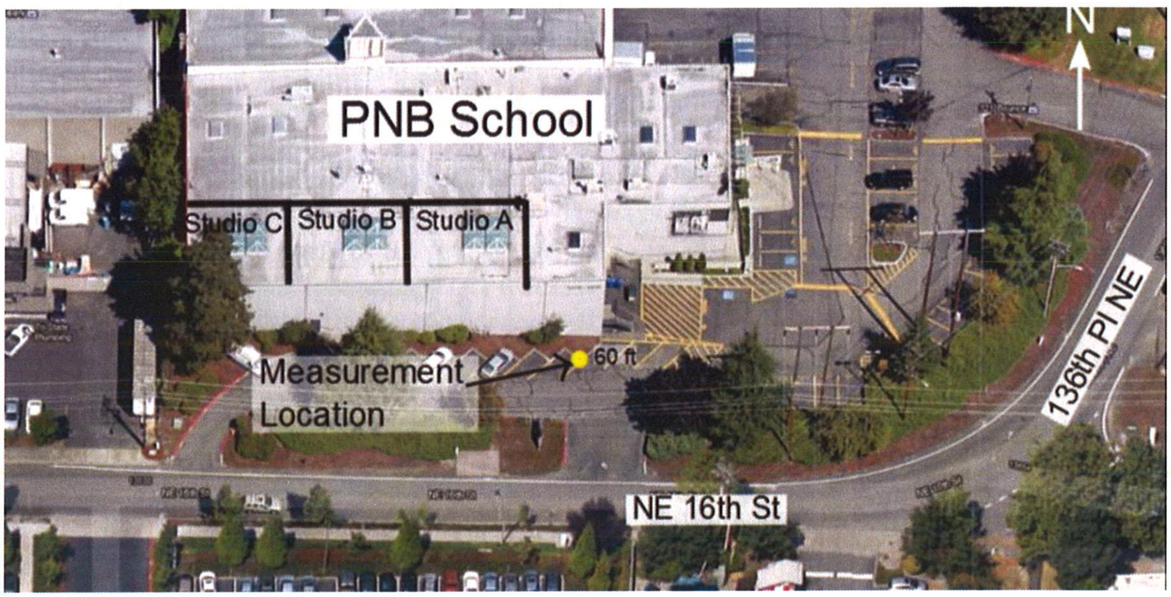


Table 5-1 shows the existing noise level, impact threshold, and predicted noise level for the PNB School. Key notes on the prediction assumptions for the PNB School include:

- There will be embedded track near the PNB School. A +3 decibel adjustment is included in the predictions to account for the embedded track. This is consistent with the recommendation for embedded track in the FTA Guidance Manual.
- The PNB School is located next to a low-radius curve. Wheel squeal from the curve is not included in the predictions because a lubricator will be installed on both the westbound and eastbound tracks to minimize wheel squeal and flanging.
- The LRVs will be traveling 30 mph near the PNB School. LRVs will not be able to operate at higher speeds due to the low-radius curve.
- No ground absorption adjustment is included in the predicted noise level because there is hard, paved ground near the school.

- Noise from train bells and a pedestrian AWD for the NE 16th Street/136th Pl NE at-grade crossing are included in the predicted noise levels.

As shown in Table 5-1, the predicted noise level at the PNB School is one decibel below the moderate impact threshold. No noise mitigation is required. It is anticipated that the design of the reconstructed PNB School building will include design elements such as double glazed windows to ensure that interior noise levels from traffic and train noise will be acceptable for classroom and performance spaces.

Table 5-1: Predicted Noise Levels at PNB School (Parcel EL310)

Parcel	Distance to WB track, ft	Speed (mph)	Existing Noise Level, dBA Leq(1-hr)	Impact Threshold, dBA Leq(1-hr)		Predicted Level, dBA, Leq(1-hr)	Amount Exceeds Moderate
				Moderate	Severe		
EL310	115	30	59	63	68	62	0

As part of the project, the existing NE 16th Street and 136th Place NE roadways will be realigned to accommodate the LRT tracks and the PNB building will be relocated further north within the parcel. The facade of the PNB School is currently 65 feet from the nearest lane of traffic. After the relocation of the building and the realignment of the roadways, the facade of the PNB School will be 80 feet from the nearest lane of traffic. The increase in distance from the traffic will result in about a 1 decibel decrease in traffic noise. There will be no traffic noise impact from the realignment of the roadway and the relocation of the building.

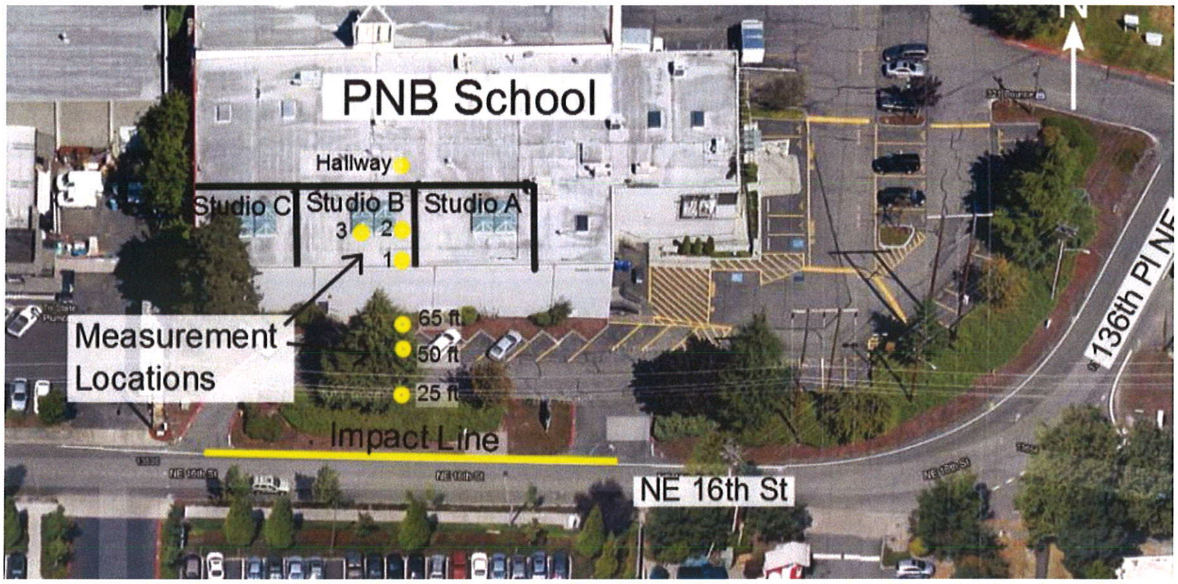
Vibration Impact Assessment for PNB School

A vibration propagation test was conducted at the PNB School on May 14, 2013. The results of the vibration propagation test were used to calculate the LSTM and to predict the vibration levels from LRT operations inside the dance studios using the FTA detailed vibration analysis procedure.

The measurement locations from the vibration propagation test are shown in Figure 5-3. Following is a summary of the measurement locations from the vibration propagation test:

- Propagation impact locations: on the north shoulder of NE 116th Street close to the location of the future eastbound track centerline
- Outdoor measurement locations: 27 ft, 50 ft, and 65 ft from the impact line. The 65 ft measurement location is outdoors adjacent to the building facade.
- Indoor measurement locations: 3 measurement locations inside studio B and one in the hallway just north of studio B.

Figure 5-3: Aerial Photograph of the PNB School Vibration Propagation Measurement



The groundborne vibration prediction methodology follows the procedure described in Section 4.3. In addition, the following assumptions and adjustments were included in the predictions:

- The westbound LRT track will be 115 feet from the new building façade housing the relocated PNB studios. The impact locations from the LSTM propagation tests (impact line) were 65 feet from the existing building facade. A distance adjustment was included in the predicted levels to account for the extra distance to the new building. Because data from outdoor measurements were only available for distances up to 65 feet, the LSTM data from site V-6 from the Final EIS was used to calculate the distance adjustment. The distance adjustment was calculated by taking the difference between the LSTM at 115 feet and at 65 feet from the Final EIS V-6 measurement results and subtracting that difference from the LSTM measured inside the dance studio.
- There will be embedded track near the PNB School. The FDL for embedded track was estimated using the FDL for ballast-and-tie track measured on the existing Central Link and adding an adjustment at high frequencies. The adjustment for embedded track is derived from measurements performed on both embedded track and ballast-and-tie track of the existing Hiawatha LRT system in Minnesota. The adjustment was only included for frequencies greater than 20 Hz because the FDLs showed good agreement at lower frequencies. Further details on the FDL measurements from the Hiawatha system are available in Appendix J of the Central Corridor Final EIS[3]. This adjustment is conservative because FDL results from other systems, such as the Portland TriMet MAX LRT system, have similar results for ballast-and-tie and embedded track systems. The ballast-and-tie FDL from the existing Central Link was measured by ATS Consulting in April 2013 on the existing ST Central Link on ballast-and-tie track on Martin Luther King Jr Way.

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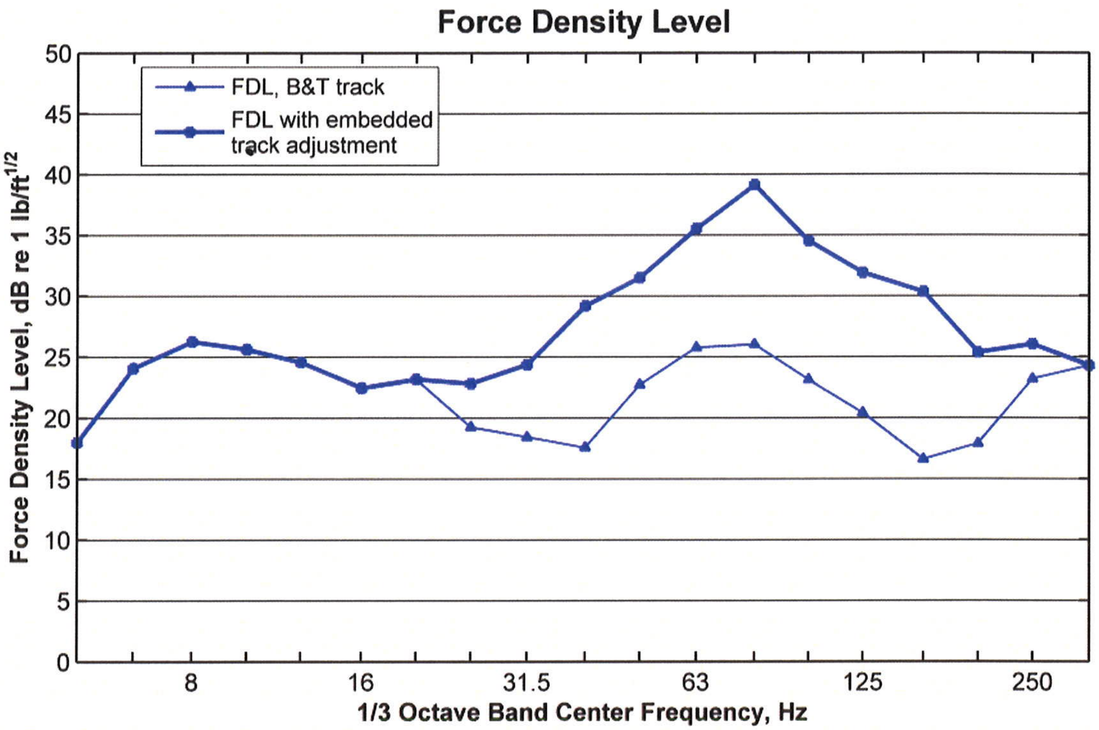
[3] Central Corridor Final Environmental Impact Statement available at:
http://www.metrocouncil.org/Transportation/Projects/Current-Projects/Central-Corridor/Environmental/FEIS.aspx

The FDL used in the predictions is shown in Figure 5-4. The LSTM and coherence measured at the PNB School is shown in Figure 5-5. The LSTM from site V-6 is available in the Final EIS. Site V-6 is Highland Park off of Bel-Red Road, and is the closest vibration propagation test site to the PNB School.

Figure 5-4: Ballast-and-tie FDL With Embedded Track Adjustment from Sound Transit, 30 mph (above) and FDLs for Ballast-and-tie Track and Embedded Track from the Hiawatha LRT System (below)



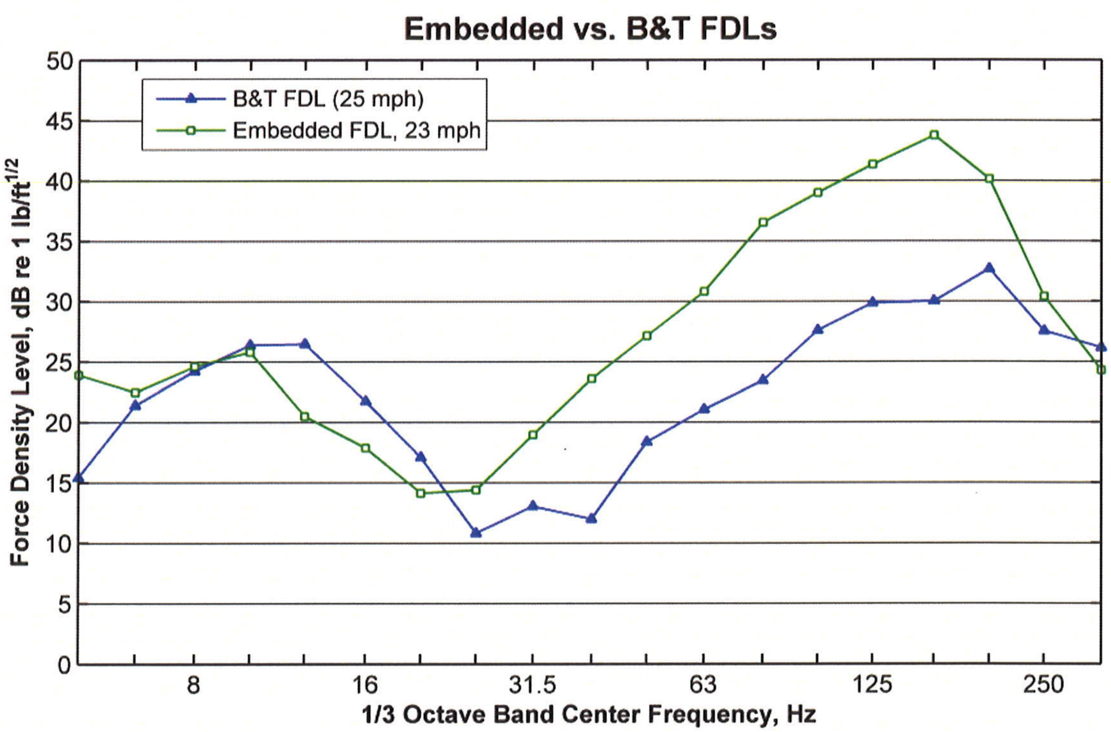
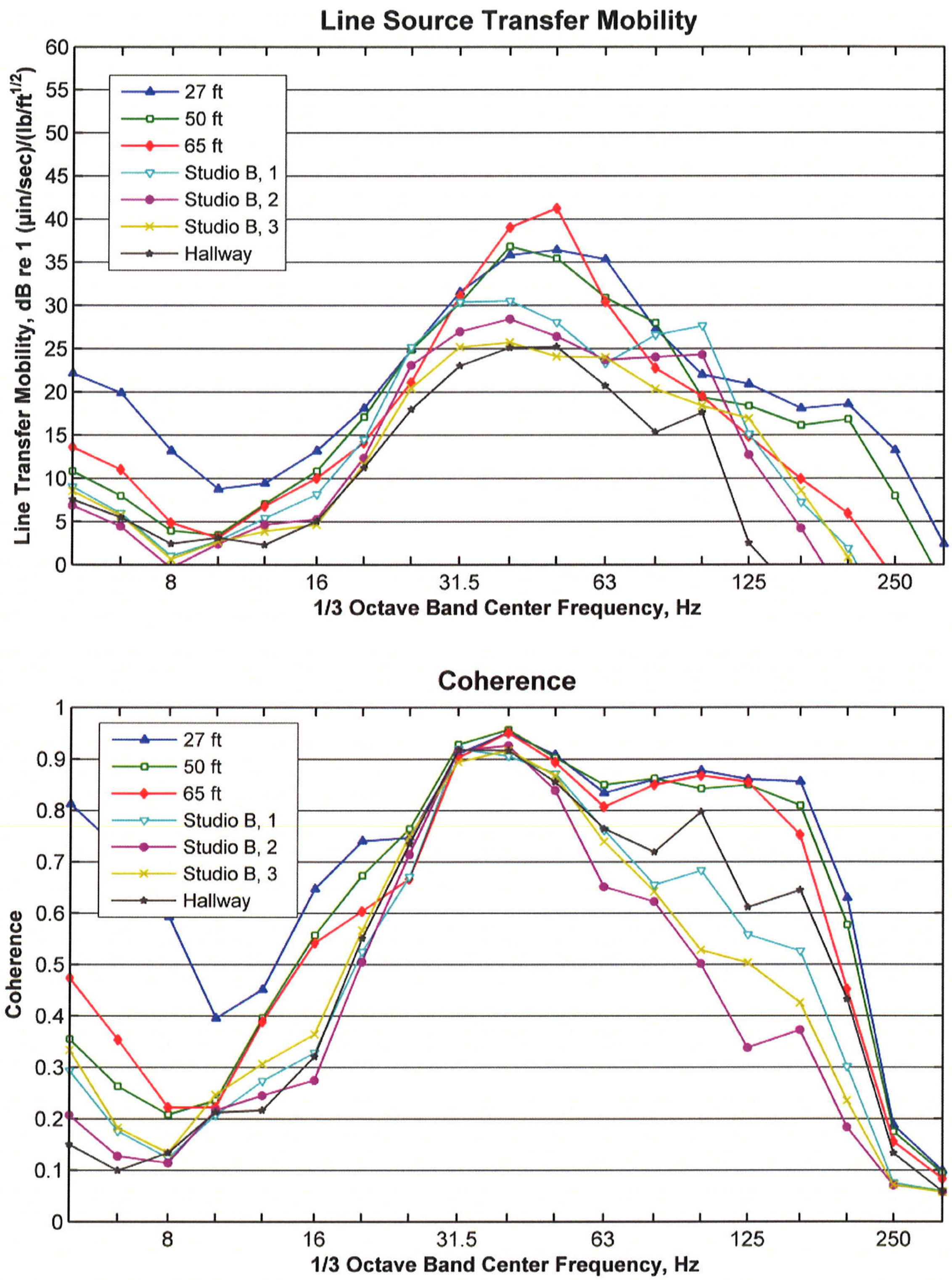


Figure 5-5: Line Source Transfer Mobility and Coherence Measured at the PNB School



The predicted groundborne vibration and groundborne noise levels for each indoor measurement location are shown in Table 5-2, Figure 5-6, and Figure 5-7. For groundborne vibration, a prediction is included for three indoor locations corresponding to the measurement locations inside Studio B. For groundborne noise, one prediction is included that is an average of all three measurement positions because the groundborne noise is the noise radiated off of all surfaces in the room.

The predicted levels for groundborne vibration are about 15 to 20 decibels below the impact threshold and the predicted level for the groundborne noise is 2 decibels below the impact threshold. Therefore, no vibration mitigation is recommended at the PNB School.

Table 5-2: Predicted Groundborne Noise and Vibration Levels at the PNB School (Parcel EL310)

Location	Predicted Vib. Vel. level in max. 1/3 octave band (VdB)	Max. 1/3 octave band	Vibration Impact Threshold (VdB)	Predicted Overall Groundborne Noise (dBA)	Groundborne Noise Impact Threshold (dBA)
Studio, corner	60	80 Hz	78	38	40
Studio, side wall	58	80 Hz	78		
Studio, center	54	80 Hz	78		

Figure 5-6: Predicted Groundborne Vibration Levels at the PNB School (Parcel EL310)

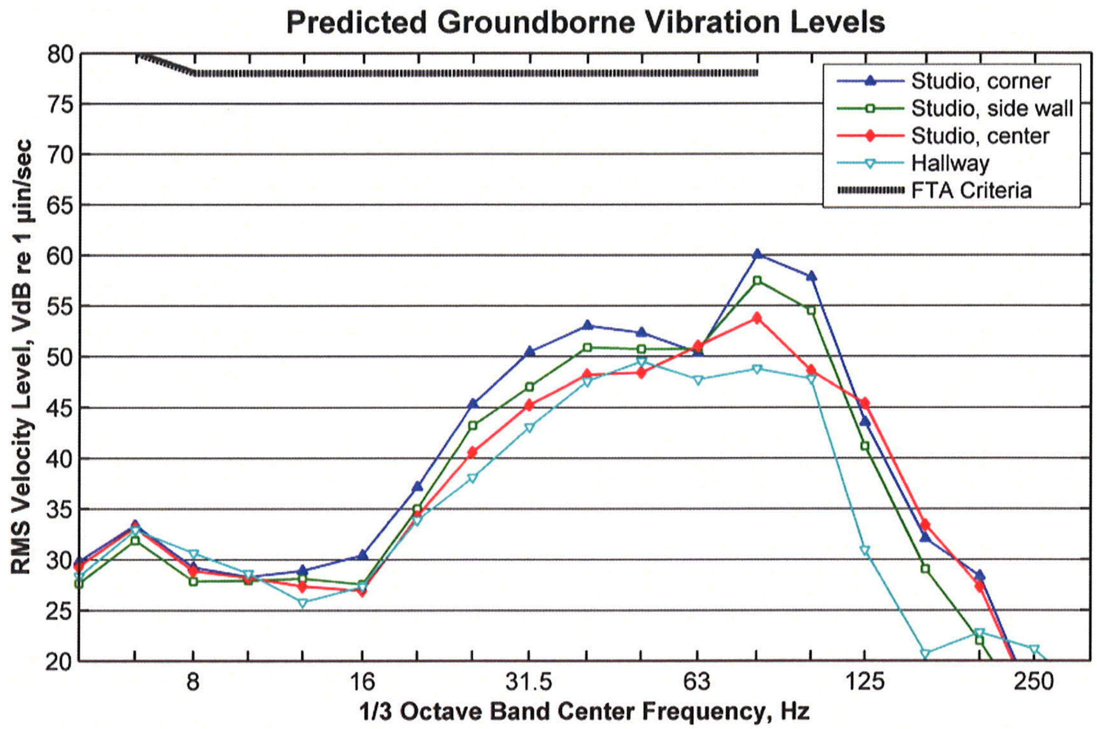
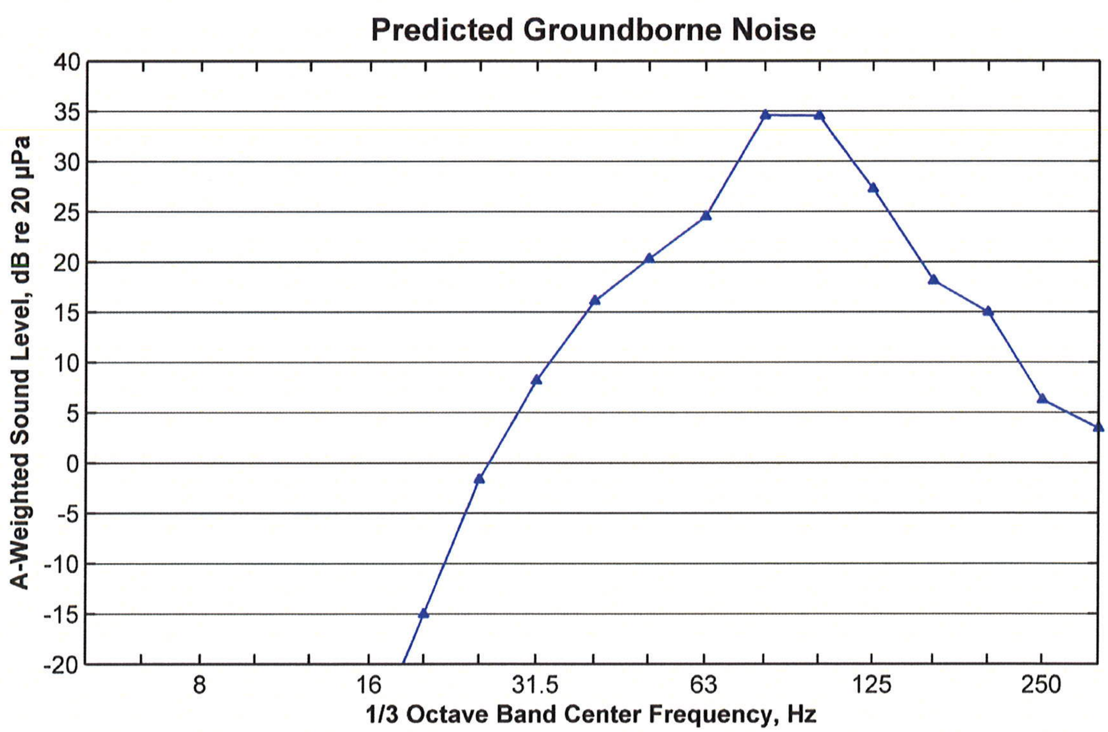


Figure 5-7: Predicted Groundborne Noise Levels at the PNB School (Parcel EL310)



perceptible. A 10-dB increase is judged by most people as an approximate doubling of the perceived loudness.

The two primary factors that reduce levels of environmental sounds are increasing the distance between the sound source and the receiver and having intervening obstacles such as walls, buildings, or terrain features that block the direct path between the sound source and the receiver. Factors that act to make environmental sounds louder include moving the sound source closer to the receiver, sound enhancements caused by reflections, and focusing caused by various meteorological conditions.

Following are brief definitions of the measures of environmental noise used in this study:

- *Maximum Sound Level (L_{max}):* L_{max} is the maximum sound level that occurs during an event such as a train passing. For this analysis L_{max} is defined as the maximum sound level using the slow setting on a standard sound level meter.
- *Equivalent Sound Level (L_{eq}):* Environmental sound fluctuates constantly. The equivalent sound level (L_{eq}) is the most common means of characterizing community noise. L_{eq} represents a constant sound that, over a specified period of time, has the same sound energy as the time-varying sound. L_{eq} is used by the FTA to evaluate noise effects at institutional land uses, such as Schools, churches, and libraries, from proposed transit projects.
- *Day-Night Sound Level (L_{dn}):* L_{dn} is basically a 24-hour L_{eq} with an adjustment to reflect the greater sensitivity of most people to nighttime noise. The adjustment is a 10 dB penalty for all sound that occurs between the hours of 10:00 p.m. to 7:00 a.m. The effect of the penalty is that, when calculating L_{dn}, any event that occurs during the nighttime is equivalent to ten occurrences of the same event during the daytime. L_{dn} is the most common measure of total community noise over a 24-hour period and is used by the FTA to evaluate residential noise effects from proposed transit projects.
- *L_{XX}:* This is the percent of time a sound level is exceeded during the measurement period. For example, the L_{99} is the sound level exceeded during 99 percent of the measurement period. For a 1-hour period, L_{99} is the sound level exceeded for all except 36 seconds of the hour. L_1 represents typical maximum sound levels, L_{33} is approximately equal to L_{eq} when free-flowing traffic is the dominant noise source, L_{50} is the median sound level, and L_{99} is close to the minimum sound level.
- *Sound Exposure Level (SEL):* SEL is a measure of the acoustic energy of an event such as a train passing. In essence, the acoustic energy of the event is compressed into a 1-second period. SEL increases as the sound level of the event increases and as the duration of the event increases. It is often used as an intermediate value in calculating overall metrics such as L_{eq} and L_{dn}.
- *Sound Transmission Class (STC):* STC ratings are used to compare the sound insulating effectiveness of different types of noise barriers, including windows, walls, etc. Although the amount of attenuation varies with frequency, the STC rating provides a rough estimate of the transmission loss from a particular window or wall.

Vibration Fundamentals

One potential community effect from the proposed project is vibration that is transmitted from the tracks through the ground to adjacent houses. This is referred to as *groundborne vibration*. When evaluating human response, groundborne vibration is usually expressed in terms of decibels using the root mean square (RMS) vibration velocity. RMS is defined as the average of the squared amplitude of the vibration signal. To avoid confusion with sound decibels, the abbreviation VdB is used for vibration decibels. All vibration decibels in this report use a decibel reference of 1 micro-inch/second (µin/sec.).[5] The potential adverse effects of rail transit groundborne vibration are as follows:

- **Perceptible Building Vibration:** This is when building occupants feel the vibration of the floor or other building surfaces. Experience has shown that the threshold of human perception is around 65 VdB and that vibration that exceeds 75 to 80 VdB may be intrusive and annoying to building occupants.
- **Rattle:** The building vibration can cause rattling of items on shelves and hanging on walls, and various different rattle and buzzing noises from windows and doors.
- **Reradiated Noise:** The vibration of room surfaces radiates sound waves that may be audible to humans. This is referred to as *groundborne noise*. When audible groundborne noise occurs, it sounds like a low-frequency rumble. When the LRT tracks are at-grade, the groundborne noise is usually masked by the normal airborne noise radiated from the transit vehicle and the rails.
- **Damage to Building Structures:** Although it is conceivable that vibration from a light-rail system could cause damage to fragile buildings, the vibration from light-rail transit systems is usually one to two orders of magnitude below the most restrictive thresholds for preventing building damage. Hence the vibration effect criteria focus on human annoyance, which occurs at much lower amplitudes than does building damage.

Vibration is an oscillatory motion that can be described in terms of the displacement, velocity, or acceleration of the motion. The response of humans to vibration is very complex. However, the general consensus is that for the vibration frequencies generated by passenger trains, human response is best approximated by the vibration velocity level. Therefore, vibration velocity has been used in this study to describe train-generated vibration levels.

When evaluating human response, groundborne vibration is usually expressed in terms of decibels using the root mean square (RMS) vibration velocity. RMS is defined as the average of the squared amplitude of the vibration signal. To avoid confusion with sound decibels, the abbreviation VdB is used for vibration decibels. All vibration decibels in this report use a decibel reference of 1 µin/sec.

Figure A-2 shows typical vibration levels from rail and non-rail sources as well as the human and structure response to such levels.

[5] One µin/sec= 10^{-6} in/sec.

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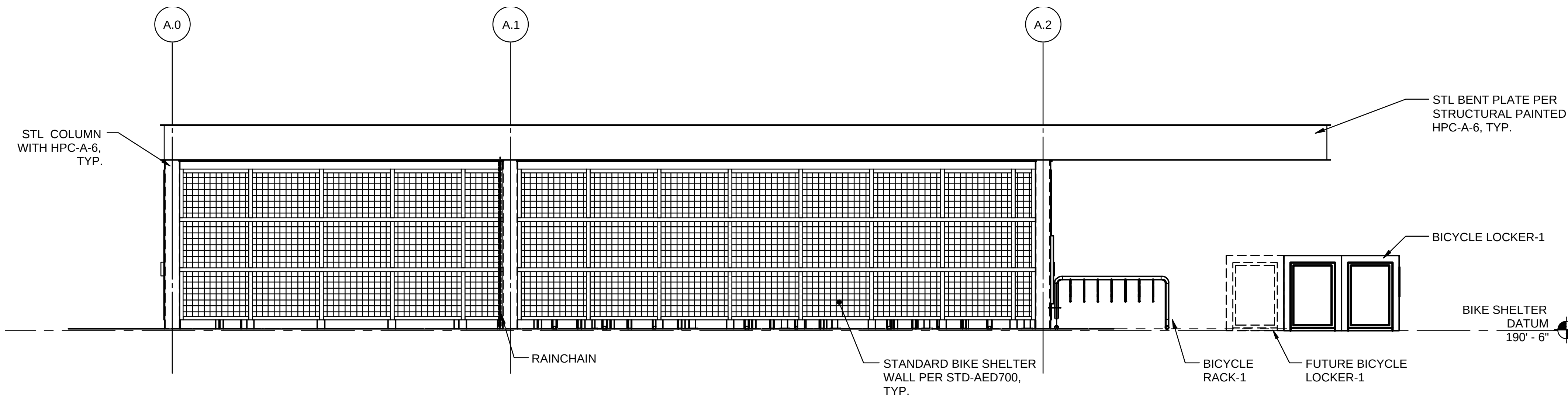

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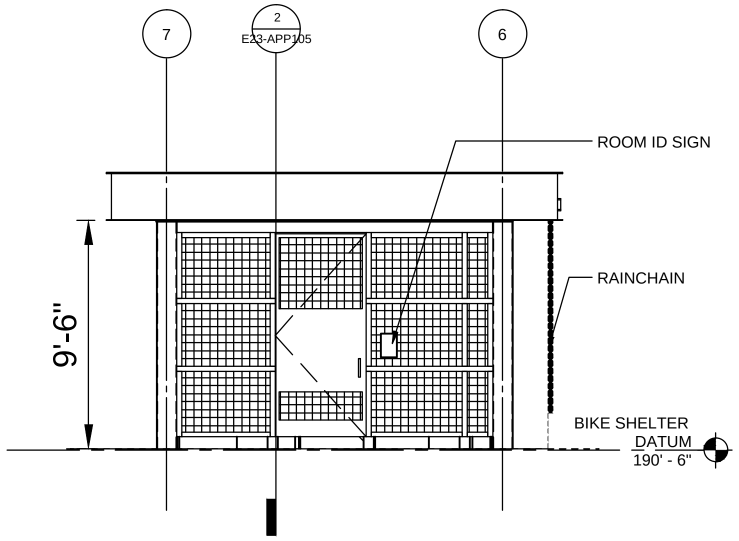

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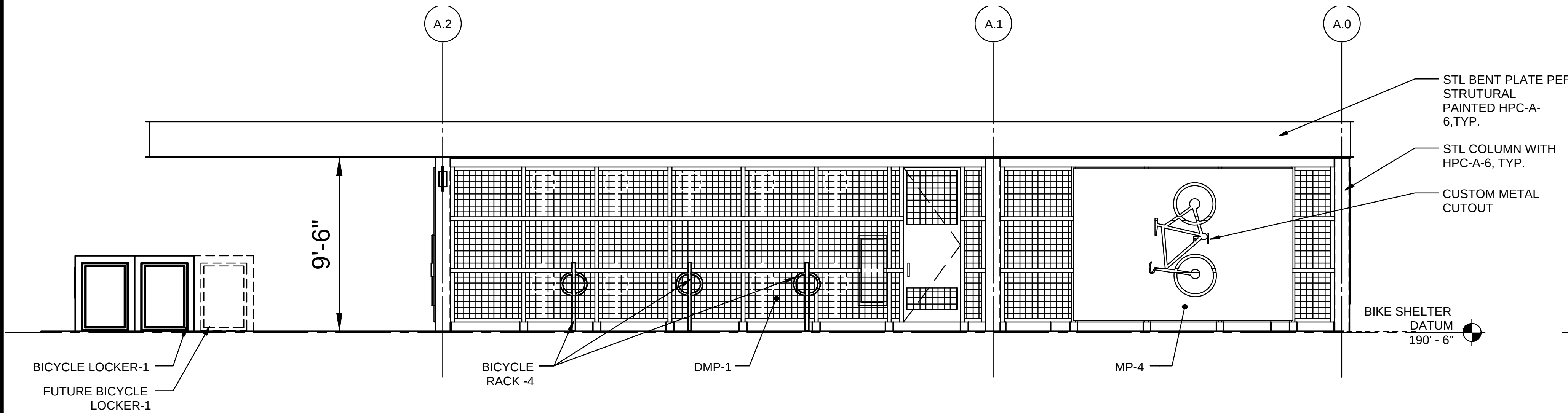

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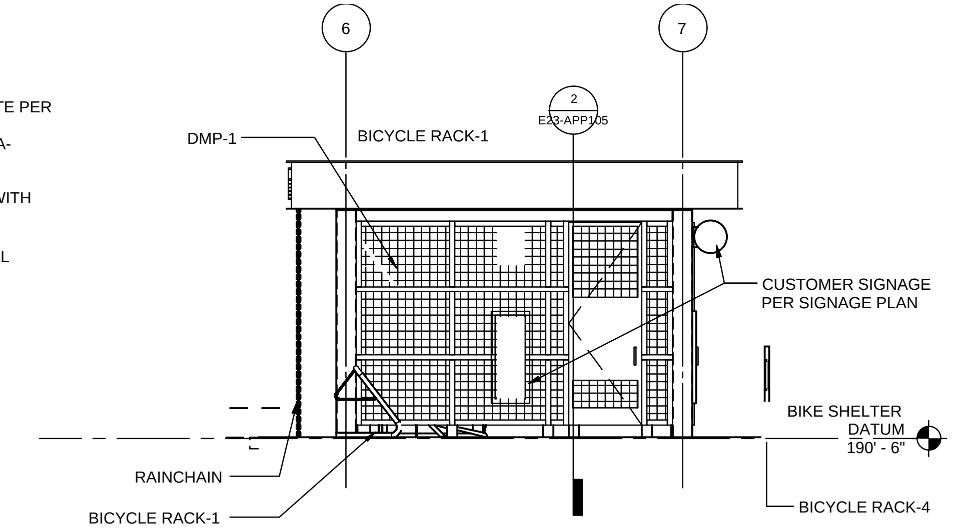

SOUTH ELEVATION - BIKE SHELTER

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No.	DATE	DSN	CHK	APP	REVISION

DESIGNED BY: A. BOTTMAN-HAASE
DRAWN BY: A. BOTTMAN-HAASE
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APPROVED BY: B. TISCARENO

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TISCARENO ASSOCIATES
ARCHITECTURE + URBAN DESIGN

SUBMITTED BY:

FINAL DESIGN PARTNERS.

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CONTRACT E340
BEL-RED
130TH STATION - ARCHITECTURAL EXTERIOR ELEVATIONS BIKE SHELTER

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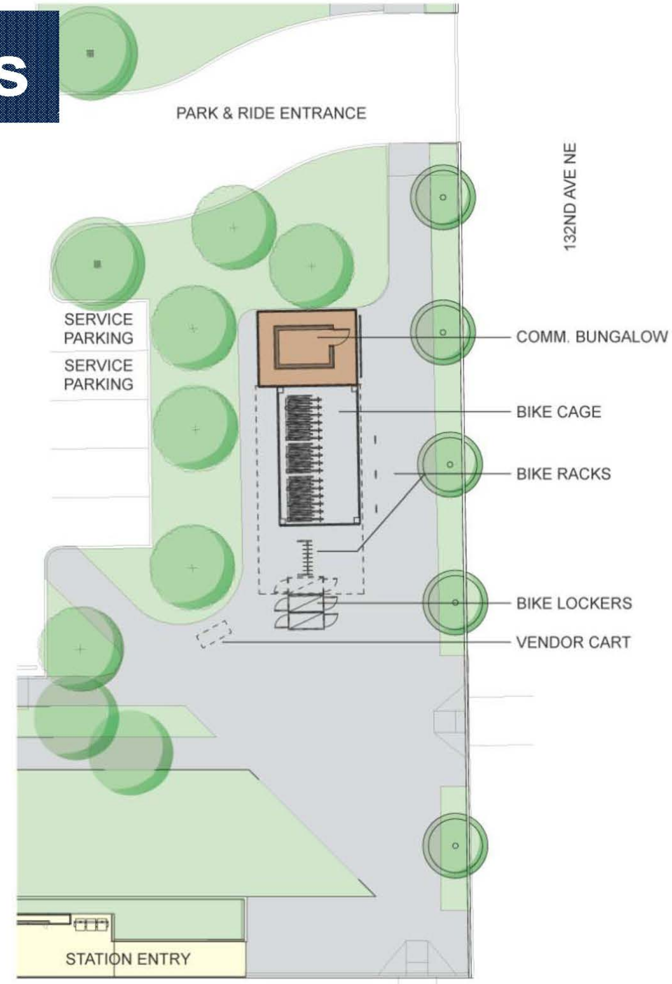
Figure 7

130th Station: Ancillary Structures



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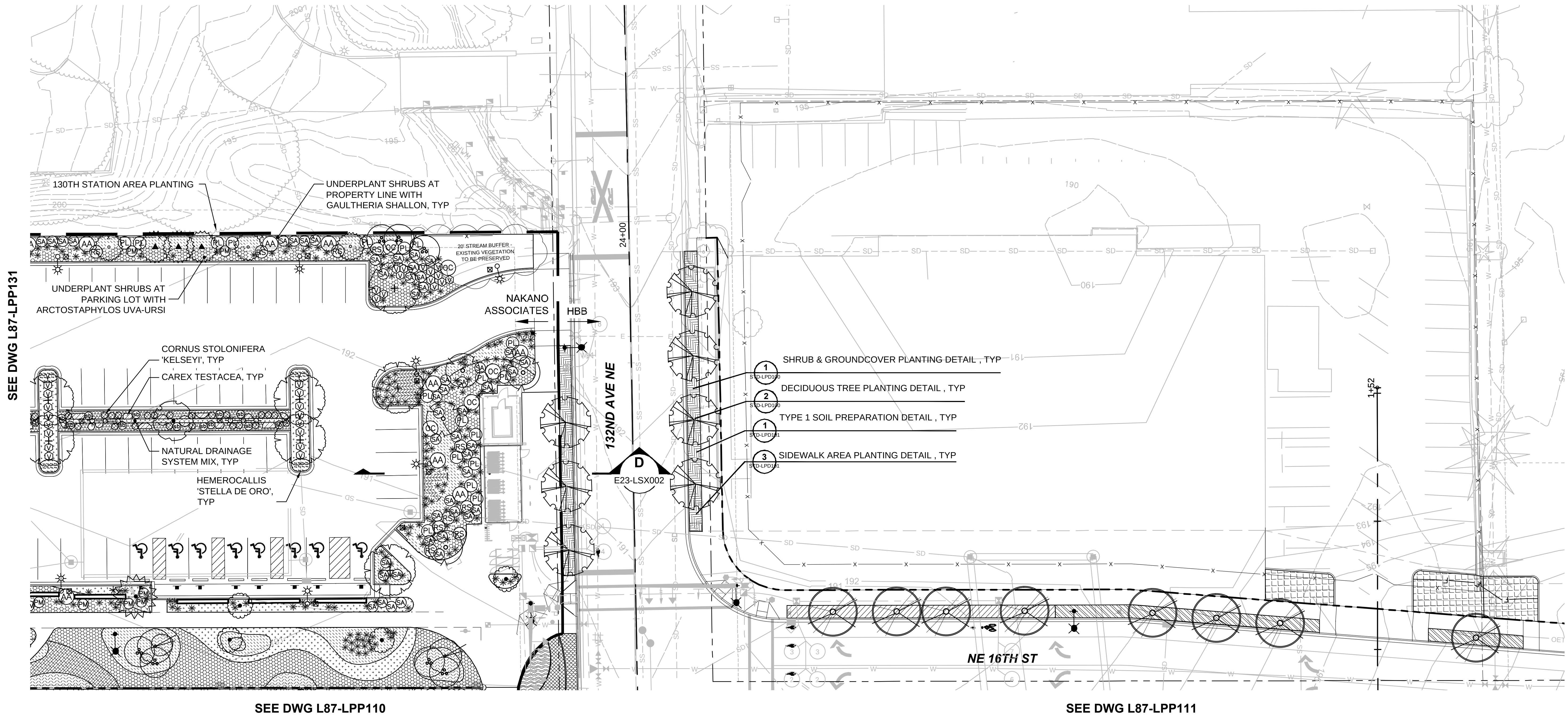

NOTES:

1. SEE SHEET L87-LPS100 FOR CORRIDOR PLANT SCHEDULE.
2. SEE SHEET L87-LPS102 FOR 130TH STATION PLANT SCHEDULE.

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853 Hiawatha Place S. Seattle, WA 98144 Tel: 206.292.9392 www.nakanoassociates.com

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No.	DATE	DSN	CHK	APP	REVISION

DESIGNED BY: J. VONG/ I.OTTESEN
DRAWN BY: M. OVIIR/H. BAUMANN
CHECKED BY: J. HOWARD/ A. WEST
APPROVED BY: J. VONG/ M.YAMAGUCHI

STATE OF WASHINGTON LICENSED LANDSCAPE ARCHITECT
JULIET B. VONG
LICENSE NO. 857
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BEL-RED
LANDSCAPE PLANTING CORRIDOR

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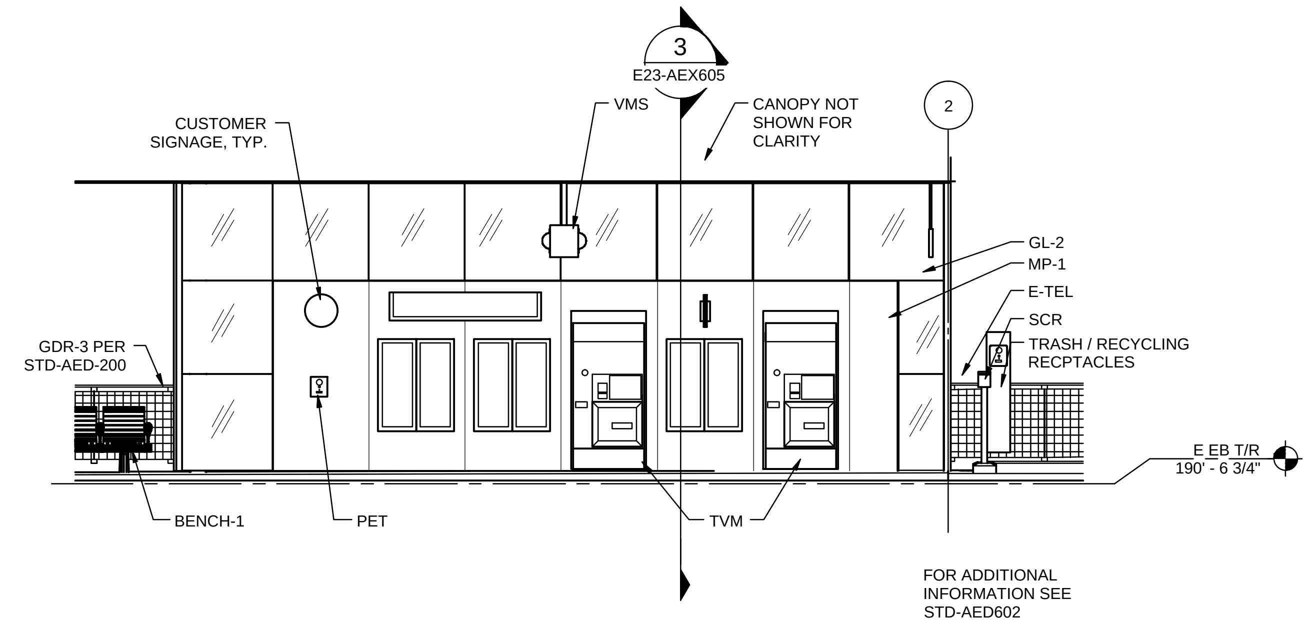

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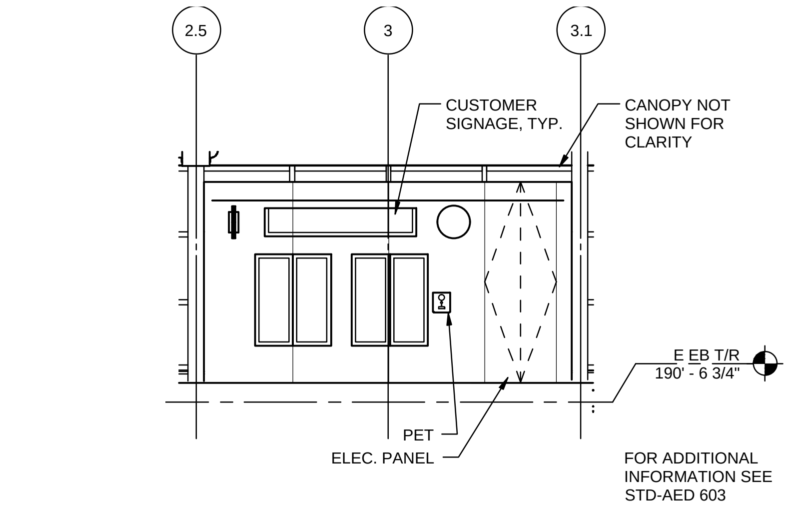

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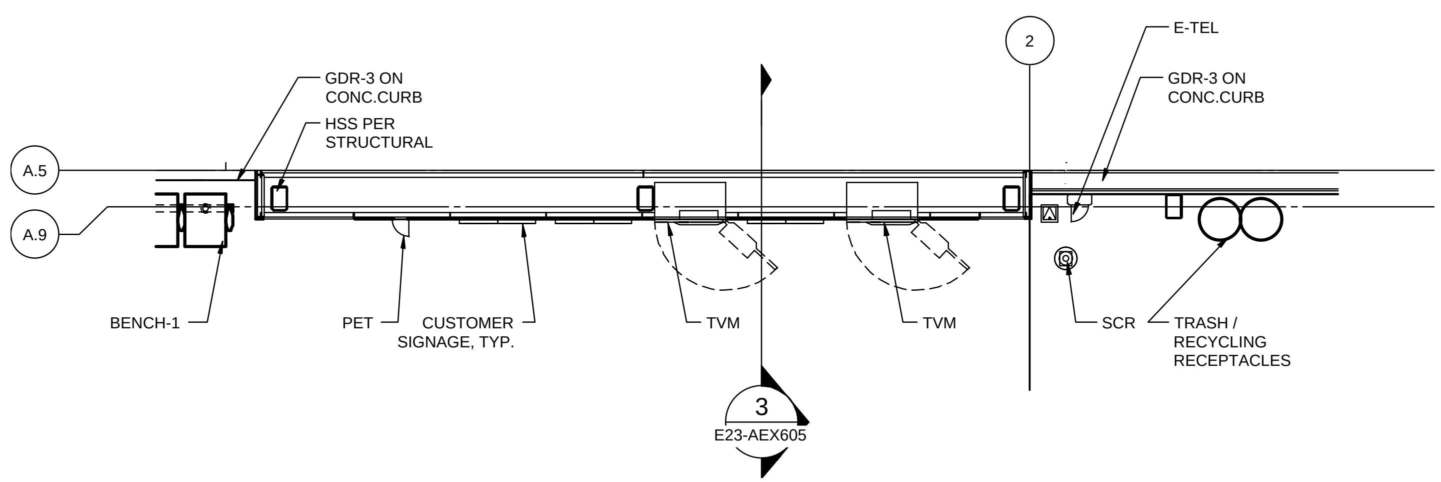

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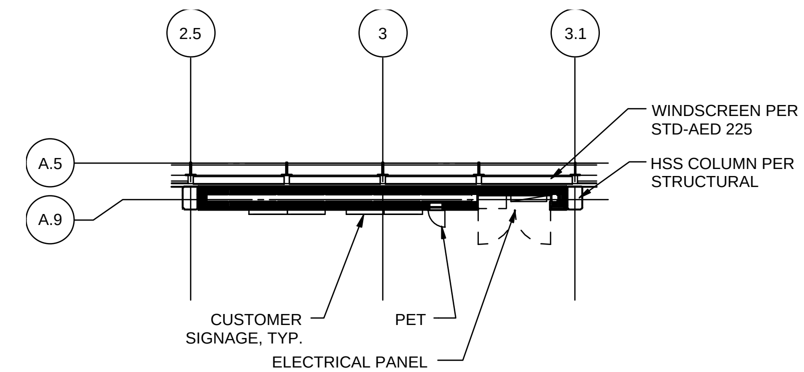

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DRAWN BY: A. BOTTMAN-HAASE
CHECKED BY: C. DOWELL
APPROVED BY: B. TISCARENO

7349 REGISTERED ARCHITECT
ROBERT TISCARENO
STATE OF WASHINGTON

TISCARENO ASSOCIATES
ARCHITECTURE + URBAN DESIGN

SUBMITTED BY:

FINAL DESIGN PARTNERS.

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CONTRACT No.: RTA/LR XXXX-XX
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EAST LINK EXTENSION
CONTRACT E340
BEL-RED

130TH STATION - ARCHITECTURAL
ENLARGED PLAN / ELEVATIONS
ENTRY AND INFO CENTER

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SHEET No.: 895
REV: 0

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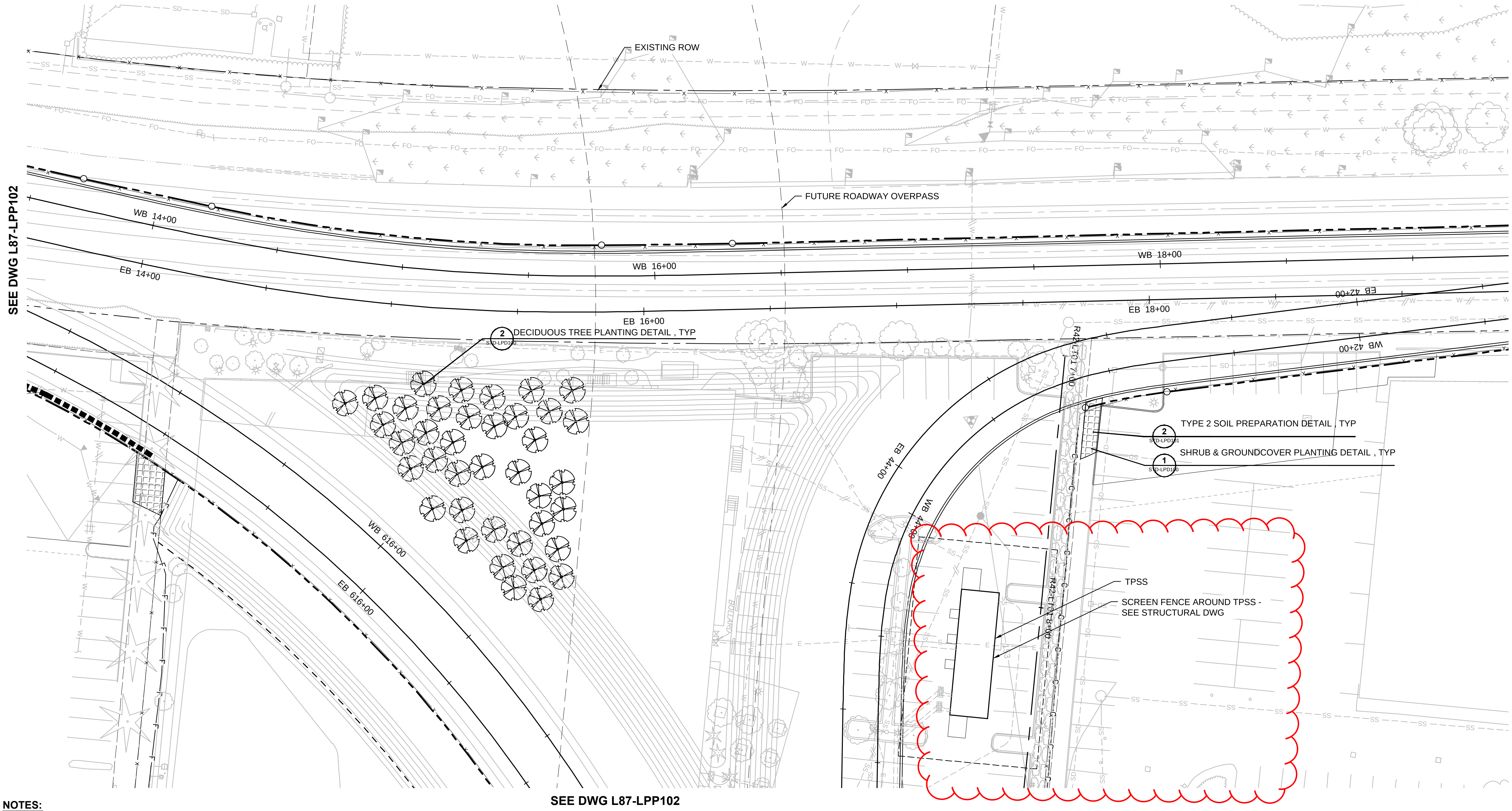

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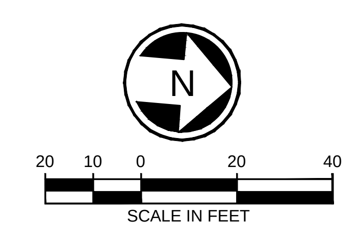
1. SEE SHEET L87-LPS100 FOR PLANT SCHEDULE.



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DRAWN BY: M. OVIIR
CHECKED BY: J. HOWARD
APPROVED BY: J. VONG

STATE OF WASHINGTON LICENSED LANDSCAPE ARCHITECT
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215 WESTLAKE AVENUE NORTH SEATTLE, WA 98109 206.682.3051 phone 206.682.3245 fax

SUBMITTED BY:

H J H FINAL DESIGN PARTNERS.

DATE:

REVIEWED BY:

LINE IS 1" AT FULL SCALE

SOUND TRANSIT

DATE:

SCALE: 1" = 20'
FILENAME: E340-L87-LPP117
CONTRACT No.: RTA/LR XXXX-XX
DATE: 07/15/2013

EAST LINK EXTENSION
CONTRACT E340
BEL-RED
LANDSCAPE PLANTING CORRIDOR

DRAWING No.: **L87-LPP117**
LOCATION ID: TBD
SHEET No.: 545
REV: 0