Appendix C
RapidRide Roosevelt Project
Supplemental Noise and Vibration Technical Report

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RAPIDRIDE ROOSEVELT PROJECT SUPPLEMENTAL NOISE AND VIBRATION TECHNICAL REPORT

Prepared for

Seattle Department of Transportation

Seattle Department of Transportation

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EXECUTIVE SUMMARY

This technical report presents a noise and vibration study for the RapidRide Roosevelt U District Option being proposed by the Seattle Department of Transportation (SDOT). The RapidRide Roosevelt Project studied in the January 2020 *RapidRide Roosevelt Project Environmental Assessment* ("January 2020 EA") has a southern terminus in Downtown Seattle and a proposed northern terminus at NE 67th St near Sound Transit's Roosevelt Light Rail Station. The U District Option, instead of continuing northward to NE 67th St, has a proposed northern terminus in the University District that would encircle Sound Transit's U District Station, and a southern terminus in Downtown Seattle. Between Downtown Seattle and the University Bridge the U District Option is unchanged from the RapidRide Roosevelt Project as described in the January 2020 EA. The U District Option north of the University Bridge would have different elements to those studied in the January 2020 EA; as such, the preparation of this supplemental technical report is necessary to identify any potentially new noise impacts associated with the U District Option.

This technical report examines areas where the U District Option departs from the study area used in the analysis presented in the October 2018 *RapidRide Roosevelt Project Noise and Vibration Technical Report* (2018 TR; The Greenbusch Group, Inc., 2018) included as Appendix D to the *RapidRide Roosevelt Project January 2020* EA (SDOT, 2020).

The objective of this technical report is to outline the assessment and report the results of a noise and vibration assessment for the U District Option study area. As directed by the Federal Transit Administration (FTA), the noise and vibration assessment for the U District Option is based upon guidance described in the FTA *Transit Noise and Vibration Impact Assessment* (FTA Manual; 2018). It should be noted that the assessment outlined in the 2018 TR was performed in accordance with the previous version of the FTA Manual issued in 2006.

Sound levels from bus operations along the U District Option were predicted at all noise sensitive receptors within the study area. These predicted sound levels were added to measured existing sound levels and then compared with FTA impact thresholds. It was determined that none of the receptors within the study area would exceed impact thresholds and are unlikely to be impacted by noise generated by bus operations. Similarly, vibration levels from bus operations were predicted at all vibration sensitive receptors within the U District Option study area and then compared with FTA impact thresholds. Again, it was found that none of the receptors would exceed impact threshold and are unlikely to be impacted by vibration generated by bus operations.

Construction activities are predicted to result in short-term noise and vibration annoyance impacts and, in some cases, may have the potential to cause cosmetic building damage to adjacent structures. Noise from construction activities is predicted to exceed City of Seattle noise criteria. With mitigation and a construction noise control plan, construction activities are likely to satisfy City of Seattle criteria. Vibration from roadway paving along NE 43rd St between Roosevelt Way NE and 12th Ave NE and jackhammering at stations and OCS pole locations has the potential to cause cosmetic building damage to adjacent structures. With a vibration control plan and the implementation of mitigation measures, such as adjusting power settings on compaction equipment or vibration monitoring, strong adverse reaction and cosmetic building damage would be unlikely.

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ACRONYMS AND ABBREVIATIONS

dB	decibel
dBA	A-weighted decibel
EA	Environmental Assessment
FTA	Federal Transit Administration
FTA Manual	FTA Transit Noise and Vibration Impact Assessment (2018)
in/sec	inches per second
KCM	King County Metro
L_{dn}	day-night sound level
L_{eq}	equivalent sound level
L_{max}	maximum sound level
L_v	root mean square vibration level
mph	miles per hour
OCS	overhead contact system
PPV	peak particle velocity
SDOT	Seattle Department of Transportation
SMC	Seattle Municipal Code
TCE	temporary construction easement
TR	Technical Report
VdB	vibration velocity decibel

1. PROJECT OVERVIEW

As shown on Figure 1-1, the U District Option would include all of the RapidRide Roosevelt Project elements south of the University Bridge as presented in the January 2020 EA. The northern turnaround for the U District Option (see inset box on Figure 1-1), would encircle the Sound Transit U District Station along NE 43rd St, 12th Ave NE, NE 45th St, and 15th Ave NE, and would include the following elements north of the University Bridge:

- Up to four new RapidRide stations to support connections to Sound Transit's U District Station and facilitate other transit connections in the vicinity.
- Full-depth concrete paving, protected bicycle lanes (PBLs), and overhead contact system (OCS) along NE 43rd St between Roosevelt Way NE and 12th Ave NE.
- New signal with adaptive signal control technology and/or transit signal priority (TSP) at the Roosevelt Way NE/NE 43rd St intersection.
- Americans with Disabilities Act (ADA)-compliant curb ramp and sidewalk upgrades, signing, and channelization.

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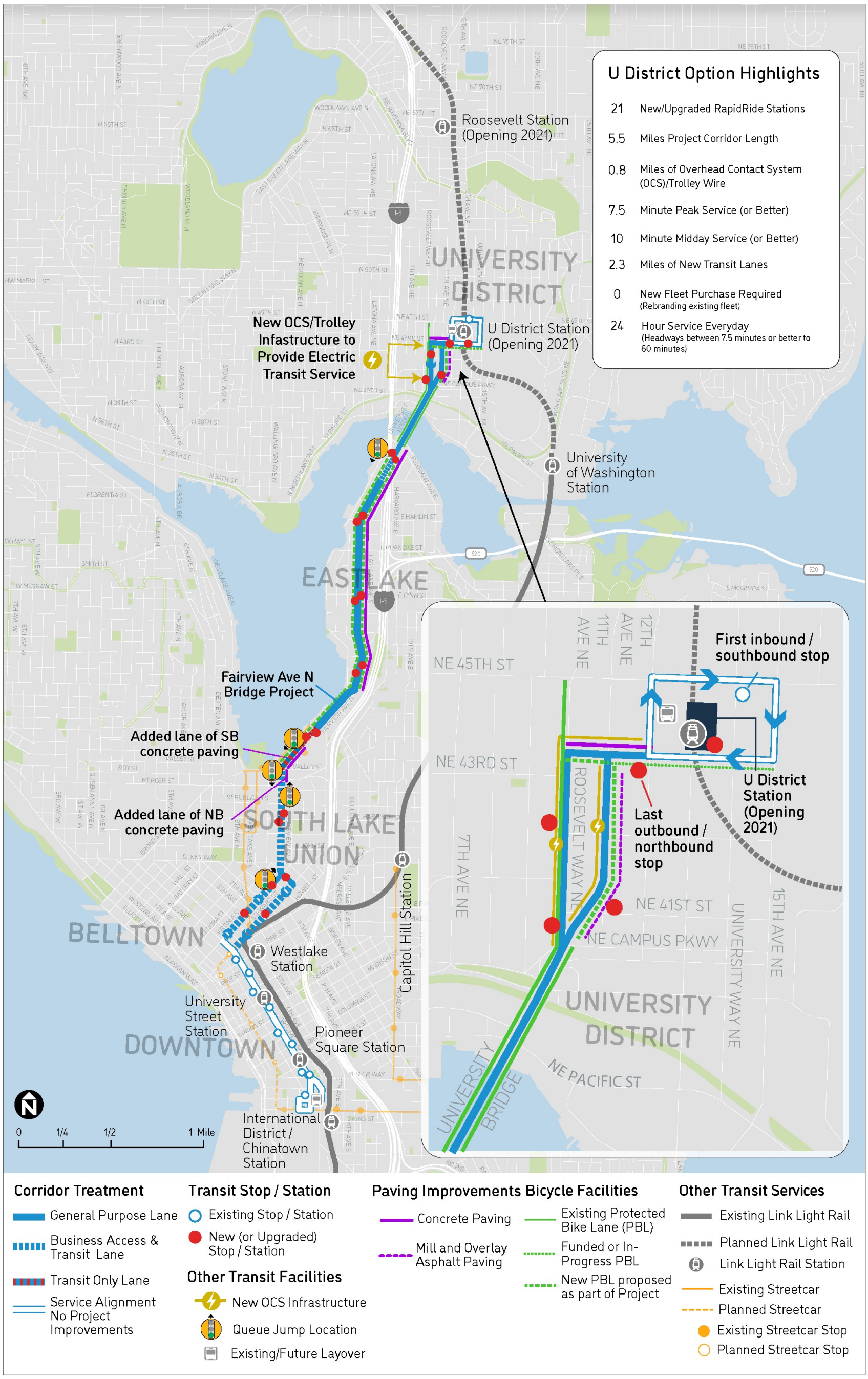

Figure 1-1. U District Option

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2. NOISE AND VIBRATION CRITERIA

2.1 Noise Impact Criteria

2.1.1 Transit Noise Impact Criteria

Noise impacts in the U District Option study area were determined based on criteria provided in the FTA Manual (2018), which defines two levels of noise impacts, moderate and severe. Moderate and severe noise impacts are defined as follows:

- Moderate Impact – a change in the cumulative noise level that would be noticeable to most people, but may not be sufficient to cause strong, adverse reactions from the community.
- Severe Impact – noise generated in the severe impact range would highly annoy a substantial percentage of people and would most likely require mitigation.

Noise impact criteria are applied to sensitive land uses or receptors as defined in the FTA Manual (2018). Noise-sensitive land use and receptor categories defined by the FTA are shown in Table 2-1.

Table 2-1. FTA Noise-Sensitive Receptor Categories

NOISE CATEGORY	DESCRIPTION
Category 1 (High Sensitivity)	Places with the highest sensitivity to airborne noise from transit sources. Examples include concert halls, recording studios, outdoor concert pavilions, and National Historic Landmarks where outdoor interpretation routinely takes place.
Category 2 (Residential)	Places where people normally sleep. Examples include apartments and condominiums, single-family homes, hotels, apartments, and shelters.
Category 3 (Daytime Use)	Places with sensitive receptors used during daytime and evening hours. Examples include schools, libraries, places of worship, theaters, and museums.

Source: FTA Manual 2018, Table 4-3

Impact criteria was determined using the Cumulative Noise Impact Criteria Presentation. The Cumulative Noise Impact Criteria Presentation is used to determine impact criteria when transit noise is included in existing sound levels. Figures 2-1 and 2-2 present the noise levels at which impacts occur for each land use category based on the existing noise level.

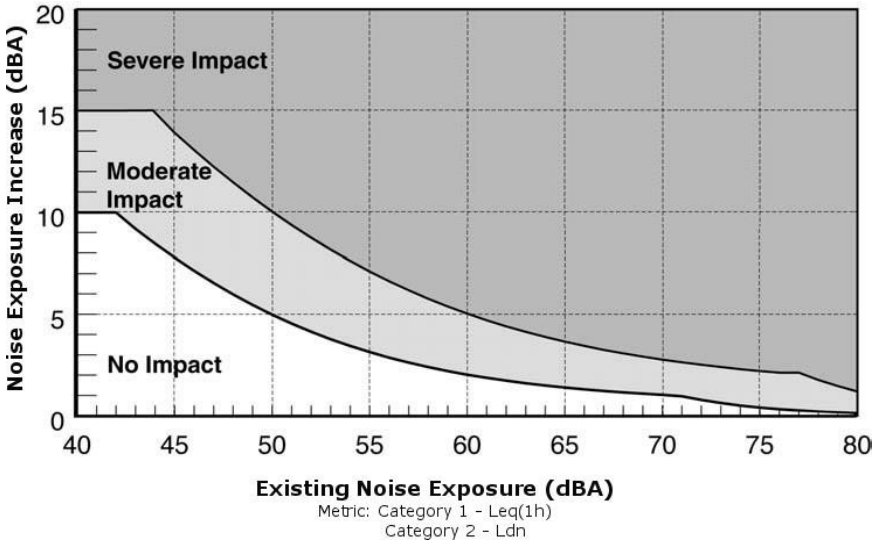

Figure 2-1. Increase in Existing Noise Levels Allowed by Criteria (Land Use Categories 1 and 2)

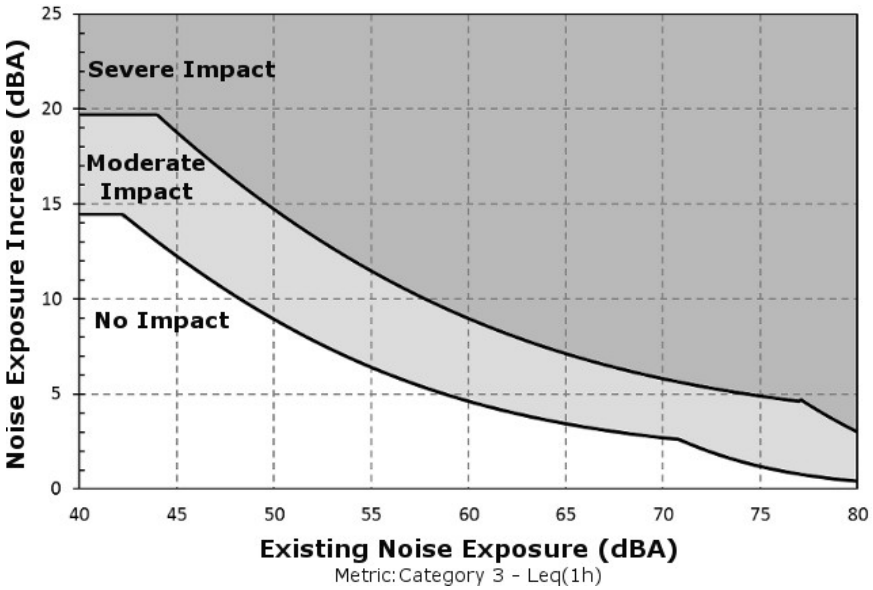

Figure 2-2. Increase in Existing Noise Levels Allowed by Criteria (Land Use Category 3)

2.1.2 Construction Noise Criteria

2.1.2.1 FTA Criteria

Noise assessments for projects funded by the FTA must be performed in accordance with the FTA Manual (2018). The FTA Manual (2018) defers to sound limits and regulations set by local jurisdictions for determining noise impacts from construction. The U District Option study area is within the City of Seattle. Therefore, construction noise impacts will be based on the City of Seattle Municipal Code (SMC).

2.1.2.2 City of Seattle Regulations

The SMC defines sound level limits for construction sites under SMC 25.08, Noise Control. These criteria are defined by the district the sound originates from and the district where the sound is received. SMC 25.08.100 defines districts as land use zones including Residential, Commercial, and Industrial. These districts include the following zones are defined in the Seattle Land Use Code, Title 23:

- Residential District: Residential and NC1 zones
- Commercial District: NC2, NC3, SM, SM-SLU, SM-D, SM-NR, C1, C2, DOC1, DOC2, DRC, DMC, PSM, IDM, DH1, DH2, PMM, and IB zones
- Industrial District: IG1, IG2, and IC zones

A summary of City of Seattle sound level limits by district for construction is shown in Table 2-2.

Table 2-2. City of Seattle Hourly Sound Level Limits for Construction Sites

DISTRICT OF SOUND SOURCE	DISTRICT OF RECEIVING PROPERTY		
	RESIDENTIAL L_{eq}/L_{max} (dBA)	COMMERCIAL L_{eq}/L_{max} (dBA)	INDUSTRIAL L_{eq}/L_{max} (dBA)
DAYTIME (7 AM TO 10 PM ON WEEKDAYS AND 9 AM TO 10 PM ON WEEKENDS)			
Residential	80 / 95	82 / 97	85 / 100
Commercial	82 / 97	85 / 100	90 / 105
Industrial	85 / 100	90 / 105	95 / 110
NIGHTTIME (10 PM TO 7 AM ON WEEKDAYS AND 10 PM TO 9 AM ON WEEKENDS)			
Residential	45 / 60	57 / 72	60 / 75
Commercial	47 / 62	60 / 75	65 / 80
Industrial	50 / 65	65 / 80	70 / 85

Source: SMC 25.08.410 and 25.08.425

dBA = A-weighted decibel

L_{eq} = equivalent sound level

L_{max} = maximum sound level

Daytime limits are enforced between 7 AM and 10 PM on weekdays and 9 AM and 10 PM on weekends and legal holidays. Nighttime hours are enforced at all other times. Additionally, nighttime sound level limits are subject to modifications delineated in SMC 25.08.420, depending on the classification of receiving properties and the type of sound generated. The modifications to the exterior sound level limits include the following reductions:

- 5 dBA for sources that carry a pure tone component,
- 5 dBA for impulsive sources not measured with an impulse sound level meter,

These modifications are additive and independent of one another.

The U District Option study area is within a commercial district. Commercial districts have an hourly construction L_{eq} limit of 85 dBA during the day and 60 dBA at night.

2.2 Vibration Impact Criteria

2.2.1 Transit Vibration Criteria

Similar to noise impact criteria, the FTA Manual (2018) categorizes vibration-sensitive land uses and receptors (Table 2-3).

Table 2-3 Vibration-Sensitive Receptor Categories

VIBRATION CATEGORY	DESCRIPTION
Special Buildings	Places with special-use facilities that are very sensitive to vibration. Examples include concert halls, TV and recording studios, and theaters.
Category 1 (High Sensitivity)	Place with high sensitivity to ground-borne noise and vibration from transit sources. Examples include concert halls, research facilities, and medical facilities with vibration-sensitive equipment.
Category 2 (Residential)	Places where people normally sleep. Examples include apartments and condominiums, single-family homes, hotels, apartments, and shelters.
Category 3 (Daytime Use)	Places with sensitive uses during daytime and evening hours. Examples include schools, libraries, places of worship, and commercial buildings with a high percentage of office space and minimal retail.

Source: FTA Manual 2018, Table 6-1

Criteria established in the FTA Manual (2018) are used to determine the likelihood of operational vibration impacts on vibration-sensitive receptors based on land use (receptor category). Land use vibration thresholds are based on the frequency of events, which includes frequent events, occasional events, and infrequent events. Vibration events from bus operations in the University District would meet the frequent event criteria. Ground-borne vibration impact criteria for frequent events can be found in Table 2-4.

Table 2-4. Operational Vibration Impact Criteria – Frequent Events

LAND USE CATEGORY	GROUND-BORNE VIBRATION (VdB)
Special Buildings	-
Concert Halls	65
TV Studios	65
Recording Studios	65
Auditoriums	72
Theaters	72
Category 1 (high sensitivity)	65
Category 2 (residential)	72
Category 3 (daytime use)	75

Source: FTA Manual 2018, Table 6-3 and Table 6-3

VdB = vibration velocity decibel

2.2.1 Construction Vibration Criteria

The FTA Manual (2018) divides assessment of vibration levels produced by construction activities into two categories: building damage and occupant annoyance. Building damage criteria uses the peak particle velocity (PPV) metric and annoyance uses VdB, which is also used for the operational vibration impact assessment.

2.2.1.1 Building Damage

Assessment criteria depends on the type of building construction, as indicated in Table 2-5. Lighter-weight timber buildings are associated with lower building damage thresholds than those built with heavier steel and concrete. The City of Seattle does not have codified regulatory criteria for vibration.

Table 2-5. Construction Vibration Criteria – Building Damage

BUILDING CATEGORY	PPV (IN/SEC)
I. Reinforced concrete, steel, or timber (no plaster)	0.50
II. Engineered concrete and masonry (no plaster)	0.30
III. Non-engineered timber and masonry	0.20
IV. Buildings extremely susceptible to vibration damage	0.12

Source: FTA Manual 2018, Table 7-5

in/sec = inches per second

2.2.1.2 Annoyance

Similar to operational vibration, criteria established in the FTA Manual (2018) are used to identify receptors that may experience annoyance due to vibration from construction. Assessment criteria for annoyance depend on receptor land use, with the same receptor classifications and criteria as operational vibration, shown in Table 2-4.

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3. METHODOLOGY

3.1 Study Area

The study area for this analysis includes the U District Option corridor as well as a screening distance which extends outward from the northbound and southbound bus route centerlines. The study area extends north of NE 45th St to approximately the third row of properties, east of 15th Ave NE just past the Burke Museum building, and south of NE 43rd St to approximately the third row of properties. An outline of the study area is shown in Figure 3-1.

The screening distance used to define the study area is sufficiently large to encompass all noise- and vibration-sensitive receptors that could be impacted. The Noise Screening Procedure outlined in the FTA Manual (2018) recommends a screening distance for unobstructed noise-sensitive receptors of 500 feet and 250 feet for obstructed noise-sensitive receptors. All noise-sensitive receptors that were greater than 250 feet were obstructed. Therefore, the noise study area extends 250 feet from the U District Option corridor. The FTA Manual's General Vibration Screening suggests a vibration study area of 100 feet from vibration sources within the U District Option corridor (FTA, 2018). However, all vibration-sensitive properties within 250 feet of the U District Option corridor were surveyed so the noise and vibration study areas are the same.

3.2 Existing Noise Conditions

Measurements were conducted in the study area to establish existing noise conditions and to determine impact assessment criteria for operational noise. Measurement locations were selected to represent the existing noise environment along the U District Option corridor.

Measurements were conducted at three locations which included one 24-hour measurement near residential land uses, and two 1-hour measurements near non-residential land uses.

Measurement equipment consisted of a microphone housed in an environmental shroud and placed on a tripod or utility pole mount, depending on the measurement location. The microphone was connected to a sound level meter inside a small case that was secured to a nearby structure. Measured sound levels and measurement locations are summarized in Table 3-1 and Figure 3-2. Refer to Appendix B, Noise and Vibration Measurements, for additional information.

Table 3-1. Noise Measurement Locations

MEASUREMENT LOCATION[a]	NEAREST ADDRESS	DATE	L_{dn}[b]	$L_{eq(H)}$
N-1	4244 11th Ave SE	12/17-18/2020	67 dBA	66 dBA
N-2	1303 NE 45th St	12/18/2020 & 12/22/2020	-	69 dBA
N-3	4300 15th Ave NE	12/18/2020 & 12/20/2020	-	69 dBA

[a] Locations shown on Figure 3-2.

[b] Sound levels increased by 10 dB between 10 PM and 7 AM

dB = decibel

L_{dn} = day-night sound level

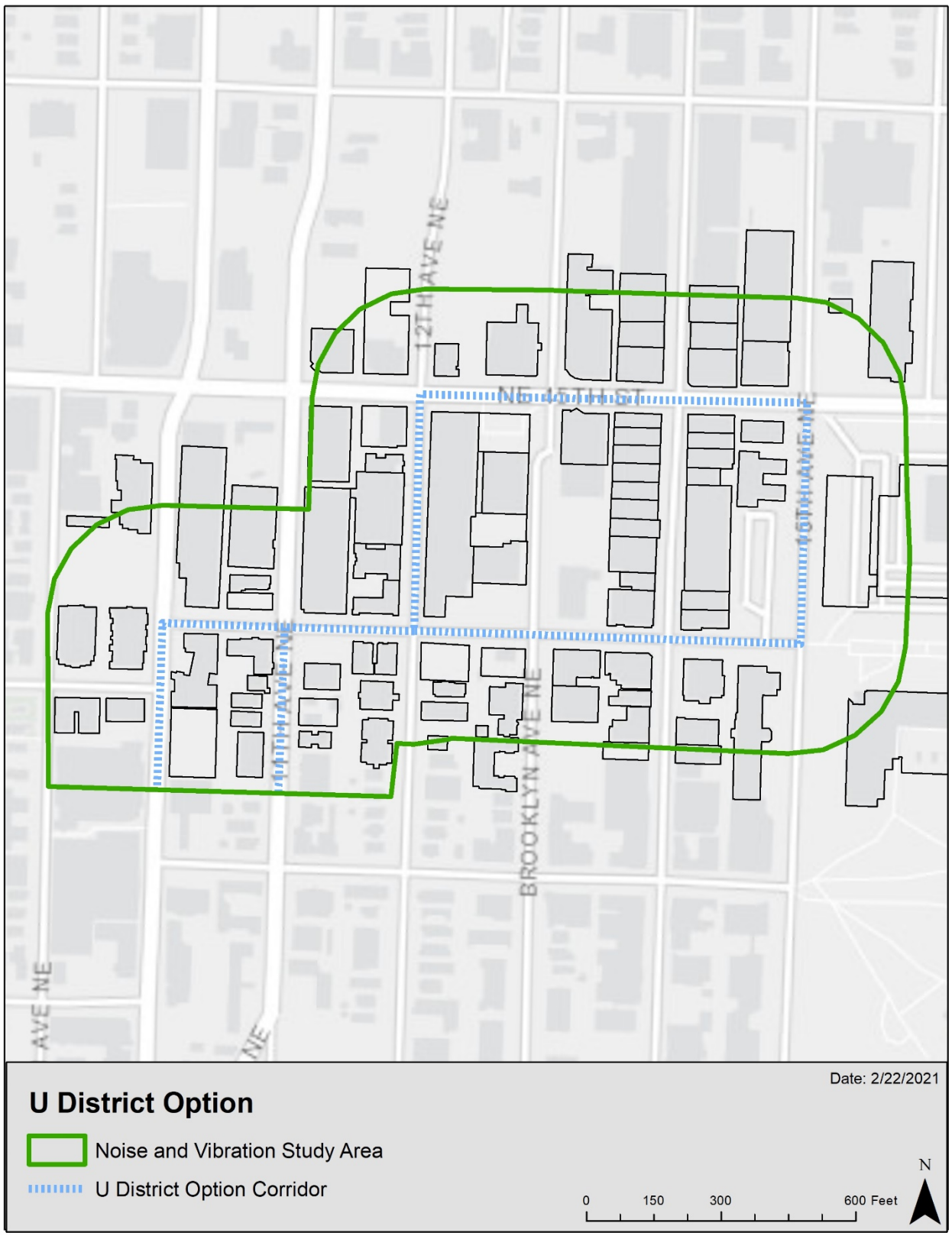

Figure 3-1. U District Option Study Area

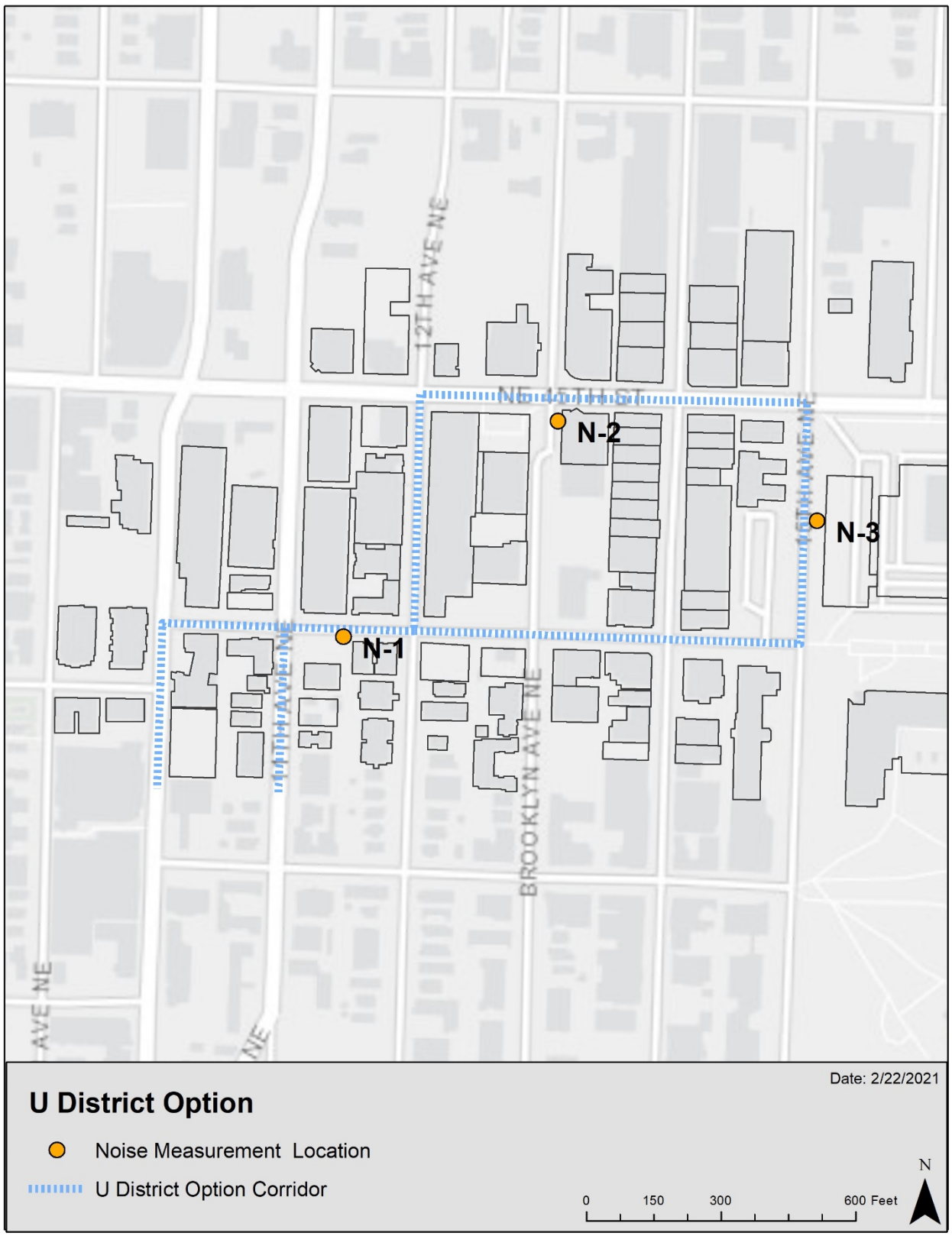

Figure 3-2. Noise Measurement Locations

3.3 Operational Noise

Procedures for evaluating noise impacts at this stage of design are defined in the FTA Manual (2018), Chapter 4, General Noise Assessment. The General Noise Assessment can be summarized in four main steps:

1. Determine project characteristics, such as: transit type, hours of operation, traffic volumes, speed, and distance to bus lane centerlines.
2. Identify project location characteristics, such as existing sound levels.
3. Calculate project noise exposure using the equations outlines in the FTA Manual (2018), Chapter 4.4.
4. Define moderate and severe impact criteria based on existing sound levels and identify impacts within the study area.

Noise exposure calculations are based on vehicle type and operating conditions (i.e., travel speed and number of buses per hour). Input parameters used in this assessment are shown in Table 3-2. The existing sound levels used to determine impact criteria are also included in Table 3-2.

Table 3-2. Sound Emission Input Parameters

DESCRIPTION	VALUE
Reference sound exposure level at 50 feet (Electric Bus)	80 dBA
Travel speed[a]	20-25 mph
Peak hourly bus volume	10 buses per hour
Average daytime hourly bus volume	7.3 buses per hour
Average nighttime hourly bus volume	2.7 buses per hour
Existing L_{dn} (Category 2)[b]	67 dBA
Existing $L_{eq(h)}$ (Category 1 and 3)[c]	66 dBA

[a] Speed limit used as analysis speed
[b] Lowest measured L_{dn} was used for impact criteria.
[c] Lowest measured $L_{eq(h)}$ was used for impact criteria.

mph = miles per hour

3.4 Existing Vibration Conditions

Vibration in the study area is associated with vehicles (i.e., buses, freight, and passenger vehicles) on the adjacent roadways and other sources include construction activities along the corridor for new developments.

One ambient vibration measurement was conducted near the Neptune Theater, a Special Building category, due to its proximity to the bus centerline and vibration sensitivity. This vibration measurement location is shown on Figure 3-3. Measured vibration levels are

summarized in Table 3-3; additional measurement details are in Appendix B, Noise and Vibration Measurements.

Table 3-3. Existing Vibration Measurement Summary

MEASUREMENT LOCATION	NEAREST ADDRESS	DATE	DURATION	VdB
V-1	1303 NE 45th St	12/18/2020 & 12/20/2020	1-hour	51

Ground-borne noise impacts from operation of the U District Option are not anticipated because buses have rubber tires and suspension systems, which provide vibration isolation (FTA, 2018). This was confirmed by screening calculations completed during the RapidRide Roosevelt Project Noise and Vibration Technical Report (The Greenbusch Group, Inc., 2018) that followed methodologies in Chapter 10 of the 2006 FTA Manual. Therefore, ground-borne noise was not included in this assessment.

As part of the 2018 TR analysis, vibration propagation testing was conducted to determine if an "efficient propagation in soil" condition (as defined by FTA, 2006) as part of the General Vibration Assessment should be applied within the study area. Test results show propagation characteristics similar to the FTA surface vibration curve, which supports the use of the FTA methodologies without "efficient propagation in soil." Soil boring sample logs made available through the Washington Geological Survey Database (Washington State Department of Natural Resources, 2021) within the study area were also examined and did not reveal soil conditions commonly associated with "efficient propagation in soil" as defined by the FTA. Based on these findings, the typical vibration models included in the 2006 and 2018 FTA Manuals are appropriate for the U District Option assessment.

3.5 Operational Vibration

The procedure for evaluating vibration impacts along the U District Option are defined in the FTA Manual (2018), Chapter 6.3 Evaluate Impact: Vibration Screening Procedure and Chapter 6.4 General Vibration Assessment. The General Vibration Assessment can be summarized into five main steps:

1. Identify, categorize, and characterize properties within the screening distance.
2. Identify speed limits along the U District Option.
3. Conduct vibration propagation measurements where efficient propagation in soil might be present (completed during the 2018 TR).
4. Calculate vibration exposure using the Rubber-Tire Vehicle Curve outlined in Chapter 6 of the FTA Manual (2018).
5. Define impact criteria based on frequency of events and identify impacts within the study area according to vibration exposure.

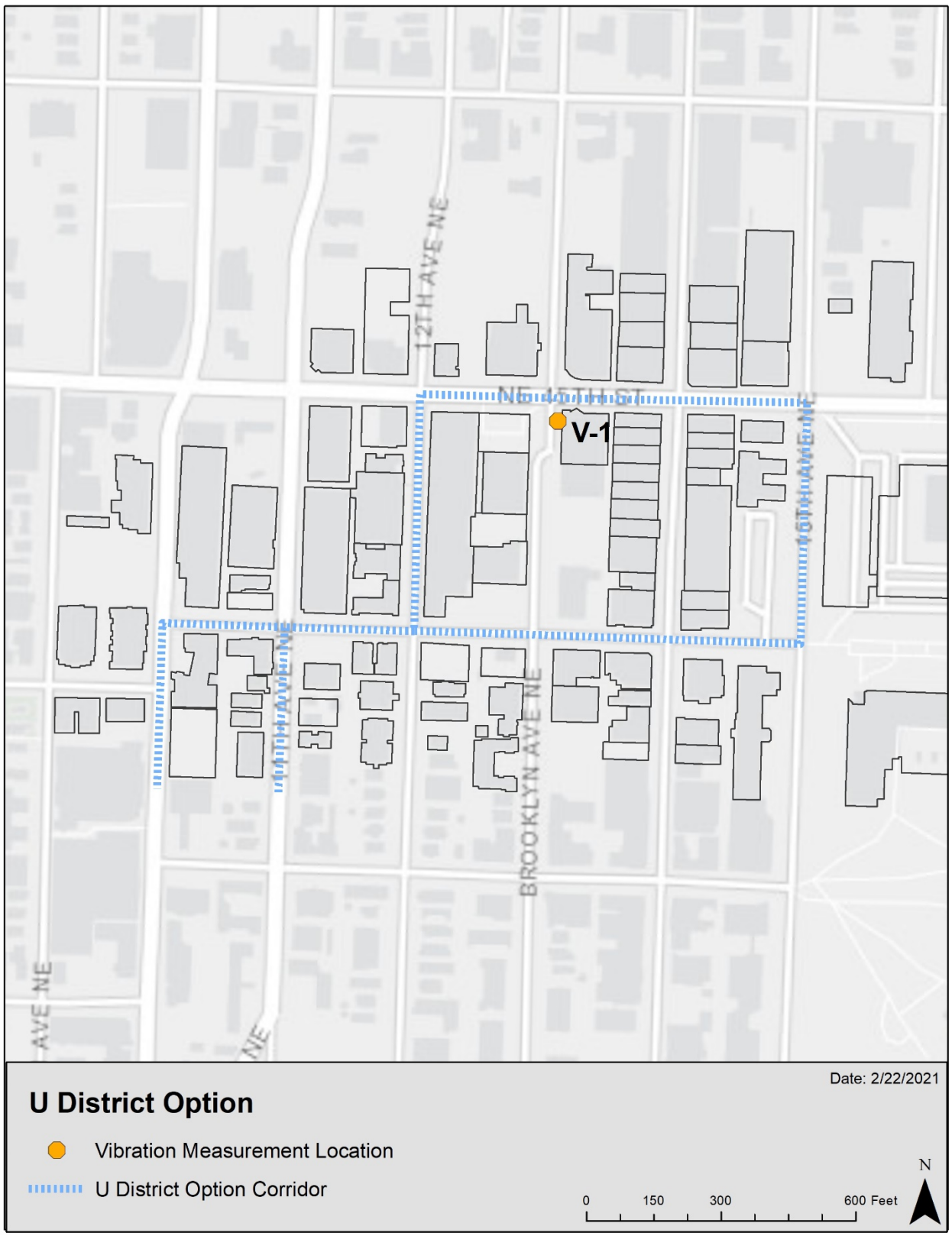

Figure 3-3. Existing Vibration Measurement Location

Predicting vibration impacts from operations was completed as follows: First a conservative approach was used to identify potential vibration impacts by excluding receptor-specific building characteristics. After potential impacts have been identified, further analysis was performed to examine the potential vibration impacts by identifying receptor-specific building characteristics. These receptor-specific characteristics consist of building foundation type, and sensitive receiver location (floor). Each characteristic has an associated vibration level adjustment that modifies the predicted vibration level. Once these adjustments are included, the adjusted predicted vibration level is compared with the impact criteria in Table 2-4 to determine if the receptor is impacted.

Vibration emissions are based on vehicle type, operating conditions, and road conditions. Input parameters are shown in Table 3-4.

Table 3-4. Vibration Emission Input Parameters

DESCRIPTION	VALUE
Reference vibration at 50 feet (30 mph)	68 VdB
Bus speed	20-25 mph
Uneven Road Surface?	No
Efficient Propagation in Soil?	No

Source: FTA Manual 2018, Table 6-11, Table 6-12

3.6 Construction

3.6.1 Construction Noise

The General Assessment of construction noise outlined in Chapter 7 of the FTA Manual (2018) provides methodologies to estimate construction noise levels at receptors. The sound levels from the two loudest pieces of equipment were calculated operating continuously for 1 hour.

Impact contours were generated for construction noise based on SMC construction sound level limits. Properties that fall within their respective impact contour would likely exceed SMC construction sound level limits and be considered impacted by FTA criteria. Impact contour distances can be found in Table 5-7.

3.6.2 Construction Vibration

The general assessment of construction vibration outlined in Chapter 7 of the FTA Manual (2018) provides methodologies to estimate construction vibration levels. Building damage and annoyance due to vibration were assessed from each piece of equipment anticipated to be used during construction. Impact contours were generated for the construction vibration based on FTA frequent event vibration criteria. The FTA provides vibration levels for construction equipment that may cause high vibration levels, PPV is used to determine building damage, and VdB is used to determine vibration annoyance. Vibration levels from construction equipment used in this analysis are provided in Section 5.4 and impact distance contours can be found in Table 5-8.

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4. AFFECTED ENVIRONMENT

4.1 Noise-Sensitive Receptors

The land uses along the U District Option corridor are mostly residential, commercial, and institutional. Much of the residential development along the corridor includes apartments and condominiums. There are single-family residences adjacent to the U District Option corridor, with the majority located outside of the study area south of NE 43rd St and west of Roosevelt Way NE.

For the operational noise assessment, receptors within the study area were categorized by noise sensitivity based on FTA criteria. City of Seattle records, King County records, and field assessment were used to determine which category each receptor belongs to. Most receptors with only commercial uses are not considered noise-sensitive; therefore, those properties were not included in the noise analysis. However, exceptions are made for some noise-sensitive commercial uses, such as theaters.

A summary of the type and number of noise-sensitive receptors in the study area is shown in Table 4-1. Figure 4-1 shows the locations of noise-sensitive receptors in the U District Option study area. Most of the noise-sensitive receptors are Category 2. Refer to Appendix A, Noise and Vibration Sensitive Receptors, for information on the noise-sensitive receptors in the study area.

Table 4-1. Noise-Sensitive Receptor Summary

RECEPTOR CATEGORY	NUMBER
Category 1	3
Category 2	37
Category 3	8

The construction noise assessment is based on SMC noise districts and their respective SMC sound level limit. SMC groups all zoning into residential, commercial, or industrial noise district. City of Seattle zoning designations within the U District Option study area include LR3, SM, NC2, NC3, and MIO. These zoning designations fall in a commercial noise district, except LR3, which is within a residential noise district. However, there is only one property within the study area that is zoned LR3. Institutional zoning falls in a commercial noise district even if the property is used for student housing. Figure 4-2 shows an overview of noise districts based upon City of Seattle zoning codes for the parcels in the U District Option study area for use in the construction noise assessment.

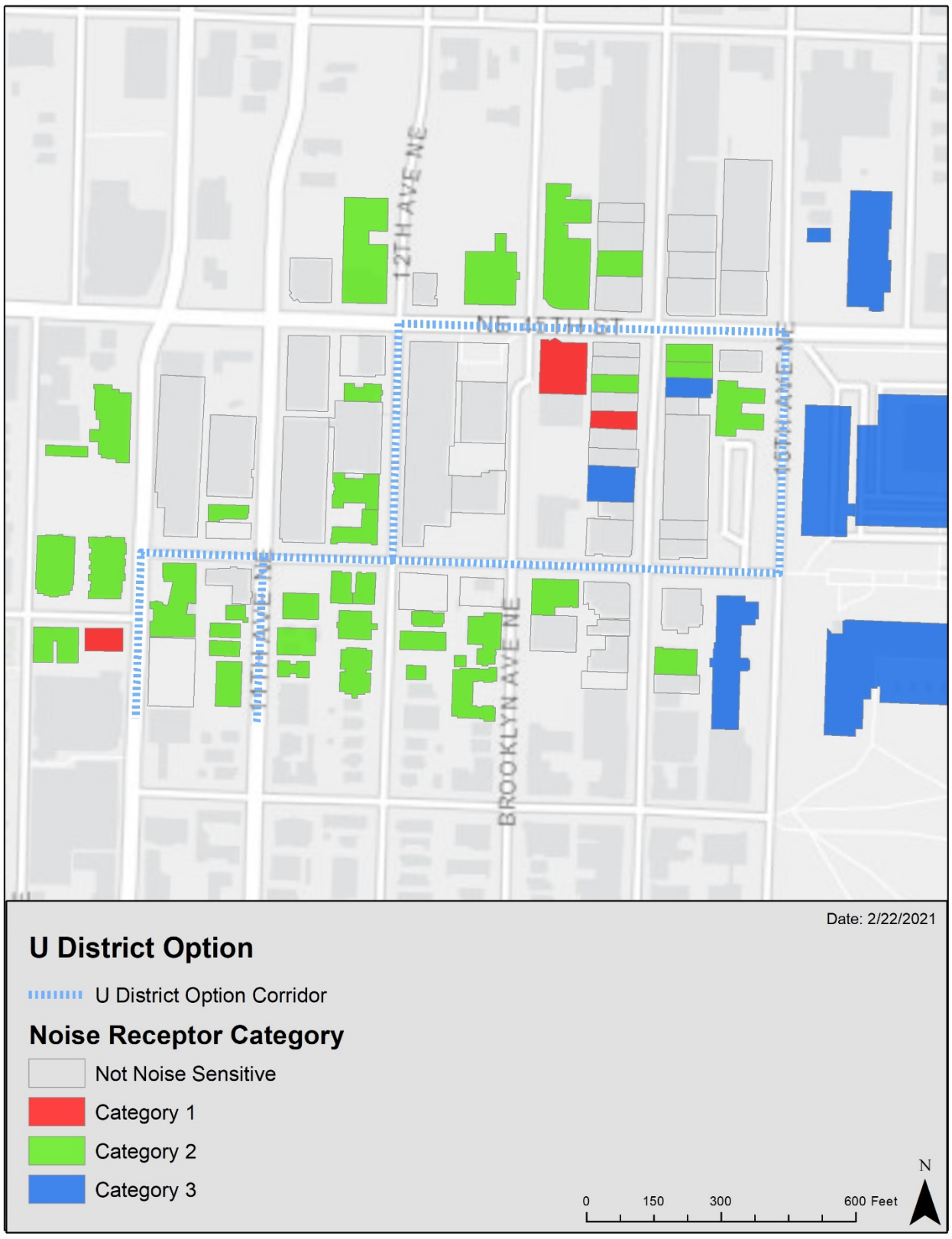

Figure 4-1. Noise-Sensitive Receptors

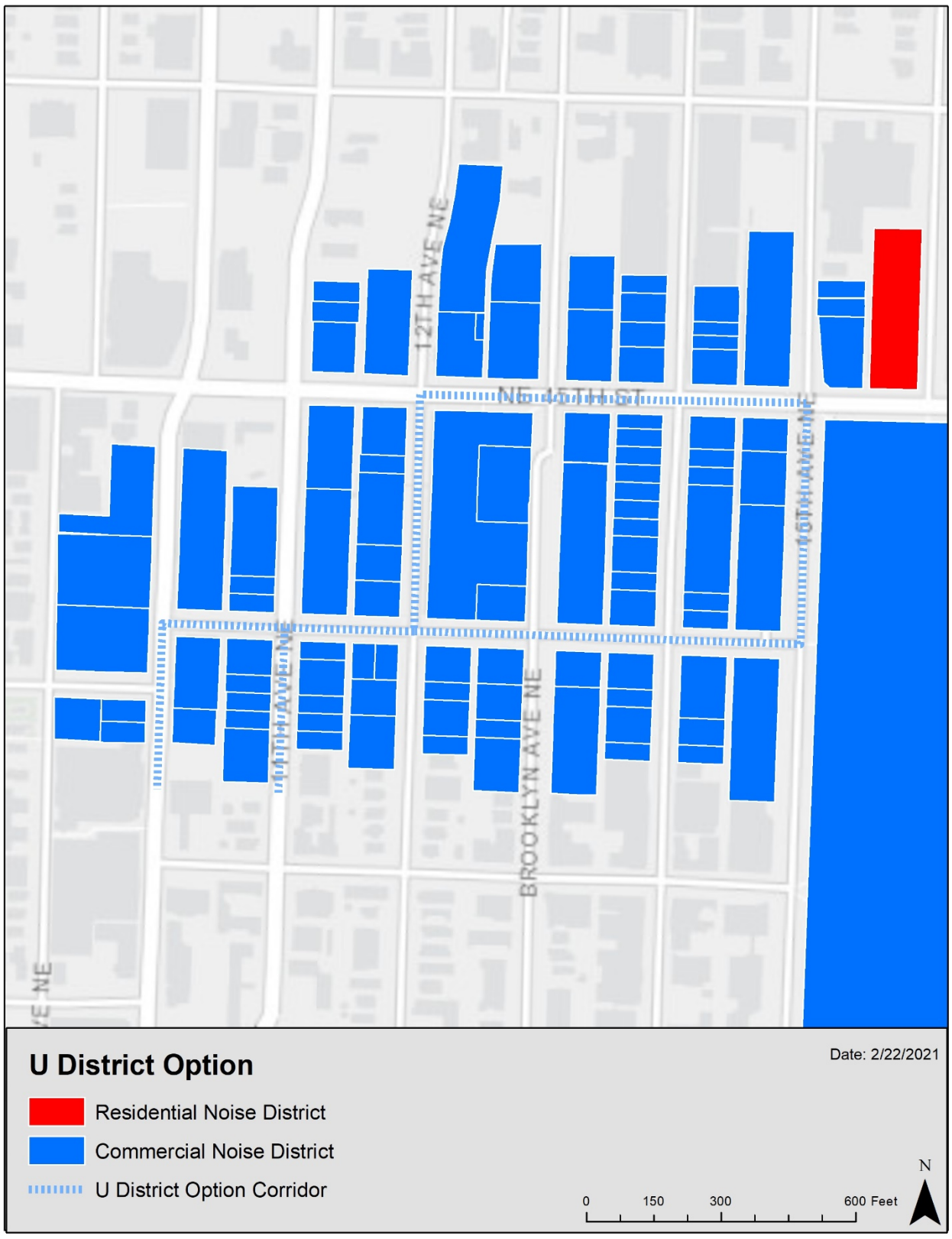

Figure 4-2. U District Option Noise Districts

4.2 Vibration-Sensitive Receptors

The category and number of vibration-sensitive receptors in the U District Option study area are provided in Table 4-2 and their locations are shown on Figure 4-3. Most of the vibration-sensitive receptors are Category 2. Refer to Appendix A, Noise- and Vibration-Sensitive Receptors, for information on the vibration-sensitive receptors in the study area.

Table 4-2 Vibration-Sensitive Receptor Summary

RECEPTOR CATEGORY	NUMBER
Special Building	3
Category 2	37
Category 3	8

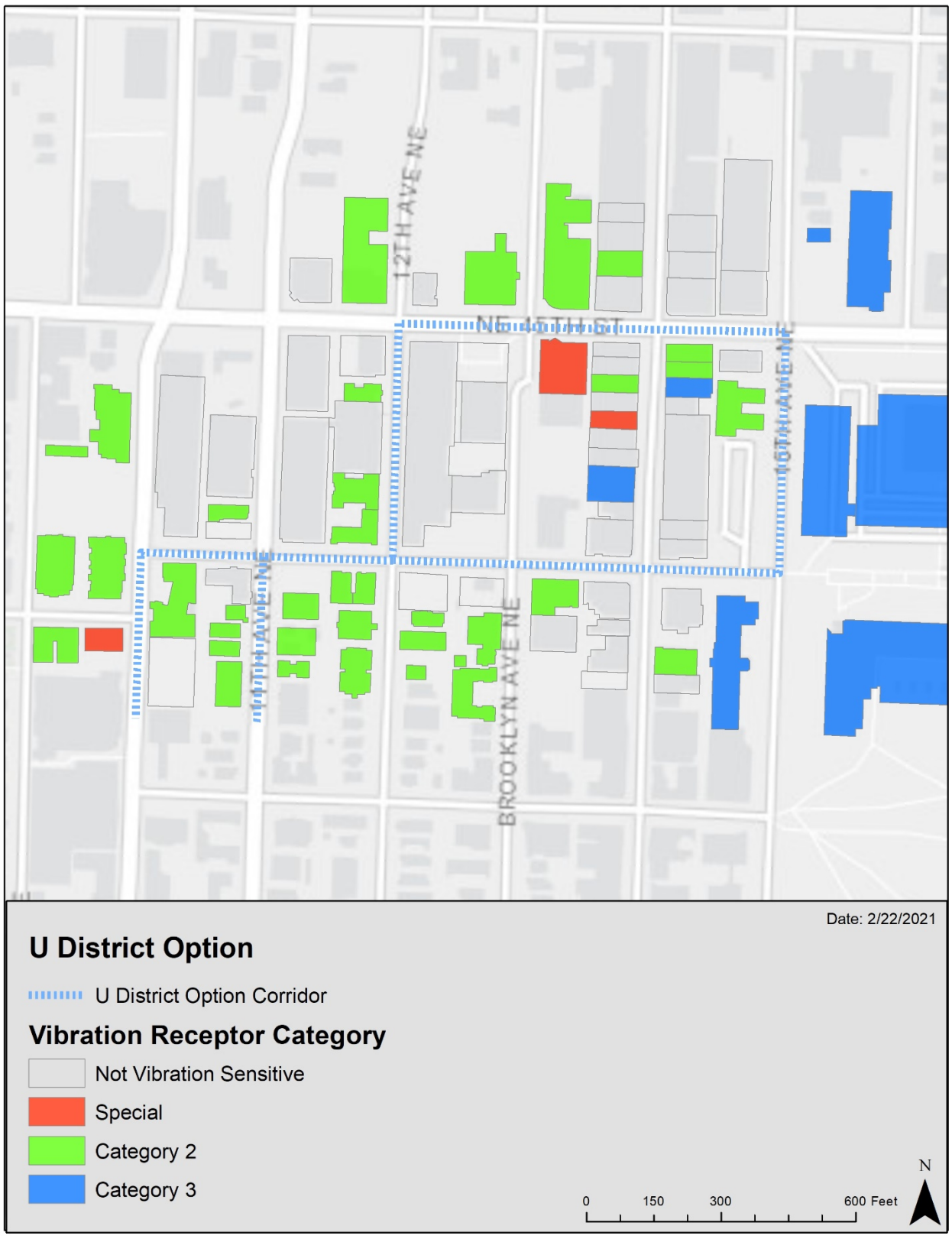

Figure 4-3 **Vibration-Sensitive Receptors**

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5. IMPACT ASSESSMENT

5.1 Operational Noise

Operational noise impacts were determined by comparing the predicted cumulative noise exposure with the impact criteria of each property. The cumulative noise exposure is a logarithmic summation of the predicted noise exposure and the measured existing sound level. Because there is existing transit in the area, the impact criteria are based on the allowable increase to cumulative sound levels. The measured sound levels, speed limits, and proximity of noise-sensitive properties to the U District Option northbound and southbound centerlines varied. Because of this, the predicted noise exposure is different for each property. Table 5-1 provides a summary of the impact assessment for each noise land use category. Detailed information for each property can be found in Appendix A.

Table 5-1. Operational Noise Impact Criteria and Impacts

NOISE CATEGORY	EXISTING SOUND LEVEL $L_{DN}/L_{EQ(H)}$	PROJECT NOISE EXPOSURE $L_{DN}/L_{EQ(H)}$	CUMULATIVE NOISE EXPOSURE $L_{DN}/L_{EQ(H)}$	ALLOWABLE INCREASE BEFORE MODERATE IMPACT ONSET[a]	SOUND LEVEL INCREASE	IMPACT
1	66 dBA	40-53 dBA	66 dBA	1 dB	0 dB	None
2	67 dBA	37-55 dBA	67 dBA	1 dB	0 dB	None
3	66 dBA	38-46 dBA	66 dBA	3 dB	0 dB	None

[a] Allowable increase before severe impact levels omitted from table because it is not required when there are not moderate impacts.

Following the methodologies outlined in Section 3.3, it was determined that the U District Option is unlikely to result in operational noise impacts at properties within in the study area.

5.2 Operational Vibration

As described in Section 3.5, the general assessment for operational vibration was performed as follows: First vibration levels were predicted at all receptors using formulas and adjustments that are not receptor-specific, then predicted levels were compared with impact criteria. Receptors that exceeded the impact criteria were flagged as potential vibration impacts and are presented in Table 5-2 and shown on Figure 5-1.

Table 5-2. Receptors with Potential Vibration Impacts

VIBRATION RECEPTOR	KING COUNTY PARCEL	ADDRESS	DESCRIPTION	VIBRATION CATEGORY
VR-1	1142000235	1303NE 45th St	Neptune Theater	Special
VR-2	1142000120	1407 NE 45th St	Avenue Building Apartments	2
VR-3	1145000165	909 NE 43rd St	Jack Straw Recording Studio	Special
VR-4	1142000015	4337 15th Ave NE	Malloy Apartments	2
VR-5	1142000450	1120 NE 43rd St	Cornell Apartments	2

Note: +6 VdB adjustment for resonances included as it applies to all receptors.

Additional investigation was then conducted for properties that were flagged as potential vibration impacts. This additional investigation applied adjustments to the predicted vibration levels based on building characteristics. These adjustments are shown in Table 5-3 and account for decreases in vibration levels due to losses through a structure.

Table 5-3 Vibration Receptor Adjustments

DESCRIPTION	VALUE
Ground to Building Foundation Coupling (Wood Framed Houses)	-5 dB
Ground to Building Foundation Coupling (1- to 2-story Masonry)	-7 dB
Ground to Building Foundation Coupling (3- to 4-story Masonry)	-10 dB
Ground to Building Foundation Coupling (Large Masonry on Piles)	-10 dB
Ground to Building Foundation Coupling (Large Masonry on Spread Footings)	-13 dB
Foundation in Rock	0 dB
Floor-to-Floor Attenuation (1 to 5 Floors Above Grade)	-2 dB / floor
Floor-to-Floor Attenuation (5 to 10 Floors Above Grade)	-1 dB / floor

Source: FTA Manual 2018, Table 6-12, Table 6-13

These adjustments were applied to the vibration levels calculated at the potentially impacted receptors. Predicted vibration levels after applying these adjustments were then compared to the FTA vibration criterion to determine if there were remaining vibration impacts (Table 2-4). It was determined that predicted vibration levels at all the potentially impacted receptors were below the impact criteria after the adjustments were made. Vibration impacts from operations are not predicted to occur within the U District Option study area.

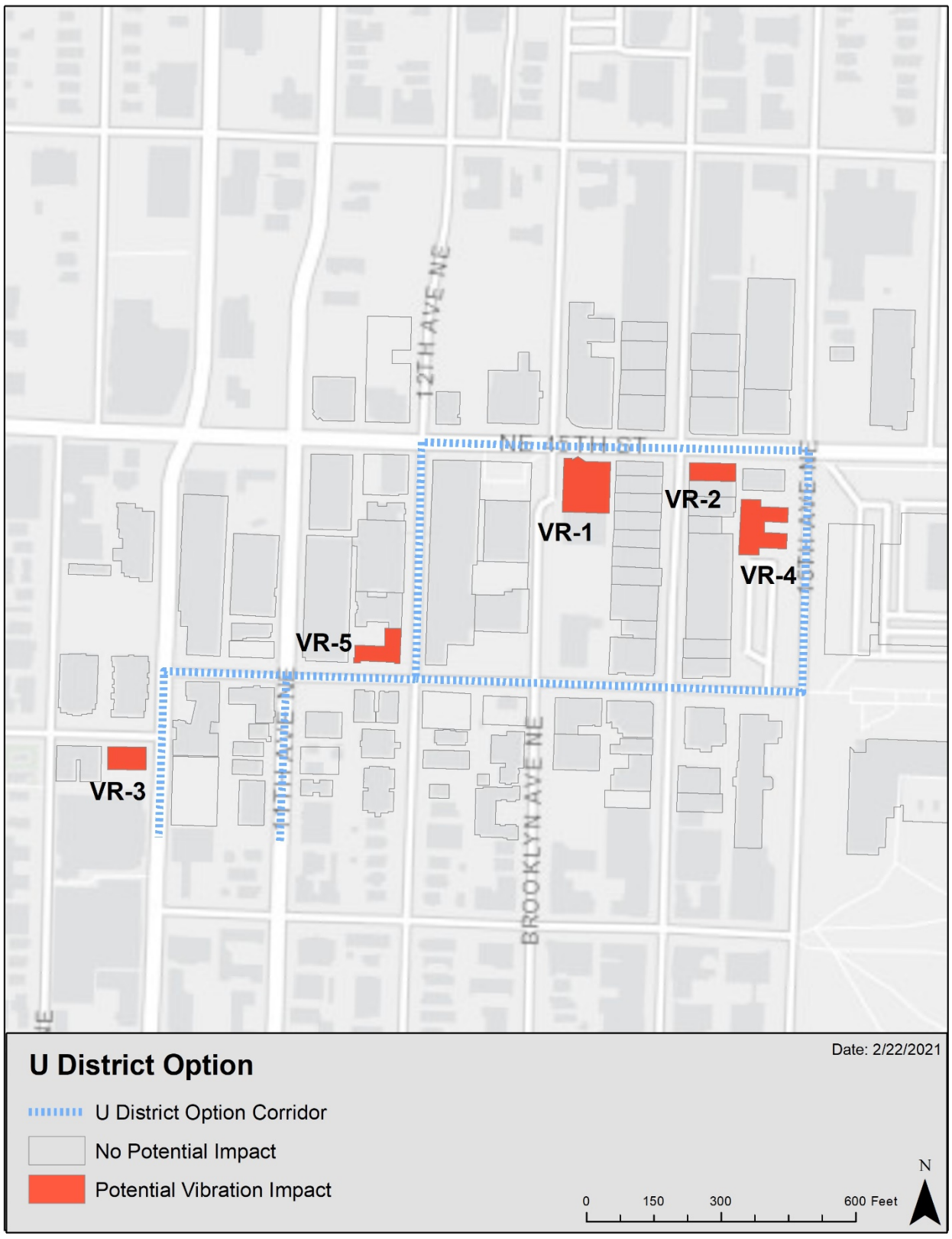

Figure 5-1 Potentially Impacted Vibration-Sensitive Receptors

Receptor specific adjustments made to the potentially impacted receptors are shown in Table 5-4.

Table 5-4 Adjusted Levels for Receptors with Potential Impacts

VIBRATION RECEPTOR	ADJUSTMENTS	PREDICTED VIBRATION LEVEL PRE-ADJUSTMENT[a]	PREDICTED VIBRATION LEVEL POST-ADJUSTMENT	IMPACT (CRITERIA)
VR-1	• Coupling to Foundation (-10 dB) 3- to 4-story Masonry	77 VdB	67 VdB	None (72 VdB)
VR-2	• Coupling to Foundation (-10 dB) 3- to 4-story Masonry • Floor-to-Floor Attenuation (-2 dB)	77 VdB	65 VdB	None (72 VdB)
VR-3	• Coupling to Foundation (-10 dB) 3- to 4-story Masonry	74 VdB	64 VdB	None (65 VdB)
VR-4	• Coupling to Foundation (-10 dB) Large Masonry	77 VdB	67 VdB	None (72 VdB)
VR-5	• Coupling to Foundation (-10 dB) 3- to 4-story Masonry	75 VdB	65 VdB	None (72 VdB)

[a] +6 VdB adjustment for resonances included as it applies to all receptors.

5.3 Construction Noise

The U District Option is expected to include the following construction activities: shallow excavation for station construction, utility relocation and installation of OCS poles, and roadwork which includes full depth paving along NE 43rd St between Roosevelt Way NE and 12th Ave NE. Table 5-5 shows the loudest anticipated sound levels from these construction activities.

Table 5-5 General Assessment of Construction Noise

EQUIPMENT	USAGE FACTOR	SOUND LEVEL AT 50 FEET, DBA
SHALLOW EXCAVATION (OCS, STATION, UTILITY)		
Concrete Mixer	1[a]	85
Jack Hammer	1[a]	88
	Total[b]	90
ROADWAY CONSTRUCTION		
Paver	1[a]	85
Scraper	1[a]	85
	Total[b]	88

Source: FTA Manual (2018), Table 7-1

[a] General Assessment assumes equipment runs continuously, which is a usage factor of 1.

[b] Logarithmic Summation

5.3.1 City of Seattle Criteria

Predicted sound levels at properties near construction areas are expected to exceed daytime and nighttime SMC construction sound level limits, based on Table 2-2. However, the FTA general assessment for construction noise is often conservative. With mitigation, construction activities would likely satisfy SMC daytime sound level limits and thereby comply with FTA criteria. If SMC sound level limits are not satisfied, or if nighttime work is necessary, it would be necessary to obtain a noise variance (SMC 25.08.655). Table 5-6 provides a summary of SMC construction sound level limits at commercial properties and impacts. Table 5-7 provides impact distances for construction noise. Properties that fall within these distances are anticipated to exceed SMC sound level limits if mitigation is not used.

Table 5-6 Construction Noise Impacts

PREDICTED SOUND LEVEL AT 50 FEET (dBA)	SMC COMMERCIAL SOUND-LEVEL LIMIT (dBA)	PREDICTED IMPACTS
SHALLOW EXCAVATION (OCS, STATION, UTILITY)		
90	85 / 60	Yes
ROADWAY CONSTRUCTION		
88	85 / 60	Yes

Table 5-7 Construction Noise Annoyance Impact Distances

DISTRICT OF RECEVING PROPERTY	IMPACT DISTANCES (FEET)[a]	
	SHALLOW EXCAVATION	ROADWAY CONSTRUCTION
Residential	146	105
Commercial[b]	82	74
Industrial	28	23

[a] When measured from the center of the construction area.

[b] U District Option study area is entirely within a commercial district.

5.3.2 Construction Noise Mitigation

A construction noise control plan will be developed during later stages of design when construction methods are better known. The control plan will include mitigation measures described in Section 6 of the 2018 TR.

5.4 Construction Vibration

The FTA Manual (2018) provides reference vibration levels produced by construction equipment. Table 5-8 provides a summary of vibration levels from equipment that may be used during construction. Specific construction methods will be developed during later stages of design and as proposed by the contractor.

Table 5-8 Construction Vibration Levels at 25 feet

EQUIPMENT	PPV (IN/SEC)	L_v
Vibratory Roller	0.210	94 VdB
Large Bulldozer	0.089	87 VdB
Loaded Truck	0.076	86 VdB
Jackhammer	0.035	79 VdB

Source: FTA Manual (2018), Table 12-2

L_v = root mean square vibration level

5.4.1 Building Damage

Potential cosmetic building damage could occur at adjacent structures that are near areas being repaved and station and OCS construction if mitigation measures are not implemented. Impact contours are calculated without reductions provided by mitigation measures. With the implementation of mitigation, the impact contours would be smaller. Nine buildings within the U District Option study area are within building damage impact contours. These nine buildings are identified in Appendix A. Cosmetic building damage would be unlikely if mitigation measures identified in Section 6.3 Construction Vibration Mitigation of the 2018 TR are followed. Table 5-9 provides building damage impact contours without mitigation for the construction equipment identified in Table 5-8.

Table 5-9 Construction Damage Impact Contours

EQUIPMENT	BUILDING CATEGORY (FEET)			
	1	2	3	4
Vibratory Roller	14	20	26	36
Large Bulldozer	8	11	15	20
Loaded Truck	7	10	13	18
Jackhammer	4	6	8	11

5.4.2 Annoyance

Vibration levels were calculated using methodologies outlined in Section 7.1 of the FTA Manual (2018) to determine occupant annoyance due to construction vibration. Table 5-10 provides vibration annoyance impact distance contours. Properties that are within their respective vibration category impact distance, when measured from the operating equipment, are anticipated to be annoyed. Most receptors near construction areas would experience short term annoyance from vibration caused by construction activities. Construction vibration is not expected to cause significant adverse reaction because the construction equipment associated with the annoyance would not operate continuously. Additionally, construction would not occur in one area for an extended period.

Table 5-10 Construction Vibration Annoyance Impact Distances

EQUIPMENT	VIBRATION CATEGORY (FEET)		
	SPECIAL[a]	2	3
Vibratory Roller	140	140	111
Large Bulldozer	82	82	65
Loaded Truck	76	76	60
Jackhammer	45	45	35

[a] 72 VdB criteria used.

5.4.3 Construction Vibration Mitigation

A construction vibration control plan will be developed during later stages of design when construction methods are better known. The control plan will include mitigation measures in Section 6 of the 2018 TR. Vibration mitigation during construction could include using low power settings on compaction equipment, phasing of high vibration activities, and vibration monitoring.

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6. REFERENCES

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Appendix A
Noise and Vibration Sensitive Receptors

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Table A-1 Receptor Inventory

King County Parcel Number	Address	Noise Category	Vibration Category
1142000175	1312 NE 43RD ST	-	-
1142000150	4325 UNIVERSITY WAY NE	-	-
1142000135	4333 UNIVERSITY WAY NE	2	2
1142000145	4329 UNIVERSITY WAY NE	1	Special
1142000125 [A]	4345 UNIVERSITY WAY NE	-	-
1142000155	4321 UNIVERSITY WAY NE	-	-
1142000065	4300 UNIVERSITY WAY NE	-	-
1142000170	4309 UNIVERSITY WAY NE	-	-
1142000235	1301 NE 45TH ST	1	Special
1142000160	4313 UNIVERSITY WAY NE	3	3
1142000130	4341 UNIVERSITY WAY NE	-	-
1142000070	4304 UNIVERSITY WAY NE	-	-
1142000120	1407 NE 45TH ST	2	2
1142000140	4337 UNIVERSITY WAY NE	-	-
1142000120	1407 NE 45TH ST	2	2
1142000075	4310 UNIVERSITY WAY NE	-	-
1142000105	4334 UNIVERSITY WAY NE	-	-
1142000110	4338 UNIVERSITY WAY NE	3	3
1142000290 [A]	4310 12TH AVE NE	-	-
8816400105	1408 NE 45TH ST	-	-
8816400130	4514 UNIVERSITY WAY NE	-	-
8816400020	4545 15TH AVE NE	-	-
8816400135	4518 UNIVERSITY WAY NE	-	-
8816400020	4545 15TH AVE NE	-	-
8816401140	1312 NE 45TH ST	-	-
8816401115	4523 UNIVERSITY WAY NE	-	-
8816401130	4509 UNIVERSITY WAY NE	2	2
7733600005	1200 NE 45TH ST	-	-
8816401120	4515 UNIVERSITY WAY NE	-	-
1142001020	4244 12TH AVE NE	-	-
1145000070	4305 ROOSEVELT WAY NE	2	2
6208500000	901 NE 43RD ST	2	2
1625049001	4300 15th Ave NE	3	3
1625049001	William H Gates Hall	3	3
1142000500	1107 NE 45TH ST	-	-
1142000400	1121 NE 45TH ST	-	-
1142000575	4307 11TH AVE NE	2	2
1142000530	4311 11TH AVE NE	-	-
1142000280	4333 BROOKLYN AVE NE	-	-
1145000165	909 NE 43RD ST	1	Special
3956660000	4341 ROOSEVELT WAY NE	2	2
3956660000	4341 ROOSEVELT WAY NE	2	2
1145000070	4305 ROOSEVELT WAY NE	2	2

King County Parcel Number	Address	Noise Category	Vibration Category
1142000550 [A]	4300 ROOSEVELT WAY NE	-	-
1142000445	4311 12TH AVE NE	2	2
1142000425	4317 12TH AVE NE	-	-
1142001140	1305 NE 43RD ST	2	2
1142001240	4224 UNIVERSITY WAY NE	-	-
1142001250	1405 NE 43RD ST	-	-
1142001025	1313 NE 43RD ST	-	-
1142001145	1415 NE 43RD ST	3	3
1142001035	4237 UNIVERSITY WAY NE	-	-
1142001130	4236 BROOKLYN AVE NE	-	-
1142001040	4229 UNIVERSITY WAY NE	-	-
1142000775 [A]	1115 NE 43RD ST	2	2
1142000780 [A]	1119 NE 43RD ST	2	2
1142000670	4225 11TH AVE NE	2	2
1142000930	4225 BROOKLYN AVE NE	2	2
1142000875	4226 11TH AVE NE	2	2
1142000805	4231 12TH AVE NE	2	2
1142000660	4235 11TH AVE NE	2	2
1142001010	4238 12TH AVE NE	2	2
1142000755 [A]	4242 ROOSEVELT WAY NE	2	2
1142000645 [A]	4241 11TH AVE NE	-	-
1142000795	4235 12TH AVE NE	2	2

King County Parcel Number	Address	Noise Category	Vibration Category
1142000925	4229 BROOKLYN AVE NE	2	2
1142000995	4224 12TH AVE NE	2	2
1142001000	4230 12TH AVE NE	2	2
1142000890	4236 11TH AVE NE	2	2
1142000665	4229 11TH AVE NE	2	2
1142000925	4229 BROOKLYN AVE NE	2	2
1142000655	4237 11TH AVE NE	2	2
1142000015	4337 15TH AVE NE	2	2
1142000005	1415 NE 45TH ST	-	-
7733600055	1100 NE 45TH ST	-	-
8817400055	4507 BROOKLYN AVE NE	2	2
8816401150	1300 NE 45TH ST	2	2
8823902310	4516 15TH AVE NE	3	3
8823902255	1514 NE 45TH ST	3	3
1142000290	4310 12TH AVE NE	-	-
1142000290	4310 12TH AVE NE	-	-
1142000290	4310 12TH AVE NE	-	-
1142001245	4234 UNIVERSITY WAY NE	2	2
7733600135	1112 NE 45TH ST	2	2
1142000415	1121 NE 45TH ST	2	2
1142000450 [A]	1120 NE 43RD ST	2	2
1142000425 [A]	4317 12TH AVE NE	-	-

King County Parcel Number	Address	Noise Category	Vibration Category
1142000880	4230 11TH AVE NE	2	2
1142000745	4240 ROOSEVELT WAY NE	-	-
1142000580	4301 11TH AVE NE	-	-
1142000905	4245 BROOKLYN AVE NE	-	-
1625049001	1413 NE 45th St	3	3
1142001050	4227 UNIVERSITY WAY NE	-	-

[A] Potential Cosmetic Building Damage if mitigation is not implemented. With Construction Vibration Control Plan, cosmetic building damage would be unlikely.

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Appendix B
Noise and Vibration Measurements

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NOISE MEASUREMENTS

N-1 4244 11th Avenue Southeast

Photo B-1 4244 11th AVE SE

Table B-1 N-1 Noise Measurement Equipment

EQUIPMENT	MANUFACTURER	MODEL	SERIAL NO.	CALIBRATION DATE
4244 11TH AVE SE				
Sound Level Analyzer	Svantek	SV307	93710	7/1/2020
Microphone	Svantek	ST30	82557	7/1/2020
Calibrator	Larson Davis	CAL200	16826	6/24/2020

Table B-2 N-1 Measurement Results

DATE	START OF HOUR	L_{eq} (dBA)
4244 11TH AVE SE		
12/17/2020	12 PM	63
12/17/2020	1 PM	63
12/17/2020	2 PM	62
12/17/2020	3 PM	62
12/17/2020	4 PM	62
12/17/2020	5 PM	62
12/17/2020	6 PM	61
12/17/2020	7 PM	61
12/17/2020	8 PM	61
12/17/2020	9 PM	60
12/17/2020	10 PM	58
12/17/2020	11 PM	58
12/18/2020	12 AM	57
12/18/2020	1 AM	56
12/18/2020	2 AM	53
12/18/2020	3 AM	53
12/18/2020	4 AM	57
12/18/2020	5 AM	58
12/18/2020	6 AM	61
12/18/2020	7 AM	62
12/18/2020	8 AM	63
12/18/2020	9 AM	63
12/18/2020	10 AM	66
12/18/2020	11 AM	75

N-2 1303 Northeast 45th Street

Photo B-2 1303 NE 45th St

Table B-3 N-2 Noise Measurement Equipment

EQUIPMENT	MANUFACTURER	MODEL	SERIAL NO.	CALIBRATION DATE
1303 NE 45TH ST				
Sound Level Meter	Svantek	958a	59108	2/7/2020
Microphone	Microtech	MK255	12529	2/7/2020
Preamplifier	Svantek	SV12L	57961	2/7/2020
Calibrator	Larson Davis	CAL200	16826	6/24/2020

Table B-4 N-2 Measurement Results

DATE	START OF HOUR	L_{eq} (dBA)
1303 NE 45TH ST		
12/18/2020	11 AM	69
12/22/2020	11 AM	68

N-3 4300 15th Avenue Northeast

Photo B-3 4300 15th AVE NE

Table B-5 N-3 Noise Measurement Equipment

EQUIPMENT	MANUFACTURER	MODEL	SERIAL NO.	CALIBRATION DATE
4300 15TH AVE NE				
Sound Level Meter	Svantek	971	72542	6/30/2020
Microphone	Aco Pacific	7052E	68284	6/30/2020
Preamplifier	Svantek	SV18	72239	6/30/2020
Calibrator	Larson Davis	CAL200	16827	6/24/2020

Table B-6 N-3 Measurement Results

DATE	START OF HOUR	L_{eq} (dBA)
4300 15TH AVE NE		
12/18/2020	11 AM	69
12/22/2020	11 AM	70

VIBRATION MEASUREMENTS

V-1 1303 Northeast 45th Street

Photo B-4 1303 NE 45th St Vibration Measurements

Table B-7 V-1 Vibration Measurement Equipment

EQUIPMENT	MANUFACTURER	MODEL	SERIAL NO.
1303 NE 45TH ST			
Vibration Level Meter	Svantek	958a	59108
Accelerometer	PCB	TLD333B50	64180

Table B-8 V-1 Measurement Results

DATE	TIME	L_v (VdB)
1303 NET 45TH ST		
12/18/2020	11AM – 12PM	51
12/22/2020	11AM – 12PM	51