Downtown Redmond Link Extension
SEPA Addendum

Appendix B
Noise and Vibration
Technical Report Addendum

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ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
dB	decibel
dBA	decibel with A-weighting
EIS	Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
HRDF	high resilience direct fixation
Hz	Hertz
in/s	inches per second
Ldn	24-hour, time-averaged, A-weighted sound level (day-night) with +10 dB weighting added to nighttime noise (10:00 p.m. to 7:00 a.m.)
Leq	equivalent continuous sound level
Lmax	maximum noise level
LSR	line source response
mm/s	millimeter per second
mph	miles per hour
NEPA	National Environmental Policy Act
PPV	peak particle velocity
ROD	Record of Decision
SEPA	State Environmental Policy Act
Sound Transit	Central Puget Sound Regional Transit Authority
SR	State Route
SR 520	State Route 520
TNM	FHWA's Traffic Noise Model software
TPSS	traction power substation
VdB	vibration velocity decibels using a reference of 1 micro-inch per second
WSDOT	Washington State Department of Transportation

1 INTRODUCTION AND SUMMARY

The Downtown Redmond Link Extension Project would add 3.4 miles of light rail and two new light rail stations from the interim terminus of the Redmond Technology Center Station (formerly called the Overlake Transit Center Station) to downtown Redmond (Figure 1-1).

This light rail corridor was evaluated as Segment E of the 2011 East Link Project Final Environmental Impact Statement (Final EIS). The Final EIS and Record of Decision (ROD) identified the Marymoor Alternative E2 as the Preferred Alternative in Segment E. The Sound Transit Board selected the Marymoor Alternative E2 (referred to hereafter as the 2011 Project) to be built as part of the full length East Link Project, although at the time Segment E was not funded for construction and operation. Since 2011, project plans as well as project area conditions have changed. As a result, Sound Transit is updating the environmental review to address these changes.

This report is an addendum to Appendix H2, Noise and Vibration Technical Report, prepared for the East Link Project (Sound Transit 2011). Analyses in this report address the changes in impacts of the Downtown Redmond Link Extension Project. Consistent with the requirements of the National Environmental Policy Act (NEPA) and the State Environmental Policy Act (SEPA), this report provides updated information about existing conditions, presents the noise and vibration analyses, identifies potential adverse impacts of the light rail project, and identifies strategies to avoid, minimize, or mitigate those impacts. Attachments A through F provide supplementary analysis information.

This report also provides design recommendations for the control of vibration generated during the operation of the Downtown Redmond Link Extension Project. The vibration analysis incorporates design changes and refines vibration predictions by introducing more details. The analysis of design changes incorporated recent vibration data from the existing Sound Transit vehicles, including soil propagation data measured at representative locations along the alignment. Collectively, these measurements allow for a refined prediction of vibration from the proposed design changes, referred to in this report as Proposed Design Refinements.

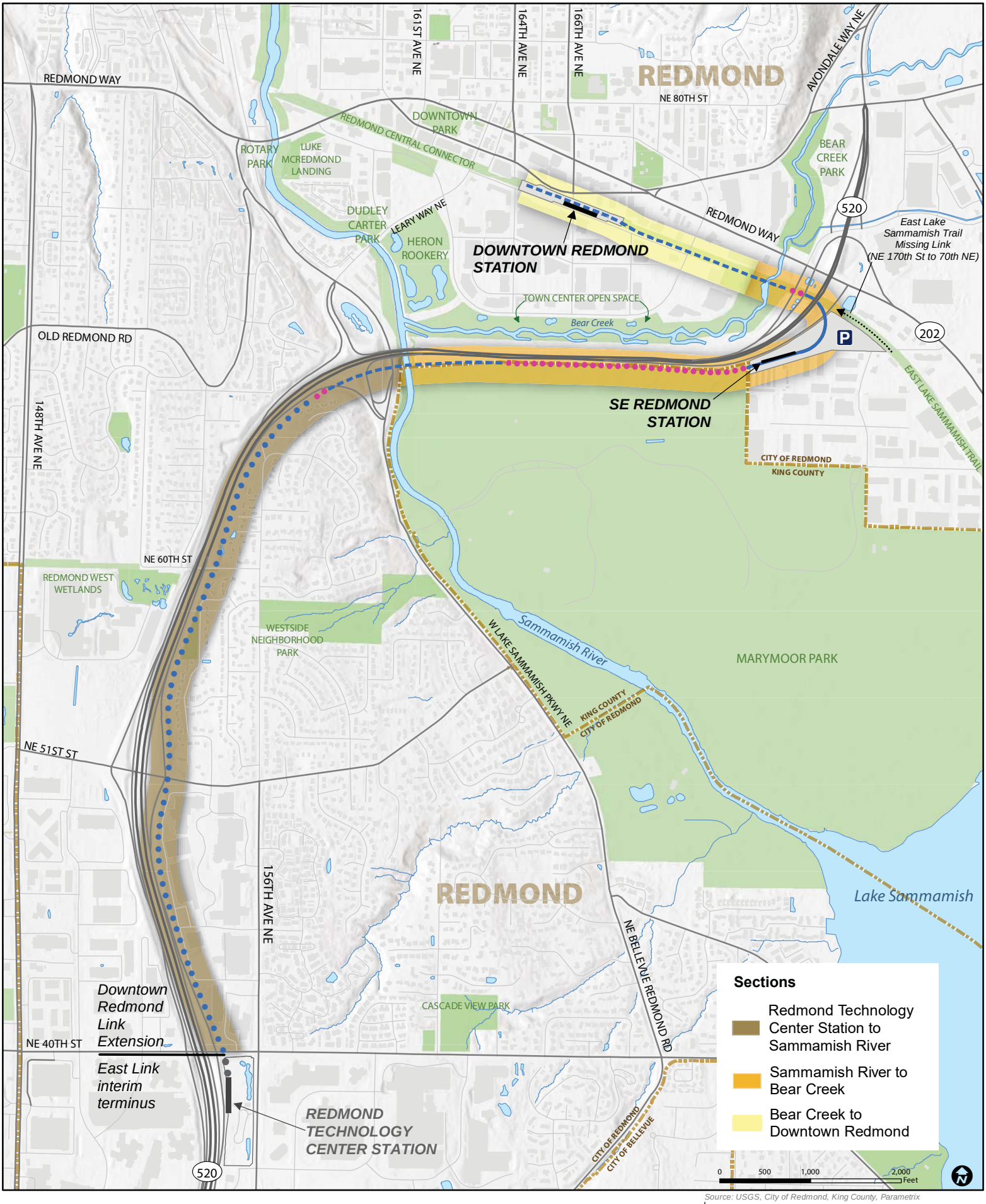
1.1 Proposed Design Refinements

The alignment with the Proposed Design Refinements is shown in Figure 1-1 and sections are described below. The Downtown Redmond Link Extension corridor is described in three geographic sections: Redmond Technology Center Station to Sammamish River, Sammamish River to Bear Creek, and Bear Creek to Downtown Redmond. Because the East Link maintenance facility has been located in Bellevue, the Proposed Design Refinements do not include a maintenance facility location.

1.1.1 Redmond Technology Center Station to Sammamish River

In the section between the Redmond Technology Center Station and the Sammamish River, the light rail route runs parallel to the east side of SR 520. The alignment would generally be at-grade with SR 520 and use retained-cut sections to cut into the hillside and pass under existing overpasses at NE 40th Street, NE 51st Street, and NE 60th Street. The retained-cut sections would range from ground level up to approximately 16 feet where the alignment passes under NE 40th Street, NE 51st Street, and NE 60th Streets. As the alignment follows SR 520 and curves east, it transitions to an elevated structure crossing over the West Lake Sammamish Parkway NE interchange and the Sammamish River.

The alignment with the Proposed Design Refinements is similar to the 2011 Project, but has been modified in several locations to minimize impacts on adjacent roadways and to accommodate the Washington State Department of Transportation (WSDOT) planned improvements (WSDOT 2013).



Source: USGS, City of Redmond, King County, Parametrix

Figure 1-1
Alignment with Proposed Design Refinements
Downtown Redmond Link Extension

Between NE 40th Street and NE 51st Street, the alignment has been shifted up to 20 feet away from SR 520 to maximize available WSDOT right-of-way and limit impacts on the adjacent property. The refined alignment has also been shifted up to 25 feet away from SR 520 south of NE 60th Street and up to 30 feet near the West Lake Sammamish Parkway NE eastbound off-ramp.

With the Proposed Design Refinements, a traction power substation (TPSS) would be located in the vicinity of SR 520 and NE 65th Street, whereas the TPSS in this area for the 2011 Project would be located under the elevated guideway near the West Lake Sammamish Parkway/SR 520 interchange.

1.1.2 Sammamish River to Bear Creek

Between the Sammamish River and the SE Redmond Station, the Proposed Design Refinements are similar to the 2011 Project. The elevated guideway would be about 50 to 60 feet above the Sammamish River with the Proposed Design Refinements, which is approximately 15 to 20 feet lower than anticipated for the 2011 Project. The elevated guideway for the Proposed Design Refinements would match the height of the SR 520 bridge and would not have any columns within the ordinary high water mark of the river. The Proposed Design Refinements would transition from elevated to a retained-fill section as it crosses Marymoor Park, whereas the 2011 Project would transition from elevated to at-grade across the park. In the Proposed Design Refinements, the retained-fill section would be between 5 and 14 feet higher than the current ground level and would provide grade separation from Marymoor Park facilities. Similar to the 2011 Project, the Proposed Design Refinements alignment would then transition to ground level as it enters the SE Redmond Station.

The major changes in this section are related to the City of Redmond's plans allowing the Marymoor Subarea to develop around the SE Redmond Station as a transit-oriented neighborhood with mixed-use developments, including a revised street network and new trail connections. Station facilities for both the 2011 Project and the Proposed Design Refinements include a 1,400-stall parking garage as well as circulation for transit, passenger pick-up and drop-off, and connections to trails in the area. The Proposed Design Refinements would rebuild NE 70th Street, currently a dead-end street, to serve the station and surrounding land uses and to connect to the SE Redmond street system consistent with City of Redmond plans. The second TPSS would be located at the SE Redmond Station, whereas the 2011 Project placed the second TPSS in the vicinity of 166th Avenue NE in the rail corridor.

From the SE Redmond Station, the alignment is similar to the 2011 Project, turning to the northwest, crossing underneath SR 520, and entering the former BNSF rail corridor. The Proposed Design Refinements would cross under SR 520 at-grade and require reconstruction of the SR 520 eastbound off-ramp and westbound on-ramp. The Proposed Design Refinements would slightly raise SR 202 and a short section of NE 76th Street to align with the reconstructed westbound on-ramp and its intersection, which would be modified. The Proposed Design Refinements and the 2011 Project alignment would both rise to cross on a new bridge elevated about 3 to 6 feet over Bear Creek. The Proposed Design Refinements would also accommodate an at-grade trail connection between the East Lake Sammamish Trail and Redmond Central Connector Trail with a bridge over Bear Creek, which may be constructed by Sound Transit as part of the project with funding provided by King County, or funded and constructed by King County at a later time. This trail connection is a missing segment of King County's East Lake Sammamish Trail, and the Proposed Design Refinements' raising of the SR 520 ramps makes this at-grade connection possible.

The Bear Creek channel and its floodplain would be regraded and broadened to remove some past fill and constrictions in the floodplain from the existing railroad bridge, which is no longer in use and would be removed. These improvements to the Bear Creek channel would complement restoration efforts

completed downstream since 2011. The improvements were not contemplated and therefore not analyzed for the 2011 Project.

1.1.3 Bear Creek to Downtown Redmond

In the section between Bear Creek and downtown Redmond, the Proposed Design Refinements have the same general alignment but with some different features than the 2011 Project. After crossing over Bear Creek, the refined alignment would continue on an elevated structure, whereas the 2011 Project alignment would return to grade. The refined alignment in downtown Redmond would shift slightly south of the 2011 Project, and it would be shorter. The elevated Downtown Redmond Station and tail tracks would shift approximately 1,600 feet east compared to the 2011 Project. The Downtown Redmond Station would span 166th Avenue NE and remain in the existing rail corridor easement on the north side of NE 76th Street. Approximately 460 feet of tail tracks for train layover and turnback operations would continue west of the station, terminating just east of 164th Avenue NE. Crossover tracks would be located just west of 170th Avenue NE in downtown Redmond, whereas the 2011 Project previously located the crossover tracks west of the SE Redmond Station.

1.2 Summary of Results and Comparison to the Final EIS

This section briefly describes the results of the noise and vibration analysis for the Proposed Design Refinements as compared to the 2011 Project.

1.2.1 Noise

The noise analysis was performed at 193 locations representing 113 single-family residences, 46 multi-family units (apartments and condominiums), 18 hotel rooms, and 2 sites in Marymoor Park. The impact analysis assumes replacement traffic sound walls between NE 51st Street and NE 60th Street and near NE 67th Place as part of the Proposed Design Refinements. The replacement wall between NE 51st Street and NE 60th Street would eliminate the potential light rail noise impacts along 154th Avenue NE as well as maintain traffic noise levels below the Federal Highway Administration (FHWA) and WSDOT criteria.

Table 1-1 summarizes the projected noise impacts, which includes 8 severe noise impacts and 29 moderate impacts. All noise impacts could be fully mitigated to below the Federal Transit Administration (FTA) criteria with a combination of at-grade sound walls, sound walls along the elevated structure, and special trackwork. Additional information on the technical assessment of impacts, including maps of all impacts and mitigation measures, are provided in Chapter 4, Environmental Impacts.

The number and severity of noise impacts considered for the 2011 Project were different than those predicted for the Proposed Design Refinements. The differences in impacts are due mainly to changes in the alignment terminus as well as modifications to the retained-cut sections along SR 520, an elevated alignment in downtown Redmond, and the construction of new noise-sensitive structures. The 2011 Project identified 33 moderate and 148 severe noise impacts compared to 29 moderate and 8 severe noise impacts under the Proposed Design Refinements.

Table 1-1. Summary of Potential Light Rail Noise Impacts

	2011 Project FTA Noise Impacts				Proposed Design Refinements FTA Noise Impacts			
Light Rail Segment	**Moderate**	**Severe**	**Total**	**Total Impacts after Mitigation**	**Moderate**	**Severe**	**Total**	**Total Impacts after Mitigation**
Redmond Technology Center Station to Sammamish River	9	4	13	0	9	0	9	0
Sammamish River to Bear Creek	0	0	0	0	0	0	0	0
Bear Creek to Downtown Redmond	24	144	168	0	20	8	28	0
Total	**33**	**148**	**181**	**0**	**29**	**8**	**37**	**0**

The differences in impacts are attributed to the following changes:

1. The terminus of the Proposed Design Refinements is approximately 1,600 feet east of the 2011 Project terminus, thus eliminating 144 severe noise impacts at several multi-family buildings between Leary Way and Redmond Way. Noise impacts at the Redmond Residence Inn and the Elan Redmond Apartments would also be eliminated.
2. New construction of one new mixed-use condominium would add 18 moderate noise impacts. In addition, the recently permitted Redmond Town Center Apartments (The Talisman), which were evaluated using the most current plan drawings, are predicted to have 8 severe and 20 moderate noise impacts. These impacts would also have occurred under the 2011 Project.
3. The reduction in the severity and number of noise impacts along the retained-cut section from 9 moderate and 5 severe to 7 moderate noise impacts is due to updated trackway plans and the noise-reducing effect of the retaining walls.
4. The Proposed Design Refinements include 4 car trains and 6-minute headways during peak hours, compared to 3 car trains and 7-minute peak headways indicated in the Final EIS, resulting in slightly higher noise levels for the Proposed Design Refinements.

1.2.2 Vibration

For the Proposed Design Refinements, vibration analysis and measurements were conducted at seven locations. The results of the vibration analysis for the Proposed Design Refinements indicate that vibration impacts are expected at five residential receptors. The groundborne noise assessment identified an additional five impacts. These receptors are in the same neighborhood (between Microsoft and Marymoor Park) as the impacts identified for the 2011 Project. Ballast mat is recommended as part of the design for vibration control at these receptors. Two sections of ballast mat are needed for a total length of 3,000 track feet (route-length of 1,500 feet). Other vibration control measures may also be considered during final design.

The Final EIS concluded that operational vibration impacts would occur at three residential receptors and proposed mitigation would be needed for a total of 700 feet (1,400 track feet). Although no specific mitigation technique is noted for the 2011 Project, likely potential mitigation measures noted in Appendix H2, Noise and Vibration Technical Report, include ballast mats or resilient rail fasteners. Compared to the 2011 Project, the Proposed Design Refinements would affect two additional residential

receptors between Microsoft and Marymoor Park, and mitigating trackwork would be reduced by 50 feet (route length).

Additional field measurements and analyses were conducted at the Jerry Baker Memorial Velodrome, located at the northeast corner of Marymoor Park, to address the potential for crack development due to vibration or vibration-induced settlement. The analysis shows that the velodrome structure should be unaffected by train or construction vibration.

2 UPDATES TO METHODOLOGY AND ASSUMPTIONS

The methodology and assumptions used to predict future noise and vibration levels related to the Proposed Design Refinements are described in Appendix H2 of the Final EIS; updates to the methodology and assumptions are discussed in this chapter.

Noise is measured in terms of sound pressure level, and expressed in terms of decibels (dB). Because the human ear is less sensitive to higher and lower frequencies, a weighing system reducing some higher and lower frequencies is used to approximate normal human perception of noise. Measurements made with this weighing system are termed “A-weighted” and are specified as “dBA”" readings.

The primary noise descriptor for transportation studies is the equivalent sound level (Leq), which is the level of a constant sound for a specified period of time that has the same sound energy as an actual fluctuating noise over the same period of time. The day-night sound level (Ldn) is the equivalent sound level for a 24-hour period with an additional 10 dBA added to nighttime sound levels occurring between 10 p.m. and 7 a.m. The Lmax and Lmin are the maximum and minimum sound level, in dBA, measured during the preset measurement period. Detailed information is provided in Appendix H2 of the Final EIS.

2.1 Noise Assumptions and Methods

Input to the noise analysis includes updated information on the number of trains, operational speeds, track type, station and park-and-ride locations, along with the location of special trackwork such as crossovers. Reference measurements for light rail operations of 79 dBA Lmax for a single-car train traveling at 40 miles per hour (mph) at a distance of 50 feet on ballast and tie track were updated in 2016. The speeds used in this analysis are the track design speeds, which are generally 55 mph throughout the corridor except on speed-limited curves and at stations. These speeds may be higher than actual speeds and therefore ensure a conservative noise impact analysis.

Other factors that influence noise, which have changed in some areas since the 2011 Project and are included in this analysis, are trenches and retained cuts. In areas with trenches or retained cuts, where the trackway is at least 4 to 6 feet below grade, a typical reduction of 5 dB or more can be achieved. The noise-reducing effects of the parapet on the elevated structures were also included where track-to-receiver geometry allowed. Parapet shielding is a reduction in noise caused by the base and the curb along the sides of the elevated structures. Receivers that are located below the structure can be shielded from the far track noise by the structure and the structure’s parapet or short concrete curb. Parapet shielding can reduce noise from the far track by 6 to 8 dB. Because noise from the near track is still dominant, the overall reduction from both trains is typically 2 to 3 dB when compared to an unshielded pair of trains. Examples of parapet and retained-cut shielding are shown on Figure 2-1.

2.2 Vibration Assumptions and Methods

The vibration analysis for the Proposed Design Refinements used the same procedures for detailed vibration assessment as the Final EIS. Updates to the vibration analysis include recent measurements of the force density level of Sound Transit’s fleet of light rail vehicles. In addition, vibration propagation measurements were performed at six locations along the corridor and used to predict impacts for this analysis.

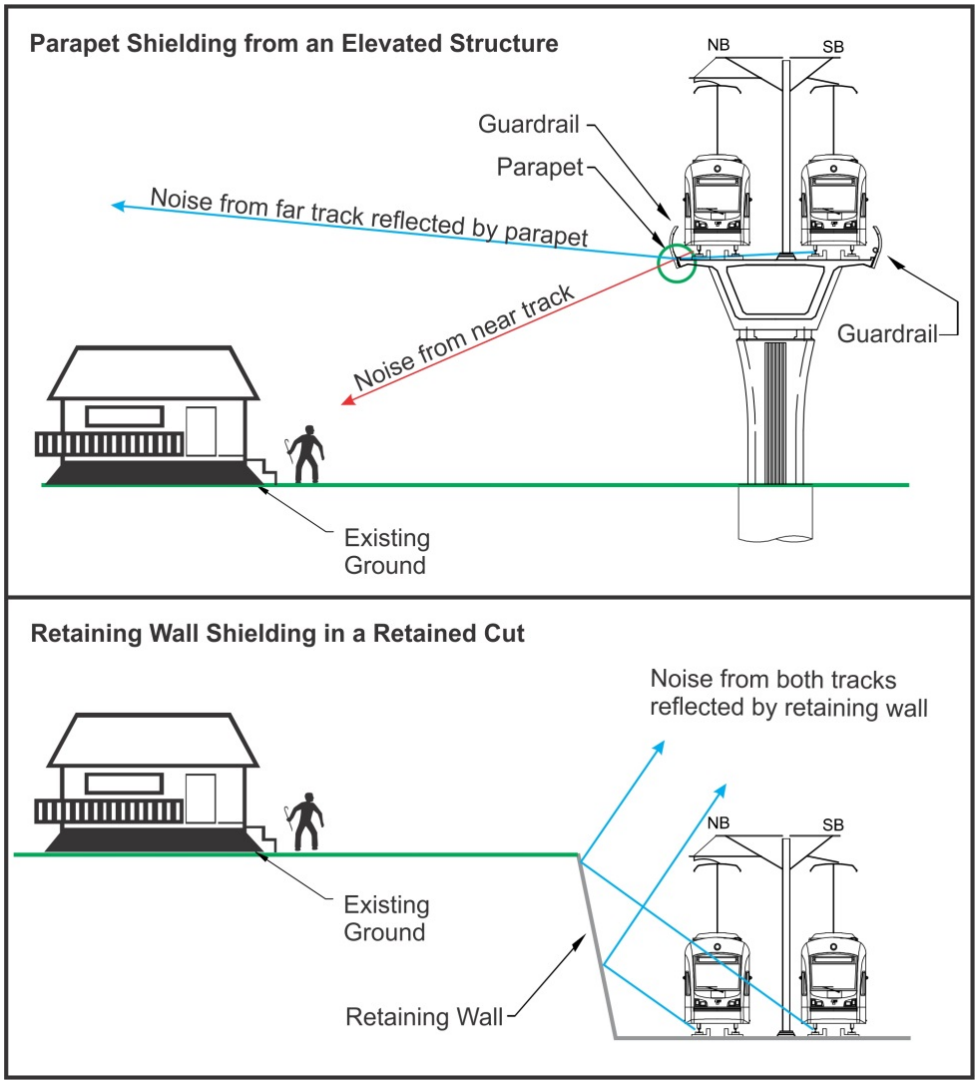


Figure 2-1. Shielding from Retained Cuts and Elevated Track Parapets

3 CHANGES TO AFFECTED ENVIRONMENT

This chapter summarizes existing land uses along the project corridor, sensitive noise and vibration receptors, existing measured noise levels, and the existing ambient vibration environment. Unlike noise, human response to vibration is not dependent on existing vibration levels. Humans respond to a new source of vibration based on the frequency of the events. Rather than measuring existing vibration levels, the affected environment analysis characterizes and measures vibration propagation through the ground at representative locations.

3.1 Land Use

Land use along the project corridor consists of single-family and multi-family residences, hotels, park lands, and commercial uses that are not considered noise-sensitive under FTA criteria. On the east side of SR 520, beginning at the connection to the Redmond Technology Center Station, from NE 40th Street to NE 51st Street, land use is commercial and consists of the Microsoft campus and the Liberty Mutual Insurance building. On the west side of SR 520, land use is also commercial, mostly Microsoft. The primary noise source in this area is traffic on SR 520 and local arterial roadways.

North of NE 51st Street to West Lake Sammamish Parkway, land use is entirely single- and multi-family residential on both sides of SR 520. On the east side of SR 520, the Proposed Design Refinements would relocate an existing traffic sound wall from NE 51st Street and NE 60th Street to accommodate the light rail alignment. There are no sound walls north of NE 60th Street on the east side of SR 520. On the west side of SR 520, from NE 51st Street to West Lake Sammamish Parkway, there is an existing traffic sound wall. The primary noise source in this area is traffic on SR 520.

Between West Lake Sammamish Parkway and the connection to the Redmond Central Connector, land use to the south of the alignment is Marymoor Park, and to the east of Marymoor Park and in the vicinity of Bear Creek are commercial and light industrial land uses. Marymoor Park has multiple uses. The primary noise source in this area is traffic on SR 520. Uses in the northern end of the park consist mainly of active sporting activities, which take place at several locations such as baseball fields, soccer fields, a cricket field, a platform for major shows and productions, and the velodrome for cycling. A climbing wall is located just south of the velodrome, at the east end of the park. King County Parks has plans to construct a new facility with indoor tennis courts near the northwest corner of the park. The central part of the park has offices, supporting facilities for park maintenance, and several parking lots and large open areas that are also used for parking during major events, such as Cirque du Soleil. The southernmost part of the park is known for birdwatching and is located well away from most noise sources in the area; it is over 2,500 feet from SR 520. This part of the park also has several trails and loops just north of Lake Sammamish.

From southeast Redmond to the terminus in downtown Redmond, land use is mainly commercial and retail with two hotels, one condominium, and a planned and permitted apartment complex. Local area traffic on several nearby arterial roadways, including NE 76th Street, Redmond Way, and Leary Way, dominates local noise sources.

Since the Final EIS was published, types of land use in the project area have not changed; however, additional development has occurred in downtown Redmond and future development is anticipated in southeast Redmond. Since 2011, construction of new, mixed-used commercial and multi-family development has added noise-sensitive receivers in downtown Redmond. The City of Redmond updated its Comprehensive Plan in June 2017 to include the newly adopted Marymoor Subarea Plan for the southeast Redmond neighborhood. These changes emphasize mixed-use and residential developments

accessed by light rail, pedestrian pathways, bike trails, and bus transit. These changes also established a Marymoor Local Center designation, which is defined as "activity nodes where employment, services and housing are accommodated in a compact manner and at sufficient densities to make efficient use of urban land and support transit and other multimodal access."

3.2 Noise- and Vibration-Sensitive Land Uses

Potential noise-sensitive land use along the project corridor consists of single-family and multi-family residences, hotels (FTA Category 2), and park lands (FTA Category 3). Vibration-sensitive receptors along the alignment are predominantly residences, but also include offices on the Microsoft campus.

3.3 Existing Ambient Noise Level Measurements

Noise measurements were taken at 14 selected locations along the project corridor (Figure 3-1). The sound level meters used for the measurements were Bruel & Kjaer Type 2238. The sound level meters meet or exceed American National Standards Institute (ANSI) S1.4-1983 for Type I Sound Measurement Devices. All measurement procedures complied with FHWA and WSDOT methods for environmental noise measurements. System calibration was performed before and after each measurement session with a Bruel & Kjaer Type 4231 sound level calibrator.

The 14 noise monitoring sites included eight residential sites between NE 51st Street and West Lake Sammamish Parkway. These sites consisted of long-term measurements of 48 hours or more. In addition, during the measurements at these eight sites, traffic counts were performed and used for the traffic noise analysis.

Short-term noise monitoring was performed in Marymoor Park, and at one site in the downtown area, the Residence Inn, across from the Elan Redmond Apartments. The measurement at the Residence Inn was taken on the fifth floor of the hotel; therefore, rooms on the second and third floors would be expected to have slightly higher noise levels due to the proximity to traffic on NE 76th Street and 164th Avenue NW. Similar existing noise levels would also be expected at the Elan Redmond Apartments. The noise measurements were used to calculate and predict the existing 24-hour Ldn and peak hour Leq noise levels along the project corridor. Noise measurement results are provided below; details of the noise monitoring at the trail entrance site are provided in Attachment C.

3.3.1 Existing Noise Environment

The measured Ldn ranged from 54 to 76 dBA, with the highest levels at residences overlooking SR 520 and Lake Sammamish Parkway. Noise levels along the entire corridor are dominated by traffic on SR 520 and nearby major arterial roadways. Peak hourly Leq noise levels ranged from 53 to 74 dBA.

Sites M-1 through M-3 are behind the traffic sound wall that would be relocated, and all have existing traffic noise levels below the FHWA and WSDOT criteria (66 dBA Leq during peak hour for residences). The replacement wall would be designed to maintain noise levels below the same criteria in this area.

Sites M-4 through M-6 are located north of NE 60th Street and have no sound walls; therefore, the existing noise levels range from 68 to 74 dBA Leq. It is assumed that most, if not all, of the front line residences along SR 520, between NE 60th Street and Lake Sammamish Parkway, currently exceed the WSDOT and FHWA criteria for traffic noise. The measured level in downtown Redmond was 64 dBA Ldn.

A summary of the measured noise levels is provided in Table 3-1, and the sites are shown on the vicinity map in Figure 3-1.

Alignment
- At-Grade
- Elevated
- Retained Cut; Retained Fill

- Station Platform
- Station Area
- City Limits
- Parks / Open Space

Source: USGS, City of Redmond, King County, Parametrix

Figure 3.1
Noise Monitoring and Vibration Measurement Sites
Downtown Redmond Link Extension

Table 3-1. Summary of Measured Noise Levels

Site Number[1]	Address[1]	FTA Land Use Category	Type[2]	Ldn[3] (dBA)	Leq[4] (dBA)
M-1	5219 154th Avenue NE	Category 2	Long-Term	54.4	56.4
M-2	5409 154th Avenue NE	Category 2	Long-Term	61.9	59.3
M-3	15406 NE 59th Way	Category 2	Long-Term	63.5	61.4
M-4	15516 NE 61st Court	Category 2	Long-Term	71.5	69.6
M-5	6219 156th Avenue NE	Category 2	Long-Term	69.9	67.8
M-6	15804 NE 67th Place	Category 2	Long-Term	76.2	74.4
M-7A	Marymoor Park: Marymoor Connector Trail near Cricket Field	Category 3	Short-Term	N/A	54.0
M-7B	Marymoor Park: Heron Loop and Sparrow Loop Trails	Category 3	Short-Term	N/A	53.1
M-8	Redmond Downtown Residence Inn, Room 525	Category 2	Long-Term	63.5	62.4
M-9	6846 156th Place NE	Category 2	Long-Term	65.9	63.9
M-10	6232 154th Avenue NE	Category 2	Long-Term	65.3	63.8

[1] Measurement sites shown on Figure 3-1.

[2] Type of measurement: Short-term measurements are 30 minutes and long-term monitoring/measurements are at least 48 hours.

[3] The Ldn is used for FTA Category 2 land use and is a 24-hour Leq with the 10 dB penalty for nighttime noise between 10:00 p.m. and 7:00 a.m. N/A = not applicable for parks.

[4] Peak-hour Leq.

3.3.2 Existing Ambient Vibration Environment

Figure 3-1 shows an overview of the vibration measurement locations along the alignment for the Proposed Design Refinements. Attachment B shows detailed maps of the six line source response (LSR) vibration measurement locations along the alignment as well as the additional location at the north end of the velodrome. Vibration impacts were made as close as possible to the future alignment path, and a string of geophones were also placed perpendicular to the top edge of the velodrome banking.

Figure 3-2 compares the LSR at 30 feet at the six measurement locations, and the averaged LSR at 30 feet. Calculated LSRs at various distances for each measurement site are provided in Attachment B. As shown in Figure 3-2, the LSRs are generally very similar, with most of the results following the same general spectrum and peaking between 31.5 Hertz (Hz) and 63 Hz. These LSRs are typical of soil above glacial till at a depth of 10 to 20 feet (or more). The two exceptions are the measurements at Microsoft Building 87 (NE 45th Street and 154th Avenue NE) and the Elan Redmond Apartments (Cleveland Street). These exceptions are typical of glacial till at a much shallower depth than the others. The LSRs over the deeper glacial till were energy-averaged, and a polynomial curve fit was applied over distance to develop the LSR coefficients that were used over most of the alignment. The coefficients of the LSRs over the shallow glacial till (V4a and V6) were used, without averaging, at receptors within the vicinity of the LSR measurement locations, based on review of geological information available on the Washington Geological Survey website. Calculated average LSR correction at various distances is provided in Attachment B.

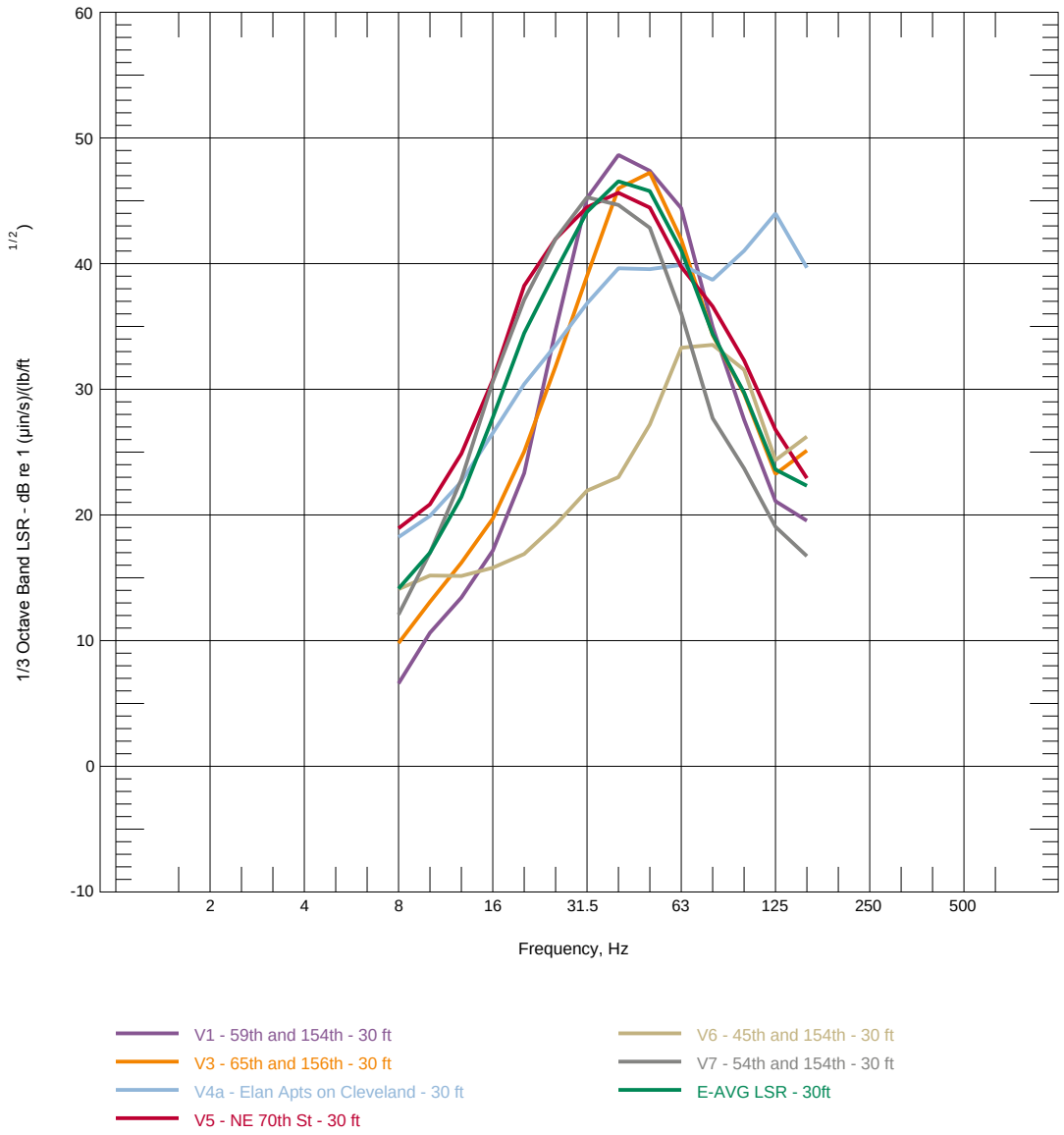


Figure 3-2. Thirty-foot LSRs for all Locations

4 ENVIRONMENTAL IMPACTS

This chapter describes noise and vibration impacts as a result of the operation and construction of the Downtown Redmond Link Extension.

4.1 Proposed Design Refinements Noise Impacts

4.1.1 Operational Noise Impacts

The noise analysis was performed at 193 locations representing 113 single-family residences, 46 multi-family units (apartments and condominiums), 18 hotel rooms, and 2 sites in Marymoor Park. In accordance with FTA regulations, the noise analysis included all sensitive properties within 175 to 350 feet, or more, from the centerline of the light rail alignment. The impact analysis included the replacement traffic sound wall between NE 51st Street and NE 60th Street because it is required as part of the Proposed Design Refinements. The replacement wall, while maintaining traffic noise levels below the FHWA and WSDOT criteria, would also eliminate eight potential severe light rail noise impacts at single-family residences along 154th Avenue NE. Table 4-1 summarizes the projected noise impacts, which includes 8 severe noise impacts and 29 moderate impacts. The noise impact locations are shown alongside the approximate locations of proposed sound walls on Figure 5-1 in Chapter 5. Additional information on the technical assessment of impacts is provided in Attachment D.

Table 4-1. Summary of Potential Noise Impacts

Light Rail Segments	Moderate Noise	Severe Noise	Total Noise Impacts
Redmond Technology Center Station to Sammamish River	9	0	9
Sammamish River to Bear Creek	0	0	0
Bear Creek to Downtown Redmond	20	8	28
Proposed Design Refinements Total	**29**	**8**	**37**

Source: FTA light rail operational noise modeling

4.1.1.1 Redmond Technology Center Station to Sammamish River

Noise impacts would not occur between the Redmond Technology Center Station and NE 51st Street because there are no sensitive receivers in this area and all land use is commercial. Between NE 51st Street and NE 60st Street, the replacement traffic sound wall would also mitigate any potential light rail-related noise impacts.

North of NE 60th Street, the majority of the alignment is in a retained cut (see Figure 2-1), which would reduce the noise from light rail operations and prevent impacts. Two moderate noise impacts were identified at homes on NE 61st Court and NE 62nd Court, where the alignment is along a slope that allows noise to propagate up the hill to the residences. An additional six moderate noise impacts were identified at single-family residences and duplexes along NE 67th Place and 159th Avenue NE at the start of the elevated structure over West Lake Sammamish Parkway. There is also a short segment of a traffic sound wall that would be replaced with the new light rail wall along the retained-cut and elevated section, just south of the SR 520 to West Lake Sammamish Parkway off-ramp.

The analysis included residences located across SR 520, west of the alignment, between NE 51st Street and West Lake Sammamish Parkway. Existing sound walls shield the majority of residences located west

of SR 520 from light rail operations, or the residences are too far from the alignment to have noise impacts. The only impact identified west of SR 520 is at one multi-family residence in the Marymoor Heights Condominium complex. The affected unit (moderate category) is the most northern of the four units located adjacent to the elevated section of the corridor. Table 4-2 provides a summary of the sites that would experience noise impacts; Attachment D provides complete tables of all receivers modeled.

Table 4-2. Summary of Noise Impacts: Redmond Technology Center Station to Sammamish River

Receiver ID	Address	Existing Noise[1]	Distance to Tracks[2]	Noise with Proposed Design Refinements[3]	FTA Category 2 Impact Criteria[4]		Exceeds Criteria[5]
		(dBA Leq)	(feet)	(dBA Leq)	(Moderate)	(Severe)	(Type)
RLNA12	15516 NE 61st Court	71	119	**66**	66	71	**0 dB Moderate**
RL134	15535 NE 62nd Court	71	119	**66**	66	71	**0 dB Moderate**
RL149	15834 NE 67th Place	74	114	**70**	66	73	**+4 dB Moderate**
RL150	15840 NE 67th Place	74	103	**71**	66	73	**+5 dB Moderate**
RLNA5	15846 NE 67th Place	74	129	**69**	66	73	**+3 dB Moderate**
None	6640 159th Avenue NE	72	193	**68**	66	72	**+2 dB Moderate**
None	6634 159th Avenue NE	72	231	**67**	66	72	**+1 dB Moderate**
None	6628 159th Avenue NE	70	314	**65**	65	70	**0 dB Moderate**
RLNA-NA	7002 155th Place NE	66	379	**65**	62	68	**+3 dB Moderate**

Source: FTA light rail operational noise modeling

1 Existing noise based on measurements

2 Distance to nearest track from modeling site

3 Noise from light rail operations, including station bells and special trackwork, if applicable

4 FTA impact criteria for residences

5 Amount light rail operation exceeds the moderate FTA criteria, as applicable, with exceeded levels in **bold** typeface

4.1.1.2 Sammamish River to Bear Creek

This segment of the project corridor includes Marymoor Park to Bear Creek. There would be no noise impacts between the east side of Marymoor Park and Bear Creek because all land use in that area is commercial and light industrial.

Marymoor Park has multiple uses, including bird watching areas, walking trails, active sports fields, an event pad, park offices and shops for park maintenance. Two of the nearest FTA Category 3 uses to the light rail, the Marymoor Connector Trail and the Heron Loop and Sparrow Loop Trails, were evaluated for

potential light rail noise impacts. Light rail noise levels at these sites ranged from 46 to 57 dBA Leq during the peak light rail operational hours. The predicted noise levels are 3 to 14 dB below the FTA criteria for noise-sensitive park uses. Noise from light rail operations may be noticeable in areas of the park south of Marymoor Way; however, it is unlikely that operations would be noticeable in the Heron Loop Trail entrance or other areas with high levels of sensitivity to noise. For reference, light rail-related noise levels in other areas are not predicted to change the total noise by an amount discernible to an average person. A summary of noise impacts from Sammamish River to Bear Creek is shown in Table 4-3.

Table 4-3. Summary of Noise Analysis: Marymoor Park

Receiver ID	Area Description	Noise Sensitive	Existing Noise[1]	Distance to Tracks[2]	Noise with Proposed Design Refinements[3]	FTA Category 3 Impact Criteria[4]		Exceeds Criteria
		(per FTA)	(dBA Leq)	(feet)	(dBA Leq)	(Moderate)	(Severe)	(Type)
M-7A	Marymoor Connector Trail near Cricket Field	Yes	54	741	57	60	67	No
M-7B	Heron Loop and Sparrow Loop Trails	Yes	53	2,550	46	60	66	No

Source: FTA light rail operational noise modeling

[1] Existing noise based on measurements

[2] Distance to nearest track from noise-sensitive site

[3] Noise from peak hour of light rail operations, including station bells and special trackwork, if applicable

[4] FTA impacts criteria for facilities with daytime use

4.1.1.3 Bear Creek to Downtown Redmond

In the downtown Redmond area, 8 severe and 20 moderate noise impacts were identified at two multi-family buildings and one hotel. All 8 of the severe impacts and 20 of the moderate impacts were identified at the newly planned Redmond Town Center Apartments. The analysis and impacts are based on the most current plans for the building. A summary of noise impacts from Bear Creek to downtown Redmond is shown in Table 4-4.

Table 4-4. Summary of Noise Impacts: Bear Creek to Downtown Redmond

Receiver ID	Area Description/ Address	Existing Noise[1]	Distance to Tracks[2]	Noise with Proposed Design Refinements[3]	FTA Category 2 Impact Criteria[4]		Exceeds Criteria[5]
		(dBA Leq)	(feet)	(dBA Leq)	(Moderate)	(Severe)	(Type)
RTC-1	Redmond Town Center Apartments 1st/2nd floor, east	64	113	**67**	61	66	**+6 dB Severe**
RTC-2	Redmond Town Center Apartments 1st/2nd floor, center	64	142	**65**	61	66	**+4 dB Moderate**
RTC-3	Redmond Town Center Apartments 1st/2nd floor, west	64	178	**63**	61	66	**+2 dB Moderate**

Table 4-4. Summary of Noise Impacts: Bear Creek to Downtown Redmond (continued)

Receiver ID	Area Description/ Address	Existing Noise[1]	Distance to Tracks[2]	Noise with Proposed Design Refinements[3]	FTA Category 2 Impact Criteria[4]		Exceeds Criteria[5]
RTC-4	Redmond Town Center Apartments 3rd/4th floor, east	64	113	**67**	61	66	**+6 dB Severe**
RTC-5	Redmond Town Center Apartments 3rd/4th floor, center	64	142	**65**	61	66	**+4 dB Moderate**
RTC-6	Redmond Town Center Apartments 3rd/4th floor, west	64	178	**63**	61	66	**+2 dB Moderate**
RL199	Residence Inn Hotel 7575 164th Avenue NE	64	135	59	61	66	**No**
RL199	Residence Inn Hotel 7575 164th Avenue NE	64	114	59	61	66	**No**
RL199	Residence Inn Hotel 7575 164th Avenue NE	64	172	59	61	66	**No**
RL200	16325 Cleveland Street	64	160	59	61	66	**No**
RL200	16325 Cleveland Street	64	187	59	61	66	**No**
RL200	16325 Cleveland Street	64	215	59	61	66	**No**

Source: FTA light rail operational noise modeling
[1] Existing noise levels from on-site noise monitoring (see Table 3-1)
[2] Distance to nearest track from modeling site
[3] Noise from light rail operations, including station bells and special trackwork, if applicable
[4] FTA impacts criteria for residences
[5] Amount the light rail operation exceeds the moderate FTA criteria, as applicable, with exceeded levels in **bold** typeface

4.1.2 Park-and-Ride Noise Impacts

The proposed SE Redmond Station, which would include 1,400 parking stalls and access to connecting bus routes, would be located in an established commercial and industrial area. The only noise-sensitive property near the proposed station or station parking area is the Redmond Inn Hotel; no project-related impacts were identified at this site. The Downtown Redmond Station would not include any parking.

4.1.3 Traffic Noise Analysis

Under FTA criteria, traffic noise impacts are considered for locations where the Proposed Design Refinements would include new roads, substantial alterations to existing roads, or removal of shielding that would increase potential traffic noise exposure to sensitive receivers. The only new or modified roadways would be in southeast Redmond where NE 70th Street would be rebuilt. In addition to improvements along NE 70th Street, the Proposed Design Refinements would relocate existing sound walls along SR 520 between NE 51st Street and NE 60th Street, and replace a short part of the sound walls near NE 67th Place with a wall along the retained fill and elevated section of the light rail.

4.1.3.1 NE 51st Street to NE 60th Street Traffic Noise Analysis

The replacement wall between NE 51st Street and NE 60th Street was modeled using the FHWA Traffic Noise Model, version 2.5 (TNM), as required by FTA and FHWA policy. Based on modeling and measurements, noise levels in this area are currently below the WSDOT and FHWA traffic noise impact criteria.

The replacement wall was modeled using the FHWA TNM, as required by FTA and FHWA policy, and must meet specific requirements as follows:

1. The replacement wall shall be designed, where possible, as to not allow for any new traffic noise impacts.
2. The replacement wall shall be designed, where possible, as to not increase the severity of any existing noise impacts.

It is important to note that based on modeling and measurements, noise levels in this area are currently below the WSDOT and FHWA traffic noise impact criteria.

Three of the ten noise monitoring sites, M-1, M-2, and M-3, were located in the area with the existing sound wall. The actual noise measurements at these three sites were also used to validate the traffic noise model using traffic counts performed simultaneously with the noise monitoring. The modeled and measured noise levels agreed within +/- 2 dB, which is an acceptable deviation between measured and modeled noise levels.

The validated noise model was used to predict the existing traffic noise levels, future baseline traffic noise levels, and future traffic noise levels with the replacement sound wall for 32 receiver sites. These 32 sites represent 67 single-family residences between NE 51st Street and NE 60th Street.

The existing traffic sound wall for this area consists of two separate barriers. The first barrier parallels the eastbound on-ramp from NE 51st Street to SR 520 eastbound for approximately 835 feet. The second barrier is located along the property line of the residences, beginning approximately 880 feet north of NE 51st Street and ending at the NE 60th Street overpass. The second barrier is approximately 1,400 feet in length.

The proposed replacement wall would be located adjacent to the light rail corridor, approximately 7 to 10 feet from the eastbound tracks. The wall would be closer to the residences, and located along a slight rise so that the base of the wall would be above the grade of SR 520. The replacement wall would be approximately 2,250 feet in length and extend from just north of NE 51st Street to NE 60th Street, with wall heights ranging from 8 feet to 16 feet. The proposed wall would maintain existing noise levels, resulting in no new noise impacts. Modeling details, including tables of modeled noise levels, are provided in Attachment E.

4.1.3.2 NE 70th Street Traffic Noise Analysis

The only noise-sensitive use in southeast Redmond is the Redmond Inn Hotel, located north of NE 70th Street along Redmond Way near the off-ramp from SR 520. The potential for traffic noise impacts was evaluated using the FHWA TNM. The analysis assumed 1,400 passenger vehicles (park-and-ride parking capacity), 10 trucks, and 10 buses would use NE 70th Street during a single hour. Although this level of traffic along the improved NE 70th Street in a single hour is not likely to occur, using these volumes ensured that any potential for impacts would be identified. The predicted hourly Leq of 66 dBA would be met or exceeded for residential land use within 60 to 65 feet of NE 70th Street. The closest rooms at the Redmond Inn Hotel to the revised NE 70th Street alignment are over 150 feet from the roadway. The predicted traffic noise level at these rooms is 60 to 61 dBA Leq, 5 to 6 dB below the residential impact criteria of 66 dBA Leq.

4.1.4 Other Project-Related Noise Analysis

4.1.4.1 Wheel Squeal Curve Analysis

Wheel squeal is caused by the oscillation of the wheel against the rail on curved sections of rail. The only curve along the alignment that has a radius of less than 1,200 feet is between the SE Redmond Station site and Bear Creek. This curve has a minimum radius of 300 feet, and the nearest sensitive land use is a hotel, approximately 350 feet from the alignment. There are no impacts predicted at the hotel from light rail operations due to the slow speed on the tight radius curve. Furthermore, to prevent wheel squeal if identified during initial system testing, the tight radius curve would be prepared to accept an automated lubricant applicator.

4.1.4.2 Ancillary Facilities Noise Analysis

Noise from other project-related activities would include noise from power substations and general system maintenance. All power substations would be contained in buildings that acoustically shield the noisy equipment from nearby noise-sensitive properties. In addition, general system maintenance would be performed in accordance with the local jurisdiction noise ordinances; therefore, no noise impacts related to ancillary activities are predicted.

4.1.5 Construction Noise Impacts

Construction noise impacts would be the same as presented in the Final EIS. The contractor would be required to adhere to the state and local ordinances regulating noise, which are described in Section 4.7.1.2 of the Final EIS.

As described in Section 4.7.5.2 of the Final EIS, areas with elevated structures, or occasionally for shoring up weak soils, may require pile driving, which would be subject to the regulatory requirements of the City of Redmond.

4.2 Proposed Design Refinements Vibration Impacts

4.2.1 Operational Vibration Impacts

Table 4-5 provides project-related vibration estimates. For each sensitive-receptor building analyzed, the table shows the land use, approximate track location indicator, building type, distance to the near track centerline, FTA vibration criterion, and the calculated highest 1/3-octave band vibration velocity level.

Table 4-5. Summary of Vibration Calculation Results

Address	Land Use Description[1]	Building Type[2]	Track Location Indicator (station)	Speed (mph)	Distance (feet)	FTA Criteria (dB)	Unmitigated Maximum 1/3 Octave Band Level (dB)[3]	Mitigated Maximum 1/3 Octave Band Level (dB)
4001 156th Avenue NE	Office	SOG	4995+00	55	122	75	54	–
15319 NE 45th Street	Office	SOG	5005+25	55	71	75	55	–
Microsoft Building 87	High Tech	SOG	5013+00	55	91	66	54	–
Microsoft Building 88	High Tech	SOG	5021+25	55	87	66	63	–
15250 NE 51st Street	SF Residence	SFR	5026+50	55	88	72	68	–
5606 154th Avenue NE	SF Residence	SFR	5026+50	55	260	72	57	–
5215 154th Avenue NE	SF Residence	SFR	5028+25	55	108	72	65	–
5614 154th Avenue NE	SF Residence	SFR	5028+25	55	228	72	57	–
5219 154th Avenue NE	SF Residence	SFR	5029+25	55	96	72	67	–

Table 4-5. Summary of Vibration Calculation Results (continued)

Address	Land Use Description[1]	Building Type[2]	Track Location Indicator (station)	Speed (mph)	Distance (feet)	FTA Criteria (dB)	Unmitigated Maximum 1/3 Octave Band Level (dB)[3]	Mitigated Maximum 1/3 Octave Band Level (dB)
5702 154th Avenue NE	SF Residence	SFR	5029+25	55	207	72	57	–
5223 154th Avenue NE	SF Residence	SFR	5030+00	55	100	72	66	–
5710 154th Avenue NE	SF Residence	SFR	5030+00	55	164	72	59	–
5227 154th Avenue NE	SF Residence	SFR	5030+50	55	71	72	71	–
5718 154th Avenue NE	SF Residence	SFR	5030+50	55	138	72	62	–
5305 154th Avenue NE	SF Residence	SFR	5031+25	55	76	72	70	–
5804 154th Avenue NE	SF Residence	SFR	5031+25	55	109	72	65	–
5315 154th Avenue NE	SF Residence	SFR	5031+50	55	68	72	71	–
5812 154th Avenue NE	SF Residence	SFR	5031+50	55	99	72	66	–
5323 154th Avenue NE	SF Residence	SFR	5032+25	55	46	72	**76**	**72**[4]
5401 154th Avenue NE	SF Residence	SFR	5033+25	55	52	72	**75**	71
5409 154th Avenue NE	SF Residence	SFR	5034+25	55	65	72	**72**	68
5417 154th Avenue NE	SF Residence	SFR	5035+00	55	67	72	71	–
5425 154th Avenue NE	SF Residence	SFR	5035+75	55	87	72	68	–
5433 154th Avenue NE	SF Residence	SFR	5036+50	55	79	72	69	–
5507 154th Avenue NE	SF Residence	SFR	5037+25	55	103	72	65	–
5517 154th Avenue NE	SF Residence	SFR	5038+25	55	129	72	62	–
15406 NE 59th Way	SF Residence	SFR	5046+25	55	47	72	**76**	**72**[4]
15504 NE 60th Street	SF Residence	SFR	5050+25	55	102	72	66	–
15512 NE 60th Street	SF Residence	SFR	5052+00	55	55	72	**74**	70
15535 NE 62nd Court	SF Residence	SFR	5054+50	55	124	72	63	–
15536 NE 62nd Court	SF Residence	SFR	5055+25	55	100	72	66	–
6205 156th Avenue NE	SF Residence	SFR	5056+25	55	75	72	70	–
6217 156th Avenue NE	SF Residence	SFR	5057+50	55	150	72	60	–
6219 156th Avenue NE	SF Residence	SFR	5058+50	55	75	72	70	–
15810 NE 67th Place	SF Residence	SFR	5069+50	55	48	72	71	–
15816 NE 67th Place	SF Residence	SFR	5069+75	55	52	72	70	–
15822 NE 67th Place	SF Residence	SFR	5070+50	55	70	72	71	–
15828 NE 67th Place	SF Residence	SFR	5071+00	55	88	72	61	–
15834 NE 67th Place	SF Residence	SFR	5071+50	55	110	72	60	–
15840 NE 67th Place	SF Residence	SFR	5072+25	55	115	72	60	–
17209 Redmond Way	Clinic	SOG	5140+00	55[5]	180	66[5]	61	–
16501 NE 76th Place	Office	PILE	5167+00	25	60	72	49	–
7575 164th Avenue NE	Hotel	PILE	5169+50	25	62	72	49	–
16325 Cleveland Street	Multi-family Residence	LMFR	5170+75	25	30	72	51	–
16175 Cleveland Street	Multi-family Residence	LMFR	5174+00	25	179	72	46	–

[1] Residence Description Types
SF Single-family

[2] Building Types
SOG Slab On Grade
PILE Large Masonry on Pile Foundation
SFR Single-Family Residence
LMFR Large Multi-Family Residence

[3] Levels that meet or exceed FTA criteria are in **bold** typeface.

[4] The modeled vibration level at this site is at the FTA criteria. At this early stage of design, modeling adds a factor of 3dB for uncertainty. The proposed mitigation, ballast mat (recommended) or other vibration control measures, would be installed and are anticipated to mitigate vibration levels to be below the FTA criteria.

[5] To be conservative, 55 mph was used in the analysis. However, with a nearby curve the train speed would likely be less in this location, which would reduce vibration. The criteria limit of 66 VdB was used to account for potentially sensitive imaging equipment.

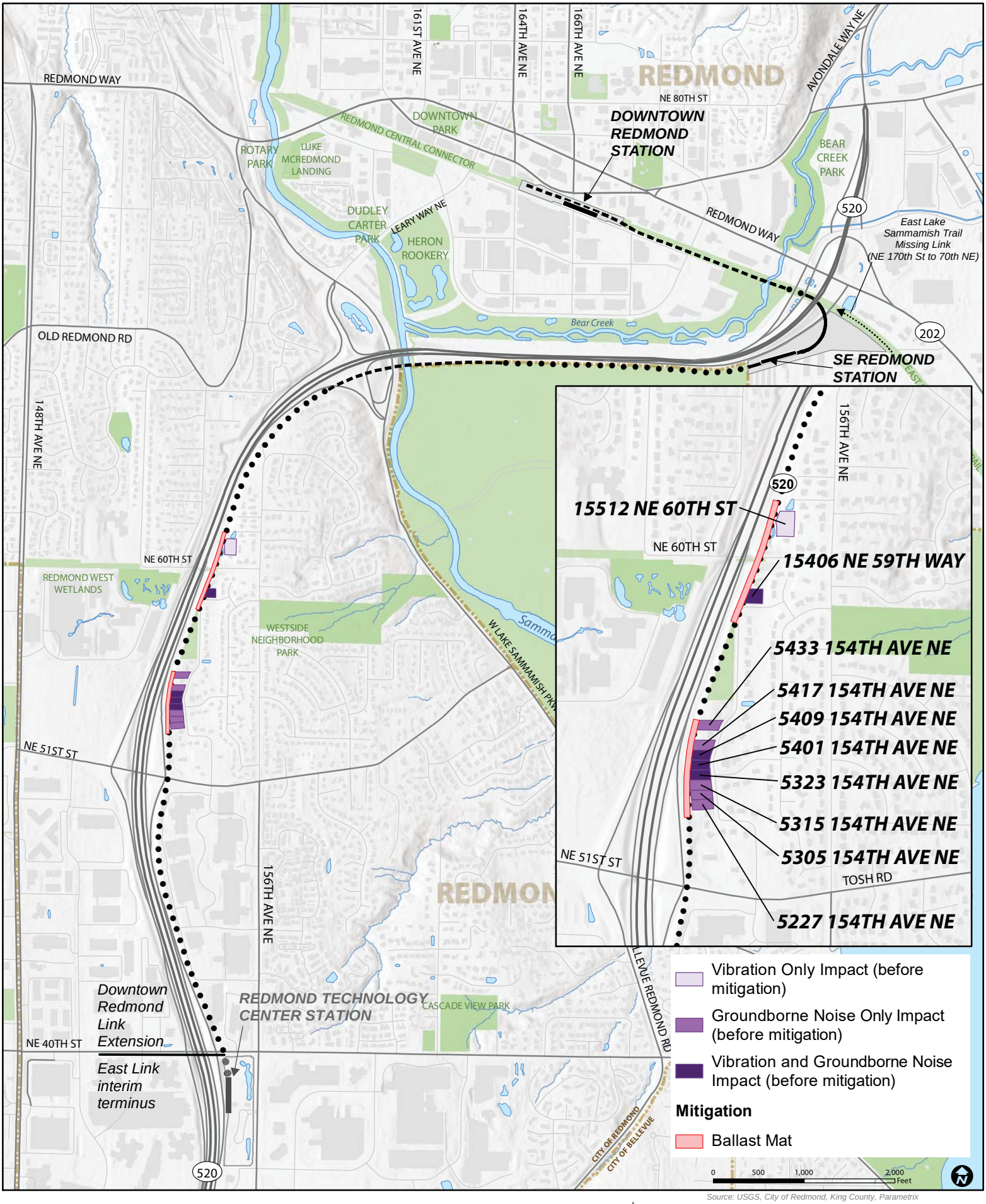
At the five sensitive receptors listed in Table 4-5 that would require mitigation, vibration is predicted to exceed the applicable 1/3-octave band FTA criterion. A map of vibration impacts is provided in Figure 4-1. All impacts would occur at single-family homes spanning a range of less than 2,000 feet along SR 520. See Attachment F for detailed spectra of the affected receivers. The impacts would be due to the proximity (<65 feet) of the homes to the alignment, the high speed (55 mph) of the trains, and the nature of the surrounding soils.

The analysis also included an urgent care clinic located in a commercial development. No vibration impacts are anticipated at this receptor.

All track on elevated structures was assumed to be installed using standard fasteners. If high resilience direct fixation (HRDF) is used for reasons other than vibration mitigation, predicted maximum 1/3-octave band levels would decrease. No impacts to sensitive-receptor buildings are predicted along the elevated sections of the light rail extension.

In addition to the vibration analysis for sensitive-receptor buildings, vibration and vibration-induced settlement at the velodrome in Marymoor Park were analyzed. At the north edge of the velodrome, approximately 65 feet from the northbound light rail track centerline, the overall vibration level is predicted to be 79 vibration velocity decibels (VdB). This level of vibration corresponds to a vibration velocity of 0.0092 inches per second (in/s). LSR results and predicted 1/3-octave band vibration levels at this location are provided in Attachment B. The FTA guidance manual (second edition) states that the crest factor is usually 4 to 5 for groundborne vibration from trains (FTA 2006). Assuming a crest factor of 4, the projected peak particle velocity (PPV) due to train passbys is 0.037 in/s (approximately 1 millimeter per second [mm/s]), at the closest corner of the velodrome. This vibration level is almost a full order of magnitude lower than the FTA damage criteria for engineered concrete and masonry (0.3 in/s) as well as below the criteria for even the most susceptible of structures (0.12 in/s).

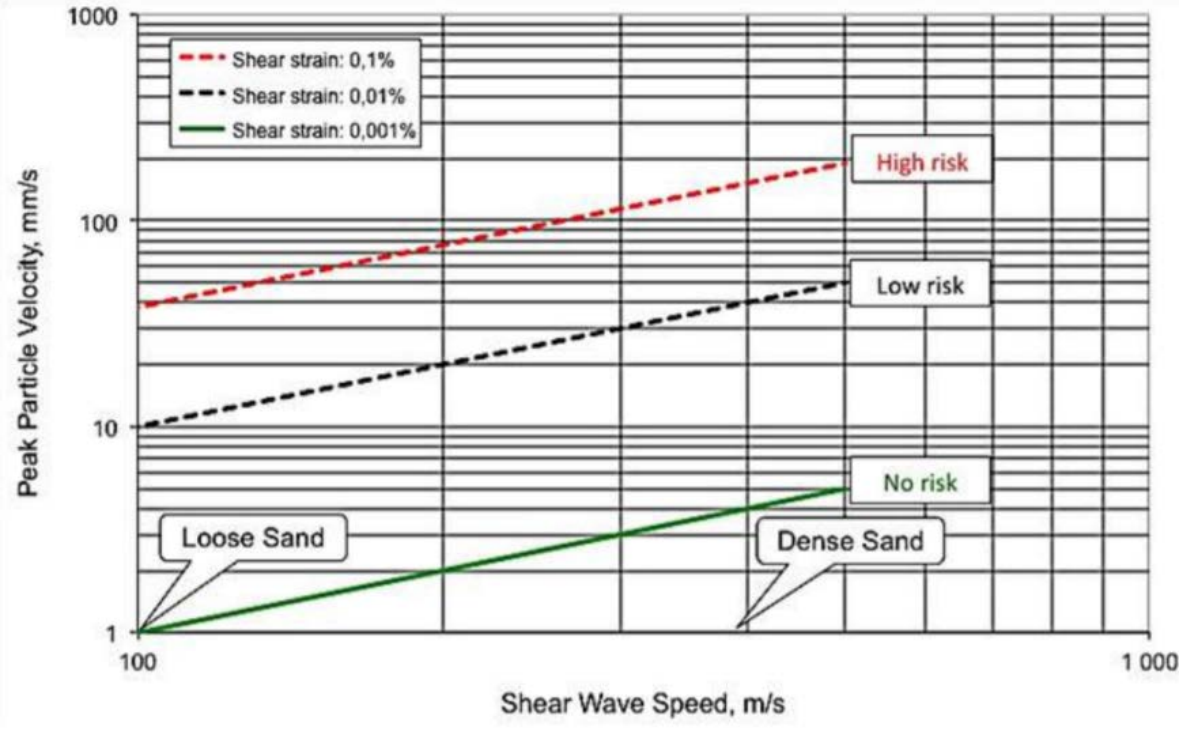
Settlement of structures due to transportation sources is extremely rare, if it occurs at all. The level of vibration needed to produce differential settlement or to crack concrete structures is at least an order of magnitude higher than the levels estimated for the Proposed Design Refinements. Figure 4-2 shows the risk of settlement as a function of PPV and sand density. There is effectively no risk of settlement in loose sand and silt when the PPV is below 1 mm/s. Settlement in loose sand becomes a low risk at approximately 10 mm/s, or 0.4 in/s PPV. A PPV of 0.4 in/s corresponds with impact pile driving at a distance of 35 feet, a vibratory roller at 15 feet, or a 40-mph Link light rail train at 10 feet. The 65-foot setback from the guideway, the higher density of the soil (relative to loose sand), and the predicted overall vibration level make settlement extremely unlikely at the velodrome. Therefore, no operational vibration or vibration-induced settlement impacts to the velodrome structure are expected.



Note: Ballast mat locations are approximate.

Source: USGS, City of Redmond, King County, Parametrix

Figure 4-1
Potential Vibration and Groundborne Noise Impacts and Mitigation
Downtown Redmond Link Extension



Source: Massarsch and Fellenius 2014

Figure 4-2. Settlement Risk in Sand

4.2.2 Operational Groundborne Noise Impacts

For at-grade sections, the groundborne noise is normally masked by the airborne noise radiated from the transit vehicle and the rails, including nearby roadways. Traditionally, groundborne noise is not addressed for above-grade systems because airborne noise typically dominates. The FTA guidance manual requires groundborne noise impacts to be assessed for all train operations, including at-grade and trench sections. For the Proposed Design Refinements, vibration analysts performed an assessment to address groundborne noise within sleeping quarters relative to light rail train passby noise and existing ambient noise.

The maximum overall A-weighted sound pressure levels of groundborne noise from individual train passbys were calculated at each of the receptors by assuming that the noise would be equal to the predicted A-weighted vibration levels minus 5 dB to account for the effects of the typical receiver room acoustics (Zapfe et al. 2009). A +3 dB margin has been added to the projected vibration levels for the operational vibration predictions to cover the uncertainty factor in how individual buildings respond to vibration. The vibration analysts calculated the Ldn for groundborne noise at each receptor by using the same techniques to calculate the Ldn for airborne noise from the trains.

The following procedure was then used to assess the groundborne noise impact at receivers where the predicted groundborne noise exceeded the FTA criteria:

- For rooms on the side of the receiver facing the alignment:
  - Take the higher of the predicted train noise (accounting for a retained-cut or sound wall) versus the measured ambient
  - Assume 30 dB reduction from the exterior to the interior
  - Consider no impact if either the above interior passby noise or interior ambient is greater than the projected groundborne noise
- For rooms on the side of the receiver away from the alignment:
  - Subtract 5 dB from the projected groundborne noise to account for distance and shielding by the building
  - Compare the above to the groundborne noise criteria
  - If the above groundborne noise is still 35 dBA or higher:
    - Subtract 15 dB from the train noise to account for distance and shielding by the building
    - Take the higher of the predicted train noise at the back of the house versus the measured ambient
    - Assume 30 dB reduction from the exterior to the interior
    - Consider no impact if the above interior passby noise or interior ambient is greater than the projected groundborne noise

The above assessment was based upon the Ldn because information on sound pressure levels of individual passbys was not readily available at the time. The groundborne noise impacts will be reassessed, where needed, after more information becomes available.

Table 4-6 provides groundborne noise estimates. For each sensitive-receptor building analyzed, the table shows the address, approximate track location indicator, FTA criteria, the calculated maximum groundborne noise level during a train passby, the predicted interior Ldn from the exterior ambient and train noise, the unmitigated Ldn from groundborne train noise, and the groundborne train noise with mitigation. Table 4-6 does not show projections for receivers adjacent to the elevated track structure, where the projected groundborne noise levels were well below the criteria. Projections were also not conducted for residential receivers in the downtown Redmond area, where train speeds would be significantly less than 55 mph and therefore have much lower levels of groundborne noise. For simplicity, Table 4-6 only shows projections for rooms on the side of the receivers facing the alignment. The results for the rooms on the side of the receivers facing away from the alignment did not show any additional impacts versus the rooms on the side facing the alignment.

Based on the vibration and groundborne noise analysis, a total of nine receivers would have groundborne noise above FTA criteria. Four of those nine receivers also have potential vibration impacts. Therefore, the groundborne noise assessment identified five additional impacts in addition to the five operational vibration impacts identified in Section 4.2.1.

Table 4-6. Summary of Groundborne Noise Calculation Results at Residential Receivers next to Retained-Cut or At-Grade Track

Address	Track Location Indicator	Speed (mph)	Distance (feet)	FTA GBN Criteria (dBA)	GBN Max. (dBA)	Estimated Ambient Interior Noise (Ldn)	Train Interior Airborne Noise (Ldn)	Unmitigated Train GBN (Ldn)[1]	Mitigated Train GBN (Ldn)[1]
15252 NE 51st Street	5026+50	55	88	35	34				
5606 154th Avenue NE	5026+50	55	260	35	15				
5215 154th Avenue NE	5028+25	55	108	35	30				
5614 154th Avenue NE	5028+25	55	228	35	18				
5219 154th Avenue NE	5029+25	55	96	35	32				
5702 154th Avenue NE	5029+25	55	207	35	19				
5223 154th Avenue NE	5030+00	55	100	35	32				
5710 154th Avenue NE	5030+00	55	164	35	23				
5227 154th Avenue NE	5030+50	55	71	35	**37**	26	23	35	29
5718 154th Avenue NE	5030+50	55	138	35	26				
5305 154th Avenue NE	5031+25	55	76	35	**36**	26	23	34	28
5804 154th Avenue NE	5031+25	55	109	35	30				
5315 154th Avenue NE	5031+50	55	68	35	**37**	28	23	35	29
5812 154th Avenue NE	5031+50	55	99	35	32				
5323 154th Avenue NE	5032+25	55	46	35	**43**	30	25	41	34
5401 154th Avenue NE	5033+25	55	52	35	**41**	32	24	39	33
5409 154th Avenue NE	5034+25	55	65	35	**38**	32	24	36	30
5417 154th Avenue NE	5035+00	55	67	35	**38**	32	23	36	29
5425 154th Avenue NE	5035+75	55	87	35	34				
5433 154th Avenue NE	5036+50	55	79	35	**35**	32	22	33	27
5507 154th Avenue NE	5037+25	55	103	35	31				
5517 154th Avenue NE	5038+25	55	129	35	28				
15406 NE 59th Way	5046+25	55	47	35	**43**	34	24	40	34
15504 NE 60th Street	5050+25	55	102	35	31				
15512 NE 60th Street	5052+00	55	55	35	**40**	41	29	38	
15535 NE 62nd Court	5054+50	55	124	35	28				
15536 NE 62nd Court	5055+25	55	100	35	32				
6205 156th Avenue NE	5056+25	55	75	35	**36**	40	32	34	
6217 156th Avenue NE	5057+50	55	150	35	25				
6219 156th Avenue NE	5058+50	55	75	35	**36**	40	23	34	
15810 NE 67th Place	5069+50	55	48	35	**37**	44	25	35	
15816 NE 67th Place	5069+75	55	52	35	**36**	44	24	34	
15822 NE 67th Place	5070+50	55	70	35	**37**	44	24	35	

GBN = groundborne noise

Levels that exceed FTA GBN criteria are in **bold** typeface.

[1] Compared with ambient interior noise Ldn

4.2.3 Construction Vibration Impacts

The potential for construction vibration impacts remains as discussed in the Final EIS. This analysis also considers construction impacts specific to the velodrome. During the construction activities near the velodrome, the highest levels of vibration are likely to be produced by vibratory rollers. No pile driving activities are expected in the vicinity. At 60 feet, a vibratory roller can be expected to produce a PPV of 0.06 in/s. This is below the expected range of settlement for medium density soils, and below even the most sensitive of damage criteria. Because of the limited duration of construction near the velodrome, settlement is extremely unlikely.

5 POTENTIAL MITIGATION OF NOISE AND VIBRATION IMPACTS

Sound Transit will perform additional noise and vibration analysis during final design to verify impacts and review mitigation measures. During final design, if it is discovered that mitigation could be achieved by a less costly means or if the detailed analysis shows no impact, then a mitigation measure may be eliminated or modified.

Figure 5-1 shows the approximate locations of proposed sound walls based on the current noise analysis.

5.1 Potential Operational Noise Mitigation Measures

The proposed mitigation measures are consistent with those presented in the Final EIS and include sound walls and special trackwork that cover the gap in the tracks at crossovers.

Mitigation for the moderate noise impacts along NE 61st Court and NE 62nd Court would be accomplished with a 6-foot-tall sound wall extending from just north of the NE 60th Street overpass to just north of the impacts where the light rail transitions into a retained cut. The wall would be approximately 475 feet in length and maintain a 6-foot-tall barrier along the part of the corridor where the tracks would not be shielded by a retaining wall and would transition to the elevated structure.

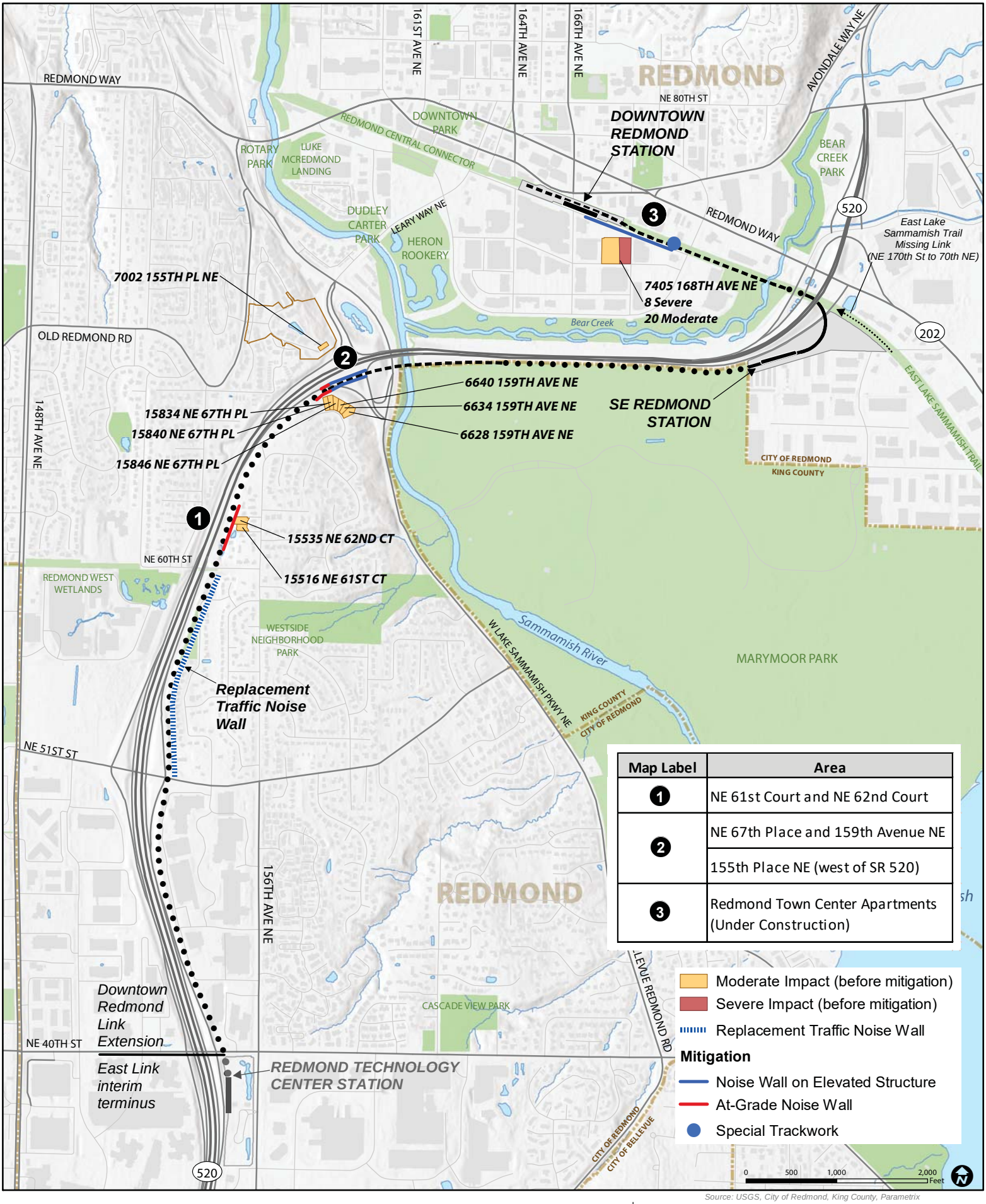
The noise impacts near West Lake Sammamish Parkway would be mitigated with two sound walls. The east sound wall would extend along the elevated structure, beginning at the end of the retained fill and continuing out on the structure for approximately 650 feet. On the west side of the structure, the wall would begin in the same area, and also extend along the structure for 500 feet. These two walls would effectively mitigate all noise impacts in this area.

No noise mitigation is required for Marymoor Park because all noise-sensitive locations in the park are below the FTA noise criteria. While predicted to have slight increases in total noise with the project, other modeling sites, including active sports fields, the event pad, and the velodrome, would still be compatible with the current and proposed uses.

Proposed mitigation for the noise impacts at the planned Redmond Town Center Apartments would include a combination of special trackwork for the crossover and acoustical absorbent sound walls along the south side of the structure. The proposed sound wall would extend for approximately 865 feet from east of 168th Avenue NE to the Downtown Redmond Station. Because of the predicted elevations of the upper floor apartments, the wall heights would be 8 feet above the trackway.

With the proposed mitigation measures summarized in Table 5-1, all noise impacts would be mitigated. Tables that show mitigated noise levels are provided in Attachment D.

The proposed noise mitigation measures under the Proposed Design Refinements are similar to those provided in the Final EIS. There would be one new sound wall near NE 61st Court and NE 62nd Court due to new impacts in this area, and another new wall on the west side of the alignment near the elevated structure over Lake Sammamish Parkway. A new sound wall is also recommended for the Redmond Town Center Apartments that are currently under construction. Several sound walls proposed for the 2011 Project west of 164th Avenue NE are no longer required because of the revised terminus location.



Map Label	Area
1	NE 61st Court and NE 62nd Court
2	NE 67th Place and 159th Avenue NE
	155th Place NE (west of SR 520)
3	Redmond Town Center Apartments (Under Construction)

Moderate Impact (before mitigation)
Severe Impact (before mitigation)
Replacement Traffic Noise Wall

Mitigation

Noise Wall on Elevated Structure
At-Grade Noise Wall
Special Trackwork

Source: USGS, City of Redmond, King County, Parametrix

Alignment
At-Grade
Elevated
Retained Cut; Retained Fill

Station Platform
Station Area

City Limits
Parks / Open Space

Note: Noise walls locations are approximate.

Figure 5-1
Noise Impacts and Mitigation
Downtown Redmond Link Extension

Table 5-1. Summary of Potential Noise Mitigation Measures

Area	Mitigation Type	Start Station	End Station	Length (feet)	Wall Height (feet)
NE 61st Court and NE 62nd Court	Sound wall	5050+00	5054+75	475	6
NE 67th Place and 159th Avenue NE	Sound wall	5070+50	5077+00	650	6
155th Place NE (west of SR 520)	Sound wall / Sound wall on elevated structure	5072+00	5077+00	500	4
Redmond Town Center Apartments	Special trackwork (crossover)	5150 (approximate)		N/A	N/A
Redmond Town Center Apartments	Sound wall on elevated structure	5153+50	5162+15	865	8

Source: FTA noise modeling

5.2 Potential Operational Vibration Mitigation Measures

The operational mitigation measures for vibration are consistent with those presented in the Final EIS; however, additional information about potential impacts is now known. Where vibration impacts are projected without mitigation, the vibration analysts used a model to assess the most cost-effective mitigation approaches at each impact location, as well as the minimum extents (i.e., the distances to either side of the receiver) required to mitigate impacts.

To mitigate the projected vibration or groundborne noise impacts, ballast mat (recommended) or other vibration control measures would be installed under both directions of track. The proposed extents of mitigation are shown in Table 5-2, with a total length of 3,000 track feet (route length of 1,500 feet).

Table 5-2. Summary of Potential Vibration Mitigation Extents

	Extent				Impacted Receiver Information			
	Mitigation Type	Begin	End	Route Length	Address	Track	Speed (mph)	Horizontal Distance (feet)
Section 1	Ballast Mat	5029+75	5036+75	700	5227 154th Avenue NE	Ballast	55	71
					5305 154th Avenue NE	Ballast	55	76
					5315 154th Avenue NE	Ballast	55	68
					5323 154th Avenue NE	Ballast	55	46
					5401 154th Avenue NE	Ballast	55	52
					5409 154th Avenue NE	Ballast	55	65
					5417 154th Avenue NE	Ballast	55	67
					5433 154th Avenue NE	Ballast	55	79
Section 2	Ballast Mat	5044+75	5052+75	800	15406 NE 59th Way	Ballast	55	47
					15512 NE 60th Street	Ballast	55	55

5.3 Potential Construction Mitigation Measures for Noise and Vibration

As discussed in the Final EIS, construction noise and vibration impacts can be reduced with operational methods and scheduling, equipment choice, and acoustical treatments. The contractor would have the flexibility of either prohibiting certain noise-generating activities during nighttime hours or providing additional noise-control measures to meet these noise limits. In the Final EIS, Section 4.7.5.2 lists potential noise control measures the contractor could implement, and Section 4.7.5.4 discusses measures to minimize construction vibration impacts.

The construction mitigation measures for noise and vibration in this report are consistent with those presented in the Final EIS.

6 REFERENCES

FTA (Federal Transit Administration). 2006. Transit Noise and Vibration Impact Assessment. FTA-VA-90-1003-06. Prepared for the Federal Transit Administration, Office of Planning and Environment, Washington, D.C. May.

Massarch, K.R., and B.H. Fellenius. 2014. Ground Vibrations from Pile and Sheet Driving. Part 2. Review of Vibration Standards. Proceedings of the DFI-EFFC International Conference on Piling and Deep Foundations, Stockholm, Sweden. May 21–23, 2014. Pp. 487–501.

Sound Transit (Central Puget Sound Regional Transit Authority). 2011. Sound Transit East Link Project, Appendix H2: Noise and Vibration Technical Report. Prepared by Miller & Hanson Inc., Michael Minor & Associates, and CH2M HILL. July.

Sound Transit (Central Puget Sound Regional Transit Authority), Washington State Department of Transportation (WSDOT), and Federal Transit Administration (FTA). 2011. East Link Light Rail Transit Project Final Environmental Impact Statement. Seattle, WA. July.

WSDOT (Washington State Department of Transportation). 2013. SR 520 Multi-modal Corridor Planning Study. Available at: http://www.wsdot.wa.gov/sites/default/files/2006/03/28/SR520_CPS_FINALExecSumm_Chapter1.pdf. April.

Zapfe, J.A., H. Saurenman, and S. Fidell. 2009. Ground-Borne Noise and Vibration in Buildings Caused by Rail Transit. Contractor's Final Report for TCRP Project D-12. Transit Cooperative Research Program, Transportation Research Board of the National Academies. December.

Attachment A

Train Force Density Level Measurements

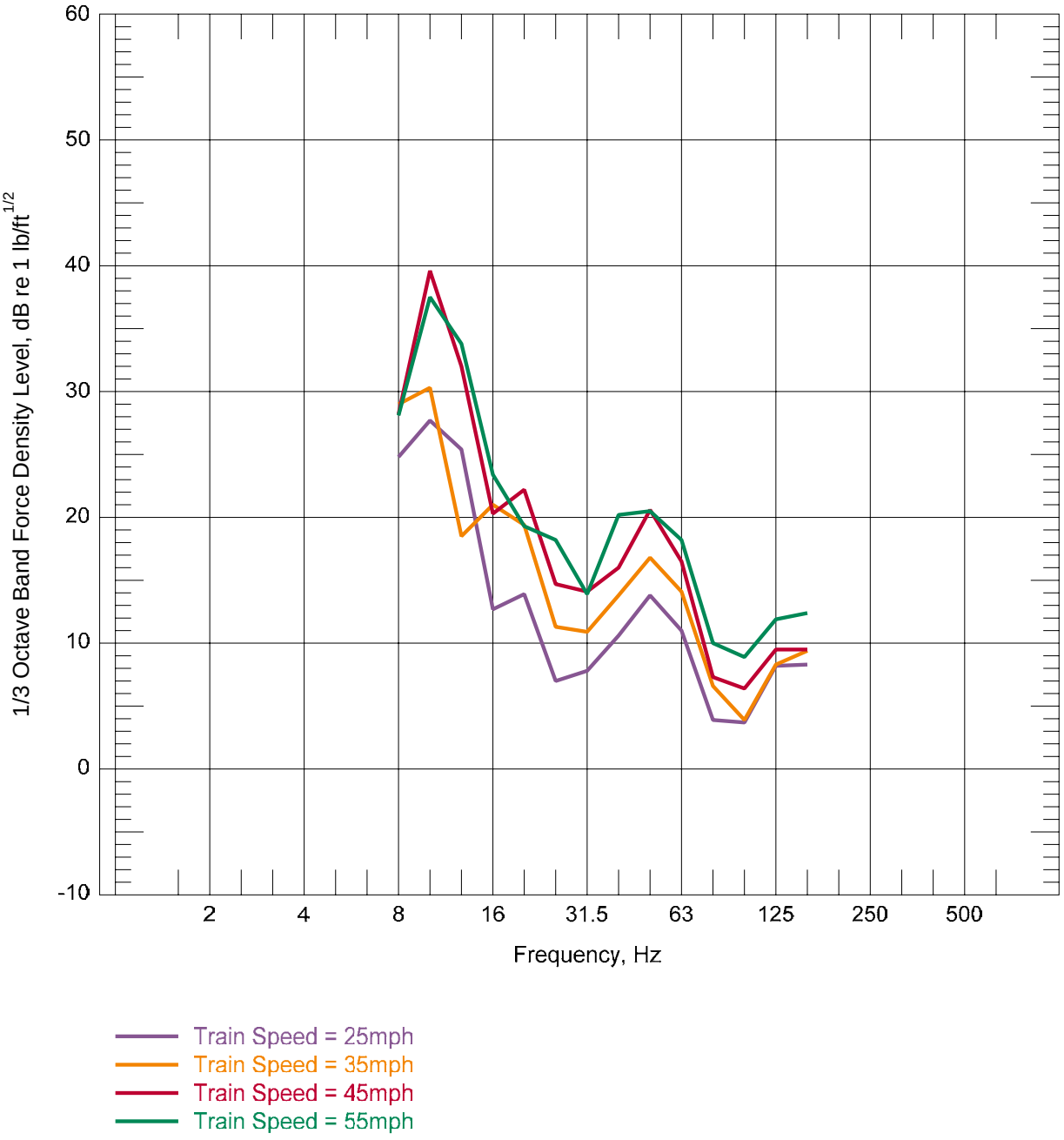


Figure A-1. 1/3-Octave Band Force Density Levels for Sound Transit Light Rail Vehicles on Elevated Track at Train Speeds from 25 to 55 mph

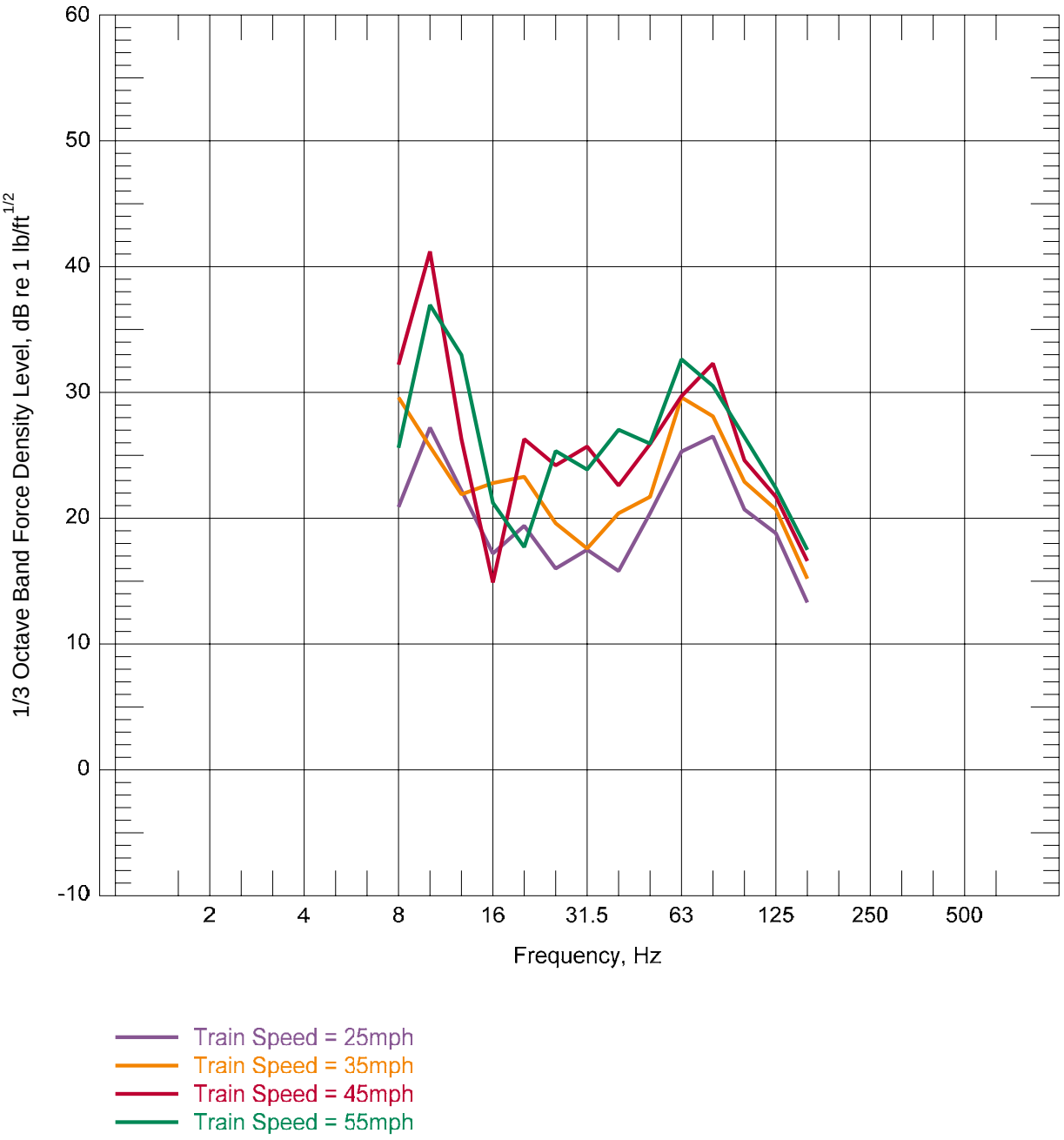


Figure A-2. 1/3-Octave Band Force Density Levels for Sound Transit Light Rail Vehicles on Ballast and Tie Track at Train Speeds from 25 to 55 mph

Attachment B

Line Source Response Measurement Locations and Results

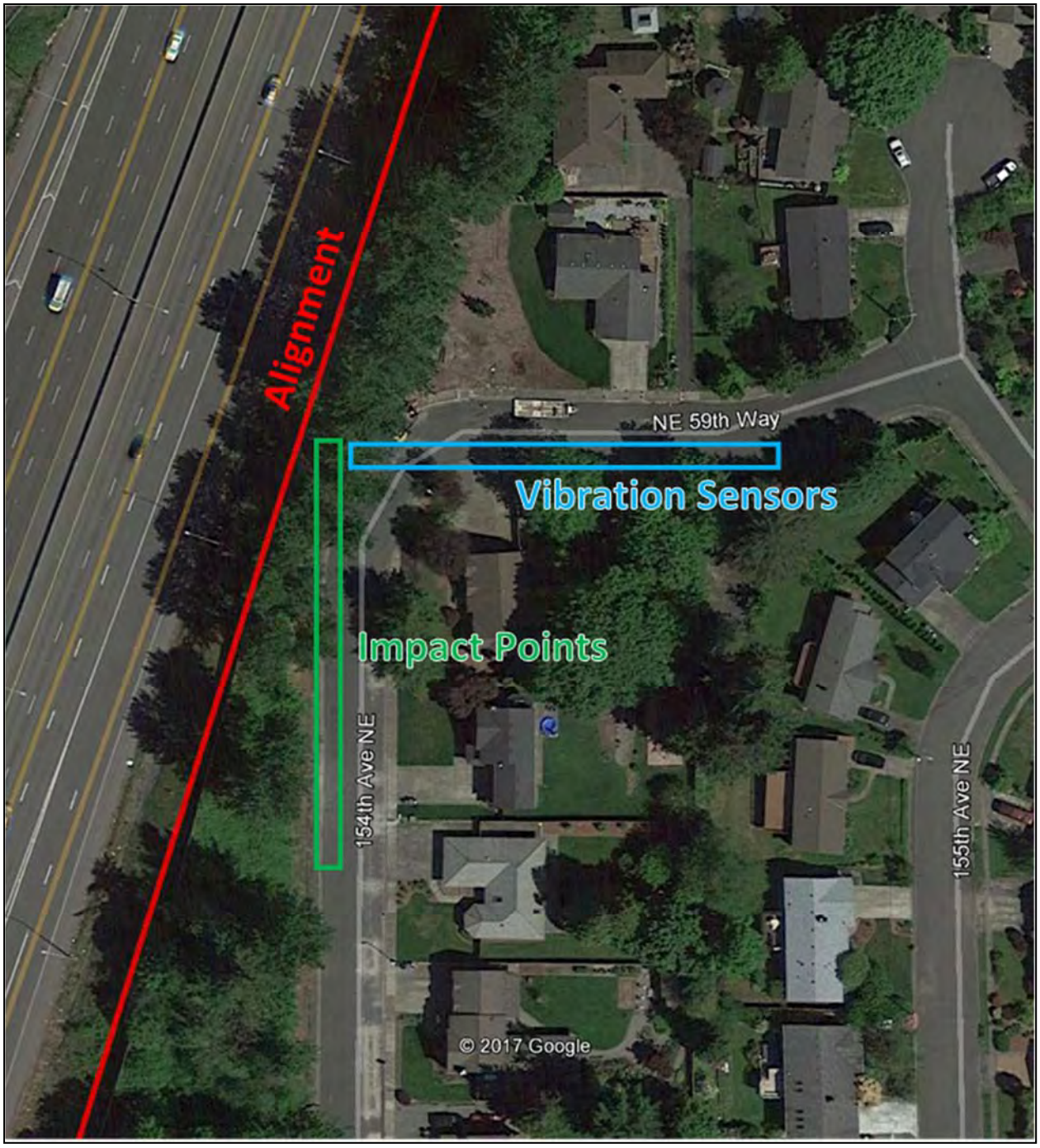


Figure B-1. LSR Measurement V1—NE 59th Way and 154th Avenue NE

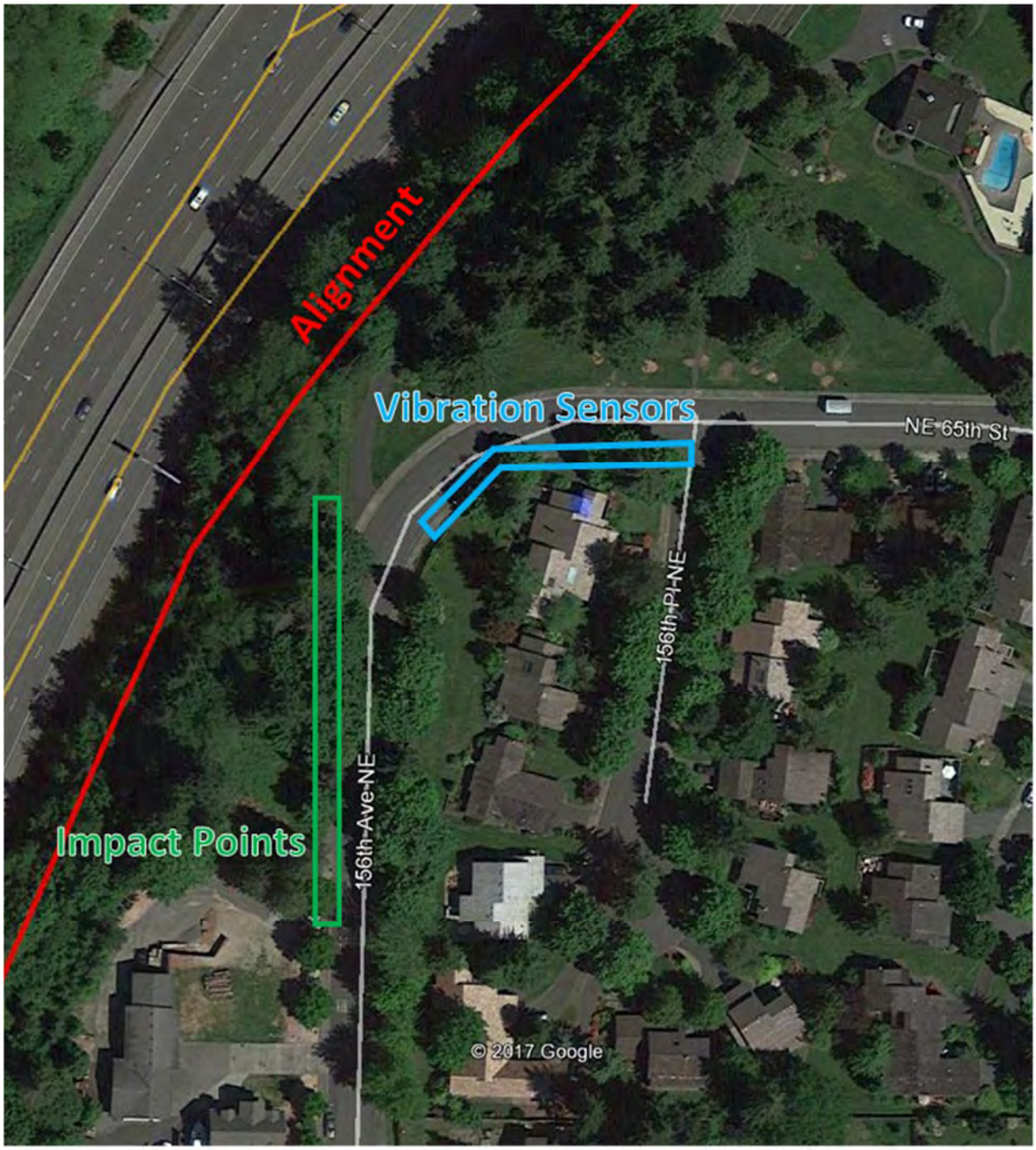


Figure B-2. LSR Measurement V3—156th Avenue NE and NE 65th Street

Figure B-3. LSR Measurement V4a— West of Elan Apartments on Cleveland Street

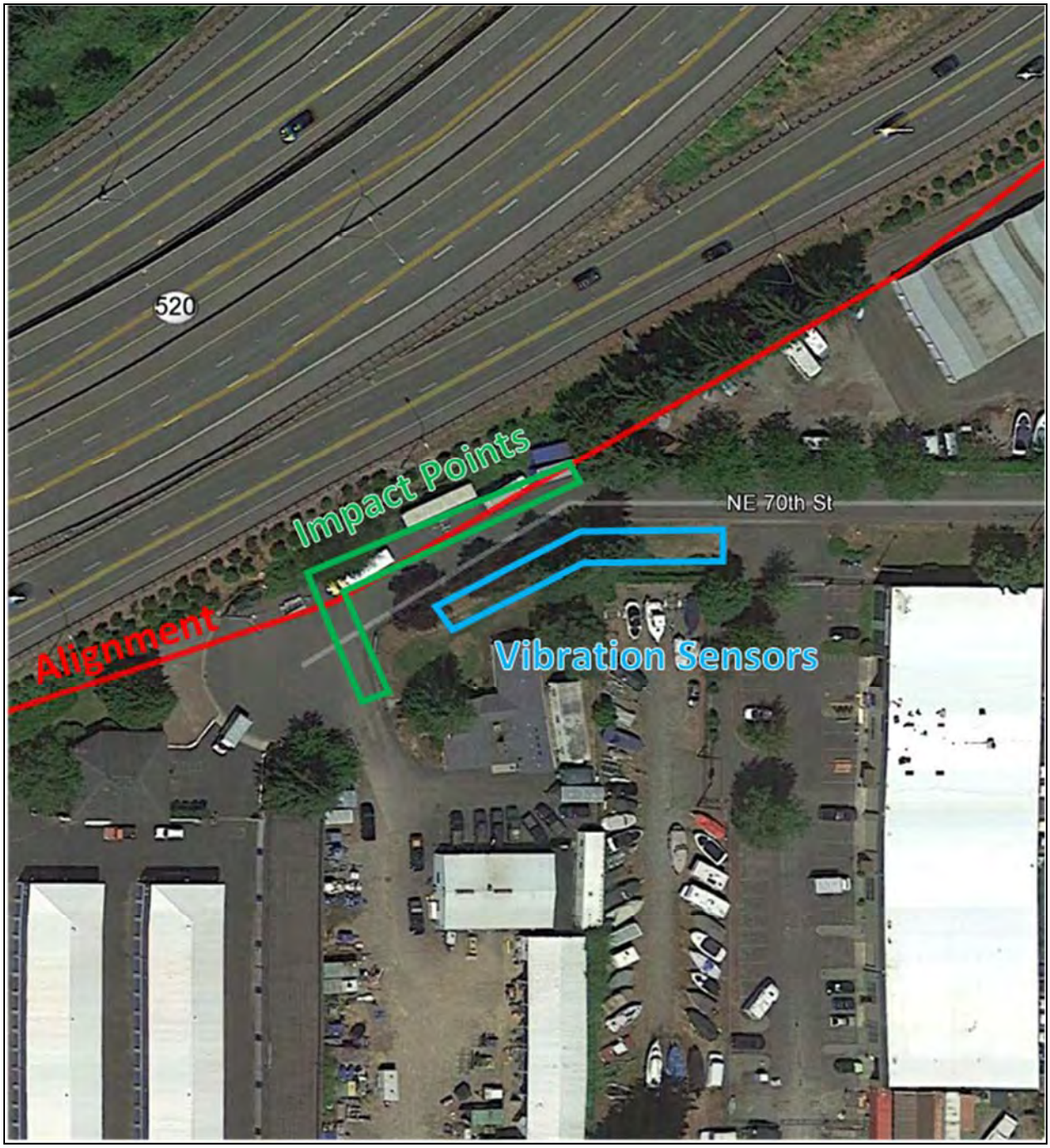


Figure B-4. LSR Measurement V5—NE 70th Street

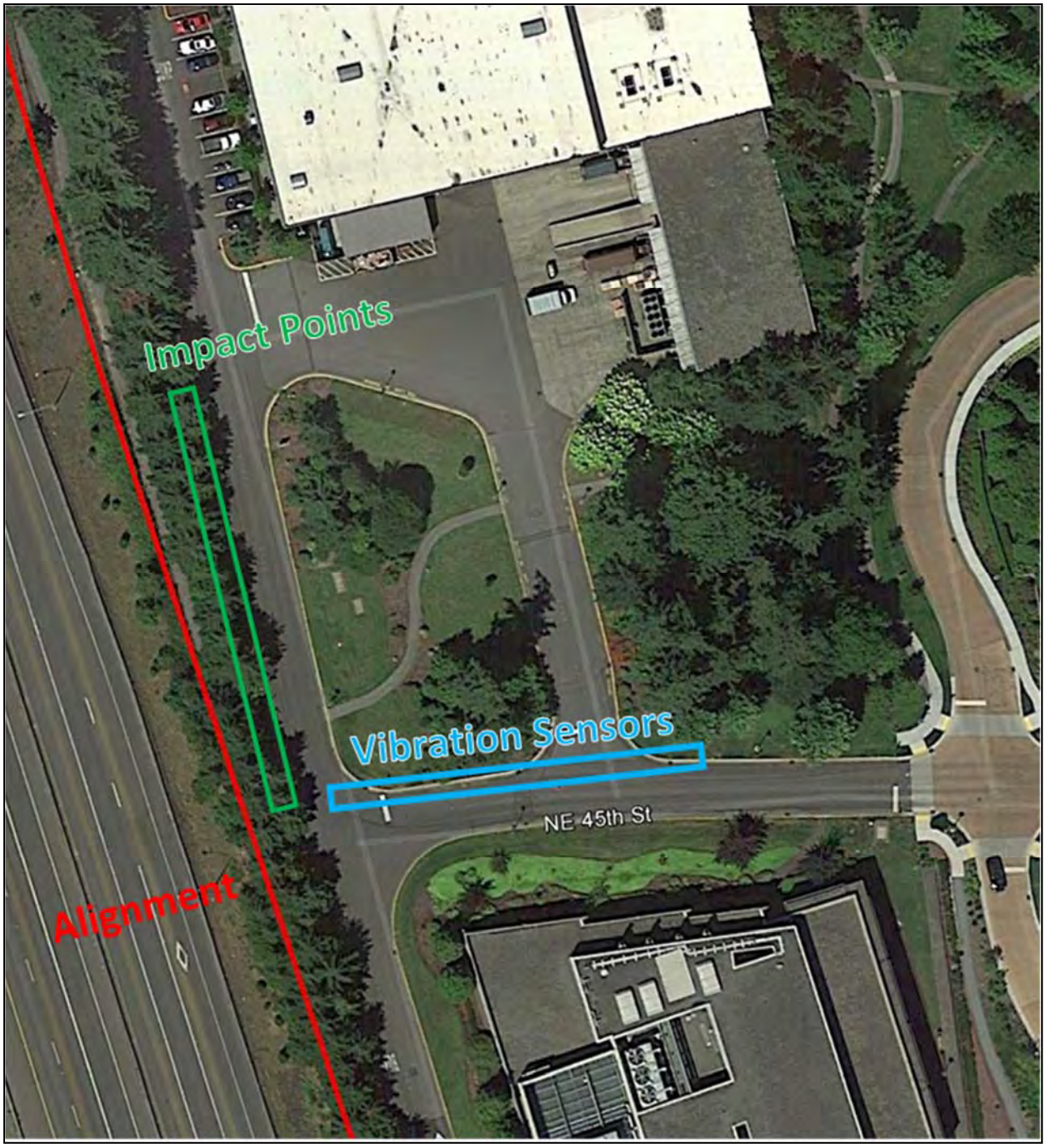


Figure B-5. LSR Measurement V6—Microsoft Building 87

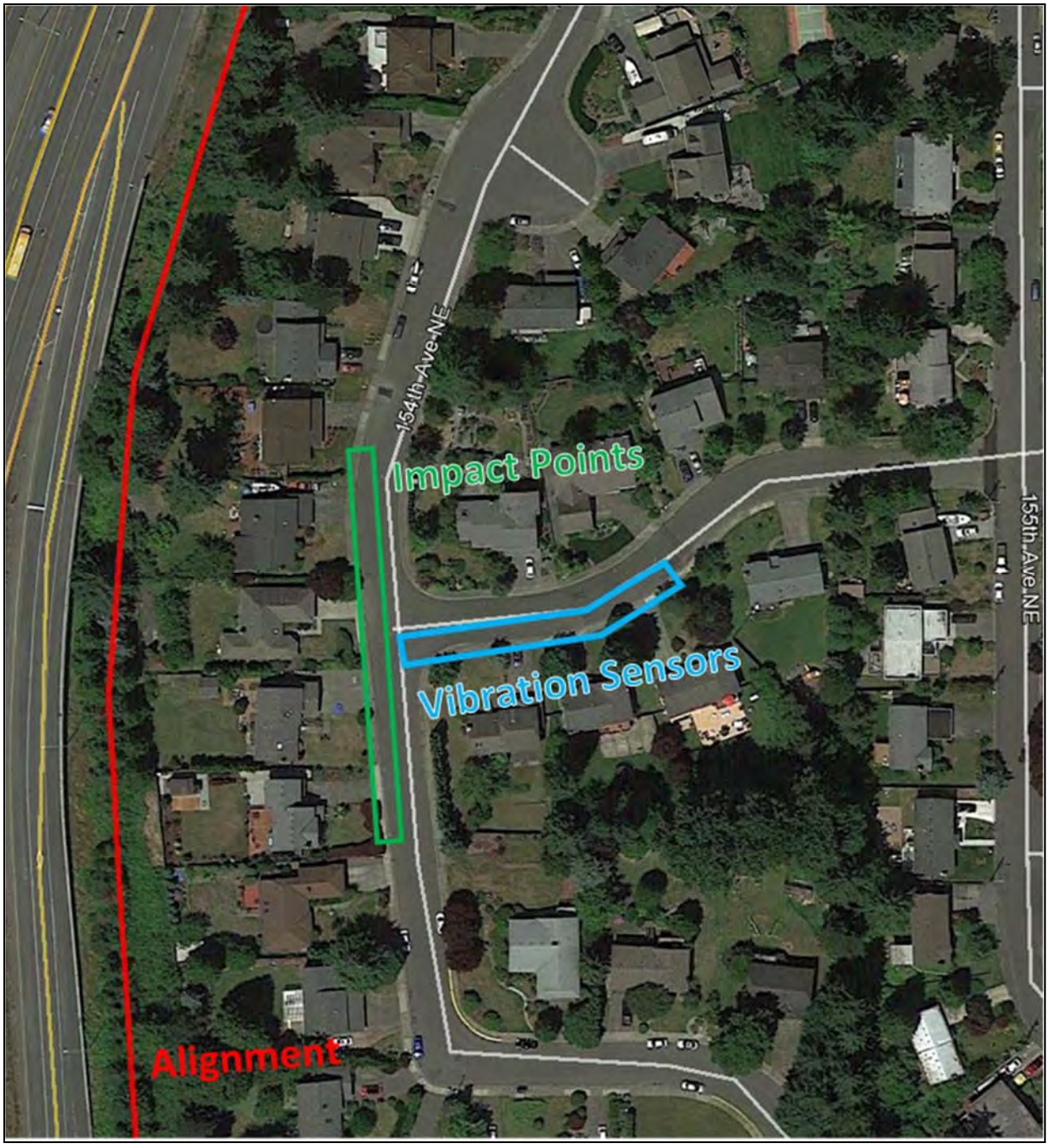


Figure B-6. LSR Measurement V7—154th Avenue NE and NE 54th Street

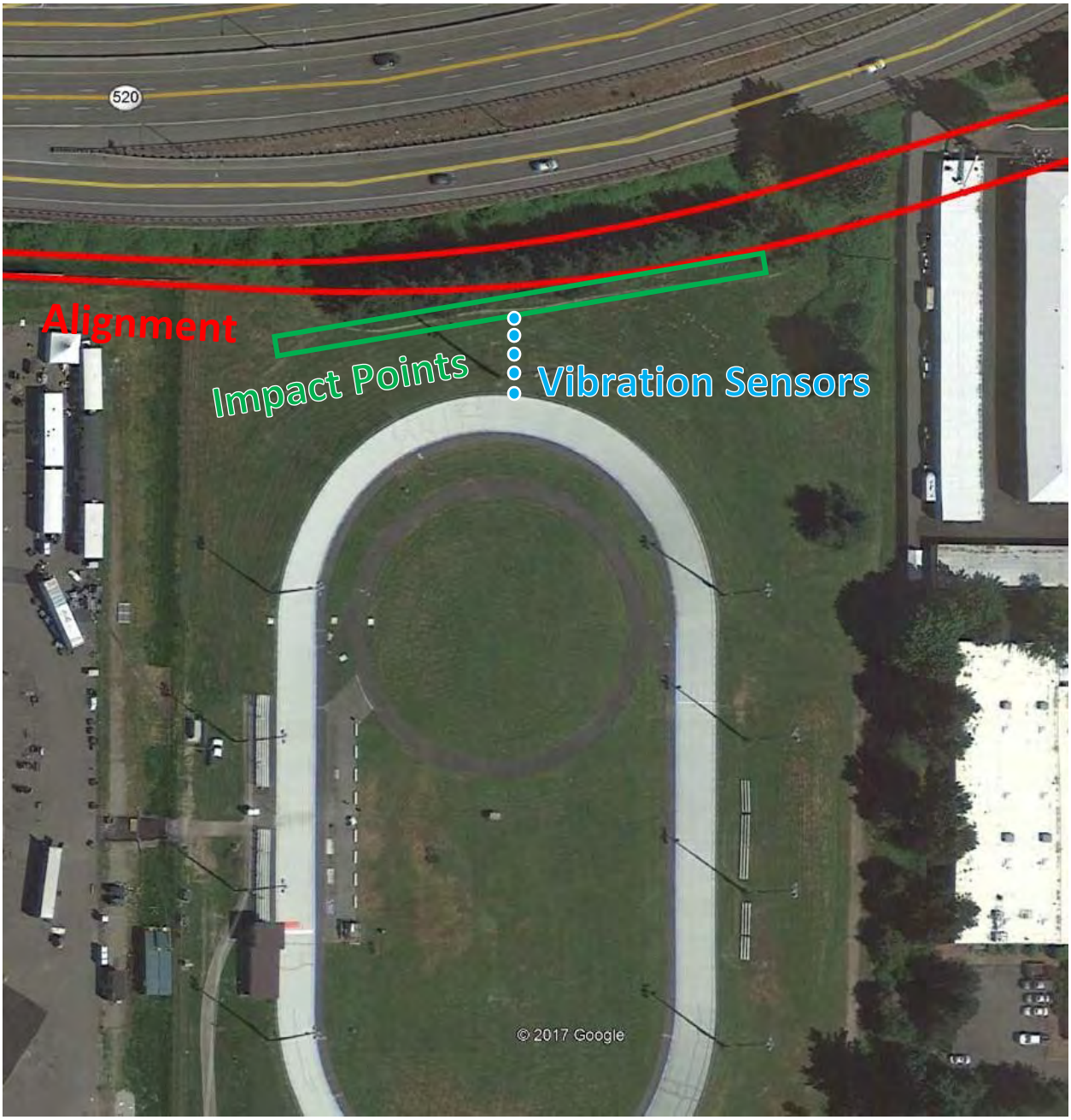


Figure B-7. LSR Measurement Location V8 - Velodrome

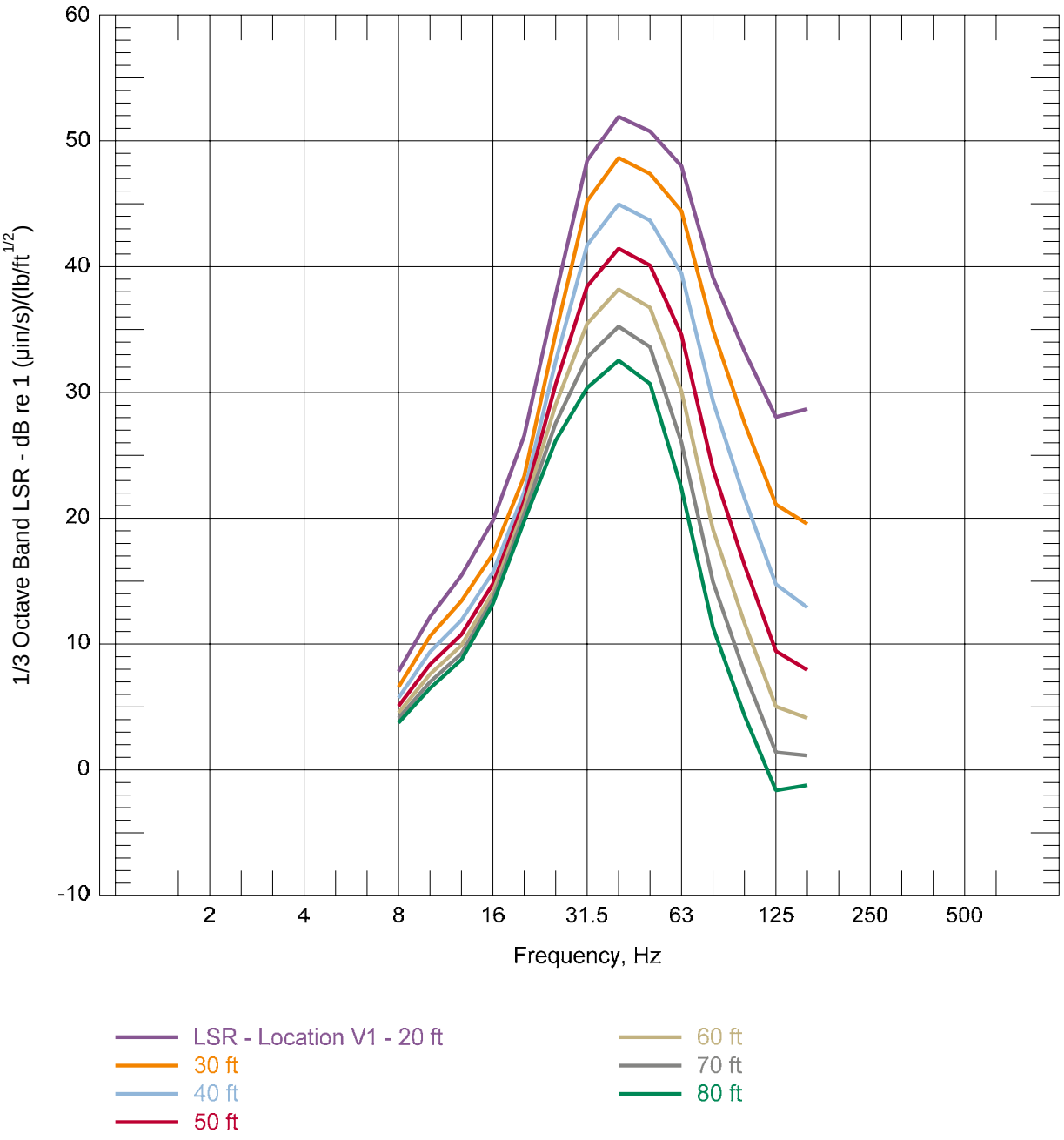


Figure B-8. LSR at V1, NE 59th Way and 154th Avenue NE, Calculated at Distances from 20 to 80 feet

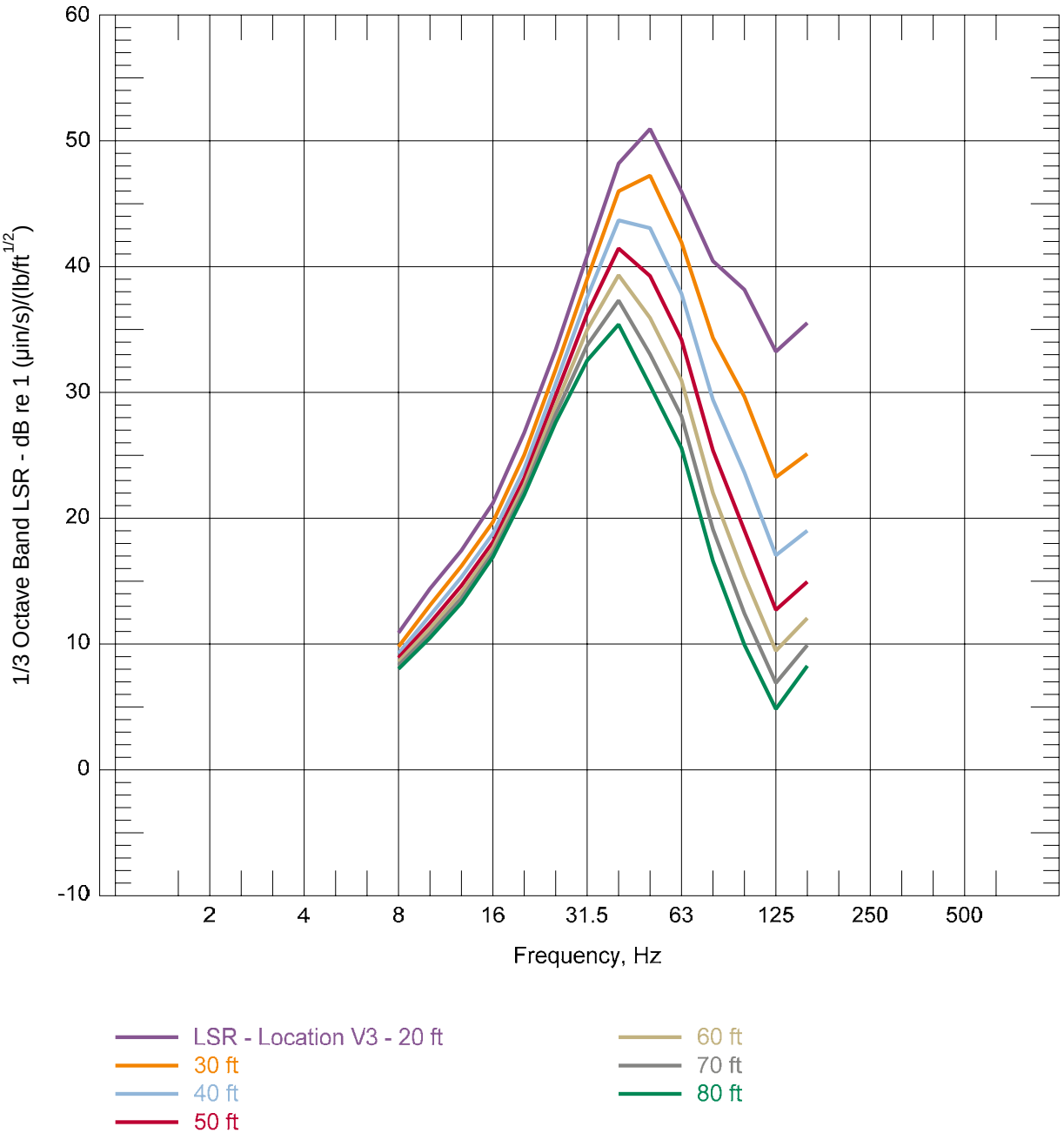


Figure B-9. LSR at V3, 156th Avenue NE and NE 65th Street, Calculated at Distances from 20 to 80 feet

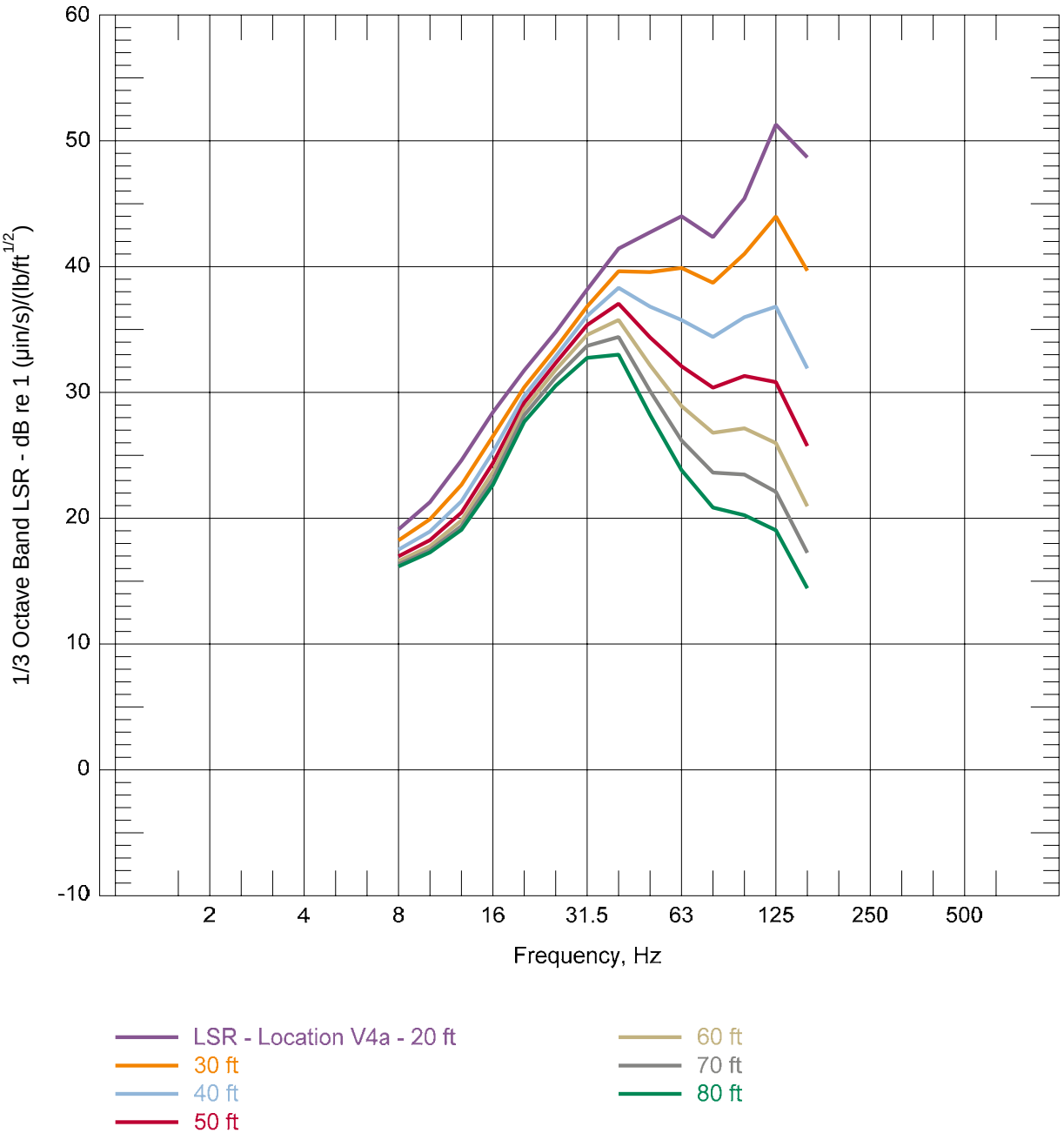


Figure B-10. LSR at V4a, Elan Apartments on Cleveland Street, Calculated at Distances from 20 to 80 feet

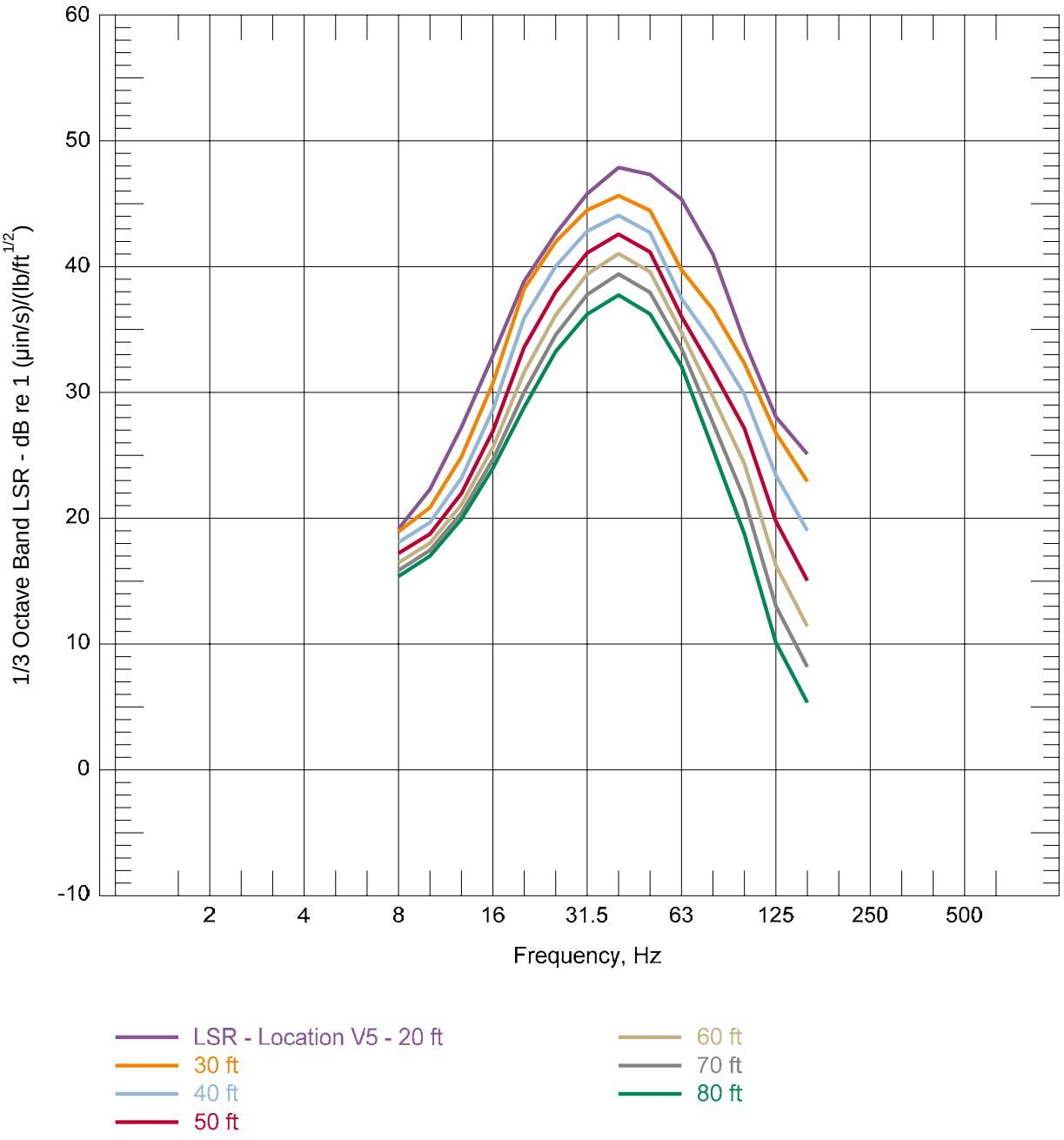


Figure B-11. LSR at V5, NE 70th Street, Calculated at Distances from 20 to 80 feet

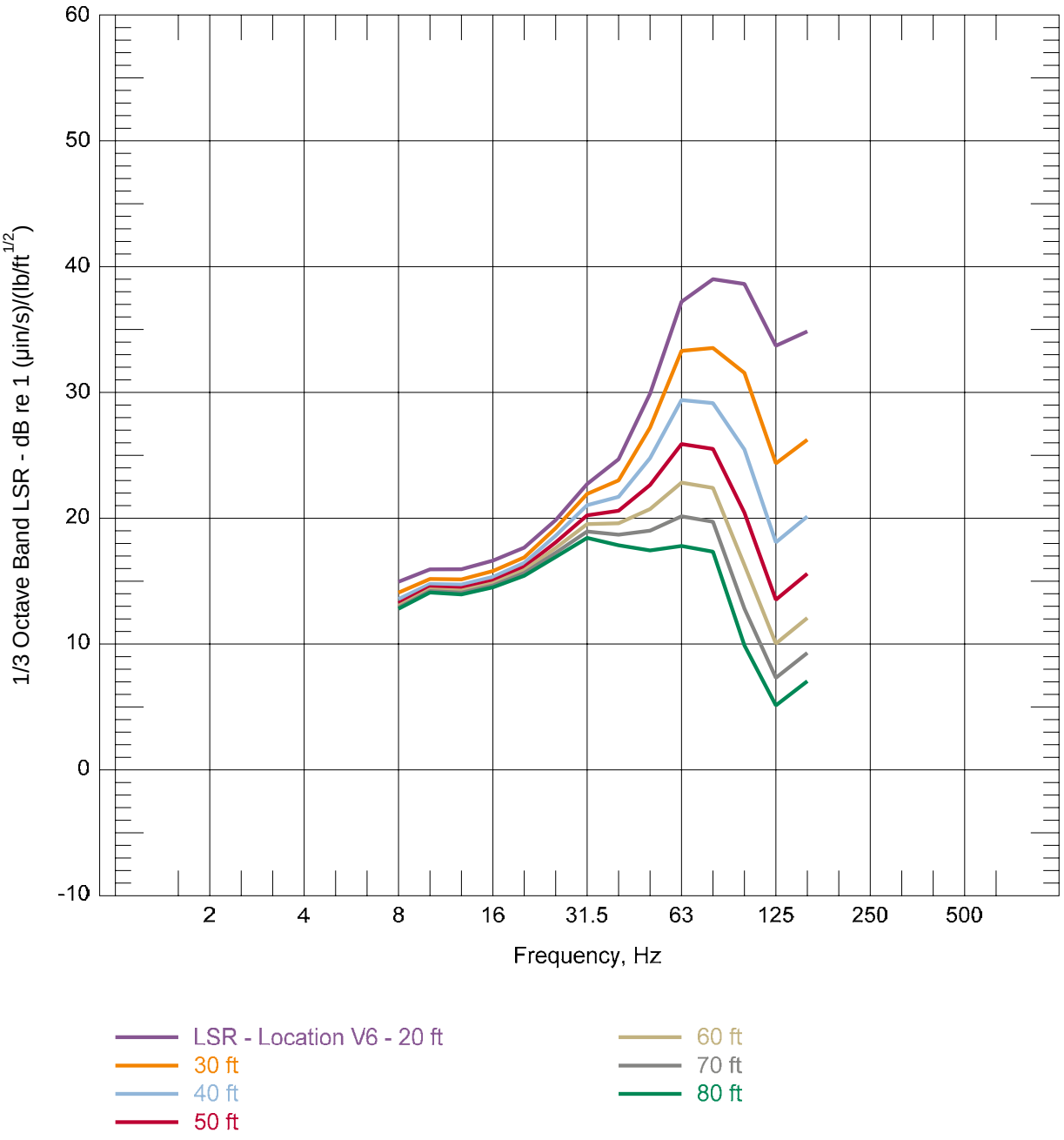


Figure B-12. LSR at V6, Microsoft Building 87, Calculated at Distances from 20 to 80 feet

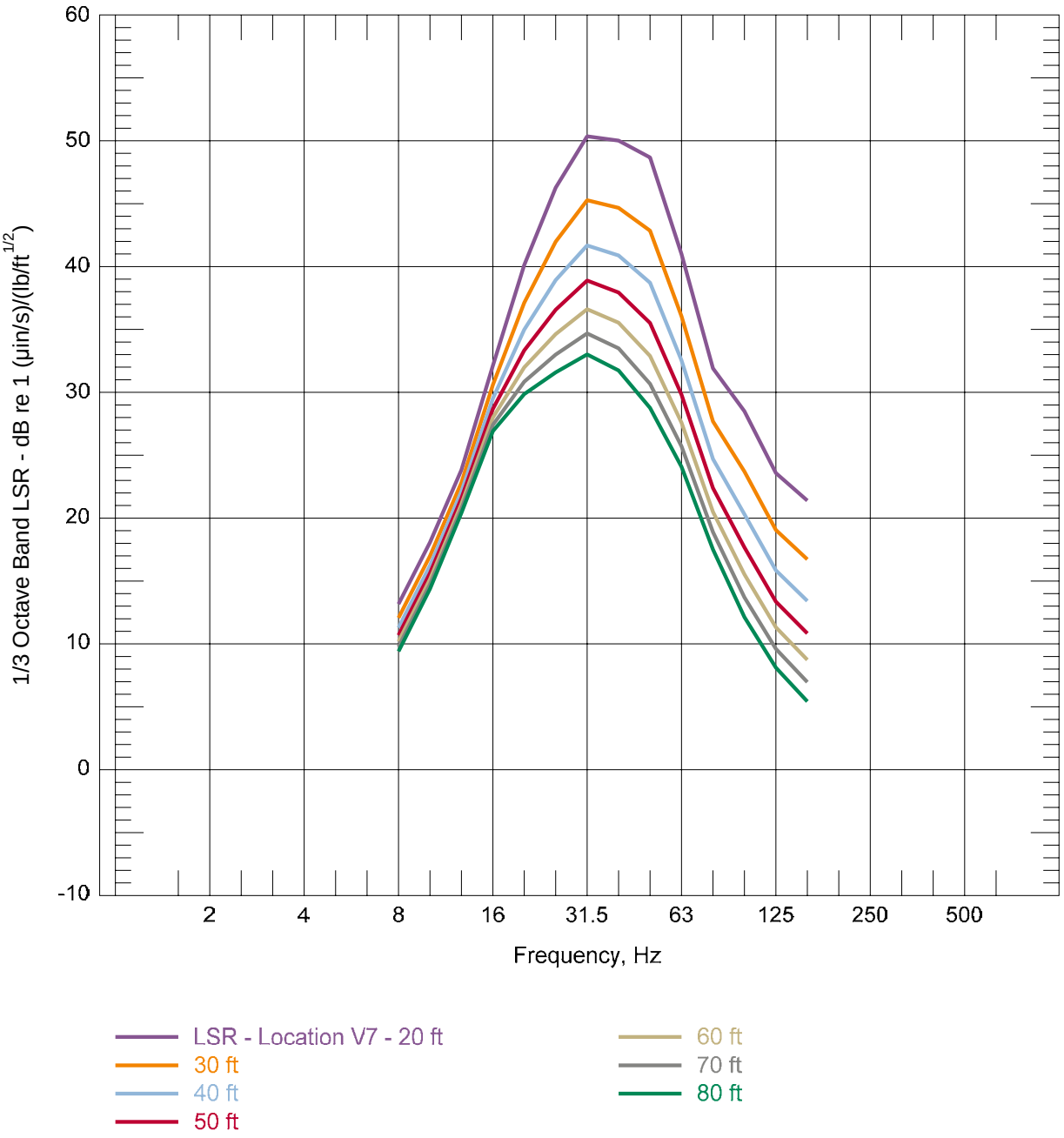


Figure B-13. LSR at V7, 154th Avenue NE and NE 54th Street, Calculated at Distances from 20 to 80 feet

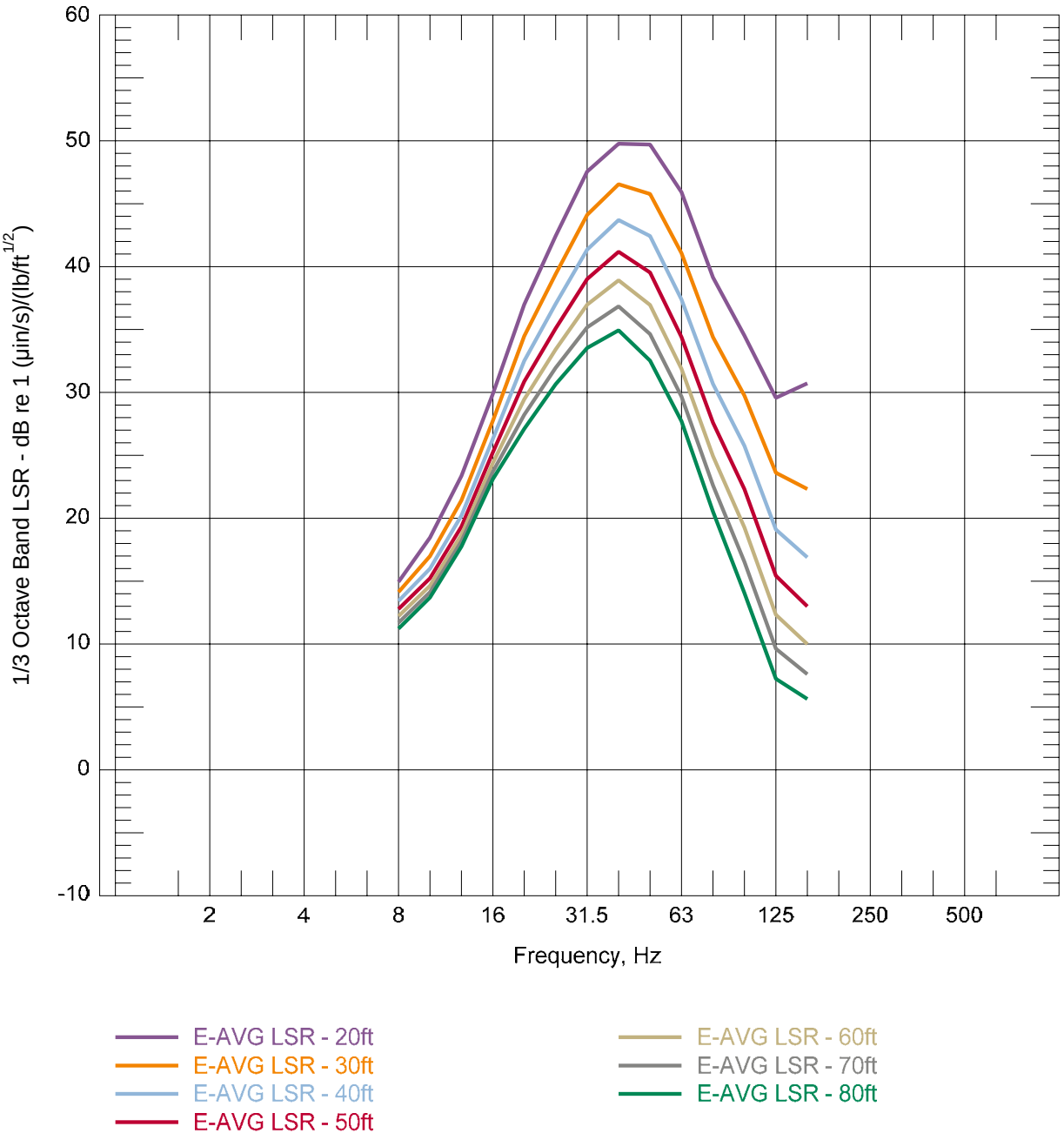


Figure B-14. Averaged LSR Used in Vibration Analysis from NE 51st Street to 166th Avenue NE

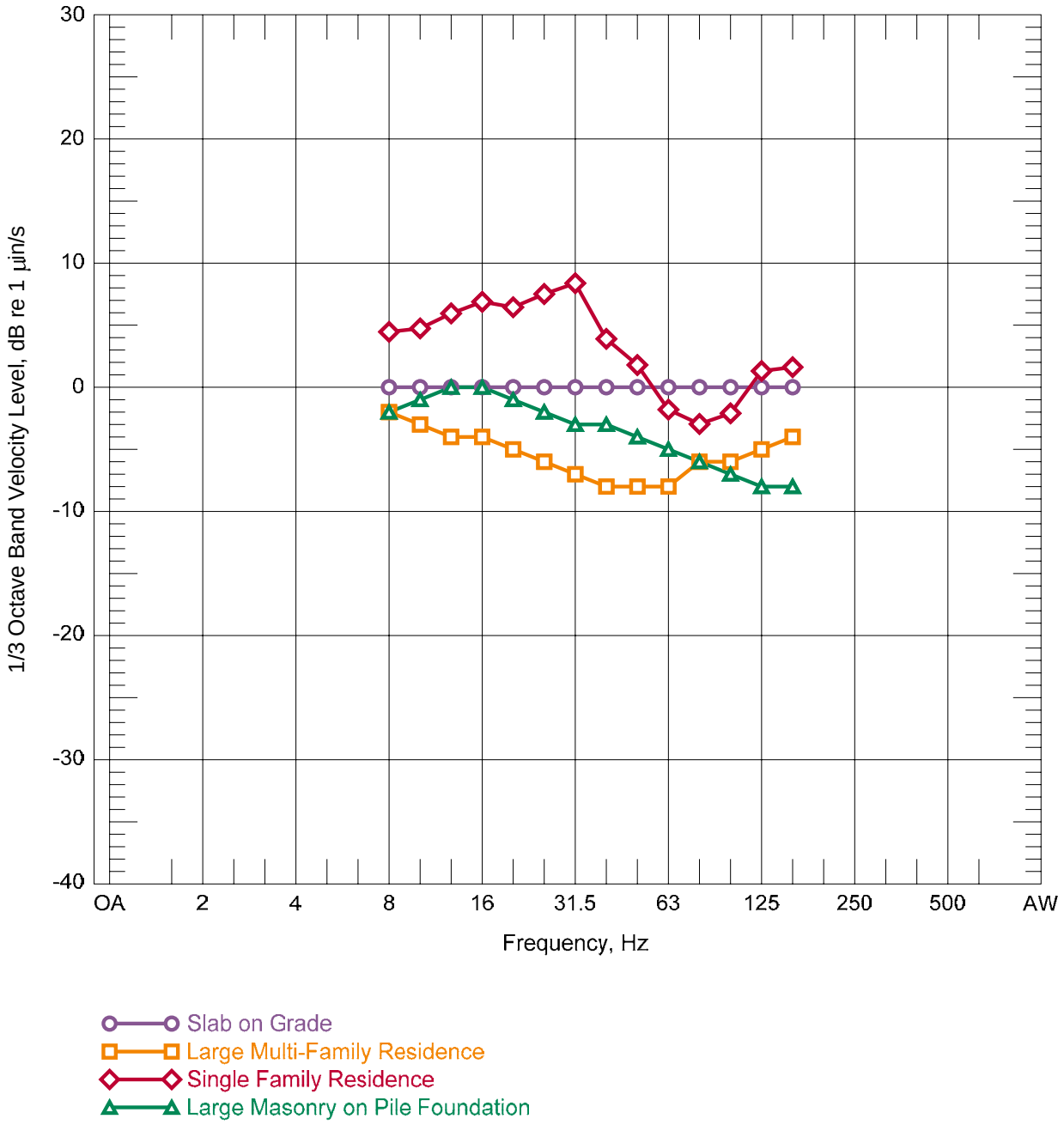


Figure B-15. BVR Factors Used in the Vibration Analysis

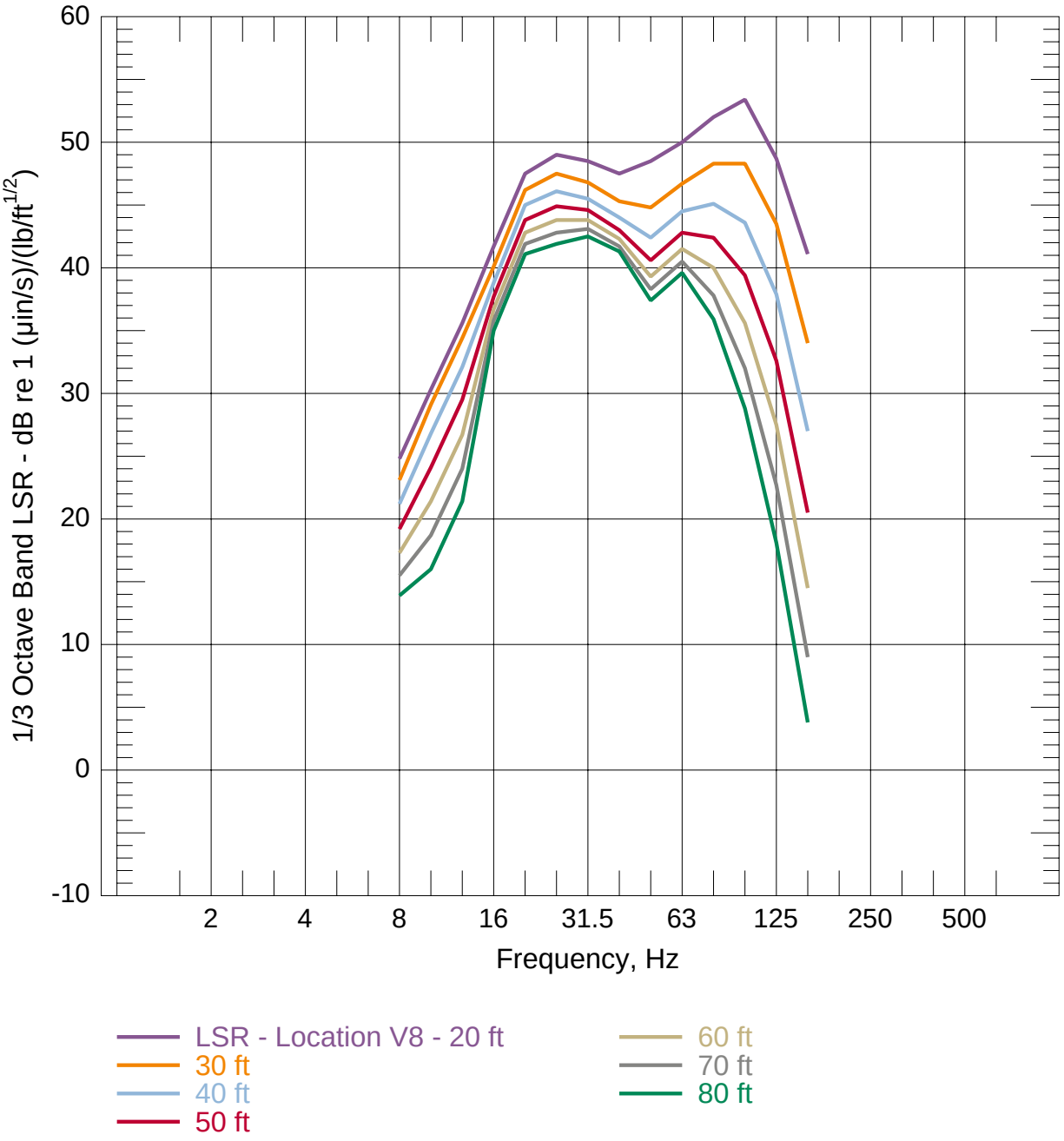


Figure B-16. LSR at V8, Velodrome, Calculated at Distances from 20 to 80 feet

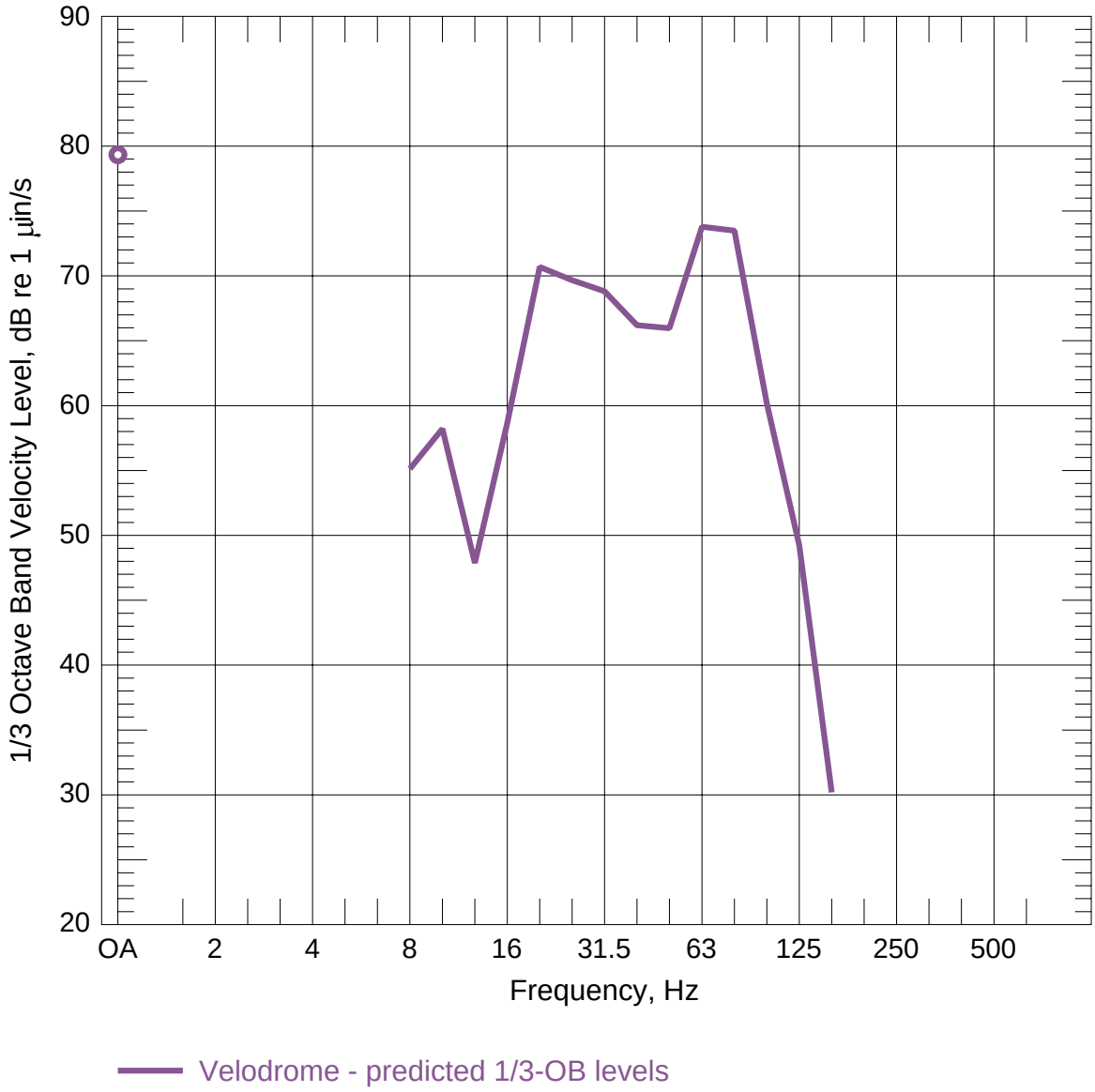


Figure B -17. Velodrome North End Predicted 1/3-OB levels

Attachment C

Noise Monitoring Details

Photo 1: Aerial View

Photo 2: Looking southeast

Photo 3: Looking southwest

Photo 4: Looking southeast toward Ballfields

Monitoring Location M1
5219 154th Avenue NE

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-1
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

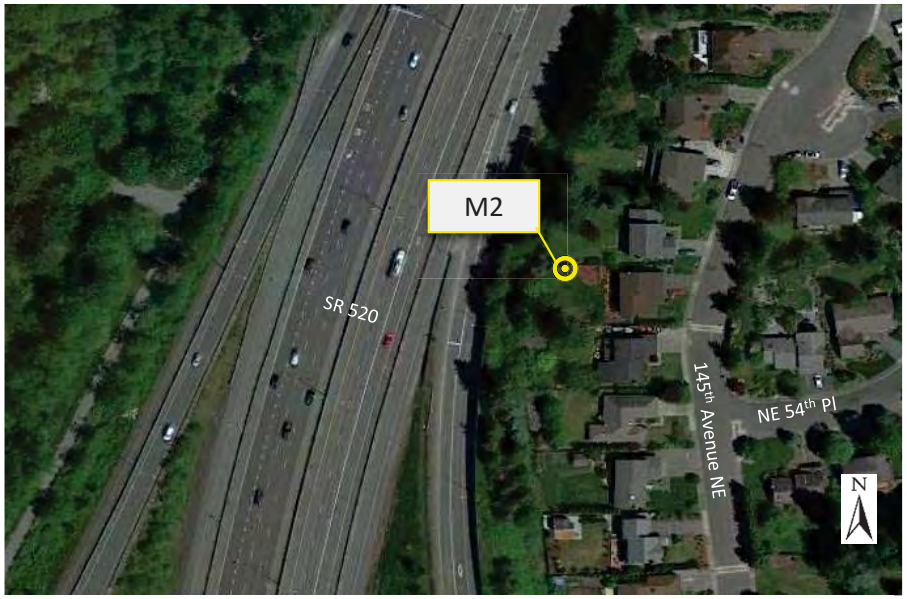


Photo 1: Aerial View

Photo 2: Looking northwest

Photo 3: Looking southeast

Photo 4: Looking north

Monitoring Location M2
5409 154th Avenue NE

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-2
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

Photo 1: Aerial View

Photo 2: Looking northeast

Photo 3: Looking southwest

Photo 4: Looking northwest

Monitoring Location M3
15406 NE 59th Way

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-3
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

Photo 1: Aerial View

Photo 2: Looking Northeast

Photo 3: Looking west from meter location

Photo 4: looking southwest from meter location

Monitoring Location M4
15516 NE 61st Court

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-4
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

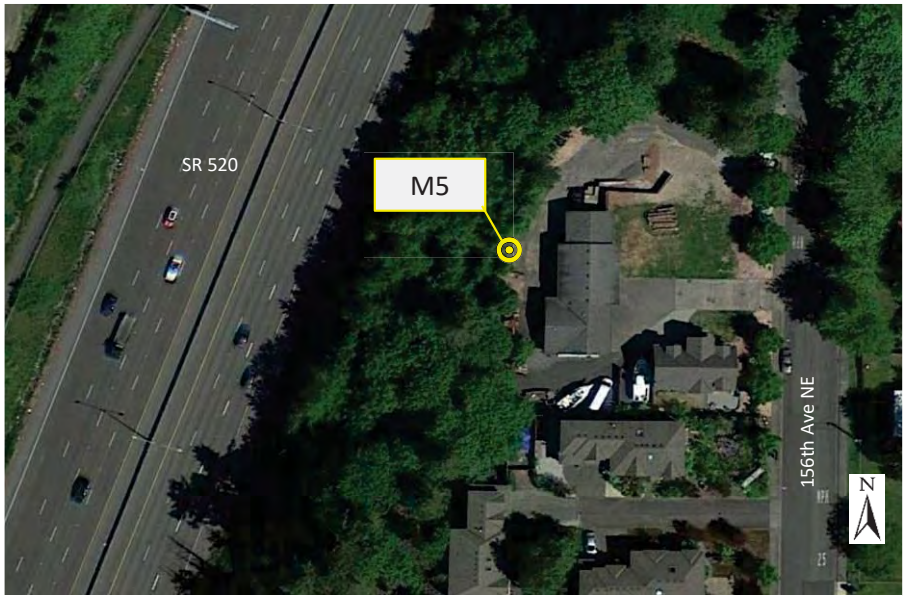


Photo 1: Aerial View

Photo 2: Looking southwest

Photo 3: Looking northwest

Photo 4: Looking west

Monitoring Location M5
6219 156th Ave NE

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-5
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

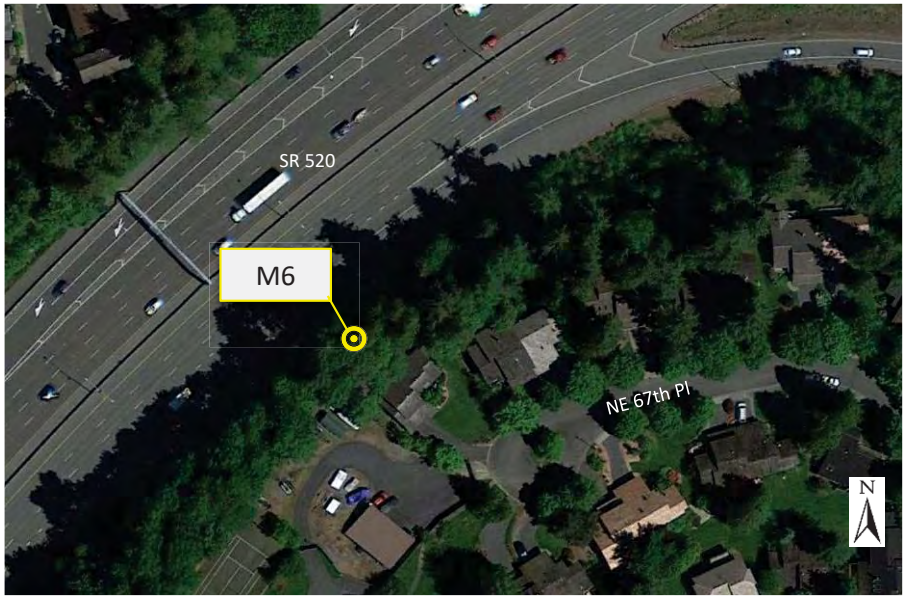


Photo 1: Aerial View

Photo 2: Looking northwest

Photo 3: Looking southwest

Photo 4: Looking east

Monitoring Location M6
15804 NE 67th Place

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-6
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

Photo 1: Aerial View

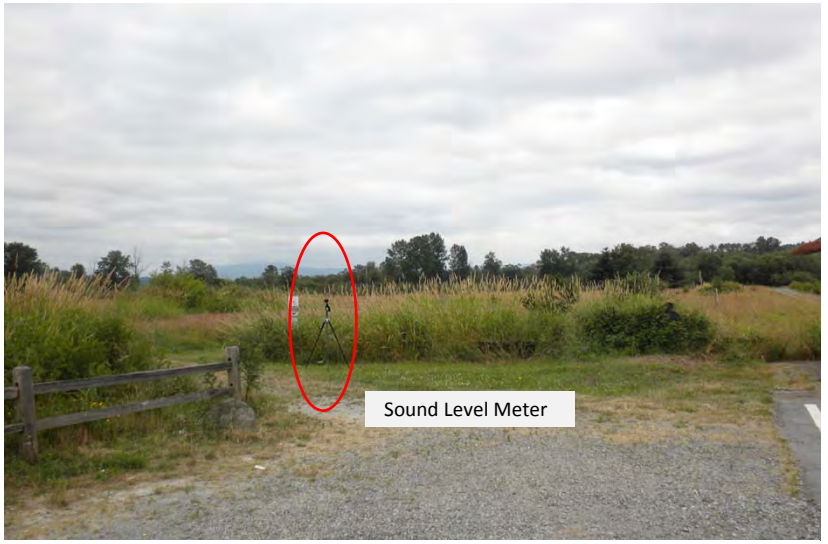


Photo 2: Looking southwest toward entrance to trails

Photo 3: Looking northwest toward Lot G

Photo 4: Looking northeast toward NE Marymoor Way

Monitoring Location M7
Entrance to Heron Loop & Sparrow Loop Trails

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-7
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

Photo 1: Aerial View

Photo 2: Birds-eye view looking south

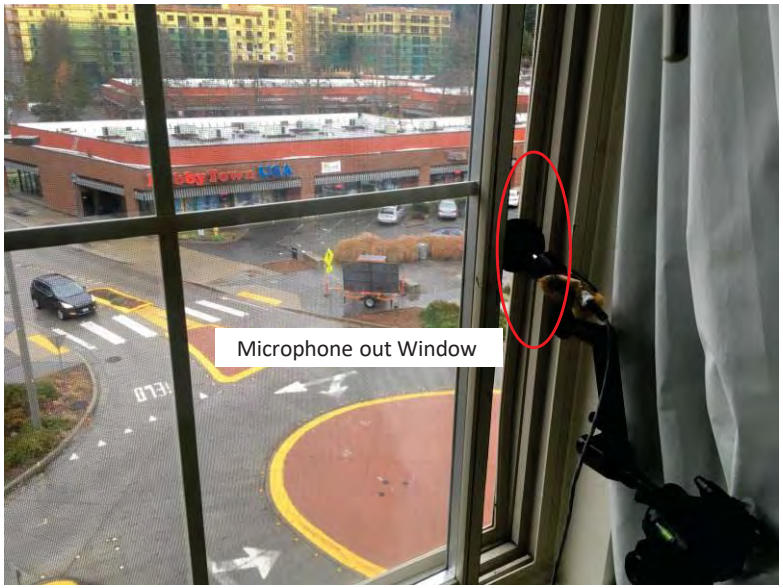


Photo 3: Looking out hotel room window to the northeast

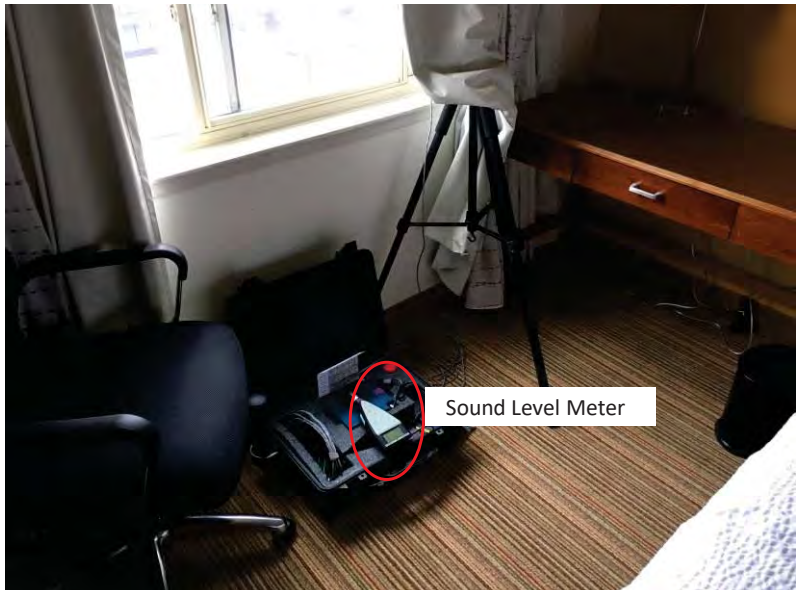


Photo 4: Inside hotel room showing meter and system setup

Monitoring Location M8
Residence Inn Hotel
Room 525: Northeast corner of hotel
7575 164th Avenue NE

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-8
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

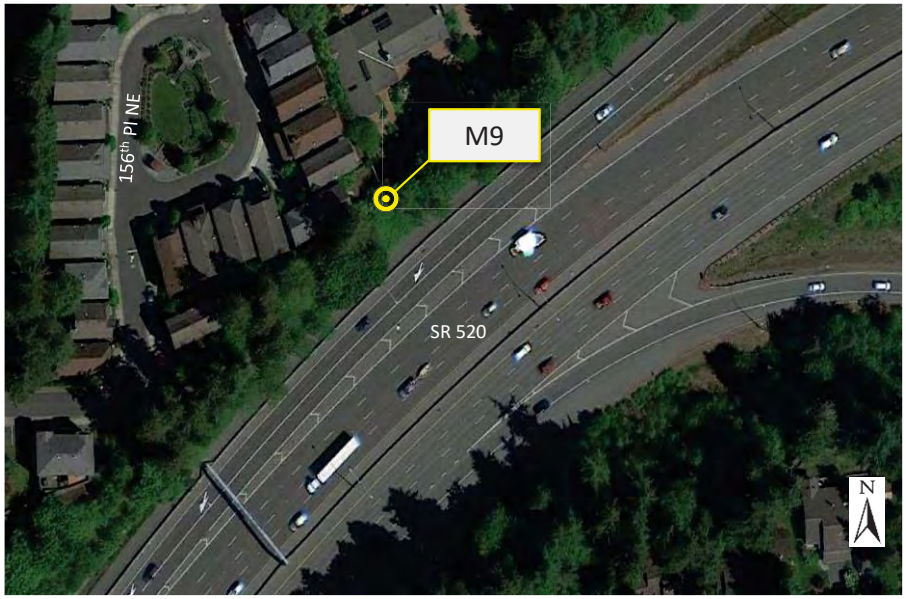


Photo 1: Aerial View

Photo 2: Looking north

Photo 3: Looking south

Photo 4: Looking east

Monitoring Location M9
6846 156th Place NE

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-9
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

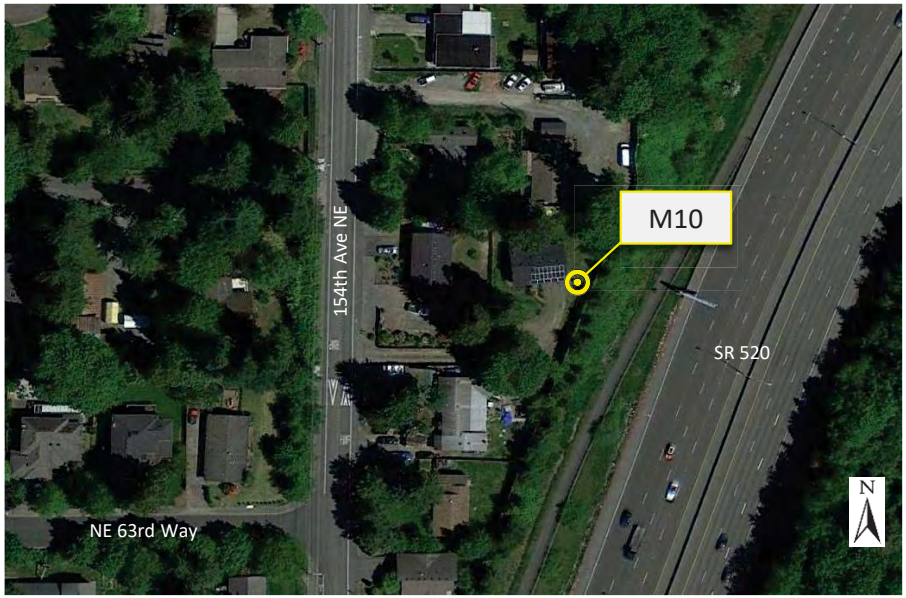


Photo 1: Aerial View

Photo 2: Looking north

Photo 3: Looking west

Photo 4: Looking east

Monitoring Location M10
6232 154th Avenue NE

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure C-10
Detailed Noise Monitoring Site Photos
Sound Transit Redmond Extension

Attachment D

Transit Noise Analysis

Redmond Light Rail Extension

Transit Noise Analysis

Total Units Analyzed	Total Impacts	Mod Imp	Sev Imp
193		29	8

1. Mitigated noise levels include any noise reduction regardless of impact (e.g., receivers without impacts located behind noise walls may have reduced noise due to the wall).
2. Sp Trk Wk = Special Track work (e.g., special crossovers).

Receiver/Area Information						Impact Analysis									Project Noise Level with Mitigation				
Area	Parcel	Address	4 Digit Identifier	Station	Description	Type	Units	Ldn/Leq	Ldn/Leq	Type	Moderate	Severe	Mod Imp	Sev Imp	Sound Wall	X-Over	Insulation	Project Levels (1)	Impacts
Redmond Technology Center Station to Sammamish River																			
	2182500082	15250 NE 51ST ST	RL107	5026	SF residence at NE 51st Street	SF	1	56	52	Ldn	56	63	--	--	Traffic Wall	--	--	52	0
	3882320040	5207 154TH AVE NE	None	5028	SF residence along 154th	SF	1	54	41	Ldn	55	62	--	--	Traffic Wall	--	--	41	0
	3882310150	5211 154TH AVE NE	None	5028	SF residence along 154th	SF	1	54	44	Ldn	55	62	--	--	Traffic Wall	--	--	44	0
	3882310140	5215 154TH AVE NE	RL108	5028	SF residence along 154th	SF	1	54	52	Ldn	55	62	--	--	Traffic Wall	--	--	52	0
	3882310130	5219 154TH AVE NE	RL109	5029	SF residence along 154th	SF	1	54	52	Ldn	55	62	--	--	Traffic Wall	--	--	52	0
	3882310120	5223 154TH AVE NE	RL110	5030	SF residence along 154th	SF	1	54	52	Ldn	55	62	--	--	Traffic Wall	--	--	52	0
	3882310110	5227 154TH AVE NE	RL111	5031	SF residence along 154th	SF	1	56	53	Ldn	56	63	--	--	Traffic Wall	--	--	53	0
	3882310100	5305 154TH AVE NE	RL112	5031	SF residence along 154th	SF	1	56	53	Ldn	56	63	--	--	Traffic Wall	--	--	53	0
	3882310090	5315 154TH AVE NE	RL113	5032	SF residence along 154th	SF	1	58	53	Ldn	57	63	--	--	Traffic Wall	--	--	53	0
	3882310080	5323 154TH AVE NE	RL114	5033	SF residence along 154th	SF	1	60	55	Ldn	58	64	--	--	Traffic Wall	--	--	55	0
	3882310070	5401 154TH AVE NE	RL115	5033	SF residence along 154th	SF	1	62	54	Ldn	59	65	--	--	Traffic Wall	--	--	54	0
	3882310060	5409 154TH AVE NE	RL116	5034	SF residence along 154th	SF	1	62	54	Ldn	59	65	--	--	Traffic Wall	--	--	54	0
	3882310050	5417 154TH AVE NE	RL117	5035	SF residence along 154th	SF	1	62	53	Ldn	59	65	--	--	Traffic Wall	--	--	53	0
	3882310040	5425 154TH AVE NE	RL118	5035	SF residence along 154th	SF	1	62	52	Ldn	59	65	--	--	Traffic Wall	--	--	52	0
	3882310030	5433 154TH AVE NE	RL119	5036	SF residence along 154th	SF	1	62	52	Ldn	59	65	--	--	Traffic Wall	--	--	52	0
	3882310020	5507 154TH AVE NE	RL120	5037	SF residence along 154th	SF	1	62	52	Ldn	59	65	--	--	Traffic Wall	--	--	52	0
	3882310010	5517 154TH AVE NE	RL121	5038	SF residence along 154th	SF	1	62	50	Ldn	59	65	--	--	Traffic Wall	--	--	50	0
	3882300070	5812 154TH AVE NE	RL123	5043	SF residence along 154th	SF	1	64	52	Ldn	61	66	--	--	Traffic Wall	--	--	52	0
	3882300090	15406 NE 59TH WAY	RL126	5046	SF residence along 154th	SF	1	64	54	Ldn	61	66	--	--	Traffic Wall	--	--	54	0
	3882320010	5220 154TH AVE NE	None	5030	SF residence along 154th	SF	1	64	43	Ldn	61	66	--	--	Traffic Wall	--	--	43	0
	3882310160	15403 NE 54TH ST	None	5032	SF residence along 154th	SF	1	64	43	Ldn	61	66	--	--	Traffic Wall	--	--	43	0
	3882310230	15406 NE 54TH ST	None	5033	SF residence along 154th	SF	1	64	44	Ldn	61	66	--	--	Traffic Wall	--	--	44	0
	3882310240	5412 154TH AVE NE	None	5035	SF residence along 154th	SF	1	64	43	Ldn	61	66	--	--	Traffic Wall	--	--	43	0
	3882310250	5420 154TH AVE NE	None	5036	SF residence along 154th	SF	1	64	42	Ldn	61	66	--	--	Traffic Wall	--	--	42	0
	3882310260	5428 154TH AVE NE	None	5036	SF residence along 154th	SF	1	64	42	Ldn	61	66	--	--	Traffic Wall	--	--	42	0
	3882310270	5510 154TH AVE NE	None	5037	SF residence along 154th	SF	1	64	42	Ldn	61	66	--	--	Traffic Wall	--	--	42	0
	3882300010	5606 154TH AVE NE	None	5039	SF residence along 154th	SF	1	64	48	Ldn	61	66	--	--	Traffic Wall	--	--	48	0
	3882300020	5614 154TH AVE NE	None	5040	SF residence along 154th	SF	1	64	48	Ldn	61	66	--	--	Traffic Wall	--	--	48	0
	3882300030	5702 154TH AVE NE	None	5040	SF residence along 154th	SF	1	64	49	Ldn	61	66	--	--	Traffic Wall	--	--	49	0
	3882300040	5710 154TH AVE NE	None	5041	SF residence along 154th	SF	1	64	50	Ldn	61	66	--	--	Traffic Wall	--	--	50	0
	3882300050	5718 154TH AVE NE	None	5042	SF residence along 154th	SF	1	64	51	Ldn	61	66	--	--	Traffic Wall	--	--	51	0
	3882300060	5804 154TH AVE NE	None	5043	SF residence along 154th	SF	1	64	52	Ldn	61	66	--	--	Traffic Wall	--	--	52	0
	9435300055	15504 NE 60TH ST	RLNA9	5050	SF residences on NE 60TH ST on 520	SF	1	71	62	Ldn	66	71	--	--	Wall at 6 Ft..	--	--	53	0
	9435300059	15512 NE 60TH ST	RL132	5051	SF residences on NE 60TH ST on 520	SF	1	71	65	Ldn	66	71	--	--	Wall at 6 Ft..	--	--	59	0
	9435300049	15530 NE 60TH ST	None	5050	SF residences on NE 60TH ST 2nd to 520	SF	1	68	59	Ldn	63	69	--	--	Wall at 6 Ft..	--	--	51	0
	9435300053	6007 156TH AVE NE	None	5051	SF residences on NE 60TH ST 2nd to 520	SF	1	68	60	Ldn	63	69	--	--	Wall at 6 Ft..	--	--	52	0
	9435300056	6011 156TH AVE NE	None	5052	SF residences on NE 60TH ST 2nd to 520	SF	1	68	59	Ldn	63	69	--	--	Wall at 6 Ft..	--	--	52	0
	9435300222	15515 NE 61ST CT	RLNA19	5053	SF residences on NE 60TH ST on 520	SF	1	71	65	Ldn	66	71	--	--	Wall at 6 Ft..	--	--	64	0
	9435300060	15516 NE 61ST CT	RLNA12	5054	SF residences on NE 60TH ST on 520	SF	1	71	66	Ldn	66	71	1	--	Wall at 6 Ft..	--	--	63	0
	9435300063	15535 NE 62ND CT	RL134	5054	SF residences on NE 60TH ST on 520	SF	1	71	66	Ldn	66	71	1	--	Wall at 6 Ft..	--	--	63	0
	9435300062	15536 NE 62ND CT	RL135	5055	SF residences on NE 60TH ST on 520	SF	1	70	62	Ldn	65	70	--	--	Wall at 6 Ft..	--	--	59	0
	9435300066	6205 156TH AVE NE	RL136	5056	SF residences on NE 60TH ST on 520	SF	1	70	62	Ldn	65	70	--	--	--	--	--	62	0
	9435300057	6207 156TH AVE NE	RLNA10	5057	SF residences on NE 60TH ST on 520	SF	1	69	55	Ldn	64	70	--	--	--	--	--	55	0
	9435300068	6217 156TH AVE NE	RL137	5057	SF residences on NE 60TH ST on 520	SF	1	68	52	Ldn	63	69	--	--	--	--	--	52	0
	9435300065	6219 156TH AVE NE	RL138	5058	SF residences on NE 60TH ST on 520	SF	1	70	53	Ldn	65	70	--	--	--	--	--	53	0
	9435300224	15521 NE 61ST CT	RLNA20	5053	SF residences on NE 60TH ST - along 156th	SF	1	66	58	Ldn	62	68	--	--	Wall at 6 Ft..	--	--	51	0
	9435300220	15522 NE 61ST CT	RLNA18	5055	SF residences on NE 60TH ST - along 156th	SF	1	66	58	Ldn	62	68	--	--	Wall at 6 Ft..	--	--	53	0
	9435300064	15541 NE 62ND CT	RLNA14	5056	SF residences on NE 60TH ST - along 156th	SF	1	66	48	Ldn	62	68	--	--	--	--	--	48	0
	9435300061	15542 NE 62ND CT	RLNA13	5056	SF residences on NE 60TH ST - along 156th	SF	1	66	49	Ldn	62	68	--	--	--	--	--	49	0
	9435300058	6203 156TH AVE NE	RLNA11	5057	SF residences on NE 60TH ST - along 156th	SF	1	67	48	Ldn	63	68	--	--	--	--	--	48	0
	5422560070	6303 156TH PL NE	None	5059	Duplex along 156th eastside	SF	1	62	42	Ldn	59	65	--	--	--	--	--	42	0
	5422560060	6311 156TH PL NE	None	5059	Duplex along 156th eastside	SF	1	62	48	Ldn	59	65	--	--	--	--	--	48	0
	5422560050	6319 156TH PL NE	None	5060	SF residences along 156th eastside	SF	1	64	48	Ldn	61	66	--	--	--	--	--	48	0
	5422560040	6405 156TH PL NE	None	5060	SF residences along 156th eastside	SF	1	64	48	Ldn	61	66	--	--	--	--	--	48	0

Redmond Light Rail Extension

Transit Noise Analysis

Total Units Analyzed	Total Impacts	Mod Imp	Sev Imp
193		29	8

1. Mitigated noise levels include any noise reduction regardless of impact (e.g., receivers without impacts located behind noise walls may have reduced noise due to the wall).
2. Sp Trk Wk = Special Track work (e.g., special crossovers).

Receiver/Area Information						Impact Analysis									Project Noise Level with Mitigation				
Area	Parcel	Address	4 Digit Identifier	Station	Description	Type	Units	Ldn/Leq	Ldn/Leq	Type	Moderate	Severe	Mod Imp	Sev Imp	Sound Wall	X-Over	Insulation	Project Levels (1)	Impacts
	5422560030	6415 156TH PL NE	None	5061	SF residences along 156th eastside	SF	1	64	49	Ldn	61	66	--	--	--	--	--	49	0
	5422560020	6423 156TH PL NE	None	5062	Duplex along 156th eastside	SF	1	66	49	Ldn	62	68	--	--	--	--	--	49	0
	5422560010	6431 156TH PL NE	None	5063	Duplex along 156th eastside	SF	1	66	49	Ldn	62	68	--	--	--	--	--	49	0
	5422560140	15603 NE 65TH ST	None	5064	Last house in group	SF	1	64	48	Ldn	61	66	--	--	--	--	--	48	0
	542256TRCT	6526 156TH AVE NE	RL143	5067	Large SF Property at Dead End	SF	1	70	51	Ldn	65	70	--	--	--	--	--	51	0
	5422560670	15810 NE 67TH PL	RL145	5069	SF on NE 67th Pl on 520	SF	1	74	55	Ldn	66	73	--	--	--	--	--	55	0
	5422560660	15816 NE 67TH PL	RL146	5070	SF on NE 67th Pl on 520	SF	1	74	54	Ldn	66	73	--	--	--	--	--	54	0
	5422560650	15822 NE 67TH PL	RL147	5070	SF on NE 67th Pl on 520	SF	1	74	54	Ldn	66	73	--	--	--	--	--	54	0
	5422560640	15828 NE 67TH PL	RL148	5071	SF on NE 67th Pl on 520	SF	1	74	62	Ldn	66	73	--	--	Wall at 6 Ft..	--	--	51	0
	5422560630	15834 NE 67TH PL	RL149	5072	SF on NE 67th Pl on 520	SF	1	74	70	Ldn	66	73	1	--	Wall at 6 Ft..	--	--	59	0
	5422560620	15840 NE 67TH PL	RL150	5072	SF on NE 67th Pl on 520	SF	1	74	71	Ldn	66	73	1	--	Wall at 6 Ft..	--	--	58	0
	5422560610	15846 NE 67TH PL	RLNA5	5073	SF on NE 67th Pl on 520	SF	1	74	69	Ldn	66	73	1	--	Wall at 6 Ft..	--	--	57	0
	5422560600	6640 159TH AVE NE	None	5073	SF on NE 67th Pl on 520	SF	1	72	68	Ldn	66	72	1	--	Wall at 6 Ft..	--	--	55	0
	5422560590	6634 159TH AVE NE	None	5073	SF on NE 67th Pl on 520	SF	1	72	67	Ldn	66	72	1	--	Wall at 6 Ft..	--	--	54	0
	5422560580	6628 159TH AVE NE	None	5073	SF on NE 67th Pl on 520	SF	1	70	65	Ldn	65	70	1	--	Wall at 6 Ft..	--	--	53	0
	5422560690	15803 NE 67TH PL	RL600	5068	Second line on NE 67th PL	SF	1	66	43	Ldn	62	68	--	--	--	--	--	43	0
	5422560700	15809 NE 67TH PL	None	5069	Second line on NE 67th PL	SF	1	66	43	Ldn	62	68	--	--	--	--	--	43	0
	5422560710	15815 NE 67TH PL	None	5070	Second line on NE 67th PL	SF	1	66	43	Ldn	62	68	--	--	--	--	--	43	0
	5422560720	15821 NE 67TH PL	None	5071	Second line on NE 67th PL	SF	1	66	58	Ldn	62	68	--	--	Wall at 6 Ft..	--	--	48	0
	5422560730	15827 NE 67TH PL	None	5071	Second line on NE 67th PL	SF	1	66	58	Ldn	62	68	--	--	Wall at 6 Ft..	--	--	47	0
	5422560740	15833 NE 67TH PL	None	5071	Second line on NE 67th PL	SF	1	66	58	Ldn	62	68	--	--	Wall at 6 Ft..	--	--	47	0
	5422560750	15841 NE 67TH PL	None	5072	Second line on NE 67th PL	SF	1	66	61	Ldn	62	68	--	--	Wall at 6 Ft..	--	--	49	0
	5422560570	6622 159TH AVE NE	None	5074	SF facing east along NE 167-159	SF	1	68	60	Ldn	63	69	--	--	Wall at 6 Ft..	--	--	47	0
	5422560560	6616 159TH AVE NE	None	5074	SF facing east along NE 167-159	SF	1	68	59	Ldn	63	69	--	--	Wall at 6 Ft..	--	--	47	0
	5422560550	6610 159TH AVE NE	None	5074	SF facing east along NE 167-159	SF	1	67	57	Ldn	63	68	--	--	Wall at 6 Ft..	--	--	45	0
	5422560540	6604 159TH AVE NE	None	5074	SF facing east along NE 167-159	SF	1	67	57	Ldn	63	68	--	--	Wall at 6 Ft..	--	--	45	0
Sammamish River to Bear Creek																			
	MM-1/M7A	Marymoor Park	None	5088	Westside Ballfields	Sports	1	58	62	Leq	N/A	N/A	N/A	N/A	--	--	--	62	N/A
	MM-2/M7B	Marymoor Park	None	5093	Willowmoor Farm, Maintenance Shops	Comm	1	53	54	Leq	N/A	N/A	N/A	N/A	--	--	--	54	N/A
	MM-3/M7C	Marymoor Park	None	5107	Westside near Connector Trail	Sports	1	54	57	Leq	60	67	--	--	--	--	--	57	0
	MM-4/M7D	Marymoor Park	None	5115	Eastside Near Velodrome	Sports	1	59	60	Leq	N/A	N/A	N/A	N/A	--	--	--	60	N/A
	MM-5/M7E	Marymoor Park	None	5120	Heron Loop and Sparrow Loop Trails	PK	1	53	46	Leq	60	66	--	--	--	--	--	46	0
	MM-6	Marymoor Park	None	5093	Marymoor Connector Trail (at Bridge)	Sports	1	52	57	Leq	60	66	--	--	--	--	--	57	0
	MM-7	Marymoor Park	None	5100	Walking Path (Near river, north of NE Maryn	Sports	1	56	56	Leq	61	68	--	--	--	--	--	56	0
	MM-8	Marymoor Park	None	5113	Walking Path (Near river, north west area)	Ent	1	54	51	Leq	60	67	--	--	--	--	--	51	0
	MM-9	Marymoor Park	None	5117	King County Parks Division Offices	Sports	1	52	50	Leq	N/A	N/A	N/A	N/A	--	--	--	50	N/A
	MM-10	Marymoor Park	None	5086	Public Use Play Area	Sports	1	50	56	Leq	59	65	--	--	--	--	--	56	0
	MM-11	Marymoor Park	None	5093	Central Parking and Green Space	Sports	1	52	54	Leq	60	66	--	--	--	--	--	54	0
	MM-12	Marymoor Park	None	5100	Community Gardens Area	Sports	1	50	52	Leq	59	65	--	--	--	--	--	52	0
	MM-13	Marymoor Park	None	5100	Center of Cricket Fields	Sports	1	60	59	Leq	N/A	N/A	N/A	N/A	--	--	--	59	N/A
	MM-14	Marymoor Park	None	5113	Center of Event Pad	Ent	1	59	60	Leq	N/A	N/A	N/A	N/A	--	--	--	60	N/A
	MM-15	Marymoor Park	None	5113	Northern Part of Velodrome	Ent	1	64	63	Leq	N/A	N/A	N/A	N/A	--	--	--	63	N/A
	MM-16	Marymoor Park	None	5117	Rock Climbing Wall	Sports	1	54	53	Leq	N/A	N/A	N/A	N/A	--	--	--	53	N/A
Bear Creek to Downtown Redmond															--	--	--		
	7202410132	Towncenter Apts	None	5155	NEW – Redmond Town Center Apartments 1	MF	4	64	67	Ldn	61	66	--	4	Wall at 8 Ft..	Sp Trk Wk (2)	--	53	0
	7202410132	Towncenter Apts	None	5156	NEW – Redmond Town Center Apartments 1	MF	4	64	65	Ldn	61	66	4	--	Wall at 8 Ft..	--	--	52	0
	7202410132	Towncenter Apts	None	5157	NEW – Redmond Town Center Apartments 1	MF	6	64	63	Ldn	61	66	6	--	Wall at 8 Ft..	--	--	50	0
	7202410132	Towncenter Apts	None	5155	NEW – Redmond Town Center Apartments 1	MF	4	64	67	Ldn	61	66	--	4	Wall at 8 Ft..	Sp Trk Wk (2)	--	58	0
	7202410132	Towncenter Apts	None	5156	NEW – Redmond Town Center Apartments 1	MF	4	64	65	Ldn	61	66	4	--	Wall at 8 Ft..	--	--	58	0
	7202410132	Towncenter Apts	None	5157	NEW – Redmond Town Center Apartments 1	MF	6	64	64	Ldn	61	66	6	--	Wall at 8 Ft..	--	--	55	0
															--	--	--		
	7202410060	7575 164TH AVE NE	RL199	5168	Upper floors only	MF	6	62	57	Ldn	59	65	--	--	--	--	--	57	0
	7202410061	7576 164TH AVE NE	RL199	5168	Upper floors only	MF	6	62	57	Ldn	59	65	--	--	--	--	--	57	0
	7202410062	7577 164TH AVE NE	RL199	5168	Upper floors only	MF	6	62	57	Ldn	59	65	--	--	--	--	--	57	0
															--	--	--		

Redmond Light Rail Extension

Transit Noise Analysis

Total Units Analyzed	Total Impacts	Mod Imp	Sev Imp
193		29	8

1. Mitigated noise levels include any noise reduction regardless of impact (e.g., receivers without impacts located behind noise walls may have reduced noise due to the wall).
2. Sp Trk Wk = Special Track work (e.g., special crossovers).

Receiver/Area Information						Impact Analysis									Project Noise Level with Mitigation				
Area	Parcel	Address	4 Digit Identifier	Station	Description	Type	Units	Ldn/Leq	Ldn/Leq	Type	Moderate	Severe	Mod Imp	Sev Imp	Sound Wall	X-Over	Insulation	Project Levels (1)	Impacts
	7198800016	16325 CLEVELAND ST	RL200	5168	Upper floors only	MF	6	62	57	Ldn	59	65	--	--	--	--	--	57	0
	7198800016	16325 CLEVELAND ST	RL200	5168	Upper floors only	MF	6	62	57	Ldn	59	65	--	--	--	--	--	57	0
	7198800016	16325 CLEVELAND ST	RL200	5168	Upper floors only	MF	6	62	57	Ldn	59	65	--	--	--	--	--	57	0
East Side of SR 520																			
Redmond Technology Center Station to Sammamish River															--	--	--		
	9265200010	6006 153RD CT NE	None	15049	SF residence east of SR 520	SF	1	64	56	Ldn	61	66	--	--	--	--	--	56	0
	9265200020	6014 153RD CT NE	None	15050	SF residence east of SR 521	SF	1	64	56	Ldn	61	66	--	--	--	--	--	56	0
	9265200030	6022 153RD CT NE	None	15051	SF residence east of SR 522	SF	1	64	56	Ldn	61	66	--	--	--	--	--	56	0
	7197350070	15329 NE 62ND CT	None	15053	SF residence east of SR 523	SF	1	64	56	Ldn	61	66	--	--	--	--	--	56	0
	7197350080	15332 NE 62ND CT	None	15054	SF residence east of SR 524	SF	1	64	56	Ldn	61	66	--	--	--	--	--	56	0
	7197350090	6201 154TH AVE NE	None	15054	SF residence east of SR 525	SF	1	64	56	Ldn	61	66	--	--	--	--	--	56	0
															--	--	--		
	9435300111	6212 154TH AVE NE	None	15050	SF residence east of SR 520	SF	1	65	58	Ldn	61	67	--	--	--	--	--	58	0
	9435300112	6218 154TH AVE NE	None	15051	SF residence east of SR 521	SF	1	65	58	Ldn	61	67	--	--	--	--	--	58	0
	9435300114	6222 154TH AVE NE	None	15051	SF residence east of SR 522	SF	1	65	58	Ldn	61	67	--	--	--	--	--	58	0
	9435300113	6228 154TH AVE NE	None	15052	SF residence east of SR 523	SF	1	65	58	Ldn	61	67	--	--	--	--	--	58	0
	9435300115	6232 154TH AVE NE	RLNA17	15054	SF residence east of SR 524	SF	1	65	58	Ldn	61	67	--	--	--	--	--	58	0
	9435300109	6450 154TH AVE NE	RLNA16	15060	SF residence east of SR 525	SF	1	65	57	Ldn	61	67	--	--	--	--	--	57	0
	9435300107	6452 154TH AVE NE	RLNA15	15061	SF residence east of SR 525	SF	1	65	57	Ldn	61	67	--	--	--	--	--	57	0
	9435300085	6530 154TH AVE NE	None	15064	SF residence east of SR 525	SF	1	65	57	Ldn	61	67	--	--	--	--	--	57	0
	9435300105	6236 154TH AVE NE	None	15059	SF residence east of SR 525	SF	1	65	55	Ldn	61	67	--	--	--	--	--	55	0
	9435300108	6446 154TH AVE NE	None	15060	SF residence east of SR 525	SF	1	65	55	Ldn	61	67	--	--	--	--	--	55	0
															--	--	--		
	7694800060	15579 NE 68TH CT	None	15066	SF residence east of SR 525	SF	1	66	57	Ldn	62	68	--	--	--	--	--	57	0
	7694800050	15573 NE 68TH CT	None	15067	SF residence east of SR 525	SF	1	66	55	Ldn	62	68	--	--	--	--	--	55	0
	7694800040	15567 NE 68TH CT	None	15067	SF residence east of SR 525	SF	1	66	54	Ldn	62	68	--	--	--	--	--	54	0
	7694800070	15585 NE 68TH CT	None	15068	SF residence east of SR 525	SF	1	66	56	Ldn	62	68	--	--	--	--	--	56	0
	7694800080	15591 NE 68TH CT	None	15068	SF residence east of SR 525	SF	1	66	58	Ldn	62	68	--	--	--	--	--	58	0
	7694800090	6801 156TH PL NE	None	15068	SF residence east of SR 525	SF	1	66	55	Ldn	62	68	--	--	--	--	--	55	0
	7694800330	6802 156TH PL NE	None	15069	SF residence east of SR 525	SF	1	66	57	Ldn	62	68	--	--	--	--	--	57	0
	7694800300	6830 156TH PL NE	None	15069	SF residence east of SR 525	SF	1	66	57	Ldn	62	68	--	--	--	--	--	57	0
	7694800290	6838 156TH PL NE	None	15070	SF residence east of SR 525	SF	1	66	57	Ldn	62	68	--	--	--	--	--	57	0
	7694800280	6846 156TH PL NE	None	15071	SF residence east of SR 525	SF	1	66	57	Ldn	62	68	--	--	--	--	--	57	0
	7694800270	6854 156TH PL NE	None	15071	SF residence east of SR 525	SF	1	66	56	Ldn	62	68	--	--	--	--	--	56	0
	1125059114	6890 156TH PL NE	None	15072	SF residence east of SR 525	SF	1	66	61	Ldn	62	68	--	--	Wall at 4 Ft..	--	--	58	0
	5196000000	7002 155TH PL NE	None	15073	MF- Southern most building	SF	1	66	60	Ldn	62	68	--	--	Wall at 4 Ft..	--	--	52	0
	5196000000	7002 155TH PL NE	None	15074	MF - Northern most building - Near units	SF	1	66	65	Ldn	62	68	1	--	Wall at 4 Ft..	--	--	56	0
	5196000000	7002 155TH PL NE	None	15075	MF-Northern most building - Second units	SF	1	66	59	Ldn	62	68	--	--	Wall at 4 Ft..	--	--	51	0

Attachment E

Traffic Noise Analysis

Downtown Redmond Link Extension
Attachment E Traffic Noise Analysis
Noise and Vibration Technical Report

August 2018

Prepared for

Central Puget Sound Regional Transit Authority
401 S. Jackson Street
Seattle, WA 98104

Prepared by

Michael Minor & Associates, Inc.
Portland, Oregon

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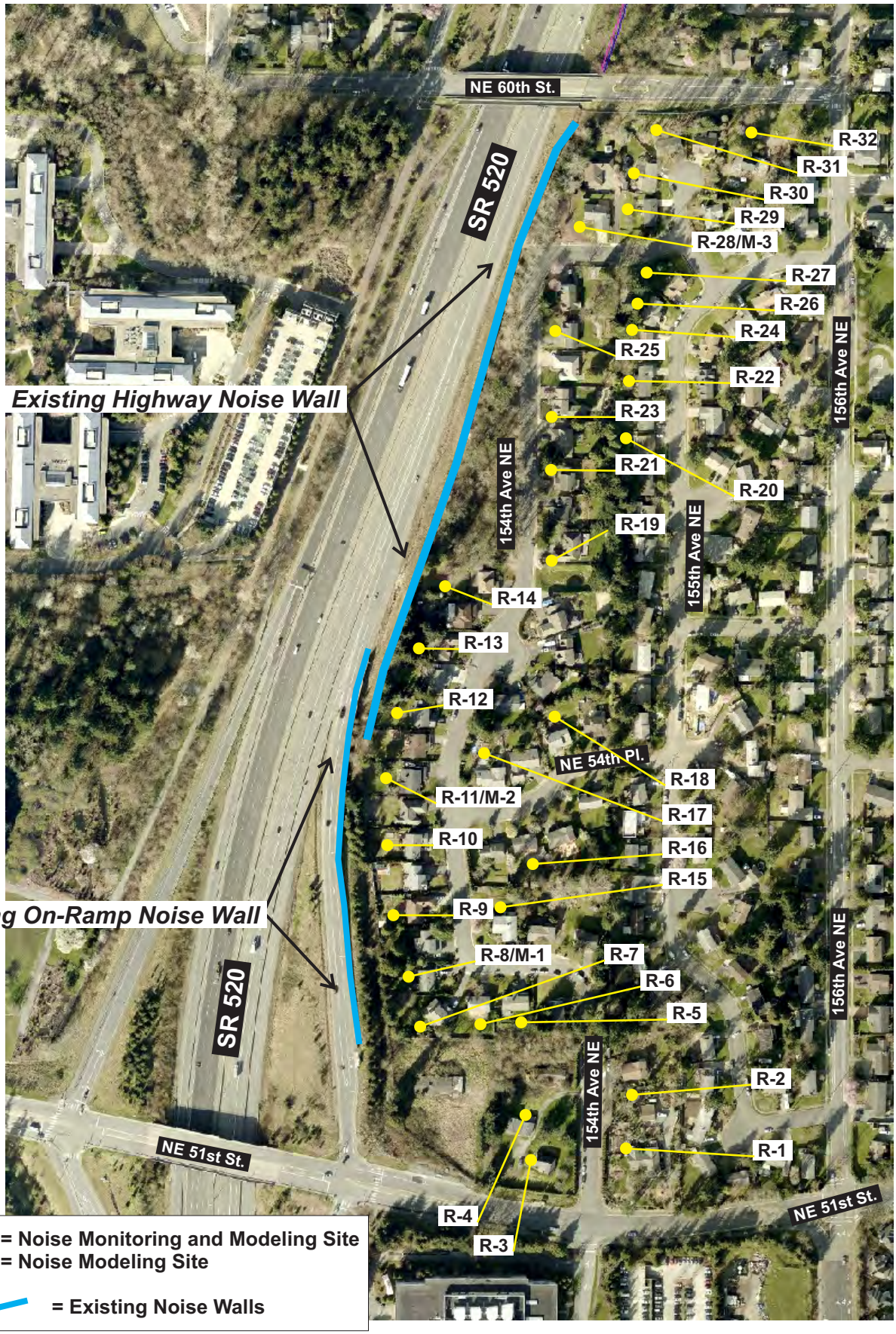
TRAFFIC NOISE INTRODUCTION

The potential to create or increase exposure to traffic noise as a result of the Downtown Redmond Link Extension Project occurs due to the relocation of two existing traffic noise walls. The two noise walls provide traffic noise abatement for residences between NE 51st Street and NE 60th Street on the east side of SR 520. Because the existing noise wall must be relocated to accommodate the light rail alignment, on-site noise monitoring, concurrent traffic counts and detailed modeling of a traffic levels was performed.

To assist in the design of the noise wall, existing traffic noise levels and future (year 2035) No Build Alternative traffic noise levels were projected and compared to the future (year 2035) traffic noise levels with the replacement noise wall. The analysis was performed at 32 sites represent 67 single-family residences between NE 51st Street and NE 60th Street.

Figure E-1 provides an overview of the area, identifies the noise monitoring locations, 32 modeling sites and the location of the existing noise walls. Receivers are denoted R-1 through R-32. Receivers that were also used for on-site noise monitoring have an additional M-# notation, for example, R-8/M-1.



0 150 300 300

1.00 in

Approximate Scale 1 inch to 300 feet

N

Michael Minor & Associates
Sound.Vibration.Air
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Figure E-1
Noise Monitoring & Modeling Sites
Existing Noise Walls

MODELING AND WALL DESIGN METHODS

Existing and future traffic noise level conditions were calculated using the FHWA Traffic Noise Model (TNM version 2.5, FHWA 2004). Prior to predicting the existing and future noise levels, the traffic noise model was verified using actual traffic counts and measured noise levels, as described below. Noise emission levels used in the model were nationwide averages for automobiles, medium trucks, and heavy trucks provided by the FHWA and are built into the TNM. The area was evaluated for noise reducing effects of front-line residences, existing outbuildings, roadway depressions and topography, all of which were included in the model where appropriate. Under the Proposed Design Refinements (Build alternative), the light rail alignment and associated retaining walls were also included in the model.

Modeling data was received from WSDOT, project traffic engineers, and project design engineers. The current SR 520 roadway configuration was obtained from the "As-Built" design files from WSDOT along with updated survey information from the project design team. This information also included the existing noise walls top and bottom elevations. Traffic data for existing year 2017, future year 2035 No Build and future year 2035 build were obtained from the traffic engineers.

Model Validation

Prior to using the model for noise predictions, a validation of the model was performed. Measurements noise levels at sites, M-1, M-2, and M-3 were used to validate the traffic noise model using traffic counts performed simultaneously with the noise monitoring. The modeled and measured noise levels agreed within +/- 2 dB, which is an acceptable deviation between measured and modeled noise levels. Table E-1 provides the results of the model validation process.

Table E-1. Noise Modeling Validation Results

Rec #	Location	Date, Time	Measured	Modeled	Difference
M-1	5219 154th Avenue NE	9/12/17, 9:00 am	54.6	56.3	-1.7
M-2	5409 154th Avenue NE	9/12/17, 9:00 am	58.2	57.8	0.4
M-3	15406 NE 59th Way	9/12/17, 9:00 am	61.2	61.0	0.2

Source: FHWA noise modeling using traffic counts taken to correspond to the measured noise levels.

TRAFFIC NOISE MODELING RESULTS

Existing and Future No Build Traffic Noise Levels

Existing condition noise levels were predicted at the 32 sites using year 2017 traffic data for the PM peak hour. Existing noise levels ranged from 54 to 65 dBA Leq. The highest existing noise levels were at the site R-1and R-3, both located adjacent to NE 51st Street, which is the dominated noise source at these homes. Under the future No Build, slight increases in traffic volumes will result in slight increases of 0 to 1 dB over the existing conditions. For reference, a typical person needs a 3 dB change in traffic noise to perceive a change in noise. Table E-2 provides a summary of the existing and future No Build traffic noise levels.

Table E-2. Summary of Potential Noise Mitigation Measures

Rec #[1]	Description/Address[2]	Units Rep[3]	Peak Hour Traffic Noise Level (Leq, dBA)			Change in dB[7]	Above Criteria[8]
			Criteria[4]	Existing[5]	No Build[6]		
R-1	R-1 through R-4 are single family residences located near 51st Street along 154th Avenue NE	1[9]	66	65	65	0	No
R-2		2	66	58	59	1	No
R-3		1	66	64	65	1	No
R-4		1	66	60	61	1	No
R-5	Homes on 154th Avenue facing north	2	66	58	58	0	No
R-6		1	66	58	59	1	No
R-7		1	66	58	59	1	No
R-8 - M-1	5219 154th Avenue NE	2	66	58	58	0	No
R-9	Adjacent to wall on 154th Avenue NE	2	66	58	59	1	No
R-10		2	66	60	60	0	No
R-11 - M-2	5409 154th Avenue NE	2	66	60	60	0	No
R-12	Adjacent to wall on 154th Avenue NE	2	66	61	61	0	No
R-13		2	66	63	64	1	No
R-14		1	66	62	63	1	No
R-15	Homes on the east side of 154th Avenue NE and NE 54th Place	2	66	57	57	0	No
R-16		4	66	54	55	1	No
R-17		3	66	58	59	1	No
R-18		3	66	56	56	0	No
R-19	Facing 520 on 154th Avenue NE	2	66	57	58	1	No
R-20	On 155th Avenue NE	7	66	57	58	1	No
R-21	Facing 520 on 154th Avenue NE	2	66	58	58	0	No
R-22	On 155th Avenue NE	4	66	58	59	1	No
R-23	Facing 520 on 154th Avenue NE	2	66	60	60	0	No
R-24	On 155th Avenue NE	1	66	60	60	0	No
R-25	Facing 520 on 154th Avenue NE	2	66	61	62	1	No
R-26	On 155th Avenue NE	1	66	60	61	1	No
R-27	On 155th Avenue NE	2	66	61	62	1	No
R-28 - M-3	15406 NE 59th Way	1	66	63	64	1	No
R-29	On 155th Avenue cul-de-sac	1	66	61	61	0	No
R-30	On 155th Avenue cul-de-sac	1	66	63	64	1	No
R-31	On 155th Avenue cul-de-sac	2	66	62	63	1	No
R-32	On 155th Avenue cul-de-sac	4	66	58	59	1	No

Source: FHWA traffic noise mode with projected traffic volumes from project traffic engineers.

1. Receivers shown on Figure E-1
2. Address of site or general description of the modeling location
3. Number of homes expected to have the same noise level
4. FHWA and WSDOT criteria for traffic noise abatement
5. Existing (year 2017) PM peak hour traffic noise levels
6. Future No Build (year 2035) PM peak hour traffic noise levels
7. Expected increase between existing traffic noise and year 2035 traffic noise levels
8. Number of units with noise levels meeting the FHWA and WSDOT criteria for traffic noise abatement
9. At this time the property represented by R-1 is under redevelopment and was assumed residential, however no permits have been issued to date

FUTURE CONDITIONS TRAFFIC NOISE LEVELS

Using traffic data predicted for the year 2035, and assuming the construction of the Downtown Redmond Link Extension Project, a replacement noise wall was designed. The proposed replacement wall would be located adjacent to the light rail corridor, approximately 7 feet from the eastbound tracks, and along a proposed retaining wall in some locations. The wall would be closer to the residences, and located along a slight rise, so the base of the wall would be above the grade of SR 520.

The design parameter for the replacement wall was to ensure there would be no new traffic noise impacts or increased severity of any existing traffic impacts. In addition, the wall must also provide noise mitigation for light rail operations. Because the light rail alignment is close to the wall, and in a retained cut through much of this area, noise walls of 4 to 8-foot walls would typically be sufficient for mitigation. Due to noise from heavy trucks and the width of the roadway, noise walls for traffic mitigation are typically much taller than light rail noise walls, and typically range from 10 feet up to 16 feet, or taller, depending on the receiver roadway geometry. In addition, because the wall would be located along the top of a retaining wall in the cut segments, the effective wall height would be increased and could provide better noise reduction at lower wall heights.

The proposed wall would be effective at maintaining noise levels within the project criteria of no new noise impacts. The replacement wall would be approximately 2,163 feet in length, extending from just north of NE 51st Street to NE 60th Street, with wall heights ranging from 6 to 10 feet (10 to 30 feet above the top of rail). The replacement wall is shown on Figure E-2 and includes the approximate height of the wall above the local grade elevation.

The modeled data from Table E-2 was used to compare the future (year 2035) traffic noise levels with the replacement noise wall. Included in the analysis was the peak hour Leq noise level from light rail operations assuming the wall was constructed. Complete modeled traffic noise levels, comparing the existing conditions, future No Build and future Build with the replacement noise wall are provided in Table E-3.

Future noise levels in the southern end of the area (receivers R-1 through R-7) will see slight increases of 1 to 2 dB in total noise levels when compared to the Future No Build, due mainly to traffic volumes increasing along 51st Street. Through the central area represented by receiver R-8 through R-14, the change in noise levels range from -1 to 2 dB. Second line receivers, R-15 through R-27, may see slight increases of 1 dB, with some having reductions of 1 dB. Finally, in the north end, near the NE 60th Street overpass, noise levels reduction of up to 2 dB could occur, with some receivers having slight increases of 1 dB.

Overall the changes in the total noise of -2 to 2 dB when compared to the No Build are not normally perceptible to the average person. It typically takes a change in the noise of more than 3 dB for that change to be clearly perceptible. With the proposed replacement wall, all receivers will have noise levels below the FHWA and WSDOT criteria even with the light rail included. Furthermore, noise from light rail operations are also well below the FTA criteria using the 24-hour Ldn metric. Light rail Ldn noise levels for the homes along this area are provided in Chapter 5 of Appendix B, Noise and Vibration Technical Report Addendum.

Table E-3. Summary of Potential Noise Mitigation Measures with Replacement Wall

	Peak Hour Traffic Noise Level (Leq, dBA)				Light Rail Peak Hour (Leq dBA)[6]	Total Peak Hour Noise (Leq dBA)[7]	Change in dB[8]		
Rec #[1]	Criteria[2]	Existing[3]	No Build[4]	Build W/Wall[5]			Vs. Existing	Vs. No Build	Above Criteria[9]
R-1[10]	66	65	65	66	39	66	1	1	No
R-2	66	58	59	60	39	60	2	1	No
R-3	66	64	65	65	46	65	1	0	No
R-4	66	60	61	62	46	62	2	1	No
R-5	66	58	58	60	42	60	2	2	No
R-6	66	58	59	60	50	60	2	1	No
R-7	66	58	59	58	50	59	1	0	No
R-8	66	58	58	58	51	59	1	1	No
R-9	66	58	59	58	51	59	1	0	No
R-10	66	60	60	60	53	61	1	1	No
R-11	66	60	60	61	52	62	2	2	No
R-12	66	61	61	62	51	62	1	1	No
R-13	66	63	64	63	51	63	0	-1	No
R-14	66	62	63	63	50	63	1	0	No
R-15	66	57	57	57	41	57	0	0	No
R-16	66	54	55	56	40	56	2	1	No
R-17	66	58	59	58	42	58	0	-1	No
R-18	66	56	56	57	40	57	1	1	No
R-19	66	57	58	58	42	58	1	0	No
R-20	66	57	58	58	40	58	1	0	No
R-21	66	58	58	59	47	59	1	1	No
R-22	66	58	59	59	40	59	1	0	No
R-23	66	60	60	60	48	60	0	0	No
R-24	66	60	60	60	40	60	0	0	No
R-25	66	61	62	61	50	61	0	-1	No
R-26	66	60	61	60	40	60	0	-1	No
R-27	66	61	62	61	38	61	0	-1	No
R-28	66	63	64	63	50	63	0	-1	No
R-29	66	61	61	61	40	61	0	0	No
R-30	66	63	64	62	42	62	-1	-2	No
R-31	66	62	63	62	40	62	0	-1	No
R-32	66	58	59	58	39	58	0	-1	No

Source: FHWA traffic noise mode with projected traffic volumes from project traffic engineers.

1. Receivers shown on Figure E-2
2. FHWA and WSDOT criteria for traffic noise abatement
3. Existing (year 2017) PM peak hour traffic noise levels
4. Future No Build (year 2035) PM peak hour traffic noise levels
5. Future Build noise traffic noise levels with proposed wall
6. Peak hour light rail noise levels using the Leq metric
7. Total noise, future traffic and light rail noise, with the proposed noise wall using the Leq metric
8. Expected increase between existing and future No Build noise and future Build traffic and light rail noise levels using Leq metric
9. Number of units with noise levels meeting the FHWA and WSDOT criteria for traffic noise abatement
10. At this time the property represented by R-1 is under redevelopment and was assumed residential, however no permits have been issued to date

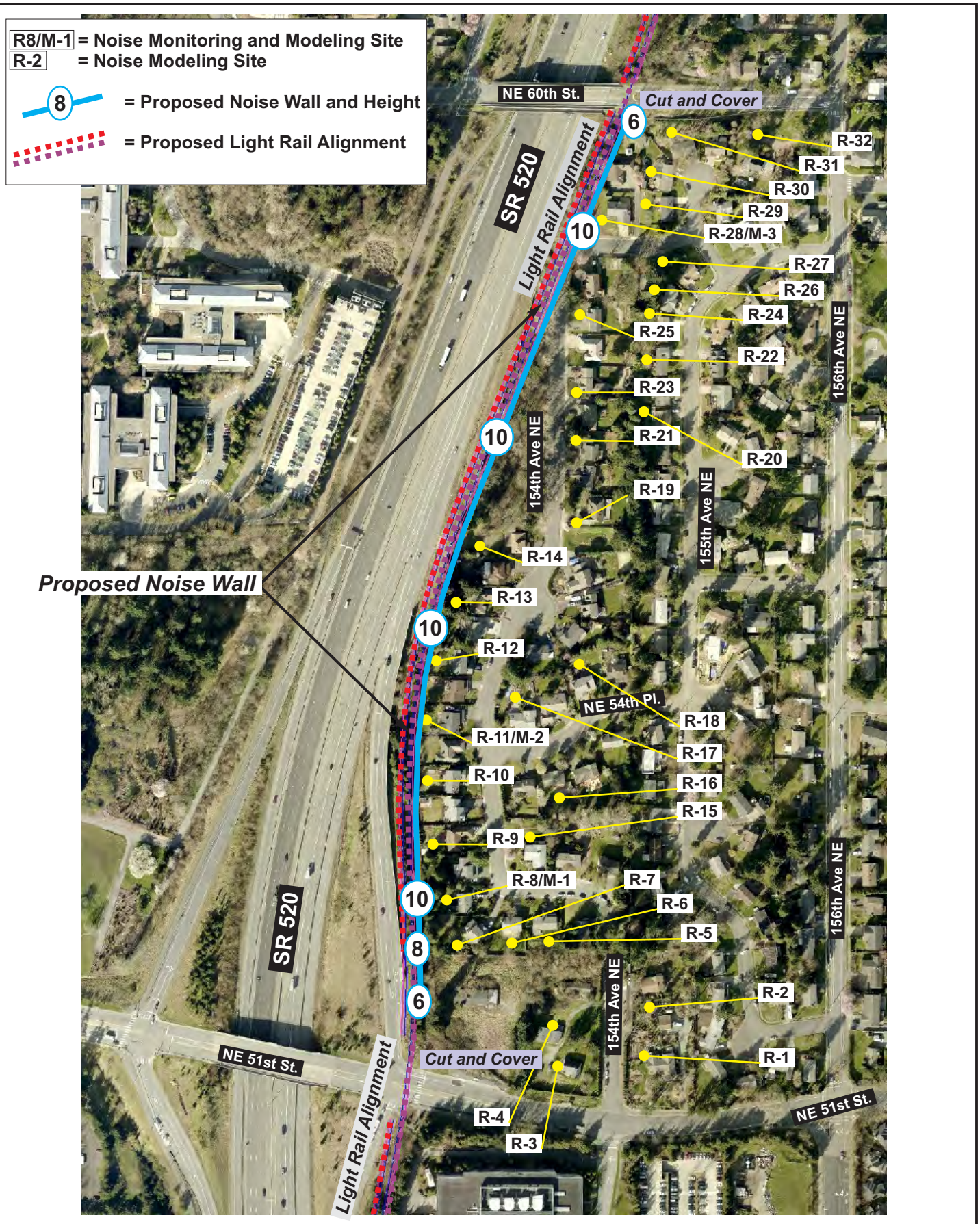

Figure E-2
Noise Monitoring & Modeling Sites
Proposed Noise Wall

REFERENCES

FHWA (Federal Highway Administration). 2004. FHWA Traffic Noise Model (TNM) version 2.5. Available at: https://www.fhwa.dot.gov/environment/noise/traffic_noise_model/tnm_v25/. April 2004.

Attachment F

Impacted Receiver Spectra

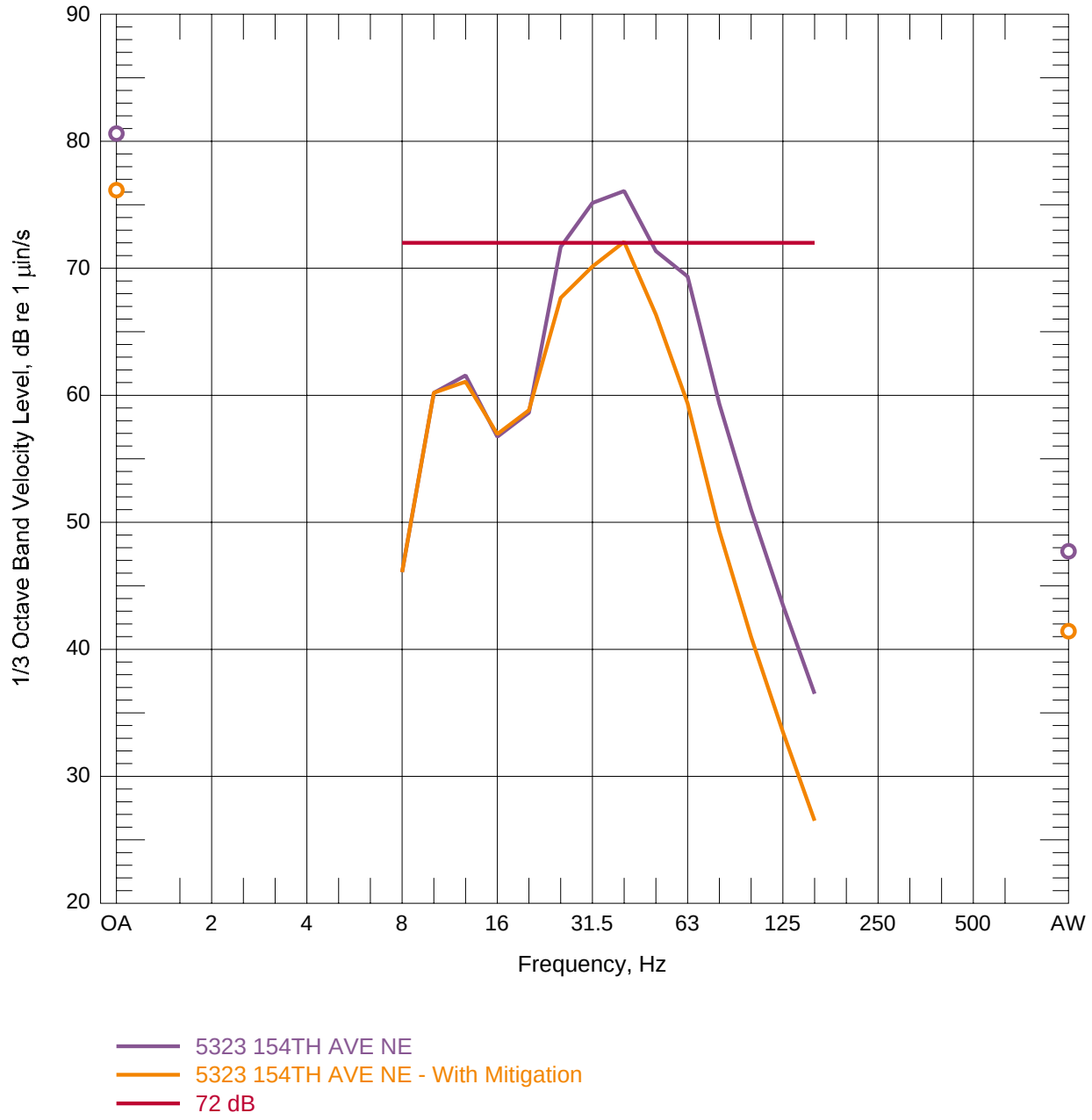

Figure F-1. 5323 154th Avenue NE—Impacted Receiver

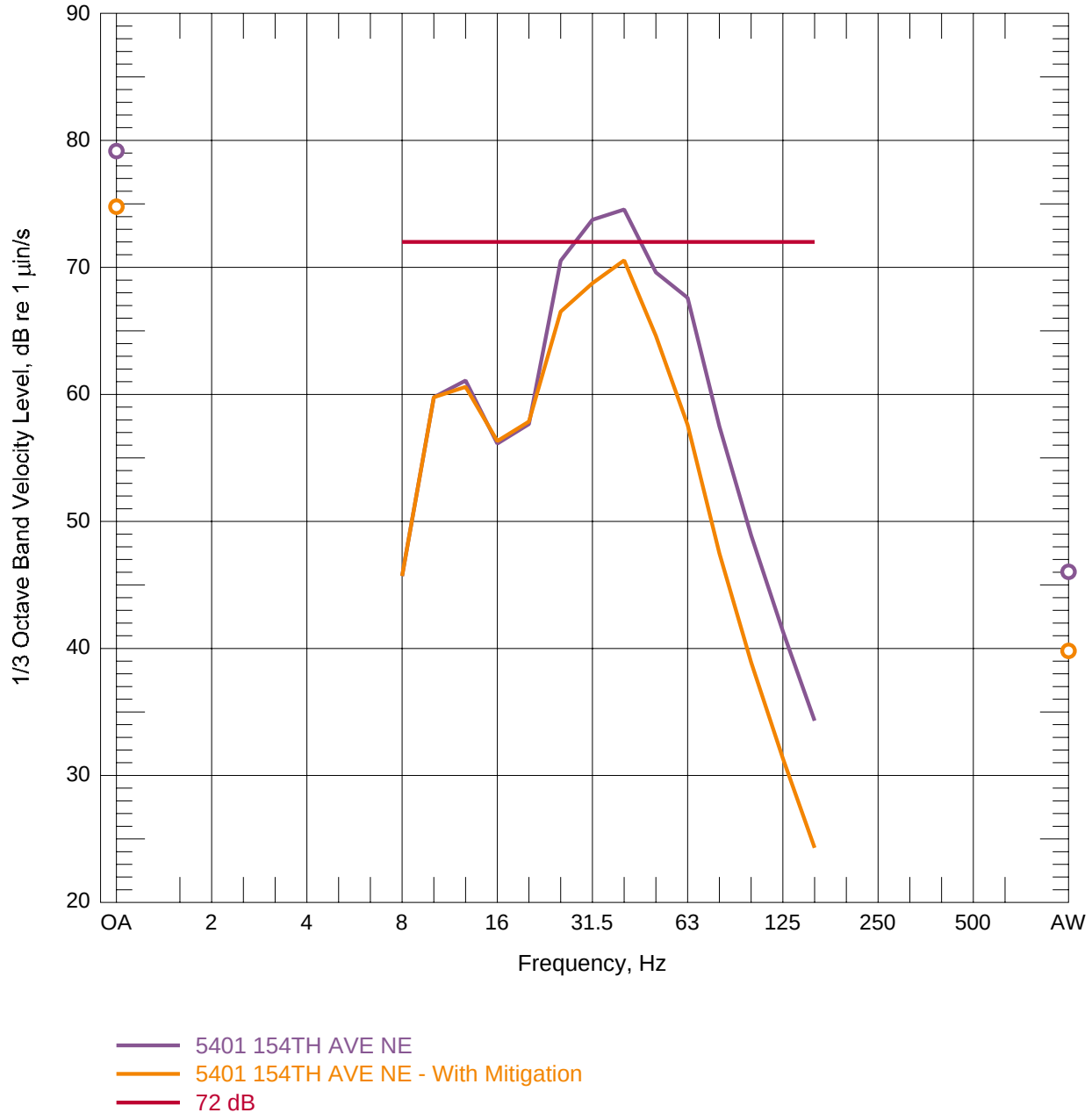

Figure F-2. 5401 154th Avenue NE—Impacted Receiver

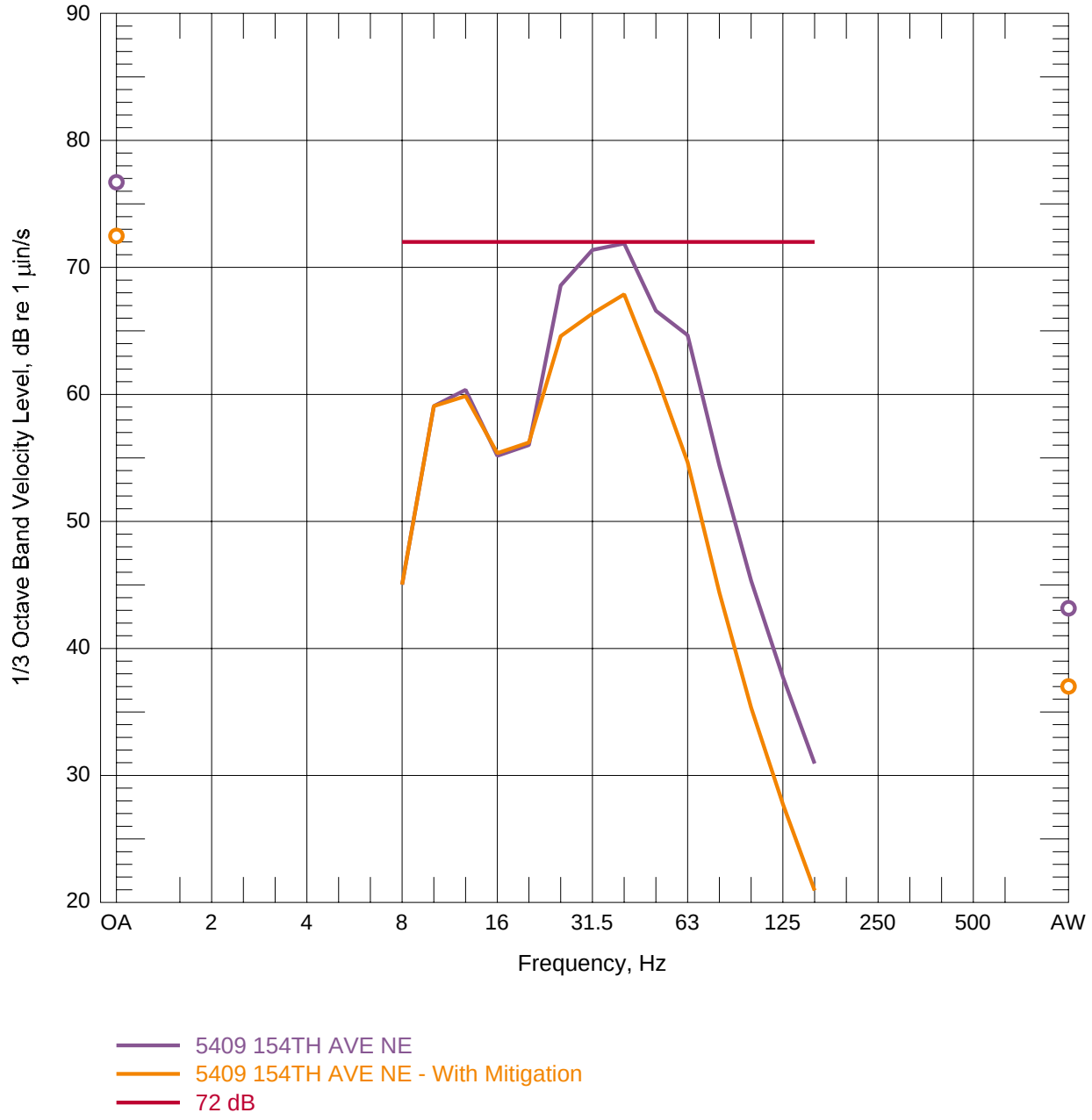

Figure F-3. 5409 154th Avenue NE—Impacted Receiver

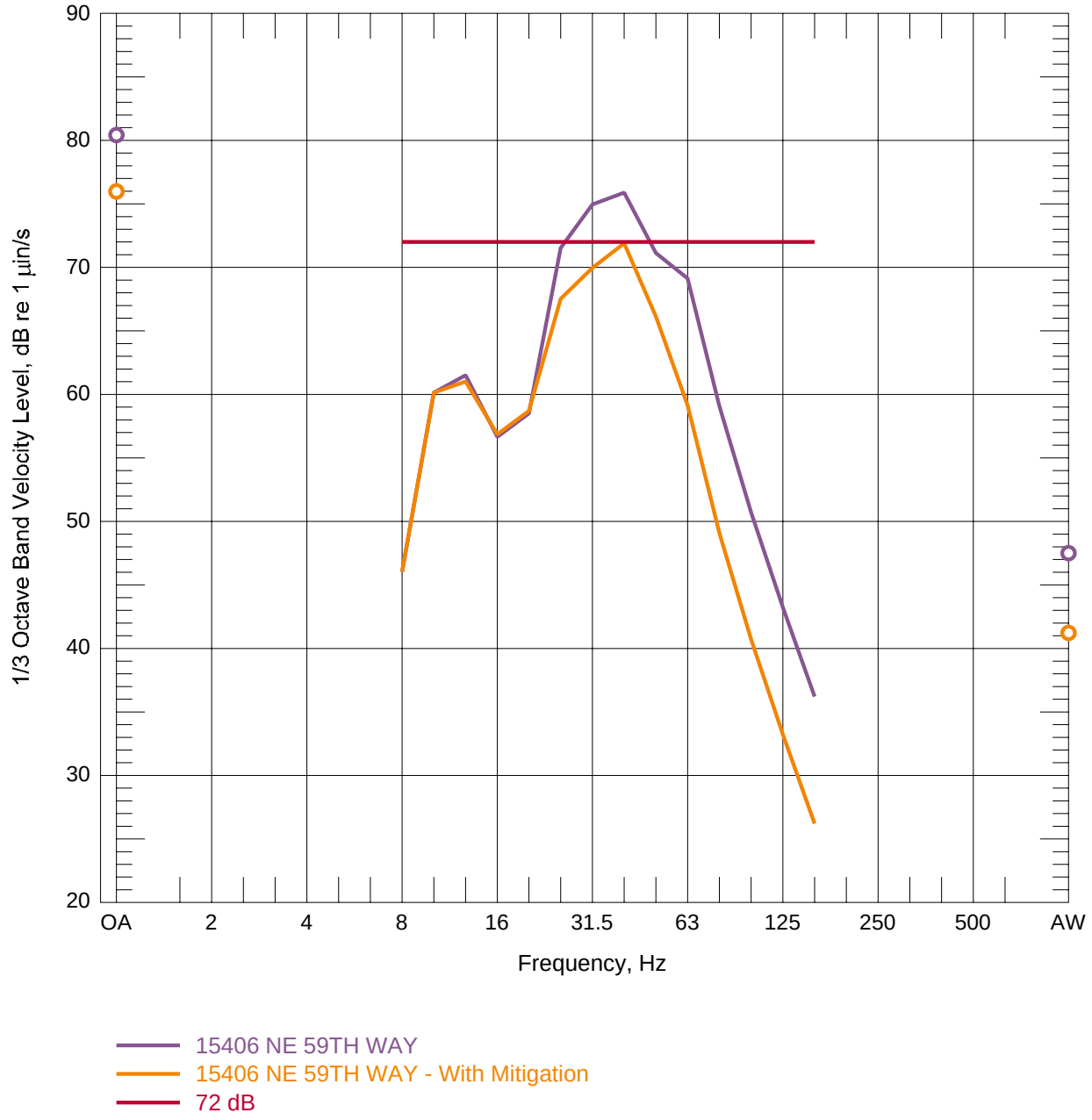

Figure F-4. 15406 NE 59th Way—Impacted Receiver

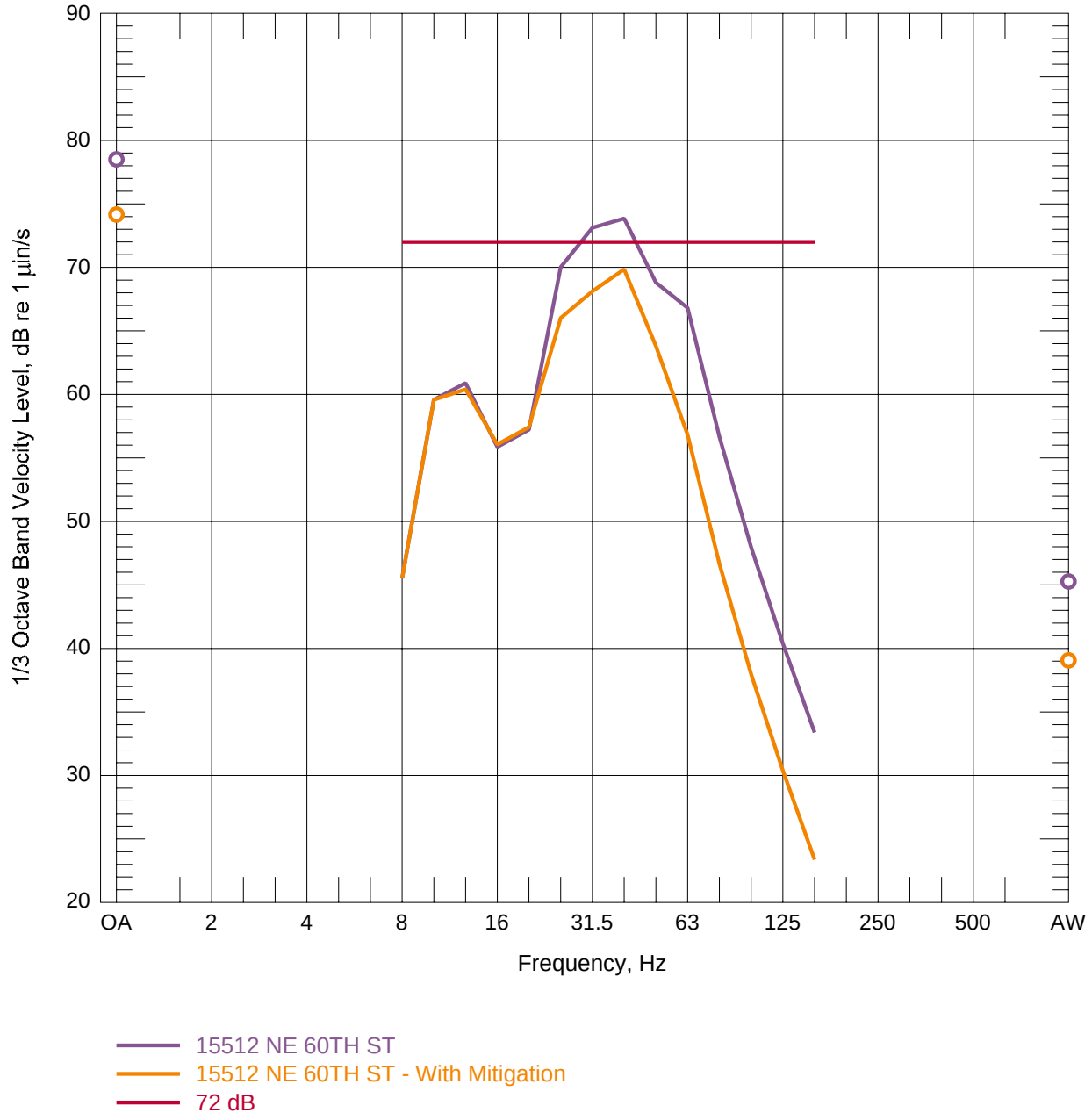

Figure F-5. 15512 NE 60th Street—Impacted Receiver