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Subject:	Second Year Noise and Vibration Testing Results
Project:	Tukwila Noise and Vibration Compliance Testing

Summary

This memorandum summarizes the results of the second year (2010) testing of noise and vibration levels along Sound Transit's Tukwila light rail alignment, as required by the approved *Noise and Vibration Compliance Testing Program Link Light Rail*: *Tukwila Segment*, July 2, 2009 (Compliance Program, 2009). Measurements performed for the second year testing took place in August and September 2010. Results of this analysis show that all locations along the light rail corridor in Tukwila, including those identified as having noise or vibration impacts in the *First Year Noise and Vibration Testing Results*, Revised December 9, 2009 (First Year Testing Results, 2009), are now below the FTA noise and vibration criteria.

Background

The City of Tukwila issued a "Notice of Decision" on September 21, 2004, which included the following condition in the light rail project's Unclassified Use Permit (UUP):

"Sound Transit shall develop a 3-year noise and vibration monitoring program for the TFR Project to be approved by the City. The 3-year period shall start from the start of revenue service. Monitoring shall be conducted at representative locations where impacts and mitigation have been identified in the Final Design Noise Analysis dated July 2004. If measured levels show that noise or vibration attributable to the TFR project exceed FTA criteria as identified in the Final Design Noise Analysis Sound Transit shall provide appropriate reasonable mitigation acceptable to the City."

Sound Transit initially submitted the Compliance Program in early spring of 2009, and after review by the City of Tukwila and their consultants, BRC Acoustics, the plan was approved in the summer of 2009. The noise and vibration criteria and analysis methodologies contained in the Federal Transit Administration's *Transit Noise and Vibration Impact Assessment Manual*, May 2006 (FTA Manual, 2006) provide the basis for the Tukwila UUP and compliance requirements described in the Compliance Program, 2009.

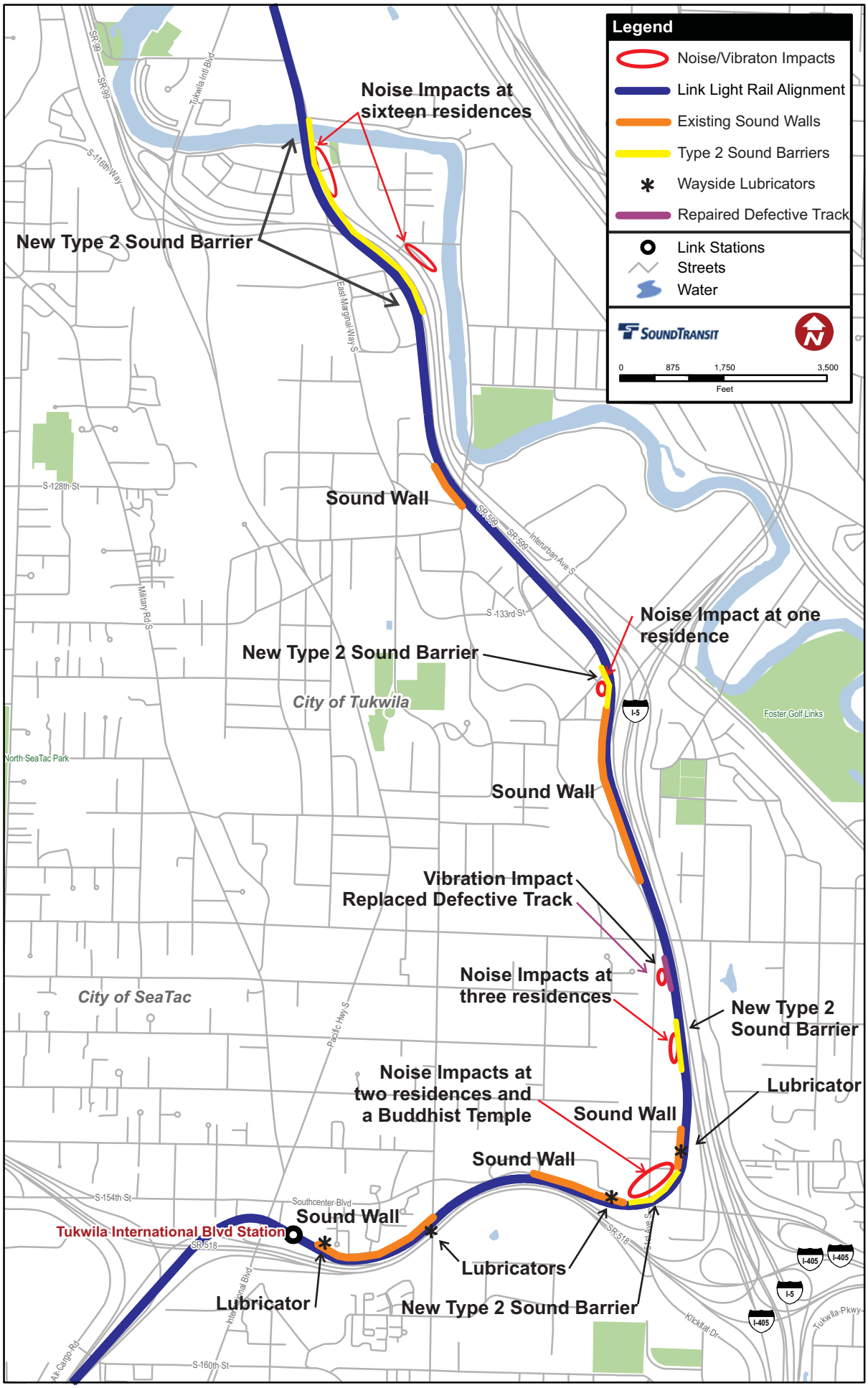
Sound Transit conducted first year compliance noise and vibration monitoring in summer and fall 2009 and the First Year Testing Results, 2009 were reviewed and approved by the City of Tukwila in January 2010. The First Year Testing Results indicated that noise levels exceeded the FTA criteria at several locations along the corridor. In addition, a section of defective track was also identified that resulted in increased vibration levels within a particular segment of the corridor. Since that time, Sound Transit has taken numerous steps,

described herein, to eliminate noise and vibration impacts within the Tukwila segment of the Central Link light rail corridor to below the FTA criteria.

Impacts and Mitigation Measures

In the First Year Testing Results, 2009 analysis, noise impacts were noted in the residential area between Interurban/E Marginal Way and the Duwamish River, represented by receivers N1,N1A, N1B and N1C, a residential property off 48th Ave S, represented by receiver N3, a group of residences in the 149 block of 51st Avenue S, represented by a receiver N6A, and a single and multi-family residence and Buddhist Temple near the curve in the vicinity of 51st/52nd Avenues S and S154th Street represented by receivers N7 and N8, along with a new receiver N8A. Receiver N8A is a new monitoring location that was added due to limited access to site N8, which exceeded the FTA criteria as stated in the First Year Testing Results, 2009. Note that N8A is directly across the street from N8, and at approximately the same distance from the track, and would be expected to have the same noise levels as N8. Prior to finalizing this report, permission was granted and measurements were also taken at Site N8.

Current measurements presented in this report show that all noise impacts identified during the First Year Testing Results, 2009 have been resolved through a combination of track grinding, installation of lubricators and Type 2 sound barriers. Details on these modifications and their overall effectiveness are provided in the following sections. Figure 1 provides an overview of the project area, existing sound walls constructed as part of the project, general locations identified with noise or vibration impacts in the First Year Testing Results, 2009, locations of the new wayside lubricators and new Type 2 sound barriers. Also identified is the segment of defective track that was replaced to remedy the lone vibration impact.


Legend
Noise/Vibraton Impacts
Link Light Rail Alignment
Existing Sound Walls
Type 2 Sound Barriers
Wayside Lubricators
Repaired Defective Track
Link Stations
Streets
Water
SoundTransit
0
875
1,750
3,500
Feet
Noise Impacts at sixteen residences
New Type 2 Sound Barrier
Sound Wall
Noise Impact at one residence
New Type 2 Sound Barrier
City of Tukwila
Sound Wall
Vibration Impact
Replaced Defective Track
Noise Impacts at three residences
New Type 2 Sound Barrier
City of SeaTac
Noise Impacts at two residences and a Buddhist Temple
Lubricator
Sound Wall
Sound Wall
Sound Wall
Tukwila International Blvd Station
Lubricators
Lubricator
New Type 2 Sound Barrier
SR 99
Tukwila Intl Blvd
S 116th Way
East Marginal Way S
S 128th St
Military Rd S
SR 599
Interurban Ave S
S 133rd St
I-5
Foster Golf Links
North SeaTac Park
Pacific Hwy S
S 154th St
Southcenter Blvd
SR 518
International Blvd
Air Cargo Rd
S 160th St
Klickitat Dr
I-405
Tukwila Pkwy

Mitigation Measures

The following section provides details on mitigation measures enacted since the completion of the First Year Testing Results, 2009. This includes the installation of wayside lubricators, Type 2 Sound Barriers and general track maintenance.

Lubricators

Sound Transit installed wayside lubricators, just prior to the curves near SR518 and just east of the Tukwila International Boulevard Station Park and Ride (see Figure 1) to mitigate wheel squeal and flanging noise. Wheel squeal is a high-frequency noise that occurs on curves due to the wheels on the train rotating at different speeds; this noise normally occurs on curves with radii of less than 600 feet. Flanging noise, a broadband grinding noise, occurs when the inner flange of the light rail vehicle wheel rubs along the inside of the rail and can also occur on some curves. The lubricators apply a small amount of friction modifier to the top and side of the rail. The installation of the wayside lubricators has substantially reduced both wheel squeal and flanging noise at both locations. The reduction in these noise sources has contributed to the overall reduction in light rail noise and also helped to reduce the noise impacts predicted in the First Year Testing Results, 2009.

Type 2 Sound Barriers

Type 2 sound barriers were also installed in response to the noise impacts identified in the First Year Testing Results, 2009. The Type 2 sound barriers are manufactured in the USA by Acoustiblok, Inc. Installed Type 2 sound barriers include a 2700 foot barrier positioned near receivers N1 through N1C in the Duwamish Point neighborhood and a 450 foot barrier near N3 off 48th Ave S. A 530 foot segment was installed near receiver N6A on the 149 block of 51st Avenue S, and a 912 foot sound barrier was installed in the vicinity of 51st/52nd Avenues S and S154th Street, connecting two existing sound walls (see Figure 1). The sound barriers have provided approximate noise reductions of 4 to 8 dBA depending on topographic conditions and elevation of the rails relative to the receivers. The Type 2 sound barriers contribute to reducing noise levels at these sites to below the FTA criteria.

Rail Grinding

Over the last year Sound Transit found that light rail noise levels were related to the condition of the rail surface left from project construction. Rail grinding was performed in December 2009 for the entire length of track in Tukwila with the intention of reducing light rail noise. Due to an unforeseeable relationship between the vehicle and residual rail roughness from the grinding, noise levels increased in some locations, most notably south of the Duwamish River. Additional grinding producing a smoother finish surface was performed in July 2010 south of the Duwamish River and at the curve near SR 518. The July grinding reduced noise levels by as much as 10 dBA, depending on the location, when compared to the pre-grinding levels.

Impact Comparison

As previously stated, several sites with noise levels meeting or exceeding the FTA criteria were identified during the First Year Testing Results, 2009. Through the combined efforts of rail grinding, installation of Type 2 sound barriers and wayside lubricators, Sound Transit has been successful in reducing noise levels along the Tukwila corridor to below the FTA criteria. Table 1 provides a comparison of the First Year Testing Results, 2009 projections and impacts as well as the 2010 projections and the changes that contributed to the improved conditions and mitigation of light rail noise impacts.

Table 1. Comparison of 2009 and 2010 Operational Ldn Projections

Site	Pre-Project Ldn[1]	FTA Noise Criteria	2009 Project L_{dn}[2]			2010 Project L_{dn}[2]			System Updates from 2009
			L_{dn}	Method[4]	Impact	L_{dn}	Method[4]	Impact	
N1	67	63 – 67	**65**	Pass-by	**Yes**	60	Pass-by	No	Type 2 Sound Barrier, Rail Grinding
N1A	70[3]	65 – 69	63	Pass-by	No	55	Pass-by	No	Type 2 Sound Barrier, Rail Grinding
N1B	64	61 – 65	**62**	Pass-by	**Yes**	53	Pass-by/L_{dn}	No	Type 2 Sound Barrier, Rail Grinding
N1C	65	61 – 66	**62**	Pass-by	**Yes**	52	Pass-by/L_{dn}	No	Type 2 Sound Barrier, Rail Grinding
N2	71	72 – 74	68	Ldn	No	69[9]	Ldn	No	N/A
N3	69	64 – 69	**64**	Pass-by	**Yes**	56	Pass-by	No	Type 2 Sound Barrier
N4	69	64 – 69	61	Pass-by	No	61	Pass-by	No	N/A
N5	73	73.6 - 75	58	Pass-by	No	72[9]	Ldn	No	Higher level due to measurement type[9]
N6	73	73.6 - 75	60	Pass-by	No	72[9]	Ldn	No	Higher level due to measurement type[9]
N6A	73	66 – 71 (2009) 73.6 - 75 (2010)	**67**	Pass-by	**Yes**	71[9]	Ldn	No	Type 2 Sound Barrier – *Note: Analyzed in 2010 using total L_{dn}*
N7	73	66 – 71	**68**	Pass-by	**Yes**	55	Pass-by	No	Type 2 Sound Barrier, Wayside Lubricators & Rail Grinding
N8	73	66 – 71	**70**	Pass-by	**Yes**	58	Pass-by	No	Type 2 Sound Barrier, Wayside Lubricators & Rail Grinding
N8A	73	73.6 - 75	--[6]	--[6]	--[6]	69[9]	Ldn	No	Type 2 Sound Barrier, Wayside Lubricators & Rail Grinding
N9	73	66 – 71	59	Pass-by	No	57	Pass-by	No	N/A
N10	73	66 – 71	--[7]	Pass-by	No	61	Pass-by	No	N/A
N11	73	66 – 71	61	Pass-by	No	65[10]	Pass-by	No	N/A
N12	73	66 – 71	58	Pass-by	No	59	Pass-by	No	N/A
N13	73	66 – 71	--[7,8]	Pass-by	No	--[7,8]	Pass-by	No	N/A
N14	63	60 – 65	--[7,8]	Pass-by	No	--[7,8]	Pass-by	No	N/A

Notes:

1. Pre-Project L_{dn} noise levels
2. Project L_{dn}, type of measurement and impact. Noise levels in **Bold-Red** typeface exceed the FTA noise impact criteria.
3. Pre-project L_{dn} taken from measurements at 11823 40th Avenue S during EIS.
4. Analysis Methods: Details on analysis methods provided under *Noise Compliance Verification Methods*
   a. Method 1 (Pass-by): Pass-by measurements used to predict L_{dn}, with existing pre-project L_{dn} and compare to criteria in Table 3.
   b. Method 2 (L_{dn}): Measure L_{dn} with light rail, use existing pre-project L_{dn}, compare total noise to criteria in Table 2.
   c. Method 3 (Pass-by/L_{dn}): Measure L_{dn} with train, measure train pass-by, predict pre-project L_{dn} and compare to criteria in Table 3.
5. New location for 2010 analysis. This location not analyzed in 2009.
6. Noise from the light rail was not measureable over the existing ambient noise.
7. Noise from buses was not measureable over the existing ambient noise.
8. Measurements using the long-term L_{dn} also include other noise sources and can be considered a worst case noise levels.
9. Measured pass-by levels included noise from other sources, and the actual noise level from light rail operations would be lower than presented. Future measurements at this site may be performed using Method 2.

Compliance Analysis

This section provides a brief introduction to noise and vibration, the FTA noise and vibration criteria, and methods of verifying that the Link light rail system is operating below the FTA criteria.

Introduction to Noise and Vibration

Human response to noise is subjective and can vary greatly from person to person. Factors that can influence individual response to noise include the loudness, frequency, the amount of background noise present before an intruding noise and the nature of the work or activity (e.g., sleeping) that the noise affects.

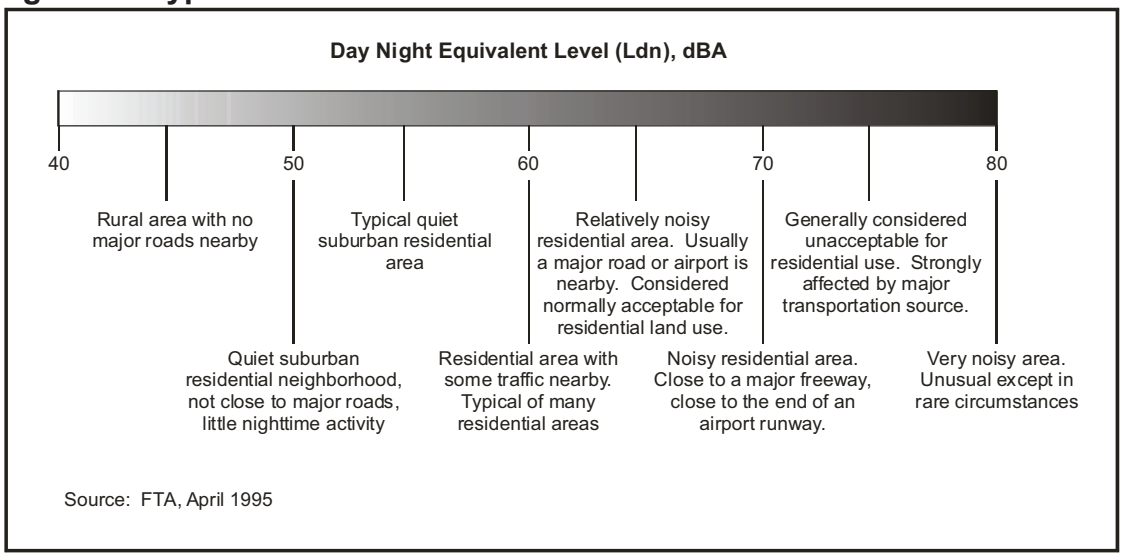
The unit used to measure the loudness of noise is the decibel (dB). To better approximate the sensitivity of the human ear to sounds of different frequencies, the A-weighted decibel scale was developed. Because the human ear is less sensitive to higher and lower frequencies, the A-weighted scale reduces the sound level contributions of these frequencies. When the A-weighted scale is used, the decibel levels are denoted as dBA. The A-scale is used in most ordinances and standards including the applicable standards for this project.

A 10-dBA change in noise levels is judged by most people as a doubling of sound level. The smallest change in noise level that a human ear can perceive is about 3 dBA, and increases of 5 dBA or more are clearly noticeable. Noise levels in a quiet rural area at night are typically between 32 and 35 dBA. Quiet urban nighttime noise levels range from 40 to 50 dBA. Noise levels during the day in a noisy urban area are frequently as high as 70 to 80 dBA. Noise levels above 110 dBA become intolerable and then painful, while levels higher than 80 dBA over continuous periods can result in hearing loss.

To account for the time-varying nature of noise, several noise metrics are useful. The equivalent sound pressure level (L_{eq}) is defined as the average noise level, on an energy basis, for a stated time-period (for example, hourly). The L_{eq} is the preferred noise descriptor for traffic noise analysis and transit analysis for daytime use facilities.

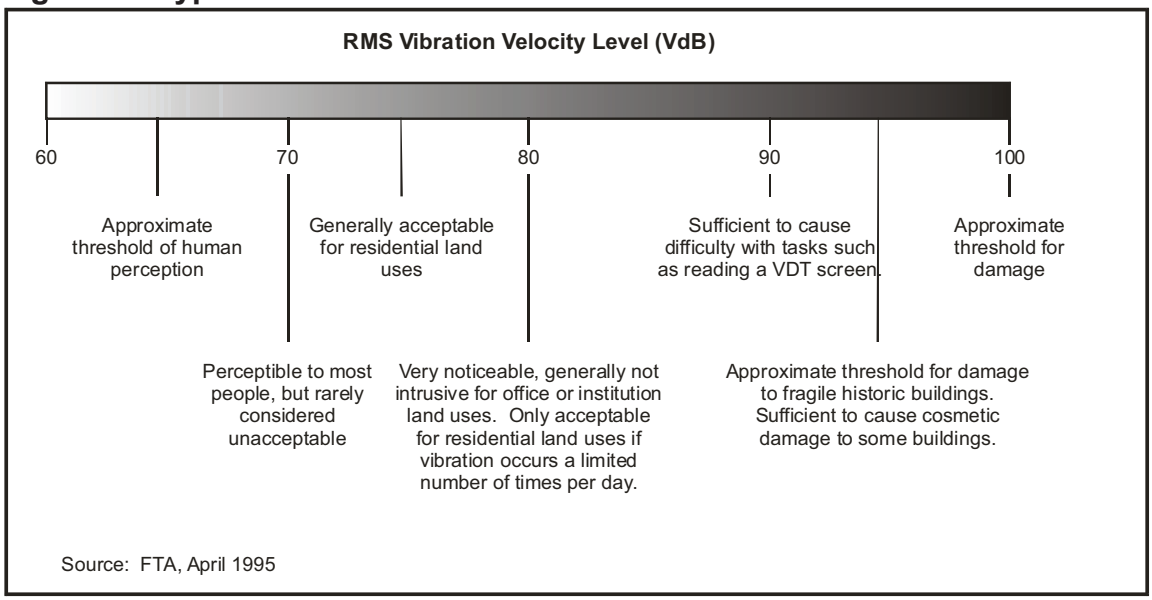
Another useful descriptor is the Day-Night Equivalent Sound Level, Ldn, also abbreviated DNL, which is defined as the 24-hour Leq, but with a 10 dB penalty assessed to noise events occurring at night (defined as 10:00 p.m. to 7:00 a.m.). The effect of this penalty is that any event during nighttime hours is equivalent to ten events during the daytime hours. This strongly weights Ldn toward nighttime noise to reflect most people being more easily annoyed by noise during nighttime hours when background noise is lower and most people are sleeping. The Ldn is the preferred noise level descriptor for transit-related noise analysis at residential structures and other locations, such as hotels and hospitals, where high nighttime noise levels can have the most severe effect. Figure 2 shows typical Ldn values for rural and urban areas.

Figure 2: Typical Ldn Values for Rural and Urban Areas



Ground-borne vibration consists of oscillatory waves that propagate from the source through the ground to adjacent buildings. On steel-wheel/steel-rail train systems, ground-borne vibration is created by the interaction of the steel wheels rolling on the steel rails. Although the vibration is sometimes noticeable outdoors, it is almost exclusively an indoor problem. Although it is conceivable for ground-borne vibration from rail rapid transit trains to cause building damage, the vibration from trains is almost never of sufficient amplitude to cause even minor cosmetic damage to buildings. The primary concern is that the vibration and radiated noise can be intrusive and annoying to building occupants. Factors that influence the amplitudes of ground-borne vibration include vehicle suspension parameters, condition of the wheels and rails, type of track, track support system, type of building foundation, and the properties of the soil and rock layers between the vibration source and receiver. As a point of reference, the average person can just barely perceive vibration velocity levels below 70 VdB. Figure 3 compares typical ground-borne vibration levels.

Figure 3: Typical Levels of Ground-borne Vibration



FTA Noise and Vibration Criteria

The criteria in the FTA guidance manual *Transit Noise and Vibration Impact Assessment* (May 2006) are founded on well-documented research on community reaction to noise and are based on change in noise exposure using a sliding scale. The amount that the transit project is allowed to change the overall noise environment is reduced with increasing levels of existing noise. The FTA Noise Impact Criteria groups noise sensitive land uses into the following three categories:

Category 1: Buildings or parks where quiet is an essential element of their purpose.

Category 2: Residences and buildings where people normally sleep. This includes residences, hospitals, and hotels where nighttime sensitivity is assumed to be of utmost importance.

Category 3: Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches and office buildings.

L_{dn} is used to characterize noise exposure for residential areas (Category 2) and maximum 1-hour L_{eq} during the period that the facility is in use is used for other noise-sensitive land uses such as school buildings (Categories 1 and 3). There are two levels of impact included in the FTA criteria. The interpretations of these two levels of noise impact are summarized below:

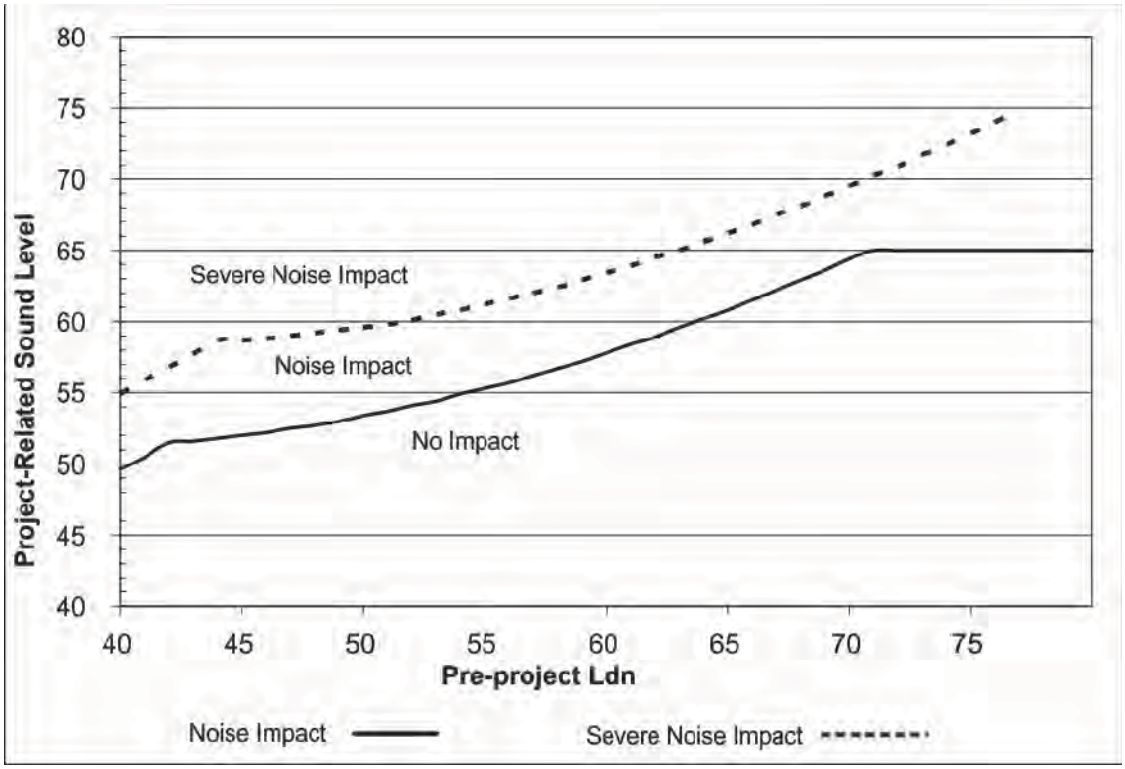
- Severe Impact: Severe noise impacts are considered "significant" as this term is used in the National Environmental Policy Act (NEPA) and implementing regulations. Noise mitigation will normally be specified for severe impact areas unless there is no practical method of mitigating the noise.

- Impact: In this range, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These other factors can include the

predicted increase over existing noise levels, the types and number of noise-sensitive land uses affected, existing outdoor-indoor sound insulation, and the cost effectiveness of mitigating noise to more acceptable levels.

The noise impact criteria for transit operations are summarized in Figure 4. The future noise exposure would be the combination of the existing noise exposure and the additional noise exposure caused by the transit project. Under the FTA noise impact criteria, as the existing noise exposure increases, the amount of the allowable increase in the overall noise exposure caused by the Project decreases. Note, that it is possible to have a noise impact under the FTA criteria even if the pre-project L_{dn} noise levels are lower than the predicted project noise. For example, a site with a pre-project L_{dn} of 68 dBA would have a moderate impact if project noise levels meet or exceed 63 dBA. All of the locations being analyzed in this memorandum are FTA Category 2 land use (residential).

Figure 4: FTA Noise Impact Criteria



Noise Compliance Verification Methods

Verification methods for project noise levels provided in the compliance plan were based on measuring light rail pass-by levels, predicting the operational L_{dn} and comparing it to the FTA noise impact criteria based on the pre-project measured or predicted L_{dn} from the Final Design Noise Technical Report (2004). To use this method the background ambient noise levels must be 10 dBA lower than the train L_{max} pass-by noise. This method (Method 1) was used wherever possible (sites N1, N3, N4, N7, N8, N9, N10, N11 and N12), however, there are several sites along the project corridor where the pass-by noise levels from the light rail are not 10 dBA over the background noise levels, and for those sites an alternative method

was required. This generally occurred in locations where an existing Type 1 sound wall or Type 2 sound barrier was installed, and reduced the light rail noise to a level that was not 10 dBA over the ambient level. The difficulty of taking accurate pass-by measurements at these sites facilitated a change in the methods of compliance verification. An alternative method was developed and reviewed and agreed to by the City of Tukwila's Noise Consultant, Ioana Park. P.E., at BRC, during the 2009 first year testing.

Finally, because there are some new sites, where pre-project L_{dn} noise levels are not available, an alternate method was also needed to predict potential impacts in these areas. For these sites, measurements of the existing L_{dn} and train noise levels were required to provide compliance verification. The methods used for the analysis are described in detail below.

Method 2 - Measured L_{dn} Direct Comparison Method

One alternative verification method for locations where background ambient noise levels are not 10 dB lower than the train L_{max} consist of measuring the current L_{dn} with light rail operating under normal revenue service and comparing it with the pre-project L_{dn}. If there is an overall noise reduction when compared to the pre-project L_{dn}, or if the current L_{dn} is less than the pre-project L_{dn} plus the FTA allowable increase, that would indicate that the project is in compliance and below FTA criteria. The FTA allowable increase based on the pre-project L_{dn} is provided in Table 2 below. This method was used for sites N2, N5, N6 and N6A, which are all behind the Type 1 sound walls and have existing L_{dn} noise levels that are lower than the pre-project noise levels.

Table 2: FTA Allowable Increase Noise Impact Criteria for Pre-project L_{dn} of 60 to 75 dBA

Pre-Project Noise Levels (L_{dn} dBA)	Allowable Cumulative Noise Level Increases			
	Category 1 or 2 Sites		*Category 3 Sites*	
	Impact	*Severe Impact*	*Impact*	*Severe Impact*
60	2	5	5	9
61	1.9	5	4	9
62	1.7	4	4	8
63	1.6	4	4	8
64	1.5	4	4	8
65	1.4	4	3	7
66	1.3	4	3	7
67	1.2	3	3	7
68	1.1	3	3	6
69	1.1	3	3	6
70	1.0	3	3	6
71	1.0	3	3	6
72	0.8	3	2	6
73	0.6	2	1.8	5
74	0.5	2	1.5	5
75	0.4	2	1.2	5

Method 3 - Measured L_{dn} and L_{max}/SEL Comparison Method

For locations where there is no sound wall or previously measured L_{dn}, compliance verification was performed using the measured L_{dn} during normal light rail revenue service along with light rail pass-by measurements. The light rail pass-by measurements are used to determine the contribution to the overall measured L_{dn} that is related to light rail operations. The light rail pass-by measurements include the L_{max}, which is the maximum sound level during the measurement period, and the SEL, which is a one-second equivalent of the acoustical energy of the pass-by. Either of these levels can be used with FTA formulas to calculate the train's contribution to the L_{dn}. Note that this method was only used for two locations in the Duwamish neighborhood, sites N1B and N1C. The main reason for this analysis method was to assist in determining the length of the recently installed Type 2 sound barriers and make sure that the noise levels were within the criteria once the walls were installed.

The following steps describe the method for verification at new locations where pass-by measurements were possible:

1. Measure the current L_{dn} with light rail operating under normal revenue service;
2. Measure several pass-bys of the light rail vehicle where the L_{max} is 10 dBA or more over ambient noise levels and predict the train's L_{dn} using the methods in the FTA Manual, 2006;
3. Subtract the train's L_{dn} contribution (Step 2) from the overall measured L_{dn} (from Step 1) using the methods described in the FTA Manual, 2006 and the measured pass-by noise levels from Step 2 to obtain the site L_{dn} without train operations;
4. Verify compliance with one of the two methods below:
   - Subtract the measured L_{dn} from the corrected no-train L_{dn} and compare the change in noise levels with the values in Table 2. This table is based on the pre-project L_{dn} and provides the amount the transit system can increase the overall noise level in an area. This is an abbreviated version of the FTA table and only contains pre-project L_{dn} noise levels expected in this corridor; or
   - Verify compliance using the predicted train L_{dn} from step 3 by comparing it to the FTA allowable project noise exposure based on the corrected pre-project site L_{dn} from Step 4. The allowable project noise exposure based on the pre-project L_{dn} can be found in Table 3.

Table 3. FTA Transit Noise Exposure Impact Criteria for Pre-project L_{dn} of 60 to 75 dBA

Pre-Project Noise Levels (L_{dn} dBA)	*Project Noise Impact Exposure, Ldn (dBA)*					
	Category 1 or 2 Sites			*Category 3 Sites*		
	No Impact	Moderate Impact	Severe Impact	No Impact	Moderate Impact	Severe Impact
60	<58	58-63	>63	<63	63-68	>68
61	<59	59-64	>64	<64	64-69	>69
62	<59	59-64	>64	<64	64-69	>69
63	<60	60-65	>65	<65	65-70	>70
64	<61	61-65	>65	<66	66-70	>70
65	<61	61-66	>66	<66	66-71	>71
66	<62	62-67	>67	<67	67-72	>72
67	<63	63-67	>67	<68	68-72	>72
68	<63	63-68	>68	<68	68-73	>73
69	<64	64-69	>69	<69	69-74	>74
70	<65	65-69	>69	<70	70-74	>74
71	<66	66-70	>70	<71	71-75	>75
72	<66	66-71	>71	<71	71-76	>76
73	<66	66-71	>71	<71	71-76	>76
74	<66	66-72	>72	<71	71-77	>77
75	<66	66-73	>73	<71	71-78	>78

It is important to note that the impact criteria presented in Figure 4, Table 2 and Table 3 are essentially identical, the only difference is how they are used. Figure 4 and Table 2 present identical information in different formats. The pre-project L_{dn} is used to obtain the allowable project L_{dn}. The data presented in Table 2, however, uses acoustical formulas to arrive at the allowable increase the project is allowed, given a pre-project L_{dn}, that will assure that the total project noise is lower than the allowable project noise exposure provided on Figure 2 and Table 3.

Summary of Noise Analysis Methods:

Method 1. Measure light rail pass-by, calculated light rail L_{dn}, and compare to FTA criteria in Table 3 based on existing pre-project L_{dn}

Method 2. Measure the L_{dn} with light rail during normal revenue service; if the measured L_{dn} is less than the existing pre-project L_{dn}, or the increase is less than provided under the allowable increased criteria in Table 2, (based on the existing pre-project L_{dn}) then there is no noise impact.

Method 3. Measure the L_{dn} with light rail during normal revenue service, measure light rail pass-bys, determine the light rail contribution to the total noise, use that to predict the pre-project L_{dn} and assess potential impact using predicted pre-project L_{dn}, light rail L_{dn}, and the criteria in Table 3.

Locations Near the 154th St Park and Ride

As identified in the 2009 first year report, there is one location on 154th Street and two locations near the Tukwila International Boulevard Station Park and Ride where the installation of sound walls for SR 518 and the park and ride have resulted in an overall reduction in noise levels. Noise levels at all three sites are lower than the ambient noise levels measured at the time of the final design studies as neither light rail nor bus operations at the park and ride were measureable at sites N13 or N14.

Second Year Noise Level Compliance

Table 4 provides a summary of the measured noise levels. There are no locations along the light rail corridor in Tukwila that meet or exceed the FTA noise impact criteria. A brief discussion on each site is provided following Table 4. Detailed tables with measured noise levels are provided in Attachment A. Detailed maps of the corridor complete with measurement locations, existing and proposed noise mitigation measures are provided in Attachment C.

Table 4. Summary of 2010 Operational Ldn Projections

Site	Area	Pre-project Ldn[1]	FTA Criteria[2]	Project L_{dn}, Impacts and Notes[3]		
				L_{dn}	Impact	Notes
N1	North Duwamish	67	63 – 67	60	No	Type 2 Sound Barrier, Rail grinding
N1A	South Duwamish	70[4]	65 – 69[5]	55	No	Type 2 Sound Barrier, Rail grinding
N1B	South Duwamish	64	61 – 65[5]	53	No	Type 2 Sound Barrier, Rail grinding
N1C	South Duwamish	65	61 – 66	52	No	Type 2 Sound Barrier, Rail grinding
N2	S 128th St	71	72 – 74[5]	69	No	
N3	48th Ave S	69	64 – 69	56	No	Type 2 Sound Barrier,
N4	S 136th St.	69	64 – 69	61	No	
N5	S 138th St.	73	73.6 - 75[5]	72	No	
N6	MacAdam/140th	73	73.6 - 75[5]	72	No	
N6A	14914 51st St	73	73.6 - 75[5]	71	No	Type 2 Sound Barrier,
N7	52nd Ave Condos	73	66 – 71	55	No	Type 2 Sound Barrier, Wayside Lubricators, Rail grinding
N8	51st Ave	73	66 – 71	58	No	Type 2 Sound Barrier, Wayside Lubricators, Rail grinding
N8A	51st Ave	73	73.6 - 75[5]	69	No	Type 2 Sound Barrier, Wayside Lubricators, Rail grinding
N9	S 154th near 51st	73	66 – 71	57	No	
N10	S 154th Apts	73	66 – 71	61	No	
N11	S 154th Apts	73	66 – 71	65[8]	No	Analyzed using total L_{dn}
N12	42nd Ave S	73	66 – 71	59	No	
N13	154th P&R	73	66 – 71	--[6,7]	No	Measurements not possible
N14	154th P&R	63	60 – 65	--[6,7]	No	Measurements not possible

Notes:

1. Measured L_{dn}
2. FTA noise impact criteria, noise levels with superscript 5 are analyzed using the total L_{dn} method and impact levels from Table 2, while all other sites used impact levels from Table 3.
3. Project L_{dn}, type of impact and any notes on impacts. Noise levels in **Bold-Red** typeface exceeding the FTA noise impact criteria.
4. Pre-project L_{dn} taken from measurements at 11823 40th Avenue S during EIS.
5. All sites were analyzed using Method 1, except sites N2, N5, N6, N6A and N8A, which used Method 2, and sites N1B and N1C, which used Method 3. Methods described under *Noise Compliance Verification Methods*.
6. Noise from the light rail was not measureable over the existing ambient noise.
7. Noise from buses was not measureable over the existing ambient noise.
8. Measured pass-by levels included noise from other sources, and the actual noise level from light rail operations would be lower than presented. Future measurements at this site may be performed using Method 2.

Site Specific Results

This section provides a summary of the noise measurements and compliance for the second year of testing. Compliance testing will be performed again in year three, as required by the UUP.

Sites N1, N1A, N1B and N1C (Duwamish Point Neighborhood)

Sites N1, N1A, N1B and N1C are in the residential area between Interurban/E Marginal Way and the Duwamish River. The pre-project L_{dn} at site N1 was determined through on-site noise monitoring between April 29, and May 1, 2009. There were no trains running during this measurement period. The L_{dn} at this site was measured at 67 dBA, and therefore a moderate impact occurs if project noise levels meet or exceed 63 dBA L_{dn}.

The pre-project noise level at site N1A of 70 dBA L_{dn} was obtained from on-site noise measurements performed during the EIS phase of the project. Existing pre-project L_{dn} noise levels for sites N1B and N1C were determined using Method 3, described under *Noise Compliance Verification Methods*. Long-term measurements were performed at site N1C between August 1 and August 4, 2010. Pass-by measurements were taken at N1C on August 11, 2010, and for site N1B, the pass-by measurements were taken on September 11, 2010. Based on the measured levels, the existing pre-project L_{dn} at site N1B is 64 dBA L_{dn} and site N1C is 65 dBA L_{dn}.

In summer 2010, a 2700 foot Type 2 sound barrier (Sound Barrier A) was installed near receivers N1 through N1C in response to the noise impacts identified during the First Year Testing Results, 2009. The addition of the Type 2 noise barrier and results of the rail grinding program have contributed to overall lower light rail noise levels in this area. The rail grinding program has reduced noise levels by up to 10 dB, when compared to pre-grinding noise levels, while the Type 2 noise barriers have also reduced noise from the trains by 4 to 6 dB.

The impact analysis for these sites relied primarily on pass-by noise measurements, with supplemental long-term measurements that were used to establish the pre-project L_{dn} for sites N1B and N1C, as previously described. Pass-by measurements performed at sites N1 through N1C in August and September 2010 resulted in predicted light rail L_{dn} measurements that range from 52 to 60 dBA, which is below the FTA criteria for residential impacts. For further verification, and in response to comments from local residents, additional pass-by measurements were taken at site N1 on November 3, 2010. The November measurements, agreed, within less than 1 dBA, with the measurements taken in August and September, 2010, with a predicted light rail L_{dn} of 60 dBA. No FTA light rail noise impacts were projected in the Duwamish Point neighborhood.

Site N2

Site N2 is at the intersection of S 128th Street and MacAdam Road S behind Sound Wall 1 (see Attachment C, figure 3). For sites that are located entirely behind sound walls, like site N2, performing a new long-term noise measurement (greater than 24 hours) and comparing the previous L_{dn} to the pre-project L_{dn} was used to verify compliance (Method 2). The long-term monitoring was performed on September 8 through 10, 2010. Using this method, the

future L_{dn} must be less than the pre-project L_{dn} added to the FTA allowable increase in Table 2.

For site N2, the pre-project measured L_{dn} is 71 dBA, and based on Table 2, if the project increases the L_{dn} by 1 to 3 dBA, it is a moderate impact, and increases over 3 dBA are considered a severe impact. Therefore, the measured L_{dn} with normal light rail operations cannot exceed 72 dBA for a moderate impact. The measured L_{dn} was 69 dBA at site N2, which is not only below the 72 dBA impact level, but also lower than the pre-project L_{dn} of 71 dBA. The overall noise reduction of approximately 3 dBA in total L_{dn} at this residence in the area is due to the shielding effects of the sound wall on SR 599 traffic in addition to the shielding of light rail noise.

Site N3

Site N3 is near an at-grade segment of track in an empty lot previously occupied by a manufactured home. The pre-project L_{dn} from a nearby measurement was 69 dBA L_{dn}, resulting in an FTA impact threshold for project noise levels in excess of 64 dBA L_{dn}. In 2010, Sound Barrier B, a 450 foot Type 2 barrier was installed near site N3 off of 48th Ave S. Because of the lower ambient measurements at this site, pass-by measurements were selected as the preferred compliance method (Method 1). Pass-by measurements taken at the site on August 27, 2010 resulted in a predicted light rail L_{dn} of 56 dBA, which is well below the FTA criteria for residential impacts.

Site N4

Site N4 is located behind Sound Wall 2. Method 1 pass-by measurements performed at this site on September 8, 2010, resulted in a predicted light rail L_{dn} measurement of 61 dBA L_{dn}, with impact criteria of 66 dBA L_{dn}. No noise impacts are predicted at any of the residences along this segment of the corridor. The sound wall is not only effective at reducing noise from light rail operations, but also reduces noise from I-5. Note that pass-by measurements were used at this site due to barking dogs and no-trespassing signs posted at the property. Once the equipment was set-up, we were able to keep the dogs from barking and obtain accurate pass-by noise measurements.

Sites N5 and N6

Sites N5 and N6 are also located behind a Type 1 sound wall. In the 2009 first year testing report, it was suggested that the next round of testing include long-term noise monitoring (Method 2) at these locations due to the assumption that the post-project L_{dn} would be lower than the pre-project L_{dn} when the noise analysis was performed.

In 2010, project noise levels at sites N5 and N6 were determined by using long-term noise measurements and comparing the previous L_{dn} to the pre-project L_{dn} to verify compliance. Long-term noise measurements at sites N5 and N6 were performed between September 8 and 11, 2010. Using this method, the future L_{dn} must be less than the pre-project L_{dn} plus the allowable exceedance from Table 2. To show compliance, the measured L_{dn} at these sites with normal light rail operations cannot exceed 73 dBA for a moderate impact. The measured L_{dn} was 72 dBA at sites N5 and N6, which is below the 73 dBA impact level. It must be

noted that this method also includes noise from other sources and should be considered as a worst case noise reading, as the actual noise level from train only operations would likely be lower.

Site N6A

Site N6A was added during the previous year's corridor inspection and was not included in the original proposed monitoring plan. Recently, a 530 foot Type 2 sound barrier (Sound Barrier C) was installed near receiver N6A on the 149 block of 51st Avenue S to mitigate a previous noise impact. In the 2010 analysis, project noise levels for this site were determined by using long-term noise measurements. The pre-project L_{dn} for this site of 73 dBA is based on nearby measurements and is also the same as other sites along I-5. At site N6A, the measured L_{dn} with normal light rail operations cannot exceed 73 dBA for a moderate impact. The measured L_{dn} of 72 dBA taken in August 2010 at site N6A using Method 2 is below the 73 dBA impact level. As with sites N5 and N6, the actual noise level from train only operations would likely be lower due to the inclusion of other noise sources in this reading, and no noise impact is predicted in this area.

Sites N7, N8 and N8A

Sites N7 and N8 are located near the curve at I-5 and SR 518 interchange, by the elevated structure approaching the 154th Street Park and Ride Station. Site N7 is on 52nd Avenue S, representing one multi-family unit. Site N8 is on the east side of 51st Avenue S at a single family residence and site N8A (new) is a test site located at the Sarana International Buddhist temple, which is located on the west side of 51st Avenue S, directly across the street from site N8. Sites N7 and N8 were analyzed using Method 1, while site N8A was analyzed using Method 2.

Because these structures are near the large radius curve where the light rail alignment transitions from I-5 to SR 518, much of the subsequent noise in this area was related to wheel squeal and flanging noise. Lubricators have been installed just before the curves near SR518 and just east of the 154th Street Park and Ride resulting in an overall reduction in wheel squeal and flanging noise.

In addition to the lubricators, Sound Barrier D, a 912 foot Type 2 sound barrier was installed in the vicinity of 51st/52nd Avenues S and S154th Street and now connects the two previously existing Type 1 sound walls. Finally, the results of the rail grinding program have contributed to overall lower light rail noise levels in this area.

The project L_{dn} noise level measured at site N7 on September 30, 2010 was 55 dBA, and at site N8 the project L_{dn} measured on September 11, 2010 was 58 dBA. The impact criterion is 66 dBA and therefore no noise impact was identified at either site. In addition, the measured long-term L_{dn} at site N8A, which used Method 2, also confirms compliance with a measured L_{dn} of 69 dBA while the criterion is 73 dBA. Note, that the measured L_{dn} at site N8A also includes noise from other sources, including traffic on SR518, local roadways, and aircraft from SeaTac airport. No impact is predicted at any of the sites in this vicinity.

Sites N9 and N10

Sites N9 and N10 are located along S 154th Street and are protected by a previously existing acoustical sound wall on the elevated structure. Operational pass-by noise levels were measured at 57 dBA L_{dn} at site N9 and 61 dBA L_{dn} at site N10. The FTA criterion is 66 dBA and therefore no noise impact was identified at either location. The project L_{dn} is based on measurements taken on September 11, 2010, and analyzed using Method 1.

Site N11

Site N11 is located at an apartment complex along S 154th Street. The project related L_{dn} at this site was predicted from measured data on September 11, 2010 using Method 1 at 65 dBA L_{dn}, with an impact criterion of 66 dBA L_{dn}. No noise impact was identified at this site. Noise measurements at this site can also be considered worst case, as northbound pass-by measurements were not 10 dBA over the background noise levels, potentially making these predictions slightly higher than actual levels.

Site N12

Site N12 is on 42nd Avenue S, almost directly under the light rail alignment and the site is protected by a structure mounted sound wall. Pass-by measurements were possible at this site; however the quality is not as good as some of the other locations. The site L_{dn} related to project operations was calculated at 59 dBA L_{dn}, which is well below the 66 dBA FTA criteria. The project L_{dn} is based on measurements taken on September 11, 2010, and analyzed using Method 1.

Site N13 and N14

Site N13 is located at the southern end of the apartment complex just east of the S 154th Park and Ride Station. Site N14 is located at the northern end of the apartment complex, east of the S 154th Park and Ride Station, near S 154th Avenue. Because of the SR-518 sound wall, light rail sound wall, and park and ride sound wall, it was not possible to obtain a noise level reading of the light rail vehicle or buses at the park and ride at either location.

Because buses operating in the park and ride were also not audible or measureable at this location, it is clear that the sound wall is effective and mitigates noise from the park and ride. Photos of the sound wall that show that the second floors are acoustically protected are provided in Attachment E. No light rail or park and ride impacts were identified at N13 or N14.

Vibration Level Compliance Discussion

Summary of Vibration Compliance

During the First Year Testing a defective rail weld was identified from a complaint near the S 144th St overpass that resulted in vibration levels above the FTA criteria. Sound Transit repaired over 30 feet of rail in the vicinity of S 144th St and recent measurements confirm that there is no longer an impact near or at site V4. Table 5 provides a summary of the 2009

and 2010 vibration test results. Currently, all vibration testing sites are well below the FTA criteria of 72 VdB.

Table 5. Comparison of 2009 and 2010 Vibration levels

Location	FTA Criteria	Max. Measured Vibration Levels	Impact	Max. Measured Vibration Levels	Impact
		2009		*2010*	
V1	72 VdB	64 VdB	No	62 VdB	No
V2	72 VdB	55 VdB	No	65 VdB	No
V3	72 VdB	60 VdB	No	61 VdB	No
V4	72 VdB	61 VdB	No	61 VdB	No

Note:
All vibration levels in this report are in terms of the vibration velocity level in decibels using a decibel reference of 1 µin/sec. The abbreviation "VdB" is used for vibration decibels to avoid confusion with noise decibels.

Measured vibration levels at site V2 are noticeably higher than those measured in the First Year Testing Results, 2009. The reason for the higher current reading was a modification to the testing location. There was on-going construction at this property during the 2009 first year testing, which prevented the transducer from being placed at the property line. Instead, the transducer was located adjacent to the house nearest the tracks. For this year's testing, the transducer was located near the property line, approximately 20 to 30 feet closer to the tracks then last year's testing. Testing for next year will likely be at the same site as this year's testing. All other tests are within 1 to 2 VdB of last year's testing, and all sites are in compliance with the FTA regulations.

The vibration test sites are shown in Attachment C on Figures 3, 4, and 5 and vibration measurement details are included in Attachment B. Vibration measurements will be taken in year 3 of the plan to assure continued compliance.

Attachment A

Noise Measurement Details

Note: Data is not presented for sites N13 or N14, where the light rail and/or buses could not be measured due to previously existing levels higher than the light rail and/or bus noise levels.

A-1A. Pass-By Measurements and L_{dn} Levels for Site N1
Measured data from August 12 and September 30 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	76.0	81.5	
NB	2	76.8	82.1	
NB	2	76.7	81.4	
NB	2	74.5	80.9	
NB	2	78.3	83.2	
NB	2	76.3	82.3	
	Minimum	**74.5**	**80.9**	
	Maximum	**78.3**	**83.2**	
	Energy Average	**76.4**	**81.9**	**58.2 dBA**
	Standard Deviation	**1.24**	**0.81**	
Southbound Trains				
SB	2	73.7	79.2	
SB	2	70.3	76.8	
SB	2	69.6	77.1	
SB	2	74.8	81.5	
SB	2	75.2	80.9	
SB	2	--	--	
	Minimum	**69.6**	**76.8**	
	Maximum	**75.2**	**81.5**	
	Energy Average	**72.7**	**79.1**	**55.4 dBA**
	Standard Deviation	**2.60**	**2.14**	
Total L_{dn} and Impact Analysis				
			Ambient L_{dn} (Measured 4/29-5/1/2009)	67 dBA
			Project L_{dn}	60 dBA
			Impact Level = 63 dBA L_{dn}	No

Notes:
- The last SB train was abnormally low (64.9 dBA L_{max}) and therefore not used in the analysis.
- The L_{dn} noise levels are calculated using Method 1.
- Ambient L_{dn} is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-1B. Pass-By Measurements and L_{dn} Levels for Site N1 *Measured Data from November 3, 2010*				
Direction	**# Cars**	**L_{max}**	**SEL**	**Project L_{dn}**
Northbound Trains				
NB	2	77.9	82.6	
NB	2	76.3	83.5	
NB	2	77.1	82.4	
NB	2	76.8	82.3	
	Minimum	76.3	82.3	
	Maximum	77.9	83.5	
	Energy Average	77.0	82.7	**59.0 (dBA)**
	Standard Deviation	0.67	0.55	
Southbound Trains				
SB	2	68.9	76.8	
SB	2	70.8	77.3	
SB	2	73.7	81.5	
SB	2	69.5	76.0	
	Minimum	68.9	76.0	
	Maximum	73.7	81.5	
	Energy Average	70.7	77.9	**54.2 (dBA)**
	Standard Deviation	2.14	2.46	
Total L_{dn} and Impact Analysis				
			Ambient L_{dn} (Measured 4/29-5/1/2009)	67 dBA
			Project L_{dn}	60 dBA
			Impact Level = 63 dBA L_{dn}	No

Notes:
- The L_{dn} noise levels are calculated using Method 1.
- Ambient L_{dn} is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-2. Pass-By Measurements and L_{dn} Levels for Site N1A (11823 40th Ave S)
Measured data from September 11, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	--	--	
NB	2	70.4	74.3	
NB	2	70.8	77.8	
NB	2	69.6	77.8	
NB	2	72.0	75.7	
NB	2	71.2	77.4	
	Minimum	**69.6**	**74.3**	
	Maximum	**72.0**	**77.8**	
	Energy Average	**70.8**	**76.6**	**52.9 dBA**
	Standard Deviation	**0.89**	**1.55**	
Southbound Trains				
SB	2	65.5	74.2	
SB	2	66.8	74.5	
SB	2	67.6	71.7	
SB	2	67.7	73.5	
SB	2	66.3	74.2	
SB	2	71.3	78.1	
	Minimum	**65.5**	**71.7**	
	Maximum	**71.3**	**78.1**	
	Energy Average	**67.5**	**74.4**	**50.7 dBA**
	Standard Deviation	**2.02**	**2.09**	
Total L_{dn} and Impact Analysis				
			Pre-Project L_{dn} (Measured during EIS)	70 dBA
			Project L_{dn}	55 dBA
			Impact Level = 65 dBA L_{dn}	No

Notes:

- The first NB train at N1A was abnormally low, (63.4 dBA L_{max}) and therefore not used in the analysis.
- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient L_{dn} is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-3. Pass-By Measurements and L_{dn} Levels for Site N1B (11820 40th Ave S) *Measured data from September 11, 2010*				
Direction	**# Cars**	**L_{max}**	**SEL**	**Project L_{dn}**
Northbound Trains				
NB	2	70.2	76.0	
NB	2	68.4	74.9	
NB	2	70.4	75.8	
NB	2	70.7	75.3	
NB	2	68.1	73.9	
NB	2	66.5	74.5	
	Minimum	**66.5**	**73.9**	
	Maximum	**70.7**	**76.0**	
	Energy Average	**69.1**	**75.1**	**51.4 dBA**
	Standard Deviation	**1.65**	**0.80**	
SB	2	64.5	70.7	
SB	2	61.3	67.9	
SB	2	62.0	69.1	
SB	2	63.6	67.9	
SB	2	62.8	73.0	
SB	2	62.0	68.4	
	Minimum	**61.3**	**67.9**	
	Maximum	**64.5**	**73.0**	
	Energy Average	**62.8**	**69.7**	**46.0 dBA**
	Standard Deviation	**1.27**	**2.16**	
Total L_{dn} and Impact Analysis				
			Ambient L_{dn} (measured 9/8/2009)	64 dBA
			Project L_{dn}	53 dBA
			Impact Level = 61 dBA L_{dn}	No

Notes:

- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient L_{dn} is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-4. Pass-By Measurements and L_{dn} Levels for Site N1C (11926 Interurban Place S)
Measured data from August 11, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	66.2	73.7	
NB	2	65.4	72.8	
NB	2	65.2	73.3	
NB	2	67.2	75.6	
NB	2	66.7	72.6	
NB	2	66.5	74.9	
	Minimum	**65.2**	**72.6**	
	Maximum	**67.2**	**75.6**	
	Energy Average	**66.2**	**73.8**	**50.1 dBA**
	Standard Deviation	**0.77**	**1.20**	
SB	2	62.7	70.5	
SB	2	63.0	73.3	
SB	2	62.3	70.9	
SB	2	62.3	72.5	
SB	2	63.8	72.2	
SB	2	65.9	74.4	
	Minimum	**62.3**	**70.5**	
	Maximum	**65.9**	**74.4**	
	Energy Average	**63.3**	**72.3**	**48.6 dBA**
	Standard Deviation	**1.38**	**1.46**	
Total L_{dn} and Impact Analysis				
			Ambient L_{dn} (measured 9/8/2009)	65 dBA
			Project L_{dn}	52 dBA
			Impact Level = 61 dBA L_{dn}	No

Notes:
- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient L_{dn} is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-5. L_{dn} Measurements for Site N2

Data Type	Date	Time	Hourly Leq
Time Block	9/8/2010	12:00 PM	66.1
Time Block	9/8/2010	1:00 PM	66.1
Time Block	9/8/2010	2:00 PM	66.6
Time Block	9/8/2010	3:00 PM	66.8
Time Block	9/8/2010	4:00 PM	66.8
Time Block	9/8/2010	5:00 PM	66.5
Time Block	9/8/2010	6:00 PM	65.7
Time Block	9/8/2010	7:00 PM	63.7
Time Block	9/8/2010	8:00 PM	63.1
Time Block	9/8/2010	9:00 PM	62.8
Time Block	9/8/2010	10:00 PM	61.4
Time Block	9/8/2010	11:00 PM	60.7
Time Block	9/8/2010	12:00 AM	60.2
Time Block	9/9/2010	1:00 AM	57.6
Time Block	9/9/2010	2:00 AM	56.4
Time Block	9/9/2010	3:00 AM	57.8
Time Block	9/9/2010	4:00 AM	60.7
Time Block	9/9/2010	5:00 AM	63.9
Time Block	9/9/2010	6:00 AM	66.2
Time Block	9/9/2010	7:00 AM	66.9
Time Block	9/9/2010	8:00 AM	66.9
Time Block	9/9/2010	9:00 AM	65.8
Time Block	9/9/2010	10:00 AM	65.4
Time Block	9/9/2010	11:00 AM	65.8
Time Block	9/9/2010	12:00 PM	65.7
Time Block	9/9/2010	1:00 PM	66.1
Time Block	9/9/2010	2:00 PM	67.0
Time Block	9/9/2010	3:00 PM	66.6
Time Block	9/9/2010	4:00 PM	72.3
Time Block	9/9/2010	5:00 PM	66.5
Time Block	9/9/2010	6:00 PM	65.6
Time Block	9/9/2010	7:00 PM	65.1
Time Block	9/9/2010	8:00 PM	63.8
Time Block	9/9/2010	9:00 PM	62.7
Time Block	9/9/2010	10:00 PM	63.0
Time Block	9/9/2010	11:00 PM	61.8
Time Block	9/9/2010	12:00 AM	60.5
Time Block	9/10/2010	1:00 AM	60.6
Time Block	9/10/2010	2:00 AM	58.3
Time Block	9/10/2010	3:00 AM	58.7
Time Block	9/10/2010	4:00 AM	61.1
Time Block	9/10/2010	5:00 AM	64.1
Time Block	9/10/2010	6:00 AM	67.0
Time Block	9/10/2010	7:00 AM	66.9
Time Block	9/10/2010	8:00 AM	66.7
Time Block	9/10/2010	9:00 AM	65.9
Time Block	9/10/2010	10:00 AM	65.8
Time Block	9/10/2010	11:00 AM	66.0
Time Block	9/10/2010	12:00 PM	65.8

A-5. L_{dn} Measurements for Site N2

Data Type	Date	Time	Hourly Leq
Time Block	9/10/2010	1:00 PM	65.8
Time Block	9/10/2010	2:00 PM	66.9
Time Block	9/10/2010	3:00 PM	65.3
Time Block	9/10/2010	4:00 PM	66.9
Time Block	9/10/2010	5:00 PM	66.2
Time Block	9/10/2010	6:00 PM	65.4
Time Block	9/10/2010	7:00 PM	65.2
Time Block	9/10/2010	8:00 PM	64.0
Time Block	9/10/2010	9:00 PM	65.4
Time Block	9/10/2010	10:00 PM	63.1
Time Block	9/10/2010	11:00 PM	61.7
Time Block	9/10/2010	12:00 AM	60.4
Time Block	9/11/2010	1:00 AM	58.6
Time Block	9/11/2010	2:00 AM	55.7
Time Block	9/11/2010	3:00 AM	56.0
Time Block	9/11/2010	4:00 AM	57.1
Time Block	9/11/2010	5:00 AM	59.6
Time Block	9/11/2010	6:00 AM	60.9
Time Block	9/11/2010	7:00 AM	62.1
Time Block	9/11/2010	8:00 AM	63.6
Time Block	9/11/2010	9:00 AM	63.5
Time Block	9/11/2010	10:00 AM	62.9
Time Block	9/11/2010	11:00 AM	62.8
Time Block	9/11/2010	12:00 PM	62.3
		Operational L_{dn}	**68.8 dBA**
		Pre-Project L_{dn}	**71.0 dBA**
		Change in L_{dn}	-2.2 dB
		Allowable Increase (see table 1)	**1.0 dB**
		Impact	**No**

Note: Sound wall also blocks traffic noise from SR599, reducing the overall noise level at the residence.

A-6. Pass-By Measurements and L_{dn} Levels for Site N3
Measured data from August 27, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	68.1	73.7	
NB	2	67.0	72.8	
NB	2	68.9	75.0	
NB	2	68.2	74.5	
NB	2	69.1	74.9	
NB	2	67.4	73.8	
	Minimum	**67.0**	**72.8**	
	Maximum	**69.1**	**75.0**	
	Energy Average	**68.1**	**74.1**	**50.4 dBA**
	Standard Deviation	**0.82**	**0.84**	
SB	2	70.3	76.5	
SB	2	71.6	77.2	
SB	2	72.1	78.1	
SB	2	72.6	78.3	
SB	2	72.9	78.2	
SB	2	72.0	78.0	
	Minimum	**70.3**	**76.5**	
	Maximum	**72.9**	**78.3**	
	Energy Average	**71.9**	**77.7**	**54.0 dBA**
	Standard Deviation	**0.92**	**0.71**	
Total L_{dn} and Impact Analysis				
			Pre-Project L_{dn}	69 dBA
			Project L_{dn}	56 dBA
			Impact Level = 64 dBA L_{dn}	No

Notes:
- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient L_{dn} is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-7. Pass-By Measurements and L_{dn} Levels for Site N4
Measured data from September 8, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	76.8	82.4	
NB	2	75.8	82.4	
NB	2	76.3	82.0	
NB	2	76.6	82.1	
NB	2	75.2	80.9	
NB	2	75.6	82.2	
	Minimum	**75.2**	**80.9**	
	Maximum	**76.8**	**82.4**	
	Energy Average	**76.1**	**82.0**	**58.3 dBA**
	Standard Deviation	**0.62**	**0.56**	
Southbound Trains				
SB	2	75.3	82.7	
SB	2	75.1	81.1	
SB	2	75.1	80.3	
SB	2	74.9	81.5	
SB	2	74.9	80.7	
NB	2	74.7	81.6	
	Minimum	**74.7**	**80.3**	
	Maximum	**75.3**	**82.7**	
	Energy Average	**75.0**	**81.3**	**57.6 dBA**
	Standard Deviation	**0.21**	**0.84**	
			Pre-Project L_{dn}	69 dBA
			Project L_{dn}	61 dBA
			Impact Level = 64 dBA L_{dn}	No

Notes:
- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient L_{dn} is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-8. L_{dn} Measurements for Site N5

Data Type	Date	Time	Hourly Leq
Time Block	9/8/2010	12:00 PM	69.7
Time Block	9/8/2010	1:00 PM	69.7
Time Block	9/8/2010	2:00 PM	69.9
Time Block	9/8/2010	3:00 PM	70.1
Time Block	9/8/2010	4:00 PM	69.9
Time Block	9/8/2010	5:00 PM	69.7
Time Block	9/8/2010	6:00 PM	69.1
Time Block	9/8/2010	7:00 PM	68.7
Time Block	9/8/2010	8:00 PM	67.0
Time Block	9/8/2010	9:00 PM	66.6
Time Block	9/8/2010	10:00 PM	66.0
Time Block	9/8/2010	11:00 PM	64.6
Time Block	9/8/2010	12:00 AM	63.4
Time Block	9/9/2010	1:00 AM	61.8
Time Block	9/9/2010	2:00 AM	61.2
Time Block	9/9/2010	3:00 AM	62.1
Time Block	9/9/2010	4:00 AM	64.1
Time Block	9/9/2010	5:00 AM	66.9
Time Block	9/9/2010	6:00 AM	68.6
Time Block	9/9/2010	7:00 AM	69.0
Time Block	9/9/2010	8:00 AM	69.8
Time Block	9/9/2010	9:00 AM	69.8
Time Block	9/9/2010	10:00 AM	69.8
Time Block	9/9/2010	11:00 AM	69.9
Time Block	9/9/2010	12:00 PM	70.0
Time Block	9/9/2010	1:00 PM	70.3
Time Block	9/9/2010	2:00 PM	70.5
Time Block	9/9/2010	3:00 PM	70.2
Time Block	9/9/2010	4:00 PM	69.8
Time Block	9/9/2010	5:00 PM	69.9
Time Block	9/9/2010	6:00 PM	69.8
Time Block	9/9/2010	7:00 PM	68.9
Time Block	9/9/2010	8:00 PM	67.9
Time Block	9/9/2010	9:00 PM	67.5
Time Block	9/9/2010	10:00 PM	67.6
Time Block	9/9/2010	11:00 PM	66.2
Time Block	9/9/2010	12:00 AM	64.2
Time Block	9/10/2010	1:00 AM	62.8
Time Block	9/10/2010	2:00 AM	62.4
Time Block	9/10/2010	3:00 AM	62.8
Time Block	9/10/2010	4:00 AM	65.1
Time Block	9/10/2010	5:00 AM	67.4
Time Block	9/10/2010	6:00 AM	69.4
Time Block	9/10/2010	7:00 AM	69.6
Time Block	9/10/2010	8:00 AM	69.9
Time Block	9/10/2010	9:00 AM	69.7
Time Block	9/10/2010	10:00 AM	70.1
Time Block	9/10/2010	11:00 AM	70.2
Time Block	9/10/2010	12:00 PM	69.9
Time Block	9/10/2010	1:00 PM	69.9

A-8. L_{dn} Measurements for Site N5

Data Type	Date	Time	Hourly Leq
Time Block	9/10/2010	2:00 PM	69.0
Time Block	9/10/2010	3:00 PM	62.4
Time Block	9/10/2010	4:00 PM	64.8
Time Block	9/10/2010	5:00 PM	67.7
Time Block	9/10/2010	6:00 PM	69.3
Time Block	9/10/2010	7:00 PM	68.6
Time Block	9/10/2010	8:00 PM	68.0
Time Block	9/10/2010	9:00 PM	67.6
Time Block	9/10/2010	10:00 PM	67.0
Time Block	9/10/2010	11:00 PM	65.8
Time Block	9/10/2010	12:00 AM	63.8
Time Block	9/11/2010	1:00 AM	63.0
Time Block	9/11/2010	2:00 AM	62.3
Time Block	9/11/2010	3:00 AM	61.2
Time Block	9/11/2010	4:00 AM	62.4
Time Block	9/11/2010	5:00 AM	64.0
Time Block	9/11/2010	6:00 AM	65.7
Time Block	9/11/2010	7:00 AM	67.1
Time Block	9/11/2010	8:00 AM	67.7
Time Block	9/11/2010	9:00 AM	68.2
Time Block	9/11/2010	10:00 AM	68.4
Time Block	9/11/2010	11:00 AM	68.2
Time Block	9/11/2010	12:00 PM	68.0
Time Block	9/11/2010	1:00 PM	67.1
		Operational L_{dn}	**72.3 dBA**
		Pre-Project L_{dn}	**73.0 dBA**
		Change in L_{dn}	-0.7 dB
		Allowable Increase (see table 1)	**0.6 dB**
		Impact	**No**

Note: Sound wall also blocks traffic noise from SR599, reducing the overall noise level at the residence.

A-9. L_{dn} Measurements for Site N6

Data Type	Date	Time	Hourly Leq
Time Block	9/8/2010	4:00 PM	68.8
Time Block	9/8/2010	5:00 PM	68.7
Time Block	9/8/2010	6:00 PM	68.5
Time Block	9/8/2010	7:00 PM	67.8
Time Block	9/8/2010	8:00 PM	67.0
Time Block	9/8/2010	9:00 PM	66.8
Time Block	9/8/2010	10:00 PM	65.9
Time Block	9/8/2010	11:00 PM	64.5
Time Block	9/8/2010	12:00 AM	63.2
Time Block	9/9/2010	1:00 AM	61.7
Time Block	9/9/2010	2:00 AM	61.2
Time Block	9/9/2010	3:00 AM	62.0
Time Block	9/9/2010	4:00 AM	64.3
Time Block	9/9/2010	5:00 AM	67.2
Time Block	9/9/2010	6:00 AM	68.8
Time Block	9/9/2010	7:00 AM	69.1
Time Block	9/9/2010	8:00 AM	69.1
Time Block	9/9/2010	9:00 AM	68.9
Time Block	9/9/2010	10:00 AM	69.0
Time Block	9/9/2010	11:00 AM	69.0
Time Block	9/9/2010	12:00 PM	69.0
Time Block	9/9/2010	1:00 PM	69.3
Time Block	9/9/2010	2:00 PM	69.4
Time Block	9/9/2010	3:00 PM	69.3
Time Block	9/9/2010	4:00 PM	68.9
Time Block	9/9/2010	5:00 PM	69.0
Time Block	9/9/2010	6:00 PM	68.9
Time Block	9/9/2010	7:00 PM	68.4
Time Block	9/9/2010	8:00 PM	67.6
Time Block	9/9/2010	9:00 PM	67.2
Time Block	9/9/2010	10:00 PM	67.3
Time Block	9/9/2010	11:00 PM	66.0
Time Block	9/9/2010	12:00 AM	63.8
Time Block	9/10/2010	1:00 AM	62.2
Time Block	9/10/2010	2:00 AM	61.9
Time Block	9/10/2010	3:00 AM	62.3
Time Block	9/10/2010	4:00 AM	64.6
Time Block	9/10/2010	5:00 AM	67.2
Time Block	9/10/2010	6:00 AM	69.3
Time Block	9/10/2010	7:00 AM	69.2
Time Block	9/10/2010	8:00 AM	69.3
Time Block	9/10/2010	9:00 AM	69.1
Time Block	9/10/2010	10:00 AM	69.4
Time Block	9/10/2010	11:00 AM	69.2

A-9. L_{dn} Measurements for Site N6

Data Type	Date	Time	Hourly Leq
Time Block	9/10/2010	12:00 PM	69.0
Time Block	9/10/2010	1:00 PM	68.9
Time Block	9/10/2010	2:00 PM	68.4
Time Block	9/10/2010	3:00 PM	63.6
Time Block	9/10/2010	4:00 PM	65.4
Time Block	9/10/2010	5:00 PM	67.2
Time Block	9/10/2010	6:00 PM	68.6
Time Block	9/10/2010	7:00 PM	68.4
Time Block	9/10/2010	8:00 PM	67.8
Time Block	9/10/2010	9:00 PM	67.4
Time Block	9/10/2010	10:00 PM	67.0
Time Block	9/10/2010	11:00 PM	65.9
Time Block	9/10/2010	12:00 AM	64.0
Time Block	9/11/2010	1:00 AM	63.0
Time Block	9/11/2010	2:00 AM	62.1
Time Block	9/11/2010	3:00 AM	61.1
Time Block	9/11/2010	4:00 AM	62.0
Time Block	9/11/2010	5:00 AM	63.6
Time Block	9/11/2010	6:00 AM	65.2
Time Block	9/11/2010	7:00 AM	66.7
Time Block	9/11/2010	8:00 AM	67.2
Time Block	9/11/2010	9:00 AM	67.8
Time Block	9/11/2010	10:00 AM	67.7
Time Block	9/11/2010	11:00 AM	67.4
Time Block	9/11/2010	12:00 PM	67.1
Time Block	9/11/2010	1:00 PM	66.3
		Operational L_{dn}	**72.1 dBA**
		Pre-Project L_{dn}	**73.0 dBA**
		Change in L_{dn}	-0.9 dB
		Allowable Increase (see table 1)	**0.6 dB**
		Impact	**No**

Note: Sound wall also blocks traffic noise from SR599, reducing the overall noise level at the residence.

A-10. L_{dn} Measurements for Site N6A

Data Type	Date	Time	Hourly Leq
Time Block	8/2/2010	7:00 AM	67.3
Time Block	8/2/2010	8:00 AM	67.2
Time Block	8/2/2010	9:00 AM	67.2
Time Block	8/2/2010	10:00 AM	67.3
Time Block	8/2/2010	11:00 AM	67.7
Time Block	8/2/2010	12:00 PM	66.9
Time Block	8/2/2010	1:00 PM	66.5
Time Block	8/2/2010	2:00 PM	67.2
Time Block	8/2/2010	3:00 PM	66.7
Time Block	8/2/2010	4:00 PM	66.6
Time Block	8/2/2010	5:00 PM	66.1
Time Block	8/2/2010	6:00 PM	66.3
Time Block	8/2/2010	7:00 PM	66.5
Time Block	8/2/2010	8:00 PM	65.8
Time Block	8/2/2010	9:00 PM	65.2
Time Block	8/2/2010	10:00 PM	64.7
Time Block	8/2/2010	11:00 PM	63.6
Time Block	8/2/2010	12:00 AM	62.3
Time Block	8/3/2010	1:00 AM	60.4
Time Block	8/3/2010	2:00 AM	60.2
Time Block	8/3/2010	3:00 AM	60.3
Time Block	8/3/2010	4:00 AM	62.2
Time Block	8/3/2010	5:00 AM	65.5
Time Block	8/3/2010	6:00 AM	67.6
Time Block	8/3/2010	7:00 AM	67.8
Time Block	8/3/2010	8:00 AM	67.9
Time Block	8/3/2010	9:00 AM	70.0
Time Block	8/3/2010	10:00 AM	67.9
Time Block	8/3/2010	11:00 AM	67.6
Time Block	8/3/2010	12:00 PM	66.4
Time Block	8/3/2010	1:00 PM	66.3
Time Block	8/3/2010	2:00 PM	66.1
Time Block	8/3/2010	3:00 PM	67.0
Time Block	8/3/2010	4:00 PM	66.4
Time Block	8/3/2010	5:00 PM	66.1
Time Block	8/3/2010	6:00 PM	66.1
Time Block	8/3/2010	7:00 PM	65.8
Time Block	8/3/2010	8:00 PM	65.7
Time Block	8/3/2010	9:00 PM	65.5
Time Block	8/3/2010	10:00 PM	65.1
Time Block	8/3/2010	11:00 PM	64.0
Time Block	8/3/2010	12:00 AM	62.7
Time Block	8/4/2010	1:00 AM	61.0
Time Block	8/4/2010	2:00 AM	60.5
Time Block	8/4/2010	3:00 AM	60.7
Time Block	8/4/2010	4:00 AM	62.6
Time Block	8/4/2010	5:00 AM	65.6
Time Block	8/4/2010	6:00 AM	67.3
Time Block	8/4/2010	7:00 AM	67.9

A-10. L_{dn} Measurements for Site N6A

Data Type	Date	Time	Hourly Leq
Time Block	8/4/2010	8:00 AM	67.7
Time Block	8/4/2010	9:00 AM	67.1
Time Block	8/4/2010	10:00 AM	66.5
Time Block	8/4/2010	11:00 AM	66.7
Time Block	8/4/2010	12:00 PM	66.3
Time Block	8/4/2010	1:00 PM	66.8
Time Block	8/4/2010	2:00 PM	66.1
Time Block	8/4/2010	3:00 PM	66.1
Time Block	8/4/2010	4:00 PM	65.9
Time Block	8/4/2010	5:00 PM	65.0
Time Block	8/4/2010	6:00 PM	65.7
Time Block	8/4/2010	7:00 PM	65.9
Time Block	8/4/2010	8:00 PM	65.9
Time Block	8/4/2010	9:00 PM	65.3
Time Block	8/4/2010	10:00 PM	65.4
Time Block	8/4/2010	11:00 PM	64.2
Time Block	8/4/2010	12:00 AM	62.4
Time Block	8/5/2010	1:00 AM	61.5
Time Block	8/5/2010	2:00 AM	60.1
Time Block	8/5/2010	3:00 AM	60.5
Time Block	8/5/2010	4:00 AM	62.6
Time Block	8/5/2010	5:00 AM	65.7
Time Block	8/5/2010	6:00 AM	67.0
Time Block	8/5/2010	7:00 AM	66.9
Time Block	8/5/2010	8:00 AM	67.1
Time Block	8/5/2010	9:00 AM	67.5
Time Block	8/5/2010	10:00 AM	68.3
		Operational L_{dn}	**70.7 dBA**
		Pre-Project L_{dn}	**73.0 dBA**
		Change in L_{dn}	-2.3 dB
		Allowable Increase (see table 1)	**0.6 dB**
		Impact	**No**

Note: Sound wall also blocks traffic noise from SR599, reducing the overall noise level at the residence.

A-11. Pass-By Measurements and L_{dn} Levels for Site N7
Measured data from September 30, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	65.1	76.1	
NB	2	65.4	75.5	
NB	2	66.2	74.8	
NB	2	66.4	77.2	
NB	2	65.8	77.5	
NB	2	66.8	77.8	
	Minimum	**65.1**	**74.8**	
	Maximum	**66.8**	**77.8**	
	Energy Average	**66.0**	**76.5**	**52.8 dBA**
	Standard Deviation	**0.64**	**1.20**	
SB	2	69.3	71.0	
SB	2	67.9	74.9	
SB	2	66.8	75.3	
SB	2	67.4	73.2	
SB	2	66.6	74.5	
SB	2	66.9	74.8	
	Minimum	**66.6**	**71.0**	
	Maximum	**69.3**	**75.3**	
	Energy Average	**67.5**	**74.0**	**50.3 dBA**
	Standard Deviation	**1.01**	**1.61**	
Total L_{dn} and Impact Analysis				
			Pre-Project L_{dn}	73 dBA
			Project L_{dn}	55 dBA
			Impact Level = 66 dBA L_{dn}	No

Notes:

- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient L_{dn} is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-12. Pass-By Measurements and L_{dn} Levels for Site N8
Measured data from September 11, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	74.3	82.3	
NB	2	68.8	77.1	
NB	2	72.6	79.8	
NB	2	70.5	79.0	
NB	2	69.7	79.9	
NB	2	68.0	78.1	
	Minimum	**68.0**	**77.1**	
	Maximum	**74.3**	**82.3**	
	Energy Average	**70.7**	**79.4**	**55.7 dBA**
	Standard Deviation	**2.39**	**1.79**	
Southbound Trains				
SB	2	70.1	79.2	
SB	2	71.5	80.1	
SB	2	73.5	79.6	
SB	2	72.1	80.5	
SB	2	68.3	77.4	
SB	2	69.2	75.5	
	Minimum	**68.3**	**75.5**	
	Maximum	**73.5**	**80.5**	
	Energy Average	**70.8**	**78.7**	**55.0 dBA**
	Standard Deviation	**1.94**	**1.91**	
Total L_{dn} and Impact Analysis				
			Pre-Project L_{dn}	73 dBA
			Project L_{dn}	58 dBA
			Impact Level = 66 dBA L_{dn}	No

Notes:

- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient Ldn is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-13. L_{dn} Measurements for Site N8A

Data Type	Date	Time	Hourly Leq
Time Block	8/2/2010	7:00 AM	64.5
Time Block	8/2/2010	8:00 AM	64.8
Time Block	8/2/2010	9:00 AM	64.6
Time Block	8/2/2010	10:00 AM	64.7
Time Block	8/2/2010	11:00 AM	65.7
Time Block	8/2/2010	12:00 PM	65.1
Time Block	8/2/2010	1:00 PM	64.9
Time Block	8/2/2010	2:00 PM	65.9
Time Block	8/2/2010	3:00 PM	67.6
Time Block	8/2/2010	4:00 PM	65.0
Time Block	8/2/2010	5:00 PM	64.7
Time Block	8/2/2010	6:00 PM	64.4
Time Block	8/2/2010	7:00 PM	65.1
Time Block	8/2/2010	8:00 PM	64.4
Time Block	8/2/2010	9:00 PM	64.1
Time Block	8/2/2010	10:00 PM	63.6
Time Block	8/2/2010	11:00 PM	61.6
Time Block	8/2/2010	12:00 AM	60.3
Time Block	8/3/2010	1:00 AM	57.3
Time Block	8/3/2010	2:00 AM	56.3
Time Block	8/3/2010	3:00 AM	57.6
Time Block	8/3/2010	4:00 AM	60.2
Time Block	8/3/2010	5:00 AM	63.2
Time Block	8/3/2010	6:00 AM	64.9
Time Block	8/3/2010	7:00 AM	65.3
Time Block	8/3/2010	8:00 AM	65.0
Time Block	8/3/2010	9:00 AM	65.0
Time Block	8/3/2010	10:00 AM	64.5
Time Block	8/3/2010	11:00 AM	64.5
Time Block	8/3/2010	12:00 PM	64.3
Time Block	8/3/2010	1:00 PM	66.4
Time Block	8/3/2010	2:00 PM	64.1
Time Block	8/3/2010	3:00 PM	65.5
Time Block	8/3/2010	4:00 PM	64.9
Time Block	8/3/2010	5:00 PM	65.0
Time Block	8/3/2010	6:00 PM	64.5
Time Block	8/3/2010	7:00 PM	64.5
Time Block	8/3/2010	8:00 PM	64.5
Time Block	8/3/2010	9:00 PM	64.7
Time Block	8/3/2010	10:00 PM	65.0
Time Block	8/3/2010	11:00 PM	62.2
Time Block	8/3/2010	12:00 AM	60.7
Time Block	8/4/2010	1:00 AM	58.5
Time Block	8/4/2010	2:00 AM	57.1
Time Block	8/4/2010	3:00 AM	57.1
Time Block	8/4/2010	4:00 AM	59.7
Time Block	8/4/2010	5:00 AM	62.9
Time Block	8/4/2010	6:00 AM	64.6
Time Block	8/4/2010	7:00 AM	65.2
Time Block	8/4/2010	8:00 AM	64.9

A-13. L_{dn} Measurements for Site N8A

Data Type	Date	Time	Hourly Leq
Time Block	8/4/2010	9:00 AM	63.9
Time Block	8/4/2010	10:00 AM	63.8
Time Block	8/4/2010	11:00 AM	64.4
Time Block	8/4/2010	12:00 PM	64.4
Time Block	8/4/2010	1:00 PM	64.1
Time Block	8/4/2010	2:00 PM	64.1
Time Block	8/4/2010	3:00 PM	64.6
Time Block	8/4/2010	4:00 PM	64.5
Time Block	8/4/2010	5:00 PM	64.8
Time Block	8/4/2010	6:00 PM	64.5
Time Block	8/4/2010	7:00 PM	64.2
Time Block	8/4/2010	8:00 PM	63.9
Time Block	8/4/2010	9:00 PM	63.9
Time Block	8/4/2010	10:00 PM	63.8
Time Block	8/4/2010	11:00 PM	62.2
Time Block	8/4/2010	12:00 AM	60.5
Time Block	8/5/2010	1:00 AM	58.4
Time Block	8/5/2010	2:00 AM	57.3
Time Block	8/5/2010	3:00 AM	57.0
Time Block	8/5/2010	4:00 AM	60.5
Time Block	8/5/2010	5:00 AM	63.1
Time Block	8/5/2010	6:00 AM	64.1
Time Block	8/5/2010	7:00 AM	64.1
Time Block	8/5/2010	8:00 AM	64.1
Time Block	8/5/2010	9:00 AM	65.4
Time Block	8/5/2010	10:00 AM	65.1
		Operational L_{dn}	**68.5 dBA**
		Pre-Project L_{dn}	**73.0 dBA**
		Change in L_{dn}	-4.5 dB
		Allowable Increase (see table 1)	**0.6 dB**
		Impact	**No**

A-14. Pass-By Measurements and L_{dn} Levels for Site N9
Measured data from September 11, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	68.9	78.0	
NB	2	67.7	75.4	
NB	2	66.0	75.8	
NB	2	67.4	76.7	
NB	2	68.4	77.9	
NB	2	66.9	76.1	
	Minimum	**66.0**	**75.4**	
	Maximum	**68.9**	**78.0**	
	Energy Average	**67.6**	**76.7**	**52.9 dBA**
	Standard Deviation	**1.04**	**1.09**	
Southbound Trains				
SB	2	68.3	76.2	
SB	2	68.5	77.8	
SB	2	69.1	77.9	
SB	2	67.0	77.1	
SB	2	70.0	81.1	
SB	2	68.4	77.2	
	Minimum	**67.0**	**76.2**	
	Maximum	**70.0**	**81.1**	
	Energy Average	**68.6**	**77.9**	**54.2 dBA**
	Standard Deviation	**0.99**	**1.69**	
Total L_{dn} and Impact Analysis				
			Pre-Project L_{dn}	73 dBA
			Project L_{dn}	57 dBA
			Impact Level = 66 dBA L_{dn}	No

Notes:
- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient Ldn is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-15. Pass-By Measurements and L_{dn} Levels for Site N10
Measured data from September 11, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	75.9	83.7	
NB	2	76.4	85.4	
NB	2	75.7	84.0	
NB	2	75.4	84.1	
NB	2	76.8	86.6	
NB	2	76.5	84.5	
	Minimum	**75.4**	**83.7**	
	Maximum	**76.8**	**86.6**	
	Energy Average	**76.1**	**84.7**	**61.0 dBA**
	Standard Deviation	**0.53**	**1.09**	
Southbound Trains				
SB	2	76.4	85.6	
SB	2	75.9	83.6	
SB	2	76.5	85.2	
SB	2	74.8	83.2	
SB	2	72.6	83.5	
SB	2	74.5	82.5	
	Minimum	**72.6**	**61.0**	
	Maximum	**76.5**	**85.6**	
	Energy Average	**75.1**	**83.9**	**60.2 dBA**
	Standard Deviation	**1.48**	**1.21**	
Total L_{dn} and Impact Analysis				
			Pre-Project L_{dn}	73 dBA
			Project L_{dn}	61 dBA
			Impact Level = 66 dBA L_{dn}	No

Notes:
- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient Ldn is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-16. Pass-By Measurements and L_{dn} Levels for Site N11
Measured data from September 11, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	75.9	85.8	
NB	2	74.0	81.2	
NB	2	74.9	81.9	
NB	2	78.3	85.0	
NB	2	77.8	85.0	
NB	2	76.2	83.3	
	Minimum	**74.0**	**81.2**	
	Maximum	**78.3**	**85.8**	
	Energy Average	**76.2**	**83.7**	**60.0 dBA**
	Standard Deviation	**1.65**	**1.87**	
Southbound Trains				
SB	2	80.7	87.6	
SB	2	81.9	87.5	
SB	2	80.3	87.4	
SB	2	80.6	86.6	
SB	2	81.2	87.7	
SB	2	81.8	87.2	
	Minimum	**80.3**	**86.6**	
	Maximum	**81.9**	**87.7**	
	Energy Average	**81.1**	**87.3**	**63.6 dBA**
	Standard Deviation	**0.66**	**0.40**	
Total L_{dn} and Impact Analysis				
			Pre-Project L_{dn}	73 dBA
			Project L_{dn}	65 dBA
			Impact Level = 66 dBA L_{dn}	No

Notes:

- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient Ldn is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

A-17. Pass-By Measurements and L_{dn} Levels for Site N12
Measured data from September 11, 2010

Direction	# Cars	L_{max}	SEL	Project L_{dn}
Northbound Trains				
NB	2	71.9	78.1	
NB	2	76.2	83.8	
NB	2	76.5	83.4	
NB	2	72.0	80.6	
NB	2	72.2	80.3	
NB	2	69.0	73.9	
NB	2	71.9	78.1	
	Minimum	**69.0**	**73.9**	
	Maximum	**76.5**	**83.8**	
	Energy Average	**73.0**	**80.0**	**56.3 dBA**
	Standard Deviation	**2.88**	**3.67**	
Southbound Trains				
SB	2	71.5	77.8	
SB	2	72.5	77.4	
SB	2	73.4	79.1	
SB	2	72.6	76.4	
SB	2	74.1	83.3	
SB	2	73.7	77.6	
SB	2	71.5	77.8	
	Minimum	**71.5**	**76.4**	
	Maximum	**74.1**	**83.3**	
	Energy Average	**73.0**	**78.6**	**54.9 dBA**
	Standard Deviation	**0.95**	**2.46**	
			Pre-Project L_{dn}	73 dBA
			Project L_{dn}	59 dBA
			Impact Level = 66 dBA L_{dn}	No

Notes:

- The L_{dn} noise levels are calculated using the average SEL and follow the methods in the FTA *Transit Noise and Vibration Assessment Manual,* April 2006.
- Ambient Ldn is without light rail operations.
- L_{dn} noise levels in **Bold-Red** typeface exceed the FTA criteria.

Attachment B

Vibration Measurement Details

Vibration levels were measured at four sites along the corridor. The vibration test sites are shown in Attachment C in Figures 3, 4, and 5. Site V1 is on a dead-end roadway with several single family homes that are currently under construction or improvements, with some buildings appearing to be abandoned. Site V2 is off 48th Ave S, along a retained fill segment of trackway. Site V3 is at the dead end of S 136th St, near a single family residence. Site V4 is along the retained cut segment of the trackway, south of the S 144th Street overpass.

The equipment used for the vibration measurements is listed in Table B-1. The accelerometers were mounted to metal plates and driven into the ground using a 6 inch steel stake. Calibration for all equipment is performed on an annual basis by PCB or Rion.

Table B-1: Summary of Equipment

Type	Manufacturer	Model/Serial Number	Calibration Information
Digital Recorder	Rion	DA-20 / 10991298	Factory on 10/25/2009
Accelerometer	PCB	393A03 / 25384	Factory on 10/25/2009
Charge Amp	PCB	480C02 / 0009620	Factory on 10/14/2009

The Lmax as well as the RMS average vibration velocity are presented for each location in Tables B2-B5. Lmax is the maximum 1-second RMS average using sequential 1-second intervals, not a running average. The “RMS average vibration velocity” is defined as the RMS average vibration velocity over the 3 decibel down points (relative to the 1-second RMS Lmax).

Site V1

Table B-2: Summary of Train Vibration Measurement at V1

Train	Track[1]	Direction[2]	Speed, mph	RMS Avg. Vibration Velocity, VdB	Lmax[4], VdB[3]
T1	NT	SB	55	61.7	64.1
T2	FT	NB	55	57.2	58.7
T3	NT	SB	55	57.5	59.9
T4	FT	NB	55	55.5	57.0
T5	FT	NB	55	55.5	57.2
T6	FT	NB	55	58.7	60.1
T7	NT	SB	55	57.9	60.3
T8	FT	NB	55	56.3	58.3
T9	NT	SB	55	58.5	60.3
T10	NT	SB	55	58.2	60.3
T11	FT	NB	55	56.2	58.1
T12	NT	SB	55	58.3	60.0

Notes:
[1] NT represents near track and FT represents far track.
[2] SB represents southbound trains and NB represented northbound trains.
[3] VdB has a reference value of 1uin/sec.
[4] Lmax is the maximum 1-second time constant RMS vibration velocity value.

Figure B-1: Time History of Vibration Measurement at Site V1

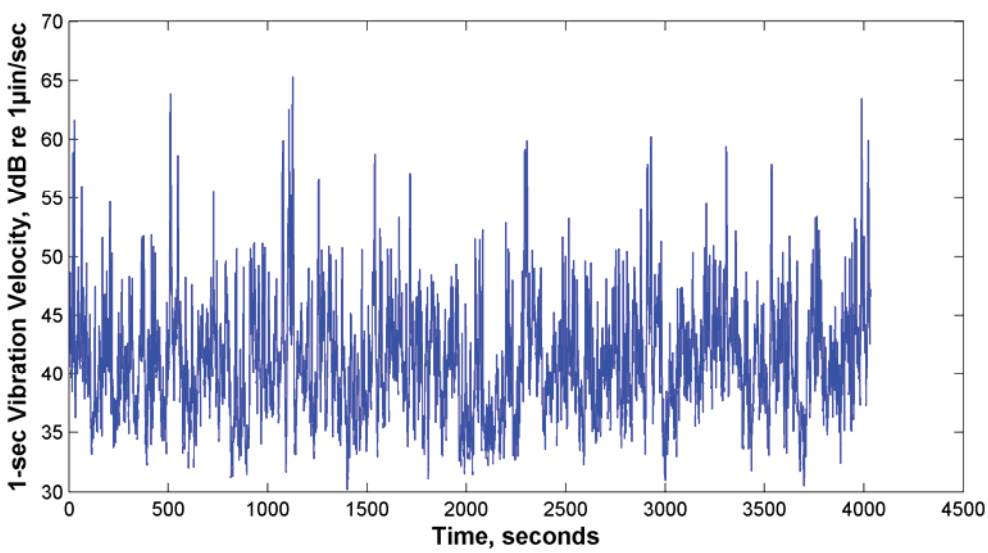
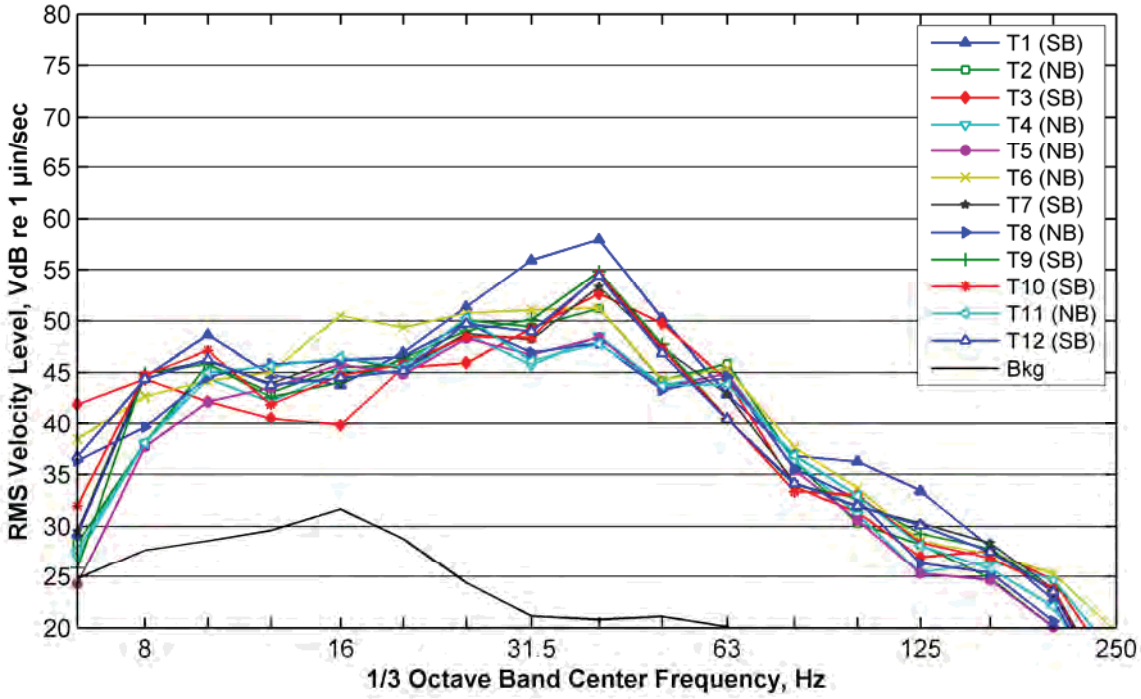


Figure B-2: Vibration Spectrum of Train Pass-bys at Site V1



Site V2

Table B-3: Summary of Train Vibration Measurement at V2

Train	Track[1]	Direction[2]	Speed, mph	RMS Avg. Vibration Velocity, VdB	Lmax[4], VdB[3]
T1	NT	SB	55	--[5]	--[5]
T2	FT	NB	55	63.9	65.6
T3	FT	NB	55	57.3	59.0
T4	NT	SB	55	64.2	65.4
T5	FT	NB	55	57.2	58.6
T6	NT	SB	55	65.0	66.5
T7	FT	NB	55	57.7	58.5
T8	FT	NB	55	57.4	58.7
T9	NT	SB	55	63.7	65.3
T10	--	NB+SB	55	63.9	65.4
T11	NT	SB	55	64.6	66.4
T12	FT	NB	55	56.9	58.1

Notes:
[1] NT represents near track and FT represents far track.
[2] SB represents southbound trains and NB represented northbound trains.
[3] VdB has a reference value of 1uin/sec.
[4] Lmax is the maximum 1-second time constant RMS vibration velocity value.
[5] Due to unknown interference, the first SB pass-by was not used, although it was still below the FTA criteria.

Figure B-3: Time History of Vibration Measurement at Site V2

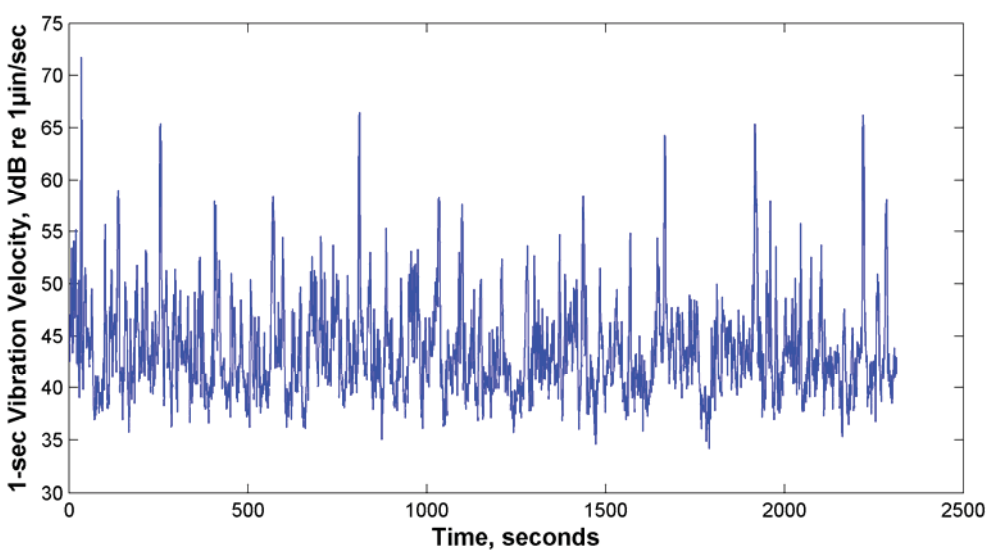
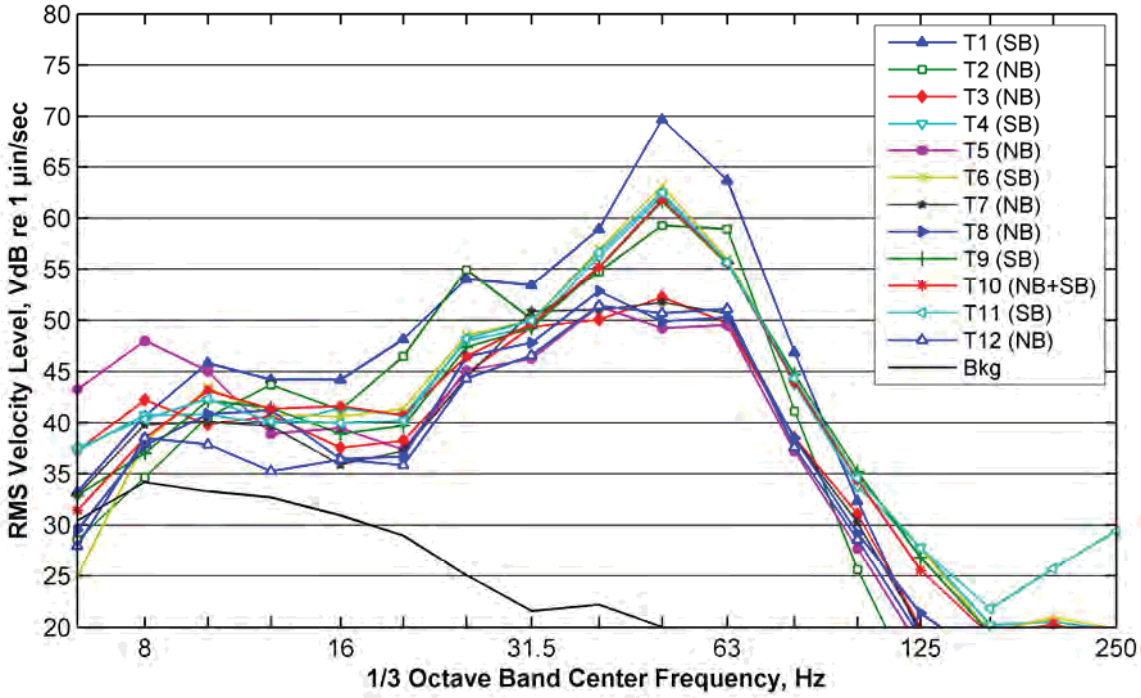


Figure B-4: Vibration Spectrum of Train Pass-bys at Site V2



Site V3

Table B-4: Summary of Train Vibration Measurement at V3

Train	Track[1]	Direction[2]	Speed, mph	RMS Avg. Vibration Velocity, VdB	Lmax[4], VdB[3]
T1	FT	NB	55	59.2	60.6
T2	NT	SB	55	59.9	62.4
T3	NT	SB	55	59.9	61.3
T4	FT	NB	55	59.7	61.1
T5	NT	SB	55	60.2	60.9
T6	FT	NB	55	60.4	62.0
T7	NT	SB	55	59.9	60.9
T8	FT	NB	55	59.1	60.8
T9	FT	NB	55	59.7	61.2
T10	NT	SB	55	61.0	62.8
T11	FT	NB	55	60.0	61.4
T12	FT	NB	55	59.0	60.7
T13	--	NB+SB	55	61.7	64.3

Notes:
[1] NT represents near track and FT represents far track.
[2] SB represents southbound trains and NB represented northbound trains.
[3] VdB has a reference value of 1uin/sec.
[4] Lmax is the maximum 1-second time constant RMS vibration velocity value.

Figure B-5: Time History of Vibration Measurement at Site V3

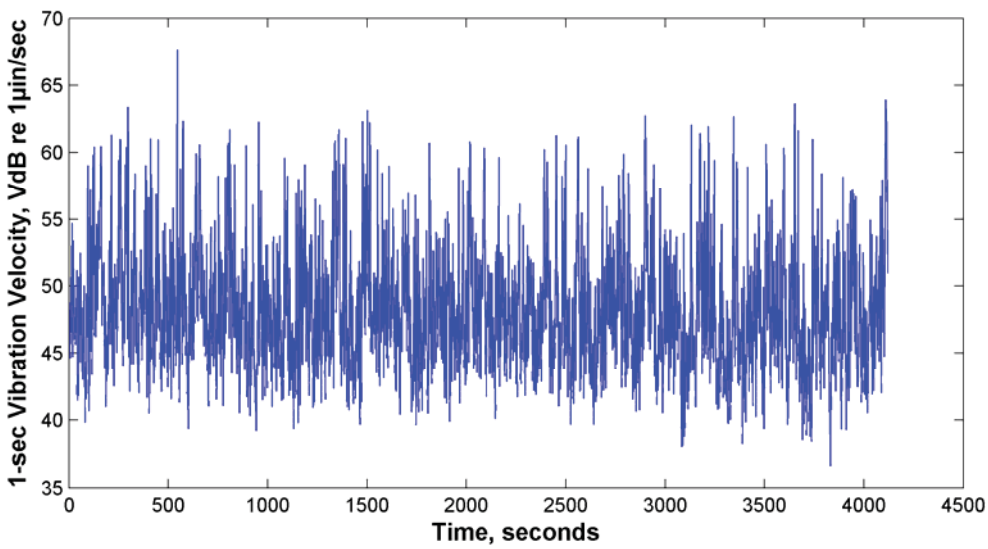
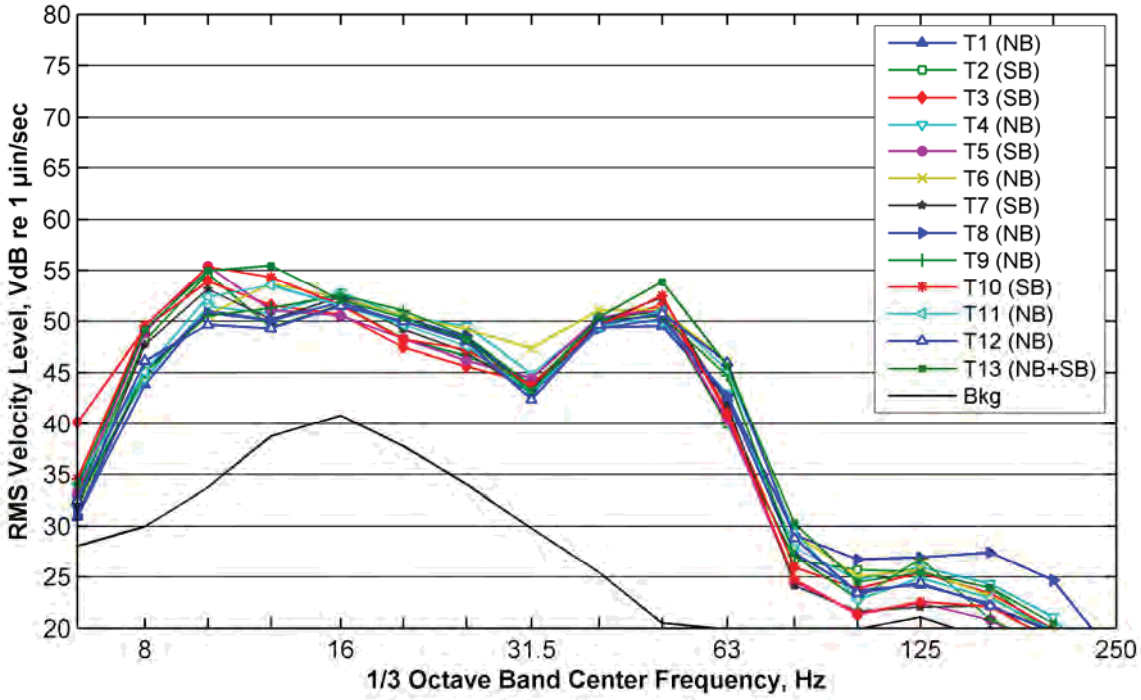


Figure B-6: Vibration Spectrum of Train Pass-bys at Site V3



Site V4

Table B-5: Summary of Train Vibration Measurement at V4

Train	Track[1]	Direction[2]	Speed, mph	RMS Avg. Vibration Velocity, VdB	Lmax[4], VdB[3]
T1	FT	NB	55	59.0	61.3
T2	NT	SB	55	59.5	61.0
T3	FT	NB	55	61.2	62.2
T4	NT	SB	55	59.0	61.0
T5	FT	NB	55	58.9	60.5
T6	NT	SB	55	60.1	61.9
T7	NT	SB	55	--	--
T8	FT	NB	55	60.3	62.0
T9	NT	SB	55	59.9	60.9
T10	FT	NB	55	59.8	61.7
T11	NT	SB	55	57.5	58.9
T12	FT	NB	55	61.1	62.9

Notes:
[1] NT represents near track and FT represents far track.
[2] SB represents southbound trains and NB represented northbound trains.
[3] VdB has a reference value of 1uin/sec.
[4] Lmax is the maximum 1-second time constant RMS vibration velocity value.
[5] Due to unknown interference, pass-by T7 was not used, although it was still below the FTA criteria.

Figure B-7: Time History of Vibration Measurement at Site V4

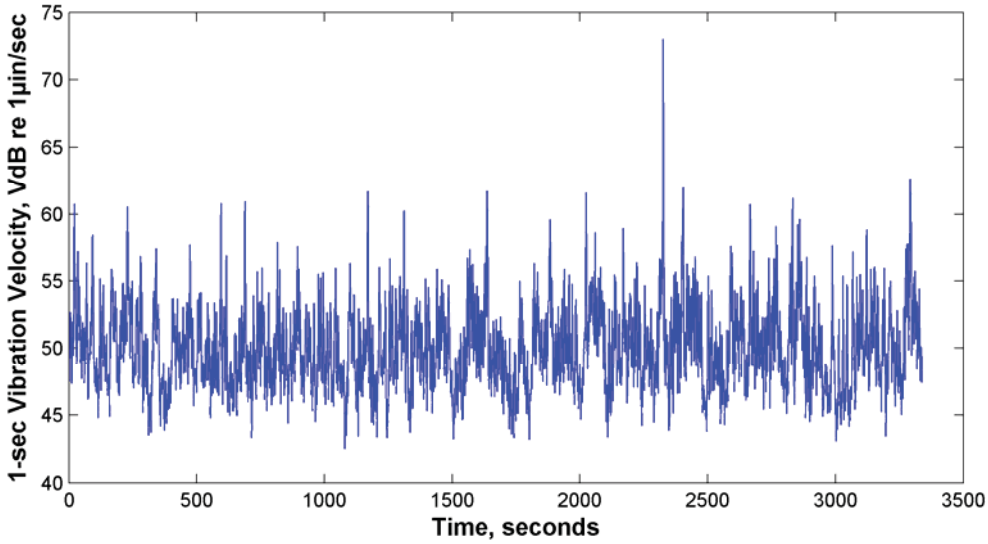
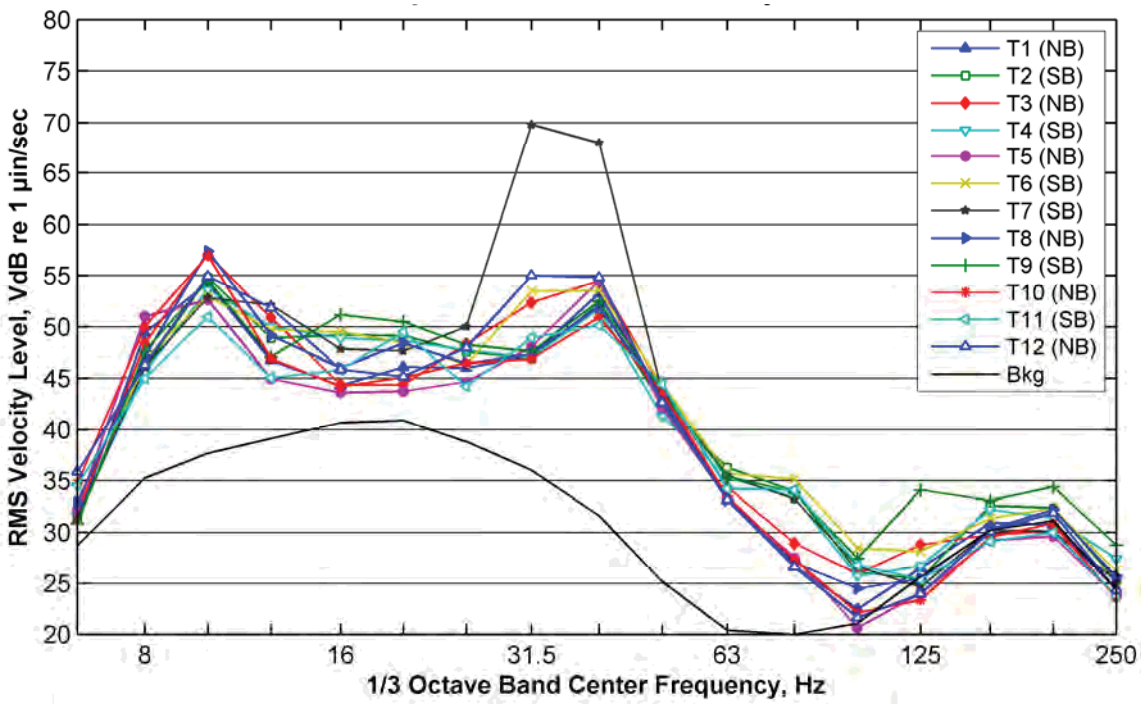
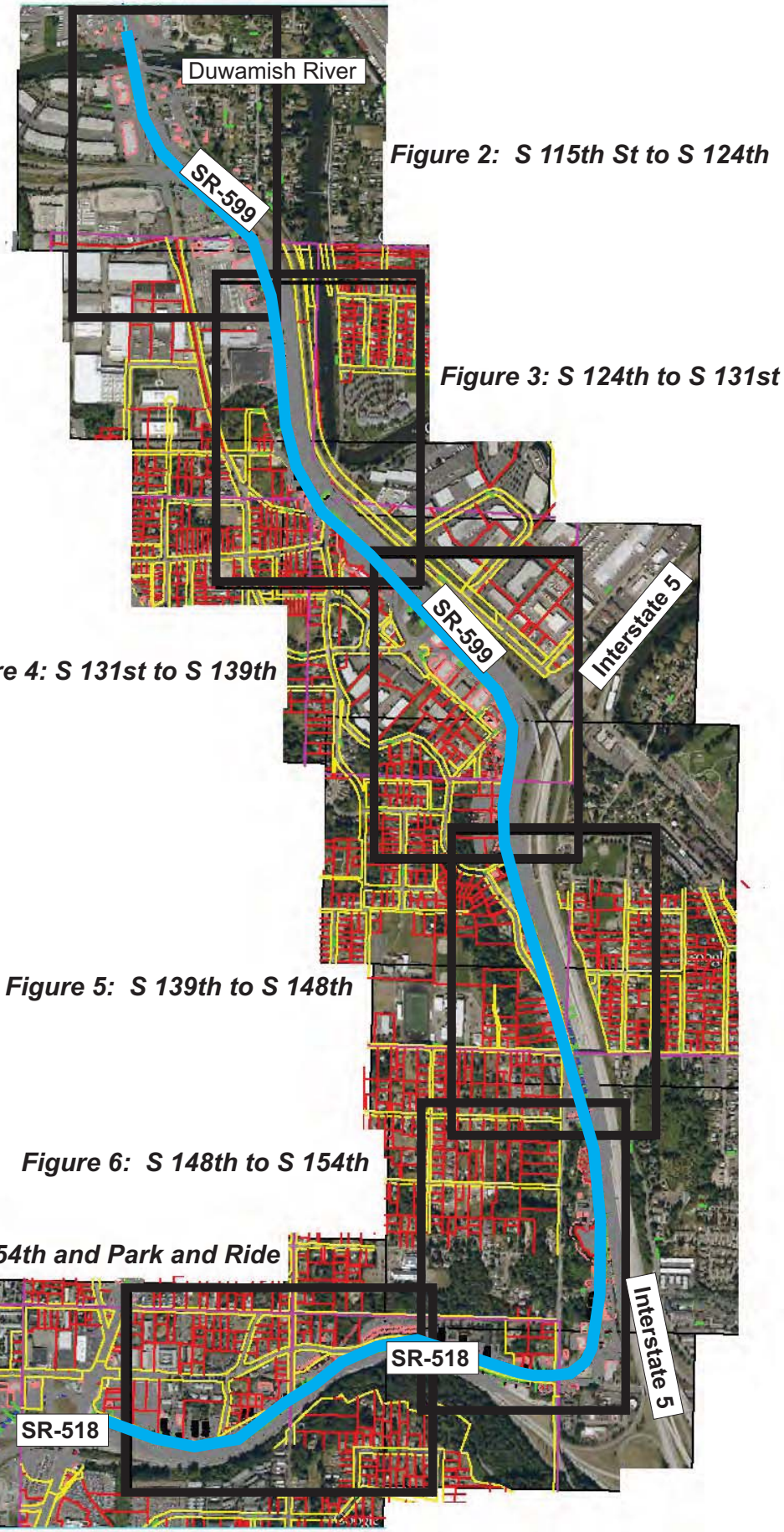


Figure B-8: Vibration Spectrum of Train Pass-bys at Site V4



Attachment C

Maps of the Project Corridor with Monitoring Sites, Existing and Proposed Mitigation



Light Rail Alignment

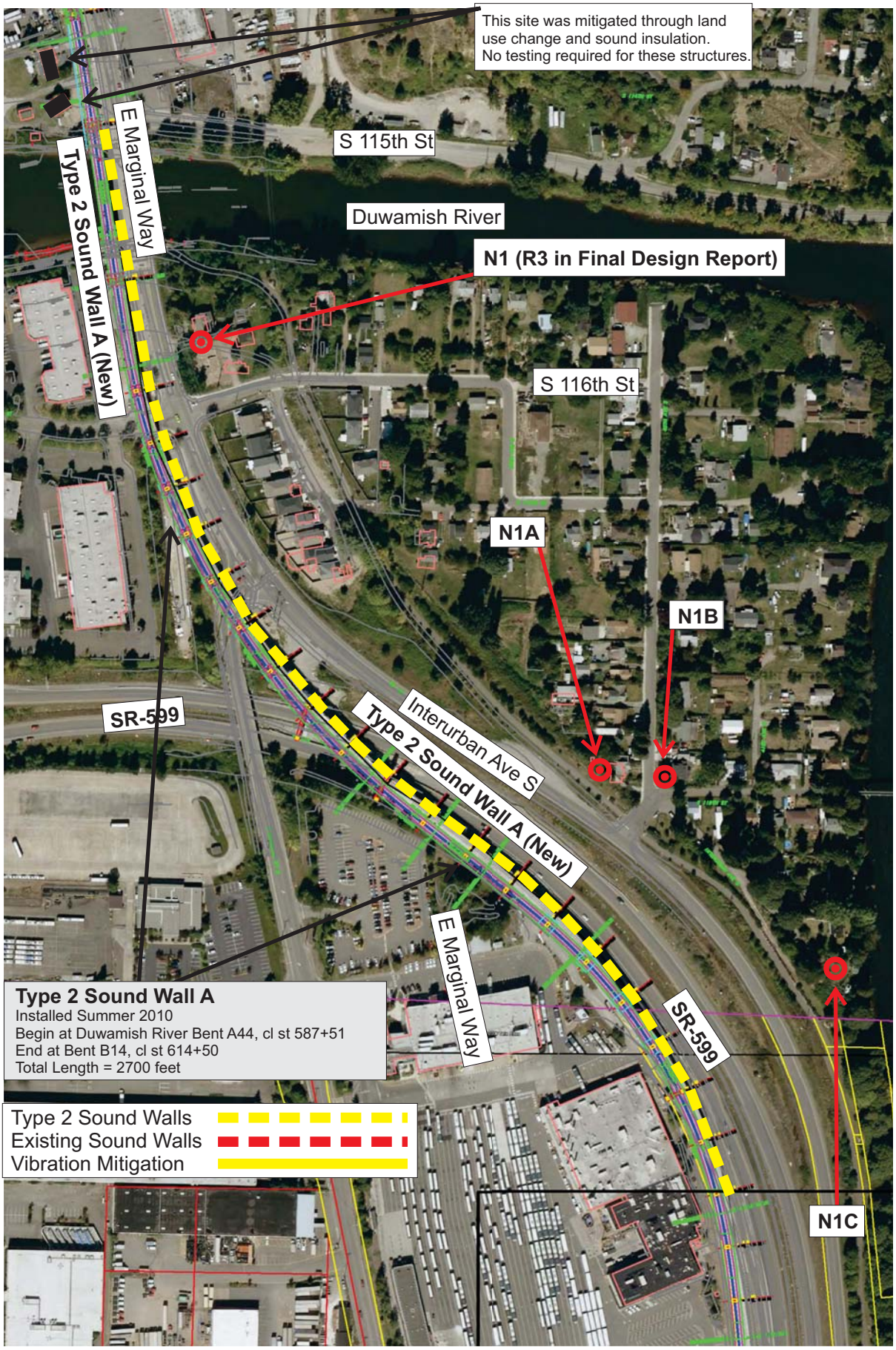
Overview map showing the boundaries of each of the six detailed maps

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

0 500 1000 2000
1.00 in

Approximate Scale 1 inch to 1000 feet (11 x 17 inch format)

Figure 1
Project Area Overview and Master Index



Noise Monitoring Location

Vibration Monitoring Location

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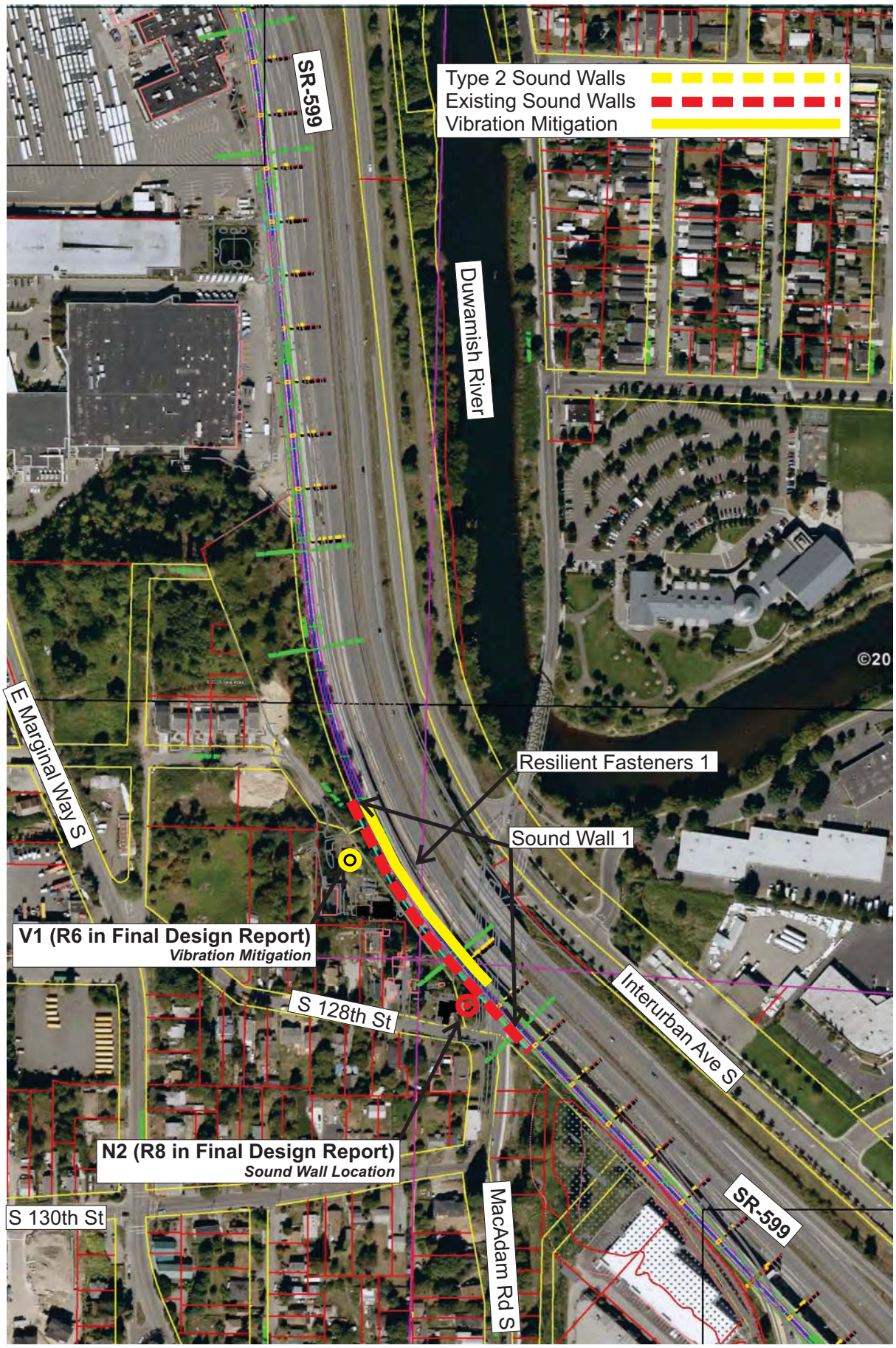
Portland, Oregon

0 100 200 400
1.00 in

Approximate Scale 1 inch to 200 feet (11 x 17 inch format)

Figure 2
Noise and Vibration Monitoring Sites



Noise Monitoring Location

Vibration Monitoring Location

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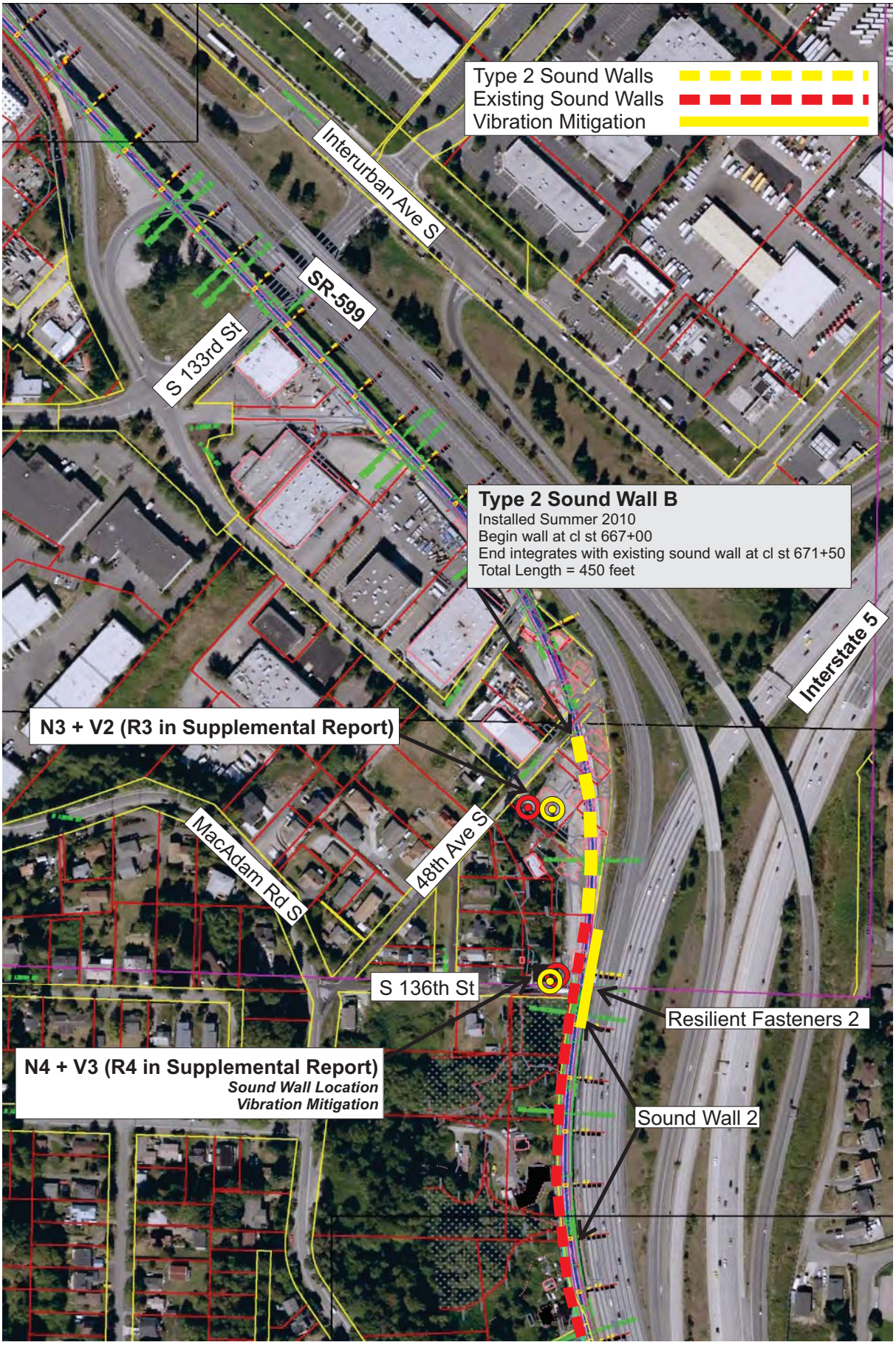
Portland, Oregon

0 100 200 400
1.00 in

Approximate Scale 1 inch to 200 feet
(11 x 17 inch format)

Figure 3
Noise and Vibration Monitoring Sites



Noise Monitoring Location

Vibration Monitoring Location

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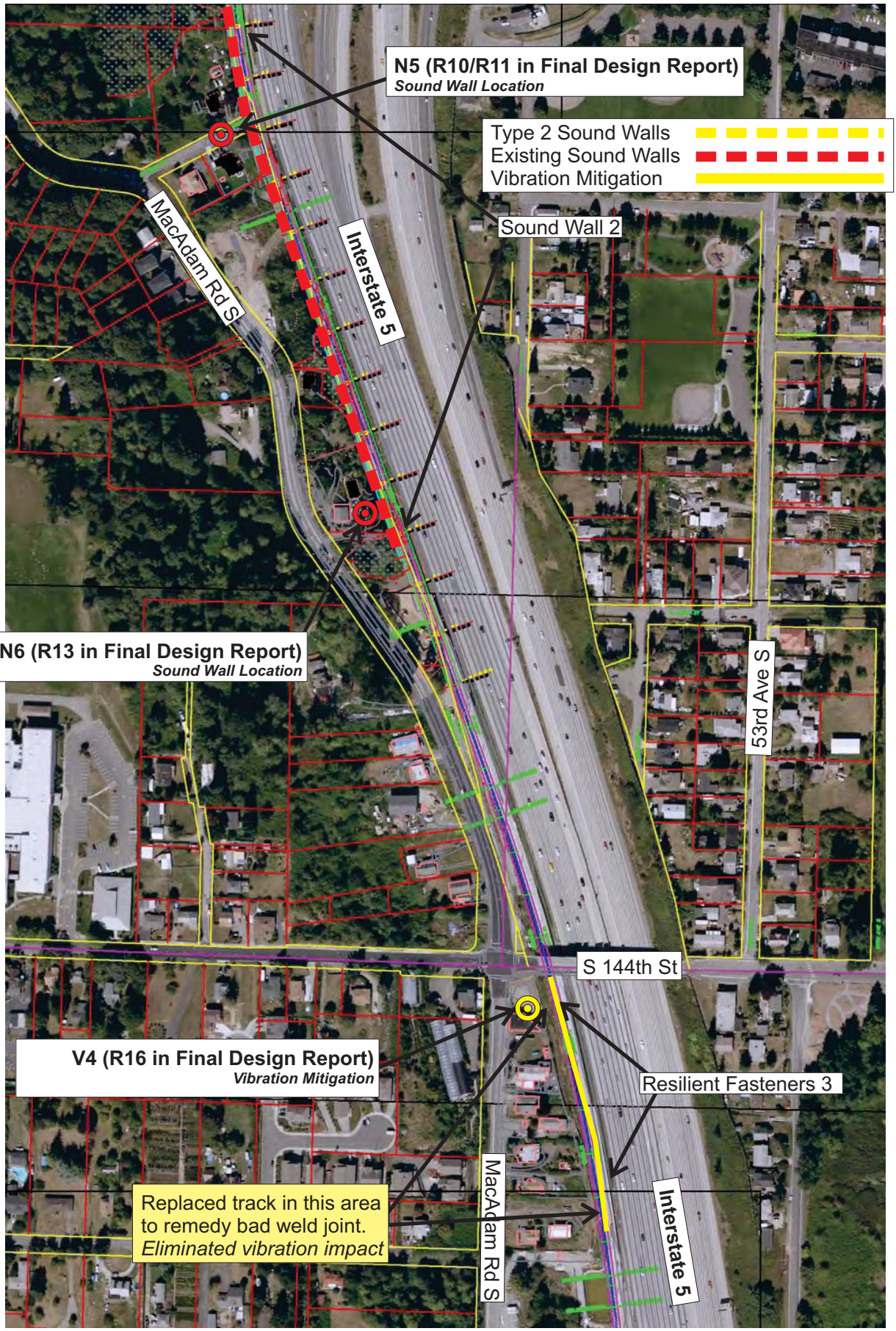
Sound.Vibration.Air
Portland, Oregon

0 100 200 400
1.00 in

Approximate Scale 1 inch to 200 feet
(11 x 17 inch format)

Figure 4
Noise and Vibration Monitoring Sites



Noise Monitoring Location

Vibration Monitoring Location

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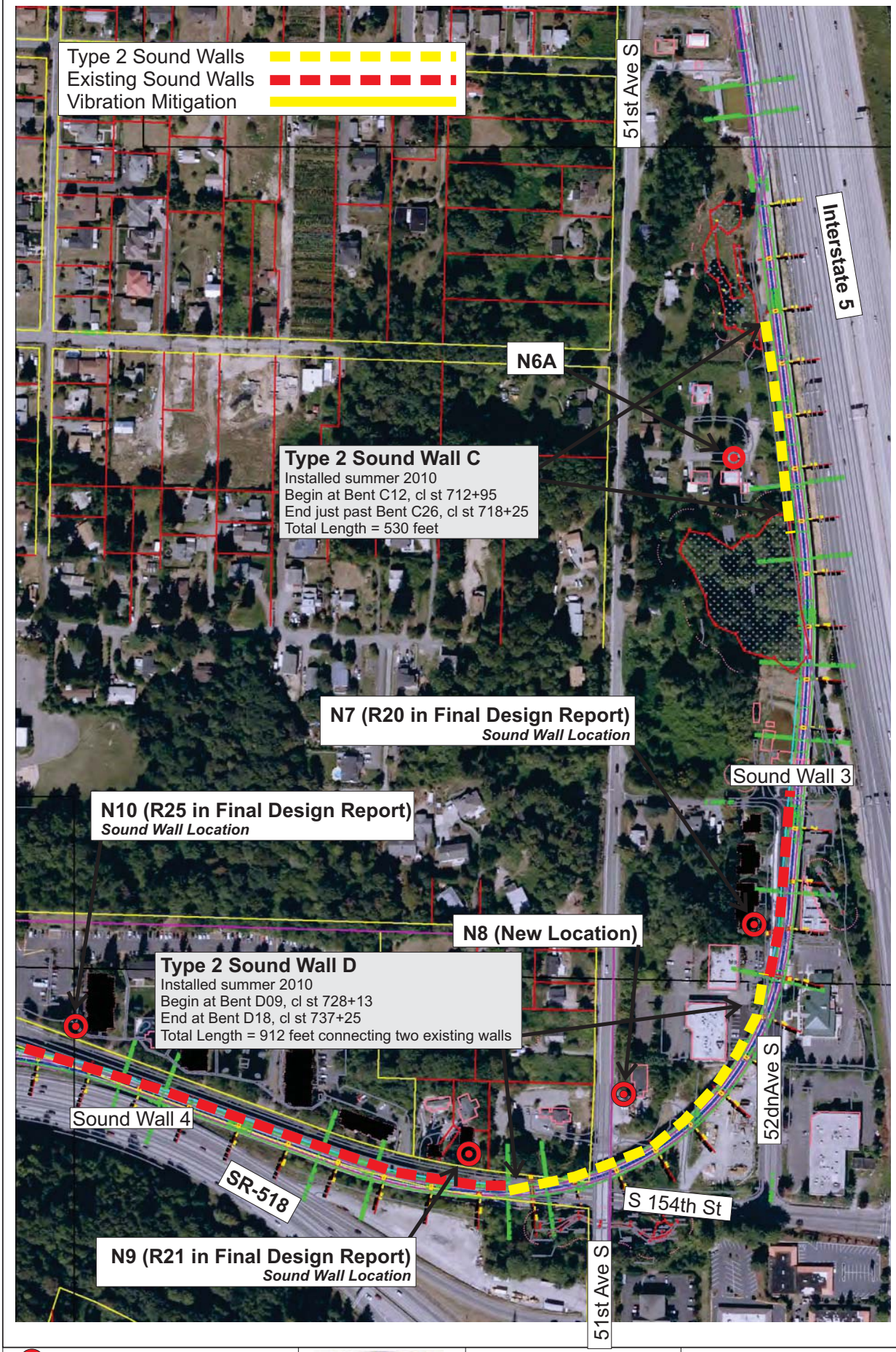
Portland, Oregon

0 100 200 400
1.00 in

Approximate Scale 1 inch to 200 feet
(11 x 17 inch format)

Figure 5
Noise and Vibration Monitoring Sites



Noise Monitoring Location

Vibration Monitoring Location

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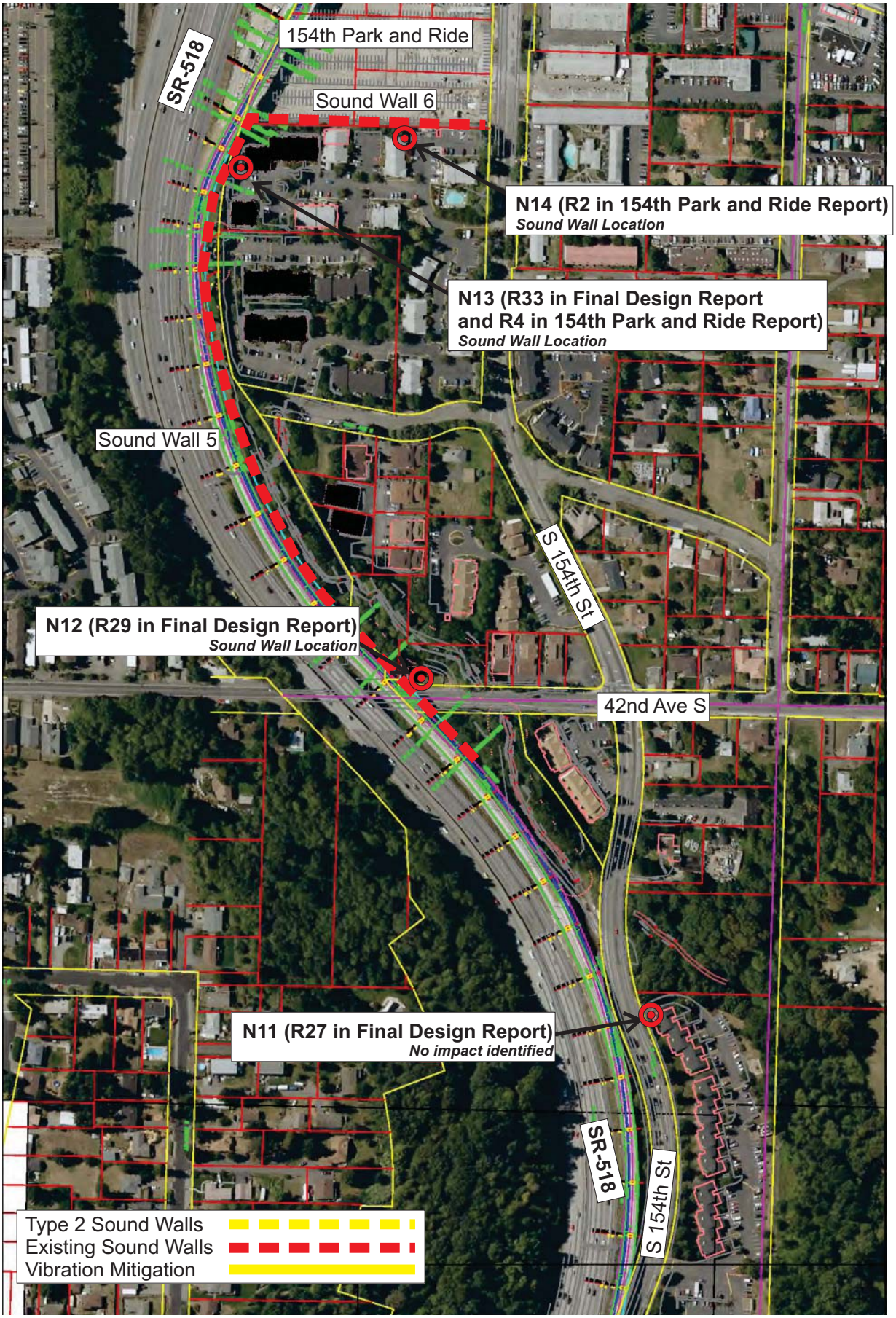
Portland, Oregon

0 100 200 400
1.00 in

Approximate Scale 1 inch to 200 feet
(11 x 17 inch format)

Figure 6
Noise and Vibration Monitoring Sites



Noise Monitoring Location

Vibration Monitoring Location

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Portland, Oregon

0 100 200 400
1.00 in

Approximate Scale 1 inch to 200 feet
(11 x 17 inch format)

Figure 7
Noise and Vibration Monitoring Sites

Attachment D
Operational Schedule

Initial Segment/Airport Link Headways Operating Plan

Weekday Frequencies

Time of Day	Service Type	Hours	Headway	Train Consist Size
5:00 am - 6:00 am	Early/Late	1.0	15	2
6:00 am - 8:30 am	Peak	2.5	6	2
8:30 am - 3:00 pm	Base	6.5	10	2
3:00 pm - 6:30 pm	Peak	3.5	6	2
6:30 pm - 10:00 pm	Base	3.5	10	2
10:00 pm - 1:00 am	Early/Late	3.0	15	2
Total		**20.0**		

Attachment E

Photos of the 154th Ave Park and Ride Sound Wall

Photo 1

Photo 2

Photo 3

Noise Barrier at the 154th Park and Ride

Photos taken from the parking area looking east toward apartments

Photo 4

Photo 5

Photo 6

Noise Barrier at the 154th Park and Ride
Photos taken from the apartment complex area looking west