ATTACHMENT F
NOISE AND VIBRATION ASSESSMENT

Franconia Third Track Project
Categorical Exclusion

Noise and Vibration Assessment

Franconia Third Track Project

Contents

1. SUMMARY 1
2. BACKGROUND - FUNDAMENTALS OF ACOUSTICS 2
2.1 Noise Descriptors 3
2.2 Fundamentals of Vibration 3
2.3 Vibration Descriptors 4
2.4 Existing Noise Levels 5
2.5 Vibration Study Area 6
3. ENVIRONMENTAL CONSEQUENCES 6
3.1 Noise 7
3.1.1 Noise Impact Criteria 7
3.1.2 Noise Impact Assessment Methodology 8
3.1.3 Noise Analysis Results 10
3.1.4 Construction Noise 10
3.2 Vibration 14
3.2.1 Vibration Impact Criteria 14
3.2.2 Vibration Prediction Methodology 16
3.2.3 Vibration Impact Assessment 17
3.2.4 Construction Vibration 20
4. REFERENCES 21

1. SUMMARY

DRPT evaluated noise and vibration associated with construction and operation of the Franconia Third Track Project in two parts:

- In Part 1, DRPT evaluated the effects of construction and operation of a third main track at existing grade plus the effects of increased passenger train service between Franconia and Occoquan in conjunction with the DC2RVA Project.
- In Part 2, DRPT evaluated the effects of the construction and operation of an elevated structure, or bypass, to carry passenger trains from one side of the corridor to the other without crossing the existing two main tracks. The bypass will be located just south of the Franconia-Springfield VRE station.

The Federal Railroad Administration (FRA) has noise and vibration impact assessment methods for trains (FRA 2012). These methodologies are appropriate to evaluate noise and vibration from trains that travel at speeds of 90 miles per hour (mph) or higher. For train speeds lower than 90 mph, FRA endorses use of noise and vibration impact assessment methodologies published by the Federal Transit Administration (FTA 2018). Train speeds proposed on the DC2RVA project corridor and within the Franconia to Occoquan third track segment are at or lower than 90 mph, therefore DRPT evaluated project-related noise and vibration using FTA methods.

DRPT's Part 1 evaluation is documented in the DC2RVA Environmental Impact Statement and Record of Decision. DRPT's noise and vibration impact assessments for the DC2RVA corridor evaluated the impacts of constructing an additional main track along the 123-mile corridor, plus the effects of additional passenger train service in the future. DRPT's analyses, presented within the DC2RVA EIS, included the Franconia to Occoquan segment in order to fully assess the potential noise and vibration effects of the additional passenger service, even though the construction of a third track between Franconia and Occoquan was advanced as a separate project. DRPT concluded there were no noise or vibration impacts in the Franconia to Occoquan segment from construction of a third track at existing grade and operation of additional passenger service.

DRPT's Part 2 evaluation is presented below, and is focused on the potential noise and vibration effects of existing passenger trains (both Amtrak passenger trains and VRE commuter trains) being routed onto an elevated bypass to allow trains to move across the existing two main tracks. DRPT conducted the additional noise and vibration assessment to fully assess the potential effects of operating the existing trains on an elevated structure. Train speed is a key factor in noise and vibration levels, and DRPT considered varying operating speeds (70, 75, and 80 mph) on the bypass. Based on the Part 2 assessment, DRPT concluded that noise impacts from passenger train operations on the bypass are not projected to occur at any of the speeds evaluated. Bypass construction noise levels could approach, but are not likely to exceed, temporary noise impact levels. DRPT also determined that vibration impacts are projected to occur at 3 locations (nearby single-family residences) if the passenger trains on the bypass are operating at 80 mph, and only one location at 75 and 70 mph. DRPT also determined the projected vibration impacts would occur when the passenger trains are approaching the elevated portion of the bypass, but not yet on the elevated structure – that is, the vibration would be transmitted through the ground, not

through the structure. There is no vibration impact projected when a passenger train operates at a speed of 65 mph or less while on the bypass.

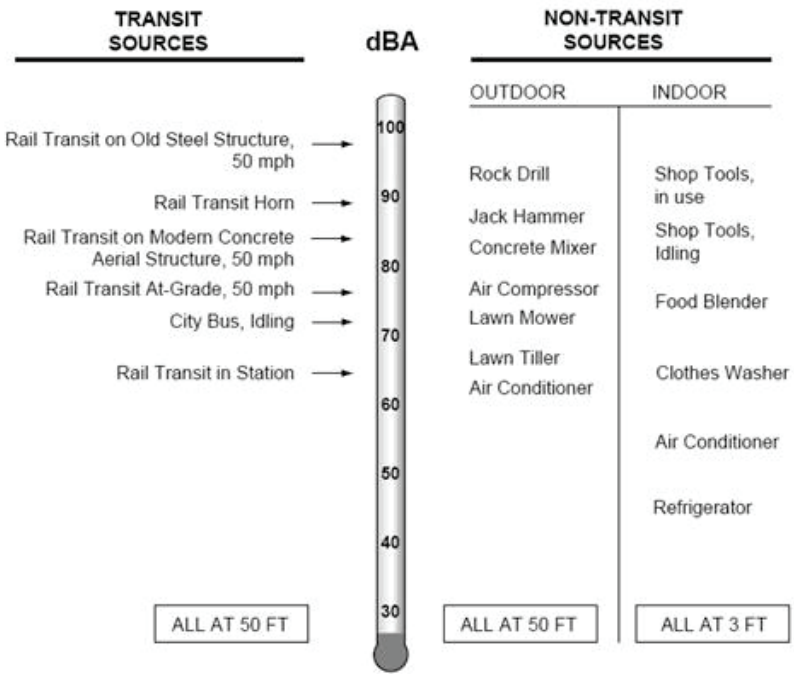
DRPT will determine the passenger and commuter train operating speed on the bypass during final design, and will conduct additional vibration assessment (potentially including propagation measurements in the field) if the bypass is designed to accommodate passenger train speeds greater than 65 mph. In addition, DRPT will require construction noise best management practices and mitigation measures be included in the bypass's construction plans to ameliorate potential temporary disturbances from construction noise.

2. BACKGROUND - FUNDAMENTALS OF ACOUSTICS

Noise is unwanted or undesirable sound. Sound travels through the air as waves of tiny air pressure fluctuations caused by vibration. The intensity or loudness of a sound is an effect of how much the sound pressure fluctuates. The magnitude of fluctuation above and below the static atmospheric pressure is the amplitude of the sound wave. Additionally, sound is quantified on the logarithmic decibel scale for convenience. Because of the logarithmic nature of the decibel unit, when two identical noise sources are added together, the resulting increase is 3 dB (not the arithmetic sum of the two noise levels).

Most sounds consist of a broad range of sound frequencies, from low frequencies to high frequencies. The average human ear does not perceive all frequencies equally. Therefore, the A-weighting scale was developed to approximate the way the human ear responds to sound levels; it mathematically applies less "weight" to frequencies we do not hear well, and applies more "weight" to frequencies we do hear well. Typical A-weighted noise levels for various types of sound sources are summarized in Figure 1.

Figure 1: Typical Noise Levels



Source: *Transit Noise and Vibration Impact Assessment* (FTA 2018)

2.1 Noise Descriptors

The equivalent average sound level (L_{eq}) is often used to describe sound levels that vary over time, usually a one-hour period. It is a mean energy-based average noise level. The L_{eq} is often described as the constant sound level that is an equivalent exposure level to the actual time-varying sound level over the period (hour). Using twenty-four consecutive 1 hour L_{eq} values it is possible to calculate a daily cumulative noise exposure. A common community noise rating is the Day-Night Average Sound Level (L_{dn}). The L_{dn} is the 24-hour L_{eq} but includes a 10 dBA penalty on noise that occurs during the nighttime hours (between 10 p.m. and 7 a.m.) where sleep interference might be an issue. The 10 dBA penalty makes the L_{dn} useful when assessing noise in residential areas, or land-uses where overnight sleep occurs. Both FTA (2018) and FRA (2012) utilize the L_{dn} descriptor to evaluate transit noise at residential properties.

2.2 Fundamentals of Vibration

Vibration is an oscillatory motion that can be described in terms of displacement, velocity, or acceleration. Displacement, in the case of a vibrating floor, is simply the distance that a point on the floor moves away from its static position. The velocity represents the instantaneous speed of the floor movement, and acceleration is the rate of change of the speed. The response of humans, buildings, and equipment to vibration is normally described using velocity or acceleration. Velocity will be used in describing ground-borne vibration.

Ground-borne vibration (GBV) can be a serious concern for residents or at facilities that are vibration-sensitive, such as laboratories or recording studios. The effects of GBV include perceptible movement of building floors, interference with vibration-sensitive instruments, rattling of windows, and shaking of items on shelves or hanging on walls. Additionally, GBV can cause the vibration of room surfaces resulting in ground-borne noise (GBN). GBN is typically perceived as a low-frequency rumbling sound.

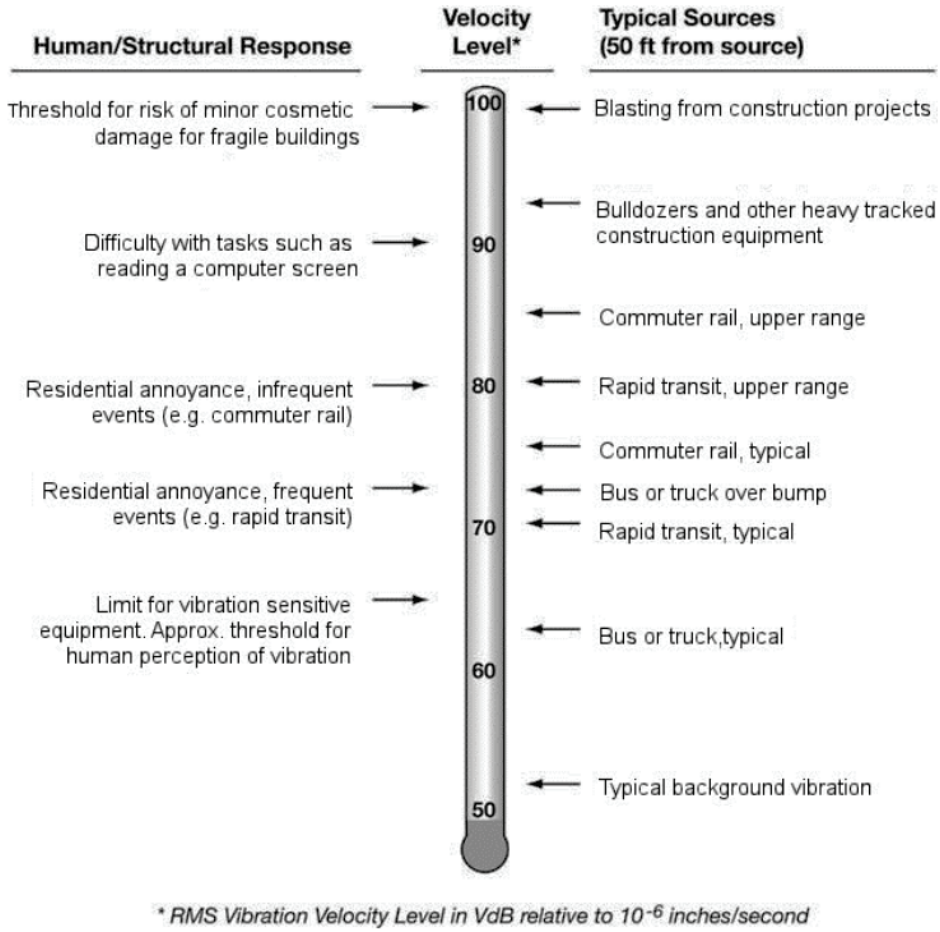
2.3 Vibration Descriptors

Vibration amplitudes are usually expressed as either peak particle velocity (PPV) or the root mean square (RMS) velocity. PPV is used to evaluate the potential for building damage. It is defined as the maximum instantaneous peak of the vibration signal. PPV is not considered the appropriate measurement for evaluating the human response to vibration. RMS is used to evaluate human response because it takes some time for the human body to respond to vibration signals. The RMS of a signal is the square root of the average of the squared amplitude of the signal. For sources such as trucks or motor vehicles, PPV levels are typically 6 to 14 dB higher than RMS levels. FRA and FTA use the abbreviation "VdB" for vibration dBs for RMS and PPV to reduce the potential for confusion with sound dBs (FRA 2012).

Decibel notation acts to compress the range of numbers required in measuring vibration. Similar to the noise descriptors, L_{eq} and L_{max} can be used to describe the equivalent vibration and the maximum vibration level observed during a single vibration measurement interval. Figure 2 illustrates common vibration sources and the human and structural responses to ground-borne vibration. As shown in Figure 2, the threshold of perception for human response is approximately 65 VdB; however, human response to vibration is not usually significant unless the vibration exceeds 70 VdB.

In contrast to airborne noise, neither GBV nor GBN is an everyday experience for most people. The background vibration level in residential areas is usually 50 VdB or lower which is well below the threshold of perception for humans. Levels at which vibration interferes with sensitive instrumentation can be much lower than the threshold of human perception, such as for medical imaging equipment or extremely high-precision manufacturing. Most perceptible indoor vibration is caused by sources within a building, such as the operation of mechanical equipment, movement of people, or slamming of doors. Typical outdoor sources of perceptible GBV are construction equipment, steel-wheeled trains, and traffic on rough roads; though in most soils, GBV dissipates very rapidly, and it is not a common environmental concern.

Figure 2 – Typical Levels of Ground-borne Vibration



Source: FTA 2018

2.4 Existing Noise Levels

In accordance with FTA and FRA noise assessment methodologies, DRPT measured existing noise levels for the DC2RVA EIS. Existing noise levels were measured for a continuous 24-hour period at a residence close to the proposed bypass alignment, and those results are used in this analysis. Table 1 presents the measured L_{dn} from the DC2RVA EIS.

Table 1 – Existing Noise Level

Location ID	Address	Measurement Type	Ldn (dBA)
ML06	6701 Jerome St	24-hr.	75

DRPT used the measured L_{dn} value of 75 dBA to determine the noise impact threshold, and to evaluate the potential for noise impacts associated with passenger trains on the bypass alignment.

2.5 Vibration Study Area

The first step in DRPT's vibration assessment consisted of identifying the vibration screening distances. Only certain land uses are considered vibration sensitive, and FTA guidance establishes three sensitive-use categories that resemble the noise land use categories but differ in a few important respects:

- Vibration Category 1–High Sensitivity: Where vibration would interfere with operations within the building, including levels that may be well below those associated with human annoyance, such as electron microscopes, high-resolution lithographic equipment, and magnetic resonance imaging devices.
- Vibration Category 2–Residential: Where people sleep, including hotels and hospitals.
- Vibration Category 3–Institutional: Where vibration has potential to interfere with activities within the building, but there is not particularly vibration-sensitive equipment present, such as schools, places of worship, quiet offices, and other institutions.

Table 2 presents the vibration screening distances for the three vibration land use categories for conventional passenger and commuter railroad projects.

Table 2 Vibration Screening Distances

	Distance from ROW or Property Line (feet)		
Type of Project	Vibration Category 1	Vibration Category 2	Vibration Category 3
Conventional Commuter Railroad	600	200	120

Source: FTA 2018

Using GIS technology, DRPT identified Vibration Category 2 land uses (single-family residences) within the screening distance of 200 feet from the bypass. DRPT then performed a General Vibration Assessment for the three single-family residences within 200 feet of the bypass.

3. ENVIRONMENTAL CONSEQUENCES

In this section, DRPT describes potential bypass-related noise and vibration effects and identifies mitigation measures to offset bypass-related impacts. These analyses evaluated noise and vibration from the existing passenger and commuter trains anticipated to operate on the proposed bypass alignment. The assessment addresses both operational and construction noise and vibration effects from the proposed bypass alignment.

3.1 Noise

3.1.1 Noise Impact Criteria

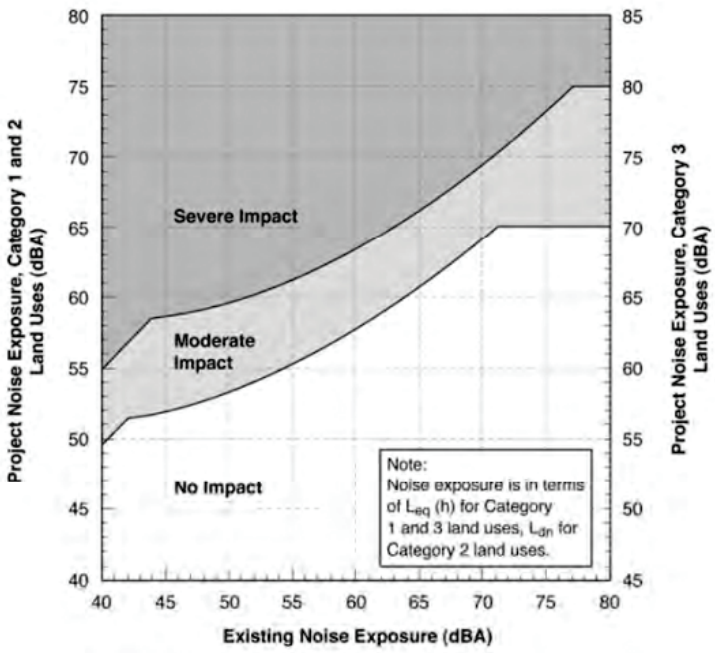
According to FRA (2012) and FTA (2018), noise-sensitive land uses are divided into one of three categories:

- Category 1: Land where quiet is an essential element (e.g., amphitheaters and concert pavilions). This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks (NHLs) with significant outdoor use.
- Category 2: Residences and buildings where people sleep. This category includes homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
- Category 3: Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material. Buildings with interior spaces where quiet is important, such as medical offices, conference rooms, recording studios, and concert halls, fall into this category. Places for meditation or study associated with cemeteries, monuments, and museums. Certain historical sites, parks, and recreational facilities are also included.

There are no Category 1 or 3 receptors within the screening distances of the proposed bypass alignment; therefore DRPT's analyses focused on the Category 2 receptors (residences), and used the L_{dn} descriptor.

Figure 3 from the FTA guidance manual shows the noise impact criteria used by both FTA and FRA, which are based on the land use category and the existing noise exposure in the area. No impact indicates projected noise levels are unlikely to cause annoyance. A moderate noise impact is a noise level increase that is noticeable to most people, yet generally not enough to cause adverse reactions. A severe noise impact is a noise level increase that could cause annoyance to a significant percentage of people. FTA guidance requires consideration and adoption of noise mitigation measures for moderate noise impacts when it is reasonable. When severe noise impacts are projected to occur, FTA assumes that mitigation measures will be implemented to reduce project noise levels below impact thresholds, unless there are truly extenuating circumstances which prevent it. In the context of environmental review under NEPA, severe noise impacts are considered significant impacts.

Figure 3 – FTA/FRA Noise Impact Thresholds



Source: FTA 2018

3.1.2 Noise Impact Assessment Methodology

The FRA and FTA noise impact assessment methodologies applied by DRPT include the following basic components:

1. Identify noise-sensitive land uses
2. Measure existing outdoor noise levels
3. Measure train specific noise source levels
4. Define impact thresholds based on measured existing noise levels
5. Calculate Project-related outdoor noise levels using identified train and operations characteristics
6. Determine if Project-related noise levels exceed FRA and FTA defined noise impact thresholds.

DRPT's train noise calculations utilized the FTA General Noise Assessment methods as implemented in the Cadna-A acoustical modeling software. A digital topographic map of the proposed bypass and cut sections was imported into Cadna-A. Ground absorption was assumed to be zero to account for the rocky cut section and retaining wall, resulting in conservative estimates in train noise at the nearest residences. The proposed alignment was imported into Cadna-A, and the train characteristics shown in Table 3 below were entered into the FTA module in Cadna-A.

Sound Exposure Level (SEL) is an acoustical descriptor that contains all acoustical energy associated with a single event such as the passing of a locomotive or railcar, or a locomotive horn use event. SEL values are used as the noise emission terms in the train noise models; they are expressed in units of dBA (A-weighted decibel). This Part 2 analysis utilized the same SEL values as those that were used in Part 1 as reported in the DC2RVA EIS. Characteristics of the passenger trains that were used by DRPT in the noise analysis are shown in Table 3, and were derived from data in the DC2RVA EIS. Trains using the proposed bypass were modeled at three different speeds (70, 75, and 80 mph) which span the range of likely operating conditions.

Table 3: Train Characteristics used in the Noise Analysis

	Amtrak Long Distance Passenger Trains	VRE Commuter Trains	Northeast Regional Passenger Trains
Throttle Setting	8	8	8
SEL For Locomotives (dBA)	97	97	97
SEL For Railcar (dBA)	82	82	82
Locomotives	2	1	1
Railcars	11	7	8
Total Trains/Day	2	16	10
Daytime Trains	2	12	10
Nighttime Trains	0	4	0
Train Speed	70	70	70
	75	75	75
	80	80	80
Northbound Daytime Locomotive	2	6	5
Northbound Nighttime Locomotive	0	2	0
Southbound Daytime Locomotive	2	6	5
Southbound Night Locomotive	0	2	0
Northbound Daytime Railcars	11	42	40
Northbound Nighttime Railcars	0	14	0
Southbound Daytime Railcars	11	42	40
Southbound Nighttime Railcars	0	14	0

Noise-sensitive land uses along the bypass alignment were identified by DRPT according to FRA and FTA land use categories. DRPT reviewed land use data from several sources, including GIS databases, digital aerial photographs, and field surveys that were performed for the DC2RVA EIS. The location coordinates of the residences nearest the proposed bypass alignment were imported into Cadna-A, and the software performed the FTA General Noise Assessment calculations. Cadna-A also calculated the shielding effects of the cut sections and retaining walls.

3.1.3 Noise Analysis Results

Table 4 presents results of DRPT's General Noise Assessment.

Table 4: General Noise Assessment Results

Residence (Receiver) ID	Existing Ldn (dBA)	Projected Ldn (dBA) by Trains Speed			No Impact (Ldn in dBA)	Moderate Impact Threshold (Ldn in dBA)	Severe Impact Threshold (Ldn in dBA)	Impact Yes or No?
		70 mph	75 mph	80 mph				
R01	75	56	56	57	<66	66-74	>74	No
R02	75	53	54	54	<66	66-74	>74	No
R03	75	53	54	54	<66	66-74	>74	No
R04	75	56	56	57	<66	66-74	>74	No
R05	75	55	55	55	<66	66-74	>74	No
R06	75	57	57	58	<66	66-74	>74	No
R07	75	56	57	57	<66	66-74	>74	No
R08	75	56	56	56	<66	66-74	>74	No
R09	75	57	57	57	<66	66-74	>74	No
R10	75	58	58	58	<66	66-74	>74	No

Noise analysis results indicate that the project, as modeled, will not cause or contribute to either moderate or severe noise impacts at the nearest residential locations modeled in this analysis. The shielding effects of the cut section/retaining wall block the direct line of sight (the path sound travels) between the proposed alignment and the nearest homes, reducing projected noise levels at the nearest noise-sensitive land uses. No additional assessment or noise mitigation is necessary.

3.1.4 Construction Noise

Construction of the proposed rail improvements would likely result in a temporary increase in noise levels. Equipment used to move soil and other earthen materials, and pile driving are often the loudest construction noise sources.

Table 5 presents typical equipment used for different phases of railroad construction with typical noise levels, quantities, and estimated utilizations for each type of equipment used. The table shows the sound power level (SWL) used to determine sound pressure levels (SPL) at different distances. The distances in the table below are based on flat terrain between the noise source and a receiver at the stated distance; therefore the distances are conservative overestimates of

construction noise that may occur where the proposed bypass alignment is in a cut section (the areas closest to Category 2 land uses).

Table 5: Estimated Construction Equipment Noise Levels

Phase	Equipment	#	Hours /day	Utiliza-tion	SWL/ unit	Total SWL	SPL (dBA) at distance (ft.)		
							100	500	1000
Clearing	Off-Highway Trucks	4	6	50%	124	127	108	94	88
	Rubber Tired Dozers	3	8	67%	122	125	106	92	86
	Rubber Tired Loaders	2	6	50%	121	121	102	88	82
	Tractors/Loaders /Backhoes	3	5	42%	118	119	100	86	80
	Trenchers	2	4	33%	117	115	96	82	76
Utility Relocation	Cranes	1	6	50%	121	118	100	86	80
	Dumper/Tender	2	4	33%	110	108	89	75	69
	Off-Highway Trucks	2	6	50%	124	124	105	91	85
	Rubber Tired Dozers	3	8	67%	122	125	106	92	86
	Rubber Tired Loaders	2	6	50%	121	121	102	88	82
	Tractors/Loaders /Backhoes	3	5	42%	118	119	100	86	80
	Trenchers	2	6	50%	117	117	98	84	78
	Welders	3	6	50%	114	116	97	83	77
Earthwork	Excavators	2	8	67%	120	121	102	88	82
	Graders	1	8	67%	120	118	100	86	80
	Off-Highway Trucks	4	8	67%	124	128	109	95	89
	Off-Highway Trucks	1	4	33%	123	118	100	86	80
	Rollers	2	6	50%	117	117	98	84	78
	Rubber Tired Dozers	1	8	67%	122	120	101	87	81
	Rubber Tired Loaders	2	6	50%	121	121	102	88	82
	Scrapers	2	8	67%	123	125	106	92	86

Table 5: Estimated Construction Equipment Noise Levels

Phase	Equipment	#	Hours /day	Utiliza-tion	SWL/ unit	Total SWL	SPL (dBA) at distance (ft.)		
							100	500	1000
	Signal Boards	3	8	67%	106	109	90	76	70
	Tractors/Loaders /Backhoes	3	6	50%	118	119	101	87	81
Bridge Construction for Elevated Track	Cranes	1	7	58%	121	119	100	86	80
	Excavators	2	8	67%	120	121	102	88	82
	Forklifts	3	8	67%	117	120	102	88	82
	Generator Sets	1	8	67%	117	115	97	83	77
	Graders	1	8	67%	120	118	100	86	80
	Pavers	2	8	67%	119	120	101	87	81
	Paving Equipment	2	8	67%	119	120	101	87	81
	Rollers	2	8	67%	117	118	99	85	79
	Rubber Tired Dozers	1	8	67%	122	120	101	87	81
	Scrapers	2	8	67%	123	125	106	92	86
	Tractors/Loaders /Backhoes	2	8	67%	118	119	100	86	80
	Welders	1	8	67%	114	113	94	80	74
Retaining Walls	Paving Equipment	2	8	67%	119	120	101	87	81
	Excavators	2	8	67%	120	121	102	88	82
	Forklifts	3	8	67%	117	120	102	88	82
	Generator Sets	1	8	67%	117	115	97	83	77
	Graders	1	8	67%	120	118	100	86	80
	Rubber Tired Dozers	1	8	67%	122	120	101	87	81
	Rubber Tired Loaders	2	7	58%	121	121	103	89	83
	Scrapers	2	8	67%	123	125	106	92	86
	Tractors/Loaders /Backhoes	3	7	58%	118	120	101	87	81
Signals	Cranes	1	7	58%	121	119	100	86	80
	Forklifts	3	8	67%	117	120	102	88	82
	Generator Sets	1	8	67%	117	115	97	83	77
	Tractors/Loaders /Backhoes	2	8	67%	118	119	100	86	80

Table 5: Estimated Construction Equipment Noise Levels

Phase	Equipment	#	Hours /day	Utiliza-tion	SWL/ unit	Total SWL	SPL (dBA) at distance (ft.)		
							100	500	1000
	Welders	1	8	67%	114	113	94	80	74
Track Installation	Air Compressors	1	6	50%	117	114	95	81	75
	Cranes	1	7	58%	121	119	100	86	80
	Forklifts	3	8	67%	117	120	102	88	82
	Generator Sets	1	8	67%	117	115	97	83	77
	Track Laying Machine	1	8	67%	129	128	109	95	89
	Track Tamper	1	8	67%	121	119	100	86	80
	Track Stabilizer	1	8	67%	126	124	106	92	86
	Tractors/Loaders /Backhoes	2	8	67%	118	119	100	86	80
	Welders	1	8	67%	114	113	94	80	74
Signal Work	Cranes	1	7	58%	121	119	100	86	80
	Forklifts	3	8	67%	117	120	102	88	82
	Generator Sets	1	8	67%	117	115	97	83	77
	Tractors/Loaders /Backhoes	2	8	67%	118	119	100	86	80
	Welders	1	8	67%	114	113	94	80	74
Install Track and Sub ballast Over Bridge and at-Grade	Air Compressors	1	6	50%	117	114	95	81	75
	Cranes	1	7	58%	121	119	100	86	80
	Forklifts	3	8	67%	117	120	102	88	82
	Generator Sets	1	8	67%	117	115	97	83	77
	Track Laying Machine	1	8	67%	129	128	109	95	89
	Track Tamper	1	8	67%	121	119	100	86	80
	Track Stabilizer	1	8	67%	126	124	106	92	86
	Ballast Regulator	1	8	67%	119	118	99	85	79
	Tractors/Loaders /Backhoes	2	8	67%	118	119	100	86	80
	Welders	1	8	67%	114	113	94	80	74
Final Cut-Over and	Cranes	1	7	58%	121	119	100	86	80
	Forklifts	3	8	67%	117	120	102	88	82
	Generator Sets	1	8	67%	117	115	97	83	77

Table 5: Estimated Construction Equipment Noise Levels

Phase	Equipment	#	Hours /day	Utiliza-tion	SWL/ unit	Total SWL	SPL (dBA) at distance (ft.)		
							100	500	1000
Removal of Turnouts	Tractors/Loaders /Backhoes	3	7	58%	118	120	101	87	81
	Welders	1	8	67%	114	113	94	80	74

Source: HDR Engineering, Inc.

DRPT determined the results presented in the table above conservatively over-estimate actual expected construction noise levels by assuming that all of the equipment (i.e., all of the dump trucks, or all of the pickup trucks) operate at the same location. Typically, construction equipment is spread throughout the construction work zone. Given the linear nature of the Project and relatively confined width of the railroad right-of-way, DRPT finds it is unlikely that all equipment would operate next to each other in the same (stationary) location for one hour.

On this basis, construction noise levels in the table above over-estimate noise levels for construction phases that would utilize more than one piece of equipment. In all other cases, the results are assumed by DRPT to be within 3 dB of likely construction noise levels assuming that the equipment has been properly maintained and the mufflers are in good condition, and there is a direct line-of-sight between the equipment and a receiver outside the ROW.

The FRA and FTA do not have standardized criteria for construction; however, FTA suggests reasonable criteria that can be used for assessment purposes. The criteria for residential land uses are 1-hour L_{eq} of 90 dBA during the day and 80 dBA during the night (FTA 2018).

Construction noise analysis results shown in the table above indicate the total combined noise for all equipment types and construction phases may exceed the 90 dBA threshold at the Category 2 land uses closest to the proposed bypass alignment. Therefore, construction noise best management practices will be implemented during the bypass construction phase, including: maintaining all equipment in a good state of repair; using original equipment manufacturer, or better mufflers on all equipment, and; limiting nighttime construction activity. These best management practices will be implemented in the areas closest to the Category 2 land uses.

3.2 Vibration

In this section, DRPT describes potential vibration effects of passenger trains operating on the proposed bypass and identifies mitigation measures to offset projected impacts. DRPT assessed vibration effects based on the methods and criteria included in the *High Speed Ground Transportation Noise and Vibration Impact Assessment* guidance manual (FRA 2012) and the *Transit Noise and Vibration Impact Assessment Manual* (FTA 2018) for the assessment in the speed regime range that the passenger trains would likely operate on the bypass.

3.2.1 Vibration Impact Criteria

The FRA and FTA vibration impact criteria are identical and were used by DRPT to predict future vibration impacts from train operations on the bypass. There are separate criteria for both

ground-borne vibration (GBV) and ground-borne noise (GBN). Ground-borne noise is often masked by airborne-noise; therefore, ground-borne noise criteria are primarily applied to subway operations in which airborne noise is negligible. The basis for evaluating rail vibration impact thresholds is the highest expected RMS vibration levels for repeated vibration events from the same source. As presented in Table 6, the thresholds are differentiated between vibration sensitive land uses and the frequency of the events.

TABLE 6: GROUND-BORNE VIBRATION (GBV) AND GROUND-BORNE NOISE (GBN) IMPACT CRITERIA FOR GENERAL ASSESSMENT

Land Use Category	GBV Impact Levels (VdB re 1 μin/s)			GBN Impact Levels (dBA re 20 μPa)		
	Frequent Events [1]	Occasional Events [2]	Infrequent Events [3]	Frequent Events [1]	Occasional Events [2]	Infrequent Events [3]
Category 1: Buildings where vibration would interfere with interior operations.	65 VdB [4]	65 VdB [4]	65 VdB [4]	N/A [5]	N/A [5]	N/A [5]
Category 2: Residences and buildings where people normally sleep.	72 VdB	75 VdB	80 VdB	35 dBA	38 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA

Source: FRA 2012.

Table Notes:

1. Frequent Events is defined as more than 70 vibration events of the same kind per day.
2. Occasional Events is defined as between 30 and 70 vibration events of the same kind per day.
3. Infrequent Events is defined as fewer than 30 vibration events of the same kind per day.
4. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration-sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.
5. Vibration-sensitive equipment is not sensitive to ground-borne noise.

Train frequency on the proposed bypass falls into the infrequent category, and this assessment is focused on Category 2 land uses; therefore the vibration impact threshold is 80 VdB. Ground-borne noise was not evaluated because the proposed alignment is not below-grade.

3.2.2 Vibration Prediction Methodology

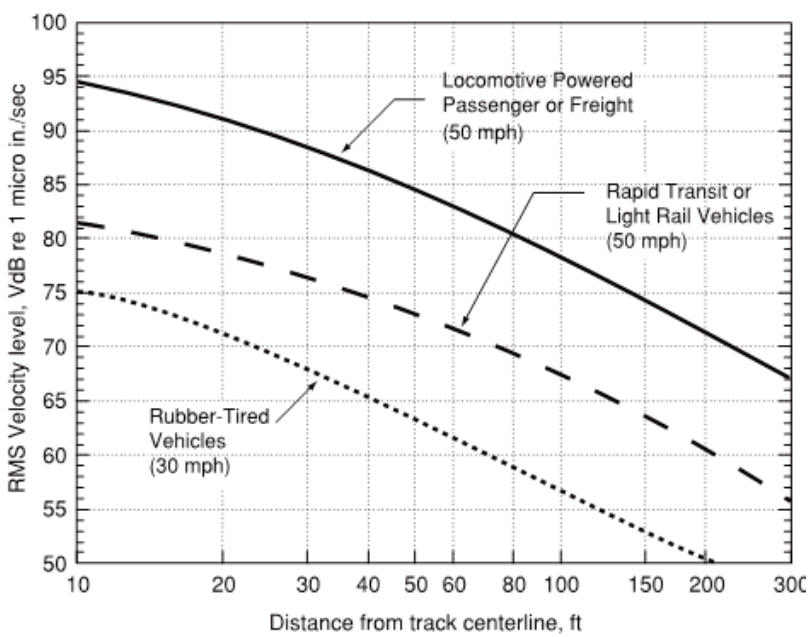
DRPT implemented the following general steps in the vibration assessment:

1. Establish the study area and identify vibration-sensitive land-uses.
2. Evaluate the traffic conditions and set corresponding impact thresholds.
3. Select the base generalized vibration curve and apply appropriate adjustments.
4. Determine the propagation from project-related vibration sources to the impact thresholds.
5. Identify receptors anticipated to experience vibration impacts.

The study area includes the residential land uses closest to where the bypass alignment is in a cut section. The vibration prediction begins with selection of a generalized base curve, depending upon the mode considered in the project. These curves represent typical ground-surface vibration as a function of distance from the source, based upon many ground-borne vibration measurements of numerous transit sources.

Figure 4 shows the generalized ground surface vibration curves suitable for assessing passenger trains on the bypass alignment. These curves similarly represent the upper range of the measurement data from equipment in good condition. The top curve represents trains that are powered by diesel-electric locomotives, and that is representative of the trains on the proposed bypass alignment.

FIGURE 4: FTA GENERALIZED GROUND SURFACE VIBRATION CURVES



Source: FTA 2018.

The base curves can be adjusted to account for project-specific vibration factors which differ from the conditions of the base curve. Adjustment parameters are given in the FRA and FTA guidance

and include train speed, wheel and rail type and condition, and type of track support system, among other adjustments. The adjustment parameters are based on typical vibration spectra, and are given as generalized single numbers to be applied to the base curve.

The adjustments are arithmetically added to the reference vibration curve and the resulting levels are compared to the impact thresholds. In this analysis, the reference speed of 50 mph was adjusted to 80, 75, and 70 mph to assess the range of likely operating speeds.

Soil types and other subsurface conditions affect GBV. For example, GBV can propagate more efficiently in areas where the soil is characterized by stiff shallow clay, or where there is shallow bedrock. The vibration assessment performed by DRPT for the DC2RVA EIS briefly reviewed publicly available and reasonably obtainable soils and geologic data for the purpose of evaluating where GBV might propagate very efficiently. Based on this limited review, most of the soils in the corridor consist of coarse-grained unconsolidated deposits, which include regions with mixed combinations of gravel, sand, and silt. There are also limited areas of fine-grained unconsolidated deposits, which include alluvium, clay, or mud, although some of the clay or mud is mixed with sand. The coarse-grained unconsolidated deposits, which make up the majority of the soils along the alignment, as well as most of the fine-grained unconsolidated deposits generally propagate GBV less efficiently than highly efficient soils such as stiff clay. However, the soils data are relatively coarse and may not identify highly localized soil-type differences or geologic features; therefore DRPT did not apply an adjustment for efficient propagation through soils nor any other adjustments to the vibration propagation calculations.

3.2.3 Vibration Impact Assessment

Table 7 presents the vibration screening distances for conventional commuter rail projects.

Table 7. Vibration Screening Distances

	Land Use		
	Category 1	Category 2	Category 3
Screening Distance (feet)	600	200	120

Source: FTA 2018

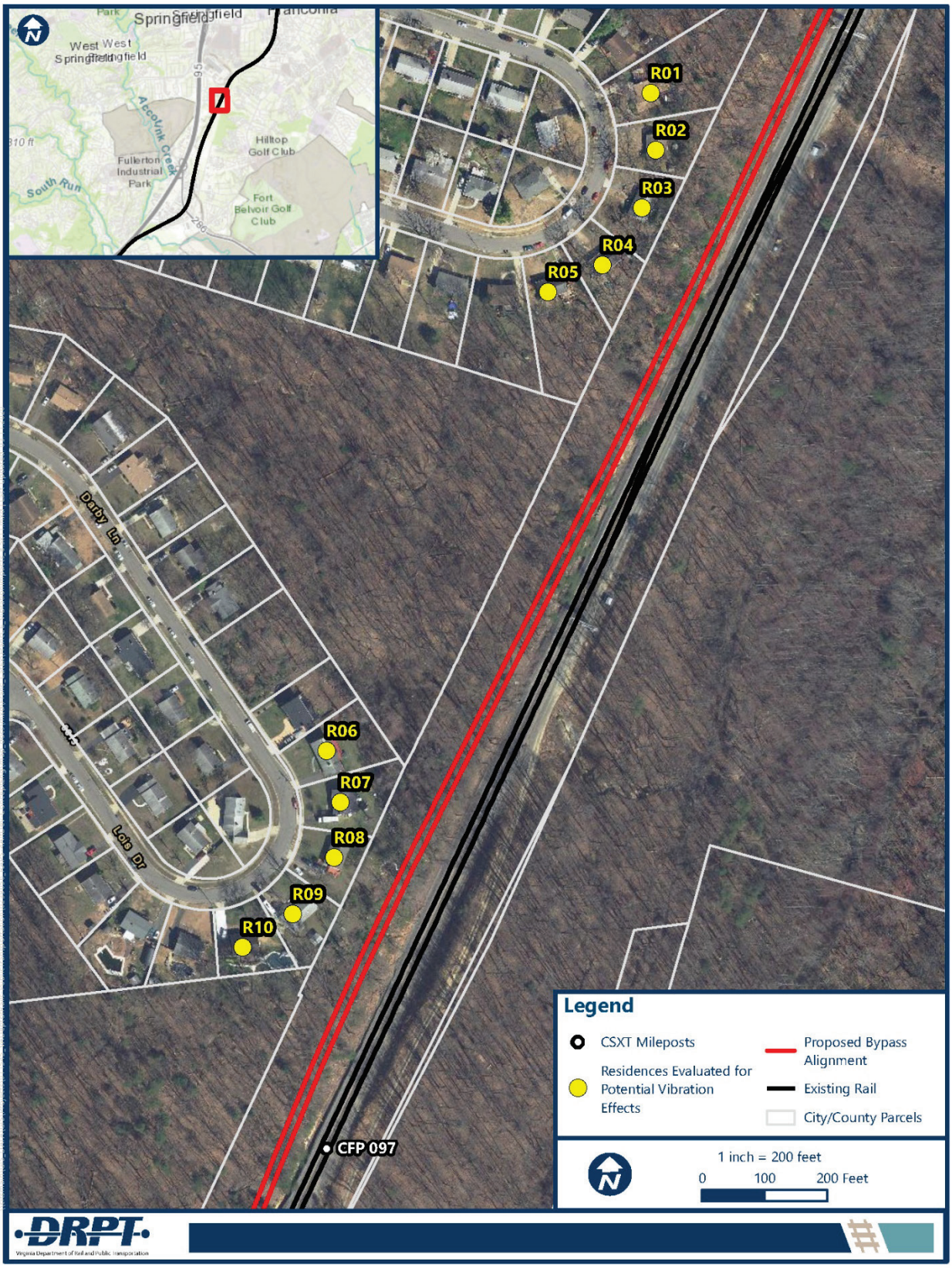
As part of the vibration analysis, DRPT did not identify any Category 1 or 3 receptors within the screening distances of the proposed bypass alignment; however Category 2 land uses (single-family residences) were identified by DRPT within the screening distance. DRPT performed a General Vibration Assessment on the Category 2 land uses. Using GIS technology, DRPT measured the distances between the closest Category 2 land uses and the proposed bypass alignment, and evaluated the potential for vibration impacts. Table 8 summarizes the results of DRPT's General Vibration Assessment for the Category 2 land uses at different train speeds. Residences within the distance from track to impact for each speed are considered by DRPT to be potentially affected by vibration.

Table 8: General Vibration Assessment Results

Residence (Receiver) ID	Distance from Track to Residence (feet)	80 mph		75 mph		70 mph	
		Distance from Track to Impact (feet)	Potential Vibration Impact?	Distance from Track to Impact (feet)	Potential Vibration Impact?	Distance from Track to Impact (feet)	Potential Vibration Impact?
R01	189	129	No	122	No	115	No
R02	143	129	No	122	No	115	No
R03	**124**	**129**	**Yes**	122	No	115	No
R04	141	129	No	122	No	115	No
R05	201	129	No	122	No	115	No
R06	192	129	No	122	No	115	No
R07	135	129	No	122	No	115	No
R08	**106**	**129**	**Yes**	**122**	**Yes**	**115**	**Yes**
R09	**127**	**129**	**Yes**	122	No	115	No
R10	177	129	No	122	No	115	No

DRPT's General Vibration Assessment shows a potential vibration impact at three residences (R03, R08, and R09) when trains operate at 80 mph on the bypass. When trains operate at 75 and 70 mph, there is a potential vibration impact at only one residence (R08). DRPT found no vibration impacts at any residence when trains operated at 65 mph. Train speed on the bypass has yet to be determined, and will be evaluated during final design. If the bypass is designed for trains to operate at speeds higher than 65 mph, DRPT will conduct an additional vibration assessment during final design to evaluate the projected vibration impact in more detail. Results of the additional detailed vibration assessment will determine if mitigation is necessary and practicable, and if so, what the mitigation could consist of.

Locations of the 10 residences are shown in the map on the following page.


Springfield
West Springfield
Accotink Creek
Fullerton Industrial Park
South Run
Hilltop Golf Club
Fort Belvoir Golf Club
95
R01
R02
R03
R04
R05
Darby Ln
R06
R07
R08
R09
R10
Lois Dr
CFP 097
Legend
CSXT Mileposts
Residences Evaluated for Potential Vibration Effects
Proposed Bypass Alignment
Existing Rail
City/County Parcels
1 inch = 200 feet
0
100
200 Feet
DRPT
Virginia Department of Rail and Public Transportation

3.2.4 Construction Vibration

Construction activity can result in varying degrees of ground vibration, depending on the equipment and methods employed. Operation of construction equipment causes ground vibrations that spread through the ground and diminish in strength with distance. Buildings in the vicinity of the construction can respond to these vibrations with varying results ranging from no perceptible effects at the lowest levels, low rumbling sounds, and perceptible vibrations at moderate levels, and slight damage at the highest levels.

Ground vibrations from construction activities do not often reach the levels that can damage structures, but they can reach the range of perceptible vibration or audible sound in buildings very close to the site; *construction activities very close to a building can also cause damage to the building*. A possible exception is the case of fragile buildings where special care must be taken to avoid damage. The construction vibration criteria include special consideration for fragile buildings. Table 9 presents the damage criteria as published by the FRA, using units of Peak Particle Velocity (PPV) expressed in inches per second.

TABLE 9: CONSTRUCTION VIBRATION DAMAGE CRITERIA

Building Category	Description	Damage Criteria, PPV (inch/second)
I	Reinforced concrete, steel, or timber (no plaster)	0.5
II	Engineered concrete and masonry (no plaster)	0.3
III	Non-engineered timber and masonry buildings	0.2
IV	Buildings extremely susceptible to vibration damage	0.12

Source: FRA 2012

DRPT plans to continue to evaluate the potential for construction vibration effects from bypass construction during the engineering and construction design phases of the project.

Table 10 presents peak particle velocities associated with typical construction equipment, as published by FTA. These vibration emission levels and factors represent a conservatively high usage as DRPT does not anticipate that all of this machinery would be used at any one particular location at the same time.

TABLE 10: CONSTRUCTION EQUIPMENT PPV

Equipment		PPV (inch/second) at 25 feet	Approx. Lv[1] at 25 feet
Pile Driver (impact)	upper range	1.518	112
	typical	0.644	104
Pile Driver (sonic)	upper range	0.734	105
	typical	0.17	93
Clam shovel drop		0.202	94
Hydromill	in soil	0.008	66
	in rock	0.017	75
Vibratory Roller		0.21	94
Hoe Ram		0.089	87
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58

Source: FTA 2018.

Table Notes:

1. RMS velocity in decibels (VdB) re 1 micro-inch/second.

4. REFERENCES

Federal Railroad Administration. 2012. *High Speed Ground Transportation Noise and Vibration Impact Assessment*. Washington, D.C.

Federal Transit Administration. 2018. *Transit Noise and Vibration Impact Assessment Manual*. FTA Report No. 0123. Washington, D.C.