15

Vibration

Contents

Figures

Tables

Acronyms/Abbreviations

FTA ..... Federal Transit Administration

PPV ..... peak particle velocities

RMS ..... root mean square

VdB ..... vibration decibels

15 Vibration

This chapter presents the results of the operational vibration analysis of the Metro Rail expansion. An analysis of vibration impacts during construction is also included. Measures to avoid, minimize, and mitigate vibration impacts are presented. Chapter 14, "Noise" addresses the assessment of potential noise impacts associated with the Proposed Action.

15.1 REGULATORY CONTEXT

The vibration analysis was conducted following procedures described in Federal Transit Administration's (FTA) *Transit Noise and Vibration Impact Assessment Manual* (FTA Guidance Manual).[1] The FTA Guidance Manual sets forth procedures for analyzing noise and vibration resulting from non-high-speed (i.e., 90 miles per hour or below) rail projects. There are no state regulatory requirements for vibration from rail projects. This chapter summarizes the methodology used to analyze vibration for the Proposed Action.

15.1.1 Vibration Fundamentals and Definitions

Fixed-railway operations can produce high vibration levels, because railway vehicles contact a rigid steel rail with steel wheels. Train wheels rolling on the steel rails create vibration energy that is transmitted into the track support system. The amount of vibrational energy strongly depends on such factors as wheel and rail smoothness and the vehicle suspension system. The vibration of the track structure "excites" the adjacent ground, creating vibration waves that propagate through the various soil and rock strata to the foundations of nearby buildings. As the vibration propagates from the foundation through the remaining building structure, certain resonant, or natural, frequencies of various components of the building could be excited.

The effects of ground-borne vibration could include discernable movement of building floors, rattling of windows, and shaking of items on shelves or hanging on walls. In extreme cases, the vibration can cause damage to buildings. The vibration of floors and walls could cause perceptible vibration, rattling such items as windows or dishes on shelves. The movement of building surfaces and objects within the building can also result in a low-frequency rumble noise. The rumble is the noise radiated from the motion of the room surfaces, even when the motion itself cannot be felt. This is called ground-borne noise.

Vibration decibels (VdB) are used to distinguish from noise decibels. All vibration levels are referenced to 1×10^{-6} inches per second, as is recommended in the FTA Guidance Manual.

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1 Federal Transit Administration. September 2018. Report No. 0123, *Transit Noise and Vibration Impact Assessment Manual.* Prepared by John A. Volpe National Transportation Systems Center. Accessed at *https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/118131/transit-noise-and-vibration-impact-assessment-manual-fta-report-no-0123_0.pdf*

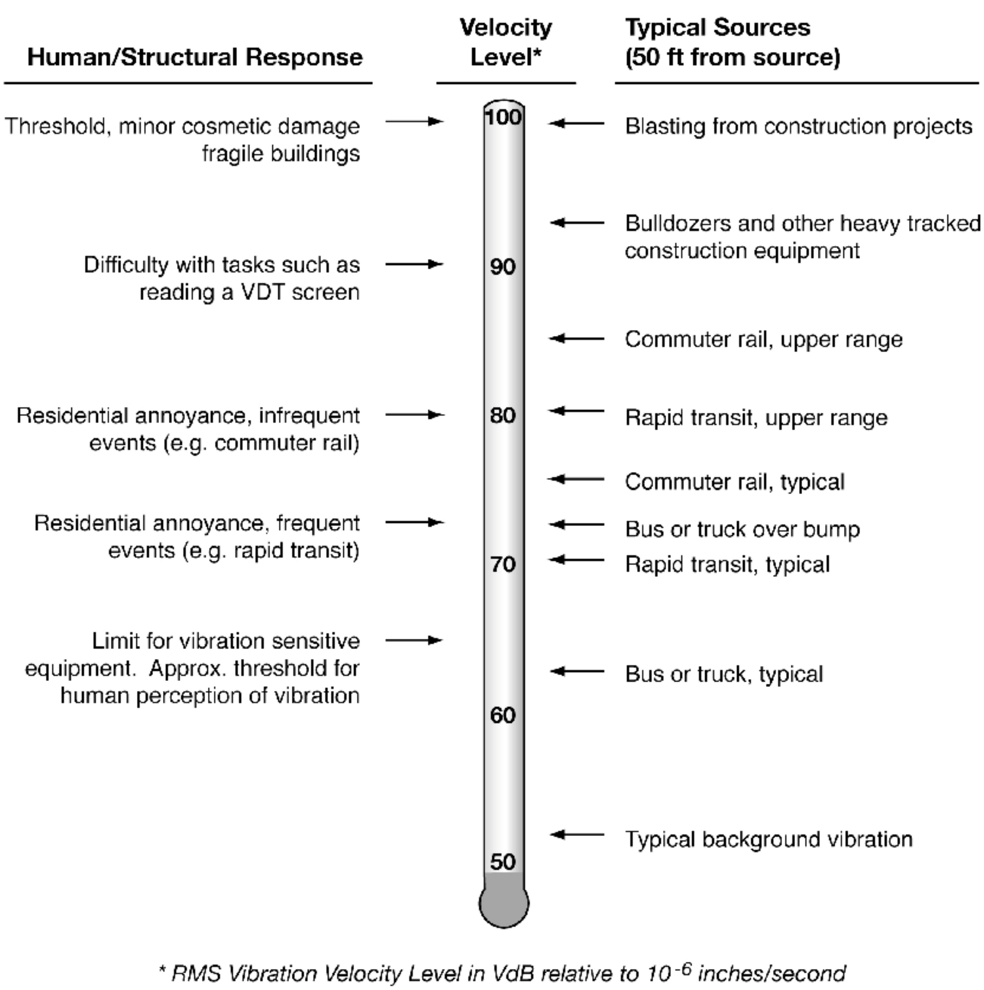
15.1.1.1 Effect of Propagation Path

Vibration is transmitted from the source to the ground, and propagates through the ground to the receptor. Soil conditions have a strong influence on the levels of ground-borne vibration. Stiff soils, such as some clay and rock, can transmit vibrations over substantial distances. Sandy soils, wetlands, and groundwater tend to absorb movement and thus reduce vibration transmission. Because subsurface conditions vary widely, measurement of actual vibration conditions (defined as transfer mobility) at the site can be the most practical way to address the variability of propagation conditions.

15.1.1.2 Human Response to Vibration Levels

In accordance with the FTA guidance manual, the perceptibility threshold is approximately 65 VdB. However, human response to vibration is not usually substantial unless the vibration exceeds 70 VdB. For example, buses and trucks rarely create vibration that exceeds 72 VdB unless there are significant bumps in the road, and these vehicles are operating at moderate speeds. Figure 15-1 shows a range of vibration levels with typical human and structural responses, as well as typical vibration sources.

Figure 15-1. Typical Levels of Ground-Borne Vibration



Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.

15.1.2 Standards and Criteria

15.1.2.1 Operational

To examine potential impacts during operation, the FTA Guidance Document outlines a three-step approach (similar to the approach for assessing airborne noise described in Chapter 14, "Noise") to analyze vibration and ground-borne noise:

- A screening procedure determines whether any vibration-sensitive receptors are within distances where impacts are likely to occur.
- A general assessment methodology determines locations or rail segments where there is the potential for impacts
- A detailed analysis methodology predicts impacts and evaluate the effectiveness of mitigation with greater precision than can be achieved with the general assessment

The FTA criteria for environmental impact from ground-borne vibration and noise are based on the land use category and maximum levels for a single event. Table 15-1 shows the land use categories as defined in the FTA Guidance Manual.

Table 15-1. FTA's Land Use Categories for General Vibration Assessment Impact Criteria

Land Use Category	Land Use Type	Description of Land Use Category
—	Special Buildings	This category includes special-use facilities that are very sensitive to vibration and noise that are not included in the categories below and require special consideration. However, if the building will rarely be occupied when the source of the vibration (e.g., the train) is operating, there is no need to evaluate for impact. Examples of these facilities include concert halls, TV and recording studios, and theaters.
1	High Sensitivity	This category includes buildings where vibration levels, including those below the threshold of human annoyance, would interfere with operations within the building. Examples include buildings where vibration-sensitive research and manufacturing* is conducted, hospitals with vibration-sensitive equipment, and universities conducting physical research operations. The building's degree of sensitivity to vibration is dependent on the specific equipment that will be affected by the vibration. Equipment moderately sensitive to vibration, such as high resolution lithographic equipment, optical microscopes, and electron microscopes with vibration isolation systems are included in this category.** For equipment that is more sensitive, a Detailed Vibration Analysis must be conducted.
2	Residential	This category includes all residential land use and buildings where people normally sleep, such as hotels and hospitals. Transit-generated ground-borne vibration and noise from subways or surface running trains are considered to have a similar effect on receivers.***
3	Institutional	This category includes institutions and offices that have vibration-sensitive equipment and have the potential for activity interference such as schools, churches, doctors' offices. Commercial or industrial locations including office buildings are not included in this category unless there is vibration-sensitive activity or equipment within the building. As with noise, the use of the building determines the vibration sensitivity.

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.
* Manufacturing of computer chips is an example of a vibration-sensitive process.
** Standard optical microscopes can be impacted at vibration levels below the threshold of human annoyance.
*** Even in noisy urban areas, the bedrooms will often be in quiet buildings with effective noise insulation. However, ground-borne vibration and noise are experienced indoors, and building occupants have practically no means to reduce their exposure. Therefore, occupants in noisy urban areas are just as likely to be exposed to ground-borne vibration and noise as those in quiet suburban areas.

Table 15-2 shows the impact criteria for land use Categories 1 through 3, as defined in the FTA Guidance Manual. The criteria for acceptable ground-borne vibration are expressed in terms of RMS velocity levels in decibels and the criteria for acceptable ground-borne noise are expressed in terms of A-weighted sound level. As shown in the table, the FTA methodology provides three different impact criteria:

- One for "infrequent" events, when there are fewer than 30 vibration events per day
- One for "occasional" events, when there are between 30 and 70 vibration events per day
- One for "frequent" events, when there are more than 70 vibration events per day

Table 15-2. Ground-Borne Vibration and Ground-Borne Noise Impact Criteria for General Assessment

Land Use Category	GBV Impact Levels (VdB re 1 micro-inch/sec)			GBN Impact Levels (dB re 20 micro Pascals)		
	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[4]	N/A[4]	N/A[4]
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: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.
Notes:
1 "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2 "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
3 "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail systems.
4 This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. For equipment that is more sensitive, a detailed vibration analysis must be performed.
5 Vibration-sensitive equipment is generally not sensitive to ground-borne noise; however, the manufacturer's specifications should be reviewed for acoustic and vibration sensitivity.

These impacts occur only if a project causes ground-borne noise or vibration levels that are higher than existing vibration levels. Thus, if the vibration level for a building in Category 1 is already 70 VdB (5 VdB above the 65 VdB threshold listed in Table 15-2) but a hypothetical project would not increase that level, then the project would not be considered to have an impact.

Special vibration level thresholds, shown in Table 15-3, are defined in the FTA Guidance Manual for land uses that have special sensitivity to ground-borne vibration and ground-borne noise.

Table 15-3. Ground-Borne Vibration and Ground-Borne Noise Impact Criteria for Special Buildings

Type of Building or Room	GBV Impact Levels (VdB re 1 micro-inch/sec)		GBN Impact Levels (dB re 20 micro Pascals)	
	Frequent Events[1]	Occasional or Infrequent Events[2]	Frequent Events[1]	Occasional or Infrequent Events[2]
Concert Halls	65 VdB	65 VdB	25 dBA	25 dBA
TV Studios	65 VdB	65 VdB	25 dBA	25 dBA
Recording Studios	65 VdB	65 VdB	25 dBA	25 dBA
Auditoriums	72 VdB	80 VdB	30 dBA	38 dBA
Theaters	72 VdB	80 VdB	35 dBA	43 dBA

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment*, September 2018.
[1] "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
[2] "Occasional or Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
[3] If the building will rarely be occupied when the trains are operating, there is no need to consider impact.

15.1.2.2 Construction

The FTA provides architectural and structural damage risk and perceptibility thresholds (Table 15-4) for residential and historic structures in proximity to the types of construction activities (Table 15-5**)** that would occur during construction of the Proposed Action. Architectural damage includes cosmetic damage, such as cracked plaster, etc., and is not considered potentially dangerous. As shown in Table 15-4, pile driving has the greatest potential to result in architectural damage to most building types. Most other construction activities require very small distances (i.e., less than 25 feet) between the structure and the construction equipment or the presence of highly fragile buildings for impacts to occur. For fragile and highly fragile buildings, the FTA recommends a limit of peak particle velocities (PPV) of 0.2 and 0.12 inches per second or 94 and 90 VdB, respectively.

Table 15-4. Vibration Source Levels for Construction Equipment

Equipment	PPV at 25 ft (in/sec)	Approximate L_v[1] at 25 ft
Pile Driver (impact)	0.644 – 1.518	104 – 112
Pile Driver (sonic)	0.170 – 0.734	93 - 105
Blasting	>0.400[2]	>100[2]
Clam Shovel drop (slurry wall)	0.202	94
Hydromill (slurry wall in soil)	0.008	66
Hydromill (slurry wall in rock)	0.017	75
Vibratory Roller	0.210	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: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment*, September 2018.
[1] RMS velocity in decibels (VdB) re 1 micro-inch/second
[2] Estimated minimum based on approximately 0.75 pound explosive

Table 15-5. Construction Vibration Damage Criteria

Building Category	PPV (in/sec)	Approximate Lv
I. Reinforced-concrete, steel or timber (no plaster)	0.50	102
II. Engineered concrete and masonry (no plaster)	0.30	98
III. Non-engineered timber and masonry buildings	0.20	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.

15.2 METHODOLOGY

The study area for the operational and construction vibration and ground-borne noise studies includes receptors within the FTA Guidance Manual screening distances as well as those locations chosen based on input from UB where research buildings contain vibration-sensitive equipment or involve vibration-sensitive research procedures. Unlike the noise analysis presented in Chapter 14, "Noise," predicted construction and operational vibration levels were compared directly to vibration criteria. Therefore, existing ambient vibration measurements were not required as part of the FTA Guidance Manual procedures.

15.2.1 Operational

The FTA vibration analysis methodology begins with a vibration screening to determine whether any vibration-sensitive receptors are within a distance where an impact is likely to occur. According to the FTA screening methodology, the potential for vibration impacts should be examined if high-sensitivity receptors are located within 450 feet of the centerline of a light rail transit system, residential receptors within 150 feet from the track centerline or institutional/office receptors within 100 feet from the track centerline. For the Proposed Action, residential land uses and high-sensitivity University at Buffalo (UB) buildings with vibration-sensitive research are within the screening distances of the Proposed Action alignment for the light-rail extension.

For each receptor identified within the screening distances, future rail vibration levels with the Proposed Action were calculated according to the FTA Guidance Manual's general analysis methodology. The predicted vibration levels were compared to the FTA vibration criteria (Table 15-2**)** to identify potential operational vibration impacts associated with the Proposed Action.

15.2.2 Construction

Following the general analysis procedures described in the FTA Guidance Manual, for each construction work area, vibration levels were projected to nearby receptors and compared to FTA vibration damage criteria (Table 15-5**)**. For the quantitative construction vibration assessment, the vibration level for the piece of equipment anticipated to produce the most vibration was used to determine the vibration levels at each receptor.

15.3 EXISTING CONDITIONS

15.3.1 Vibration Measurement Locations

Although not required as part of the FTA Guidance Manual procedures, three locations on the UB North Campus were selected for vibration measurements for the purposes of quantifying existing ambient vibration levels without the operation of the Proposed Action. UB identified these locations as having vibration-sensitive equipment utilized for research and are near the Proposed Action alignment. Table 15-6 lists these receptors and the measured ambient vibration levels.

Table 15-6. Existing Vibration Measurement Locations

Receptor[1]	Location	Approximate Distance to Proposed Action Alignment (feet)	Measured Ambient Vibration Level (VdB)
1	Cooke Hall, Basement Room C-16	95	39
2	Park Hall, Basement Room B-12	125	20
3	Davis Hall, Basement near SB01 stairwell	195	45

[1] Ambient vibration levels collected on March 26, 2019.

Existing condition vibration levels measured in all three locations on the UB North Campus are below the ground-borne vibration criteria for buildings with vibration-sensitive research presented in Table 15-1.

15.3.2 Vibration Receptors

Receptors that fall within the FTA Guidance Manual's vibration analysis screening distance from the Proposed Action were identified. Table 15-7 lists the receptors used in the vibration analysis, with corresponding FTA Land Use Categories per Table 15-1.

Table 15-7. Vibration Receptor Locations

Receptor	Location	Distance to Vibration Source (Feet)	FTA Land Use Category[1]
1	Department of Oral Biology, University at Buffalo South Campus	311	1
2	School of Dental Medicine, University at Buffalo South Campus	327	1
3	Allan Hall, University at Buffalo South Campus	87	1
4	Cornerstone Community Church	93	3
5	Residences on Kenmore Avenue at Niagara Falls Boulevard	63	2
6	252 Niagara Falls Boulevard	52	2
7	Trinity United Methodist Church	60	3
8	Christian Fellowship Baptist Church	60	3
9	800 Niagara Falls Boulevard	65	3
10	839 Niagara Falls Boulevard	89	3
11	885 Niagara Falls Boulevard	113	3
12	1280 Sweet Home Road	142	2
13	Hadley Village 110	100	2

Receptor	Location	Distance to Vibration Source (Feet)	FTA Land Use Category[1]
14	Cook Hall, University at Buffalo North Campus	100	1
15	Park Hall, University at Buffalo North Campus	100	1
16	Lockwood Memorial Library, University at Buffalo North Campus	43	3
17	Baird Hall, University at Buffalo North Campus	122	1
18	Slee Hall, University at Buffalo North Campus	292	1
19	Center for the Arts, University at Buffalo North Campus	440	1
20	Davis Hall, University at Buffalo North Campus	204	1
21	Greiner Hall, University at Buffalo North Campus	161	2
22	Mechanical and Astrospace Engineering, University at Buffalo North Campus	200	1
23	25 Bluebird Lane	90	2
24	Muir Woods Future Residential Development	90	2

[1] FTA Land Use Categories as described in Table 15-1.

15.4 PROPOSED ACTION

Vibration impacts were assessed for the Proposed Action using the FTA assessment methodology. The Proposed Action would introduce new ground-borne noise and vibration sources into the environment, which could affect sensitive receptors.

15.4.1 Operational Effects

The Proposed Action would extend the existing Metro Rail from the city of Buffalo into the towns of Amherst and Tonawanda, consisting of an underground section from the existing UB South Campus station to a tunnel portal on Niagara Falls Boulevard between Kenilworth and Princeton Avenues, followed by at-grade track construction along the remainder of the proposed alignment, except for an underground section at the intersection of Maple Road and Sweet Home Road. The anticipated frequency of rail activity associated with the schedule of the Proposed Action would classify in the "frequent events" category as described in FTA vibration assessment procedures and shown in Table 15-2.

As described previously, receptors are located within the screening distance from the Proposed Action. Consequently, a general vibration analysis was conducted for the 24 receptors that represent the locations most likely to experience vibration and/or ground-borne noise impacts. Table 15-8 and Table 15-9 shows the general analysis results. Vibration levels resulting from rail activity for these receptors were calculated using the general vibration assessment methodology previously described.

As shown in Table 15-8 and Table 15-9, the vibration levels and ground-borne predicted to result from operation of the Proposed Action would not exceed FTA vibration or ground-borne noise impact criteria at Receptors 1, 2, 4, 7, 8, 9, 10 ,11, 12, 13, 14, 15 ,16 ,17 ,18 ,19, 20, 21, 22 or 24. Receptor 3 is anticipated to experience a ground-borne noise impact, but no vibration impact as a result of the Proposed Action operation.

Receptors 14, 15, 17, 18, 19, 20 and 22 are UB North Campus buildings that could contain specialized vibration-sensitive research and/or equipment. Specifically, the following UB North Campus buildings were identified prior to the study as containing specific equipment:

- **Bonner Hall** – Electro Chemistry System, Atomic Force Microscope, Atom Probe Tomography, Bio Design Core System, Mass Spectrometer
- **Davis Hall** – Clean Room, Scanning Electron Microscopes
- **Furnas Hall** - Atomic Force Microscopes, Material Characterization Laboratory, IGA System, Electrophysiology Experiments, and General Microscopes

Table 15-8. Vibration Impact Assessment Summary

Receptor	Location	Distance from closest rail (feet)	Vibration Levels		
			Impact Threshold	Rail Generated Level	Impact or No Impact
1	Department of Oral Biology, University at Buffalo South Campus	311	65	38	No Impact
2	School of Dental Medicine, University at Buffalo South Campus	327	65	38	No Impact
3	Allan Hall, University at Buffalo South Campus	87	65	52	No Impact
4	Cornerstone Community Church	93	75	57	No Impact
5	Residences on Kenmore Avenue at Niagara Falls Boulevard	63	72	77	**Impact**
6	252 Niagara Falls Boulevard	52	72	80	**Impact**
7	Trinity United Methodist Church	60	75	71	No Impact
8	Christian Fellowship Baptist Church	60	75	71	No Impact
9	800 Niagara Falls Boulevard	65	75	73	No Impact
10	839 Niagara Falls Boulevard	89	75	71	No Impact
11	885 Niagara Falls Boulevard	113	75	65	No Impact
12	1280 Sweet Home Road	142	72	60	No Impact
13	Hadley Village 110	100	72	60	No Impact
14	Cook Hall, University at Buffalo North Campus	100	65	60	No Impact
15	Park Hall, University at Buffalo North Campus	100	65	60	No Impact
16	Lockwood Memorial Library, University at Buffalo North Campus	43	75	67	No Impact
17	Baird Hall, University at Buffalo North Campus	122	65	59	No Impact
18	Slee Hall, University at Buffalo North Campus	292	65	49	No Impact
19	Center for the Arts, University at Buffalo North Campus	440	65	44	No Impact
20	Davis Hall, University at Buffalo North Campus	204	65	53	No Impact
21	Greiner Hall, University at Buffalo North Campus	161	72	56	No Impact
22	Mechanical and Astrospace Engineering, University at Buffalo North Campus	200	65	54	No Impact
23	25 Bluebird Lane	90	72	76	**Impact**
24	Muir Woods Future Residential Development	90	72	63	No Impact

Table 15-9. Ground-Borne Noise Impact Assessment Summary

Receptor	Location	Distance from closest rail (feet)	Ground-Borne Noise Levels		
			Impact Threshold	Rail Generated Level	Impact or No Impact
1	Department of Oral Biology, University at Buffalo South Campus	311	40	18	No Impact
2	School of Dental Medicine, University at Buffalo South Campus	327	40	18	No Impact
3	Allan Hall, University at Buffalo South Campus	87	25	32	**Impact**
4	Cornerstone Community Church	93	40	37	No Impact
5	Residences on Kenmore Avenue at Niagara Falls Boulevard	63	35	42	**Impact**
6	252 Niagara Falls Boulevard	52	35	45	**Impact**
7	Trinity United Methodist Church	60	40	36	No Impact
8	Christian Fellowship Baptist Church	60	40	36	No Impact
9	800 Niagara Falls Boulevard	65	40	38	No Impact
10	839 Niagara Falls Boulevard	89	40	36	No Impact
11	885 Niagara Falls Boulevard	113	40	30	No Impact
12	1280 Sweet Home Road	142	35	25	No Impact
13	Hadley Village 110	100	35	25	No Impact
14	Cook Hall, University at Buffalo North Campus	100	40	25	No Impact
15	Park Hall, University at Buffalo North Campus	100	40	25	No Impact
16	Lockwood Memorial Library, University at Buffalo North Campus	43	40	32	No Impact
17	Baird Hall, University at Buffalo North Campus	122	40	24	No Impact
18	Slee Hall, University at Buffalo North Campus	292	40	14	No Impact
19	Center for the Arts, University at Buffalo North Campus	440	40	9	No Impact
20	Davis Hall, University at Buffalo North Campus	204	40	18	No Impact
21	Greiner Hall, University at Buffalo North Campus	161	35	21	No Impact
22	Mechanical and Astrospace Engineering, University at Buffalo North Campus	200	40	19	No Impact
23	25 Bluebird Lane	90	35	41	**Impact**
24	Muir Woods Future Residential Development	90	35	28	No Impact

Although these receptors were evaluated using the vibration impact criteria for FTA Land Use Category 1 (High Sensitivity), this may not account for all particularly vibration-sensitive equipment or procedures in these buildings. Section 15.5 discusses possible approaches for addressing highly sensitive equipment or procedures (if applicable). However, implementation of such measures would require a more detailed study of potential vibration effects than would be possible at the current stage of design. Consequently, further study of potential vibration effects would be undertaken before implementing such measures. Based on the results of the general vibration assessment and expectation that vibration mitigation measures would be implemented for especially vibration-sensitive equipment as necessary, the Proposed Action would not result in any adverse vibration or ground-borne noise impacts at these receptor sites.

As shown in Table 15-8, predicted vibration levels would exceed applicable vibration impact criteria at Receptors 5, 6 and 23. As shown in and Table 15-9, predicted ground-borne noise levels would exceed applicable ground-borne noise impact criteria at Receptors 3, 5, 6, and 23.

- Receptor 3 represents Alan Hall on the UB South Campus, which contains a music performance hall and is consequently especially sensitive to ground-borne noise. The predicted ground-borne noise levels at this receptor would constitute the potential for an adverse impact at this building.
- Receptor 5 represents residences on Niagara Falls Boulevard that would be within 140 feet of underground track. The predicted vibration and ground-borne noise levels at this receptor would constitute the potential for an adverse impact at these residences.
- Receptor 6 represents residences on Niagara Falls Boulevard that would be within 165 feet of at-grade track. The predicted vibration and ground-borne noise levels at this receptor would constitute the potential for an adverse impact at these residences.
- Receptor 23 represents residences along the east side John James Audubon Parkway between Dodge Road and the Amherst Police Station that would be within 160 feet of at-grade track. The predicted vibration and ground-borne noise levels at this receptor would constitute the potential for an adverse impact at these residences.

15.4.2 Construction Effects

The Proposed Action would include the following construction:

- Tunnel blasting, cut-and-cover tunnel construction, and tunnel shaft construction to extend the existing rail tunnel (including
- Tunnel portals
- At-grade track and catenary
- Stations
- Electrical substations
- A light maintenance/storage facility north of I-990

Construction could result in vibration adjacent to the construction work areas, at the staging areas used to facilitate construction, and along major truck routes to and from the construction work areas.

Construction-related vehicles (including worker vehicles) generally do not result in vibration levels that could result in building damage and/or human annoyance and consequently do not typically result in adverse construction vibration impacts. However, construction equipment operating within the Proposed Action study area and/or in construction staging areas, as well as heavily loaded trucks along truck routes could produce perceptible vibration levels. The equipment used in construction of the Proposed Action that would have the greatest potential to result in elevated vibration levels include caisson drill rigs and loaded trucks. Vibration levels produced by these pieces of equipment are shown in Table 15-4. Based on the general vibration analysis techniques described in the FTA Guidance Manual, for each construction work area, the maximum vibration levels produced by the equipment used in that area for the nearest receptor locations and compared them to the vibration evaluation criteria shown in Figure 15-1 for human annoyance and Table 15-1 for potential building damage.

15.4.2.1 Surface Track Construction

The nearest vibration receptors to the construction work area for the surface track construction would be the residences along Niagara Falls Boulevard (vibration Receptors 5 and 6) and the Lockwood Memorial Library (Receptor 16). The residences would be as close as 52 feet to track construction, and the library would be as close as 43 feet. Caisson drilling would occur within all surface track work areas and could produce high levels of vibration. This vibration could be perceptible at distances of up to 63 feet and would exceed the threshold for human annoyance from vibration, although it would not result in damage to any buildings. Because only a small portion of track construction would occur within 63 feet of any particular receptor, vibration would be perceptible for only a very limited period of time. Because the drilling would not result in vibration at a level that could result in damage to these buildings, and because the drilling would result in potentially annoying vibration only over a very limited portion of the construction activity, the drilling would not result in an adverse construction vibration impacts. At other receptors farther from the surface track construction work areas than the Niagara Falls Boulevard residences and Lockwood Memorial Library, vibration levels would be lower and would also not constitute adverse vibration impacts.

15.4.2.2 Tunnel Construction – University at Buffalo South Campus to Niagara Falls Boulevard

Construction of the tunnel segments of the Proposed Action alignment would consist of tunnel blasting as well as cut-and-cover construction. The construction would include shaft construction and would make use of an empty lot at the northeast corner of Kenmore Avenue and Niagara Falls Boulevard as a staging area. Cut-and-cover tunnel construction would progress along the alignment from approximately Kenmore Avenue at Capen Boulevard to the tunnel portal on Niagara Falls Boulevard between Kenilworth and Princeton Avenues. Additionally, construction would occur at the tunnel segment near Sweet Home Road and Maple Road. The spoils removal would be achieved by use of trucks.

All blasting would occur underground and the blasting program would be carefully monitored and designed to minimize impacts. Vibration from blasting depends on geological conditions, depth, methodology and other factors that must be evaluated at the time of construction. Vibration monitoring would be implemented as necessary for any blasting operation as part of safety requirements. As such, tunnel blasting would not result in an adverse impact at any receptors.

No tunnel boring devices are anticipated at this time.

MAIN STREET SHAFT

A shaft at Main Street would be constructed utilizing a variety of excavation equipment, including caisson drills, loaders, and heavy trucks. The shaft would take approximately six months to construct and would be utilized for approximately three years as a staging and material removal area for the tunnel construction. Caisson drilling could produce high levels of vibration near the shaft. However, heavily loaded trucks could also produce vibration at nearby receptors. The area near the Main Street shaft is primarily a commercial business area with associated parking lots, as well as UB on-campus parking lots. No sensitive receptors are near the proposed shaft; however, residential receptors in the area that could experience heavily loaded truck traffic within 63 feet of Kenmore Avenue and Niagara Falls Boulevard could experience perceptible vibration throughout the approximate three-years. Truck traffic routes have not yet been established but would be limited to daytime operations only. Vibration caused by caisson drilling, or movement of heavily loaded trucks would be anticipated to generate ground-borne vibration levels up to 72 VdB (which is perceptible) at distances of up to 63 feet and would exceed the threshold for human annoyance from vibration, although it would not result in damage to any buildings. Because the heavily loaded truck traffic would not result in vibration at a level that could result in damage to these residences, and because the truck traffic would result in potentially annoying vibration only when trucks travel routes that would take them within 63 feet of residences, it would not result in an adverse construction vibration impact. The shaft would be backfilled when use is completed.

WORK AREA – KENMORE AVENUE / NIAGARA FALLS BOULEVARD

Construction activity in the empty lot at the intersection of Kennmore Avenue and Niagara Falls Boulevard would include the use of excavation equipment, including caisson drills, loaders, and trucks. The work area would initially be used to facilitate the cut-and-cover staging and material removal for the tunnel construction, and would remain in use for approximately four years. Caisson drilling would have the greatest potential to produce high levels of vibration near the shaft. However, heavily loaded trucks could produce vibration at nearby receptors. Truck traffic routes have not yet been established but would be limited to daytime operations only. Truck routes to and from this work area are anticipated along Kenmore Avenue and Niagara Falls Boulevard. This vibration could be perceptible at distances of up to 63 feet, which would exceed the threshold for human annoyance from vibration, although it would not result in damage to any buildings. Because the heavily loaded truck traffic would not result in vibration at a level that could result in damage to these residences, and because truck traffic would result in vibration levels as high as 72 VdB (which is perceptible) with potentially annoying vibration only when trucks travel routes that take them within 63 feet of residences, truck traffic would not result in an adverse construction vibration impact.

15.4.2.3 Tunnel Construction – Maple Road / Sweet Home Road

Tunnel construction between Maple Road and Sweet Home Road would utilize cut-and-cover methodology. Caisson drilling could produce high levels of vibration near the shaft. However, heavily loaded trucks could also produce vibration at nearby receptors. Truck traffic routes have not yet been established but would be limited to daytime operations only. Truck routes to and from this area of tunnel construction are anticipated along Maple Road and Sweet Home Road. This vibration could be perceptible at distances of up to 63 feet. However, no sensitive receptors are within 63 feet of Maple Road and Sweet Home Road tunnel area. Because the heavily loaded truck traffic would not result in vibration at a level that could result in damage to buildings within anticipated truck routes, and because it would result in vibration levels as high as 72 VdB (which is perceptible) with potentially annoying vibration only when trucks travel routes that take them within 63 feet of buildings, truck traffic would not result in adverse construction vibration impacts.

15.5 MITIGATION

The measures described in this section have been incorporated into the Proposed Action to avoid, minimize, and mitigate the potential for vibration impacts. The vibration analysis incorporated them into the assumptions on which conclusions about the location and magnitude of potential impacts are based.

15.5.1 Operational Effects

Primary vibration impacts result from the movement of light-rail vehicles, which are supported by wheels on steel rail. Any discontinuity between the steel rail and the wheel can cause vibration, which is transmitted into the ground by the support system for the rails. Even the smallest of discontinuity can result in elevated vibration. The transmission of vibration to the surrounding environment depends on how the rail system is supported and geological ground conditions. The Proposed Action would utilize standard procedures for reducing vibration as described in the following sections.

15.5.1.1 Trackwork

Newly installed track associated with the Proposed Action would utilize resilient fasteners and resiliently supported rail ties. Resilient fasteners would be used to fasten the rail to the primary support ties. Similarly, resiliently supported rail tie systems (such as ballast mats) would be used to separate and support rail ties from the ground. Both approaches would help dissipate vibration energy from the rail system before it enters the ground. This would minimize vibration and eliminate discontinuities in main rail sections (e.g., rail sections without crossovers, changes, etc.).

15.5.1.2 Vehicle Construction and Preventative Maintenance

Wheel and rail interaction is the primary source of vibration in rail systems. The Proposed Action would utilize all-new vehicles with wheels that are as close to perfectly round as is practical. A program of preventive maintenance, including rail grinding, rail head grinding, and wheel truing would be implemented on the rail vehicles and tracks.

Rough wheels or rails can significantly increase vibration levels. Over time, rail vehicle wheels can develop “flat” spots along the circumference of the wheel, which produce vibration. Further, over time, constant repetitive impact from rolling heavy-rail vehicles with flat spot wheels can cause corrugation of the steel rails. Effective maintenance of rail wheels, through service removal upon identification of audible wheel flat sounds and rail grinding would avoid this condition. Specifically, preventive maintenance would keep both systems at “like new” conditions and significantly reduce vibration from the Proposed Action.

15.5.1.3 Highly Sensitive Research / Equipment – UB North Campus (if applicable)

The vibration analysis did not find any predicted exceedances of FTA's Category 1 (i.e., High Sensitivity) vibration impact criteria at the UB North Campus buildings. However, these buildings contain vibration-sensitive equipment and activities that could not be accounted for by the FTA's generalized impact criteria. As such, it could be necessary to study potential vibration effects further and implement measures to reduce vibration for equipment or areas particularly sensitive to vibration (i.e., vibration at levels below the threshold of human perceptibility.)

A more detailed analysis of vibration would incorporate manufacturer-specific vibration criteria for sensitive equipment, exact details of building foundation and construction, geological conditions, and exact alignment location. A detailed vibration analysis would be necessary to identify the potential need for further vibration mitigation at sensitive locations and to specify the nature of such mitigation.

As necessary, mitigation measures could include the following:

- Relocating potentially sensitive research or equipment to buildings that are farther from the final alignment of the Proposed Action.
- In cases where relocation is not possible, specialized isolated construction or isolation tables could be required for continued use of sensitive equipment and/or research.
- Using specialized resilient bedding of track and rail utilizing floating slabs and/or resilient ballast bedding in the area adjacent to highly sensitive equipment/activities.

15.5.2 Construction Effects

Most construction-related vibration would be generated by tunnel blasting, caisson drilling, and loaded trucks along routes to and from the construction work areas. Construction of the Proposed Action would occur during the day, avoiding night-time hours (i.e., 10:00 p.m. to 7:00 a.m.). The movement of construction trucks on roadways passing residences would not occur during night-time hours. In general, trucks would be routed to avoid passing by noise-sensitive land uses (e.g., residences, schools, religious uses, open space, etc.) wherever possible.

Blasting programs would occur only underground and would be carefully designed to avoid vibration impacts. Pre-qualified blasting contractors would employ protective measures to avoid excessive vibration and would design good blasting plans. Examples of protective measures could include careful assessment of existing geological conditions prior to blasting, observation of open joints in underground rock, close spacing of smaller charges, and time-delayed charges.

At existing structures within 25 feet of vibration-intensive construction activity, vibration monitoring would be provided during construction to ensure that Peak Particle Velocity levels do not exceed the acceptable thresholds shown in Table 15-5. Additionally, vibration monitoring would be required for any blasting activities that could result in vibration at an existing structure exceeding the acceptable thresholds in Table 15-5.

15.5.3 Summary

After conducting the general vibration analysis according to FTA analysis guidance, and incorporating the mitigation measures described above, exceedances of the FTA ground-borne vibration thresholds, indicating the potential for adverse vibration impacts, were identified at the following:

- Residences on Niagara Falls Boulevard within 140 feet of underground track
- Residences on Niagara Falls Boulevard within 165 feet of at-grade track
- Residences along the east side John James Audubon Parkway between Dodge Road and the Amherst Police Station within 160 feet of at-grade track

The general ground-borne noise analysis predicted exceedances of the FTA thresholds, indicating the potential for adverse ground-borne noise impacts, at the following:

- Alan Hall on the University at Buffalo South Campus
- Residences on Niagara Falls Boulevard within 140 feet of underground track
- Residences on Niagara Falls Boulevard within 165 feet of at-grade track
- Residences along the east side John James Audubon Parkway between Dodge Road and the Amherst Police Station within 160 feet of at-grade track

The vibration and ground-borne noise analysis found that at other receptors, noise resulting from operation of the Proposed Action would not exceed FTA impact criteria and would consequently not rise to the level of an adverse impact.

Construction of the Proposed Action is anticipated to generate vibration levels that exceed 72 VdB, the threshold of annoyance, in some receptor areas closest to caisson drilling and loaded trucking routes, but is not anticipated to result in vibration that could cause damage to any buildings. Construction-related vibration would be perceptible at each receptor only for a limited time and consequently would not constitute an adverse impact.