# APPENDIX J.1

# NOISE AND VIBRATION

# A. INTRODUCTION

This FEIS appendix was prepared to support the analyses provided in Chapter 12, "Noise and Vibration." The appendix is divided in two main sections: section B, which examines the potential for airborne noise impacts; and section C, which examines the potential for vibration and ground-borne noise impacts. Each section includes a discussion of fundamentals, standards, analysis methodology, and impact criteria, as well as an evaluation of potential impacts. (Potential impacts and various mitigation measures being explored by NYCT are discussed in detail in Chapter 12.)

# B. AIRBORNE NOISE

## INTRODUCTION

The analysis of airborne noise for the Second Avenue Subway was performed using the procedures set forth in the Federal Transit Administration (FTA) guidance manual, *Transit Noise and Vibration Impact Assessment*, April 1995. This FTA guidance document sets forth methodologies for analyzing airborne noise during construction and operation.

For analyzing a project's potential impacts during construction, the document provides a two-step process: a general assessment methodology and a detailed assessment methodology. The general noise assessment methodology is a screening methodology that examines noise from the two noisiest pieces of construction equipment operating during a 1-hour period to determine locations where there is the potential for impacts. At locations where the general assessment indicates the potential for impacts, the detailed noise assessment methodology is used to predict impacts and evaluate the effectiveness of mitigation with greater precision than can be achieved with the general noise assessment.

To examine potential impacts during operation, the FTA guidance document provides a three-step process for analysis: a noise screening procedure, a general noise assessment methodology, and a detailed analysis methodology. The screening procedure is used to determine whether any noise-sensitive receivers are within distances where impacts are likely to occur; the general noise assessment methodology is used to determine locations or rail segments where there is the potential for impacts; and the detailed noise analysis methodology is used to predict impacts and evaluate the effectiveness of mitigation with greater precision than can be achieved with the general noise assessment.

## STANDARDS AND CRITERIA FOR AIRBORNE NOISE

### *NOISE FUNDAMENTALS*

Quantitative information on the effects of airborne noise on people is well documented. If sufficiently loud, noise may adversely affect people in several ways. For example, noise may interfere with human activities, such as sleep, speech communication, and tasks requiring concentration or coordination. It may also cause annoyance, hearing damage, and other physiological problems. Several noise scales and rating methods are used to quantify the effects of noise on people. These scales and methods consider such factors as loudness, duration, time of occurrence, and changes in noise level with time. However, all the stated effects of noise on people are subjective and depending on the individual.

Sound is a fluctuation in air pressure. Sound pressure levels are measured in units called "decibels" (dB). The particular character of the noise that we hear (a whistle compared with a French horn, for example) is determined by the speed, or "frequency," at which the air pressure fluctuates, or "oscillates." Frequency defines the oscillation of sound pressure in terms of cycles per second. One cycle per second is known as 1 Hertz (Hz). People can hear over a relatively limited range of sound frequencies, generally between 20 Hz and 20,000 Hz, and the human ear does not perceive all frequencies equally well. High frequencies (the whistle, for example) are more easily discerned and therefore more intrusive than many of the lower frequencies (the lower notes on the French horn, for example).

#### *"A"-Weighted Sound Level (dBA)*

To bring a uniform noise measurement that simulates people's perception of loudness and annoyance, the decibel measurement is weighted to account for those frequencies most audible to the human ear. This is known as the A-weighted sound level, or "dBA," and it is the most often used descriptor of noise levels where community noise is the issue. As shown in Table J.1-1, the threshold of human hearing is defined as 0 dBA; very quiet conditions (as in a library, for example) are approximately 40 dBA; levels between 50 dBA and 70 dBA define the range of acceptable daily activity; levels above 70 dBA would be considered noisy, and then loud, intrusive, and deafening as the scale approaches 130 dBA. In considering these values, it is important to note that the dBA scale is logarithmic, meaning that each increase of 10 dBA actually describes a doubling of sound pressure. Thus, the background noise in an office, at 50 dBA, is perceived as twice as loud as a library at 40 dBA. For most people to perceive an increase in noise, it must be at least 3 dBA. At 5 dBA, the change will be readily noticeable.[1]

It is also important to understand that combinations of different sources are not additive, because of the dBA scale's logarithmic nature. For example, two noise sources—a vacuum cleaner operating at approximately 72 dBA and a telephone ringing at approximately 58 dBA—do not combine to create a noise level of 130 dBA, the equivalent of a jet airplane or air raid siren (see Table J.1-1). In fact, the noise produced by the telephone ringing may be masked by the noise of the vacuum cleaner and not be heard. The combination of these two noise sources would yield a noise level of 72.2 dBA. Noise levels are combined on a logarithmic scale.

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[1] Average ability to perceive changes in noise levels from Bolt Beranek and Neuman, Inc., *Fundamentals and Abatement of Highway Traffic Noise, Report No. PB-222-703.* Prepared for the Federal Highway Administration, June 1973.

**Table J.1-1**
**Common Noise Levels**

| Sound Source | (dBA) |
|---|---|
| | |
| Military jet, air raid siren | 130 |
| | |
| Amplified rock music | 110 |
| | |
| Jet takeoff at 330 feet, or a passing subway train from a subway platform | 100 |
| Freight train at 100 feet | 95 |
| Train horn at 100 feet | 90 |
| Heavy truck or lawn mower at 50 feet | |
| Busy city street or loud shout | 80 |
| | |
| Highway traffic at 50 feet, train | 70 |
| | |
| Predominantly industrial area | 60 |
| Light car traffic at 50 feet, city or commercial areas or residential areas close to industry | |
| Background noise in an office | 50 |
| Suburban areas with medium density transportation | |
| Public library | 40 |
| | |
| Soft whisper at 16 feet | 30 |
| | |
| Threshold of hearing | 0 |

**Note:** A 10 dBA increase in level appears to double the loudness, and a 10 dBA decrease halves the apparent loudness.

**Sources:**

Cowan, James P., *Handbook of Environmental Acoustics*. Van Nostrand Reinhold, New York, 1994.

Egan, M. David, *Architectural Acoustics*. McGraw-Hill Book Company, 1988.

### *Effects of Distance on Noise*

Noise varies with distance. For example, highway traffic 50 feet away from a receptor (such as a person listening to the noise) typically produces sound levels of approximately 70 dBA. The same highway noise measures 66 dBA at a distance of 100 feet. This decrease is known as "drop-off." The outdoor drop-off rate for moving noise sources, such as traffic, is a decrease of 4.5 dBA for every doubling of distance between the noise source and receiver. For stationary noise sources, such as amplified rock music, the outdoor drop-off rate is a decrease of 6.0 dBA for every doubling of distance between the noise source and receiver.

### *Noise Descriptors Used in Impact Assessment*

Because the sound-pressure level unit of dBA describes a noise level at just one moment but since very few noises are constant, other ways of describing noise over more extended periods have been developed. One way of describing fluctuating sound is to describe the fluctuating noise heard over a specific period as if it were a steady, unchanging sound (i.e., as if it were averaged over that time period). For this condition, a descriptor called the "equivalent sound level," $L_{eq}$, can be computed. $L_{eq}$ is the constant sound level that, in a given situation and period (e.g., 1 hour, denoted by $L_{eq(1)}$, or 24 hours, denoted as $L_{eq(24)}$), conveys the same sound energy as the actual time-varying sound. Statistical sound level descriptors, such as $L_1$, $L_{10}$, $L_{50}$, $L_{90}$, and $L_{x,}$ are sometimes used to indicate noise levels that are exceeded 1, 10, 50, 90, and x percent of the time, respectively. Discrete event peak levels are given as $L_{01}$ levels.

For impact analyses where noise levels are predicted to exceed a given impact criterion, the relationship between $L_{eq}$ and level of exceedance is worth noting. Because $L_{eq}$ is defined in energy rather than straight numerical terms, it is not simply related to the level of exceedance. If the noise fluctuates very little, $L_{eq}$ will approximate $L_{50}$, or the median level ($L_{50}$ indicates noise levels that are exceeded 50 percent of the time). If the noise fluctuates broadly, the $L_{eq}$ will be approximately equal to the $L_{10}$ value. If extreme fluctuations are present, the $L_{eq}$ will exceed $L_{90}$ or the background level by 10 or more decibels. Thus, the relationship between $L_{eq}$ and the levels of exceedance will depend on the character of the noise. In community noise measurements, it has been observed that the $L_{eq}$ is generally between $L_{10}$ and $L_{50}$. The relationship between $L_{eq}$ and exceedance levels is used to characterize the noise sources and to determine the nature and extent of their impact at all receptor locations.

A descriptor for cumulative 24-hour exposure is the day-night sound level, abbreviated as $L_{dn}$. This is a 24-hour measure that accounts for the moment-to-moment fluctuations in A-weighted noise levels due to all sound sources during 24 hours, combined. Mathematically, the $L_{dn}$ noise level is the energy average of all $L_{eq(1)}$ noise levels over a 24-hour period, where nighttime noise levels (10 PM to 7 AM) are increased by 10 dBA before averaging.

Following FTA guidance, the maximum 1-hour equivalent sound level ($L_{eq(1)}$) or the day-night sound level ($L_{dn}$) is used for impact assessment, depending on land use category as described below.

### *NOISE STANDARDS AND CRITERIA*

Airborne noise levels associated with the construction and operation of the proposed Second Avenue Subway are subject to the noise criteria defined by the FTA. In addition, noise levels from some construction equipment are regulated by the Noise Control Act of 1972, 49 USC § 4901 et. seq. These are both addressed in detail in Chapter 12.

## AIRBORNE NOISE PREDICTION METHODOLOGY

Following the procedures set forth in FTA's guidance manual, existing noise levels were first determined by field measurement. Then, project-generated noise levels from construction activities and subway operations were calculated. Finally, those levels were evaluated using the impact criteria discussed above to determine the project's potential for significant adverse impacts. This methodology is discussed in more detail below.

### *DETERMINATION OF EXISTING NOISE LEVELS*

Noise measurements were performed at various receptor locations along the Second Avenue Subway alignment to establish existing conditions. In each case, traffic on adjacent roadways and streets was the dominant noise source.

### *Selection of Noise Receptors*

As described in Chapter 12, a total of 17 receptor locations were chosen along the project alignment; these sites, which are distributed across the various neighborhood study areas, were selected for assessment because they encompass the range of conditions that could occur along the entire alignment. (Information regarding the location of residences, institutions, historic resources, and other sensitive receptors is provided in Chapter 6, "Social and Economic Conditions," and Chapter 9 "Historic Resources" of this FEIS.) In many areas of Manhattan, institutional land uses that can be classified as land use category 3 (see Table 12-1) are adjacent to residences, which are classified as land use category 2. The locations chosen as noise receptors are summarized in Table J.1-2 (which also indicates each site's FTA land use category) and shown in Figures 12-2 and 12-3 in Chapter 12.

### *Noise Monitoring*

Noise monitoring was conducted at all 17 noise receptor sites. While the majority of analysis locations for ambient noise levels were measured in 2002, at some locations, measurements made in November 1997 as part of the Major Investment Study (MIS) and Draft Environmental Impact Statement (DEIS) for the Manhattan East Side Transit Alternatives (MESA) study were also used for this assessment. This approach is warranted given that in New York City, existing noise levels at all locations within the study area are primarily a function of traffic volumes. As a result, significant changes in traffic conditions would have to occur for any appreciable change in noise levels to be experienced. For example, without others changes in background conditions, a fairly insignificant increase in ambient noise levels of 1 dBA would require an increase in traffic volumes of over 25 percent. Since traffic generally increases in Manhattan by about 0.5 percent per year, the 1997 measured values are likely within about 0.1 dBA of 2002 measured values, an imperceptible difference. In addition, use of the 1997 data at some locations provided for a more accurate assessment of the noise levels that would normally be expected in the study area because they do not reflect the altered traffic patterns that have occurred in some portions of the study area as a result of the September 11, 2001, terrorist attacks.

As shown in Table J.1-2, noise levels at each site were measured using either a continuous 24-hour noise measurement or for four 20-minute periods during the AM peak, midday, PM peak, and nighttime. At receptor sites 1, 3, 6, 7, 11, 13, and 16, a continuous 24-hour noise measurement was made. At receptor sites 2, 4, 5, 8, 9, 10, 12, 14, 15, and 17, measurements were made during four 20-minute periods during the day and nighttime, and 24-hour $L_{dn}$ values were estimated based on these values. In addition, at receptor site 12, 10-minute measurements were made throughout the AM and PM peak hour to confirm that for locations in Manhattan, 20-minute measured noise levels are representative of 1-hour measured levels.

Measurements were performed on weekdays (generally, Tuesday, Wednesday, or Thursday) to avoid weekend and holiday conditions, which might bias the measurements. As discussed above, at some locations measurements made in November 1997 as part of the MESA DEIS were used, and at some locations measurements were made in February, May, and June 2002 specifically for this FEIS.

**Table J.1-2**
**Noise Receptor Sites and Locations**

| Site | Location | Zone | FTA Land Use Category[1] | Type of Measurement | Year of Measurement[2] |
|---|---|---|---|---|---|
| 1 | Second Ave between 128th and 127th Sts | East Harlem | 3 | 24-Hour | 2002 |
| 2 | 125th St between Park and Lexington Aves | East Harlem | 2 | 20-Minutes | 2002 |
| 3 | Second Ave between 117th and 116th Sts | East Harlem | 2 | 24-Hour | 2002 |
| 4 | Second Ave between 109th and 107th Sts | East Harlem | 2 | 20-Minutes | 1997 |
| 5 | Second Ave between 99th and 97th Sts | East Harlem | 2 | 20-Minutes | 1997 |
| 6 | Second Ave between 96th and 95th Sts | Upper East Side | 2 | 24-Hour | 2002 |
| 7 | Second Ave between 79th and 78th Sts | Upper East Side | 3 | 24-Hour | 1997 |
| 8 | 66th St between Second and Third Aves | Upper East Side | 2 | 20-Minutes | 2002 |
| 9 | Second Ave between 65th and 64th Sts | Upper East Side | 2 | 20-Minutes | 1997 |
| 10 | Second Ave between 55th and 54th Sts | East Midtown | 2 | 20-Minutes | 1997 |
| 11 | Second Ave between 34th and 33rd Sts | East Midtown | 2 | 24-Hour | 2002 |
| 12 | Second Ave between 29th and 28th Sts | Gramercy Park/ Union Square | 2 | 20-Minutes | 1997 |
| 13 | Second Ave between 2nd and 1st Sts | East Village/ Lower East Side/Chinatown | 2 | 24-Hour | 2002 |
| 14 | Chrystie St between Delancey and Rivington Sts | East Village/ Lower East Side/Chinatown | 2 | 20-Minutes | 2002 |
| 15 | Forsyth St between Delancey and Rivington Sts | East Village/ Lower East Side/ Chinatown | 2 | 20-Minutes | 2002 |
| 16 | Water St between Beekman and Fulton Sts | Lower Manhattan | 2 | 24-Hour | 1997 |
| 17 | Water St between Pine and Wall Sts | Lower Manhattan | 2 | 20-Minutes | 1997 |

**Note:** [1] For definition of land use categories, see Table 12-2.
[2] Measurements were made in 1997 as part of the original MESA MIS/DEIS and in 2002 to supplement those locations.

### *Calculation of $L_{dn}$ Noise Levels*

$L_{dn}$ noise levels can be calculated directly from 24-hour noise levels, but must be approximated if noise levels are not measured over a 24-hour period. The FTA guidance manual provides equations to approximate the $L_{dn}$ noise level using either a peak, midday, and nighttime hourly $L_{eq}$ noise level or daytime, early nighttime, or late nighttime $L_{eq}$ value. At receptor sites where continuous 24-hour measurement data were not conducted and where $L_{dn}$ values were needed, the procedures contained in the FTA guidance manual were used to calculate the $L_{dn}$ noise levels.

### *MODELING TO PREDICT FUTURE CONDITIONS FOR THE NO BUILD ALTERNATIVE AND PROPOSED PROJECT*

For noise, future conditions common to all alternatives (including the so-called “No Build” Alternative) reflect background changes in traffic that would occur by the year 2025. A proportional modeling technique was used to determine approximate changes in noise levels due to predicted future changes in traffic volumes without the proposed Second Avenue Subway.

Using this technique, project-generated traffic noise levels during construction were then calculated using existing noise levels, existing traffic data, and estimated future traffic data. In general, with this technique, vehicular traffic volumes were converted into passenger car equivalent (PCE) values, for which one medium-duty truck (having a gross weight between 9,900 and 26,400 pounds) was assumed to generate the noise equivalent of 13 cars, and one heavy-duty truck (having a gross weight of more than 26,400 pounds) was assumed to generate the noise equivalent of 47 cars, and each bus was assumed to generate the noise equivalent of 18 cars. Project-generated noise levels from traffic sources were calculated using a formula based on methodologies recommended in New York City's *City Environmental Quality Review (CEQR) Technical Manual* (October 2001).

Because sound levels use a logarithmic scale, this model proportions logarithmically with traffic changes. For example, if the existing traffic volume on a street is 100 PCE with a noise level of 70 dBA, and if the future traffic volumes for No Build and Build conditions were 120 PCE and 150 PCE, respectively, then the No Build noise level would be 70.8 dBA, the Build noise level would be 71.8 dBA, and the project-generated noise level would be 64.8 dBA. This example assumes that traffic is the dominant noise source at a particular location, a condition that is true at all of the receptor locations for the Second Avenue Subway.

### *MODELING TO PREDICT IMPACTS DUE TO CONSTRUCTION ACTIVITIES*

Airborne noise from construction activities was estimated following the methodologies set forth in the April 1995 FTA guidance manual. See Chapter 12 for details.

### *MODELING TO PREDICT IMPACTS DUE TO SUBWAY OPERATIONS*

Airborne noise from subway operations was also analyzed using the methodologies set forth in the FTA guidance manual. The analysis considered three major noise sources associated with subway operations: noise from fixed-rail operations, noise from mechanical equipment operations, and noise from subway train yards.

For noise from fixed-rail operations, due to the short distances between sources and sensitive noise receptors, the detailed noise analysis methodology (rather than the screening analysis procedures or general noise assessment methodology contained in the FTA guidance manual) was used to determine project-generated noise levels and to examine potential impacts. Following the FTA methodology, computation of $L_{eq(1)}$ and $L_{dn}$, noise levels for free-field acoustic conditions (no reflections) from fixed-rail sources were calculated at 50 feet, using the specified equations, which account for the type of track, the average number of cars per train, and the number of trains per hour during the day and at night. Noise levels calculated at 50 feet were corrected for the actual distance to the receptor.

At locations adjacent to the proposed subway line, noise from rail vehicle operations would reverberate in the enclosed space of the underground rail tunnels and stations. Noise levels calculated as described above predict noise that results from the source, but do not take into account reverberation effects from the tunnels and stations, nor do they account for attenuation effects of the ventilation shafts and station entrances. Reverberation effects of the tunnel and stations would cause significantly higher noise levels that would be the result of the source noise and the reflected noise. To account for this phenomenon, the reflected effect, approximately 6 dBA, was added to the free-field predicted noise levels and adjusted for noise receptor locations based on distance and acoustical attenuation through a station entrance, ventilation shaft, or subway grating. The analysis assumes that the design of these system elements would provide approximately 20 to 25 dBA attenuation.

For noise from rail storage yards, the general noise assessment methodology, rather than the screening analysis procedures contained in the FTA guidance manual, was used to determine project-generated noise levels and to examine potential impacts. Following the FTA methodology, computation of $L_{eq(1)}$ and $L_{dn}$, noise levels for free-field acoustic conditions (no reflections) from fixed-rail sources were calculated at 50 feet, using the same equations described above for fixed-rail operations. Noise levels calculated at 50 feet from the equations were similarly corrected for distance.

## EXISTING CONDITIONS: AIRBORNE NOISE

As described above, continuous 24-hour noise was measured at receptor sites 1, 3, 6, 7, 11, 13, and 16; at receptor sites 2, 4, 5, 8, 9, 10, 12, 14, 15, and 17, measurements were made during four 20-minute periods for the AM peak, midday, PM peak, and the night. Measured $L_{eq(1)}$ and $L_{dn}$ noise levels for the 24-hour continuous measurement receptor sites are shown in Table J.1-3**,** and measured $L_{eq(1)}$ for the peak periods and calculated $L_{dn}$ noise levels for the other receptor sites are shown in Table J.1-4. As shown in the tables, the measured noise levels are relatively high and reflect the study area's high level of vehicular activity.

In addition to the measurements shown in Tables J.1-3 and J.1-4, 10-minute measurements were made throughout the AM and PM peak hours at receptor site 12 to confirm that the 20-minute measured noise levels are representative of 1-hour measured levels. The 10-minute measurements and the corresponding calculated 20-minute and 1-hour $L_{eq}$ noise levels are shown in Table J.1-5. All of the 20-minute measured values are within 1 dBA of the 1-hour value.

## FUTURE CONDITIONS COMMON TO ALL ALTERNATIVES: AIRBORNE NOISE

In the future, traffic volumes throughout the study area are expected to increase by approximately 0.5 percent per year, which will cause small increases in ambient noise levels (for more information on traffic conditions, see Chapter 5D, "Vehicular Traffic"). In addition to general background growth, some discrete projects would also add traffic to the study area and were accounted for in the assessment (see Chapter 5D). Future noise levels were determined using measured existing noise levels and the previously described traffic noise modeling methodology. Table 12-4 in Chapter 12 shows maximum predicted $L_{eq(1)}$ and $L_{dn}$ noise levels in the year 2025 without the proposed Second Avenue.

## CONSTRUCTION IMPACTS OF THE PROJECT ALTERNATIVES: AIRBORNE NOISE

The No Build Alternative would not involve construction activities, and therefore would not increase noise levels related to construction.

As described in Chapter 12, the project would unavoidably create significant adverse airborne noise impacts because of the nature of the construction activities and because of their proximity to residences and other sensitive uses.

## Table J.1-3
## Measured 24-Hour Existing Noise Levels

| Hour Ending | Site 1 Measured $L_{eq(1)}$ Noise Level | Site 3 Measured $L_{eq(1)}$ Noise Level | Site 6 Measured $L_{eq(1)}$ Noise Level | Site 7 Measured $L_{eq(1)}$ Noise Level | Site 11 Measured $L_{eq(1)}$ Noise Level | Site 13 Measured $L_{eq(1)}$ Noise Level | Site 16 Measured $L_{eq(1)}$ Noise Level |
|---|---|---|---|---|---|---|---|
| 01:00 AM | 68.7 | 72.1 | 67.8 | 73.5 | 78.0 | 68.1 | 67.3 |
| 02:00 AM | 67.7 | 71.4 | 67.4 | 73.5 | 70.8 | 66.7 | 64.5 |
| 03:00 AM | 66.5 | 70.1 | 68.9 | 72.1 | 71.2 | 69.4 | 63.6 |
| 04:00 AM | 63.7 | 70.6 | 70.8 | 73.4 | 73.0 | 68.2 | 63.9 |
| 05:00 AM | 66.3 | 73.0 | 72.1 | 74.0 | 74.3 | 71.1 | 66.1 |
| 06:00 AM | 72.3 | 75.1 | 73.7 | 75.8 | 78.5 | 73.2 | 68.3 |
| 07:00 AM | 71.5 | 76.4 | 74.0 | 78.1 | 75.7 | 71.4 | 70.4 |
| 08:00 AM | 73.3 | 77.4 | 73.6 | 79.4 | 76.5 | 71.9 | 72.6 |
| 09:00 AM | 70.6 | 71.6 | 72.3 | 79.3 | 77.3 | 73.5 | 71.5 |
| 10:00 AM | 69.9 | 68.9 | 71.1 | 79.8 | 75.7 | 71.6 | 70.3 |
| 11:00 AM | 71.1 | 77.8 | 73.3 | 78.0 | 75.3 | 72.4 | 69.2 |
| Noon | 69.4 | 74.6 | 69.4 | 82.2 | 75.4 | 70.7 | 72.1 |
| 01:00 PM | 68.7 | 72.8 | 71.4 | 77.8 | 74.8 | 70.4 | 71.7 |
| 02:00 PM | 69.0 | 76.3 | 70.8 | 76.5 | 76.4 | 70.9 | 68.1 |
| 03:00 PM | 69.5 | 74.0 | 71.2 | 84.1 | 74.5 | 70.3 | 68.0 |
| 04:00 PM | 69.3 | 73.4 | 71.6 | 80.1 | 75.5 | 72.4 | 68.1 |
| 05:00 PM | 71.0 | 74.4 | 71.8 | 82.6 | 74.1 | 70.0 | 68.8 |
| 06:00 PM | 69.7 | 73.4 | 70.7 | 76.6 | 74.4 | 69.8 | 68.8 |
| 07:00 PM | 72.1 | 75.1 | 69.9 | 74.8 | 73.7 | 69.6 | 68.1 |
| 08:00 PM | 72.7 | 72.4 | 72.3 | 76.6 | 72.8 | 69.7 | 69.4 |
| 09:00 PM | 69.5 | 70.2 | 69.6 | 73.7 | 75.3 | 71.5 | 68.0 |
| 10:00 PM | 69.4 | 71.4 | 69.7 | 74.3 | 75.2 | 69.4 | 67.6 |
| 11:00 PM | 69.0 | 70.7 | 67.9 | 74.4 | 73.6 | 68.7 | 68.1 |
| Midnight | 69.6 | 77.7 | 67.9 | 74.2 | 72.5 | 71.3 | 66.0 |
| $L_{dn}$ | 75.7 | 80.3 | 77.3 | 82.4 | 81.4 | 76.8 | 74.0 |

## Table J.1-4
## Measured 20-Minute Existing Noise Levels

| Site | Time Period | Measured $L_{eq(1)}$ Noise Level | Measured $L_{10(1)}$ Noise Level | FTA Calculated $L_{dn}$ Noise level |
|---|---|---|---|---|
| 2 | AM Peak | 73.6 | 76.5 | 75.6 |
| | Midday | 72.9 | 75.5 | |
| | PM Peak | 72.9 | 76.0 | |
| | Late night | 70.8 | 73.5 | |
| 4 | AM Peak | 74.9 | 78.5 | 77.5 |
| | Midday | 75.1 | 79.0 | |
| | PM Peak | 75.5 | 78.5 | |
| | Late night | 72.6 | 75.5 | |
| 5 | AM Peak | 75.6 | 78.0 | 75.0 |
| | Midday | 73.9 | 77.0 | |
| | PM Peak | 73.3 | 76.0 | |
| | Late night | 69.6 | 73.0 | |
| 8 | AM Peak | 66.4 | 68.5 | 67.8 |
| | Midday | 63.3 | 65.5 | |
| | PM Peak | 64.5 | 66.0 | |
| | Late night | 63.3 | 65.0 | |
| 9 | AM Peak | 75.9 | 79.0 | 78.4 |
| | Midday | 76.6 | 79.5 | |
| | PM Peak | 76.3 | 79.0 | |
| | Late night | 73.4 | 76.0 | |
| 10 | AM Peak | 78.6 | 81.5 | 77.7 |
| | Midday | 75.7 | 78.5 | |
| | PM Peak | 77.8 | 80.0 | |
| | Late night | 72.5 | 76.2 | |
| 12 | AM Peak | 75.3 * | 80.0 | 78.1 |
| | Midday | 76.8 | 80.0 | |
| | PM Peak | 73.6 * | 76.6 | |
| | Late night | 73.0 | 76.5 | |
| 14 | AM Peak | 72.1 | 75.5 | 73.9 |
| | Midday | 70.6 | 73.5 | |
| | PM Peak | 69.7 | 73.0 | |
| | Late night | 69.3 | 72.5 | |
| 15 | AM Peak | 66.8 | 68.0 | 66.9 |
| | Midday | 62.6 | 64.5 | |
| | PM Peak | 62.3 | 64.0 | |
| | Late night | 62.4 | 64.5 | |
| 17 | AM Peak | 74.7 | 77.5 | 76.0 |
| | Midday | 72.9 | 75.5 | |
| | PM Peak | 70.9 | 74.0 | |
| | Late night | 71.3 | 73.0 | |

**Note:** * Indicates the 20-minute noise level values calculated based on the 10-minute measured noise levels.

### Table J.1-5
### Comparison of 10-Minute, 20-Minute, and Hourly $L_{eq}$ Noise Levels at Site 12

| Time Period | 10-Minute $L_{eq}$ Noise Level | 20-Minute $L_{eq}$ Noise Level | Hourly $L_{eq}$ Noise Level |
|---|---|---|---|
| AM Peak | 74.9 | 74.9 | 75.3 |
| | 74.9 | | |
| | 74.4 | 75.3 | |
| | 76.1 | | |
| | 76.2 | 75.6 | |
| | 74.9 | | |
| PM Peak | 73.3 | 73.3 | 73.6 |
| | 73.3 | | |
| | 72.4 | 72.9 | |
| | 73.4 | | |
| | 75.0 | 74.6 | |
| | 74.1 | | |

Typical noise levels for construction equipment that may be used during construction of the new subway are presented in Table J.1-6. Noise from construction equipment is regulated by EPA noise emission standards. These federal requirements mandate that certain classifications of construction equipment and motor vehicles meet specified noise emission standards. MTA and NYCT would ensure that this regulation would be carefully followed.

NYCT is committed to developing and implementing an extensive mitigation program to reduce and alleviate the proposed project's impacts. The potential measures currently under consideration to mitigate airborne noise impacts are discussed in Chapter 12.

## PERMANENT IMPACTS OF THE PROJECT ALTERNATIVES: AIRBORNE NOISE

An analysis was conducted to evaluate the potential effects from noise due to fixed-rail operations and mechanical equipment operations (e.g., supply and exhaust fans, climate conditioning equipment, and vents), and noise from the existing 36th-38th Street Yard. Noise at this location was analyzed using the methodologies previously described.

### *NOISE FROM SUBWAY OPERATIONS IN MANHATTAN*

As discussed in Chapter 12 and presented in detail in Table 12-7, all of the predicted 2025 noise levels once the subway is operational would be well below the impact criteria, and these sources would not be expected to perceptibly increase ambient noise levels. The maximum change in Build $L_{dn}$ and $L_{eq(1)}$ noise levels, when compared with No Build noise levels, would be less than 1 dBA. These changes would be insignificant and imperceptible.

## Table J.1-6
## Construction Equipment Noise Emission Levels

| Equipment | Typical Noise Level (dBA) 50 feet from source |
|---|---|
| Air compressor | 81 |
| Backhoe | 80 |
| Bulldozer | 85 |
| Compactor | 82 |
| Concrete Mixer | 85 |
| Concrete Pump | 82 |
| Concrete Vibrator | 76 |
| Crane, Derrick | 88 |
| Crane, Mobile | 83 |
| Drilling Rig | 106 |
| Generator | 81 |
| Grader | 85 |
| Impact Wrench | 85 |
| Jack Hammer | 88 |
| Loader | 85 |
| Paver | 89 |
| Pile Driver (Impact) | 101 |
| Pile Driver (Sonic) | 96 |
| Pneumatic Tool | 85 |
| Pump | 76 |
| Rail Saw | 90 |
| Rock Drill | 98 |
| Roller | 74 |
| Saw | 76 |
| Scarifier | 83 |
| Scraper | 89 |
| Shovel | 82 |
| Spike Driver | 77 |
| Tie Cutter | 84 |
| Tie Handler | 80 |
| Tie Inserter | 85 |
| Truck | 88 |

**Source:** *Transit Noise and Vibration Impact Assessment*, FTA, April 1995.

*NOISE AT TRAIN STORAGE YARDS*

As described in Chapter 12, an analysis was also conducted of the increase in noise that would occur at the existing 36th-38th Street Yard[1] in Brooklyn as a result of the new Second Avenue Subway. The 36th-38th Street Yard is currently used for work trains and storage of a small number of passenger trains.

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[1] The potential expansion to the Coney Island Yard discussed in the SDEIS has been eliminated from further consideration as a result of continuing engineering investigations.

As previously discussed, the potential for noise impacts due to the yard operations from the proposed Second Avenue Subway were assessed using the general noise assessment procedures outlined in FTA's guidance manual. Table J.1-7 shows the train input data used for the analysis. Given the small number of electric trains that would be stored at the 36th-38th Street Yard and the small increase in noise that would be expected as a result, no measured data were collected at receptor locations near the yard. In such cases, for purposes of a general assessment, the FTA allows existing noise levels to be estimated based on either distance from interstate highways, other roadways, or rail lines, or on population density. Using the FTA procedures, existing $L_{eq(1)}$ and $L_{dn}$ noise levels were estimated to be approximately 65 dBA.

**Table J.1-7**
**Number of Trains Analyzed for the Potential Brooklyn Storage Yard**

| | Project-Generated (Build) Number of Trains | | |
|---|---|---|---|
| **Rail Yard** | **Peak Hour** | **7AM - 10 PM** | **10 PM - 7 AM** |
| 36th-38th Street Yard | 8 | 8 | 8 |

### AIRBORNE NOISE MITIGATION

See Chapter 12 for a discussion of mitigation of airborne noise during construction and operation of the Second Avenue Subway.

## C. VIBRATION AND GROUND-BORNE NOISE

### INTRODUCTION

Construction activities and subway operations have the potential for producing high vibration levels that may be perceptible. Some construction activities have the potential to generate vibration levels enough to cause architectural and structural damage. Even where vibration levels are lower or imperceptible, vibrations can nonetheless produce ground-borne noise.

Construction activities typically producing the highest vibration and ground-borne noise levels are those involving the use of impact equipment or blasting. In terms of operations, subway trains have the potential to produce high vibration levels, since rail 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 is strongly dependent on such factors as how smooth the wheels and rails are, and the vehicle suspension system and the resiliency of the rails' installation hardware. 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 are excited.

The effects of ground-borne vibration may include discernable 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 may cause perceptible vibration, rattling of such items as windows or dishes on shelves. The vibration 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 vibration of the room surfaces, even when the vibration itself cannot be felt. This is called ground-borne noise.

The vibration analysis for the proposed project was performed using the procedures described in the FTA guidance manual, *Transit Noise and Vibration Impact Assessment*, April 1995. These include measures to assess impacts both during construction and operation. To examine potential impacts during construction, the FTA guidance document provides a screening procedure to determine the magnitude of vibratory levels so that they can be compared to vibration damage threshold criteria to determine the potential for significant impacts and whether mitigation measures may be necessary to prevent damage to buildings. To examine potential impacts during operation, the FTA guidance document (similar to the approach for assessing noise) lays out a three-step approach for the analysis of vibration and ground-borne noise: a screening procedure, a general assessment methodology, and a detailed analysis methodology. The screening procedure is used to determine whether any vibration sensitive receivers are within distances where impacts are likely to occur; the general assessment methodology is used to determine locations or rail segments where there is the potential for impacts; and the detailed analysis methodology is used to predict impacts and evaluate the effectiveness of mitigation with greater precision than can be achieved with the general assessment. The detailed vibration analysis methodology requires rail-system-specific and site-specific data on the specific vibration levels generated by the proposed rail equipment (referred to as "force density," since they represent the actual force applied to the ground by the train); the effects of site-specific geology at the project alignment on the propagation of vibration (referred to as "transfer mobility"); and the ability of specific building foundations to transmit that vibration (which depends on the building "coupling" or connection to the ground). These factors are determined through detailed field measurements, which are typically performed as part of the design process, when the general vibration assessment prepared as part of the DEIS process indicates that a proposed facility could cause potential impacts.

## IMPACT CRITERIA AND METHODOLOGY FOR VIBRATION AND GROUND-BORNE NOISE

### *VIBRATION FUNDAMENTALS*

Vibrations consist of rapidly fluctuating motions in which the object moves in equal distances from its initial starting point, so that there is no "net" movement. Any object can vibrate in three dimensions: directions: vertical, horizontal, and lateral. It is common to describe vibration levels in terms of velocity, which represents the instantaneous speed of the vibration movement at a point on the object that is displaced. This descriptor is used to assess damage to building (typically evaluated in terms of peak particle velocity, or the maximum instantaneous velocity, since this determines the stress being placed on a building).

This measure is not used to evaluate human perception and response to vibration, however. To capture the human perception, another type of average is used, known as the root mean square (rms) amplitude. This calculated number represents the average of the range of vibration motion in a way that represents human perception.

#### *Measurement of Vibration Levels*

The root mean square of a vibration signal is the average of the squared amplitude of the signal over a given time period (usually 1 second). The rms velocity is normally described in inches per second in the United States and meters per second in the rest of the world.

Decibel notation is in common use for vibration level, defined as:

$$Lv = 20 \times \log_{10} (V / V_{ref}),$$

where $L_v$ is the velocity level in decibels, V is the rms velocity amplitude, and $V_{ref}$ is the reference velocity amplitude. All vibration levels in this document are referenced to $1 \times 10^{-6}$ inches per second. "Vdb" is used in this document for vibration decibels to reduce the potential for confusion with noise decibels.

### *Effect of Propagation Path*

Vibrations are transmitted from the source to the ground, and propagate through the ground to the receiver. Soil conditions have a strong influence on the levels of ground-borne vibration. Stiff soils, such as some clay and rock, transmit vibrations over substantial distances. Sandy soils, wetlands, and groundwater tend to absorb movement and thus reduce vibration transmission. Because subsurface conditions vary widely, there is no way to accurately model the propagation path through soil. Therefore, vibration levels are most accurately determined as close to the source as possible. However, soil conditions give an important insight to the eventual propagation of vibrations to neighboring sites. Preliminary information available on the location of bedrock along the project alignment was used to estimate the effect of the vibration propagation paths for the proposed subway in the general assessment conducted.

## *VIBRATION PREDICTION METHODOLOGY*

### *Modeling to Predict Impacts Due to Construction Activities*

The FTA guidance manual provides some simple screening methodologies for determining where there is a significant potential for impact from construction activities. Such activities include pile driving, demolition, drilling, excavation, or blasting in close proximity to sensitive structure. The procedure includes: (1) selecting the equipment and determining the vibratory levels at a reference distance of 25 feet; (2) determining peak particle velocity at a receptor location using a formula that accounts for the peak particle velocity of the equipment and the distance from the receptor; and (3) if consideration of annoyance or interference with vibration-sensitive activities is of concern, estimate the vibration level and apply the vibration impact criteria (described in Chapter 12).

### *Modeling to Predict Impacts Due to Subway Operations*

Similar to the approach for noise, FTA's guidance document lays out a three-step approach for the analysis of vibration and ground-borne noise. The first step is to perform a screening analysis to determine if the project has any potential for vibration impact. The screening analysis is based on the distance between the source and receiver. If, based on the screening analysis, the potential for impacts exists, the next step is to perform a general vibration assessment. The general vibration assessment estimates the vibration level at specific locations, based on generalized ground surface vibration curves that yield vibration levels as a function of distance from the track centerline, and a series of adjustment factors affecting the vibration source (i.e., train speed, crossovers and other special track work, type of transit structure, etc.), factors affecting the vibration path (i.e., geologic conditions that affect vibration propagation), and factors affecting the vibration receiver (i.e., floor-to-floor attenuation, amplification due to resonances of floors, walls, and ceilings, and radiated sound). Finally, for areas where the potential for significant impact is identified using the general vibration assessment, a more detailed analysis is performed using test data from sample vehicles and accurate geological data for the affected locations. This detailed analysis is generally performed as part of the design process. For the

Second Avenue Subway SDEIS and FEIS, a general vibration assessment was performed to determine potential impacts of subway operations on nearby land uses. That work consisted of the following steps.

*Identify Sensitive Land Uses Within the Area of Potential Impact*. Sensitive land uses include the following: buildings where low ambient vibration is essential for interior operations, such as hospitals and university research operations (category 1); residences and buildings where people normally sleep (category 2); institutional land uses with primarily daytime use, such as schools, libraries, churches, and offices (category 3); and buildings that can be very sensitive to vibration and noise but do not fit into any of the three categories, such as concert halls, TV studios, recording studios, auditoriums, theaters, etc. (category special). Similar to the noise assessment, different impact criteria are applied to those different land use criteria. For the entire project corridor, sensitive land uses were identified in conjunction with the field surveys undertaken for the SDEIS. For purposes of the analysis, for any building that housed a sensitive use, that use was assumed to be on the ground floor.

*Calculate Unadjusted Ground Vibration Levels*. The unadjusted vibration level was developed assuming rapid transit type system vehicles, as provided in the FTA guidance manual. The level at the affected buildings was determined based on the diagonal distance between the top-of-rail and the building foundation. That distance was then used to identify the unadjusted vibration level based on the generalized ground surface vibration curve for rapid transit vehicles (see Figure J.1-1).

For this analysis, vibration levels were calculated in aggregate for each block along the proposed route. For each block, the worst-case scenario (shortest distance) was assumed and this calculation measured for all buildings on the block. This provides the most conservative estimate of potential impacts on all of the block's buildings.

*Adjustment Factors*. Adjustments to the estimated ground-borne vibration were then made to account for train speed, track system and support, foundation coupling, propagation in soil and rock, the type of subway structure, resonance amplification and basement structure, and radiated sound, as follows:

- *Train Speed*. A speed adjustment was made to the unadjusted vibration level based on the average speed of the proposed train at each block.
- *Track System and Support*. An adjustment was made to account for the locations of crossovers. This adjustment, recommended in the FTA guidance document, is intended to account for the increased vibration at points where trains may switch tracks.
- *Foundation Coupling*. Certain recommended adjustments were based on foundation type, depth of bedrock, and the distance between the foundation depth and the rail depth. Foundation depths of surface buildings were estimated based on building height and type and the depth of the bedrock. Bedrock depths from the surface were taken from the current profiles of the proposed rail alignment, and represent the geological conditions known to the project team at this time. Foundation depths as well as foundation types were estimated relating the building height to the foundation depth:
- *Propagation in Soil and Rock*. A propagation path (i.e., between building foundation and rail) adjustment was made to account for different geologic conditions with efficient propagation factors. As recommended in the FTA guidance manual, if the path was in rock,

VdB increases were as follows: a 2 VdB increase for 50 feet, a 4 VdB increase for 100 feet, a 6 VdB increase for 150 feet, and a 9 VdB increase for 200 feet.

- *Subway Structure*. An adjustment was also made for the type of subway structure proposed. These adjustments, recommended in the FTA guidance document, are intended to account for the mass of a subway structure. The general rule is that vibration levels will be lower for heavier subway structures. The following deductions were made for different subway structures:
  - If the subway structure is the site of a proposed subway station, a 5 VdB reduction was introduced.
  - If the subway structure is proposed for a tunnel constructed using the cut-and-cover construction method, a 3 VdB reduction was introduced.
  - If the subway structure is proposed for a subway tunnel in rock, a 15 VdB reduction was introduced.
- *Resonance Amplification and Basement Reduction*. Two additional adjustments were also made to the unadjusted vibration levels to account for the way vibration can propagate in a building. As recommended in the FTA guidance document, a 6 VdB amplification due to resonance of floor/wall/ceiling was made to account for the presence of sensitive receptors on the ground floor and a 2 VdB attenuation was introduced for the fact that each building has an assumed basement. In total, a 4 VdB addition was given to every block.
- *Radiated Sound*. A final noise adjustment was made to the adjusted vibration level (VdB) to estimate the ground-borne noise level (dBA). This adjustment for the frequency spectrum, as recommended in the FTA guidance document, accounts for the average vibration amplitude of room surfaces and the acoustical absorption of typical rooms. Following the guidance of FTA's manual, the following adjustments were made, where possible:
  - Low Frequency: In locations where the new subway would be surrounded by cohesiveless sandy soil or whenever a vibration isolation track support system would be used, a 50 VdB deduction was introduced to account for the low-frequency vibration characteristics that would occur.
  - Typical: Based on the detailed vibration measurements performed for the project, a 30 VdB deduction was used for buildings in soil.
  - High Frequency: In locations where the new subway would be founded in rock or where there would be very stiff clayed soil around the structure, a 20 VdB deduction was introduced.

    Given the wide variation in soil conditions along the proposed route, if the route subway was not surrounded by bedrock, the more conservative stiff soil deduction was used. Soil tests and maps can provide a per block analysis of the types of soil present if an impact is estimated after the initial analysis.

*Projected Ground-borne Vibration and Noise Levels*. After those adjustments were made, the ground-borne vibration and noise levels for the proposed subway were calculated following the FTA's guidance.

## EXISTING CONDITIONS: VIBRATION AND GROUND-BORNE NOISE

Currently, throughout most of the Second Avenue Subway corridor, there are no activities that would be expected to produce high vibration or ground-borne noise levels. While there are high traffic volumes at most locations in the corridor, vibration levels are generally not perceptible, even in locations adjacent to major roadways with high bus and truck volumes, except when there are trains operating with untrued wheels or on defective tracks, buses and/or trucks on rough roads, or construction activities involving blasting, impact equipment, or heavy earth-moving equipment.

## FUTURE CONDITIONS COMMON TO ALL ALTERNATIVES: VIBRATION AND GROUND-BORNE NOISE

In the future without the Second Avenue Subway, vibration levels are expected to be comparable to those currently existing in the corridor. These levels will be below the levels of perceptibility and below the levels that produce annoyance and interference with activities.

## CONSTRUCTION IMPACTS OF THE PROJECT ALTERNATIVES: VIBRATION AND GROUND-BORNE NOISE

Construction activities associated with the proposed Second Avenue Subway would result in varying degrees of ground-borne noise and vibration, depending on the stage of construction, the equipment and construction methods employed, and the distance from the construction to buildings and vibration-sensitive structures. Chapter 12 discusses construction-related vibration and ground-borne noise impacts in detail.

## PERMANENT IMPACTS OF THE PROJECT ALTERNATIVES: VIBRATION AND GROUND-BORNE NOISE

For a detailed discussion of the proposed Second Avenue Subway's potential permanent vibration and ground-borne noise impacts, see Chapter 12.

A summary of the locations and ground-borne vibration and noise levels where the FTA impact criteria are exceeded and where impacts would be created based on project plans as of May 2003 is provided in Table J.2-1, with more details provided in Table J.2-2. This analysis does not assume the implementation of any mitigation measures or special design features which, if implemented, would reduce these levels. Potential mitigation measures currently under study are discussed in Chapter 12.

## VIBRATION AND GROUND-BORNE NOISE MITIGATION

Chapter 12 describes the variety of mitigation measures NTCT is exploring to minimize vibration and ground-borne noise impacts during construction and operation of the proposed project.

Additional details on mitigation measures to address potential construction-related impacts during drill and controlled blasting and other general vibration control measures are presented below.

### *Drilling and Controlled Blasting*

As discussed in Chapter 12, NYCT will require that a specification be inserted into construction contracts with regard to blasting operations requiring the contractor to implement a monitoring program and to protect nearby structures from damage, particularly if the structure is within the zone of influence.

All blasts would be limited to all applicable rules and regulations including those propagated by the U.S. Bureau of Mines Standard for maximum air blast. Borehole size and matrix would be determined on-site by a New York State-licensed blaster based on prevailing rock conditions. A licensed blasting contractor would comply with applicable regulations concerning workplace safety and hazardous materials, under the direction of a licensed blaster. Each blast would be contained through the use of rubber or steel cable blasting mats, earthen cover, or by utilization of the original overburden to prevent flyrock, all in accordance with New York State Department of Transportation Standard Specifications. Line drilling and smooth-wall techniques would be used to reduce ground vibration. Modern controlled blasting techniques such as timed multiple charges, which lessen the severity of vibration levels, would be implemented. The use of explosives would be limited to labor skilled in their use and all work would be performed under supervision of a licensed blaster. Blasting programs, including the amount and type of explosives and number and type of delays to be used, would be in accordance with all applicable municipal requirements. A daily log would be maintained by the blasting contractor for each blast detonated on each working day. This log would include the date, exact time of firing, number of holes, total poundage used, the distribution of instantaneous and millisecond delay caps, poundage per delay, and location and spacing of drilling holes. The log would be submitted to the project superintendent at the end of each working day.

*General Vibration Control Measures*

Additional vibration control plans and practices would include routing truck traffic and heavy equipment to avoid impacts to sensitive receptors, properly securing street decking over cut-and-cover excavations, scheduling work to limit nighttime impacts in residential areas, and minimizing the duration of vibration impacts. ✷