

## 4.13 VIBRATION

### 4.13.1 Introduction

Construction activities have the potential to produce vibration levels that may be annoying or disturbing to humans and may cause damage to structures. Architectural and even structural damage to existing structures surrounding a site could occur if appropriate precautions are not taken.

The effects of ground-borne vibration include discernable movement of building floors, rattling of windows, shaking of items on shelves or hanging on walls, and rumbling sounds. The vibration from the construction-related activity “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 may be excited. In extreme cases, vibration can cause damage to buildings.

This Section describes existing vibration conditions in the vicinity of the preferred Shaft Site and assesses the potential for construction at the preferred Shaft Site to result in vibration impacts. The methodology used to prepare this Section is described in Section 3.13, “Vibration,” of Chapter 3, “Impact Methodologies.”

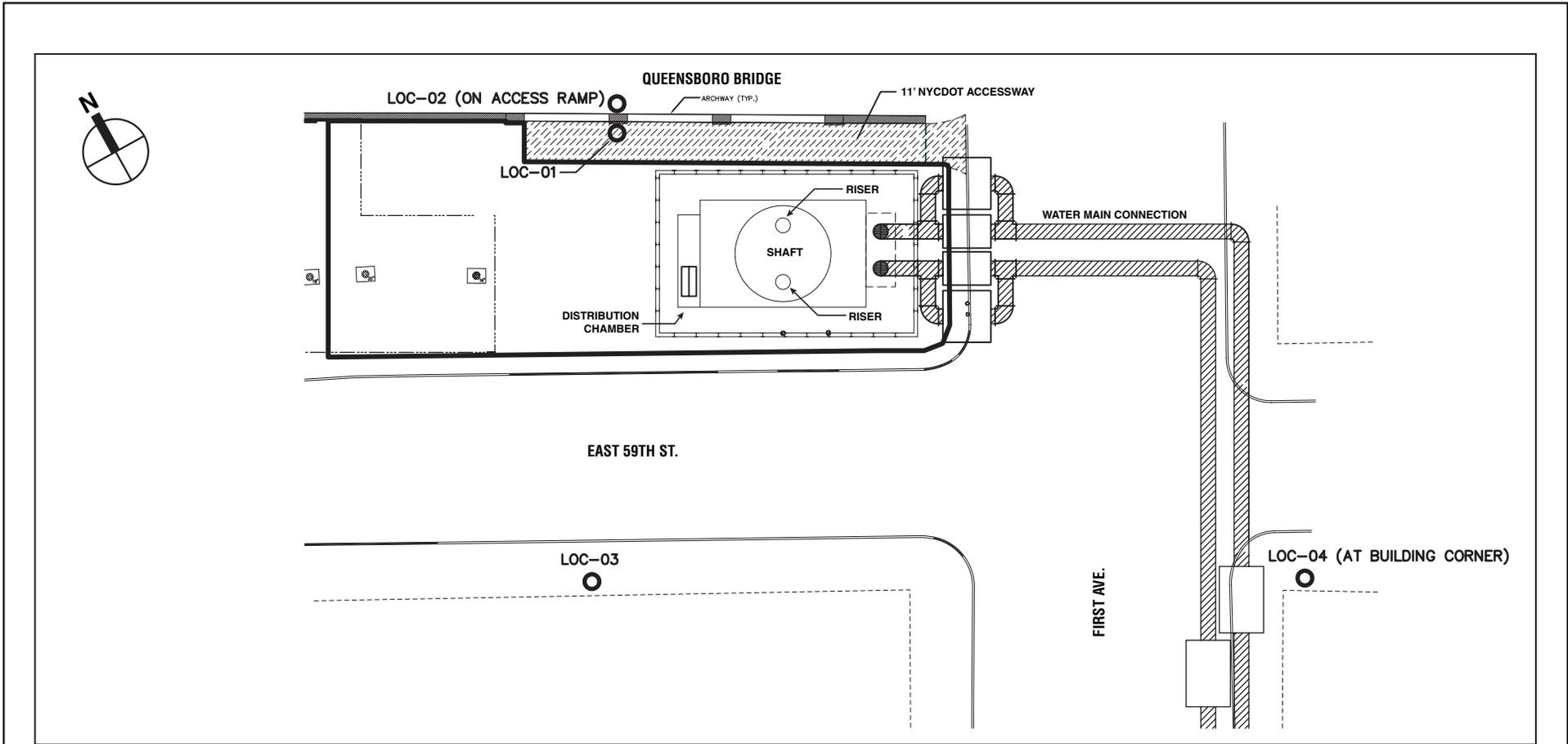
### 4.13.2 Existing Conditions

An ambient vibration survey was conducted to establish the baseline vibration levels at the preferred Shaft Site from traffic traveling over the Queensboro Bridge (Bridge). As further explained in Section 3.13, “Vibration,” of Chapter 3, “Impact Methodologies” this was necessary to determine whether there would be cumulative vibration effects with the shaft construction activities.

Ambient measurements were taken at four locations on June 20 and/or June 22, 2005. Vibration levels are provided in Peak Particle Velocity (PPV) measured in inches per second (ips). As shown in Figure 4.13-1, vibration monitoring locations were:

- Location 1: At base of the Bridge next to preferred Shaft Site.
- Location 2: On lower Bridge deck above preferred Shaft Site.
- Location 3: At a residence (ground floor locksmith) directly across E. 59<sup>th</sup> Street from preferred Shaft Site.
- Location 4: At a multi-family residential building on the southeast corner of E. 59<sup>th</sup> Street and First Avenue.

The ambient vibration levels in the locations monitored were generally within the range of 0.01 to 0.04 ips. Occasional spikes were observed as a result of normal construction activities (interior



NOT TO SCALE

**Legend:**

- Site Boundary
- Building Line
- ==== Cofferdam
- Curbline
- Multi-Use Area
- Instrument Locations



NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION  
 PROPOSED SHAFT 33B TO CITY WATER TUNNEL NO. 3  
 STAGE 2-MANHATTAN LEG  
 PREFERRED SHAFT SITE

**VIBRATION MEASUREMENT LOCATIONS**

FIGURE 4.13-1

remodeling near Location 3) and truck traffic. The spikes observed during the monitoring program were all below 0.1 ips. In general, vibrations at the lower Bridge deck (Location 2) were the highest.

The results of the vibration monitoring show that existing vibration levels are negligible and would not result in cumulative vibration effects with those of the project that would affect the impact criteria for structural damage or procedures for the proposed construction activities.

#### **4.13.3 Future Conditions Without the Project**

None of the projects identified for development between 2006 and 2012 would be expected to introduce significant vibration levels in the Study Area. Therefore, vibration levels would be expected to be comparable to those currently existing in the vicinity of the preferred Shaft Site.

#### **4.13.4 Future Conditions With the Project**

##### **Construction**

###### *Overview*

Controlled blasting, pavement breaking (including jack hammers), rock drilling, soil compaction, and pile installation would produce the highest vibration levels during construction of the preferred Shaft Site. Blasting is discussed first, followed by a discussion of other construction activities at the site. There are no substantive differences between the base configuration and alternate site configuration with regard to vibration impacts and, therefore, the assessment provided below would apply to both.

The assessment below discusses protective measures that would be implemented to avoid potential construction-related vibration impacts at the preferred Shaft Site. A discussion of special protection measures that will be put in place to protect historic structures is also provided.

A detailed vibration control plan that will include the measures discussed below will be developed by the construction contractor prior to construction. The plan will include a vibration monitoring program to be implemented during construction. The detailed vibration plan will account for specific geological conditions, foundation assessment of structures near vibration-causing construction activities, and the appropriateness of the vibration thresholds to affected buildings. Finally, the detailed plan will include specific measures and best management practices to avoid potential vibration impacts.

In advance of certain activities that are likely to result in high vibration levels such as blasting, NYCDEP and its contractor would conduct extensive outreach to those in the vicinity of the preferred Shaft Site that could be affected. This would include providing the nearby community with the expected start date for blasting operations, the general time pattern during the ensuing months, and the timing and significance of the warning whistles.

Finally, NYCDEP would not permit construction activities to occur between 11:00 p.m. and 7:00 a.m. with the exception of the 3 months of continuous (24 hours per day and 7 days per week) raise boring activities.

### *Blasting*

Of the construction activities proposed, blasting would result in the highest potential vibration levels. Blasting would be necessary at the preferred Shaft Site to enlarge the shaft and form the distribution chamber at the top of the shaft. Blasting would not occur at the ground surface since the bedrock at the site is more than 20 feet below the ground surface. Blasting would be expected to occur for roughly eight months. Depending on the procedures employed, the timing of rock removal, and other considerations, blasting could occur on a daily or less frequent than daily basis over this eight month period.

Vibration levels associated with blasting are dependent on the amount of explosive used, geological conditions between the blast site and the receptor, and the fact that blasting will take place at least 20 feet below the surface. NYCDEP will implement the protective measures described below, including monitoring and control measures, to minimize or avoid vibration effects. These measures will primarily address potential structural or architectural damage. Human annoyance vibration thresholds are much lower than structural or architectural damage criteria, and vibration levels from blasting could be at levels annoying or disturbing to humans.

As part of developing the detailed vibration control plan discussed above, a blasting/vibration expert would be retained by the contractor to evaluate and optimize the blasting procedure. This process would involve detailed analysis of shaft geometry, geology, and relative locations of sensitive structures, and determination of likely blasting procedures and resulting vibration levels. Analyses would be performed to determine the maximum vibration levels that would be expected at specific locations due to construction activities. Specific locations would also be examined structurally, to determine how the project's construction activities would interact with a building's foundation and construction type.

### *Blasting Procedures*

Blasting procedures are developed on a site-specific basis depending on site-specific geological conditions as well as traffic and other environmental conditions at the time of blasting. This subsection describes the typical approach to blasting based on blasting experience at other NYCDEP shaft sites and other construction projects throughout Manhattan.

Blasting would occur during construction of the distribution chamber (Stage 2B) and slashing the shaft (Stage 2C). One to two blasts would be expected to occur on a given day during this period. The typical blasting sequence is as follows:

- Contractor places explosives—1 to 2 hours
- Contractor places blasting mats—1 hour
- Contractor detonates the explosives—instantaneous
- Contractor removes the blast mats—1 hour

After this sequence, the contractor could either place a new round of explosives (if holes are already drilled) or clear the rock down the hole. Because the entire process takes three to four hours or more, it is highly unlikely that more than two blasts would occur on a given day. Based on experience with other construction projects that involve blasting, it is expected that blasting would typically occur during the first shift (7:00 am to 3:00 pm). In general, blasting would not likely occur until 10:00 a.m. since it can take two to three hours to prepare for the blast. The second blast, if it occurred, would generally occur in the early afternoon, but could be delayed until 6:30 p.m., after peak evening traffic conditions. The New York City Fire Department (FDNY) restricts blasting times to between 7:00 a.m. and 7:00 p.m. or from sun up to sun down. Although not expected to be needed based on blasting at other NYCDEP shaft sites, subject to prior approval of FDNY and as necessary, extension of blasting hours may be granted on a case-by-case basis.

Typically a few minutes prior to blasting, warning whistles would alert the area that blasting was about to begin. The warning whistle communication protocol is expected to be as follows:

- 1 long whistle—vehicular and pedestrian traffic stopped,
- 2 short whistles—blast will commence,
- 3 short whistles—all clear; blast is completed and traffic flow can resume.

While this warning whistle communication protocol could take up to five minutes to implement, the FDNY has indicated that they could issue a waiver to the protocol and reduce the whistle warning time to one minute. The contractor intends to seek this waiver.

Blasting operations would be limited to a PPV of 0.5 ips at the nearest structure or lower based on the detailed vibration plan discussed above and monitoring during construction of structural conditions in the vicinity of the blast site, or as modified by the New York City Landmarks Preservation Commission (NYCLPC).

For an additional level of protection and to ensure that blasting activities would meet the established vibration limits, blasting initially would be carried out with small explosive charges and procedures that would create only minimal vibration levels. As the monitoring program confirmed the vibration levels associated with specific charges at the surrounding structures, progressively larger explosive charges would be utilized, provided that the vibration levels in the surrounding structures do not exceed tolerable limits.

Blasting is regulated by a NYCDEP Tunnel Construction permit and by the FDNY. To reduce vibration levels associated with blasting, construction specifications would require adherence to all applicable rules and regulations (including the rules and regulations of the FDNY) and would require the use of modern blasting techniques including timed multiple charges, blast mats, etc. These techniques would be used to reduce vibration levels to the required limits.

During construction, vibration levels would be monitored in nearby structures and/or at the site perimeter during all blasting activities. Recordings will be made by qualified personnel in the employ of an independent vibration consulting firm. The contractor would submit promptly to the NYCDEP Engineer a record of all data concerning each blast. Blasting activities resulting in

PPV levels in excess of appropriate damage criteria as measured in the foundations of nearby structures would be immediately stopped until further precautionary measures were taken to reduce potential blasting-related vibration impacts. Work would not begin again until the steps proposed to stabilize and/or prevent damage to the designated buildings were approved. In addition, the project would carry insurance to cover the expense of restoration caused by any damage that might occur despite this precaution. (See also “Additional Measures to Protect Fragile, Sensitive, and Historic Buildings,” below.)

Alternative techniques, including hydraulic rock splitting or manual excavation using hand tools, if warranted, could also be employed to minimize the potential for any inadvertent damage to such structures. However, these measures would be implemented only if necessary, as these measures would increase the duration of construction.

#### *Other Construction Activities*

Other construction activities would result in varying degrees of ground-borne vibration, depending on the stage of construction, the equipment and construction methods employed, the distance from the construction to vibration-sensitive receptors and geotechnical and soil conditions. The following activities and equipment could induce the highest vibration levels:

- Raise boring from the tunnel upwards with rotary drilling equipment.
- Pile installation with a pile drill rig.
- Soil compaction with a compactor.
- Rock drilling with crawlers or pneumatic hammers.
- Pavement breaking with jackhammers.
- Delivery and cement trucks.

The raise bore operations would consist of two phases. First, a 12- to 18-inch pilot hole would be drilled from the top of the bedrock down towards City Tunnel No. 3. Once the pilot hole penetrates the tunnel, a 10-foot diameter raise bore head would be attached to the shaft from within the Tunnel. Drilling to enlarge the shaft would proceed from Tunnel No. 3 upwards towards the surface. The drilling would be stopped before the raise bore head resurfaces, approximately 10 feet below the top of the bedrock. Although the rotary drilling equipment used for raised boring operations produces high levels of vibration, much of this activity would occur many feet below ground entirely within bedrock. Vibration sources in rock tend to result in low amplitudes of vibration levels.

Piles would be drilled with a pile drill rig; impact pile drivers would not be used. This operation is similar to drilling borings for geotechnical sampling and produces far lower levels of vibration than impact pile driving. Drilling for piles would advance about five feet into sound bedrock to create the pile socket.

As discussed above, rock drilling consists of drilling a pilot hole from the ground surface downward into the bedrock to intercept the future water supply tunnel at a depth of about 550 feet below ground surface. The single pilot hole is required to operate the raise bore machine.

**CHAPTER 4: PREFERRED SHAFT SITE**  
**4.13 VIBRATION**

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Short rock drill holes would also be used to place explosives to form the distribution chamber foundation in bedrock and to enlarge the shaft diameter after the raise bore is completed. Much of the rock drilling activity would occur many feet below ground within bedrock.

At locations where pavement breaking (with the use of jackhammers) is required, deep saw cuts would be made between areas of pavement breaking. These saw cuts would minimize the transmission of vibrations from pavement-breaking operations to the foundations of nearby structures.

Typical vibration levels for construction equipment similar to that being proposed for use at the preferred Shaft Site is shown in Table 4.13-1. Note that values provided for caisson drilling/large bulldozer are representative of those for the proposed pile drill rig and soil compactor. Levels shown for jackhammers are similar to or greater than those that can be expected for rock drilling and pneumatic hammering. The values provided in the table are based on the literature. Actual vibration levels are dependent on construction procedures, soil and geological conditions, and the structural characteristics of the receptor (e.g. foundation, construction materials).

The closest sensitive structures to the site are the residential buildings located across E. 59<sup>th</sup> Street and the Queensboro Bridge. For the residential buildings across E. 59<sup>th</sup> Street, which are approximately 77 feet from the edge of the shaft chamber, PPV levels are expected to be well below the 2.0 ips threshold to avoid structural damage and below the 0.5 ips threshold to protect more fragile structures or against cosmetic/architectural damage. This would be expected to be the case even with more than one piece of machinery operating. The contractor will be required to have a vibration control plan and monitoring program in place during all construction activities.

**Table 4.13-1**  
**Typical Levels of Vibration for Construction Equipment Similar to that Proposed for Shaft Site Construction**

Construction Activity	PPV at 75 feet (ips)	PPV at 50 feet (ips)	PPV at 25 feet (ips)
Caisson Drilling/Large Bulldozer	0.0	0.03	0.089
Loaded Trucks	0.0	0.027	0.076
Jack Hammer	0.0	0.015	0.035
<b>Sources:</b>	Federal Transit Administration (FTA), <i>Transit Noise and Vibration Impact Assessment</i> , April 1995.		
<b>Notes:</b>	PPV at 25 feet are based on FTA 1995. To calculate PPV at other distances, the following equation (FTA 1995) was used: $\text{PPV at Distance D} = \text{PPV (at 25 ft)} * [(25/D)^{1.5}]$		

With regard to the Queensboro Bridge (at a distance of 23 feet from the edge of the shaft chamber), measures based on actual site conditions will be put in place to ensure that there are no adverse vibration impacts to the Bridge which is a historic and critical transportation structure.

For a discussion of these measures, see “Additional Measures to Protect Fragile, Sensitive, and Historic Buildings,” below.

There is the potential that, at times, vibration effects would reach levels that would be annoying to residents in nearby buildings. These buildings contain ground floor commercial uses and vibration levels are likely to be lower on the second floor and above, where the residences are located, depending on the building construction. Much of the vibrating equipment, such as rock drills, the raise bore, and pile drilling rig would be used below the ground surface where additional distance and ground attenuation would reduce vibration levels. Lastly, much of the vibration-causing construction equipment would be used on an intermittent basis during the construction period.

*Additional Measures to Protect Fragile, Sensitive, and Historic Buildings*

To protect vibration sensitive structures including fragile, sensitive, and historic buildings, NYCDEP will develop a fragile buildings identification strategy and guidelines to limit vibrations for the various types of structures near the site. The overall approach is provided here, but will be more fully developed by the contractor prior to construction.

As part of the detailed vibration control plan discussed above, the contractor would conduct an inventory of buildings within the zone of potential construction influence. The most appropriate time to conduct a detailed inventory would be after a Shaft Site has been selected and a construction contract is in place, but prior to the start of construction. The contractor would hire blasting and other experts to assist in this effort.

Each building that falls within Structural Category IV (defined in Table 4.13-2) would be physically examined by the contractors under NYCDEP’s supervision using both internal and external inspections. In addition, historic buildings would be noted (see “Special Provisions for Historic Structures” below) and buildings with sensitive uses, such as hospitals, eye clinics, audio recording studios, and laboratories with sensitive equipment, would be identified.

Using this information, maximum permissible vibration levels would then be determined on a receptor-specific basis to ensure that no architectural or structural damage or damage to sensitive uses would occur due to construction activities. These site-specific values may be equivalent to, or potentially higher or lower than, the vibration impact threshold of 0.5 ips discussed in Section 3.13 but would be established at a level that would protect against cosmetic or structural damage to the structures.

For fragile and/or historic structures that fall within the zone of potential construction influence, buildings would be documented using photographs to identify any existing cracks or other cosmetic or structural damage at the buildings. Zones of influence for both ground movement and vibrations would be identified. A preconstruction survey would be performed and threshold or limiting values would be established that take into account each structure’s or use’s ability to withstand the loads and displacements due to construction vibrations.

**Table 4.13-2  
Building Classification Guidelines (the Swiss Standard)**

Structural Category	Definition	
I	Foundation:	Competent
	Framing: Interior	Reinforced concrete
	Finish:	No plaster
	Examples:	Industrial buildings, Bridges, masts, concrete retaining walls, unburied pipelines, underground structures such as cavern tunnels and lined or unlined galleries
II	Foundation:	Concrete or competent masonry
	Framing: Interior	Any framing, except as described for Category III below
	Finish:	No plaster
	Examples:	Engineered concrete and masonry buildings, masonry retaining walls, and buried pipelines
III	Foundation:	Less competent masonry
	Framing: Interior	Horizontal timber framing supported on masonry walls
	Finish:	Any finish, including plaster “Non-engineered” buildings
	Examples:	“Non-engineered” buildings
IV	Buildings that are extremely susceptible to damage from vibration, such as all historic structures	

*Special Provisions for Historic Structures*

NYCDEP also would work with the NYCLPC to develop protective measures for historic buildings and structures. At the preferred Shaft Site, the Queensboro Bridge is the only known or potential historic resource within 100 feet of the site. NYCDEP, through its construction contractors, will implement special vibration protection measures to be included as part of the construction protection program for historic resources, which will include the following:

- Inspect and report on current foundation and structural conditions of any historic resources;
- Set up a vibration monitoring program to measure vertical and lateral movement and vibration to the historic structures within the zone of impact identified as part of the fragile buildings assessment process detailed above. Details as to the frequency and duration of the vibration monitoring program would be determined in consultation with NYCLPC;
- Establish and monitor construction methods to limit vibrations to levels that would not cause structural damage to the historic structures, as determined by the condition survey; and
- Issue “stop work” orders to the construction contractor, as required, to prevent damage to the structures, based on any vibration levels that exceed the design criteria in lateral or vertical direction. Work would not begin again until the steps proposed to stabilize and/or prevent further damage to the designated buildings were approved and put in place.

Due to its close proximity to the project site, critical transportation importance, and historic status, the Queensboro Bridge would be thoroughly evaluated after a Shaft Site is selected and prior to construction to determine an appropriate protective level. NYCDEP will work closely with the New York City Department of Transportation (NYCDOT) to ensure that the Bridge would not experience vibration levels exceeding a limit acceptable to NYCDOT.

*Conclusions*

With implementation of the measures discussed above, vibration levels during construction would be limited to levels that would not cause structural damage. However, at times, vibration levels would still occur at levels that would be likely to cause annoyance to residents and other sensitive receptors in the immediate vicinity of the site. Blasting, which would cause the most intrusive vibration effects, would occur over a period of eight months. Other vibration-causing construction equipment would be used on an intermittent basis during the construction period or would be used primarily below the surface. These potential impacts are considered short-term and temporary in nature. The contractor will be required to have a vibration control plan and monitoring program in place during all construction activities. Therefore, no potential significant adverse vibration impacts would be anticipated to occur from construction at the preferred Shaft Site. A combined assessment of potential vibration impacts from construction of Shaft 33B and its water main connections at the preferred Shaft Site is presented in Section 5.13, “Vibration,” in Chapter 5, “Water Main Connections.”

**Operation**

None of the activities associated with the activation or operation of the shaft would cause potential vibration impacts, as there would be no significant vibration-causing machinery associated with these activities. Therefore, no potential significant adverse impacts are anticipated to occur.

