APPENDIX E

ANTIOCH WHARF STRUCTURAL UPGRADE PROJECT CONSTRUCTION NOISE AND VIBRATION ASSESSMENT

Contra Costa County, California

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INTRODUCTION

The project proposes a structural upgrade to the Antioch wharf by replacing existing dolphins and constructing new connected walkways and a roll-on roll-off (RoRo) ramp to connect the wharf to the shoreline. The project is located offshore along the San Joaquin River in an unincorporated area of Contra Costa County. The existing wharf is surrounded by industrial and commercial facilities to the west, east, and south, and the San Joaquin River to the north.

This report evaluates the potential for project construction activities to result in significant noise or vibration impacts with respect to applicable California Environmental Quality Act (CEQA) guidelines. The report is divided into two sections: 1) the Setting Section provides a brief description of the fundamentals of environmental noise and groundborne vibration summarizes applicable regulatory criteria, and discusses the existing noise conditions; and 2) the Impacts and Mitigation Measures Section describes the significance criteria used to evaluate project impacts, provides a discussion of each project impact, and presents measures, where necessary, to mitigate the impacts of the project on sensitive receptors in the vicinity.

SETTING

Fundamentals of Environmental Noise

Noise may be defined as unwanted sound. Noise is usually objectionable because it is disturbing or annoying. The objectionable nature of sound could be caused by its *pitch* or its *loudness*. *Pitch* is the height or depth of a tone or sound, depending on the relative rapidity (frequency) of the vibrations by which it is produced. Higher pitched signals sound louder to humans than sounds with a lower pitch. *Loudness* is intensity of sound waves combined with the reception characteristics of the ear. Intensity may be compared with the height of an ocean wave in that it is a measure of the amplitude of the sound wave.

In addition to the concepts of pitch and loudness, there are several noise measurement scales which are used to describe noise in a particular location. A *decibel (dB)* is a unit of measurement which indicates the relative amplitude of a sound. The zero on the decibel scale is based on the lowest sound level that the healthy, unimpaired human ear can detect. Sound levels in decibels are calculated on a logarithmic basis. An increase of 10 decibels represents a ten-fold increase in acoustic energy, while 20 decibels is 100 times more intense, 30 decibels is 1,000 times more intense, etc. There is a relationship between the subjective noisiness or loudness of a sound and its intensity. Each 10 decibel increase in sound level is perceived as approximately a doubling of loudness over a fairly wide range of intensities. Technical terms are defined in Table 1.

There are several methods of characterizing sound. The most common in California is the *A-weighted sound level (dBA).* This scale gives greater weight to the frequencies of sound to which the human ear is most sensitive. Representative outdoor and indoor noise levels in units of dBA are shown in Table 2. Because sound levels can vary markedly over a short period of time, a method for describing either the average character of the sound or the statistical behavior of the variations must be utilized. Most commonly, environmental sounds are described in terms of an average level that has the same acoustical energy as the summation of all the time-varying events.

This *energy-equivalent sound/noise descriptor* is called L_{eq}. The most common averaging period is hourly, but L_{eq} can describe any series of noise events of arbitrary duration.

The scientific instrument used to measure noise is the sound level meter. Sound level meters can accurately measure environmental noise levels to within about plus or minus 1 dBA. Various computer models are used to predict environmental noise levels from sources, such as roadways and airports. The accuracy of the predicted models depends upon the distance the receptor is from the noise source. Close to the noise source, the models are accurate to within about plus or minus 1 to 2 dBA.

Since the sensitivity to noise increases during the evening and at night -- because excessive noise interferes with the ability to sleep -- 24-hour descriptors have been developed that incorporate artificial noise penalties added to quiet-time noise events. The *Community Noise Equivalent Level* (*CNEL*) is a measure of the cumulative noise exposure in a community, with a 5 dB penalty added to evening (7:00 pm - 10:00 pm) and a 10 dB addition to nocturnal (10:00 pm - 7:00 am) noise levels. The *Day/Night Average Sound Level* (L_{dn} or *DNL*) is essentially the same as CNEL, with the exception that the evening time period is dropped and all occurrences during this three-hour period are grouped into the daytime period.

Effects of Noise

Sleep and Speech Interference

The thresholds for speech interference indoors are about 45 dBA if the noise is steady and above 55 dBA if the noise is fluctuating. Outdoors the thresholds are about 15 dBA higher. Steady noises of sufficient intensity (above 35 dBA) and fluctuating noise levels above about 45 dBA have been shown to affect sleep. Interior residential standards for multi-family dwellings are set by the State of California at 45 dBA L_{dn}/CNEL. Typically, the highest steady traffic noise level during the daytime is about equal to the L_{dn}/CNEL and nighttime levels are 10 dBA lower. The standard is designed for sleep and speech protection and most jurisdictions apply the same criterion for all residential uses. Typical structural attenuation is 12-17 dBA with open windows. With closed windows in good condition, the noise attenuation factor is around 20 dBA for an older structure and 25 dBA for a newer dwelling. Sleep and speech interference is therefore possible when exterior noise levels are about 57-62 dBA L_{dn}/CNEL with open windows and 65-70 dBA L_{dn}/CNEL if the windows are closed. Levels of 55-60 dBA are common along collector streets and secondary arterials, while 65-70 dBA is a typical value for a primary/major arterial. Levels of 75-80 dBA are normal noise levels at the first row of development outside a freeway right-of-way. In order to achieve an acceptable interior noise environment, bedrooms facing secondary roadways need to be able to have their windows closed; those facing major roadways and freeways typically need special glass windows.

Annoyance

Attitude surveys are used for measuring the annoyance felt in a community for noises intruding into homes or affecting outdoor activity areas. In these surveys, it was determined that the causes for annoyance include interference with speech, radio and television, house vibrations, and interference with sleep and rest. The L_{dn}/CNEL as a measure of noise has been found to provide a valid correlation of noise level and the percentage of people annoyed. People have been asked to judge the annoyance caused by aircraft noise and ground transportation noise. There continues to be disagreement about the relative annoyance of these different sources. When measuring the percentage of the population highly annoyed, the threshold for ground vehicle noise is about 50 dBA L_{dn}/CNEL. At a L_{dn}/CNEL of about 60 dBA, approximately 12 percent of the population is highly annoyed. When the L_{dn}/CNEL increases to 70 dBA, the percentage of the population highly annoyed increases to about 25-30 percent of the population. There is, therefore, an increase of about 2 percent per dBA between a L_{dn}/CNEL of 60-70 dBA. Between a L_{dn}/CNEL of 70-80 dBA, each decibel increase increases by about 3 percent the percentage of the population highly annoyed. People appear to respond more adversely to aircraft noise. When the L_{dn}/CNEL is 60 dBA, approximately 30-35 percent of the population is believed to be highly annoyed. Each decibel increase to 70 dBA adds about 3 percentage points to the number of people highly annoyed. Above 70 dBA, each decibel increase results in about a 4 percent increase in the percentage of the population highly annoyed.

Fundamentals of Groundborne Vibration

Ground vibration consists of rapidly fluctuating motions or waves with an average motion of zero. Several different methods are typically used to quantify vibration amplitude. One method is the Peak Particle Velocity (PPV). The PPV is defined as the maximum instantaneous positive or negative peak of the vibration wave. In this report, a PPV descriptor with units of mm/sec or in/sec is used to evaluate construction generated vibration for building damage and human complaints. Table 3 displays the reactions of people and the effects on buildings that continuous or frequent intermittent vibration levels produce. The guidelines in Table 3 represent syntheses of vibration criteria for human response and potential damage to buildings resulting from construction vibration.

Construction activities can cause vibration that varies in intensity depending on several factors. The use of pile driving and vibratory compaction equipment typically generates the highest construction related groundborne vibration levels. Because of the impulsive nature of such activities, the use of the PPV descriptor has been routinely used to measure and assess groundborne vibration and almost exclusively to assess the potential of vibration to cause damage and the degree of annoyance for humans.

The two primary concerns with construction-induced vibration, the potential to damage a structure and the potential to interfere with the enjoyment of life, are evaluated against different vibration limits. Human perception to vibration varies with the individual and is a function of physical setting and the type of vibration. Persons exposed to elevated ambient vibration levels, such as people in an urban environment, may tolerate a higher vibration level.

Structural damage can be classified as cosmetic only, such as paint flaking or minimal extension of cracks in building surfaces; minor, including limited surface cracking; or major, that may threaten the structural integrity of the building. Safe vibration limits that can be applied to assess the potential for damaging a structure vary by researcher. The damage criteria presented in Table 3 include several categories for ancient, fragile, and historic structures, the types of structures most at risk to damage. Most buildings are included within the categories ranging from "Historic and some old buildings" to "Modern industrial/commercial buildings". Construction-induced vibration that can be detrimental to the building is very rare and has only been observed in instances where the structure is at a high state of disrepair and the construction activity occurs immediately adjacent to the structure.

The annoyance levels shown in Table 3 should be interpreted with care since vibration may be found to be annoying at lower levels than those shown, depending on the level of activity or the sensitivity of the individual. To sensitive individuals, vibrations approaching the threshold of perception can be annoying. Low-level vibrations frequently cause irritating secondary vibration, such as a slight rattling of windows, doors, or stacked dishes. The rattling sound can give rise to exaggerated vibration complaints, even though there is very little risk of actual structural damage.

TABLE 1 Definition of Acoustical Terms Used in this Report

Term	Definition
Decibel, dB	A unit describing, the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for air is 20 micro Pascals.
Sound Pressure Level	Sound pressure is the sound force per unit area, usually expressed in micro Pascals (or 20 micro Newtons per square meter), where 1 Pascal is the pressure resulting from a force of 1 Newton exerted over an area of 1 square meter. The sound pressure level is expressed in decibels as 20 times the logarithm to the base 10 of the ratio between the pressures exerted by the sound to a reference sound pressure (e.g., 20 micro Pascals). Sound pressure level is the quantity that is directly measured by a sound level meter.
Frequency, Hz	The number of complete pressure fluctuations per second above and below atmospheric pressure. Normal human hearing is between 20 Hz and 20,000 Hz. Infrasonic sound are below 20 Hz and Ultrasonic sounds are above 20,000 Hz.
A-Weighted Sound Level, dBA	The sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.
Equivalent Noise Level, L_{eq}	The average A-weighted noise level during the measurement period.
L_{max}, L_{min}	The maximum and minimum A-weighted noise level during the measurement period.
L_{01}, L_{10}, L_{50}, L_{90}	The A-weighted noise levels that are exceeded 1%, 10%, 50%, and 90% of the time during the measurement period.
Day/Night Noise Level, L_{dn} or DNL	The average A-weighted noise level during a 24-hour day, obtained after addition of 10 decibels to levels measured in the night between 10:00 p.m. and 7:00 a.m.
Community Noise Equivalent Level, CNEL	The average A-weighted noise level during a 24-hour day, obtained after addition of 5 decibels in the evening from 7:00 p.m.to 10:00 p.m. and after addition of 10 decibels to sound levels measured in the night between 10:00 p.m. and 7:00 a.m.
Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.
Intrusive	That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, and time of occurrence and tonal or informational content as well as the prevailing ambient noise level.

Source: Handbook of Acoustical Measurements and Noise Control, Harris, 1998.

TABLE 2 Typical Noise Levels in the Environment

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
	110 dBA	Rock band
Jet fly-over at 1,000 feet		
	100 dBA	
Gas lawn mower at 3 feet		
	90 dBA	
Diesel truck at 50 feet at 50 mph		Food blender at 3 feet
	80 dBA	Garbage disposal at 3 feet
Noisy urban area, daytime		
Gas lawn mower, 100 feet	70 dBA	Vacuum cleaner at 10 feet
Commercial area		Normal speech at 3 feet
Heavy traffic at 300 feet	60 dBA	
		Large business office
Quiet urban daytime	50 dBA	Dishwasher in next room
Quiet urban nighttime	40 dBA	Theater, large conference room
Quiet suburban nighttime		
	30 dBA	Library
Quiet rural nighttime		Bedroom at night, concert hall (background)
	20 dBA	
		Broadcast/recording studio
	10 dBA	
	0 dBA	

Source: Technical Noise Supplement (TeNS), California Department of Transportation, September 2013.

TABLE 3 Reactions of People and Damage to Buildings from Continuous or Frequent Intermittent Vibration Levels

Velocity Level, PPV (in/sec)	Human Reaction	Effect on Buildings
0.01	Barely perceptible	No effect
0.04	Distinctly perceptible	Vibration unlikely to cause damage of any type to any structure
0.08	Distinctly perceptible to strongly perceptible	Recommended upper level of the vibration to which ruins and ancient monuments should be subjected
0.1	Strongly perceptible	Virtually no risk of damage to normal buildings
0.25	Strongly perceptible to severe	Threshold at which there is a risk of damage to historic and some old buildings.
0.3	Strongly perceptible to severe	Threshold at which there is a risk of damage to older residential dwellings such as plastered walls or ceilings
0.5	Severe - Vibrations considered unpleasant	Threshold at which there is a risk of damage to newer residential structures

Source: Transportation and Construction Vibration Guidance Manual, California Department of Transportation, September 2013.

Regulatory Background

The State of California and Contra Costa County have established regulatory criteria that are applicable in this assessment. The CEQA Guidelines, Appendix G, are used to assess the potential significance of impacts pursuant to local General Plan policies, Municipal Code standards, or the applicable standards of other agencies. A summary of the applicable regulatory criteria is provided below.

State CEQA Guidelines. CEQA contains guidelines to evaluate the significance of effects of environmental noise attributable to a proposed project. Under CEQA, construction-related noise or vibration impacts would be considered significant if the project would result in:

(a) Generation of a substantial temporary or permanent increase in ambient noise levels in the vicinity of the project in excess of standards established in the local General Plan or Noise Ordinance, or applicable standards of other agencies; or

(b) Generation of excessive groundborne vibration or groundborne noise levels.

Contra Costa County General Plan. The Noise Element in the Contra Costa County 2020 General Plan contains the following noise goals and policies applicable to the Project:

11.8 Goals

11-A: To improve the overall environment in the County by reducing annoying and physically harmful levels of noise for existing and future residents and for all land uses.

11-B: To maintain appropriate noise conditions in all areas of the County.

11-C: To ensure that new developments will be constructed so as to limit the effects of exterior noise on the residents.

11.9 Policies

11-8: Construction activities shall be concentrated during the hours of the day that are not noise-sensitive for adjacent land uses and should be commissioned to occur during normal work hours of the day to provide relative quiet during the more sensitive evening and early morning periods.

11.10 Implementation Measures: Development Review

11-a Continue to require a review and analysis of noise-related impacts as part of the existing project development review procedures of the County.

11-b Evaluate the noise impacts of a proposed project upon existing land uses in terms of the applicable Federal, State, and local codes, and the potential for adverse community response, based on a significant increase in existing noise levels.

11-c Encourage use of the following mitigation measures to minimize noise impacts of proposed development projects:

4) Construction modifications: If site planning, architectural layout, noise barriers, or a combination of these measures does not achieve the required noise reduction, then construction modification to walls, roofs, ceilings, doors, windows, and other penetrations may be necessary.

Contra Costa County Municipal Code. The Contra Costa County Municipal Code contains the following regulations that are applicable to the Project:

> *716-8.1004 – Grading Regulation Work hours.* If operations under the permit are within five hundred feet (152.4 meters) of residential or commercial occupancies, except as otherwise provided by conditions of approval for the project, grading operations shall be limited to weekdays and to the hours, between seven-thirty a.m. and five-thirty p.m., except that maintenance and service work on equipment may be performed at any time.

Existing Noise Environment

The project site is located offshore along the San Joaquin River at 2301 Wilbur Avenue. The existing wharf is surrounded by industrial and commercial facilities to the west, east and south, and the San Joaquin River to the north. The Gaylord Sports Fields and Antioch Youth Sports Complex are located 2,300 feet to the southwest. Single family residential units are located 2,600 feet to the southwest and 1,850 feet to the southeast. The Sardis Unit of the Antioch Dunes National Wildlife Refuge is located approximately 1,400 feet to the west.

The noise environment at the site and in the surrounding areas results primarily from industrial activity of adjacent properties on shore and vessel traffic along the San Joaquin River. Local vehicle traffic along Wilbur Avenue and SR 160, and occasional railroad traffic would also contribute to the existing noise environment.

NOISE IMPACTS AND MITIGATION MEASURES

This section describes the significance criteria used to evaluate construction-related impacts under CEQA and provides a discussion of each project impact. Significant impacts are not expected as a result of the project; therefore, mitigation measures are not proposed.

Significance Criteria

The following criteria were used to evaluate the significance of environmental noise and vibration resulting from the project:

1. **Temporary Noise Increases in Excess of Established Standards.** A significant impact would be identified if project construction would result in a substantial temporary increase in ambient noise levels at sensitive receivers in excess of the local noise standards contained in the Contra Costa County General Plan or Municipal Code. A significant temporary noise impact would be identified if construction would occur outside of the hours specified in the Municipal Code or if construction-related noise would result in hourly average noise levels exceeding 60 dBA L_{eq} at the property lines shared with residential land uses, and the ambient by at least 5 dBA L_{eq}, for a period of more than one year.

2. **Generation of Excessive Groundborne Vibration.** A significant impact would be identified if the construction of the project would generate excessive vibration levels. Groundborne vibration levels exceeding 0.3 in/sec PPV would be considered excessive as such levels would have the potential to result in cosmetic damage to buildings.

Impact 1: **Temporary Noise Increases in Excess of Established Standards.** Temporary construction activities would not result in a substantial noise level increase or expose existing noise-sensitive land uses to noise levels in excess of the applicable noise thresholds. **This is a less-than-significant impact.**

Neither Contra Costa County nor the State of California specify quantitative thresholds for the impact of temporary increases in noise due to construction. As discussed in the Setting section of this report, the threshold for speech interference indoors is 45 dBA. Assuming a 15 dBA exterior-to-interior reduction for standard residential construction and a 25 dBA exterior-to-interior reduction for standard commercial construction, this would correlate to an exterior threshold of 60 dBA L_{eq} at residential land uses. Additionally, temporary construction would be annoying to surrounding land uses if the ambient noise environment increased by at least 5 dBA L_{eq} for an extended period of time. Therefore, the temporary construction noise impact would be considered significant if project construction activities exceeded 60 dBA L_{eq} at nearby residences and exceeded the ambient noise environment by 5 dBA L_{eq} or more for a period longer than one year.

Construction activities will include structural and operational safety repairs and improvements, demolition of structures without replacement, demolition and replacement of existing structures, and new construction and repairs. The proposed project would include construction with crane barges, material barges, tugboats, vibratory hammers, and impact hammers. A vibratory hammer would be used for both removal and installation of piles, whereas the impact hammer would be used only to drive concrete piles and complete the installation of new steel piles after the vibratory hammers has driven piles to refusal.

Construction equipment noise varies greatly depending on the construction activity performed, type and specific model of equipment, and the condition of equipment used. Typical noise levels for different construction equipment at a distance of 50 feet are shown in Table 4. Table 4 levels are consistent with construction noise levels calculated for the project in the Federal Highway Administration Roadway Construction Noise Model (RCNM), including the anticipated equipment that would be used for each phase of the project. Most demolition and construction noise ranges from 80 to 90 dBA at 50 feet from the source. Construction-generated noise levels drop off at a rate of about 6 dBA per doubling of the distance between the source and receptor. Shielding by buildings or terrain can provide an additional 5 to 10 dBA noise reduction at distant receptors, however, the effects of intervening shielding were not accounted for in the calculations.

Noise impacts resulting from construction depend on the noise generated by various pieces of construction equipment, the timing and duration of noise-generating activities, the distance between construction noise sources and noise-sensitive receptors, any shielding provided by intervening structures or terrain, and ambient noise levels. Construction noise impacts primarily result when construction activities occur during noise-sensitive times of the day (early morning, evening, or nighttime hours), when construction occurs in areas immediately adjoining noise-sensitive land uses, or when construction durations last over extended periods of time.

Construction activities would include demolition, site preparation, grading and excavation, trenching and foundation, building with a vibratory pile driver, building with an impact pile driver, architectural coating, and paving. The in-water work is expected to start July 1, 2019 and is expected to be completed by December 2019. All work would occur between 7:00am and 6:00pm on weekdays and between 9:00am and 5:00pm on weekends and holidays. Work on structures raised above the water may occur outside of this window, supported by construction barges as-needed.

For each phase, the equipment is summarized in Table 5 in hourly average noise levels. Noise levels are reported at a reference distance of 50 feet, as well as at distances to the nearest receptors. The hourly average noise level is calculated by an energy summation of the hourly average noise levels for each piece of equipment. Therefore, with more equipment operating simultaneously, the combined hourly average noise level may be greater than the maximum instantaneous noise level. The noise levels summarized in Table 5 during each phase would occur over a span of four acres in size, including the wharf itself, surrounding waters, and portions of the adjacent shoreline. Assuming worst-case scenario conditions, where each piece of equipment listed in Table 5 (per phase) would operate simultaneously, the estimated noise levels at 50 feet propagated from the edge of the construction site to the nearest property lines of the surrounding noise-sensitive receptors.

Based on the results of Table 5, the nearest noise-sensitive receptors would be exposed to temporary construction noise in excess of 60 dBA L_{eq} only during pile driving. Since total project construction is expected to last for a period of approximately six months, the temporary noise increase would be considered **less-than-significant**.

TABLE 4 Construction Equipment, 50-foot Noise Emission Limits

Equipment Category	L_{max} Level (dBA)[1,2]	Impact/Continuous
Arc Welder	73	Continuous
Auger Drill Rig	85	Continuous
Backhoe	80	Continuous
Bar Bender	80	Continuous
Boring Jack Power Unit	80	Continuous
Chain Saw	85	Continuous
Compressor[3]	70	Continuous
Compressor (other)	80	Continuous
Concrete Mixer	85	Continuous
Concrete Pump	82	Continuous
Concrete Saw	90	Continuous
Concrete Vibrator	80	Continuous
Crane	85	Continuous
Dozer	85	Continuous
Excavator	85	Continuous
Front End Loader	80	Continuous
Generator	82	Continuous
Generator (25 KVA or less)	70	Continuous
Gradall	85	Continuous
Grader	85	Continuous
Grinder Saw	85	Continuous
Horizontal Boring Hydro Jack	80	Continuous
Hydra Break Ram	90	Impact
Impact Pile Driver	105	Impact
Insitu Soil Sampling Rig	84	Continuous
Jackhammer	85	Impact
Mounted Impact Hammer (hoe ram)	90	Impact
Paver	85	Continuous
Pneumatic Tools	85	Continuous
Pumps	77	Continuous
Rock Drill	85	Continuous
Scraper	85	Continuous
Slurry Trenching Machine	82	Continuous
Soil Mix Drill Rig	80	Continuous
Street Sweeper	80	Continuous
Tractor	84	Continuous
Truck (dump, delivery)	84	Continuous
Vacuum Excavator Truck (vac-truck)	85	Continuous
Vibratory Compactor	80	Continuous
Vibratory Pile Driver	95	Continuous
All other equipment with engines larger than 5 HP	85	Continuous

Notes: [1] Measured at 50 feet from the construction equipment, with a "slow" (1 sec.) time constant.
[2] Noise limits apply to total noise emitted from equipment and associated components operating at full power while engaged in its intended operation.
[3]Portable Air Compressor rated at 75 cfm or greater and that operates at greater than 50 psi.

TABLE 5 Summary of Construction Noise Levels at the Nearest Receptors

Phase	Estimated Noise Levels at Nearby Land Uses, dBA L_{eq}			
	Reference Level (50 ft)	**Southeast Residential Receptor (1,850 ft)**	**Southwest Sports Fields (2,300 ft)**	**Southwest Residential Receptor (2,600 ft)**
Demolition	85	54	52	51
Site Preparation	83	52	50	49
Grading/ Excavation	84	53	51	50
Trenching/ Foundation	77	46	44	43
Building – Vibratory Pile Driving	94	**63**	**61**	**60**
Building – Impact Pile Driving	95	**64**	**62**	**61**
Building – Architectural Coating	75	44	42	41
Paving	81	50	48	47

Mitigation Measure 1: None required.

Impact 2: Exposure to Excessive Groundborne Vibration. Construction-related vibration levels would not exceed 0.3 in/sec PPV at the nearest structures. **This is a less-than-significant impact.**

For structural damage, the California Department of Transportation recommends a vibration limit of 0.5 in/sec PPV for buildings structurally sound and designed to modern engineering standards, 0.3 in/sec PPV for buildings that are found to be structurally sound but where structural damage is a major concern, and a conservative limit of 0.25 in/sec PPV for historic and some old buildings (see Table 3). The 0.3 in/sec PPV vibration limit would be applicable to properties in the vicinity of the project site.

Construction activities would include demolition of existing structures, replacement of existing structures, and new construction and repairs. Table 6 presents typical vibration levels that could be expected from construction equipment at a distance of 25 feet. Project construction activities may generate substantial vibration in the immediate vicinity of work areas, but vibration levels would vary at off-site receptor locations depending on distance from the source of the vibration, soil conditions, construction methods, and equipment used.

The nearest off-site structures are located 1,260 feet to the south and 1,865 feet to the southeast of the intersection of the wharf and the shoreline. At this distance, vibration levels would be barely perceptible (0.015 in/sec PPV or less) and would not have an effect on building structure.

TABLE 6 Vibration Source Levels for Construction Equipment

Equipment		PPV at 25 ft. (in/sec)	PPV at 1,260 ft. (in/sec)	PPV at 1,865 ft. (in/sec)
Pile Driver (Impact)	upper range	1.158	0.015	0.010
	typical	0.644	0.009	0.006
Pile Driver (Sonic)	upper range	0.734	0.010	0.006
	typical	0.170	0.002	0.001
Clam shovel drop		0.202	0.003	0.002
Hydromill (slurry wall)	in soil	0.008	0.000	0.000
	in rock	0.017	0.000	0.000
Vibratory Roller		0.210	0.003	0.002
Hoe Ram		0.089	0.001	0.001
Large bulldozer		0.089	0.001	0.001
Caisson drilling		0.089	0.001	0.001
Loaded trucks		0.076	0.001	0.001
Jackhammer		0.035	0.000	0.000
Small bulldozer		0.003	0.000	0.000

Source: Transit Noise and Vibration Impact Assessment, United States Department of Transportation, Office of Planning and Environment, Federal Transit Administration, May 2006 and modified by Illingworth & Rodkin, Inc., May 2019.

Mitigation Measure 2: None required.