WILSON IHRIG
ACOUSTICS, NOISE & VIBRATION

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Pier 22.5 Fire Station 35 Project

Noise and Vibration Technical Memo

Planning Department Case No. 2012.0893ENV

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1 Introduction

The Pier 22.5 Fire Station 35 project consists of demolition of the existing finger piers, the parking/storage area located south of the historic fire station building, and the existing gates and fences located north and south of the historic fire station building. New construction associated with the proposed project includes construction of a steel pier, a new steel float (building substructure for the new fire station building), an access ramp that links the new steel float to the steel pier, and a new two-level fire station building that will be located on the new steel float.

Pile driving can generate extreme levels of noise and vibration and is anticipated as part of the project. A barge-mounted vibratory hammer would drive the piles to vibratory refusal and an impact hammer would then finish driving to the design tip elevation. The steel pier will be supported on one 24-inch diameter steel pipe pile and four 48-inch diameter steel pipe piles. The float will be held in place by up to six steel pipe guide piles up to 60-inch diameter. In addition, an access ramp is proposed just east of the historic Fire Station 35 structure to provide vehicular and pedestrian access to the fire boat facility. Five additional piles would be required to support an addition to the main pier that would provide a more seismically secure attachment area for the landward end of the access ramp. To minimize potential effects on aquatic species, in-water pile driving would be completed within the environmental window established for work in the Bay.

The new fire station warm shell would be built upon the deck of the steel float at Pier 1 on Treasure Island, over a period of about 9 months. Thus, materials for the building construction would be delivered to Treasure Island Pier 1 via trucks, off-loaded and staged onto Pier 1, and picked up by small crane from the pier onto the steel float for installation. The steel float completed building shell would be towed to the project area.

The existing historic fire station is approximately 100 years old and could be susceptible to construction vibration damage during demolition of the existing finger piers, the parking/storage area located south of the historic fire station building, and installation of the barge guide piles and the piles that would support the addition to the main pier. It is possible that any final modifications to the sidewalk, roadway, curb cuts, etc. would occur at night to reduce effects on traffic and promenade/sidewalk effects during the daytime. The potential for construction activities to adversely impact the existing historic fire station and nearby receptors will be evaluated.

During the operational phase, potential noise sources include ongoing fire department operations (e.g., emergency response events) and the operation of HVAC systems at the new firehouse. Ongoing fire department operations would not change under the project (i.e., a similar number of responses is anticipated using the same equipment/vehicles). Therefore, no new CEQA impacts related to operations are anticipated. The potential for the HVAC systems to affect nearby sensitive receptors will be evaluated.

2 Existing Noise Levels

To determine the existing noise and vibration in the project vicinity, an ambient noise and vibration survey was performed by Wilson Ihrig between September 27 and October 3, 2017 at several noise or vibration sensitive locations in the Project area, shown in Figure 1. Noise measurements at Locations LT-1 and LT-2 documented the environmental noise environment at the closest residential buildings. Vibration measurements at location ST-1 and ST-2 documented the environmental vibration environment at the closest occupied structures. Ambient noise was not measured on Treasure Island. At Treasure Island, there are no noise sensitive receptors within 1,000 ft of the temporary construction work area at Pier 1.

A glossary of acoustical terms can be found at the end of this report.

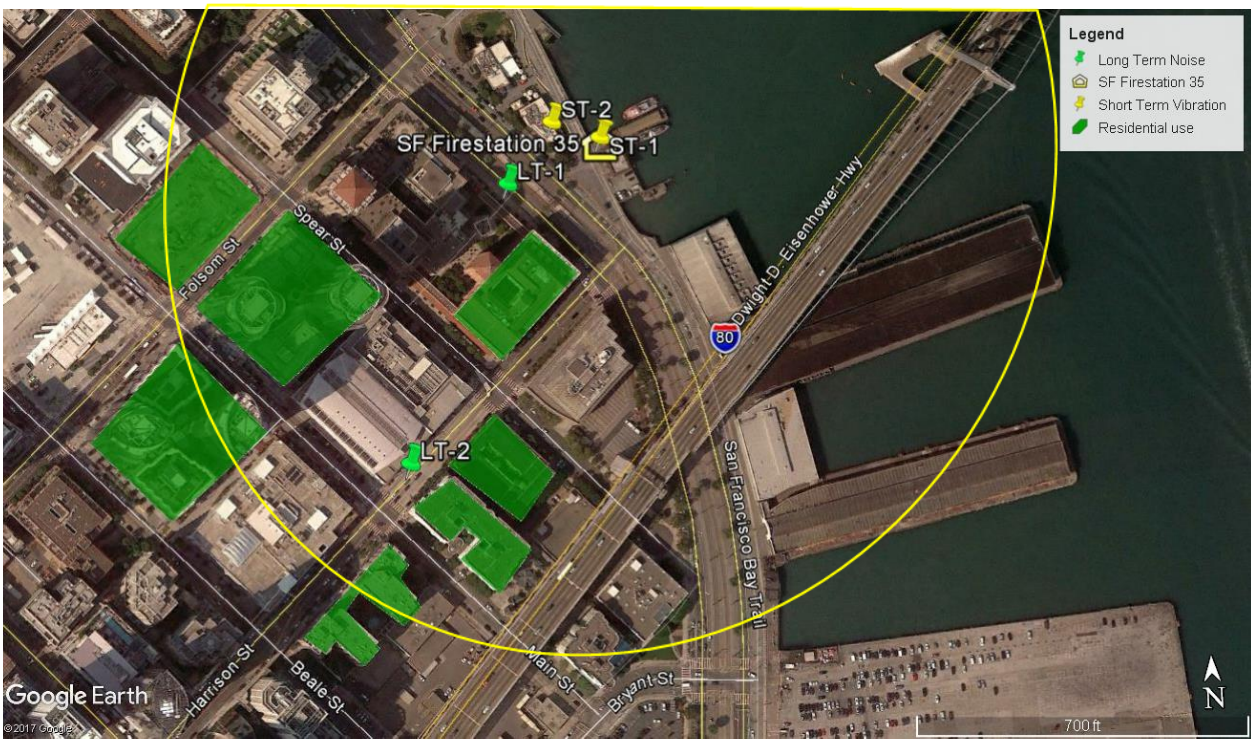

Figure 1 Project area and measurement locations

The measured noise survey results are presented in 15-minute increments in Figures 2 through 5. Figures 2 and 3 show the equivalent noise level (L_{eq}) for each interval. The average daytime level between 7 AM and 8 PM is 70 dBA at LT-1 (Embarcadero) and also 71 dBA at LT-2 (Harrison), which is normal for busy arterials in an urban setting. The primary contributor to the noise levels at both locations is traffic on the nearby arterials (Embarcadero for LT-1 and Harrison Street for LT-2). Additionally, the sites experience noise from more distant city traffic.

Figure 4 and Figure 5 show the corresponding background levels (L_{90}) for each interval. The typical background noise levels range from 58 to 64 dBA at LT-1 and 62 to 68 dBA at LT-2 throughout the survey (Table 1). Again, these background noise levels are typical for an urban setting near busy arterials.

Typical values for the daytime and nighttime periods are summarized in Table1.

Table 1 Typical Values for Daytime and Nighttime Periods

Location	Energy Average (L_{eq})		Ambient (L_{90})	
	Daytime (7 am to 8 pm)	Nighttime (8 pm to 7 am)	Daytime (7 am to 8 pm)	Nighttime (8 pm to 7 am)
LT-1	69–71	64–68	63–64	58–62
LT-2	70–73	66–69	67–68	62–66

Source: Wilson Ihrig noise measurements, 2017.

Short term vibration measurements were taken on September 27, 2017 at two locations, one at the fire station structure and the other at the nearest occupied building, a restaurant. The measurements indicate that the traffic in the area does not generate substantial vibration. At both locations, the peak particle velocity was 0.020 in/sec vibration or less. The primary vibration sources were vehicles on the surface streets such as trucks, buses and motorcycles.

3 Noise Receivers

The immediate area around the Project site consists of primarily commercial buildings, retail and light manufacturing facilities with some mixed-use/downtown residential. The properties within 1,000 feet of the Project site with a direct line of sight to the Project site have been evaluated to determine the contribution to the sound levels from Project construction activities and roof top mechanical equipment. There are seven residential properties, indicated in green in Figure 1 and are described as follows:

- 75 Folsom Street. This landmark building (Hills Bros Coffee) is zoned for mixed use with lower level retail and office and 10 stories of residential above providing 67 condominium units. The closest unit would be about 200 ft from the project.
- 124 Folsom Street. This property was just recently a surface parking lot. It is currently under construction for a downtown residential building. If there were units in place today, the closest unit would be about 740 ft from the project roof, partially shielded by 75 Folsom St.
- The Infinity Residential. The Infinity includes four towers that provide 650 residential condominium units. All four towers fall within 1,000 ft, of the project, ranging from 540 ft to the nearest high-rise (338 Spear Street) to about 760 ft distance to the farthest high rise (301 Main Street). The other two mid-rise buildings are located at 318 Spear Street and 333 Main Street. The high-rise buildings have line of sight to the building.
- The Lumina Residential. These four buildings located at 201 Folsom Street house 655 condominium units in a 2 tower, 2 mid-rise configuration with ground floor retail. Only the two buildings that front Main Street fall within 1,000 ft of the project, with closest at 920 ft distance.
- The Baycrest Towers. 201 Harrison houses condominium units, some of which would have line of sight to the project at just over 900 ft from the project.
- 400 Spear St, contains 46 converted live/work lofts, some of which would have line of sight to the project, about 540 ft from the project.
- The Portside residential. 403 Main Street is a condominium project. Some units would have line of sight down Harrison Street, at over 710 ft distance from the project.

4 Impact Criteria

4.1 Local Code

The most recent guidance and enforcement policies for noise are contained in the "Citywide Noise Guidance" dated December 2014, which references the San Francisco Police Code Article 29: Regulation of Noise. The relevant noise restrictions are provided here to inform the noise analysis.

The term ambient, defined in Section 2901, means the lowest sound level repeating itself during a minimum ten-minute period as measured with a Type 1, precision sound level meter, using slow response and "A" weighting. The minimum sound level shall be determined with the noise source at issue silent, and in the same location as the measurement of the noise level of the source or sources at issue. However, for purposes of this chapter, in no case shall the ambient be considered or determined to be less than: (1) 35 dBA for interior residential noise, and (2) 45 dBA in all other locations. For measurements that contain statistical metrics, the ambient noise level can be equated with the L_{90}, or the noise level exceeded 90% of the time.

Construction: No substantial nighttime construction is anticipated for this project; final modifications to the sidewalk and curbs would occur at night to limit impacts to pedestrian and vehicular traffic on the promenade and roadway. For daytime construction, the San Francisco Police Code, Section 2907 applies to noise generated by any construction equipment on a permitted construction site, except for impact tools such as jackhammers (provided that they are equipped with acoustically attenuating shields or shrouds). The limits in this section do not apply during emergencies. For non-impact equipment, powered construction equipment is limited to a noise level of 80 dBA at a distance of 100 feet from the equipment. Construction is allowed during the daytime hours (7:00 AM – 8:00 PM) every day of the week. Because the San Francisco Noise Ordinance does not identify a quantitative noise limit standard for impact equipment, such equipment has also been evaluated based on application of FTA guidelines, as described below. The evaluation also considers proximity to existing or future noise-sensitive receptors, the potential duration these receptors would be subject to this type of noise, and feasibility of using alternative, quieter methods.

Fixed Noise Sources: Operational noise from exterior sources is covered under Section 2909(b) for commercial and industrial property, as the Fire Station and related structures are not open to the public. In this case, such fixed noise sources are limited to 8 dBA above the ambient at any point outside of the property plane.

Since the project operational hours would be the same as the existing operation with potential HVAC or other mechanical equipment operating (24 hours a day, 7 days a week), the ambient nighttime level (L_{90}) at the LT-1 location is the controlling criterion and was measured as 58 dBA at the nearest residential areas (Table 1; Figure 1). Therefore, Section 2909(b) would limit the total noise from fixed noise sources that operate both daytime and nighttime to 66 dBA at the project property line. For daytime only operations (e.g. standby generator testing during the weekday), with an ambient daytime level (L_{90}) of 63 dBA at LT-1 (Table 1; Figure 1), the Section 2909(b) limit would be 71 dBA at the project property line.

In Section 2909(d), interior noise limits are provided for fixed noise sources. At residential areas, in order to prevent sleep disturbance, fixed noise sources cannot intrude into a sleeping or living room in any dwelling unit located on residential property to produce interior noise levels that exceed 45 dBA between the hours of 10:00 PM to 7:00 AM or 55 dBA between the hours of 7:00 AM to 10:00PM with windows open except where building ventilation is achieved through mechanical systems that allow windows to remain closed. For the purposes of evaluating noise impact per 2909(d), an equivalent exterior noise threshold of 60 dBA for nighttime and 70 dBA for daytime at the exterior of the receiving building façade is used, with the understanding that the building will provide 15 dBA noise reduction from the exterior to the interior with windows open. (WHO, 1999, and CBC, 2010) This will be used to evaluate operational noise that exceeds the 2909(b) threshold. This criterion has also been used to evaluate nighttime construction.

Section 2901(h) specifies that the San Francisco City government is not a "Person", which has been interpreted to mean that the City is exempt from the limits set forth in Section 2909.

4.2 Substantial Noise Increase

For the purposes of this analysis, if the fixed operational noise[1] exceeds the noise limit at the Project property line, a substantial noise increase will be determined based on consistency with the noise ordinance at the nearest noise sensitive receptors. For fixed operation noise, the noise limit would thus be 71 dBA for exterior noise per 2909(b) and 45 dBA for interior noise per 2909(d).

Finally, to determine whether the project would cause an impact with respect to temporary daytime increases (from construction) in noise levels in the project vicinity above levels existing (L_{eq}) without the project, a threshold increase of 10 dBA over existing noise levels is considered a substantial temporary increase in noise levels; such an increase is considered a perceived doubling of loudness. This threshold would be 79 dBA at LT-1 and 80 dBA at LT-2.

The determination of potential impact would take into account combined construction noise from simultaneously operating on-site equipment, Noise Ordinance standards, as well as proximity of existing or future noise sensitive uses, and the potential duration that these receptors would be subject to this type of noise.

4.3 Other Noise Evaluation Guidance

Construction-related noise impacts were assessed in part using the construction noise data provided by the Federal Highway Administration (FHWA) in their Roadway Construction Noise Manual (FHWA 2006). This document provides noise levels and usage factors for each piece of equipment in the database to account for the time that the equipment is in use over the specified time period and estimated the L_{eq} for a typical hour. While many pieces of equipment could be "on" at the same time, to determine the maximum construction analysis, this analysis combines noise levels from the simultaneous operation of the two noisiest pieces of equipment expected to be used in each construction phase. This calculation method is part of the method described by the Federal Transit Administration (FTA) in their discussion on construction noise (FTA 2006).

Impact equipment such as impact pile drivers was evaluated against the FTA thresholds of 90 dBA for daytime operation evaluated on an hourly L_{eq} basis. No nighttime pile driving is anticipated.

[1] Also applied for nighttime project construction noise.

4.4 Vibration Impact Criteria

Caltrans' Transportation and Construction Vibration Guidance Manual provides a standard for transient sources of 2.0 in/sec peak particle velocity (PPV) for modern industrial/commercial buildings and 0.5 in/sec PPV for continuous or frequent intermittent sources.[2] This information is summarized in Table 2 below. Caltrans guidance also includes annoyance criteria (Table 20. Guideline Vibration Annoyance Potential Criteria), of which the "Strongly Perceptible" response threshold of 0.9 in/sec PPV for transient and 0.10 in/sec PPV for continuous/frequent intermittent sources could be used to evaluate the annoyance potential of vibratory pile driving.

Structures potentially sensitive to vibration include the historic Fire Station 35 building and the Water Bar restaurant. Ads an historic structure, the building damage criteria for the Fire Station 35 building is 0.5 in/sec for transient sources and 0.25 in/sec for frequent intermittent. The previous pile/pier replacement work in 2009/2010 was evaluated using a threshold limit of 0.75 in/sec.

Table 2 Maximum Vibration Levels for Various Building Types

	Maximum PPV (in/sec PPV)	
Structure and Condition	**Transient Sources**	**Continuous/Frequent Intermittent Sources**
Extremely fragile historic buildings, ruins, ancient monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	0.25
Older residential structures	0.5	0.3
New residential structures	1.0	0.5
Modern industrial/commercial buildings	2.0	0.5
Note: Transient sources create a single isolated vibration event, such as blasting or drop balls. Continuous/frequent intermittent sources include impact pile drivers, pogo-stick compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.		

Source: Caltrans 2013

For any occupied building near the project, annoyance criteria can also be considered to evaluate the effects of on-going construction activities, as summarized in Table 3.

[2] California Department of Transportation, 2013, *Transportation and Construction Vibration Guidance Manual*, Table 19. Available: http://www.dot.ca.gov/hq/env/noise/pub/TCVGM_Sep13_FINAL.pdf.

Table 3 Guideline Vibration Annoyance Criteria

Human Response	Maximum PPV (in/sec) Transient Sources	Continuous/Frequent Intermittent Sources
Barely perceptible	0.04	0.01
Distinctly perceptible	0.25	0.04
Strongly perceptible	0.9	0.10
Severe	2.0	0.4

Note: Transient sources create a single isolated vibration event, such as blasting or drop balls. Continuous/frequent intermittent sources include impact pile drivers, pogo-stick compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.

Source: Caltrans 2013

4.5 Marine Animals

The National Oceanic and Atmospheric Administration (NOAA) criteria for marine mammals are provided in its "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing,"[3] which includes Permanent Threshold Shift (PTS) onset thresholds to evaluate sounds based on the frequency-based hearing of different groups of marine mammals. A PTS results in permanent hearing loss. The non-impulsive criterion is applied to anything that is not impulsive (e.g., impact pile driving is impulsive, but vibratory pile driving can be non-impulsive). These limits are listed below in Table 4.

Table 4 NOAA Permanent Threshold Shifts Onset Acoustic Thresholds[4] (receiver)

Hearing Group	Impulsive (peak)	Impulsive (24-hr)	Non-impulsive (24-hr)
Low-Frequency (LF) Cetaceans	$L_{pk,flat}$: 219 dB	$L_{E,LF,24h}$: 183 dB	$L_{E,LF,24h}$: 199 dB
Mid-Frequency (MF) Cetaceans	$L_{pk,flat}$: 230 dB	$L_{E,MF,24h}$: 185 dB	$L_{E,MF,24h}$: 198 dB
High-Frequency (HF) Cetaceans	$L_{pk,flat}$: 202 dB	$L_{E,HF,24h}$: 155 dB	$L_{E,HF,24h}$: 173 dB
Phocid Pinnipeds (PW)	$L_{pk,flat}$: 218 dB	$L_{E,PW,24h}$: 185 dB	$L_{E,PW,24h}$: 201 dB
Otariid Pinnipeds (OW)	$L_{pk,flat}$: 232 dB	$L_{E,OW,24h}$: 203 dB	$L_{E,OW,24h}$: 219 dB

Note: Peak sound pressure (Lpk) has a reference value of 1 µPa, and cumulative sound exposure level (LE) has a reference value of 1µPa2s. In this Table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, peak sound pressure is defined by ANSI as incorporating frequency weighting, which is not the intent for this Technical Guidance. Hence, the subscript "flat" is being included to indicate peak sound pressure should be flat weighted or unweighted within the generalized hearing range. The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting function (Low-frequency (LF), Mid-frequency (MF), and High-frequency (HF) cetaceans, and Phocids in Water (PW) and Otariids in Water (OW) pinnipeds) and that the recommended accumulation period is 24 hours. The cumulative sound exposure level thresholds could be exceeded in a multitude of ways (i.e., varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these acoustic thresholds will be exceeded.

Source: NOAA 2016

[3] Found online http://www.nmfs.noaa.gov/pr/acoustics/Acoustic%20Guidance%20Files/opr-55_acoustic_guidance_tech_memo.pdf

[4] If a non-impulsive sound presents the potential to exceed an impulsive sound threshold, that impact should be considered.

For fish, the studies on the effects of sound have focused on the peak sound level and the sound exposure level (SEL[5]) to capture the relationship between sound level and permanent or temporary effects on fish. The current Interim Criteria (FHWG, 2008) for pile driving (impact noise source) for fish species is a peak underwater sound pressure level of 206 dB and an accumulated SEL of 183 dB for fish smaller than 2 grams, up to an accumulated SEL of 187 dB for fish 2 grams or larger. These criteria were derived to limit or reduce any potential effects from pile driving that could affect fish survival (e.g., temporary threshold shift or temporary loss of hearing) on all fish species.

5 Methodology

The basic steps to the analysis are as follows:

- Noise (and vibration) receptors and the baseline noise environment are determined.
- Noise and vibration impact criteria are defined, which may be influenced by the existing noise or vibration conditions.
- Expected project noise and vibration from construction and operations are then calculated.
    - The radiation of sound and vibration energy is inversely proportional to the distance from the source.
    - Distances from construction equipment are based on the closest distance from the project boundary to the noise sensitive location. Distances from fixed exterior project equipment are based on the center of the project to the noise sensitive location. For the project noise sources, sound pressure levels are inversely proportional to the square of the distance and will decrease by 6 dB for each doubling of distance.
    - Reference noise levels are listed in Section 6 for construction equipment, and in Section 7 for operations.
        - For nighttime noise estimates, construction noise sources were grouped according to construction phase, and the maximum hourly L_{eq} was determined using the two highest noise level pieces of equipment which could be operated simultaneously in any given hour. These two noise sources were added together at the same location, and the corresponding noise levels at receptors near each site were then predicted based on the approximate distance between the nearest receptors and the project worksite.
        - Exterior operational noise sources were also lumped together at one location to calculate the distance and estimate the total noise level at the property plane and at the closest residence.
    - Interior noise levels are determined by subtraction 15 dBA from the exterior noise level. Even with windows open, buildings should provide a minimum 15 dBA noise

[5] Given a constant sound pressure level (SPL) in RMS, the SEL is the SPL+ 10log(duration in seconds)

reduction. This is a commonly used value when converting exterior noise criteria to interior noise criteria. (WHO, 1999, and CBC, 2010)

  - The vibration sources and analysis are provided in Section 6.2. The rate of propagation through the soil is based on the Caltrans methodology (Caltrans, 2013), which expects that vibration velocity will reduce by a factor of 0.4 for each doubling of distance.

- The estimated noise levels are compared to the applicable criteria.
- Where applicable, potential control measures are discussed to reduce noise or vibration.

6 Construction Analysis

Construction activities will include demolition of the existing piers and installation of a new steel pier, steel float, and fire station building. This work will be done in phases, and the three which typically would generate the highest noise are demolition, pile driving, and pouring of concrete. The highest vibration would typically be generated during excavation and pile driving.

6.1 Construction Noise

Typical maximum noise levels for all equipment at distances of 50 feet and 100 feet are listed in the Table 5 below. As shown, consistent with Section 2907, intermittent noise levels from non-impact sources would not exceed the 80 dBA noise limit at 100 feet. Impact equipment, such as impact pile driving would exceed 90 dBA at 100 feet.

Estimated construction noise levels at the nearest residential receptors are presented in Table 6. More detail for Tables 5 and 6 is provided in Appendix B.

Table 5 Typical construction equipment and source noise levels

Noise Sources	Noise Level (dBA) at 50 ft distance	Noise Level (dBA) at 100 ft distance	Typical Usage Factor[1] (%)	Typical Phase
Mobile				
Excavators	81	75	40	Demolition
Jackhammers	89	83	20	Demolition
Concrete Pump Truck	81	75	20	Building
Drum Mixer	80	74	50	Building
Impact Pile Driving	101	94	20	Steel float/steel pier
Vibratory Pile Driving (no impediments)	91	84	20	Steel float/steel pier
Delivery and Haul Trucks	77	71	40	All phases
Stationary				
Air compressors	78	72	40	All phases
Crane	81	75	16	All phases
Drill Rig	79	73	20	Foundation
Nighttime				
Idling pickup truck	75	69	40	Minor finish work
Air compressors	78	72	40	Minor finish work
Note 1: Usage factor used only for FTA-type analysis to evaluate substantial noise increases and noise from impact pile driving				

Source: FHWA Roadway Construction Noise Model (2006)

Table 6 Estimated Hourly L_{eq} Construction Noise Levels (exterior sources)

Maximum Noise	**Noise Level at 75 Folsom**	**Noise Level at 400 Spear**
Temporary Substantial Threshold[1]	79 dBA Hourly L_{eq}	80 dBA Hourly L_{eq}
Demolition	71 dBA	63 dBA
Building	67 dBA	58 dBA
Steel Float/Steel Pier	72 dBA vibratory/non-impact[2] 82 dBA impact driver	72 dBA
Average/Typical all phases (daytime)	73 dBA	64 dBA
Nighttime Noise Thresholds	68 dBA Hourly L_{eq} 63 dBA maximum	72 dBA Hourly L_{eq} 68 dBA maximum
Nighttime work (hourly **L_{eq}**)	62 dBA	53 dBA
Maximum	66 dBA	57 dBA
Note 1: Temporary Substantial Thresholds were calculated as 10 dBA above daytime baseline noise levels or 5 dBA above nighttime baseline presented in Table 1 **Note 2: Vibratory driving that encounters obstructions can cause comparable noise to impact pile driving**		

6.1.1 Non-impact equipment

Regarding on-going construction noise, all construction activities would be within the substantial temporary noise increase threshold of 79 dBA at 75 Folsom.

At 400 Spear, all construction activities are expected to be below the 80 dBA temporary noise increase threshold.

These calculations do not include the effect of noise barriers or shielding that could be provided by intervening buildings at 400 Spear which would further reduce the noise.

See Appendix B.

Nighttime construction activities could occur for minor sidewalk finishing, to avoid blocking the sidewalk during the busy daytime period. As summarized above in

Table 6, some activities could generate noise levels that exceed the 63 dBA nighttime noise limit at 75 Folsom. No impacts would occur at 400 Spear. As shown in Appendix B, any construction activity that generates a noise level exceeding 75 dBA at 50 ft distance would exceed the nighttime threshold.

6.1.2 Impact Equipment

Impact pile driving would be less than the 90 dBA hourly L_{eq} threshold (FTA) for daytime construction at both 75 Folsom and 400 Spear. Additional details are shown in Appendix B.

6.2 Construction Vibration

Construction vibration sources would include pile driving in the water. Typical vibration levels from construction activities are summarized in Table 7 as measured at the surface. The buffer distances to remain at or below the guidance thresholds are also indicated in Table 7, using the attenuation formula for Class I "weak" [6] (Caltrans 2013). This provides a conservative estimate of the vibration amplitude for activities from the project. Since the vibration from the pile driving will be generated at depth, traveling up the piles to the surface, the mode of vibration propagation has been taken into account; the effect of the pile supported deck for Fire Station 35 would further reduce the vibration. The nearest occupied buildings to the pile driving are the Fire Station 35 (perhaps 35 ft at closest distance) and the Water Bar (150 ft at closest distance), and the annoyance buffer distance has been calculated to maintain vibration at or below the "strongly perceptible" threshold. Of the nearby buildings, the historic fire station falls just beyond the buffer distance for potential building damage from impact or vibratory driving. For annoyance, only the historic fire station falls within the buffer distance for potential annoyance from impact or vibratory pile driving.

Table 7 Anticipated Construction Equipment and Vibration at 25 feet

Heavy (Vibration-Generating) Equipment	Source Character	Peak Particle Velocity at 25 ft. (in/sec)	Buffer Distance (ft.)		
			Bldg. Damage (Commercial)	Bldg. Damage (Historic)[1]	Annoyance
Loaded Trucks	Transient	0.076	3	7	5
Jackhammer	Transient	0.035	<1	<1	<1
Small Bulldozer	Transient	0.003	<1	<1	<1
Impact or Vibratory Pile Driver ***(at depth)***	Frequent Intermittent	0.650	23	32	45
Vibration/Concrete Compactor	Frequent Intermittent	0.210	14	22	40
Note 1: The fire station building is located on a pile-supported pier. With regards to the fire station building, the buffer distance is the horizontal distance between the driven pile and the nearest support piles directly beneath the fire station building.					

[6] The attenuation rate of n=1.4 is used. The soil in the area is fill underlain by bay mud. Calculations are in Appendix C

Source: Caltrans 2013

6.3 Effects on Marine Animals

Impact pile driving is a broad-band noise which generates a relatively flat frequency sound; the frequencies generated from vibratory pile driving without significant obstructions are often low frequency, corresponding to the vibratory driver operation (e.g., 40 to 300 Hz), which would be in the low frequency (LF) range for mammals per NOAA.

Hydroacoustic noise from impact pile driving proposed for the project could be as high as 210 dB[7] peak (up to 185 dB per pile SEL) if 66-inch pipe piles are used as measured at 10 m distance (Caltrans, 2015) without control techniques. Wilson Ihrig measured 163 to 185 dB peak (175 dB SEL) at 10 m distance with an air bubble curtain from pipe pile driving activities conducted December 2009 to February 2010 during retrofit of the pier that supports the historic fire station. Vibratory pile driving data compiled by Caltrans (Caltrans 2015) indicates that hydroacoustic noise could reach 183 dB peak (170 dB SEL) at 10 m distance without control techniques.

Active pile driving could occur for as much as 6 hours in a 24-hour day to install 1 to 6 piles, and depending on how much resistance is encountered, each pile could require anywhere from 100 to 600 strikes each. For this analysis we have assumed a maximum 3,000 strikes per day. Table 8 lists the buffer distance to reach the criteria for each kind of mammal or fish. Buffer distances required if impact pile driving is used are represented under the “Impulsive (peak)” and “Impulsive (24-hour)” columns, while buffer distances required if vibratory pile driving is used are represented under the “Non-impulsive (24-hr)” column. Table 8 also shows the expected buffer distances that could be required for the smaller driven piles, based on data for a 30-inch pile. See (biology section) for more discussion of impacts on marine animals.

[7] As discussed previously, all hydroacoustic decibels are referenced to 1 microPascal. This is different from decibels in air which are referenced to 20 microPascals.

Table 8 Estimated impact buffer distances (meters) assuming 3000 strikes per day

Hearing Group	Impulsive (peak)	Impulsive (24-hr)	Non-impulsive (24-hr)
No Mitigation – Impact Pile Driving – 66-inch pipe piles 210 dB peak/195 dB RMS/185 dB SEL – impulsive[1]			
Low-Frequency (LF) Cetaceans	3	2154	N/A
Mid-Frequency (MF) Cetaceans	0	2080	N/A
High-Frequency (HF) Cetaceans	34	2154	N/A
Phocid Pinnipeds (PW) (Underwater)	3	2080	N/A
Otariid Pinnipeds (OW)	0	131	N/A
Fish ≥ 2 g	18	1530	N/A
Fish < 2 g	18	2154	N/A
No Mitigation – Impact Pile Driving – 30-inch pipe piles 210 dB peak/190 dB RMS/177 dB SEL - impulsive			
Low-Frequency (LF) Cetaceans	3	631	N/A
Mid-Frequency (MF) Cetaceans	0	609	N/A
High-Frequency (HF) Cetaceans	34	631	N/A
Phocid Pinnipeds (PW) (Underwater)	3	609	N/A
Otariid Pinnipeds (OW)	0	38	N/A
Fish ≥ 2 g	14	448	N/A
Fish < 2 g	14	631	N/A
No Mitigation – Vibratory Pile Driving – 183 dB peak/170 dB RMS/170 dB SEL – non-impulsive			
Low-Frequency (LF) Cetaceans	N/A	N/A	24
Mid-Frequency (MF) Cetaceans	N/A	N/A	28
High-Frequency (HF) Cetaceans	N/A	N/A	215
Phocid Pinnipeds (PW) (Underwater)	N/A	N/A	18
Otariid Pinnipeds (OW)	N/A	N/A	1
Fish ≥ 2 g	N/A	N/A	215
Fish < 2 g	N/A	N/A	215

N/A: not applicable
Note 1: Data obtained from 66-inch piles (Caltrans 2015)

6.4 Construction Noise and Vibration Control Techniques

The non-impact construction equipment would generate noise consistent with the Noise Ordinance requirements or threshold criteria. Noise from impact pile driving would not exceed the 90 dBA criterion at the nearest residences (75 Folsom), but the noise would exceed 10 dBA above the existing condition. Use of a vibratory pile driver into subsurface conditions without obstructions would eliminate the noise impact. However, this may not be feasible to do under all circumstances. Thus, noise from pile driving could be difficult to control to a level below the threshold.

Nighttime noise activities could exceed the noise ordinance threshold of 63 dBA at the nearest residences (75 Folsom). Limiting work to quiet activities 75 dBA or lower as measured at 50 ft would eliminate this impact, or shielding the noise sources with a temporary plywood shield or other solid barrier (e.g., truck) that blocks line of sight to the residences at 75 Folsom would also be effective.

Hydroacoustic noise from pile driving would generate noise impacts for aquatic animals within the buffer zones listed above in Table 8. The size of these buffer zones would depend on the size of the piles being driven and the number of strikes in a 24-hour period. For biological species, the preferred control options are described below (see the biology section for more discussion of noise control measures for marine animals.)

Two possible options expected to adequately address the potential adverse effect:

- Sole use of vibratory pile driving to minimize the energy imparted into the water with an on-site mammal monitor to document effects on mammals and verify that a buffer distance is not required
- Combination of vibratory and impact pile driving to reduce the time duration of impulsive sound imparted into the water, with hydro-acoustic monitoring to confirm the buffer distance(s), air bubble curtain (air bubble curtains are expected to provide 5 dB reduction due to uncertainties with maintaining a vertical column of bubbles; at best, air bubble curtains can reduce the sound by 10 dB or more) and mammal monitor. With 10 dB reduction, the buffer distances would be reduced to 464 meters for LF cetaceans and less.

Whichever option is implemented, in-water pile driving should be conducted during periods of low protected species activity; consult with NOAA and NMFS for possible calendar year restrictions.

Vibration from vibratory or impact pile driving is not expected to exceed the building damage vibration criteria of 0.25 in/sec at the historic fire boat station as long as a buffer distance of 32 ft from the driven pile to the historic building and its nearest support piles is maintained. If this is not possible, the following measures are recommended:

1. The Port of San Francisco shall be notified in writing prior to construction activity that construction may occur within 32 feet of the Fire Station 35 building.
2. The project sponsor shall retain a structural engineer, an architectural historian, and a licensed historical architect (hereafter referred to as the building evaluation team) to evaluate potentially affected buildings and determine their susceptibility to damage. The structural engineer shall evaluate the building structure. The architectural historian and licensed historical architect shall evaluate architectural elements. This building evaluation team shall then establish building-specific vibration thresholds that will:
    a. Identify the level of vibration the affected historic buildings will tolerate so as to preclude structural damage to the building of a nature that would result in material damage to any historic features of the buildings, and
    b. Identify the level of vibration at which cosmetic damage may begin to occur to buildings.

3. The building evaluation team shall inventory and document existing cracks in paint, plaster, concrete, and other building elements.
4. The building evaluation team shall develop a ground-borne vibration monitoring plan that will include monitoring vibration at the buildings of concern to determine if the established thresholds are exceeded.
5. The project sponsor shall retain a qualified acoustical consultant or engineering firm to implement the vibration monitoring plan at Pier 22.5. As part of the monitoring plan, the consultant shall conduct regular periodic inspections for cosmetic damage to the Fire Station 35 building.
6. Should vibration levels be observed in excess of the cosmetic damage threshold or cosmetic damage be observed below that level, the driving of piles within 32 feet of the Fire Station 35 structure (or within the impact distance determined by the study of building-specific vibration thresholds, per second bullet above, whichever distance is shorter) shall be halted until measures are implemented to prevent cosmetic damage to the extent feasible. These measures include use of alternative construction techniques, including, but not limited to, use of pre-drilled piles if soil conditions allow, use of smaller, lighter equipment, using vibratory hammers in place of impact hammers, and using pile cushioning or equipping the impact hammer with wooden cushion blocks to increase the period of time over which the energy from the driver is imparted to the pile.
7. Should cosmetic damage to a building occur as a result of ground-disturbing activity on the site, notwithstanding the use of alternative construction techniques, the building(s) shall be remediated to its pre-construction condition at the conclusion of ground-disturbing activity on the site.
8. Should vibration levels be observed that reach the threshold designed to protect historic buildings from material damage to historic features, pile-driving within impact distances of the Fire Station 35 building, as determined by the building evaluation team, shall be halted and a structural bracing program or other appropriate protective measures for the potentially affected buildings shall be designed by the building evaluation team and implemented by the project sponsor. The structural bracing program or other protective measures shall be designed to prevent damage to the potentially affected buildings that could materially impair their historic resource status consistent with CEQA Guidelines Section 15064.5(b)(2). In addition, the structural bracing program shall be consistent with the proposed rehabilitation of the Fire Station 35 building and meet the Secretary of the Interior's Standards for Rehabilitation.
9. Following completion of construction, the project sponsor shall conduct a second inspection to inventory changes in existing cracks and new cracks or damage, if any, that occurred as a result of pile driving. If new damage is found, then the project sponsor shall promptly arrange to have the damage repaired in accordance with recommendations made by the building evaluation team.

Vibration from frequent intermittent activities such as pile driving or ground/concrete compaction would exceed annoyance criterion. Manage construction activities to minimize disturbance to occupants of the fire station.

Consistency with the impact thresholds notwithstanding, the following noise and vibration control measures are offered for consideration:

1. Maintain buffer distances from vibration generating activities as needed to avoid exceeding the applicable criteria for continuous or frequent intermittent activities.

2. For vibration activities within the buffer distance of occupied buildings, provide outreach to neighboring buildings with advance notification of construction activity schedules.

3. Where feasible and practicable, utilize acoustic jackets, shrouds or other shielding methods to reduce the effect of impact equipment noise at neighboring businesses.

7 Fixed Operational Noise

While not known at this time, it is possible that some new HVAC equipment could be situated on the new fire station building, in particular on the roof. For purposes of evaluating the potential impact, typical equipment that could be used are listed in Table 9. Such equipment would be subject to the exterior ambient-based fixed noise limits defined above (Section 2909).

Table 9 Possible Outdoor Noise-Generating Equipment

Equipment Type	Number	Maximum Sound Power Level (dBA)
Rooftop Exhaust Fans	2	88
Rooftop Air Conditioning units (heat pump)	2	78
Emergency Generator (10 kW)	1	90

If all of the equipment is located at the westernmost edge of the new building, the equipment would be as close as 100 ft. from the public right of way along Embarcadero and 200 ft, from the closest residential property line (75 Folsom). Assuming equipment as listed in Table 9 above and no parapet wall or acoustical shielding, this configuration of equipment would generate 51 dBA at the public right of way, depending on the actual layout of the equipment on the roof. And 45 dBA at 75 Folsom. Both of these noise levels would be well below the 58 dBA limit at the property line per 2909(b). Thus, no noise control would be required to comply with 2909(b). The noise level at the nearest residential structures (75 Folsom Street), about 200 ft. away from the roof, would also fall within the 60 dBA limit established above per 2909(d). Thus, no noise control measures are required to comply with the requirements of 2909(d).

Daytime testing of the emergency generator would be subject to the daytime noise limit per 2909(b) of 71 dBA. At the public right of way, the generator noise would be 53 dBA and at the nearest residence (75 Folsom) the noise levels would be 47 dBA. Thus, the generator noise would comply with 2909(b) and 2909(d) requirements.

8 References

California Building Code (CBC), Title 24, Section 1207, 2010.

Caltrans, *Transportation and Construction Vibration Guidance Manual*, September 2013.

Caltrans, *Technical Guidance for the Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish*, November 2015.

FHWA, *Roadway Construction Noise Model - User's Guide*, January 2006.

San Francisco, Police Code, Article 29, updated November 25, 2008.

U.S. National Oceanic and Atmospheric Administration (NOAA), *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing – Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts*, NOAA Technical Memorandum NMFS-OPR-55, July 2016

U.S. Department of Transportation, Federal Transit Administration (FTA), Transit Noise and Vibration Impact Assessment, Section 12.1.1 Quantitative Noise Assessment Methods, May 2006, pp. 12-4 to 12-8. Available online at http://www.fta.dot.gov/12347_2233.html. Accessed on March 13, 2016.

World Health Organization (WHO), *Guidelines for Community Noise*, ed. Berglund et al, 1999.

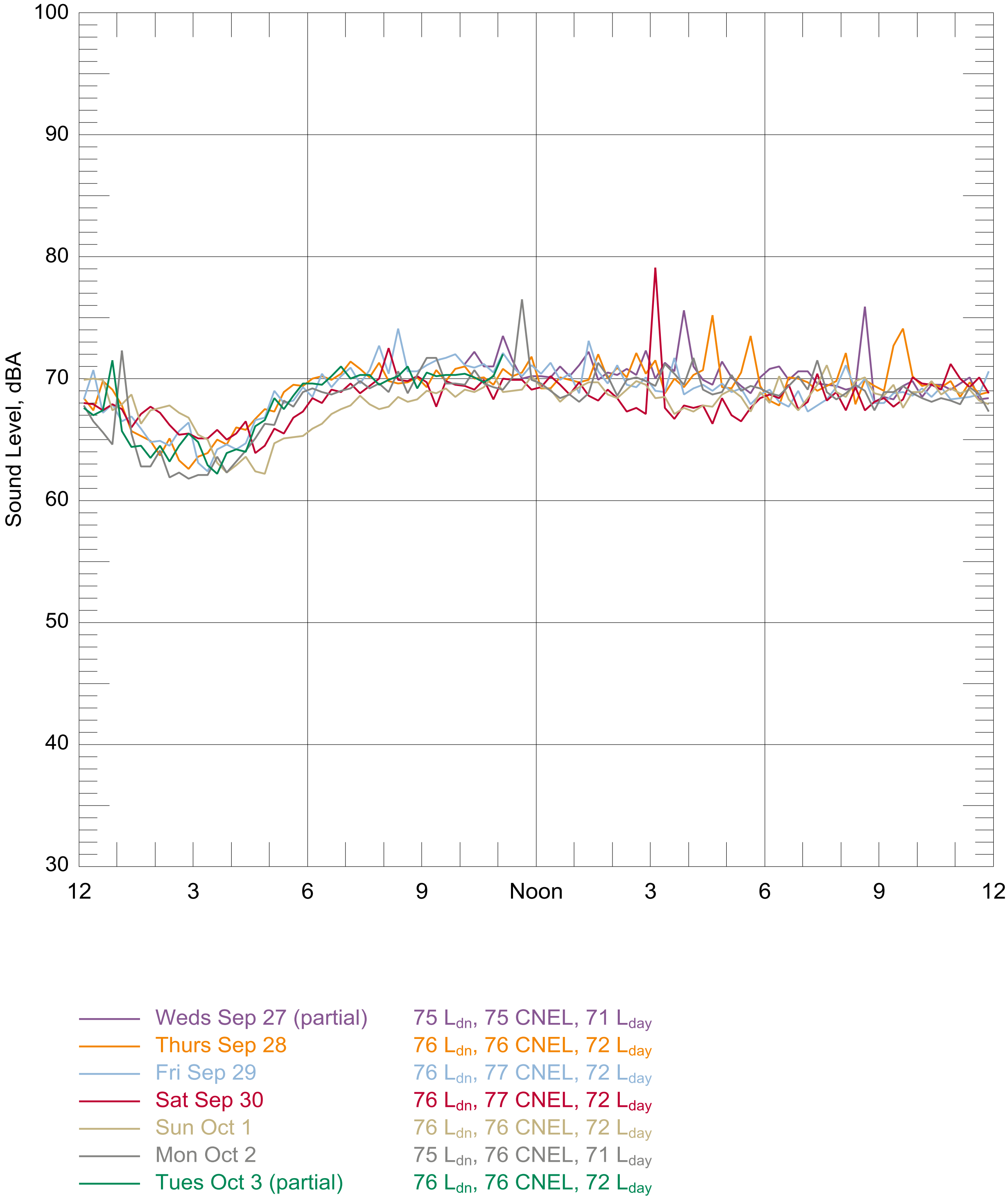

Figure 2 Long-term noise survey, 15-minute equivalent noise levels (L_{eq}) at LT-1 (Embarcadero)

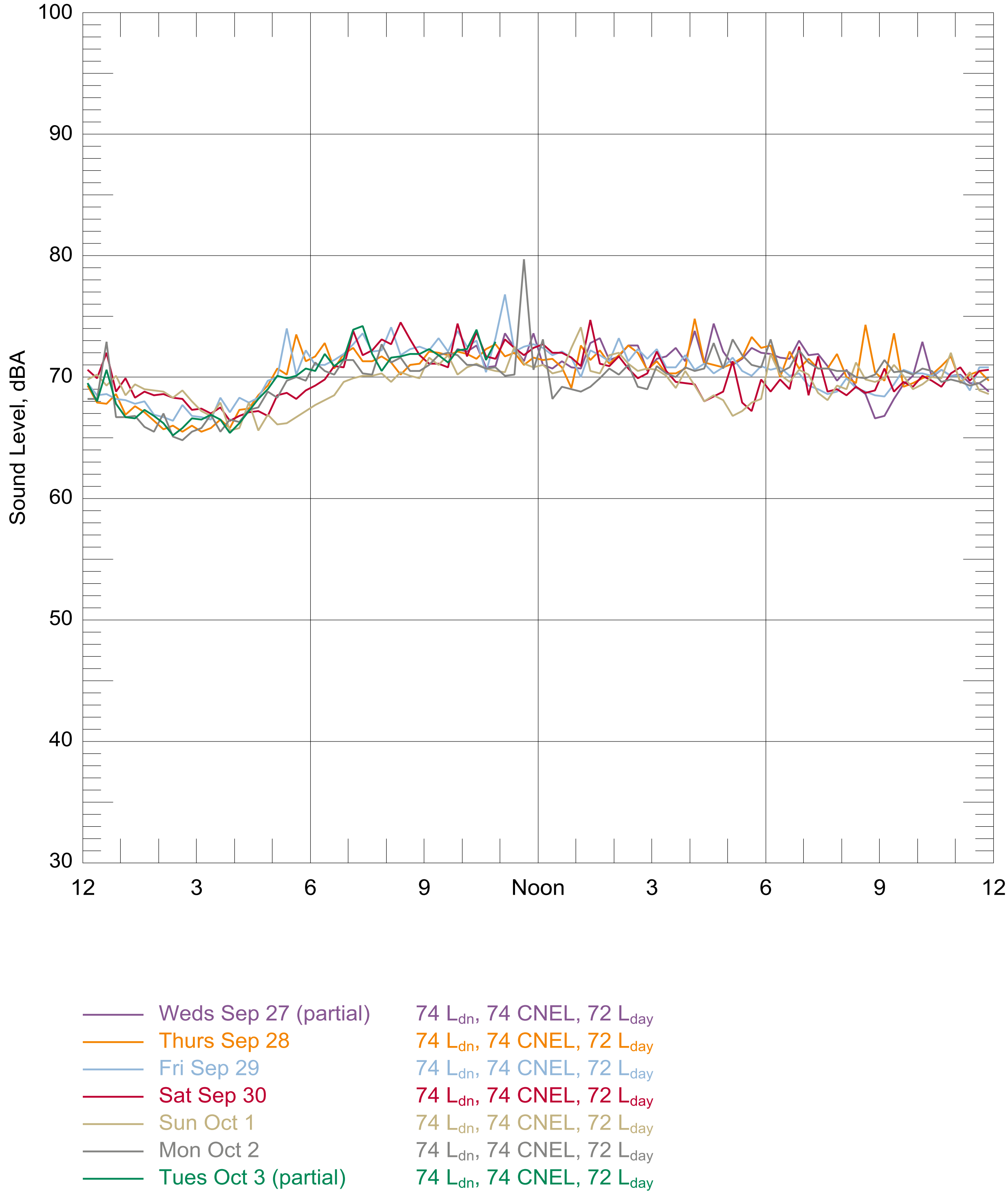

Figure 3 Long-term noise survey, 15-minute equivalent noise levels (L_{eq}) at LT-2 (Harrison)

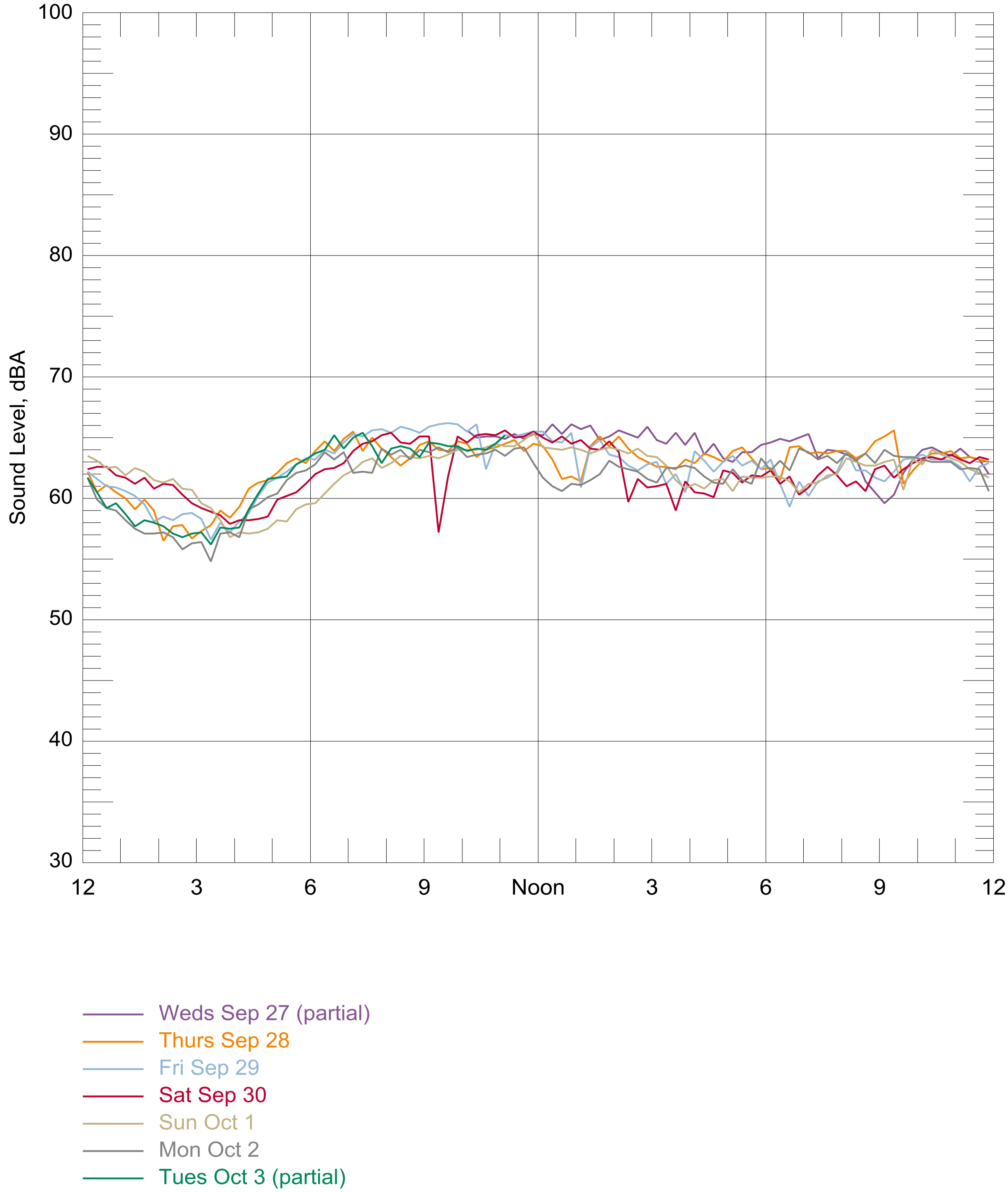

Figure 4 Long-term noise survey, 15-minute background noise levels (L_{90}) at LT-1 (Embarcadero)

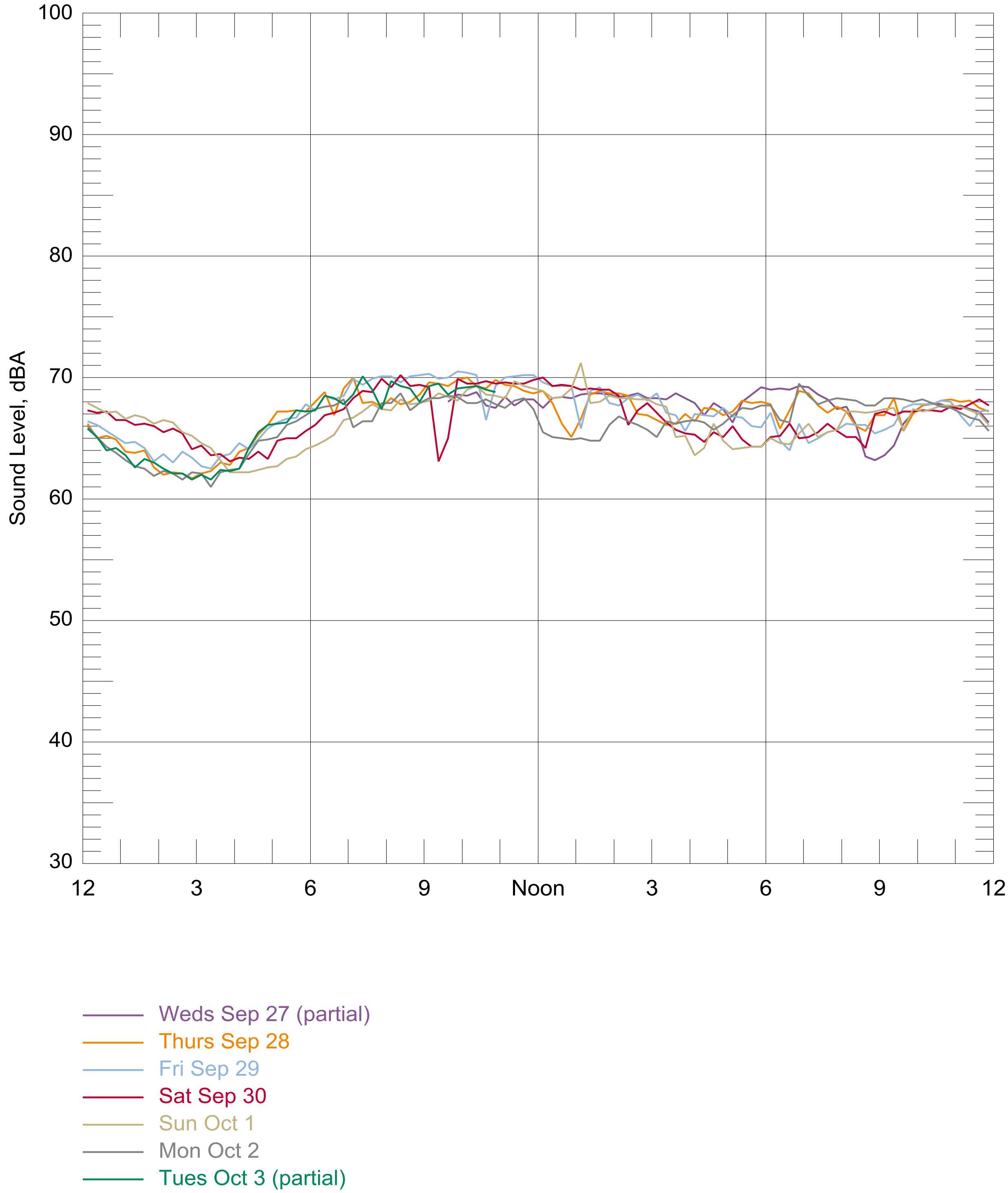

Figure 5 Long-term noise survey, 15-minute background noise levels (L_{90}) at LT-2 (Harrison)

Appendix A Glossary of Acoustical Terms Relevant To Environmental Projects

A-Weighted Sound Level (dBA):

The sound pressure level in decibels as measured on a sound level meter using the internationally standardized A-weighting filter or as computed from sound spectral data to which A-weighting adjustments have been made. A-weighting de-emphasizes the low and very high frequency components of the sound in a manner similar to the response of the average human ear. A-weighted sound levels correlate well with subjective reactions of people to noise and are universally used for community noise evaluations.

Airborne Sound:

Sound that travels through the air, as opposed to structure-borne sound.

Ambient Noise:

The prevailing general noise existing at a location or in a space, which usually consists of a composite of sounds from many sources near and far.

Background Noise:

The general composite non-recognizable noise from all distant sources, not including nearby sources or the source of interest. Generally background noise consists of a large number of distant noise sources and can be characterized by L_{90} or L_{99}.

Community Noise Equivalent Level (CNEL):

The L_{eq} of the A-weighted noise level over a 24-hour period with a 5 dB penalty applied to noise levels between 7 PM and 10 PM and a 10 dB penalty applied to noise levels between 10 PM and 7 AM

Day-Night Sound Level (L_{dn}):

The L_{eq} of the A-weighted noise level over a 24-hour period with a 10 dB penalty applied to noise levels between 10 PM and 7 AM

Decibel (dB):

The decibel is a measure on a logarithmic scale of the magnitude of a particular quantity (such as sound pressure, sound power, sound intensity) with respect to a standardized quantity.

Energy Equivalent Level (L_{eq}):

The level of a steady noise which would have the same energy as the fluctuating noise level integrated over the time period of interest. L_{eq} is widely used as a single-number descriptor of environmental noise. L_{eq} is based on the logarithmic or energy summation and it places more emphasis on high noise level periods than does L_{50} or a straight arithmetic average of noise level over time. This energy average is not the same as the average sound pressure levels over the period of interest, but must be computed by a procedure involving summation or mathematical integration.

Frequency (Hz):

The number of oscillations per second of a periodic noise (or vibration) expressed in Hertz (abbreviated Hz). Frequency in Hertz is the same as cycles per second.

Groundborne Noise:

Noise propagated through soil and building structures. It is normally radiated by the ground in open air and by walls, floors and ceilings inside a building as a result of vibration which, after being produced by a source some distance away, travels through the soil in the form of elastic waves.

Octave Band - 1/3 Octave Band:

One octave is an interval between two sound frequencies that have a ratio of two. For example, the frequency range of 200 Hz to 400 Hz is one octave, as is the frequency range of 2000 Hz to 4000 Hz. An octave band is a frequency range that is one octave wide. A standard series of octaves is used in acoustics, and they are specified by their center frequencies. In acoustics, to increase resolution, the frequency content of a sound or vibration is often analyzed in terms of 1/3 octave bands, where each octave is divided into three 1/3 octave bands.

Sound Pressure Level (SPL):

The sound pressure level of sound in decibels is 20 times the logarithm to the base of 10 of the ratio of the RMS value of the sound pressure to the RMS value of a reference sound pressure. The standard reference sound pressure is 20 micro-pascals as indicated in ANSI S1.8-1969, "Preferred Reference Quantities for Acoustical Levels".

Statistical Distribution Descriptors (L_1, L_{10}, L_{50}, L_{90}, etc.):

Also called *Exceedance Levels,* they represent the level of the noise (A-weighted for environmental studies) which is exceeded a percentage of the duration of the measurement period, as denoted by the subscript. So, for instance, L_{10} is the level of the noise exceeded for 10% of the measurement period (usually 1 hour in long-term environmental studies)

L_{99} and L_{90} are descriptors of the typical minimum or "residual" background noise (or vibration) levels observed during a measurement period, normally made up of the summation of a large number of sound sources distant from the measurement position and not usually recognizable as individual noise sources. Generally, the prevalent source of this residual noise is distant street traffic. L_{90} and L_{99} are not strongly influenced by occasional local motor vehicle passbys. However, they can be influenced by stationary sources such as air conditioning equipment.

L_{50} represents a long-term statistical median noise level over the measurement period and does reveal the long-term influence of local traffic.

L_{10} describes typical levels or average for the maximum noise levels occurring, for example, during nearby passbys of trains, trucks, buses and automobiles, when there is relatively steady traffic. Thus, while L_{10} does not necessarily describe the typical maximum noise levels observed at a point, it is strongly influenced by the momentary maximum noise level occurring during vehicle passbys at most locations.

L_1, the noise level exceeded for 1% of the time is representative of the occasional, isolated maximum or peak level which occurs in an area. L_1 is usually strongly influenced by the maximum short-duration noise level events which occur during the measurement time period and are often determined by aircraft or large vehicle passbys.

Appendix B Construction Calculations

Firestation 35 construction noise

Noise Sources	Noise Level (dBA) at 50 ft distance	Typical Usage Factor (%)	Equipment Leq	Note	Hill Bros Coffee (75 Folsom)		*400 Spear (540 ft)*	
					distance (ft)	Leq	distance (ft)	Leq
Mobile								
Excavators	81	40	77.0		200	65	540	56
Jackhammers	89	20	82.0		200	70	540	61
Concrete Pump Truck	81	20	74.0		200	62	540	53
Drum Mixer	80	50	77.0		200	65	540	56
Impact Pile Driving	101	20	94.0	impact OR vib	200	82	540	73
Vibratory Pile Driving (no impediments)	91	20	84.0	impact OR vib	200	72	540	63
Delivery and Haul trucks	77	40	73.0		200	61	540	52
Stationary					200		540	
Air compressors	78	40	74.0		200	62	540	53
Crane	81	16	73.0		200	61	540	52
Drill rig	79	20	72.0		200	60	540	51
					Leq	73		64
				Demolition		71		63
				Pier foundation		82		73
				building foudnation		67		58

Firestation 35 construction noise

Noise Sources	Noise Level (dBA) at 50 ft distance	Typical Usage Factor (%)	Equipment Leq	Note	Hill Bros Coffee (75 Folsom)			*400 Spear (540 ft)*		
					distance (ft)	Leq	Lmax	distance (ft)	Leq	Lmax
Nighttime										
Idling pickup truck	75	40	71.0		200	59	63	540	50	54
Air compressors	78	20	71.0		200	59	66	540	50	57
				nighttime		62			53	

	Acoustic Metric				
	Peak	SEL	RMS	Effective Quiet	
Measured single strike level (dB	210	177	190	150	30 INCH PIPE PILES REF Caltrans
Distance (m)	10	10	10		
Estimated number of strikes	3000				
Cumulative SEL at measured distance					
211.77					
	Distance (m) to threshold				
	Onset of Physical Injury			Behavior	
	Peak	Cumulative SEL dB**		RMS	
	dB	Fish ≥ 2 g	Fish < 2 g	dB	
Transmission loss constant (15 if	206	187	183	150	FISH
15	18	448	631	4642	
	Distance (m) to threshold				
	Onset of Physical Injury			Behavior	
	Peak	Cumulative SEL dB**		RMS	
	dB	impulsive	non-impul	dB	
Transmission loss constant (15 if	202	155	173		HF Cetaceans
15	34	631	631		
Transmission loss constant (15 if	230	185	198		MF Cetaceans
15	0	609	83		
Transmission loss constant (15 if	219	183	199		LF cetaceans
15	3	631	71		
Transmission loss constant (15 if	218	185	201		Phocid Pinnipeds
15	3	609	52		
Transmission loss constant (15 if	232	203	219		Otariid Pinnipeds
15	0	38	3		
** This calculation assumes that single strike SELs < 150 dB do not accumulate to cause injury (Effective Quiet)					

	Acoustic Metric					
	Peak	SEL	RMS	Effective Quiet		
Measured single strike level (dB	200	167	180	150	30 INCH PIPE PILES REF Caltrans	WITH -10 dB CURTAIN
Distance (m)	10	10	10			
Estimated number of strikes	3000					
Cumulative SEL at measured distance						
201.77						
	Distance (m) to threshold					
	Onset of Physical Injury			Behavior		
	Peak	Cumulative SEL dB**		RMS		
	dB	Fish ≥ 2 g	Fish < 2 g	dB		
Transmission loss constant (15 if	206	187	183	150	FISH	
15	4	97	136	1000		
	Distance (m) to threshold					
	Onset of Physical Injury			Behavior		
	Peak	Cumulative SEL dB**		RMS		
	dB	impulsive	non-impul	dB		
Transmission loss constant (15 if	202	155	173		HF Cetaceans	
15	7	136	136			
Transmission loss constant (15 if	230	185	198		MF Cetaceans	
15	0	131	18			
Transmission loss constant (15 if	219	183	199		LF cetaceans	
15	1	136	15			
Transmission loss constant (15 if	218	185	201		Phocid Pinnipeds	
15	1	131	11			
Transmission loss constant (15 if	232	203	219		Otariid Pinnipeds	
15	0	8	1			
** This calculation assumes that single strike SELs < 150 dB do not accumulate to cause injury (Effective Quiet)						

	Acoustic Metric				
	Peak	SEL	RMS	Effective Quiet	
Measured single strike level (dB	186	170	170	150	Vib driver REF Calt
Distance (m)	10	10	10		
Estimated number of strikes	3000				
Cumulative SEL at measured distance					
204.7712125					
	Distance (m) to threshold				
	Onset of Physical Injury			Behavior	
	Peak	Cumulative SEL dB**		RMS	
	dB	Fish ≥ 2 g	Fish < 2 g	dB	
Transmission loss constant (15 if	206	187	183	150	FISH
15	0	153	215	215	
	Distance (m) to threshold				
	Onset of Physical Injury			Behavior	
	Peak	Cumulative SEL dB**		RMS	
	dB	impulsive	non-impul	dB	
Transmission loss constant (15 if	202	155	173		HF Cetaceans
15	1	215	215		
Transmission loss constant (15 if	230	185	198		MF Cetaceans
15	0	208	28		
Transmission loss constant (15 if	219	183	199		LF cetaceans
15	0	215	24		
Transmission loss constant (15 if	218	185	201		Phocid Pinnipeds
15	0	208	18		
Transmission loss constant (15 if	232	203	219		Otariid Pinnipeds
15	0	13	1		
** This calculation assumes that single strike SELs < 150 dB do not accumulate to cause injury (E					

	Acoustic Metric				
	Peak	SEL	RMS	Effective Quiet	
Measured single strike level (dB	210	185	195	150	30 INCH PIPE PILES REF Caltrans
Distance (m)	10	10	10		
Estimated number of strikes	3000				
Cumulative SEL at measured distance					
219.77					
	Distance (m) to threshold				
	Onset of Physical Injury			Behavior	
	Peak	Cumulative SEL dB**		RMS	
	dB	Fish ≥ 2 g	Fish < 2 g	dB	
Transmission loss constant (15 if	206	187	183	150	FISH
15	18	1530	2154	10000	
	Distance (m) to threshold				
	Onset of Physical Injury			Behavior	
	Peak	Cumulative SEL dB**		RMS	
	dB	impulsive	non-impul	dB	
Transmission loss constant (15 if	202	155	173		HF Cetaceans
15	34	2154	2154		
Transmission loss constant (15 if	230	185	198		MF Cetaceans
15	0	2080	283		
Transmission loss constant (15 if	219	183	199		LF cetaceans
15	3	2154	243		
Transmission loss constant (15 if	218	185	201		Phocid Pinnipeds
15	3	2080	178		
Transmission loss constant (15 if	232	203	219		Otariid Pinnipeds
15	0	131	11		
** This calculation assumes that single strike SELs < 150 dB do not accumulate to cause injury (Effective Quiet)					

	Acoustic Metric					
	Peak	SEL	RMS	Effective Quiet		
Measured single strike level (dB	200	175	185	150	30 INCH PIPE PILES REF Caltrans	WITH -10 c
Distance (m)	10	10	10			
Estimated number of strikes	3000					
Cumulative SEL at measured distance						
209.77						
	Distance (m) to threshold					
	Onset of Physical Injury			Behavior		
	Peak	Cumulative SEL dB**		RMS		
	dB	Fish ≥ 2 g	Fish < 2 g	dB		
Transmission loss constant (15 if	206	187	183	150	FISH	
15	4	330	464	2154		
	Distance (m) to threshold					
	Onset of Physical Injury			Behavior		
	Peak	Cumulative SEL dB**		RMS		
	dB	impulsive	non-impul	dB		
Transmission loss constant (15 if	202	155	173		HF Cetaceans	
15	7	464	464			
Transmission loss constant (15 if	230	185	198		MF Cetaceans	
15	0	448	61			
Transmission loss constant (15 if	219	183	199		LF cetaceans	
15	1	464	52			
Transmission loss constant (15 if	218	185	201		Phocid Pinnipeds	
15	1	448	38			
Transmission loss constant (15 if	232	203	219		Otariid Pinnipeds	
15	0	28	2			
** This calculation assumes that single strike SELs < 150 dB do not accumulate to cause injury (Effective Quiet)						

Firestation 35 Vibration					Type of soil	n					
	(equipment)				Class I weak	1.4	fill, mud				
pile driving	0.65	in/sec PPV	25	ft distance	Class II competent soil	1.3	sand, clay				
	Depth to surface				Class III hard soil	1.1	Franciscan			freq intermitten	
					Class IV hard rock	1				0.25 in/sec crit historic	
										.5 for commercia	
								Founding			
ID	**sample receptor**		**at grade el**	**Pile start depth (ft)**	**Horizontal distance (closest bldg)**	**basement depth (none)**	**Slant dista**	**Type of soil**	**n**	**Vibration per caltran**	**VdB**
	75 Folsom		0	-15	200	0	201	Class I weak	1.4	0.002	53.6
	400 Spear		0	-15	540	0	540	Class I weak	1.4	0.000	29.5
	water bar		0	-15	150	0	151	Class I weak	1.4	0.004	60.5
	historic fire station		0	-15	35	0	38	Class I weak	1.4	0.200	94.0

Firestation 35 Vibration					Type of soil	n					
	(equipment)				Class I weak	1.4	fill, mud				
Loaded truck	0.076	in/sec PPV	25	ft distance	Class II competent soil	1.3	sand, clay				
	Surface to surface				Class III hard soil	1.1	Franciscan			TRANSIENT	
					Class IV hard rock	1				0.5 in/sec crit historic	
										2 in/sec for commercia	
								Founding			
ID	**sample receptor**		**at grade el**	**Pile start depth (ft)**	**Horizontal distance (closest bldg)**	**basement depth (none)**	**Slant dista**	**Type of soil**	**n**	**Vibration per caltran**	**VdB**
	75 Folsom		0	0	200	0	200	Class I weak	1.4	0.004	60.3
	400 Spear		0	0	540	0	540	Class I weak	1.4	0.001	48.2
	water bar		0	0	150	0	150	Class I weak	1.4	0.006	63.8
	historic fire station		0	0	16	0	16	Class I weak	1.4	0.142	91.0

Firestation 35 Vibration					Type of soil	n					
	(equipment)				Class I weak	1.4	fill, mud				
compactor	0.21	in/sec PPV	25	ft distance	Class II competent soil	1.3	sand, clay				
	Surface to surface				Class III hard soil	1.1	Franciscan			freq intermitten	
					Class IV hard rock	1				0.25 in/sec crit historic	
										.5 for commercia	
								Founding			
ID	**sample receptor**		**at grade el**	**Pile start depth (ft)**	**Horizontal distance (closest bldg)**	**basement depth (none)**	**Slant dista**	**Type of soil**	**n**	**Vibration per caltran**	**VdB**
	75 Folsom		0	0	200	0	200	Class I weak	1.4	0.011	69.1
	400 Spear		0	0	540	0	540	Class I weak	1.4	0.003	57.0
	water bar		0	0	150	0	150	Class I weak	1.4	0.017	72.6
	historic fire station		0	0	25	0	25	Class I weak	1.4	0.210	94.4