DOWNTOWN SAN FRANCISCO TERMINAL EXPANSION PROJECT

HYDROACOUSTIC MONITORING PLAN

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INTRODUCTION

The purpose of this Hydroacoustic Monitoring Plan is to describe the methodology proposed for measuring underwater sound levels during the installation of steel pipe piles for the development of the Downtown San Francisco Ferry Terminal Expansion Project. This monitoring plan addresses the underwater sound monitoring required to assess the project's potential effect on both fish and marine mammals. The project consists of demolishing existing deck and piles between the Ferry Building and Agriculture Building (just to the south of the Ferry Building) and constructing two new ferry gates and new deck and pile-supported structures for pedestrian circulation in San Francisco. Construction activities commenced in 2017 and included demolition activities and pile installation by vibratory driving. Pile installation is planned to be completed during the 2018 in-water construction season. Table 1 shows a summary of the piles being installed during the 2018 construction season.

Table 1
Summary of 2018 Pile Installation

Project Element	Pile Diameter	Pile Type	Method	Number of Piles/Schedule
Embarcadero Plaza, East Bayside Promenade, and Interim Access Structure	30 inches	Steel: 135 to 155 feet in length	Impact or Vibratory Driver	(18) 30-inch piles/up to 9 days
Embarcadero Plaza, East Bayside Promenade, and Interim Access Structure	24 inches	Steel: 135 to 155 feet in length	Impact or Vibratory Driver	(30) 24-inch piles/up to 15 days
Gates E, F, and G Dolphin Piles	36 inches	Steel: 145 to 155 feet in length	Impact or Vibratory Driver	10 total: two at each of the floats for protection; two between each of the floats/up to 5 days
Gate F and G Guide Piles	36 inches	Steel: 140 to 150 feet in length	Impact or Vibratory Driver	12 (6 per gate)/up to 6 days
Gate E Guide Piles	36 inches	Steel: 145 to 155 feet in length	Impact or Vibratory Driver	Six/up to 3 days
Barrier Piles near Pier 14	24 inches	Steel: 135 to 155 feet in length	Impact or Vibratory Driver	Five/up to 3 days

PILE INSTALLATION

The pile driving will consist of the piles being installed using a vibratory hammer where feasible or an impact hammer. Hydroacoustic monitoring will be conducted for ten percent of all impact pile driving of 24-, 30- and 36-inch steel shell piles. Hydroacoustic monitoring of vibratory driving was completed during the 2017 construction season.

The hydroacoustic monitoring will be conducted in accordance with the requirements of the California Department of Fish and Wildlife (CDFW) Incidental Take Permit[1] the National

[1] California Endangered Species Act Incidental Take Permit 2081-2015-013-07 Dated July 9, 2015

Marine Fisheries Service (NMFS) Biological Opinion,[2] and the NMFS Marine Mammal Incidental Harassment Authorization.[3] The monitoring will be done in accordance with the methodology outlined in this Hydroacoustic Monitoring Plan. The monitoring will be conducted to achieve the following:

- Be based on the dual metric criteria (Popper et al., 2006) and the accumulated sound exposure level (SEL);
- Establish field locations that will be used to document the extent of the area experiencing 187 decibels (dB) SEL accumulated;
- Verify the SEL and RMS values used to establish the area of the Marine Mammal Level A Exclusion zone and Level B Harassment zone thresholds;
- Describe the methods necessary to continuously assess underwater noise on a real-time basis, including details on the number, location, distance and depth of hydrophones, and associated monitoring equipment;
- Provide a means of recording the time and number of pile strikes, the peak sound energy per strike, and interval between strikes;
- Provide provisions to provide all monitoring data to the CDFW and NMFS.

Two hydrophone systems are proposed to record the sound levels at two locations and determine the extent that sound levels decrease spatially. One hydrophone will be located 10 meters (33 feet) from the pile being driven and the second hydrophone will be located 124 meters (408 feet) from the pile being driven with a clear line of sight between the pile and the hydrophones. The second hydrophone will be used to determine if the cumulative SEL is in compliance with the levels shown in the Incidental Take Permit, Biological Opinion, and Incidental Harassment Authorization. This hydrophone may be moved either further out or closer in depending on the levels measured.

CHARACTERISTICS OF UNDERWATER SOUND

Several descriptors are used to evaluate underwater noise impacts. Two common descriptors are the instantaneous peak sound pressure level (SPL) and the Root Mean Square (RMS) pressure level during the impulse, which are sometimes referred to as the SPL and RMS level respectively. The peak pressure is the instantaneous maximum or minimum overpressure observed during each pulse and can be presented in Pascals (Pa) or decibels (dB) referenced to a pressure of 1 microPascal (µPa). Since water and air are two distinctly different media, a different sound pressure level reference pressure is used for each. In water, the most commonly used reference pressure is 1 µPa, whereas the reference pressure for air is 20 µPa. For comparison, an underwater sound level of equal perceived loudness would be 62 dB higher to a comparable sound level in air.

The RMS level is the square root of the sum of the squared pressures multiplied by the time increment and divided by the impulse duration. This level, presented in dB referenced 1 µPa, is the mean square pressure level of the pulse. It has been used by NMFS in criteria for judging

[2] National Marine Fisheries Service, West Coast Region, Tracking Number SWR-2013-9595, Dated June 30, 2014
[3] Marine Mammal Protection Act, Incidental Harassment Authorization approval is pending.

impacts to marine mammals from underwater impulse and continuous -type sounds. The majority of literature uses peak sound pressures to evaluate barotrauma injuries to fish.

Sound Exposure Level (SEL), frequently used for human noise exposures, is now used as a metric to quantify impacts to fish[4] and marine mammals[5]. SEL is calculated by summing the cumulative pressure squared (p^2) over the measurement duration, integrating over time, and normalizing to 1 second. This metric accounts for both negative and positive pressures because p^2 is positive for both negative and positive pressure and thus both are treated equally in the cumulative sum of p^2. The units for SEL are dB re: 1 microPascal^2-sec. (1 µPa^2-sec).

METHODOLOGY

One hydrophone will be placed at mid water depth at the nearest distance, at approximately 10 meters (33 feet) depending on site conditions, from each pile being monitored. An additional hydrophone will be placed at mid water depth at a distance of 124 meters (408 feet) from the pile, to provide two sound level readings during ambient and pile driving recording. The 10-meter (33-foot) and the 124-meter (408-foot) locations will be monitored live to determine compliance with permit conditions. A weighted tape measure will be used to determine the depth of the water. The hydrophones will be attached to a nylon cord or a steel chain if the current is swift enough to cause strumming of the line. One end of the nylon cord or chain will be attached to an anchor that will keep the hydrophone at the specified distance from the pile. The opposite end of the nylon cord or chain will be attached to a float or tied to a static line at the surface at the specified recording distance from the pile. The distance will be measured by a tape measure, where possible, or a range finder. To the extent practicable, there will be an unobstructed path between the pile and the hydrophones.

Ambient underwater sound levels will be measured for at least one minute prior to initiation of pile driving, as well as in the absence of construction activities. Ambient levels will be reported as SEL and include a representative spectral analysis. The inspector/contractor will inform the hydroacoustics specialist when pile driving is about to start.

Underwater sound levels will be continuously monitored during the entire duration of each pile being driven. Peak levels of each strike will be monitored in real time. Sound levels will be measured in decibels.

Prior to and during the pile driving activity, environmental data will be gathered including, but not limited to, wind speed and direction, air temperature, water depth, wave height, weather conditions, and other factors (e.g., aircraft, boats, etc.) that could contribute to influencing the underwater sound levels. Start and stop time of each pile driving event will be recorded.

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[4] Hastings, M.C., and A.N. Popper 2005. "Effects of sound on fish." Report to California Department of Transportation Contract No. 43A0139, Task order1, http://www.dot.ca.gov/hq/env/bio/files/Effects_of_Sound_on_Fish23Aug05.pdf.

[5] NMFS (National Marine Fisheries Service), 2016. Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-55, 178 p.

Ten percent of all impact pile driving of 24-, 30- and 36-inch steel shell and concrete piles shall be monitored to determine the efficacy of the sound attenuation system and to determine if the calculated sound pressure levels and associated distances from piles differ from the actual measurements. Verification of underwater noise levels for vibratory pile driving was completed in 2017. Table 2 details the equipment that will be used to monitor underwater sound pressure levels.

The chief construction inspector will supply the hydroacoustics specialist with the substrate composition, hammer model, and size; depth the pile is driven and blows per foot for the piles monitored. Hammer energy settings will also be recorded by the chief construction inspector, as well as any changes made to those settings during the pile monitoring period.

Table 2
Equipment for Underwater Sound Monitoring

Item	Specifications	Quantity	Usage
Hydrophone	Minimum Sensitivity – 211 dB ± 3 dB re 1 V/μPa	2	Capture underwater sound pressures and convert to voltages that can be recorded/analyzed by other equipment.
Signal Conditioning Amplifier	Amplifier Gain – 0.1 mV/pC to 10 V/pC Transducer Sensitivity Range – 10^{-12} to 10^{3} C/MU	2	Adjust signals from hydrophone to levels compatible with recording equipment.
Calibrator (pistonphone-type)	Accuracy – IEC 942 (1988) Class 1	1	Calibration check of hydrophone in the field.
SLM and Solid State Recorder	Sampling Rate – 48K Hz or greater	2	Measures and Records data.
Laptop computer	Compatible with digital analyzer	1	Store digital data on hard drive.
Post-analysis	Real time Analyzer –	1	Monitor real-time signal and post-analysis of sound signals.

Note: All have current National Institute of Standards and Technology (NIST) traceable calibration.

EQUIPMENT

Measurements will be made using hydrophones that have a flat frequency response and are omni-directional over a frequency range of at least 10 to 20,000 Hertz (Hz). For example, a G.R.A.S. CT-10 hydrophone with PCB in-line charge amplifiers (Model 422E13) and PCB Multi-Gain Signal Conditioners (Model 480M122) or equivalent systems could be used to measure sound pressures that pile driving could generate. The signals will be fed into Larson Davis Model 831 Integrating Sound Level Meters (SLM). Quality recordings using a digital audio recorder would be made during attended measurements.

The SLM will be used to establish the 187 dB cumulative SEL zone and to approximate the Level A and Level B Marine Mammal Safety and Harassment zones in the field.

The peak pressure RMS sound pressure level and SEL will be measured using an SLM. The SLM has the ability to measure the Z-weighted peak sound pressure levels over the relative short periods (e.g., time constant of 35 milliseconds). The SLM can closely approximate the unweighted SEL of each pile strike by measuring the 1-second equivalent sound energy level ($L_{eq\ (1\text{-}sec)}$) using the linear integration setting. The SLM also approximates the unweighted $RMS_{90\%}$ (where the time period containing 90% of the energy is used in the integration) of each pile strike by measuring the maximum (using the L_{max} setting) with the SLM detector set to Z-weighted "impulse." Note that underwater pile strike acoustic events have durations typically between 50 and 100 milliseconds, so use of the "impulse" setting to approximate RMS sound pressure levels for impact pile strikes would likely provide a higher level.

All measurement equipment used would be required to have a frequency response of ±1 dB from 10 Hz to 20,000 Hz over the anticipated measurement range of 170 to 220 dB linear peak re: 1 μPa. Hydrophones of different sensitivities may be required depending on the acoustic environment.

CALIBRATION

Calibration of measurement systems shall be established prior to use in the field each day. An acoustical piston phone and hydrophone coupler would be used along with manufacturer calibration certificates. Calibration of measurement systems would be established as follows:

- Use an acoustically certified piston phone and hydrophone coupler that fits the hydrophone and that directly calibrates the measurement system**.** The volume correction of the hydrophone coupler using the hydrophone is known so that the piston phone produces a known signal that can be compared against the measurement system response**.** The response of the measurement system is noted in the field book and applied to all measurements.

The SLMs are calibrated to the calibration tone prior to use in the field. The tone is then measured by the SLM and is recorded on to the beginning of the digital audio recordings that will be used. The system calibration status would be checked by measuring the calibration tone and recording the tones. The recorded calibration tones are used for subsequent detailed analyses of recorded pile strike sounds.

All field notes would be recorded in water-resistant field notebooks. Such notebook entries would include operator's name, date, time, calibration notes, measurement positions, pile-driving information, system gain setting, and equipment used to make each measurement.

The equipment will be calibrated and set to properly measure sounds in the proper range; that is, pile-driving sounds will not overload the instrumentation and the noise floor of the instrumentation is not set too high that pile-driving sounds above 170 dB_{peak} cannot be properly measured.

REPORTING

In coordination with the Construction Liaison and Project Biologist, the hydroacoustic data consisting of Peak sound levels single strike SEL levels and accumulated SEL levels will be submitted to the CDFW bi-weekly or on a daily basis if requested by either CDFW or NMFS. These will be considered preliminary data and include:

- The observed typical and maximum peak pressures as recorded in field notebooks or depicted from instrument raw data output.
- The typical and maximum single strike SEL and the daily cumulative SEL as recorded from the SLM.
- The measured RMS level from the SLM and the $RMS_{90\%}$ calculated during the post processing of the recorded signals.

A Final Hydroacoustic Report will be prepared and submitted within 30 days following the completion of pile driving activities. This report will contain acoustical information (peak, RMS, and SEL) for all piles where measurements were made. The report shall include:

1. Size and type of piles.

2. A detailed description of the sound attenuation device including design specifications.

3. The make and model of the pile driver used.

4. The impact hammer force used to drive the piles.

5. A description of the monitoring equipment and a summary of the methods used to monitor sound.

6. The distance between hydrophones and pile.

7. The depth of the hydrophone.

8. The distance from the pile to the wetted perimeter.

9. The depth of water in which the pile was driven.

10. The depth into the substrate that the pile was driven.

11. The physical characteristics of the bottom substrate into which the piles were driven.

12. The total number of pile strikes per pile, the total number of strikes per day, and the interval between strikes.

13. The ranges and means for peak, $RMS_{90\%}$, and SELs for each pile.

14. The results of the hydroacoustic monitoring, including the frequency spectrum, and maximum and median values of the following: Peak and RMS and $RMS_{90\%}$ SPLs; single-strike SEL; and cumulative SEL. Any averaging of values of sound levels should be done linearly (i.e., averaging the physical quantities before converting to dB).

15. Pulse duration for RMS during impact driving.

16. A description of any observable fish, marine mammal, or bird behavior in the immediate area, as recorded by the biological monitor(s). If possible, correlation between observed fish, marine mammal, or bird behavior and underwater sound levels occurring at the time will be noted.