State of California Department of Transportation

San Francisco – Oakland Bay Bridge
East Span Seismic Safety Project

Final Hydroacoustic Monitoring Plan for Driving of Temporary Access Trestle Piles for the Self-Anchored Suspension Span

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INTRODUCTION

The California Department of Transportation (Caltrans) is in the process of replacing the East Span of the San Francisco-Oakland Bay Bridge (SFOBB) with a new bridge immediately to the north of the existing span. Construction of the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project (SFOBB Project) has been divided into four major components: Oakland Touchdown, Skyway, Self-Anchored Suspension (SAS) Span, and Yerba Buena Island Transition Structure. As part of construction of the SAS Span portion of the SFOBB Project, it is necessary to construct a temporary access trestle. The temporary access trestle will provide pedestrian, vehicle, equipment access from Yerba Buena Island (YBI) to the main tower of the SAS, Tower 1 (T1) marine foundation, during construction. The trestle will have a boat landing for marine / boat access and will support an elevator which provides access to the tower, during construction.

PROJECT DESCRIPTION

The T1 access trestle will be located in San Francisco Bay at the eastern end of YBI, connecting YBI to T1. Construction of the trestle is scheduled to begin in late Summer / Fall 2009. All pile driving associated with the construction of the trestle will be completed prior to November 30, 2009 to avoid the peak migration period for salmonids and spawning adult green sturgeon.

The trestle will be supported by 22 steel pipe piles, each with a diameter of 90 centimeters (36 inches). Of the 22 total piles, 4 will be driven in water less than 5.0 meters (16.4 feet) deep. The 18 remaining piles will be driven in water depths between 8.9 to 13.6 meters (29.2 to 44.6 feet).

The piles will be installed with a vibratory hammer and then driven with a Delmag D-62 diesel impact hammer to seat. The vibratory hammer will be used to the extent practicable. During impact driving, the Delmag D-62 will be operated with minimal energy, approximately 107,110 Newton meters (79,000 foot-pounds).

It is expected that when the piles are initially stabbed, they will run for several meters under their own weight and the weight of the hammer. The piles will then be vibrated through the soft bay mud until the vibratory hammer can no longer overcome the resistance, which is expected to be at a depth of approximately 2.0 to 4.5 meters (6.6 to 14.8 feet) below the surface. The piles will then be impact driven 1.0 to 2.0 meters (3.3 to 6.6 feet) into competent substrate. It is anticipated that the impact driving will

require an average of approximately 60 blows per pile, requiring an average impact driving time of 5 minutes per pile to reach the required depth. A maximum of 2 hours total impact driving time is anticipated to install all 22 piles. The majority of piles are expected to require less than 60 blows; however a few piles may require more than 60 blows to reach the required depth.

An air bubble curtain sound attenuation system will be used to minimize sound pressures and impacts to fish during impact driving of 18 of the 22 piles. An air bubble curtain will not be used during installation of the 4 piles closest to the YBI shoreline. The 4 piles closest to the shoreline will be installed at the lowest tide practical based upon the minimum draft of the pile driving barge. The water depth at this location is less than 5 meters (16 feet). Installation of these 4 piles at low tide will further reduce the water depth by up to 0.8 meter (2.6 feet). Generally in shallow water, less sound is transmitted into the water column.

On June 12, 2008, the Fisheries Hydroacoustic Working Group agreed in principle on interim criteria for injury to fish from pile driving. The agreed upon criteria identify sound pressure levels of 206 decibels (dB) peak and 187 dB accumulated sound exposure level (SEL) for all fish except those that are less than 2.00 grams (0.07 ounces). The agreed upon criteria for fish less than 2.00 grams (0.07 ounces) is 183 dB accumulated SEL. To approximate the distance at which sound levels will exceed the interim criteria for injury to fish from pile driving, an estimate of attenuated impact pile driving sound levels was prepared. This estimate was developed assuming the driving of 4 piles per day. It is expected that sound levels will not exceed the 206 dB peak criteria beyond 10 meters (32.8 feet) from the pile being driven, and the 187 dB and 183 dB cumulative SEL criteria will not be exceeded beyond 28.0 meters (91.9 feet) and 52.0 meters (107.6 feet) from the pile driving activity, respectively. There is uncertainty as to the behavioral response of fish to underwater sounds. Until new information indicates otherwise the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA-Fisheries) believes a 150 dB root-mean-square (RMS) pressure threshold for behavioral responses for salmonids and green sturgeon is appropriate. It is expected that sound levels will not exceed the 150 dB RMS threshold beyond 1,000 meters (3,281 feet) from the pile being driven.

It is expected that 4 piles will be driven per day and completion of the operation will take approximately 5 to 6 days of pile driving. The resulting accumulated SEL is a function of the sound generated from the pile and the duration of pile driving. Should it be determined through hydroacoustic monitoring that more than 4 piles can be installed per day without exceeding the 187 dB cumulative SEL beyond 28.0 meters (91.9 feet), Caltrans may choose to install more than 4 piles per day.

This monitoring plan is consistent with the project's previous hydroacoustic monitoring efforts for marine pile driving. Monitoring will include underwater sound measurements at different depths and distances from the piles, observation of bird predation, and identification of dead or moribund fish observed during pile driving activities.

HYDROACOUSTIC MONITORING METHODS

Underwater sound measurements will be collected during all impact pile driving. Previous monitoring protocols for the SFOBB Project required monitoring during 10% of pile driving activities. This trestle installation is a relatively small project requiring the driving of only 22 piles.

Measurement Positions

Underwater sound measurements are planned at 3 positions: about 10 to 20 meters (33 to 66 feet), 30 to 40 meters (98 to 131 feet), and 1,000 meters (approximately 3,300 feet) from the pile that is being driven. Hydrophones will be placed at a depth of about 2 meters (7 feet) below the water surface. If water depth is shallower than 2 meters (7 feet), hydrophones will be positioned at a depth of 1 meter (3 feet) below the water surface. The positions at 10 to 20 meters (33 to 66 feet) from the pile are dependent on access to the construction area; therefore, the distance for this close-in position will likely vary from pile to pile. The other positions are also approximate due to potential access issues, concerns for safety of the monitors, and fluctuations caused by currents, waves and wind.

Underwater Sound Descriptors

When a pile driving hammer strikes a pile a pulse is created. The pulse propagates through the pile and radiates sound into the water and the ground substrate as well as the air. Sound pressure pulse as a function of time is referred to as the waveform.

Impacts to fish will be evaluated using the peak sound pressure and the accumulated unweighted SEL. The peak pressure is the highest absolute value of the measured waveform, and can be a negative or positive pressure peak. Another measure of the pressure waveform that can be used to describe the pulse is the sound energy itself. The total sound energy in the pulse is referred to in many ways, such as the "total energy flux". The "total energy flux" is equivalent to the unweighted SEL for a plane wave propagating in a free field, a common unit of sound energy used in airborne acoustics to describe short-duration events. The unit is dB re $1\mu Pa^2$-sec. Resource agencies on the West Coast have been using SEL to evaluate pile

driving sound impacts to fish. All sound pressure measured during pile driving in one day at a location is accumulated and referenced to one second. This is referred to as the accumulated SEL. It can also be approximated if one knows the SEL associated with each pile strike at a position and assume each strike has equal energy. The accumulated SEL would be the SEL per strike plus 10 times the 10-based logarithm of the number of strikes. The peak pressure and accumulated SEL are the current sound descriptors used to describe potential sound effects to fish.

For behavioral response of fish, the RMS sound pressure level of a pile driving pulse is used. The RMS level is determined by analyzing the waveform and computing the average of the squared pressures over the time that comprise that portion of the waveform containing 90 percent of the sound energy. This RMS term is described as $RMS_{90\%}$. This has been approximated in the field for pile driving sounds by measuring the signal with a precision sound level meter set to the "impulse" RMS setting ($RMS_{impulse}$). For this project, peak pressures and RMS sound pressure levels are expressed in decibels re 1 µPa. Table 1 includes the definitions of terms commonly used to describe underwater sounds.

Table 1 - Definitions of Underwater acoustical terms

TERM	DEFINITIONS
Peak Sound Pressure, unweighted (dB)	Peak sound pressure level based on the largest absolute value of the instantaneous sound pressure. This pressure is expressed in this report as a decibel (referenced to a pressure of 1 µPa) but can also be expressed in units of pressure, such as µPa or PSI.
RMS Sound Pressure Level, (NOAA-Fisheries Criterion) dB re 1 µPa	The average of the squared pressures over the time that comprise that portion of the waveform containing 90 percent of the sound energy for one pile driving impulse[1].
Sound Exposure Level (SEL), dB re 1 μPa^2 sec	Proportionally equivalent to the time integral of the pressure squared and is described in terms of μPa^2 sec over the duration of the impulse. Similar to the unweighted Sound Exposure Level (SEL) standardized in airborne acoustics to study noise from single events.
Accumulated Sound Exposure Level (SEL), dB re 1 μPa^2 sec	Same as above (SEL), but for one day of pile driving at a fixed position.
Waveforms, µPa over time	A graphical plot illustrating the time history of positive and negative sound pressure of individual pile strikes shown as a plot of µPa over time (i.e., seconds)
Frequency Spectra, dB over frequency range	A graphical plot illustrating the distribution of sound pressure vs. frequency for a waveform, dimension in RMS pressure and defined frequency bandwidth

[1] The underwater sound measurement results obtained during the Pile Installation Demonstration Project indicated that most pile driving impulses occurred over a 50 to 100 millisecond (msec) period. Most of the energy was contained in the first 30 to 50 msec. Analysis of that underwater acoustic data for various pile strikes at various distances demonstrated that the acoustic signal measured using the standard "impulse exponential-time-weighting" (35-msec rise time) correlated to the RMS (impulse) level measured over the duration of the impulse.

Measurement Equipment

Measurements will be made using hydrophones that have a flat frequency response and are omni-directional over a frequency range of 25 to 10,000 Hz. For example, Reson Model TC-4013 or Model TC-4033 hydrophones with PCB in-line charge amplifiers (Model 422E13) and PCB Multi-Gain Signal Conditioners (Model 480M122) or equivalent systems may be used to adjust the received signals to appropriately measure and record the large range of sound pressures that pile driving could generate. The signals will be fed into Integrating Sound Level Meters (SLM). Quality recordings using a digital audio recorder (either solid state or tape) would be made at times during attended measurements.

The peak pressure and SEL will be measured using a SLM. The SLM will have the ability to measure the unweighted peak sound pressure levels over the relative short periods (e.g., less than 50 milliseconds). The SLM can closely approximate the unweighted SEL of each pile strike, by measuring the one-second equivalent sound energy level (Leq [1-sec]) using the C-weighting network setting.

All measurement equipment used would be required to have a frequency response of $\pm$1dB from 10 Hz to 10,000 Hz over the anticipated measurement range of 170 to 210 dB linear peak re: 1 µPa. Hydrophones of different sensitivities may be required depending on the acoustic environment.

Quality Control

Calibration of measurement systems would be established prior to use in the field. An acoustical piston phone and hydrophone coupler would be used along with manufacturer calibration certificates. Calibration of measurement systems would be established in one of two ways:

1. Use an acoustically certified piston phone and hydrophone coupler that fits the hydrophone to directly calibrate the measurement system. In this case, 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.

2. The procedure described above is used to calibrate a “reference” hydrophone. The reference hydrophone is then replaced with the field hydrophone used to make actual measurements. Both the field and reference hydrophones would be required to have manufacturer calibration certifications that would include the hydrophone sensitivities. The sensitivity of the field hydrophone would be compared with the sensitivity of the “Reference” hydrophone. The

difference between the two hydrophones is the offset that would be applied to the measurements made using the "field" hydrophone. This procedure is used for different model hydrophones that do not fit the piston phone coupler. These types of hydrophones are typically more rugged, and therefore, may be preferable in construction environments. With this method, the response of the reference system to the calibration tone is noted in the field book along with the calculated "offset." The calibration is applied to all measurements made using the "field" hydrophone.

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 calibration notes, measurement positions, pile-driving information, system gain setting, and equipment used to make each measurement.

Some of the pile driving sounds would be recorded for subsequent analysis. Additional subsequent analyses of selected acoustical pulses will be performed using a Real Time Analyzer or equivalent signal processing equipment capable of providing 1/3rd octave band frequency and corresponding pressure over time analysis (waveform).

BIRD PREDATION MONITORING

Monitoring will be performed during all impact pile driving activities. The purpose of the monitoring will be to observe and record any occurrence of birds feeding on fish during and immediately following pile driving activities. A congregation of birds feeding on fish which appear near the surface of the water, concurrent with pile driving, can be assumed to be evidence of fish mortality and/or injury due to the underwater pressure wave generated during pile driving in open water. Monitors will be prepared to collect and release any fish impacted by pile driving for the purpose of species identification. In accordance with the Terms and Conditions of the NOAA-Fisheries 2009 Supplemental Biological Opinion for the SFOBB Project, if mortality of a green sturgeon or salmonid is observed, the fish will be collected, frozen and transferred to the NOAA-Fisheries Southwest Fisheries Science Center Santa Cruz Laboratory Tissue Repository within 30 days of collection. Monitoring during pile driving has several goals:

- Monitoring to confirm the presence or absence of bird predation as an indicator of fish mortality;
- Observation to gauge the magnitude of bird predation by quantifying the number of bird strikes per minute and the duration of the event;
- Identification of size and species of fish affected; and
- Collection and transfer of any dead green sturgeon or salmonids to NOAA-Fisheries.

Methods

Bird predation monitors will be located on a boat within 200 meters (656 feet) of the pile driving activity. Monitors will record bird feeding activity during pile driving on standardized data sheets (Attachment 1). If feeding is observed, one-minute counts of bird strikes will be initiated. These counts will be repeated throughout the duration of the monitoring period. Birds, such as gulls, that appear to scavenge fish from the surface will be recorded during each strike upon the surface. Diving birds which may be present, but which can not be confirmed to scavenge on injured fish while diving, will be noted on the data sheet but will not be included in the count of bird strikes.

Monitors will be prepared to identify the species and size of any dead or moribund fish, either through observation with binoculars, or by collection and release of specimens with a dip-net. In addition, general bird activity and behavior during pile driving and throughout the day will be noted and recorded.

REPORTING

Monitors will provide daily hydroacoustic and bird predation monitoring reports to Caltrans summarizing preliminary monitoring results. These daily monitoring reports will be forwarded by Caltrans to appropriate staff at NOAA-Fisheries and California Department of Fish and Game (CDFG) by close of business the day following monitoring. Reports will include the following:

- A description of hydroacoustic monitoring stations, including the number, location, distances and depths of hydrophones;
- The total number of pile strikes per day, the peak sound pressure level, and accumulated SEL per day for each hydroacoustic monitoring location; and
- Bird predation and behavior, and evaluation of fish mortality and injury through use of visual observation and collection.

Hydroacoustic and bird predation monitors will prepare a final monitoring report once construction of the T1 access trestle is complete. This report will be provided to NOAA-Fisheries and CDFG. The report will include the following:

- A list of pile driving activities conducted during the period including dates and times of pile driving;
- A summary of monitoring activities conducted during the period;
- Preliminary hydroacoustic data in terms of peak sound pressure and accumulated SEL measured for each pile and each distance; and
- A summary of bird predation activity during pile driving, including bird strike counts, size and species of fish observed to be dead or moribund, and the occurrence of any mortality of salmonids or green sturgeon, and the detail of collection for those species.

Attachment 1

Caltrans Bay Bridge Project - SAS Pile Driving
Bird Predation Monitoring and Fish Collection

Date: _____ Monitors: _____Start time:_____ End time: _____

Comments: _____
_____

		Pile Driving Duration					
Pile #	Method	Start Time	End Time	Bird Predation Observed (Y/N)	General Bird Activity/Behavior	Dead/Injured Fish Observed (Y/N)	Dead/Injured Fish Collected (Y/N)

Bird Predation Counts:

Time	Predation Count (#/1 minute)	Time	Predation Count (#/1 minute)	Time	Predation Count (#/1 minute)	Time	Predation Count (#/1 minute)	Time	Predation Count (#/1 minute)

Additional Observations: _____
_____
_____
_____
_____
_____

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