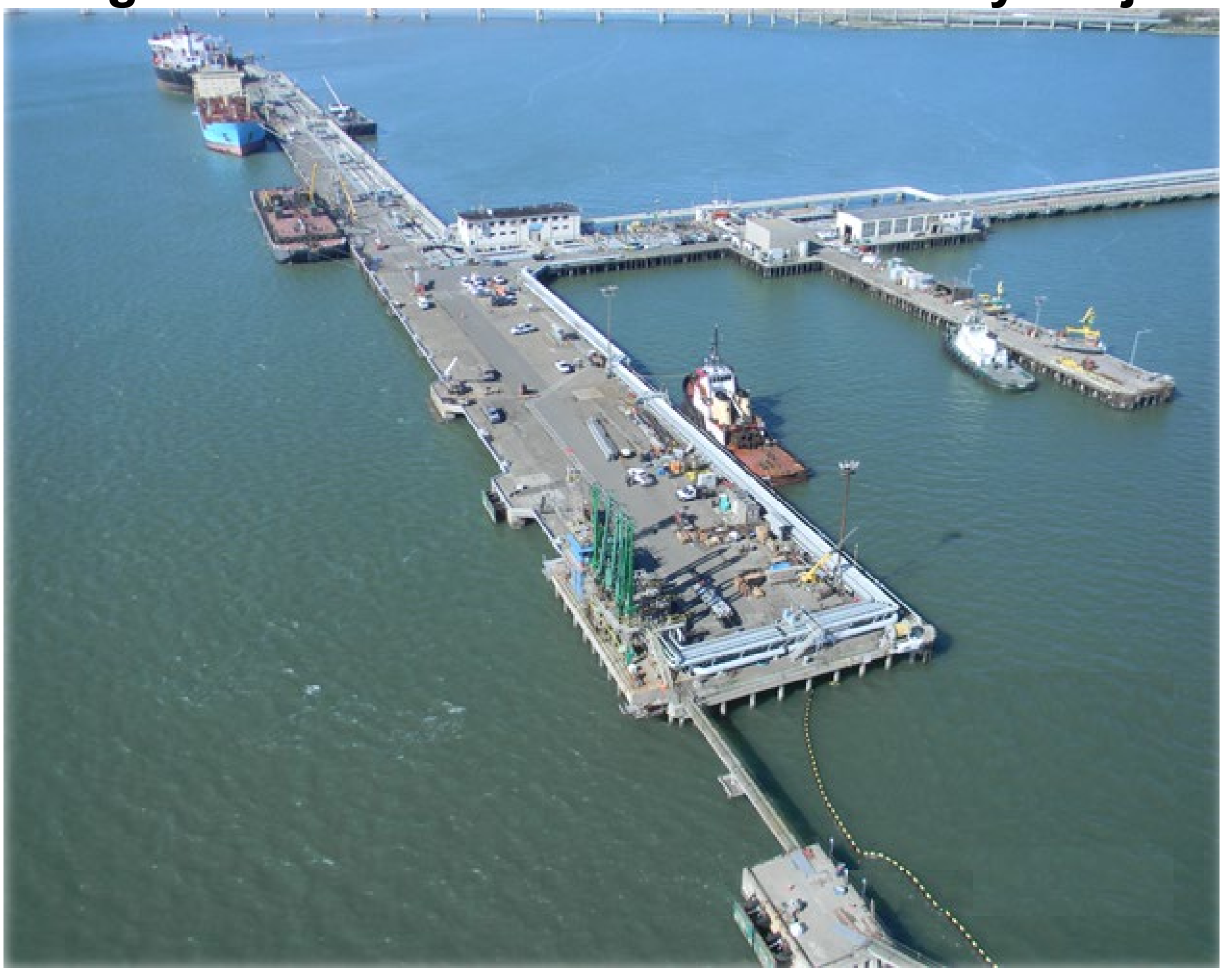
Hydroacoustic Monitoring Plan

Chevron Richmond Refinery
Long Wharf Maintenance and Efficiency Project



Chevron Richmond Refinery – Capital Projects

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TABLE OF CONTENTS

Page

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

CDF	Cumulative Distribution Function
CDFW	California Department of Fish and Wildlife
dB	decibel
Hz	Hertz
kHz	kilohertz
L_{eq}	Equivalent Sound Level
L_{max}	Maximum Sound Pressure Level
µPa	microPascal
msec	millisecond
NMFS	National Marine Fisheries Service
Peak	peak pressure
Plan	Acoustic Noise Monitoring Plan
RMS	Root Mean Square
SEL	Sound Exposure Level
SLM	sound-level meter
USFWS	U.S. Fish and Wildlife Service

Chapter 1
Introduction

The Chevron Richmond Refinery Long Wharf (RLW) is the largest marine oil terminal in California. The RLW has six berths for receiving raw materials and shipping final products, and has existed in its current location since the early 1900s (Figure 1). Marine loading arms and gangways were installed in 1972. Since then it has become increasingly difficult to obtain spare parts for these features. Changes in the vessel fleet (e.g., larger and taller vessels) since the original installation necessitated changes in the configuration of the loading arms and gangways.

The Berth 2 fender system (timber pile and whaler) was designed and installed in 1940. Marine loading arms, gangways, and fender systems at Berths 1, 3 and 4 were installed in 1972. The marine loading arms were recently replaced between 2016 and 2018. The Berth 4 fender panels were replaced in 2011 and the Berth 1 fender panels were replaced in 2012. The existing configuration of these systems have limitations to accepting more modern, fuel efficient vessels with shorter parallel mid-body hulls and in some cases do not meet current MOTEMS requirements. The Long Wharf Maintenance and Efficiency Project (LWMEP, Project) was designed to upgrade the Wharf to bring it to current codes.

Construction of the Project began in 2018 and was to be completed in 2-3 years. Since 2018, a number of items have been completed under previous IHAs, including installation of fendering systems and a seismic retrofit of Berth 4. The need for unanticipated and unscheduled dredging in 2019 prior to installing piles for the Berth 4 seismic retrofit caused a one-year delay in the Project. The 2020 COVID-19 pandemic, and associated work restrictions, have caused further schedule delays, pushing the completion date to 2021. The Project activities that require hydroacoustic monitoring include installation and extraction of piles using both vibratory and impact-driving methods.

Construction would be scheduled such that the Long Wharf remains operational during construction. Pile driving activities would occur within the standard NMFS work windows for listed fish species (June 1 through November 30). The Project's remaining pile driving and extraction, planned to occur during the 2021 work season, is provided in Table 1.

Table 1: Pile Driving Summary for 2021 Work Season

Pile Type	Pile Driver Type	Number of Piles	Number of Driving Days
Pile Driving:			
24-inch square concrete piles	Impact	9	8
14-inch composite piles	Vibratory	52	11
Pile Extraction:			
16-inch timber piles	Vibratory	106	9
14-inch steel H pile	Vibratory	36	6
36-inch steel pipe piles	Vibratory	8	2

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FIGURE 1
Chevron Richmond Long Wharf Project Location

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Chapter 2
Project Area and Pile Installation Location

The Long Wharf is located in central San Francisco Bay just south of the eastern terminus of the Richmond-San Rafael Bridge in Contra Costa County (see Figure 1). The United States Geological Survey Hydrologic Unit is San Francisco Bay (cataloging unit code 18050004).

The remaining modifications in 2021involve ongoing modifications at Berths 2 and 4 (Figure 1). Modifications at these berths include adding new standoff fenders, a mooring hook and adding protective barrier piles for the Berth 4 seismic retrofit. In addition, temporary piles and existing timber piles would be removed. The work to be done at Berths 2 and 4 is summarized below.

Berth 2 Modifications

The remaining modifications at Berth 2 include the following:

- Replace one bollard with a new hook.
- Install (4) new standoff fenders in Berth 2.
- Remove up to 106 existing ageing timber fender piles (approximately 16-inches in diameter) and 36 temporary 14-inch steel H piles would be removed, using vibratory methods.

Nine (9) 24-inch square concrete piles will be driven to support the standoff fenders. These modifications are shown on Figure 2.

Berth 4 Modifications

The remaining modifications at Berth 4 include the following:

- The Project will add 4 clusters of 13 composite piles 14-inches in diameter (52 total composite piles) as markers and protection for the new 60-inch seismic retrofit batter piles on the east side of Berth 4 that were installed in 2020. Features are shown on Figure 3.

Up to eight (8) 36-inch steel piles that were used to support temporary templates for the Berth 4 seismic retrofit will be removed using vibratory methods.

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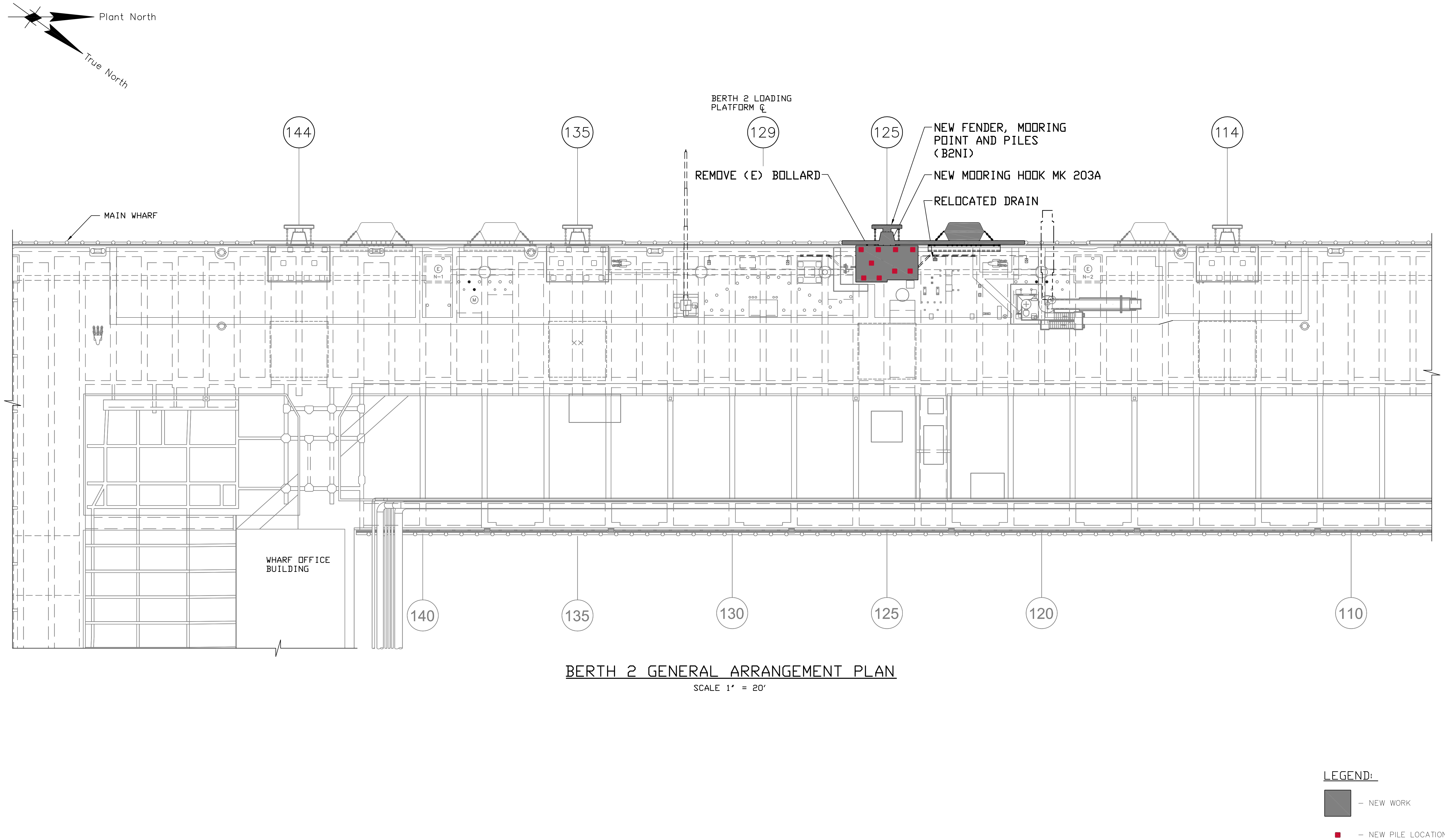

BERTH 2 GENERAL ARRANGEMENT PLAN

SCALE 1" = 20'

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FIGURE 2

Berth 2 Features

Source: Moffat & Nichol Engineers, 2015

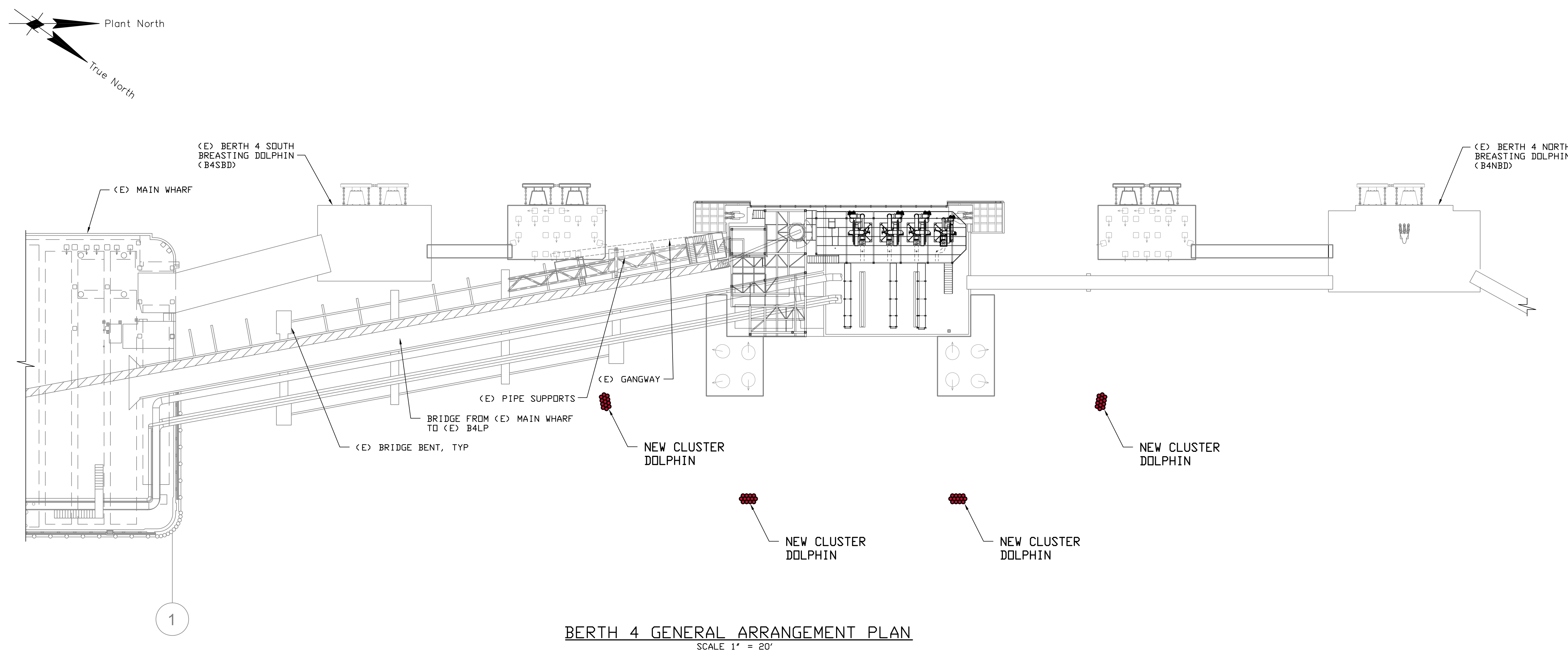

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FIGURE 3

Berth 4 Features

Source: Moffat & Nichol Engineers, 2015

Chapter 3
Permit/Endangered Species Act Conditions

Specific to pile-driving activity that are presented in the Biological Assessment to reduce project effects on sensitive resources include:

- Pile driving, which could result in take of listed species, would, to the extent practical, comply with standard long-term management strategy windows (June 1 through November 30) to avoid periods when the most sensitive life stage of the majority of these species occurs in the Bay;
- Vibratory hammers would be used to drive non-structural piles to reduce noise impacts;
- Piles driven with an impact driver would employ a “soft start” technique to give fish an opportunity to move out of the area before full-powered impact driving begins; and
- Bubble curtains will be used during impact driving of the 24-inch concrete piles.

Chapter 4
Pile Extraction and Installation Monitoring

The purpose of the acoustic monitoring plan (Plan) is to collect underwater sound-level information at both near and distant locations during vibratory pile extraction and installation and impact pile installation. The Plan provides a protocol for hydroacoustic measurements during pile extraction and driving operations.

The Plan has the following objectives:

1. Measure underwater sounds generated from project activities to verify modeled harassment, adverse physiological effects, or behavior disturbance zones for marine mammals and fish.

    a. Levels of harassment for marine mammals are defined in the Marine Mammal Protection Act of 1972, as follows:

        i. Level A: Updated NOAA guidance on assessing the effects of underwater noise on marine mammals for agency impact analysis was adopted in 2016. The 2016 guidance includes sound thresholds for slight injury to an animal's hearing, or PTS (Level A Harassment). The underwater sound pressure threshold for slight injury or PTS (Level A harassment) is a dual metric criterion for impulse noise (e.g., impact pile-driving), including both a peak pressure and cSEL threshold, which is specific to the species hearing group (i.e., high-frequency cetaceans [i.e., harbor porpoise], mid-frequency cetaceans [i.e., bottlenose dolphin], low-frequency cetacean [i.e., gray whale], phocids [i.e., Pacific harbor seal and northern elephant seal], and otariids [i.e., California sea lion and northern fur seal]). For continuous noise (e.g., vibratory pile extraction or driving), the PTS threshold is based on cSEL for each species hearing group.

        ii. Level B: Level B is defined as "Any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to migration, breathing, nursing, breeding, feeding, or sheltering." The Level B harassment thresholds for both cetaceans and pinnipeds are 160 dB re: 1 μPa RMS for impact pile driving, and 120 dB re: 1 μPa RMS for vibratory pile driving.

    b. Zone of adverse physiological and behavioral effects to fish species:

        i. On June 12, 2008, the National Marine Fisheries Service (NMFS); the U.S. Fish and Wildlife Service (USFWS); California, Oregon, and Washington Departments of

Transportation; the California Department of Fish and Game (now called the California Department of Fish and Wildlife); and the U.S. Federal Highway Administration agreed in principle to interim criteria to protect fish from pile driving activities. The agreed-upon threshold criteria for impulse-type noise to harm fish have been set at 206 dB re: 1 μPa peak, as well as 187 dB re: 1 μPa^2 per second accumulated sound exposure level (SEL) for fish over 2 grams (0.07 ounce).

ii. Threshold for potential adverse behavioral effects to fish species: NMFS considers sounds of 150 dB re: 1 μPa to potentially affect fish behavior.

2. Compute the rate that sounds drop off with distance from the source (spreading loss) so that, along with measured levels, impact zones described in (1) above can be estimated. This plan includes the methodology to:
   a. Achieve acoustic measurements for both the stationary and vessel-based hydrophones at appropriate locations.
   b. Record information that will be vital to the success of the plan's implementation (i.e., timing of data collection, environmental conditions, and information the acoustic engineer shall gather from the contractor).
3. Describe post-analysis procedures for the following:
   a. Sound level signal processing
   b. Data analysis
   c. Reporting

The majority of pile types to be installed or removed were monitored in prior years of the project, the only pile installation to be monitored in 2021 are the 14-inch composite piles, which will be installed with a vibratory driver. Hydroacoustic monitoring would be conducted for two of the 14-inch composite pile installations. The removal of two timber piles via vibratory extraction would also be monitored. Piles chosen to be monitored will be representative of mid-channel or typical water depths where piles will be driven.

The location of the specific piles to be monitored and the approximate hydrophone locations for each pile being monitored will be determined in the field with the approval of the Project Engineer. At each location, a hydrophone will be positioned at one depth, with a clear line-of-sight between the pile and the hydrophone at the following distances:

1. As close as feasible to10 meters;

2. Between 20 meters and 50 meters (depending on water depth at the pile);[1] and
3. Between 200 meters and 1,000 meters at mid-water column depth measured concurrently with the close-in measurements (i.e., 10-meter and 20- to 50-meter) to estimate the site-specific transmission loss.

[1] The distance from the pile will be approximately three times the water depth.

Chapter 5
Contractor Requirements

The contractor will submit a detailed description of their qualifications, which must include a minimum of a bachelor's degree in a related field and 3 years' experience in noise monitoring and analysis, and monitoring plan based on this template for approval by NMFS. A list of the contractors' proposed sound level monitoring equipment shall be included along with specifications and a description of the purpose. The measurement range in terms of amplitude (in decibels (dB) referenced to one micropascal (re: 1 uPa)), sensitivity and frequency shall be stated. A minimum frequency range of 20 Hz to 20 kHz and a minimum sampling rate of 44,000 Hz will be used when monitoring. The following methodology section describes the minimum requirements of the procedures and equipment to be used. In addition to the equipment selection, quality control/quality assurance procedures should be described (e.g., how will system responses be verified and how will data be managed).

Table 3 details the equipment specifications that will be adhered to during measurement of sound-pressure levels.

To facilitate further analysis of data, full bandwidth, time-series underwater signals shall be recorded as a text file (.txt), wave file (.wav), or similar format. Recorded data shall not use data compression algorithms or technologies (e.g., MP3, compressed .wav, etc.).

Table 2
Equipment Specifications for Sound Monitoring

Item	Approximate Specifications	Quantity	Usage
Hydrophone	Receiving Sensitivity 211 dB ± 3 dB re 1 V/μPa OR 203 dB + 2 dB re 1 V/μPa	3	Capture underwater sound pressures and convert to voltages that can be recorded/analyzed by other equipment. The more sensitive hydrophone would be used to measure distant sounds or background levels
Signal Conditioning Amplifier	Amplifier Gain 0.1 mV/pC to 10 V/pC Transducer Sensitivity Range 10^{12} to 10^{3} C/MU	3	If necessary, used to adjust signals from hydrophone to levels compatible with recording equipment.
Calibrator (pistonphone- type)	Accuracy conforms IEC 942 (1988) Class 1	1	Calibration check of hydrophone and microphones in the field.
SLM and Solid State Recorder (SSR)	ANSI S1.4-1983 Type 1 SLM Sampling Rate >48 KHz	3 SLMs 3 SSR	Measure and record acoustic data.
Laptop Computer	Compatible with digital analyzer	1	Store and analyze digital data
Real Time and Post-Analysis software	NA	1	Monitor real-time signal and post-analysis of sound signals

Chapter 6
Methodology

6.1 Underwater Measurements

Three locations are proposed for hydrophone systems to record sound; the data would be used to compute the spatial sound-level decrease. Measurements would be taken at one depth: the mid-water column, or at least 3 feet above the bottom. One hydrophone will be located 10 meters from the pile being driven. The second hydrophone will be located between 20 and 50 meters from the pile being driven, maintaining a clear line-of-sight between the pile and the hydrophones, and allowing a measurement at a distance equal to three times the water depth at the pile. The third hydrophone will be placed from a vessel at mid-water column depth at a distance between 200 and 1,000 meters from the pile, to assist in finding the marine mammal Level B harassment zone for both impact and vibratory pile driving.

Either a depth finder or 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. 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 verified by a tape measure, where possible, or a range finder. To the extent practicable, there will be a direct line-of-sight between the pile and the hydrophones.

Appropriate measures will be taken, when necessary, to ensure that the flow-induced noise at the hydrophone will not interfere with the recording and analysis of the relevant sounds. As a general rule, current speeds of 1.5 meters/second or greater are expected to generate significant flow-induced noise, which may interfere with the detection and analysis of low-level sounds such as the sounds from a distant pile driver or background sounds.

Background underwater sound levels will be measured for at least 1 minute prior to initiation of pile extraction or installation, as well as in the absence of construction activities during other periods of monitoring days. These background levels would be used to assist in the interpretation or filtering of recorded pile driving noise, and would not be utilized to modify the marine mammal harassment zones. Background levels will be reported as RMS, and a spectral analysis of the frequencies will be developed. The inspector/contractor will need to inform the acoustics specialist when pile driving is about to start to ensure proper measurements are taken.

Underwater sound levels will be continuously monitored for the duration of pile extraction or installation. NMFS Northwest Region has defined the estimated auditory bandwidth for marine mammals. For this project location, the functional hearing groups are low-frequency cetaceans (gray whales), high-frequency cetaceans (harbor porpoises), and pinnipeds (California sea lions and harbor seals). For pile driving, the majority of the acoustic energy is confined to frequencies below 2 kilohertz (kHz), and there is very little energy above 20 kHz.

For impact pile-driving, the Peak, impulse RMS[2], and SEL levels of each strike will be monitored in real time using sound-level meters (SLMs). The $SEL_{cumulative}$ will be subsequently computed. The impact pile driving pulse RMS levels[3] will be subsequently measured from recordings. Vibratory monitoring data will be analyzed by calculating 10-second RMS values for every 10 seconds for each pile. The 10-second RMS values will be linearly averaged for the entire pile and reported as the average RMS. The average RMS will be calculated for each marine mammal functional hearing group described above.

6.2 Other Measurements

Prior to and during the pile extraction or driving monitoring, 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., presence of aircraft, boats that could influence underwater sound levels). Start and stop times of each pile-driving event will be recorded.

The inspector/contractor will inform the acoustics specialist when pile driving is about to start to ensure that the monitoring equipment is operational. Sound levels will be continuously monitored during the entire duration of each pile drive. Peak levels of each strike will be monitored in real time.

The Project Engineer will provide the acoustics specialist with a description of the substrate composition, approximate depth of significant substrate layers, hammer model and size, initial hammer energy settings and any changes to those settings during the pile-driving monitoring, depth the pile was driven, blows per foot for the piles monitored, and total number of strikes to drive each pile that is monitored.

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2 Impulse levels is the maximum RMS of the instantaneous sound pressure measured over a 0.035 second period that is measured by a sound level meter.

3 Pulse RMS level is RMS of the sound pressure measured over a time period where 90 percent of the pile strike's acoustic energy occurs.

6.3 Calibration

Calibration of measurement systems shall be established prior to use in the field each day. NIST traceable calibration forms shall be provided by the contractor for all relevant monitoring equipment. An acoustical piston phone and microphone or hydrophone coupler would be used along with manufacturer calibration certificates. An acoustically certified piston phone and coupler that fits the hydrophone or microphone would directly calibrate the measurement system. The volume correction of the coupler for each hydrophone or microphone would be known so that the piston phone would produce a known signal that would be compared against the measurement system response. The response of the measurement system would then be noted in the field book and applied to all subsequent measurements.

For underwater acoustic recordings, 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 onto the beginning of the digital audio recordings that will be used. The system calibration status is 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.

6.4 Signal Processing

Post-signal analysis should only be required for impact pile-driving. SLMs are anticipated to provide direct measurements of L_{max} and L_{eq} sound-pressure levels for underwater vibratory pile-driving. Post-signal analysis of the underwater impact sound-level signals will include measurement of the maximum absolute value of the instantaneous pressure in each strike, pulse RMS sound pressure level and duration for each pile strike, median, mean and standard deviation of the RMS for all pile strikes of each pile, the SEL per strike, median, mean and standard deviation of the SEL for all pile strikes of each pile, and the $SEL_{cumulative}$ for each pile. A frequency spectrum between 20 and 20,000 Hz for up to eight successive strikes with similar sound levels would be prepared and reported.

Post-analysis of the underwater pile-driving sounds will include:

- Number of pile strikes per pile and per day;
- For each recorded strike (or each strike from a subset), report the following:
    - The peak pressure, defined as the maximum absolute value of the instantaneous pressure (overpressure or underpressure);

- The RMS sound pressure across 90 percent of the pile strike's acoustic energy (pulse RMS),
- The pulse duration used to compute the pulse RMS sound pressure level, and
- SEL, measured across the accumulated sound energy during pile strikes (AppendixA);

- Maximum, median, mean, and range of the peak pressure—with, and if applicable, without—attenuation;

- Maximum, median, mean, range, and Cumulative Distribution Function (CDF) of the pulse RMS, with—and if applicable, without—attenuation, where the CDF is used to report the percentage of pulse RMS or $RMS_{impulse}$ values above the thresholds;

- Maximum, median, mean, and range of cumulative 187 and 183 dB SEL, with—and if applicable, without—attenuation;

- The accumulated SEL ($SEL_{cumulative}$) across all of the pile strikes for each pile measured; if SEL is to be calculated based on the number of strikes, $SEL_{cumulative}$ is estimated as follows: $SEL_{cumulative} = SEL_{mean} + 10*\log(\text{total \# strikes})$, including unweighted cumulative SEL used to assess impacts to fish and weighted cumulative SEL for the various marine mammal hearing groups that may be present, following NMFS noise exposure guidance;

- Where surrogate piles are monitored to represent a larger project, an estimate of the accumulated SEL during a typical day of construction driving would be reported by summing the SEL over the expected number of pile strikes in a typical day for the larger project: $SEL_{cumulative} = SEL_{mean} + 10*\log(\#strikes)$; the SEL_{mean} used in this calculation must correspond with the actual sound-attenuation measures that will be used during construction of the larger project; and

- A frequency spectrum with and without attenuation (if noise-attenuation-system testing is conducted), between a minimum of 20 and 20,000 Hz for up to eight successive strikes with similar sound levels.

- For vibratory driving, the maximum and median RMS calculated from 10-second RMS values during the drive of each pile.

- For vibratory driving, the maximum and median 1-second SEL will be calculated for the driving of each pile.

Chapter 7
Analysis

The RMS values for this project will be computed sometime between where 5 percent and 95 percent of the energy of the pulse occurs. In addition, a waveform analysis of the individual absolute peak pile strikes will be performed to illustrate any effects to the waveform with the use of bubble curtains. The frequency content with the bubble curtain will be presented.

Chapter 8
Reporting

A draft report, including data collected and summarized from all monitoring positions, will be submitted to the USFWS and NMFS within 60 days of the completion of acoustic monitoring. The results will be summarized in graphical form and will include summary statistics and time histories of impact sound values for each monitored pile. A final report will be prepared and submitted to the USFWS and NMFS within 30 days following receipt of comments on the draft. Figure 4 shows a sample template of the data to be collected. The report shall include:

1. The size and type of piles removed and installed;
2. Number of strikes or driving time for each pile and per day;
3. A detailed description of the bubble curtain or other noise attenuation device used, including design specifications;
4. The make, model, and energy rating of the impact hammer used to drive the piles;
5. A description of the sound monitoring equipment used;
6. The distance between hydrophone(s) and microphone(s) and pile;
7. The depth of the hydrophone(s) and depth of water at hydrophone locations;
8. The depth of water in which each pile was driven;
9. The depth into the substrate that each pile was driven;
10. The physical characteristics of the bottom substrate into which the piles were driven;
11. Calibration notes as described in Sections 6.3.
12. The background sound-pressure level reported as the 50 percent cumulative distribution function;
13. One-third band spectrum and power spectral density plot;
14. The results of the hydroacoustic monitoring as described in Section 6.4, including the frequency spectrum, ranges, medians and means (including standard deviation for Peak and

pulse RMS sound-pressure level (for impact pile driving) and associated pulse duration, single-strike, and $SEL_{cumulative}$); and

15. An estimate of the distance at which the Peak and $SEL_{cumulative}$ values reach their respective thresholds for fish, and the distance at which the RMS and $SEL_{cumulative}$ values reach the relevant marine mammal thresholds and background sound levels.

Date and Time	Pile ID	Hammer Type	# Strikes/ Seconds Driving	Hydrophone Distance from Pile/ depth (m)	Water Depth (m)		Peak (dB)		$SEL_{90\%}$ (dB)			$RMS_{90\%}$ (dB)			Notes
					At Pile	At H-phone	Max	Mean/ Median	Max	Mean/ Median	SEL cumulative	Max	Mean/ Median	Duration	

Figure 4 Example Table for Required Information for Reporting the Results of Hydroacoustic Monitoring of Pile Driving

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Chapter 9
References

FHWG (Fisheries Hydroacoustic Working Group), 2008. Agreement in Principle for Interim Criteria for Injury to Fish from Pile Driving Activities. June 12.

Illingworth and Rodkin, Inc., 2001. Noise and Vibration Measurements Associated with the Pile Installation Demonstration Project for the San Francisco-Oakland Bay Bridge East Span, Final Data Report, Task Order 2, Contract No. 43A0063.

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Appendix A

Calculation of Cumulative SEL

An estimation of individual SEL values can be calculated for each pile strike by calculating the following integral, where T is T_{90}, the period containing 90% of the cumulative energy of the pulse (eq. 1).

$$SEL = 10\log\left(\int_0^T \frac{p^2(t)}{p_0{}^2}dt\right) \quad dB \qquad \text{(eq. 1)}$$

Calculating a cumulative SEL from individual SEL values cannot be accomplished simply by adding each SEL decibel level arithmetically. Because these values are logarithms they must first be converted to antilogs and then accumulated. Note, first, that if the single strike SEL is very close to a constant value (within 1 dB), then cumulative SEL = single strike SEL + 10 times log base 10 of the number of strikes N, *i.e.,* $10Log_{10}(N)$. However if the single strike SEL varies over the sequence of strikes, then a linear sum of the energies for all the different strikes needs to be computed. This is done as follows: divide each SEL decibel level by 10 and then take the antilog. This will convert the decibels to linear units (or $uPa^2 \bullet s$). Next compute the sum of the linear units and convert this sum back into dB by taking $10Log_{10}$ of the value. This will be the cumulative SEL for all of the pile strikes.