PIER 62 PROJECT
ACOUSTIC MONITORING SEASON 1 (2017/2018) REPORT
(NWS-2016-WRD, WCR-2016-5583, 01EWF00-2016-F-1325)

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1.0 EXECUTIVE SUMMARY

This Technical Report presents the results of airborne and underwater sound level measurements conducted during the removal of two steel piles and 63 timber piles with a vibratory hammer during Season 1 (2017/2018 in-water work window) of the Pier 62/63 Replacement Project (“Project”).

Average unweighted underwater 10-second root mean square (RMS) sound levels generated by the removal of steel and timber piles ranged between 140 and 169 decibels (dB) re: 1 micropascal (μPa) and peak values ranged between 156 and 184 dB re: 1 μPa. Measured underwater sound levels for each marine mammal hearing group and unweighted sound levels are summarized in Table 1.1 below.

Table 1.1 Average Underwater Sound Levels, dB re: 1 μPa

Noise Metric	Unweighted	LF-Cetaceans	MF-Cetaceans	HF-Cetaceans	Phocid pinnipeds	Otariid pinnipeds
Peak	156-184	156-184	156-184	156-184	156-184	156-184
RMS	140-169	129-160	134-163	135-163	127-155	125-153
SEL	150-179	139-170	144-173	145-173	137-165	135-163

Note: Reported sound levels are normalized to 33 feet (10 meters) from piles using the practical spreading model.

Median 1-second unweighted RMS airborne sound levels ranged between 72 and 106 dB re: 20 μPa at 50 feet (15 meters) from pile removal activities. Generally, airborne sound levels during Season 1 were below the levels assumed in the Project’s Request for Incidental Harassment Authorization (IHA) under the Marine Mammal Protection Act (MMPA).

Based on the highest average weighted RMS sound levels measured during vibratory pile removal (163 dB re: 1 µPa HF Cetaceans) and marine mammal threshold criteria, the distance required for underwater sound levels to reach the marine mammal injury threshold (Level A) is up to 392 feet (120 meters) for high frequency cetaceans. This distance is farther than the anticipated distance of 84 feet (26 meters), however no species within this category were observed. Up to 24,136 feet (7,356 meters) may be needed to reach the marine mammal disturbance threshold (Level B) of 120 dB re: 1 μPa. Airborne sound levels are expected to reach the 90 dB re: 20 μPa disturbance threshold for harbor seals 50 feet (15 meters) from pile removal and reach the 100 dB re: 20 μPa disturbance threshold for other pinnipeds at a distance of 16 feet (5 meters).

Background sound levels were also measured in the absence of in-water construction activities, as summarized in Table 1.2.

Table 1.2 Background Sound Levels, dB re: 1 μPa

Hearing Group	Median Background Sound Level	Distance to Background
LF Cetaceans	118	19,641 feet (5,986 meters)
MF Cetaceans	121	21,405 feet (6,524 meters)
HF Cetaceans	121	19,610 feet (5,977 meters)
Phocids	115	14,337 feet (4,370 meters)
Otariids	115	11,299 feet (3,444 meters)

Utilizing the highest average 10-second RMS underwater sound levels measured during vibratory pile removal (163 dB re: 1 µPa) and median background sound levels, a distance up to 21,405 feet (6,524 meters) could be needed for sound from pile removal to reach background sound levels.

2.0 INTRODUCTION

This Technical Report presents the results of airborne and underwater sound levels measured during the removal of two steel piles and 63 timber piles with a vibratory hammer during Season 1 (2017/2018 in-water work window) of the Pier 62/63 Replacement Project ("Project").

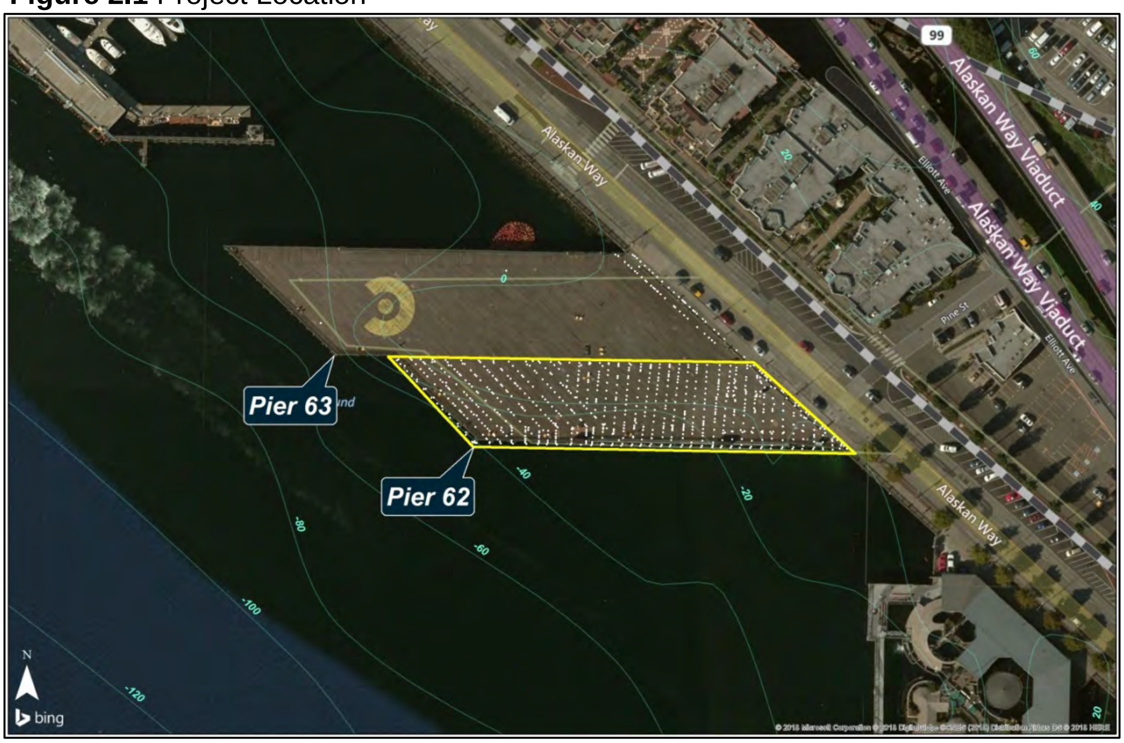
Consultation with the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service (USFWS) under the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) required airborne and underwater noise monitoring during two days of each pile driving method, or if multiple hammers will be used, each combination of driving methods. This Acoustic Monitoring Technical Report fulfills the requirements of the Project's Biological Opinion issued by NOAA and USFWS, and the MMPA Incidental Harassment Authorization (IHA), issued by NOAA.

The Project area is located at Pier 62/63 on Alaskan Way near Pine Street in Seattle, Washington (see Figure 2.1). Measurements of airborne and underwater sound levels were conducted on January 19 and January 22, 2018 during the removal of steel and timber piles with a vibratory hammer. Due to the short duration between pile extractions, the hydrophones were not able to be relocated between each pile extraction. As a result, not all the hydroacoustic measurements were able to establish an unobstructed acoustical transmission path or a 33 foot (10 meter) measurement distance from the piles.

Background sound levels were also measured approximately 5,419 feet (1,651 meters) northwest of the construction area. These measurements were used to calculate the distance needed for underwater sound levels from pile removal to reach the background sound levels in Elliott Bay.

One day of marine mammal monitoring occurred on December 29, 2018. Monitoring resumed on January 19, 2018, which coincided with the beginning of acoustic monitoring.

Figure 2.1 Project Location



3.0 NOMENCLATURE

The auditory response to sound is a complex process that occurs over a wide range of frequencies and intensities. Decibel levels, or “dB,” are a form of shorthand that compresses this broad range of levels with a convenient, logarithmic scale.

Decibels are defined as the squared ratio of the sound pressure level (SPL) with a reference sound pressure. The reference pressure for airborne sound is 20 micropascals (μPa) and for underwater sound the reference pressure is 1 μPa. The use of 20 μPa in air is convenient because 1 dB re: 20 μPa correlates to the human threshold for hearing. It is important to note that because of these different reference pressures, airborne and underwater sound levels cannot be directly compared.

The following descriptors are referenced in this Report:

- **Background Sound Level**

  The background sound level is the sound pressure level that describes the sound environment at a specified location during a specified time period and is also referred to as “ambient sound levels”. The measured sound levels include contributions from all sound sources, both local and distance, excluding specific sound sources of interest or under investigation.

- **Peak**

  The peak sound pressure level is the instantaneous absolute maximum pressure observed during a measured event. Peak pressure can be presented as a pressure or dB referenced to a standard pressure (20 μPa for airborne and 1 μPa for underwater).

- **Root Mean Square (RMS)**

  The RMS level is the square root of the average squared-pressure over a given time period. For vibratory pile driving RMS levels are calculated over 10 second periods. In hydroacoustics, the RMS level has been used by the National Marine Fisheries Service (NMFS) in criteria for assessing impacts to marine mammals.

- **Sound Exposure Level (SEL)**

  The SEL is the squared sound pressure integrated or summed over time referenced to a standard pressure squared (20 μPa for airborne and 1 μPa for underwater) normalized to one second and converted to decibels.

- **Cumulative Sound Exposure Level (cSEL)**

  The cSEL is the SEL accumulated over time. In this report cSEL is calculated by combining the individual SEL values.

4.0 REGULATORY CRITERIA

Anticipated underwater sound levels 33 feet (10 meters) from pile driving are listed in the Project's Biological Opinion and are provided in Table 4.1 below.

Table 4.1 Predicted Underwater Sound Levels

Pile Type	Installation/Removal	Source Sound Levels (RMS)
Installation		
30-inch Steel Pile	Vibration	177[1]/180[2]
30-inch Steel Pile	Impact	189
Removal		
14-inch Timber Pile	Vibration	152[1]/155[2]

1. One pile driven at a time.
2. Two piles driven simultaneously.

Marine Mammal Monitoring Plan for the Pier 62 Project (May 23, 2017)

The Project's IHA and Biological Opinion require hydroacoustic monitoring for at least two days of each pile type and driving method shown in Table 4.1 above. At least two hydrophones and one microphone are required and must have a direct line of acoustic transmission between the hydrophones and piles whenever possible.

Reported sound levels from underwater noise monitoring must include frequency spectra for each marine mammal hearing group outlined in the NOAA 2016 Guidance as well as the range, standard deviation and average of 10-second RMS and peak sound pressure levels for each marine mammal hearing group normalized to 33 feet (10 meters) from the piles. These sound levels must be used to estimate the distances at which RMS values reach relevant marine mammal disturbance and injury thresholds as well as background sound levels.

The NMFS Biological Opinion requires reporting of the range and average unweighted RMS sound levels from airborne measurements and the estimated distance for airborne sound to attenuate to species specific criteria, which are included in the Project's Request for Incidental Harassment Authorization under the Marine Mammal Protection Act for harbor seals and other pinnipeds. Airborne sound levels are to be normalized to 50 feet (15 meters) from pile driving or removal activities and the frequency spectra between 10 Hz and 20 kHz must also be reported.

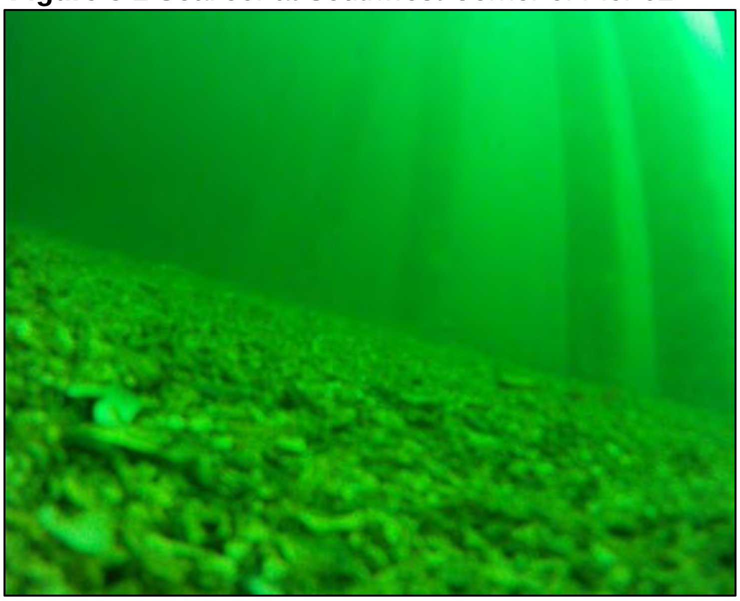
Additionally, the size and type of piles, description of any noise attenuation used, description of the vibratory or impact hammers, description of sound monitoring equipment, distance between the hydrophones, depth of water at the monitoring and pile locations, depth of the hydrophones, distances from the piles to the water's edge, depth into the substrate the piles were driven into and the physical characteristics of the substrate must be reported.

Measurements of underwater background sound levels are also required by the Project's IHA and Biological Opinion. The location of background sound level measurements should be between 1 and 1.5 kilometers away from construction activities in the absence of in-water work, was discussed in an email from NOAA on August 15, 2017. The Project's Incidental Harassment Authorization (IHA) requires these background measurements to follow the NMFS's 2012 Guidance Document "Data Collection Methods to Characterize Underwater Background Sound Relevant to Marine Mammals in Coastal Nearshore Waters and Rivers of Washington and Oregon."

5.0 PILE AND PILE DRIVING EQUIPMENT INFORMATION

During Season 1, all pile removal during hydroacoustic monitoring was initiated with a vibratory extractor suspended from an excavator. Prior to pile extraction the decking and stringers were removed to expose the top of the piles. The vibratory extractor was used to extract the exposed piles several feet before the hammer was put down by the excavator and the piles were lifted onto a barge for disposal. The vibratory hammer was typically used between 20 and 60 seconds per pile. Piles ranged in length from 35 to 75 feet and were embedded 15 to 30 feet into the seafloor. Generally, the substrate the piles were extracted from was hard, rocky and covered with silt and marine debris. A photo of the seafloor near the southwest corner of Pier 62 is provided in Figure 5.1.

Figure 5.1 Seafloor at Southwest Corner of Pier 62



An ICE Model 28B Hydraulic Vibratory Driver/Extractor was used to remove the steel and timber piles. The ICE Model 28B operates at a maximum frequency of 1,700 VPM with a maximum line pull for extraction of 54 tons. The suspended weight of the driver without hoses or clamp is 7,750 pounds. A cut sheet of the ICE Model 28B Vibratory Driver/Extractor can be found in the Appendix of this Report.

Piles removed during acoustic monitoring were between 175 feet and 240 feet (53 to 73 meters) from the water's edge. During pile removal, water depth at the pile locations ranged between 34 feet and 45 feet (10 to 14 meters).

6.0 PILE REMOVAL MEASUREMENT METHODOLOGY

6.1 Equipment

Equipment used to collect airborne sound data during the removal of steel and timber piles with the vibratory pile driver are identified in Table 6.1.

Table 6.1 Airborne Sound Measurement Equipment

Make and Model	Quantity	Description	Serial Number
Brüel & Kjaer Type 2250	1	Sound Level Analyzer	3006756
PCB 426E01	1	Preamplifier	47476
Brüel & Kjaer 4189	1	Microphone	2550228
Brüel & Kjaer 4231	1	Acoustic Calibrator	2545696

Table 6.2 identifies equipment used to monitoring underwater sound levels during vibratory removal as well as background sound levels.

Table 6.2 Hydroacoustic Monitoring Equipment

Make and Model	Quantity	Description	Serial Number
Brüel & Kjaer Type 2270	1	Sound Level Analyzer	2679351
Reson TC-4013	3	Hydrophone	2513032
			0712213
			0515084
Brüel & Kjaer Type 2647-A	2	Charge Converter (1 mV/pC)	2638260
			2638259
Brüel & Kjaer Type 2647-B	1	Charge Converter (10 mV/pC)	3019408
G.R.A.S. Type 42AC	1	Pistonphone	201835
Brüel & Kjaer 1704-A-002	1	Signal Conditioner	101161
NTi Audio ICP Adaptor	1	ICP Power Supply	-
Tascam DR-100MKII	1	Digital Audio Recorder	0460561
Tascam DR-100MKIII	1	Digital Audio Recorder	1690316

All measurement equipment used to monitor airborne and underwater sound levels were factory calibrated within 1 year of the measurement date. Calibration tones were also recorded before and after each day of monitoring for verification of calibration factors used during post-processing. Microphones were calibrated using the Brüel & Kjaer 4231 acoustic calibrator and the G.R.A.S. pistonphone was used to calibrate the hydrophones.

Airborne sound levels were monitored using the Brüel & Kjaer 2250 which recorded a WAV file at a sample rate of 48,000 samples per second for subsequent signal analysis. Underwater sound levels measured during vibratory pile removal were measured using two Reson TC-4013 hydrophones connected to Brüel & Kjaer Type 2647-A charge converters and Brüel & Kjaer 1704-A-002 signal conditioner. The signal conditioner was connected to the Tascam DR-100MKII digital audio recorder, which recorded the signal as a WAV file at a sample rate of 48,000 samples per second to allow for post processing of the audio signals. The Brüel & Kjaer Type 2270 was used to allow for real-time approximations of peak and cSEL sound levels while the measurements were being performed. The Brüel & Kjaer Type 2270 was only used to measure real-time sound levels from the lower hydrophone. The lower hydrophone was selected based on measurements made during the Elliott Bay Seawall Project, which showed sound levels from the deeper hydrophone were typically louder than those from hydrophones located at shallower depths. Photos of the airborne and underwater measurement equipment used to measure the vibratory pile extractions are provided in Figure 6.1 and Figure 6.2.

Figure 6.1 Airborne Monitoring Equipment

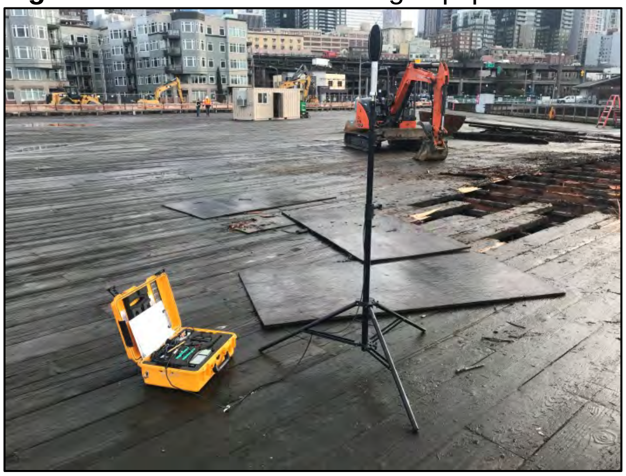


Figure 6.2 Hydroacoustic Equipment

6.2 Measurement Locations

Airborne sound levels were measured approximately 50 feet (15 meters) from each extracted pile. The distances between the microphone and the piles were determined using a laser distance measurement device. During the measurements the microphone was located 5 to 7 feet (1.5 to 2 meters) above the Pier and a direct line of site was maintained between the microphone and piles throughout the duration of each pile removal.

The hydrophones were lowered to appropriate measurement depths and secured to Pier 62. Due to the short duration between pile extractions (often less than 20 seconds), hydrophones were only able to be relocated when the vibratory hammer was not in use or the previously extracted piles were being placed on the barge. As a result, hydrophones were unable to maintain an unobstructed acoustical transmission path or a 33 foot (10 meter) distance from all the piles at all times. However, care was taken in selecting the monitoring locations to maximize the number of unobstructed piles and the number of piles located approximately 33 feet (10 meters) from the hydrophones.

The distance between the monitoring locations and the piles were verified using a laser distance measurement device. Water depth at all hydroacoustic measurement locations were measured prior to deploying the hydrophones. In addition to the water depth measurements made prior to the deployment of the hydrophones, tidal information was obtained from NOAA Station #9447130 and was used to track tidal changes during construction. The depth of the upper hydrophone was checked frequently to ensure it maintained the proper depth during tidal changes and the lower hydrophone was fixed 3.3 feet (1 meter) above the sea floor by securing the cable to the Pier.

Hydroacoustic monitoring on January 19 and January 22, 2018 was conducted using two hydrophones located between 15 and 60 feet (4.6 to 18 meters) from the piles. One hydrophone was positioned 3.3 feet (1 meter) below the surface and the second hydrophone was deployed 3.3 feet (1 meter) above the sea floor.

During the measurements water depth at the hydroacoustic monitoring locations ranged between 32 feet and 44 feet (10 and 13 meters). The distance between the upper and lower hydrophones varied between 26 feet and 38 feet (8 meters to 12 meters) and the distance between the piles and hydrophones varied between 15 feet and 60 feet (4.6 and 18 meters).

7.0 PILE REMOVAL ANALYSIS AND RESULTS

Airborne and underwater sound levels were measured on January 19 and January 22, 2018 during the removal of 2 steel pipe piles and 63 timber piles with the ICE Model 28B Vibratory Driver/Extractor.

Hydroacoustic data was recorded as a digital audio (WAV) file at a rate of 48,000 samples per second during the removal of the piles. The data was then frequency-weighted for each of the marine mammal hearing groups defined in the NOAA technical guidance document titled "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing" dated July, 2016. This Technical Guidance divides marine mammals into five hearing groups, as summarized in Table 7.1

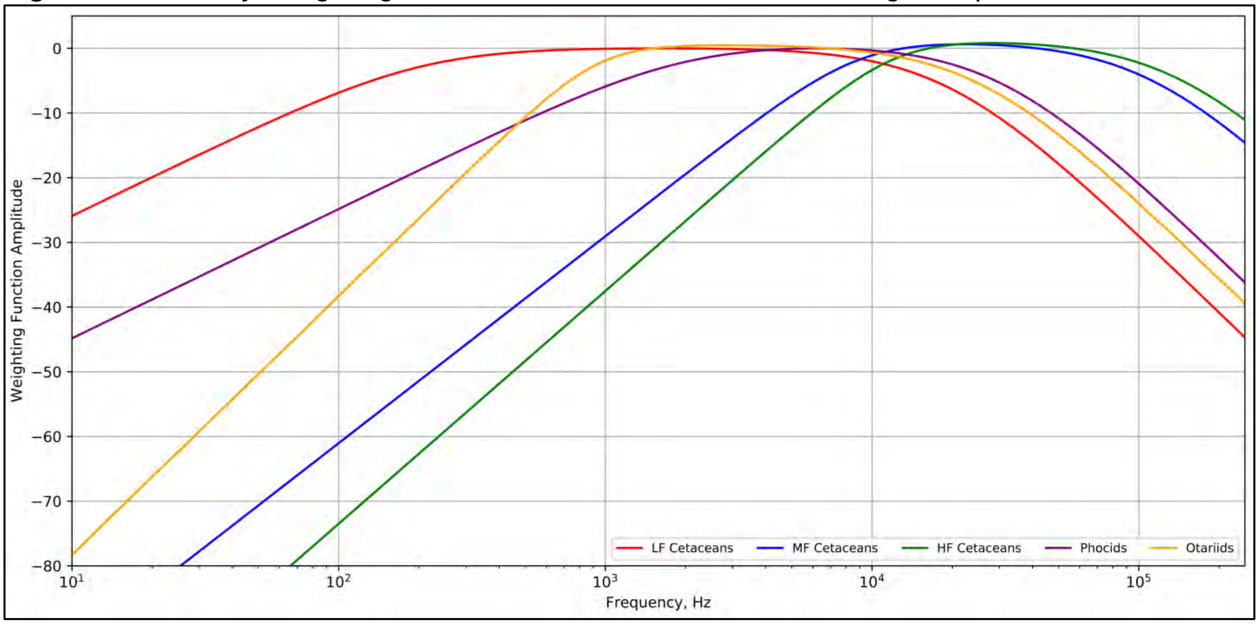
Table 7.1 Marine Mammal Hearing Groups

Hearing Group	Generalized Hearing Range
Low-frequency (LF) cetaceans (baleen whales)	7 Hz – 35 kHz
Mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whaled, bottlenose whales)	150 Hz – 160 kHz
High-frequency (HF) cetaceans (true porpoise, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger & L. australis*)	275 Hz – 160 kHz
Phocid pinnipeds (PW) (underwater) (true seals)	50 Hz – 86 kHz
Otariid pinnipeds (OW) (underwater) (sea lions and fur seals)	60 Hz -39 kHz

Source: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing, July, 2016

The auditory weighting functions for each of the marine mammal hearing groups are illustrated in Figure 7.1.

Figure 7.1 Auditory Weighting Functions for Marine Mammal Hearing Groups



The range, average and standard deviation of 10-second peak and RMS values were calculated for each pile during periods when the vibratory hammer was operational. RMS values were calculated from unweighted data and each marine mammal hearing group. Peak sound levels are unweighted.

Sound levels are reported from both the upper and lower hydrophones normalized to 33 feet (10 meters). Standard deviation values were calculated using decibel values. Average sound levels were determined by calculating the decibel level (re: 1 µPa) of the average sound pressure (Pascals).

Cumulative distribution function (CDF) plots of average underwater sound levels measured by the lower hydrophone during vibratory pile removal are shown in Figure 7.2 through Figure 7.4. The ranges of underwater sound levels for each marine mammal hearing group are provided in Table 7.2. Underwater sound levels are provided for each pile in the Appendix.

Figure 7.2 CDF of Average Peak Values, dB re: 1 μPa

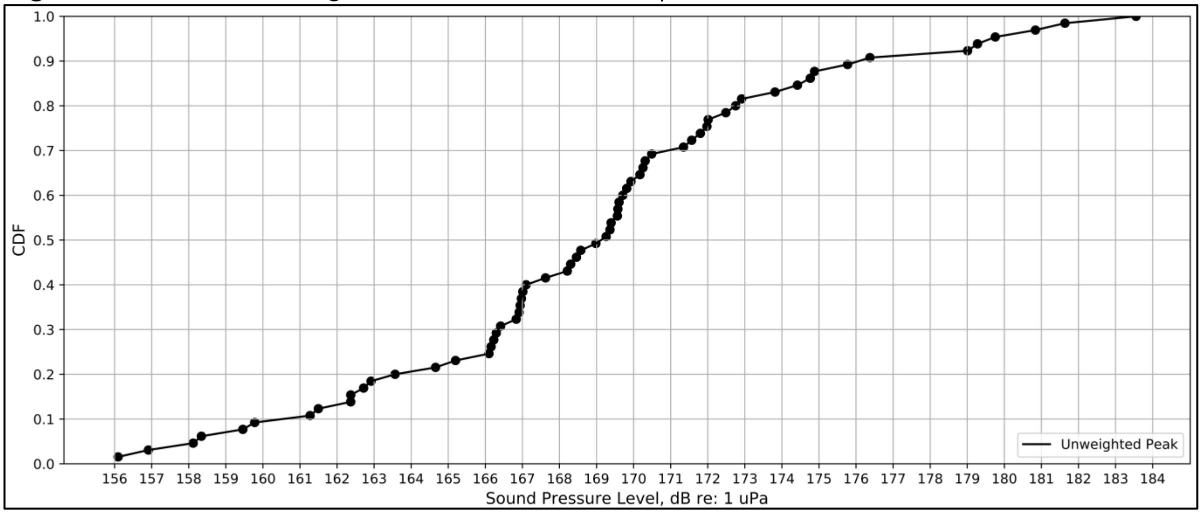


Figure 7.3 CDF of Average RMS Values, dB re: 1 μPa

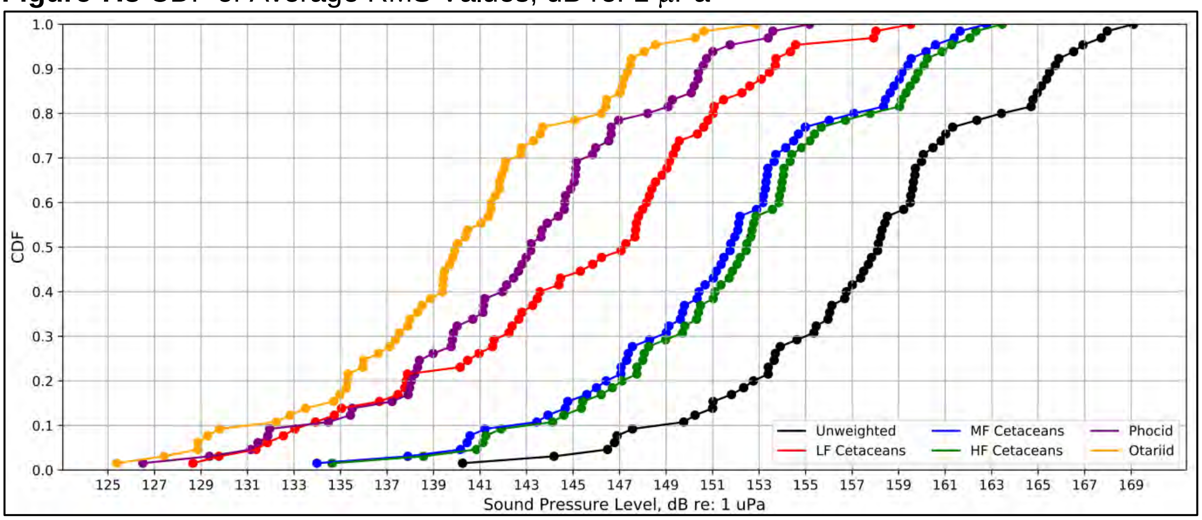


Figure 7.4 CDF of Average SEL Values, dB re: 1 μPa

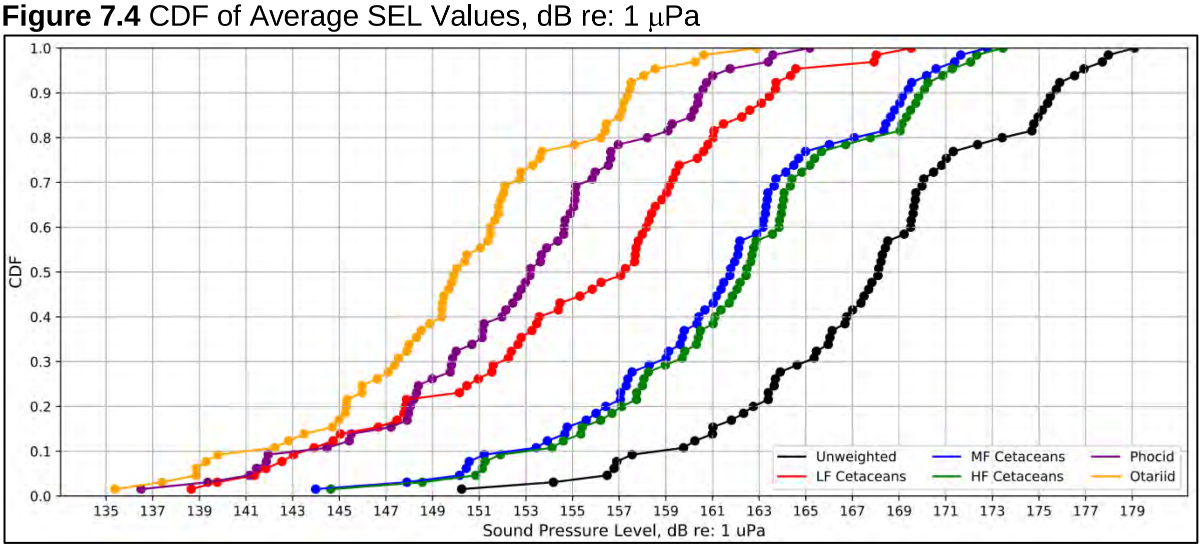


Table 7.2 Ranges of Underwater Sound Levels, dB re: 1 μPa

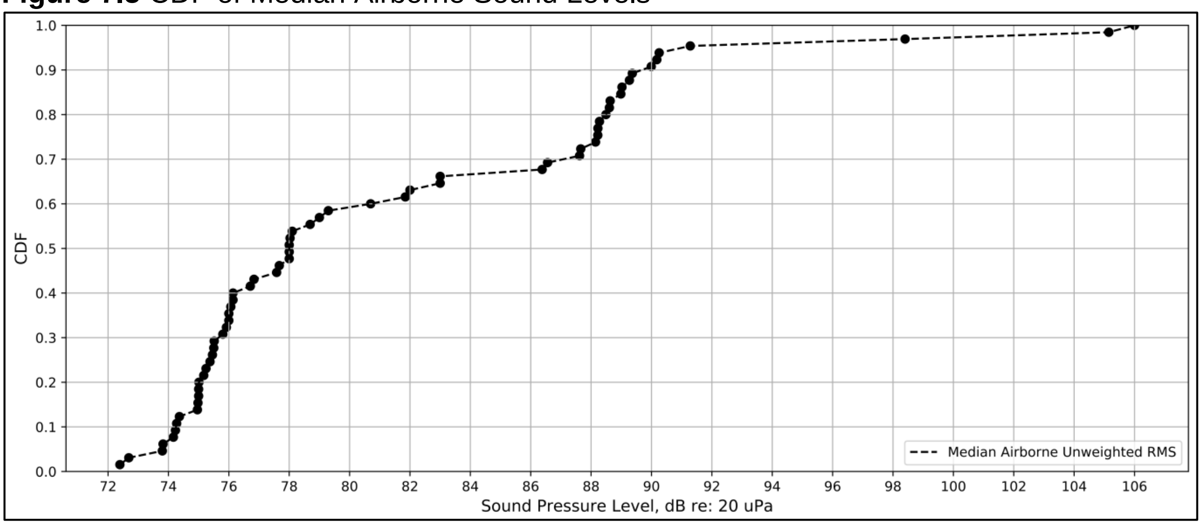
Metric	Unweighted	LF-Cetaceans	MF-Cetaceans	HF-Cetaceans	Phocid pinnipeds	Otariid pinnipeds
Peak	156-184	156-184	156-184	156-184	156-184	156-184
RMS	140-169	129-160	134-163	135-163	127-155	125-153
SEL	150-179	139-170	144-173	145-173	137-165	135-163

Note: Sound levels are normalized to 33 feet (10 meters) from piles

The average unweighted frequency spectrum and the average frequency spectrum for each hearing group are provided for each pile in the Appendix. The unweighted waveform of each pile removal, waveform of the highest unweighted absolute peak sound pressure, and spectrogram of the peak waveform are also included.

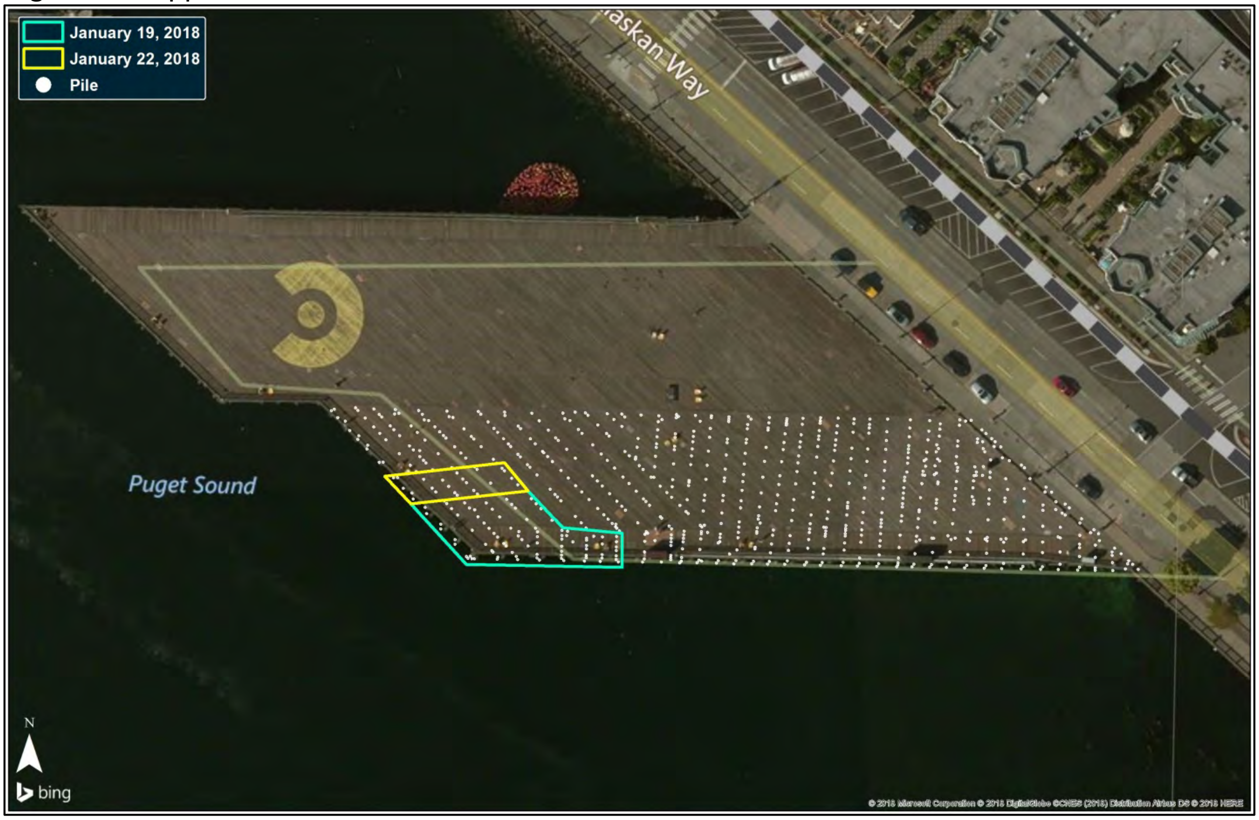
Airborne data was recorded as a digital audio (WAV) file at a rate of 48,000 samples per second and was used to determine the range and median of unweighted 1-second RMS values. The average frequency spectrum from each pile removal is provided in the Appendix. A CDF plot of the median airborne sound levels measured during both days of acoustic monitoring is provided in Figure 7.5. Median airborne sound levels ranged between 72 dB and 106 dB re: 20 μPa.

Figure 7.5 CDF of Median Airborne Sound Levels



The approximate pile locations of monitored piles are shown in Figure 7.6.

Figure 7.6 Approximate Pile Locations



8.0 BACKGROUND SOUND LEVEL MEASUREMENT METHODOLOGY

Continuous background underwater sound level measurements were made between March 19 and March 22, 2018 after the end of the Project's in-water work window. These measurements were conducted to determine the distances required for RMS sound levels produced by pile removal activities to attenuate to background sound levels and to satisfy the background sound measurement requirements of the Project's IHA and Biological Opinion. Measurements were made in accordance with the NOAA Guidance Document "Data Collection Methods to Characterize Underwater Background Sound Relevant to Marine Mammals in Coastal Nearshore Waters and Rivers of Washington and Oregon" dated January 31, 2012.

Equipment used to collect background sound data consisted of a Reson TC-4013 connected to a Brüel & Kjaer Type 2647-B charge converter. The charge converter was attached to an NTi Audio ICP Adaptor, which provided power to the charge converter. The signal was then recorded using the Tascam DR-100MKIII digital audio recorder, which recorded the signal at a rate of 48,000 samples per second. Equipment used to measure background sound levels is shown in Figure 8.1 below.

Figure 8.1 Background Sound Measurement Equipment

The background monitoring equipment was deployed 5,419 feet (1,652 meters) northwest of Pier 62 at a depth of 180 feet (55 meters). Water depth at the monitoring location was approximately 200 feet (61 meters). This location was selected based on proximity to the construction site, water depth and to avoid deploying the equipment in a ferry or shipping lane. The location of the background measurement location is shown in Figure 8.2.

Figure 8.2 Background Sound Level Measurement Location

30-second RMS background sound data collected between 8:00 AM and 6:20 PM were used to calculate the CDF of each marine mammal hearing group. The marine mammal hearing groups were calculated using the hearing groups defined in Section 7.0 of this report, not those defined in the 2012 NOAA Guidance Document.

CDF plots of unweighted background sound levels and each marine mammal hearing group are shown in Figure 8.3. The average frequency spectra and the unweighted waveform recorded during daytime hours are shown in Figure 8.4 and Figure 8.5.

Figure 8.3 CDF Plots of Background Sound Levels (30-second RMS), dB re: 1 μPa

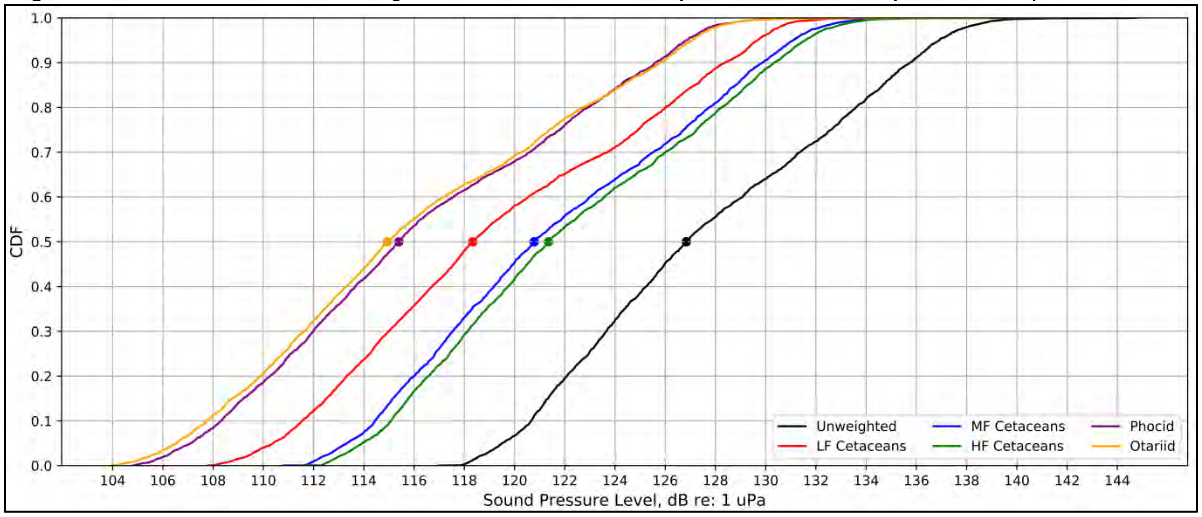


Figure 8.4 Average Daytime Background Frequency Spectrum, dB re: 1 μPa

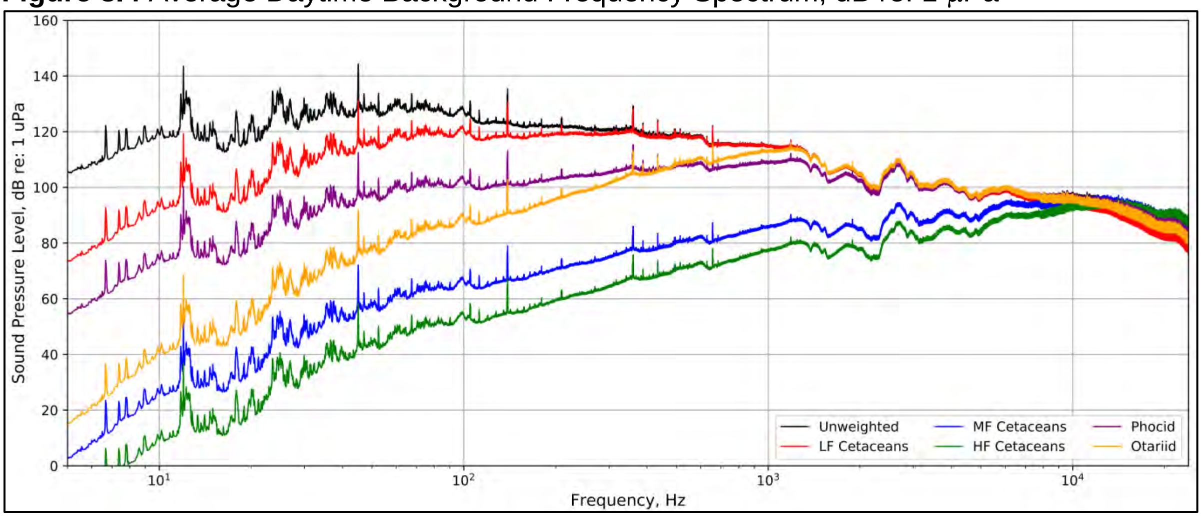
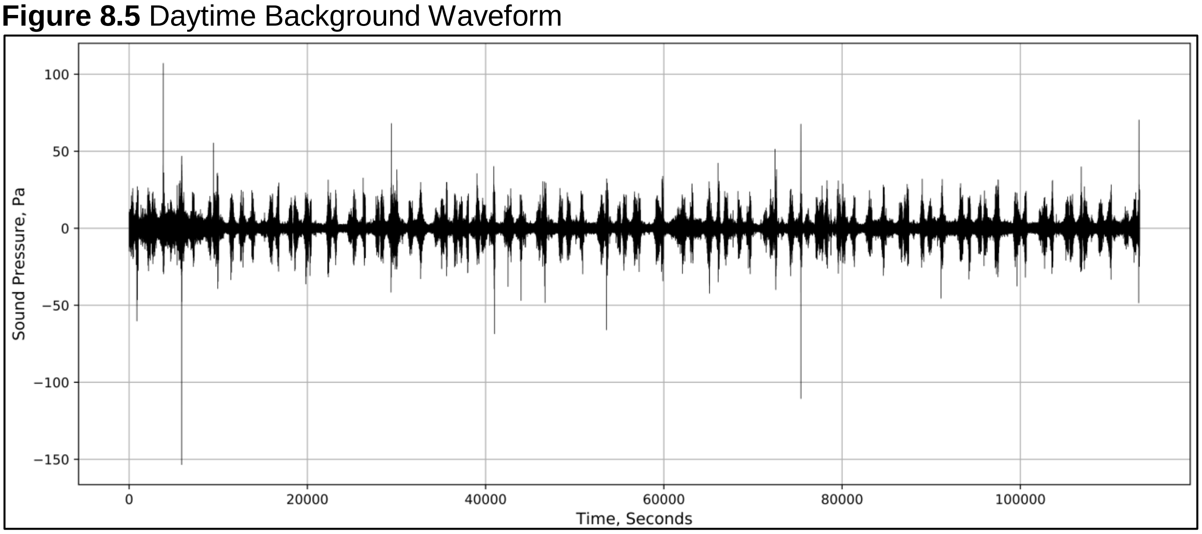


Figure 8.5 Daytime Background Waveform



Median background sound levels for each hearing group are reported as the 50th percentile of the CDFs. The range, average and standard deviation (SD) of background sound levels are shown in Table 8.1.

Table 8.1 Background Sound Levels, dB re: 1 μPa

Hearing Group	Minimum	Maximum	SD	Average[1]
Unweighted	117	145	5.6	**127**
LF Cetaceans	108	139	6.2	**118**
MF Cetaceans	111	142	5.8	**121**
HF Cetaceans	111	142	5.7	**121**
Phocids	105	139	6.4	**115**
Otariids	104	139	6.5	**115**

1. The median of 30-second RMS sound levels was used to calculate average sound levels.

9.0 DISTANCES TO INJURY AND DISTURBANCE THRESHOLDS

The results of the background sound level measurements were used in conjunction with hydroacoustic data collected during vibratory pile removal to estimate the distances required for underwater sound levels to reach the marine mammal injury (Level A) and disturbance (Level B) thresholds and existing background sound levels.

In July 2016, NOAA issued updated technical guidance for determining the effects of underwater sound on marine mammals titled “Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing”. This Technical Guidance includes criteria for injury from impulsive and non-impulsive sounds. The injury criteria for non-impulsive sounds, such as vibratory pile driving, are based on 24-hour cSEL criteria, which are shown in Table 9.1 below.

Table 9.1 Injury Criteria (24-hour cSEL), dB re: 1 μPa

Hearing Group	Injury Criteria (Level A)
LF Cetaceans	199
MF Cetaceans	198
HF Cetaceans	173
Phocids	201
Otariids	219

Marine mammal disturbance thresholds (Level B) are based on RMS sound levels from previous guidance and are shown in Table 9.2.

Table 9.2 Disturbance Thresholds (RMS), dB re: 1 μPa

Marine Mammal	Vibratory Disturbance Threshold
Cetaceans	120 dB
Pinnipeds	

Distances required for underwater sound resulting from vibratory pile extraction to reach the marine mammal thresholds and measured background sound levels were calculated using the “practical spreading model” currently used by NOAA. The practical spreading formula is provided below.

$$SPL_{D2} = SPL_{D1} + \beta * \log_{10}\left(\frac{D_1}{D_2}\right)$$

Where SPL_{D1} is the sound pressure measured at a distance, D_1 and SPL_{D2} is the estimated sound pressure at a distance, D_2. β is the attenuation factor resulting from acoustic spreading over distance. The California Department of Transportation (Caltrans) reported in the “Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish” dated November, 2015, that β can range between 5 and 30 depending upon site specific conditions such as water depth, pile type, pile length and the substrate the pile is driven into. Currently NOAA uses the practical spreading model with β equaling 15, which results in a 4.5 dB reduction in underwater sound levels for each doubling of distance.

The formula provided above was also used to calculate the distances for airborne noise to reach the disturbance levels for harbor seals and other pinnipeds. In the case of airborne noise β is equal to 20, which is consistent information provided in the WSDOT document “Biological Assessment Preparation for Transportation Projects-Advanced Training Manual-Version 2015” for sound propagation from a point source over hard soil.

The estimated distances for underwater noise to reach the marine mammal thresholds and background sound levels are estimated using the highest average 10-second RMS sound levels measured during pile removal and by solving the practical spreading formula for D_2 resulting in the following:

$$D_2 = D_1 * 10^{\left(\frac{SPL_{D1} - SPL_{D2}}{\beta}\right)}$$

The sound level exceeding 90% of the average 1-second RMS sound levels (90^{th} percentile) was used to calculate the distances for airborne sound levels to reach disturbance thresholds for harbor seals and other pinnipeds. This sound level was selected because the loudest average sound levels appear to be outliers and not representative of typical pile removal activities, which is shown in Figure 7.5.

9.1 Marine Mammal Disturbance and Injury Distances

The practical spreading model, the highest 24-hour cSEL values, and the loudest average RMS sound levels recorded during pile removal were used to calculate the distances necessary for underwater sound produced by vibratory pile removal to reach Level A and Level B thresholds. The resulting distances are shown in Table 9.3.

Table 9.3 Distances to Marine Mammal Thresholds

Hearing Group	Measured Sound Level		Marine Mammal Threshold		Distance to Threshold	
	cSEL	RMS	Level A	Level B	Level A	Level B
LF Cetaceans	183	160	199 cSEL	120 RMS	2.9 feet (0.9 meters)	15,229 feet (4,642 meters)
MF Cetaceans	188	163	198 cSEL	120 RMS	7.6 feet (2.3 meters)	24,136 feet (7,356 meters)
HF Cetaceans	189	163	173 cSEL	120 RMS	392 feet (120 meters)	24,136 feet (7,356 meters)
Pinnipeds (Phocids)	180	155	201 cSEL	120 RMS	1.3 feet (0.4 meters)	7,069 feet (2,154 meters)
Pinnipeds (Otariids)	177	153	219 cSEL	120 RMS	0.1 feet (0.02 meters)	5,200 feet (1,585 meters)

As shown in Table 9.3, the distance to the Level A threshold for high frequency cetaceans is farther that the distance anticipated. The Level A threshold was anticipated to be reached approximately 84 feet (26 meters) from pile removal, but results from hydroacoustic monitoring suggests the distance is up to 392 feet (120 meters). For all other hearing groups, the Level A threshold occurred within the established exclusion zone. Figure 9.1 shows measured sound as it relates to the Level A thresholds.

Table 9.3 also shows the distance to the Level B thresholds, based on measured noise. The anticipated distance at which the Level B threshold would be reached was 6,119 feet (1,865 meters). However, measurements suggest that the Level B impacts may occur as far as 24,136 feet (7,356 meters) from pile removal, as indicated in Figure 9.2. However, background sound levels (124 dB) from measurements previously conducted by the Washington State Department of Transportation (WSDOT) were used to calculate the anticipated distances to Level B thresholds. Distances calculated based on hydroacoustic monitoring use the Level B threshold of 120 dB.

Figure 9.1 Level A Thresholds

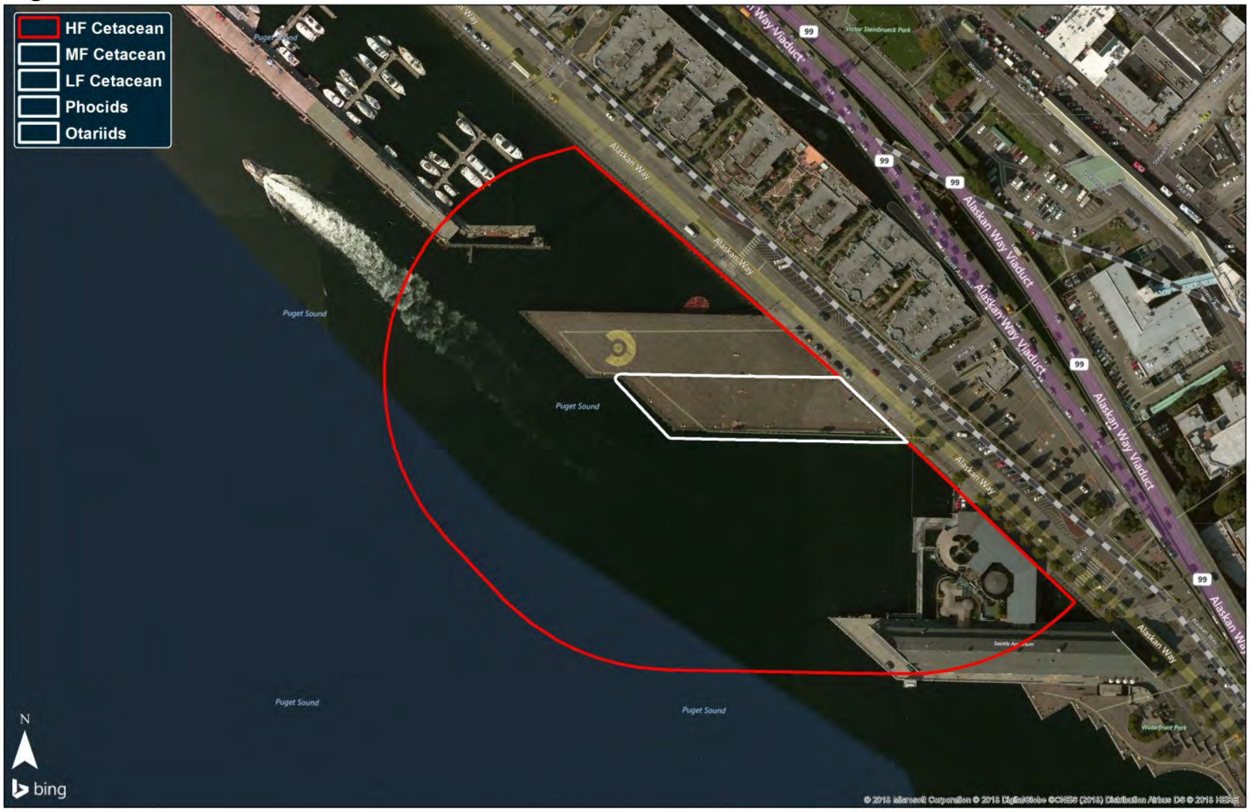
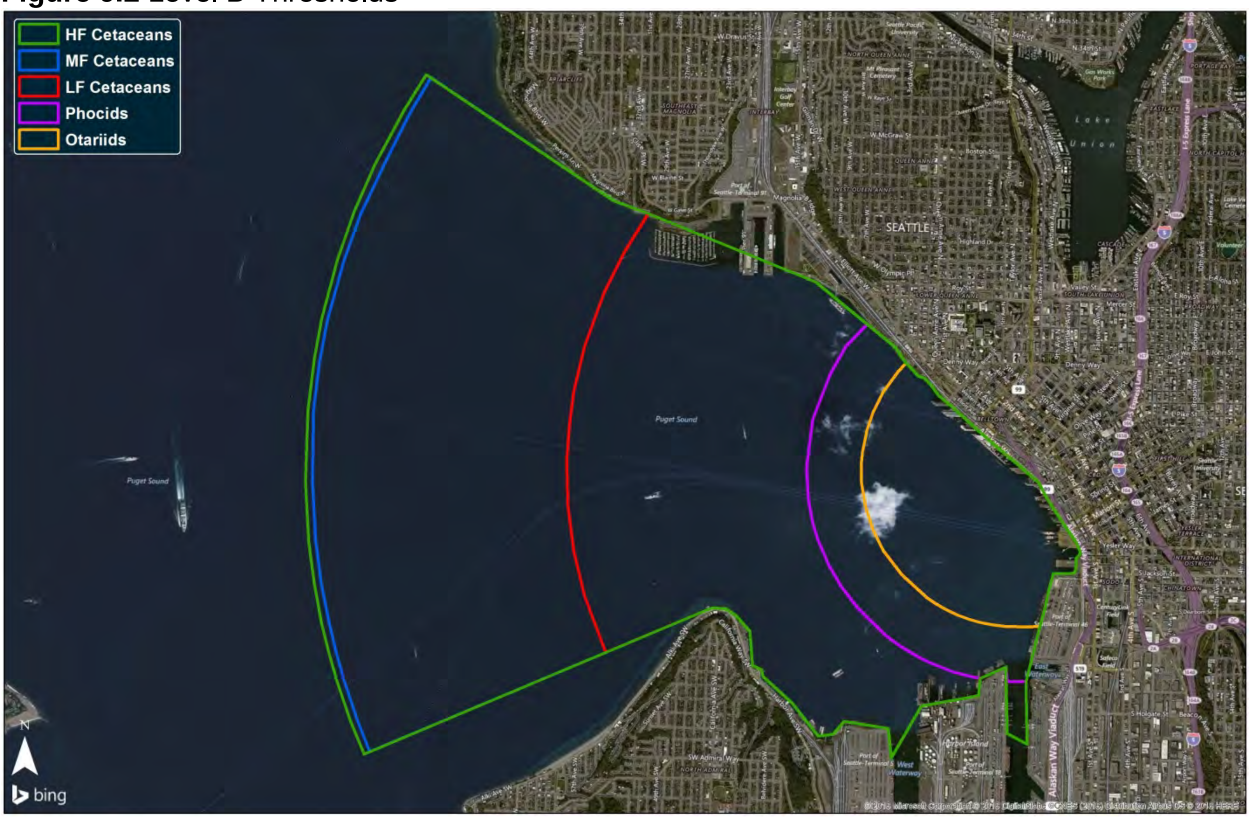


Figure 9.2 Level B Thresholds



The distances required for airborne sound levels to reach the disturbance levels for harbor seals and other pinnipeds are shown in Table 9.4.

Table 9.4 Distances to Pinniped Airborne Thresholds, dB re 20 μPa

Species	Measured RMS Sound Level	Level B[1]	Distance
Harbor Seal	90	90	50 feet (15 meters)
Other Pinnipeds		100	16 feet (5 meters)

1. Level A threshold not established

Areas where airborne sound levels are expected to exceed the disturbance thresholds for harbor seals and other pinnipeds are illustrated in Figure 9.3.

Figure 9.3 Pinniped Airborne Disturbance Zones

9.2 Distance to Background Sound Levels

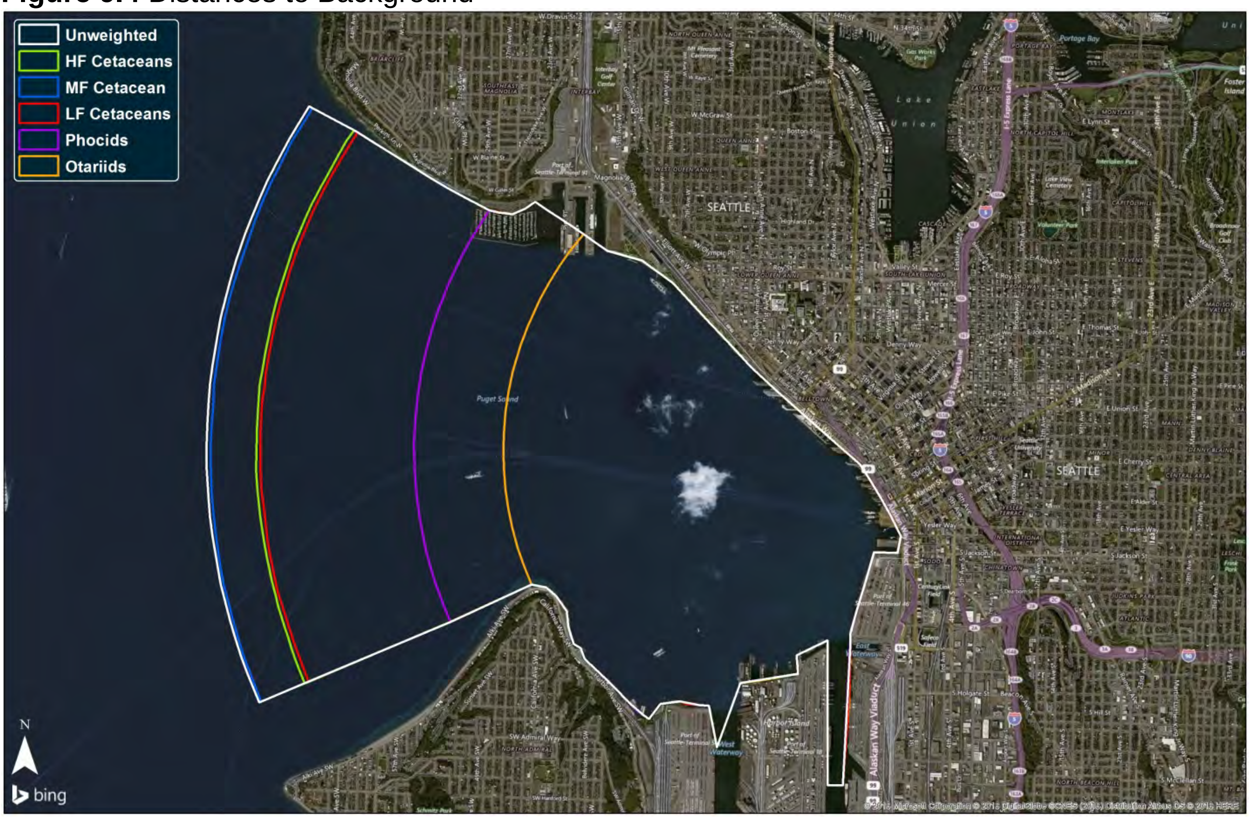
Distances needed to reach background sound levels were calculated using the median daytime background sound levels for each marine mammal hearing group, are shown in Table 9.5.

Table 9.5 Distances to Background Sound Levels

Hearing Group	Highest Average RMS	Background Sound Level	Distance to Background
LF Cetaceans	160	118	19,641 feet (5,986 meters)
MF Cetaceans	163	121	21,405 feet (6,524 meters)
HF Cetaceans	163	121	19,610 feet (5,977 meters)
Phocids	155	115	14,337 feet (4,370 meters)
Otariids	153	115	11,299 feet (3,444 meters)

The calculated distances required for underwater sound generated during vibratory pile removal to reach background sound levels is up to 21,405 feet (6,524 meters). Figures illustrating the areas where underwater sound levels are expected to exceed background sound levels are shown in Figure 9.4.

Figure 9.4 Distances to Background



9.3 Marine Mammal Monitoring

Monitors observed California sea lion and harbor seal within the monitoring zone; however, these animals did not exhibit any changes in behavior associated with pile removal or installation activities. Details of marine mammal monitoring are presented in a separate report entitled “Pier 62 Project Draft Marine Mammal Monitoring Season 1 (2017-2018) Report.”

10.0 REFERENCES

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