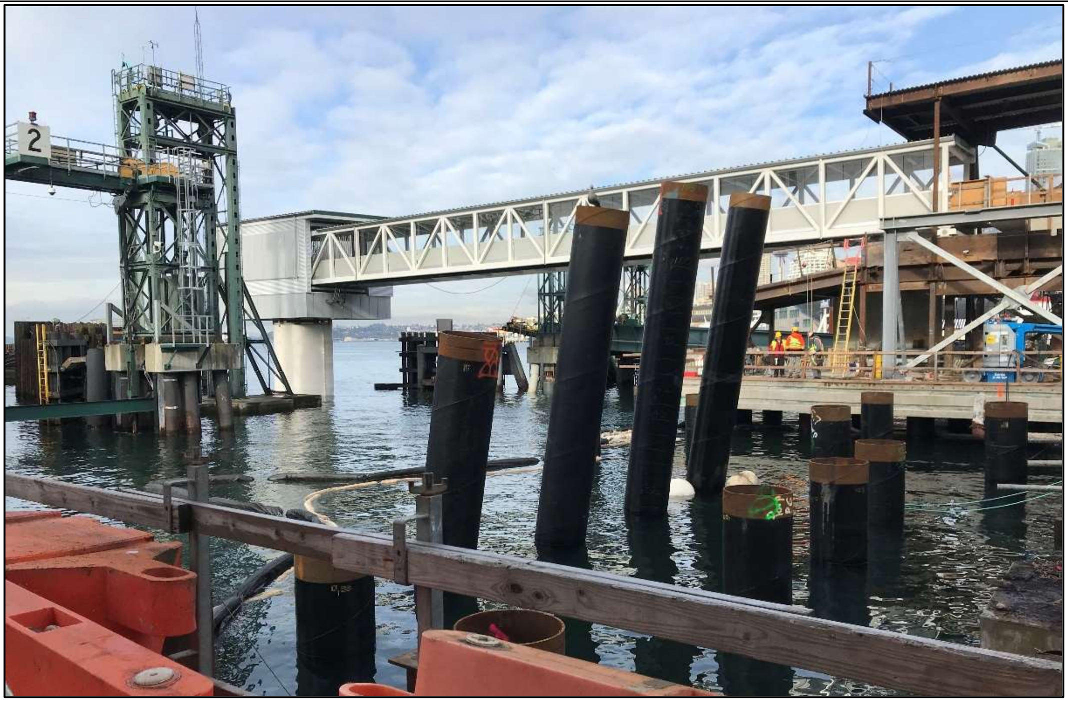

COLMAN DOCK SEASON 3
HYDROACOUSTIC MONITORING REPORT

May 13, 2020

Prepared For:

Pacific Pile & Marine

Prepared By:

THE GREENBUSCH GROUP, INC.

1900 West Nickerson Street Suite 201
Seattle, Washington 98119

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1.0 EXECUTIVE SUMMARY

This Hydroacoustic Monitoring Report presents the results of underwater (hydroacoustic) and airborne sound level measurements made between November 2019 and February 2020 during the installation of 24-inch and 36-inch steel pipe piles with diesel impact hammers. This monitoring was conducted during Season 3 of the Seattle Multimodal Terminal at Colman Dock (Project).

Average unweighted underwater 90% RMS (RMS_{90}) sound levels measured approximately 33 feet (10 meters) from impact pile driving ranged between 170 and 183 dB re: 1 μPa for 36-inch diameter piles driven below the waterline, 155 and 159 dB re: 1 μPa for 36-inch piles driven on-land. The average unweighted RMS_{90} sound level from a 24-inch diameter Wedge Pile was 168 dB re: 1 μPa. Average peak sound levels from 36-inch piles driven below the waterline ranged between 180 and 196 dB re: 1 μPa, 162 and 165 dB re: 1 μPa from 36-inch piles driven above the waterline. The 24-inch Wedge Pile generated an unweighted average peak sound level of 179 dB re: 1 μPa.

Based on the highest average peak and daily cSEL levels measured by the far-field hydrophone, the distance required for sound to dissipate to below marine mammal injury thresholds (Level A) are estimated to be 16,442 feet (5,011 meters) for high-frequency cetaceans, up to 194 feet (59 meters) for other cetaceans, and 92 feet (28 meters) for pinnipeds. RMS_{90} sound levels are estimated to dissipate to below the 160 dB marine mammal disturbance threshold (Level B) after 852 feet (260 meters).

2.0 INTRODUCTION

The Project Specifications and the Underwater Noise Monitoring Plan issued by the Washington State Department of Transportation (WSDOT), dated July 27, 2016 include requirements for hydroacoustic monitoring. These requirements include the number of piles to be monitored, monitoring equipment, signal processing requirements, measurement locations, analysis methodology, and information required to be reported to the Services. This Hydroacoustic Monitoring Report fulfills the Project's hydroacoustic monitoring and reporting requirements.

The Project is located west of Alaskan Way between Marion Avenue and Yesler Way in downtown Seattle, Washington (see Figure 2.1). Underwater and airborne sound level measurements were conducted between November 2019 and February 2020.

Figure 2.1 Vicinity Map of Seattle Multimodal Terminal at Colman Dock Project

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:

- **A-Weighted Decibel (dBA)**

  The human ear has a unique response to sound pressure. It is less sensitive to those sounds falling outside the speech frequency range. Sound level meters and monitors utilize a filtering system to approximate human perception of sound. Measurements made utilizing this filtering system are referred to as “A weighted” and are called “dBA”.

- **Equivalent Sound Level (L_{eq})**

  Equivalent Sound Level is the level of a constant sound having the same energy content as the actual time-varying level during a specified interval. The L_{eq} is used to characterize complex, fluctuating sound levels with a single number.

- **Maximum Sound Level (L_{max})**

  L_{max} is the maximum recorded root mean square (rms) A-weighted sound level for a given time interval or event. L_{max} can be defined for two time weightings, “slow” and “fast.” “Slow” uses 1-second time constant, and “fast” uses a 125-millisecond time constant. For transient events of very short duration, L_{max} “fast” will be greater than L_{max} “slow.” This report utilized L_{max} “fast”.

- **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).

- **Percent Sound Level (L_n)**

  Percent Sound Level is the sound level that is exceeded n percent of the time; for example, L_{08} is the level exceeded 8% of the time. L_{25} is the sound level exceeded 25% of the time. This report utilizes the L_{90} and L_{95} descriptors.

- **Root Mean Square (RMS)**

  The RMS level is the square root of the average squared pressure over a given time period. In hydroacoustics, the RMS level has been used by the National Marine Fisheries Service (NMFS) in criteria for assessing sound pressure impact on marine mammals.

- **90% Root Mean Square (RMS_{90})**

  The RMS_{90} level is used for the analysis of impact pile driving and is the RMS level containing 90 percent of the energy in a pile strike. The RMS_{90} energy is established between the 5% and 95% of the pile energy and is calculated for each pile strike.

- **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 single strike SEL values for each pile.

4.0 HYDROACOUSTIC MONITORING AND REPORTING REQUIREMENTS

Requirements for the Project's hydroacoustic monitoring, signal processing, and reporting are included in the Project Specifications dated July 21, 2017; the Seattle Multimodal Terminal at Colman Dock-Phase 1 Underwater Noise Monitoring Plan authored by WSDOT dated July 27, 2016; and the Colman Dock Phase 3 Underwater Noise Monitoring Plan issued by The Greenbusch Group, Inc. dated August 12, 2019. Underwater sound level limits are not included in either the Project Specifications or the Underwater Noise Monitoring Plans authored by WSDOT and Greenbusch.

4.1 Project Specifications

Section 00 72 00 1-07.6(6) of the Project Specifications includes the following underwater noise monitoring requirements for the Contractor:

- The Contractor will comply with the provisions of the Underwater Noise Monitoring Plan authored by WSDOT. To comply with the WSDOT Underwater Noise Monitoring Plan, the Contractor will conduct hydroacoustic monitoring during construction to document the sound transmission during impact pile driving of steel piles.
- A representative subset of impact driven steel piles will be monitored at the start of each in-water work season, per the noise monitoring plan.
- Underwater sound levels will be continuously monitored for the entire duration of each pile being driven.
- The Contractor shall provide qualified staff and appropriate equipment to conduct impact driven steel pile hydroacoustic monitoring. Only staff with appropriate hydroacoustic expertise, as approved by the Contracting Agency, shall perform this monitoring.

4.2 WSDOT Underwater Noise Monitoring Plan

The Underwater Noise Monitoring Plan issued by WSDOT includes requirements regarding the number of piles to be monitored, hydroacoustic monitoring equipment, signal processing requirements, measurement locations, analysis methodology and information required to be reported to the Services.

The WSDOT Underwater Noise Monitoring Plan requires hydroacoustic monitoring locations to be 33 feet (10 meters) away from the pile at mid water depth and 3H, where H is the water depth of the pile being monitored. The 3H hydrophone should be at 80% of the water depth at the measurement location. Monitoring locations are required to have a clear acoustic line-of-sight between the pile and the hydrophones.

Sound levels measured at these locations must include the frequency spectrum, ranges, means, and L_{50} for peak, RMS_{90} and SEL_{90} sound pressure levels for each marine mammal functional hearing group as well as the broadband sound pressure levels. L_{50} levels reported in this document are the median sound levels from each pile drive. The estimated distance at which peak, RMS and cSEL values exceed the respective threshold values must also be reported.

Airborne sound level measurements are required to be made between 50 feet and 200 feet from impact pile driving. Notes are also required to be made to document any anomalous noise events such as boats and low flying aircraft that could influence the measurements and these events must be excluded from the measurement results. Ambient airborne sound levels must also be made for at least 15 minutes in the absence of construction activities to document background sound levels. The results of airborne sound monitoring must include the frequency spectrum, L_{max}, L_{eq}, and L_{90} for each pile including time history plots and an estimation of the received sound levels at the nearest residences.

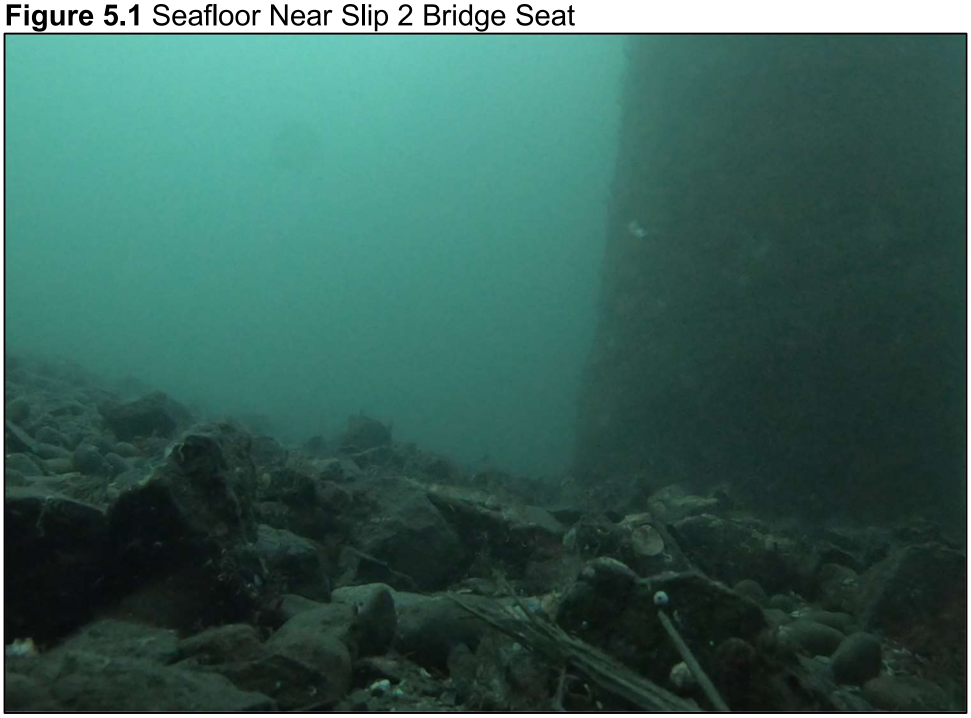
4.3 Greenbusch Underwater Noise Monitoring Plan

The Colman Dock Phase 3 Underwater Noise Monitoring Plan authored by the Greenbusch Group, Inc. was prepared based on the requirements of the Project Specifications and the WSDOT Underwater Noise Monitoring Plan and provides details of how the hydroacoustic monitoring will be implemented. The Greenbusch Underwater Noise Monitoring Plan includes specific types of equipment that will be used during the monitoring, the resumes of hydroacoustic monitoring staff and a discussion of which piles will be monitored.

5.0 PILE AND PILE DRIVING EQUIPMENT INFORMATION

During Season 3, all steel pipe piles were initially driven with a vibratory hammer and then proofed with a diesel impact hammer. The piles for the Wedge Pilings are 24-inch diameter steel pipe piles with a wall thickness of 5/8-inch. The Wedge Piling measured during Season 3 (Pile W1) was approximately 82-feet long. North Trestle and Slip 2 Bridge Seat piles are 36-inch diameter steel pipe piles with wall thicknesses of 1-inch. Piles measured at the North Trestle ranged in length from approximately 70-feet to 97-feet. The Slip 2 Bridge Seat piles were battered piles and were approximately 105-feet long. The substrate is primarily composed of sand, shell hash, silt and includes some gravel and cobble. A photo of the seafloor near the Slip 2 Seat Piles is shown in Figure 5.1.

Figure 5.1 Seafloor Near Slip 2 Bridge Seat



Measured piles driven at the west side of the North Trestle (North Trestle Group B) and the Slip 2 Bridge Seat were driven with an APE D100-52 diesel impact hammer with an energy rating of 248,063 foot-pounds. The ram weighed 22,050 pounds with a stroke length of 11.25 feet. A cut sheet of the APE D100-52 diesel impact hammer can be found in the Appendix of this Report.

All other piles installed during hydroacoustic monitoring were driven using an APE D62 diesel impact hammer. The APE D62 has a maximum energy rating of 162,052 foot-pounds, a ram weight of 13,671 pounds and a stroke length of 12 feet. Specifications for the APE D62 are shown in the Appendix.

Table 5.1 provides a summary of the steel pipe piles driven with impact pile drivers during the measurements.

Table 5.1 Summary Pipe Piles, Feet (Meters)

Pile ID	Date Driven	Sound Attenuation	Distance to Water's Edge	Water Depth	Embedment[1]	Number of Strikes[2]
West Side of North Trestle (North Trestle Group B)						
N12.5-NF	11/8/2019	Bubble Curtain	274 (84)	28 (9)	56 (17)	550
N11-NC.7	12/4/2019	Bubble Curtain	284 (87)	41 (13)	49 (15)	267
N12-NC.7	12/4/2019	Bubble Curtain	310 (95)	43 (13)	49 (15)	234
Slip 2 Bridge Seat (battered piles)						
Pile 4	1/17/2020	Bubble Curtain	395 (120)	43 (13)	59 (18)	511
Pile 3	1/17/2020	Bubble Curtain	393 (120)	41 (13)	59 (18)	731
Pile 2	1/17/2020	Bubble Curtain	389 (119)	38 (12)	59 (18)	629
Pile 1	1/17/2020	Bubble Curtain	384 (117)	38 (12)	59 (18)	328
Wedge Piling						
W1	2/26/2020	Bubble Curtain	165 (50)	30 (9)	35 (11)	197
East Side of North Trestle (North Trestle Group A)						
E1.1-10 (on-land)	2/26/2020	On-Land	15 (5)	N/A	60 (18)	831
E1.1-8 (on-land)	2/26/2020	On-Land	15 (5)	N/A	61 (19)	366
E3-5	2/26/2020	Bubble Curtain	25 (8)	6 (2)	67 (20)	742

1. N12.5-NF and N11-NC.7 embedment depths listed on pile logs. N12-NC.7 was extrapolated from nearby piles. Embedment of all other piles were estimated from water depth and information found on the Project Drawings.
2. Number of strikes included in analysis.

During hydroacoustic monitoring an unconfined bubble curtain was used during all impact pile driving. The unconfined bubble curtain consisted of six 2.5-inch nominal diameter aluminum rings with four rows of 1/16th inch diameter bubble release holes in the axial direction. Photos of the unconfined bubble curtain are shown in Figure 5.2 and Figure 5.3. The system design calculations and drawings of the bubble curtain are provided in the Appendix.

Figure 5.2 Bubble Curtain

Figure 5.3 Operating Bubble Curtain

6.0 MEASUREMENT METHODOLOGY

6.1 Equipment

The hydroacoustic and airborne monitoring equipment used during Season 3 are identified in Table 6.1 and Table 6.2.

Table 6.1 Hydroacoustic Monitoring Equipment

Make and Model	Quantity	Description	Serial Number
Brüel & Kjaer Type 2250	1	Sound Level Analyzer	3006756
Reson TC-4013	2	Hydrophone	2513032
			0712213
Brüel & Kjaer Type 2647-A	2	Charge Converter (1 mV/pC)	2638259
			2582112
Brüel & Kjaer 1704-A-002	1	Signal Conditioner	101161
G.R.A.S. Type 42AC	1	Pistonphone	201835
Tascam DR-100MKIII	1	Digital Audio Recorder	1690316

Table 6.2 Airborne Monitoring Equipment

Make and Model	Quantity	Description	Serial Number
Svantek 979	1	Sound Level Analyzer	46177
Svantek SV17	1	Preamplifier	57824
G.R.A.S. 40AE	1	Microphone	258193
Larson Davis CAL200	1	Acoustic Calibrator	16828
Svantek 307	1	Sound Level Analyzer	78646
Svantek ST30	1	Microphone	82620
Larson Davis CAL200	1	Acoustic Calibrator	16826

Monitoring equipment was 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 during post-processing. Hydrophones were calibrated using the G.R.A.S. pistonphone and microphones were calibrated with the Larson Davis CAL200 acoustic calibrators.

Underwater sound levels were measured using two Reson TC-4013 hydrophones connected to the Brüel & Kjaer Type 2647-A charge converters and Brüel & Kjaer 1704-A-002 signal conditioner. The signal conditioner was connected to the Tascam DR-100KMIII digital audio recorder, which recorded the signals as WAV files at a sample rate of 48,000 samples per second for subsequent signal analysis. The Brüel & Kjaer Type 2250 allowed for real-time approximations of peak and cSEL sound levels while the measurements were being performed.

Airborne sound levels on November 8, 2019 were measured using the Svantek 979 sound level analyzer. All other airborne sound measurements were made using the Svantek 307. Both the instruments meet the requirements for a Type 1 sound level analyzer. This equipment recorded a WAV file at a sample rate of 48,000 samples per second for subsequent signal analysis as well as 1-second logging of unweighted and A-weighted L_{eq}, L_{max}, L_{90}, and L_{95} sound levels. 1-second spectral data were recorded at 1/3 octave resolution.

Photographs of the monitoring equipment are provided Figure 6.1 and Figure 6.2.

Figure 6.1 Hydroacoustic Monitoring Equipment

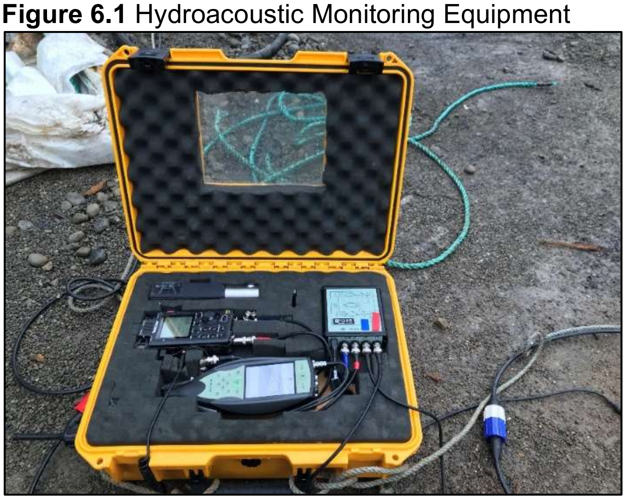


Figure 6.2 Airborne Monitoring Equipment

6.2 Measurement Locations

Two hydrophones were used to measure underwater sound produced by impact pile driving. One near-field hydrophone was located at mid water depth approximately 33 feet (10 meters) from the pile. A far-field hydrophone was positioned at approximately 80% water depth 3H from the pile, where H was the water depth at the pile. Whenever possible, the hydrophones were positioned with a clear acoustic line-of-sight between the hydrophones and pile.

Distances between the pile and microphone ranged between 64 feet and 142 feet. The microphone was located approximately 7-feet above the dock and at least 5-feet from any acoustically reflective surfaces. A direct line-of-sight was maintained between the microphone and piles throughout the measurements.

The distances between the hydrophones and piles were verified using a laser distance measurement device. Water depth was measured at all monitoring locations prior to deploying the hydrophones. Hydrophones were secured to existing portions of Colman Dock and construction platforms.

In addition to water depth measurements, tidal information was obtained from NOAA Station #9447130 and was used to track tidal changes during construction. Table 6.3 presents the depths of the hydrophones, water depth at the measurement locations as well as distances between the hydrophones and piles. Figures illustrating the hydroacoustic measurement positions are presented in Section 7.1 through Section 7.4 of this Report.

Table 6.3 Hydrophone Location Summary, Feet (Meters)

Pile ID	Hydrophone	Depth at Measurement Location	Hydrophone Depth	Distance to Pile
West Side of North Trestle (North Trestle Group B)				
N12.5-NF	Near-Field	30 (9)	16 (5)	30 (9)
	Far-Field	32 (10)	26 (8)	76 (23)
N11-NC.7	Near-Field	41 (13)	35 (11)	30 (9)
	Far-Field	41 (13)	29 (9)	97 (30)
N12-NC.7	Near-Field	43 (13)	35 (11)	30 (9)
	Far-Field	41 (13)	29 (9)	97 (30)
Slip 2 Bridge Seat (battered piles)				
Pile 4	Near-Field	43 (13)	25 (8)	56 (17)
	Far-Field	49 (15)	37 (11)	96 (29)
Pile 3	Near-Field	41 (13)	23 (7)	46 (14)
	Far-Field	47 (14)	35 (11)	89 (27)
Pile 2	Near-Field	38 (12)	20 (6)	36 (11)
	Far-Field	44 (13)	32 (10)	80 (24)
Pile 1	Near-Field	38 (12)	20 (6)	27 (8)
	Far-Field	44 (13)	32 (10)	73 (22)
Wedge Piling				
W1	Near-Field	29 (9)	11 (3)	30 (9)
	Far-Field	37 (11)	25 (8)	92 (28)
East Side of North Trestle (North Trestle Group A)				
E1.1-10 (on-land)	Near-Field	10 (3)	6 (2)	73 (22)
E1.1-8 (on-land)	Near-Field	10 (3)	6 (2)	61 (19)
E3-5	Near-Field	10 (3)	6 (2)	23 (7)

7.0 IMPACT PILE DRIVING ANALYSIS AND RESULTS

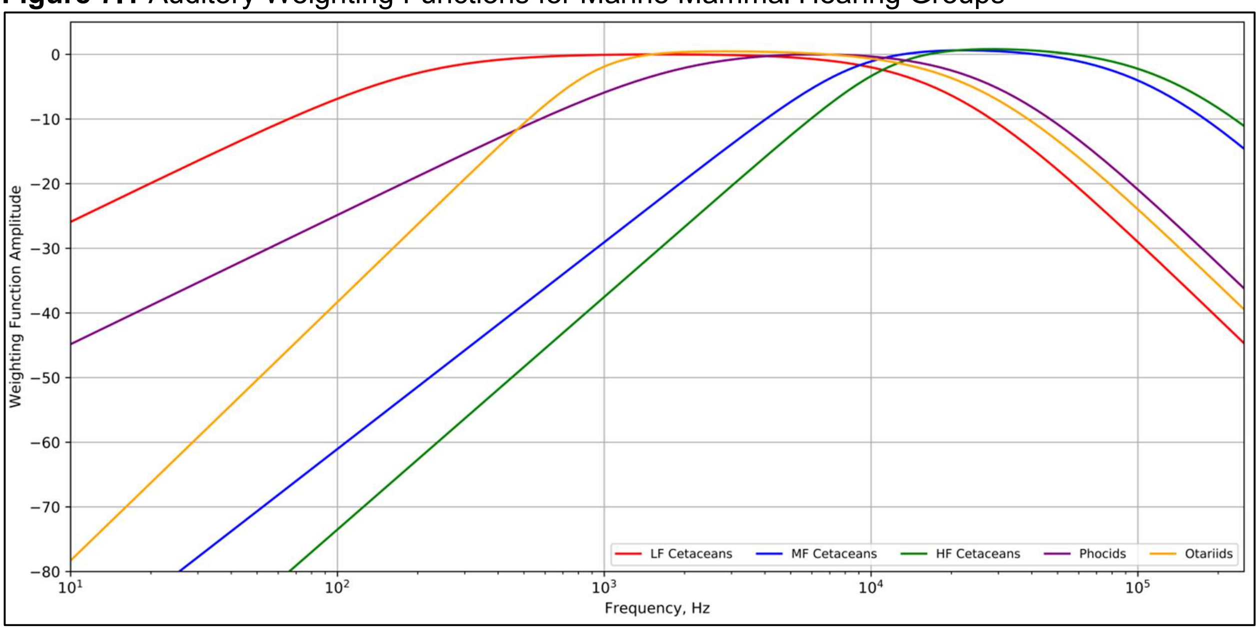
During post-processing the hydroacoustic data were frequency-weighted for each of the marine mammal hearing groups defined in the NOAA technical guidance document titled "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing" dated April 2018. This Technical Guidance 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

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



Underwater noise data collected during impact pile driving were analyzed to determine the range, mean, L_{50} and standard deviation of peak, RMS_{90} and SEL values as well as the cSEL of each pile for each marine mammal functional hearing group as required by the WSDOT Underwater Noise Monitoring Plan. Standard deviation and L_{50} were calculated using decibel values and mean values were calculated using mean sound pressure levels. Periods when pile driving was not occurring under full power were excluded from this analysis. Reported sound levels from the near-field hydrophone have been normalized to 33 feet (10 meters) from the piles using the practical spreading model. For additional information on the practical spreading model please see Section 8.0 of this Report.

The RMS_{90} was established between the 5th percentile and 95th percentile for each recorded pile strike. Figures illustrating the waveforms produced by the pile strikes that generated the absolute highest peak sound pressure level from each pile are provided in the Appendix of this Report. The green portion of these waveforms represents the duration of the strike containing 90% of the acoustical energy.

SEL values were calculated for each pile strike over the duration of the strike containing 90% of the acoustic energy using the following formula:

$$\mathrm{SEL} = \mathrm{RMS(dB)} + 10\log_{10}(\tau)$$

Where τ is the time interval containing 90% of the acoustic energy in each pile strike.

cSEL values were calculated by combining the single strike SEL values for each pile. The resulting cSEL values from each pile driven were combined (logarithmically) to produce daily cSEL values.

Airborne data were analyzed to determine the range and median of 1-second unweighted L_{eq} and L_{max} sound levels as well as A-weighted L_{eq}, L_{max}, L_{90}, and L_{95} sound levels. The 1/3 octave L_{eq} and L_{max} spectral data was also calculated. Periods when pile driving was not occurring are exclude from the analysis.

Details and results of the hydroacoustic and airborne monitoring at the North Trestle, Slip 2 Bridge Seat, and Wedge Piling are discussed in Section 7.1 through Section 7.4.

7.1 West Side of North Trestle (North Trestle Group B) 36-Inch Piles

Acoustic measurements were made during impact pile driving of three 36-inch steel pipe piles at the west side of the North Trestle (North Trestle Group B) on November 8, 2019 and December 4, 2019. During the November measurements the water temperature was approximately 51 degrees Fahrenheit and 53 degrees Fahrenheit during the December measurements. There was no precipitation during the measurements.

During the measurements, both hydrophones were suspended from portions of Colman Dock that had not been demolished. An unobstructed acoustical path between Pile N12-NC.7 and the far-field hydrophone was unable to be established however, both hydrophones maintained an unobstructed path during all other measurements. The microphone was positioned approximately 7-feet above the existing dock with an unobstructed acoustical path to the piles. The locations of the hydrophones, microphone, and piles are shown in Figure 7.2 and Figure 7.3.

Soft start procedures were followed before the drive of Pile N12.5-NF and Pile N11-NC.7. After completion of the soft start for Pile N12.5-NF pile driving commenced for a couple of minutes but was suspended to attached sensors for PDA testing. Pile driving resumed after the attachment of the sensors.

Figure 7.2 November 8, 2019 Pile and Monitoring Locations

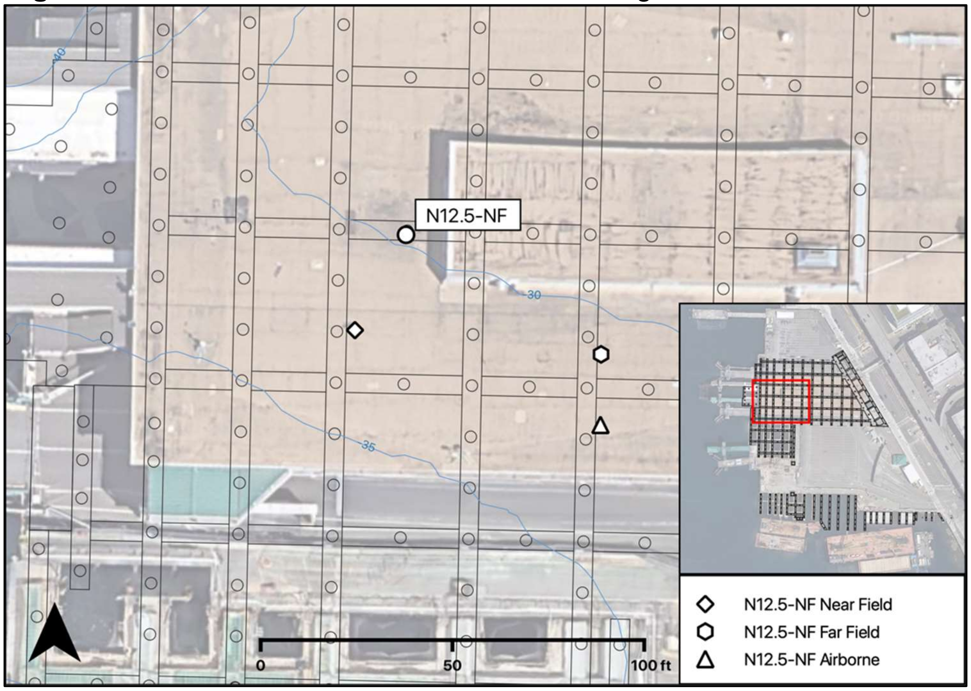
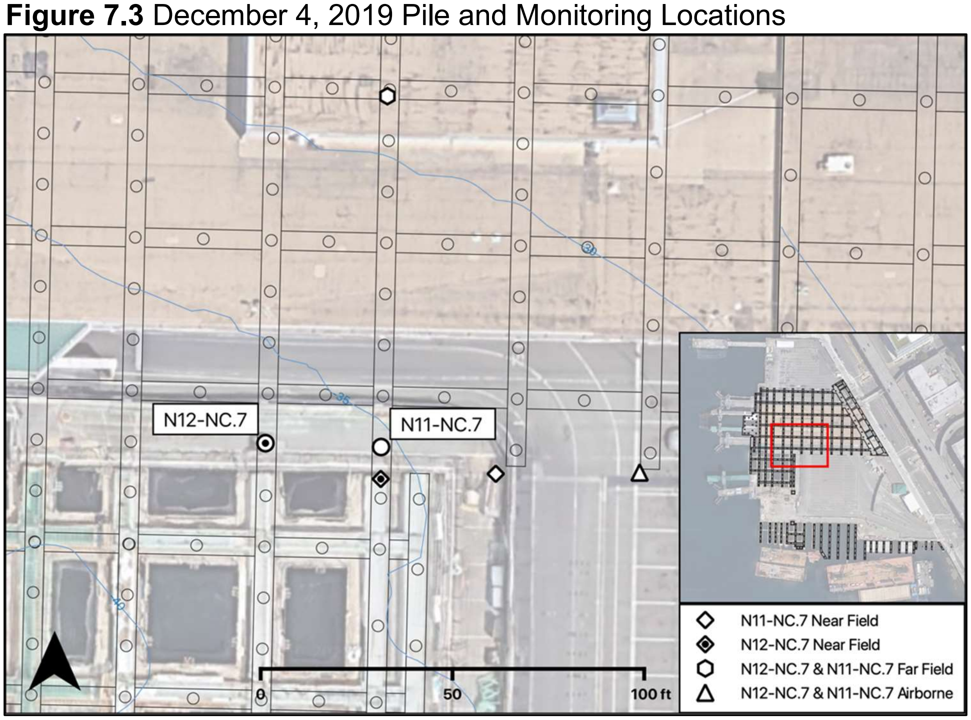


Figure 7.3 December 4, 2019 Pile and Monitoring Locations



Summaries of the airborne and underwater sound levels produced by impact pile driving at the west side of the North Trestle (North Trestle Group B) are shown in Table 7.2 through Table 7.7.

Table 7.2 Pile N12.5-NF Underwater Sound Levels, dB re: 1 μPa

Frequency Range	Peak					RMS_{90}					SEL					cSEL
	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	
Near-Field Hydrophone (measured 30 feet from pile, reported levels normalized to 33 feet)																
Unweighted	173	189	2.6	181	180	162	177	1.8	170	170	154	166	1.4	161	160	188
LF Cetacean						152	167	2.1	160	160	142	155	1.6	150	149	177
MF Cetacean						157	171	1.5	164	164	148	160	1.4	155	154	182
HF Cetacean						158	171	1.5	165	165	149	161	1.4	156	155	183
PW						148	163	1.6	156	156	139	152	1.3	147	146	174
OW						145	160	1.5	154	154	136	148	1.3	145	144	172
Far-Field Hydrophone (76 feet from pile)																
Unweighted	172	184	1.2	181	181	164	178	1.9	175	175	155	166	1.2	164	164	191
LF Cetacean						147	164	1.3	156	155	140	153	1.0	148	148	175
MF Cetacean						160	172	1.8	169	170	150	160	1.2	158	158	186
HF Cetacean						161	173	1.8	170	170	151	160	1.2	159	159	186
PW						150	161	1.4	159	159	141	150	1.1	149	149	176
OW						147	157	1.3	156	156	138	148	1.2	146	146	174

Table 7.3 Pile N12.5-NF Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
94	109	104	104	115	110	91	107	102	100	112	106	79	95	83	75	93	83

1. Sound levels measured 75 feet from pile. Reported sound levels have been normalized to 50 feet.

Table 7.4 Pile N11-NC.7 Underwater Sound Levels, dB re: 1 μPa

Frequency Range	Peak					RMS_{90}					SEL					cSEL
	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	
Near-Field Hydrophone (measured 30 feet from pile, reported levels normalized to 33 feet)																
Unweighted	176	192	2.7	182	181	167	180	2.3	173	172	158	171	2.0	163	163	188
LF Cetacean						155	171	2.3	161	160	147	159	2.0	150	149	174
MF Cetacean						162	175	2.1	167	167	153	165	1.9	157	157	182
HF Cetacean						163	176	2.1	168	167	154	166	1.9	158	157	182
PW						154	167	2.1	159	158	144	156	1.8	149	148	173
OW						151	167	2.1	157	156	141	155	1.8	146	146	171
Far-Field Hydrophone (97 feet from pile)																
Unweighted	167	183	1.7	173	173	160	173	1.3	165	165	151	163	1.3	155	155	180
LF Cetacean						146	160	1.9	152	151	137	151	1.7	143	142	167
MF Cetacean						155	167	1.1	159	159	146	158	1.2	150	150	174
HF Cetacean						155	168	1.1	160	160	146	158	1.2	151	150	175
PW						145	158	1.2	150	150	136	149	1.2	141	141	165
OW						142	156	1.3	148	147	134	147	1.2	139	138	163

Table 7.5 Pile N11-NC.7 Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
91	107	105	105	114	111	87	107	105	105	114	111	81	88	83	80	87	82

1. Sound levels measured 94 feet from pile. Reported sound levels have been normalized to 50 feet.

Table 7.6 Pile N12-NC.7 Underwater Sound Levels, dB re: 1 μPa

Frequency Range	Peak					RMS_{90}					SEL					cSEL
	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	
Near-Field Hydrophone (measured 30 feet from pile, reported levels normalized to 33 feet)																
Unweighted	175	186	1.8	181	180	166	174	0.7	171	171	158	164	0.6	162	162	186
LF Cetacean						153	165	1.6	161	161	144	154	1.1	151	150	175
MF Cetacean						161	169	0.7	166	166	152	160	0.6	157	157	181
HF Cetacean						162	169	0.7	167	167	153	161	0.6	158	157	181
PW						152	161	1.0	158	158	143	152	0.8	149	149	173
OW						150	161	1.4	157	157	141	151	1.2	148	147	172
Far-Field Hydrophone (97 feet from pile)																
Unweighted	169	183	1.6	175	174	161	169	1.2	164	164	152	159	1.1	155	155	179
LF Cetacean						149	155	0.9	153	153	140	146	0.7	144	143	167
MF Cetacean						157	166	1.2	160	159	148	157	1.2	150	150	174
HF Cetacean						157	166	1.2	160	160	149	158	1.2	151	151	175
PW						147	156	0.9	151	151	139	148	0.9	142	142	166
OW						145	154	1.0	150	150	136	145	0.9	141	140	164

Table 7.7 Pile N12-NC.7 Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
87	106	104	102	112	109	84	105	103	101	111	109	75	86	80	75	85	80

1. Sound levels measured 64 feet from pile. Reported sound levels have been normalized to 50 feet.

The underwater sound levels measured over the duration of each pile drive, the waveform of the of the pile strike which produced the absolute highest peak sound pressure level, and the average underwater frequency spectrum from all pile strikes are provided in the Appendix.

7.2 Slip 2 Bridge Seat 36 Inch Battered Piles

Four 36-inch battered piles were measured the afternoon of January 17, 2020 at the Slip 2 Bridge Seat. During the measurements, the water temperature was 49 degrees Fahrenheit and no precipitation occurred during the measurements.

Both hydrophones were secured to completed sections of Colman Dock and an unobstructed acoustical transmission path was maintained to both hydrophones during all pile driving. The microphone was positioned south of the piles approximately 7 feet above the dock with a direct line-of-sight to the piles. The locations of the piles, microphone, and hydrophones are shown in

Figure 7.4 and a photo of the battered piles is provided in Figure 7.5. Soft start procedures were followed at the start of Pile 1.

Figure 7.4 Slip 2 Bridge Seat Pile and Measurement Locations

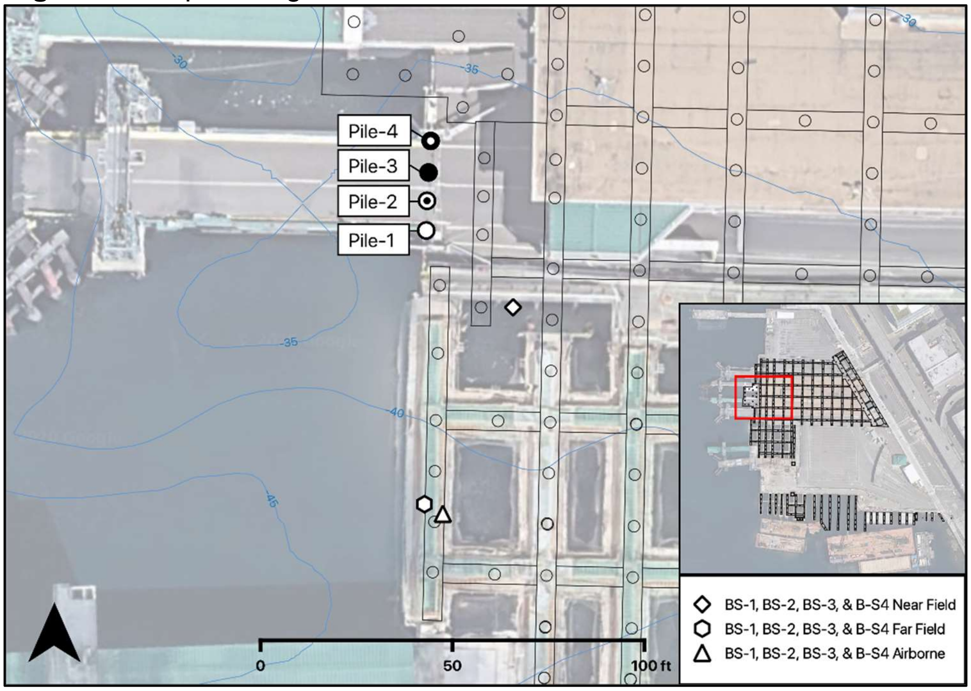
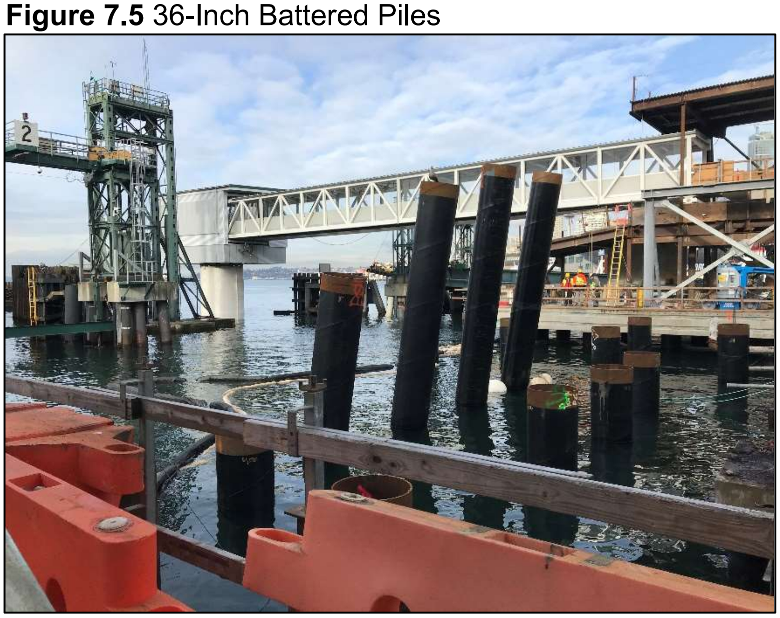


Figure 7.5 36-Inch Battered Piles



Summaries of airborne and underwater sound levels measured during impact pile driving at the Slip 2 Bridge Seat are shown in Table 7.8 through Table 7.15.

Table 7.8 Pile 4 Underwater Sound Levels, dB re: 1 μPa

Frequency Range	Peak					RMS_{90}					SEL					cSEL
	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	
Near-Field Hydrophone (measured 56 feet from pile, reported levels normalized to 33 feet)																
Unweighted	187	197	0.9	195	195	174	185	1.2	182	182	162	171	1.0	169	169	196
LF Cetacean						169	178	1.1	176	176	155	165	1.0	163	163	190
MF Cetacean						168	178	1.1	176	175	156	165	0.9	163	163	190
HF Cetacean						169	179	1.2	176	176	156	166	0.9	163	163	191
PW						165	175	0.9	171	171	151	161	0.9	159	159	186
OW						165	175	1.0	171	171	151	162	0.9	159	159	186
Far-Field Hydrophone (96 feet from pile)																
Unweighted	180	189	1.0	186	185	165	176	1.4	172	172	154	164	1.0	161	161	188
LF Cetacean						160	170	1.2	167	167	147	158	1.0	155	155	182
MF Cetacean						159	170	1.3	166	166	148	158	1.0	155	155	182
HF Cetacean						159	170	1.3	166	166	149	159	1.0	156	156	183
PW						154	164	1.1	162	162	143	153	1.0	150	150	177
OW						153	164	1.1	161	161	141	152	1.0	150	150	177

Table 7.9 Pile 4 Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
93	108	105	106	113	110	90	106	102	104	110	108	75	88	80	74	85	79

1. Sound levels measured 96 feet from pile. Reported sound levels have been normalized to 50 feet.

Table 7.10 Pile 3 Underwater Sound Levels, dB re: 1 μPa

Frequency Range	Peak					RMS_{90}					SEL					cSEL
	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	
Near-Field Hydrophone (measured 46 feet from pile, reported levels normalized to 33 feet)																
Unweighted	187	200	0.8	196	196	174	185	1.0	182	181	161	170	0.8	168	168	197
LF Cetacean						170	180	0.9	176	176	155	164	0.8	162	162	191
MF Cetacean						168	179	1.0	175	175	155	164	0.8	162	162	191
HF Cetacean						168	180	1.0	176	176	156	164	0.8	163	162	191
PW						165	175	0.9	172	172	151	160	0.8	158	158	187
OW						165	175	0.9	173	173	151	161	0.8	159	159	187
Far-Field Hydrophone (89 feet from pile)																
Unweighted	180	190	1.1	187	187	164	176	1.3	171	171	154	164	0.8	161	160	189
LF Cetacean						160	171	1.1	166	166	148	157	0.9	154	154	183
MF Cetacean						158	169	1.1	166	165	148	158	0.9	154	154	183
HF Cetacean						159	170	1.1	166	166	149	159	0.9	155	155	184
PW						154	166	1.1	162	161	144	153	0.9	150	150	178
OW						155	165	1.0	162	161	143	152	0.9	150	150	178

Table 7.11 Pile 3 Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
92	108	105	105	112	110	88	106	102	101	111	108	77	89	81	77	86	80

1. Sound levels measured 89 feet from pile. Reported sound levels have been normalized to 50 feet.

Table 7.12 Pile 2 Underwater Sound Levels, dB re: 1 μPa

Frequency Range	Peak					RMS_{90}					SEL					cSEL
	Min	**Max**	**SD**	**Mean**	L_{50}	**Min**	**Max**	**SD**	**Mean**	L_{50}	**Min**	**Max**	**SD**	**Mean**	L_{50}	
Near-Field Hydrophone (measured 36 feet from pile, reported levels normalized to 33 feet)																
Unweighted	188	196	0.9	193	193	174	183	1.2	180	180	161	169	0.8	167	167	195
LF Cetacean						169	178	1.0	175	175	154	163	0.8	161	161	189
MF Cetacean						168	177	1.1	174	174	155	163	0.8	161	161	189
HF Cetacean						168	177	1.1	174	174	155	164	0.8	162	162	190
PW						165	174	1.0	170	170	151	159	0.8	157	157	185
OW						166	174	1.2	170	170	151	160	0.9	157	156	185
Far-Field Hydrophone (80 feet from pile)																
Unweighted	182	193	1.6	188	188	164	177	1.2	173	173	154	165	0.9	162	162	190
LF Cetacean						160	173	1.3	168	168	147	159	1.0	156	155	184
MF Cetacean						159	172	1.0	167	167	148	160	0.9	156	156	184
HF Cetacean						159	172	1.0	168	168	149	160	0.9	157	156	185
PW						155	168	1.3	163	163	143	155	1.0	151	151	179
OW						154	169	1.5	163	163	142	155	1.1	151	151	179

Table 7.13 Pile 2 Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
90	108	105	104	112	111	87	105	103	101	110	109	77	88	80	75	85	79

1. Sound levels measured 80 feet from pile. Reported sound levels have been normalized to 50 feet.

Table 7.14 Pile 1 Underwater Sound Levels, dB re: 1 μPa

Frequency Range	Peak					RMS_{90}					SEL					cSEL
	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	
Near-Field Hydrophone (measured 27 feet from pile, reported levels normalized to 33 feet)																
Unweighted	180	194	1.8	191	191	168	182	1.6	179	178	156	168	1.2	165	165	190
LF Cetacean						163	177	1.5	174	173	149	162	1.3	159	159	184
MF Cetacean						163	176	1.5	172	172	150	162	1.2	159	159	184
HF Cetacean						163	176	1.5	173	173	151	163	1.2	160	160	185
PW						157	173	1.7	169	169	145	158	1.4	155	155	180
OW						158	174	2.0	169	169	144	159	1.8	155	155	180
Far-Field Hydrophone (73 feet from pile)																
Unweighted	181	192	1.1	189	189	165	175	1.0	173	173	154	163	0.8	162	162	187
LF Cetacean						160	170	1.0	168	168	147	157	0.9	155	155	181
MF Cetacean						159	169	1.1	167	167	148	157	0.8	156	156	181
HF Cetacean						159	170	1.1	168	168	149	158	0.8	156	156	182
PW						154	165	1.0	164	164	143	153	0.9	151	151	177
OW						153	166	1.0	164	164	142	153	1.0	151	151	177

Table 7.15 Pile 1 Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
91	107	105	104	112	110	88	105	103	101	110	108	78	87	80	77	85	79

1. Sound levels measured 73 feet from pile. Reported sound levels have been normalized to 50 feet.

The underwater sound levels measured over the duration of each pile drive, the waveform of the of the pile strike which produced the absolute highest peak sound pressure level, and the average underwater frequency spectrum from all pile strikes are provided in the Appendix.

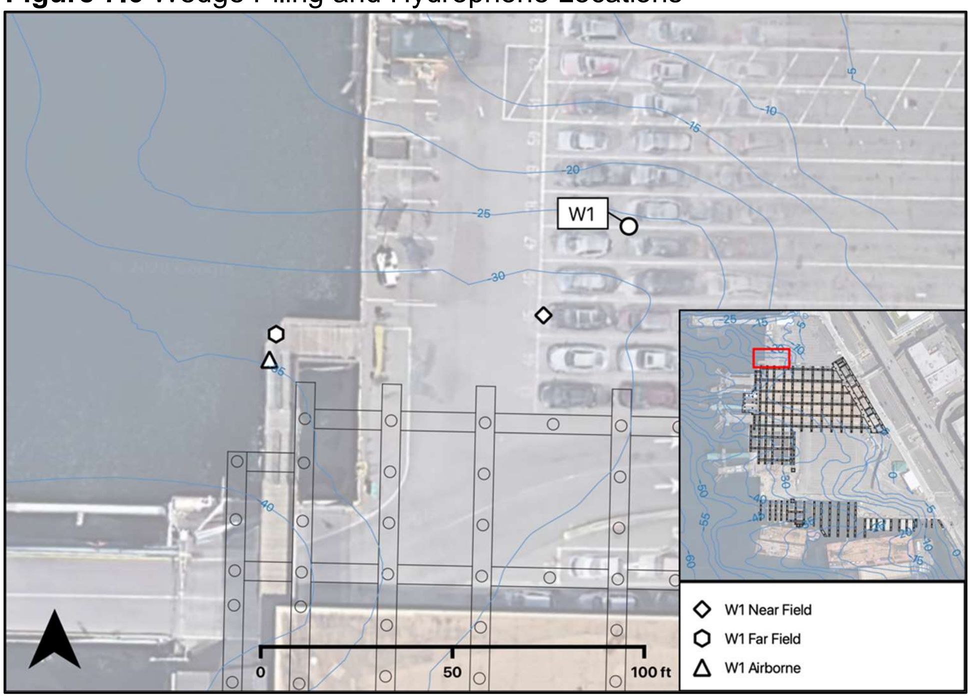
7.3 Wedge Piling

Acoustic measurements were made during impact pile driving of one 24-inch steel pipe pile during the morning of February 26, 2020. During the measurements, the water temperature was approximately 48 degrees Fahrenheit and there was no precipitation.

Both hydrophones were secured to completed sections of Colman Dock and an unobstructed acoustical transmission path was maintained to both hydrophones during the drive. The microphone was 7 feet above the dock and was approximately 91 feet from the pile. The locations of the pile, microphone, and hydrophones are shown in Figure 7.6.

Soft start procedures were followed at the beginning of the drive. However, the APE D62 diesel impact hammer was unstable on top of the pile. The hammer was also misfiring, and the piston height varied through the pile drive which resulted in variable sound levels.

Figure 7.6 Wedge Piling and Hydrophone Locations



Summaries of the airborne and underwater sound levels generated by impact pile driving of the 24-inch pile are shown in Table 7.16 and Table 7.17.

Table 7.16 Pile W1 Underwater Sound Levels, dB re: 1 μPa

Frequency Range	Peak					RMS90					SEL					cSEL
	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	
Near-Field Hydrophone (measured 30 feet from pile, reported levels normalized to 33 feet)																
Unweighted	175	189	2.1	180	179	162	174	2.4	168	168	152	162	2.0	157	156	180
LF Cetacean						156	168	2.2	161	160	144	154	1.9	148	147	171
MF Cetacean						157	168	2.1	163	162	147	156	1.9	151	150	174
HF Cetacean						157	169	2.2	163	163	147	156	2.0	151	151	174
PW						154	167	2.4	159	158	142	153	2.1	146	145	169
OW						153	167	2.8	159	158	141	154	2.4	146	144	169
Far-Field Hydrophone (92 feet from pile)																
Unweighted	167	184	2.5	173	172	158	168	1.8	163	162	149	158	1.8	153	153	176
LF Cetacean						146	159	2.6	153	151	137	147	2.1	142	141	165
MF Cetacean						153	162	1.8	157	156	144	152	1.7	147	147	170
HF Cetacean						153	162	1.8	157	157	144	153	1.7	148	148	171
PW						144	158	3.0	150	148	135	148	2.5	141	139	164
OW						142	160	3.9	150	146	133	148	3.1	139	137	162

Table 7.17 Pile W1 Airborne Sound Levels, dB re: 20 μPa1

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
93	106	102	104	112	108	89	103	100	100	110	106	79	90	81	77	89	80

1. Sound levels measured 91 feet from pile. Reported sound levels have been normalized to 50 feet.

The underwater sound levels measured over the duration of the pile drive, the waveform of the of the pile strike which produced the absolute highest peak sound pressure level, and the average underwater frequency spectrum from all pile strikes are provided in the Appendix.

7.4 East Side of North Trestle (North Trestle Group A) 36-Inch Piles

Measurements were made of impact pile driving of three 36-inch piles at the east side of the North Trestle (North Trestle Group A) during the afternoon of February 26, 2020. Water temperature during the measurements was approximately 48 degrees Fahrenheit and there was no precipitation. Due to tidal conditions Pile E1.1-10 and Pile E1.1-8 were driven above the waterline.

Only one hydrophone was used to monitor underwater sound levels because two of the piles were driven above the waterline and the far-field hydrophone would have been positioned closer than 33 feet (10 meters) from the pile due to the shallow water depth at the pile. The hydrophone was suspended from a temporary work trestle and maintained a direct path of acoustical transmission to the in-water pile and no piles were located between the hydrophone and the two piles driven above the waterline. The microphone was located south of the piles and was approximately 7-feet above the dock. The locations of the piles, microphone, and hydrophone are shown in Figure 7.7 and a photograph of Pile E1.1-10 being driven above the waterline is provided in Figure 7.8.

Soft start procedures were followed at the start of Pile E1.1-10 even though the pile was located above the waterline.

Figure 7.7 North Trestle (Group A) Pile and Hydrophone

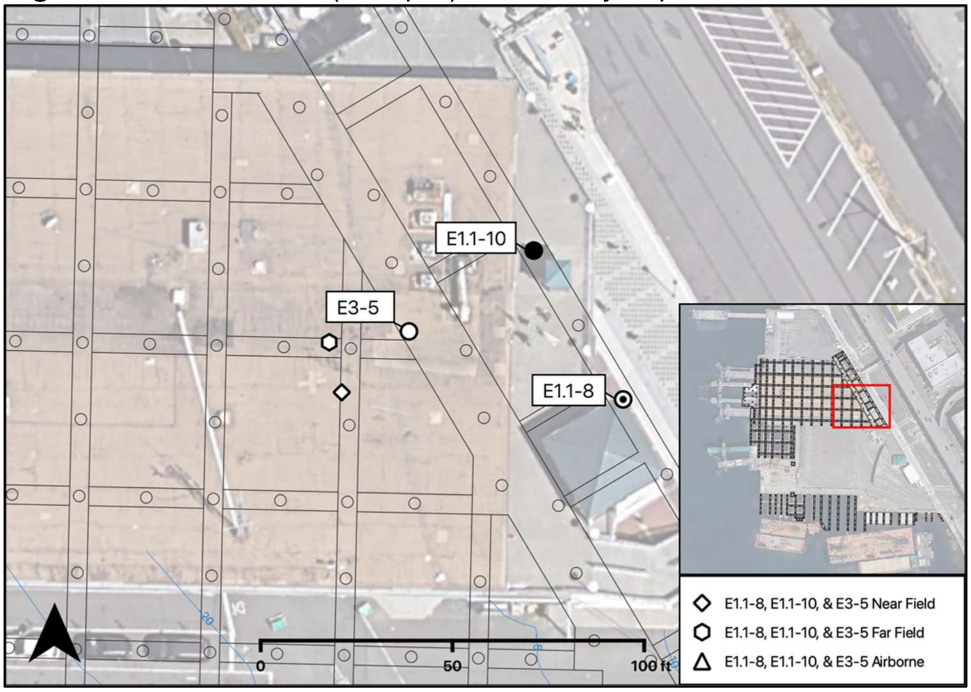


Figure 7.8 Pile E1.1-10 Above the Waterline

Summaries of the airborne and underwater sound levels generated by impact pile driving of the 36-inch piles are shown in Table 7.18 through Table 7.23.

Table 7.18 Pile E1.1-10 Underwater Sound Levels, dB re: 1 μPa

<table>
<tr><th rowspan="2">Frequency Range</th><th colspan="5">Peak</th><th colspan="5">RMS90</th><th colspan="5">SEL</th><th rowspan="2">cSEL</th></tr>
<tr><th>Min</th><th>Max</th><th>SD</th><th>Mean</th><th>L50</th><th>Min</th><th>Max</th><th>SD</th><th>Mean</th><th>L50</th><th>Min</th><th>Max</th><th>SD</th><th>Mean</th><th>L50</th></tr>
<tr><td colspan="17">Near-Field Hydrophone (measured 73 feet from pile, reported levels normalized to 33 feet)</td></tr>
<tr><td>Unweighted</td><td rowspan="6">161</td><td rowspan="6">166</td><td rowspan="6">0.9</td><td rowspan="6">165</td><td rowspan="6">165</td><td>139</td><td>160</td><td>1.3</td><td>158</td><td>159</td><td>130</td><td>148</td><td>1.1</td><td>146</td><td>146</td><td>175</td></tr>
<tr><td>LF Cetacean</td><td>133</td><td>139</td><td>0.8</td><td>137</td><td>138</td><td>124</td><td>131</td><td>0.7</td><td>129</td><td>129</td><td>158</td></tr>
<tr><td>MF Cetacean</td><td>140</td><td>154</td><td>2.0</td><td>152</td><td>152</td><td>130</td><td>141</td><td>0.9</td><td>140</td><td>140</td><td>169</td></tr>
<tr><td>HF Cetacean</td><td>140</td><td>155</td><td>2.1</td><td>152</td><td>153</td><td>130</td><td>142</td><td>0.9</td><td>141</td><td>141</td><td>170</td></tr>
<tr><td>PW</td><td>135</td><td>142</td><td>1.2</td><td>140</td><td>140</td><td>127</td><td>132</td><td>0.8</td><td>131</td><td>131</td><td>160</td></tr>
<tr><td>OW</td><td>133</td><td>139</td><td>0.9</td><td>137</td><td>137</td><td>125</td><td>130</td><td>0.7</td><td>128</td><td>128</td><td>158</td></tr>
</table>

Table 7.19 Pile E1.1-10 Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
90	108	105	10	114	110	86	104	101	100	111	107	74	92	82	74	91	81

1. Sound levels measured 92 feet from pile. Reported sound levels have been normalized to 50 feet.

Table 7.20 Pile E1.1-8 Underwater Sound Levels, dB re: 1 μPa

<table>
<tr><th rowspan="2">Frequency Range</th><th colspan="5">Peak</th><th colspan="5">RMS90</th><th colspan="5">SEL</th><th rowspan="2">cSEL</th></tr>
<tr><th>Min</th><th>Max</th><th>SD</th><th>Mean</th><th>L50</th><th>Min</th><th>Max</th><th>SD</th><th>Mean</th><th>L50</th><th>Min</th><th>Max</th><th>SD</th><th>Mean</th><th>L50</th></tr>
<tr><td colspan="17">Near-Field Hydrophone (measured 61 feet from pile, reported levels normalized to 33 feet)</td></tr>
<tr><td>Unweighted</td><td rowspan="6">158</td><td rowspan="6">164</td><td rowspan="6">0.8</td><td rowspan="6">162</td><td rowspan="6">162</td><td>149</td><td>157</td><td>1.5</td><td>155</td><td>155</td><td>141</td><td>145</td><td>0.8</td><td>144</td><td>144</td><td>170</td></tr>
<tr><td>LF Cetacean</td><td>132</td><td>137</td><td>0.6</td><td>135</td><td>135</td><td>125</td><td>129</td><td>0.6</td><td>128</td><td>128</td><td>153</td></tr>
<tr><td>MF Cetacean</td><td>143</td><td>149</td><td>0.8</td><td>146</td><td>146</td><td>135</td><td>139</td><td>0.7</td><td>138</td><td>138</td><td>164</td></tr>
<tr><td>HF Cetacean</td><td>144</td><td>150</td><td>0.8</td><td>147</td><td>147</td><td>136</td><td>140</td><td>0.7</td><td>139</td><td>139</td><td>165</td></tr>
<tr><td>PW</td><td>134</td><td>139</td><td>0.7</td><td>137</td><td>137</td><td>126</td><td>130</td><td>0.6</td><td>129</td><td>129</td><td>155</td></tr>
<tr><td>OW</td><td>132</td><td>136</td><td>0.6</td><td>135</td><td>135</td><td>124</td><td>128</td><td>0.5</td><td>127</td><td>127</td><td>152</td></tr>
</table>

Table 7.21 Pile E1.1-8 Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
95	110	106	108	117	112	90	105	102	103	111	107	80	90	83	79	88	82

1. Sound levels measured 139 feet from pile. Reported sound levels have been normalized to 50 feet.

Table 7.22 Pile E3-5 Underwater Sound Levels, dB re: 1 μPa

Frequency Range	Peak					RMS90					SEL					cSEL
	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	Min	Max	SD	Mean	L_{50}	
Near-Field Hydrophone (measured 23 feet from pile, reported levels normalized to 33 feet)																
Unweighted	189	201	2.1	196	195	180	186	1.1	183	183	165	170	1.0	168	168	197
LF Cetacean						175	181	1.2	178	178	159	165	1.0	163	163	191
MF Cetacean						174	181	1.1	178	178	159	165	1.0	162	162	191
HF Cetacean						175	181	1.1	178	178	159	165	1.0	163	163	191
PW						173	180	1.3	176	176	157	163	1.1	161	161	189
OW						174	181	1.4	177	177	158	164	1.2	162	162	190

Table 7.23 Pile E3-5 Airborne Sound Levels, dB re: 20 μPa[1]

Unweighted						A-Weighted											
L_{eq}			L_{max}			L_{eq}			L_{max}			L_{90}			L_{95}		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
91	108	103	101	114	109	86	107	101	99	114	107	79	93	82	78	91	81

1. Sound levels measured 142 feet from pile. Reported sound levels have been normalized to 50 feet.

The underwater sound levels measured over the duration of each pile drive, the waveform of the of the pile strike which produced the absolute highest peak sound pressure level, and the average underwater frequency spectrum from all pile strikes are provided in the Appendix.

8.0 DISTANCE TO MARINE MAMMAL DISTURBANCE AND INJURY THRESHOLDS

Data collected during impact pile driving was used to estimate the distance required for underwater sound levels to reach the disturbance and injury thresholds for fish and marine mammals.

The distances were calculated using the "practical spreading model" currently used by NOAA. The practical spreading formula is provided below.

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

Where $\mathrm{SPL_{D1}}$ is the sound pressure measured at a distance, D_1 and $\mathrm{SPL_{D2}}$ 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 distances required for underwater noise to reach the disturbance and injury thresholds for fish and marine mammals are estimated by solving the practical spreading formula for D_2 resulting in the following:

$$\mathrm{D_2} = \mathrm{D_1} * 10^{\left(\frac{\mathrm{SPL_{D1}} - \mathrm{SP\ \ D2}}{15}\right)}$$

To estimate the distances required for underwater noise to reach the disturbance and injury thresholds sound levels measured by the far-field hydrophone were normalized to their average measurement distance of 80 feet (24 meters) to allow for comparison of measured sound levels. After calculating the far-field sound levels at 80 feet (24 meters), the highest median peak, RMS_{90} and highest daily cSEL values were used to calculate the distances required for sound to reach marine mammal thresholds. The far-field hydrophone provides a more accurate estimate of sound levels at greater distances, as described in the National Marine Fisheries Service Guidance Document titled “Data Collection Methods to Characterize Impact and Vibratory Pile Driving Source Levels Relevant to Marine Mammals”, dated January 31, 2012.

8.1 Marine Mammal Threshold Distances

The results of the acoustic monitoring and analysis were used to estimate the distances required for underwater sound levels to reach the marine mammal injury (Level A) and disturbance (Level B) thresholds.

In April 2018, 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”. The Technical Guidance utilizes dual threshold criteria for injury from impulsive sounds, such as impact pile driving. These criteria are peak sound pressure and cSEL values accumulated over a 24-hour period. The peak sound pressure criteria are unweighted and the cSEL values are frequency-weighted for each marine mammal hearing group. Injury thresholds from impulsive sounds are in Table 8.1.

Table 8.1 Injury Thresholds, dB re: 1 μPa

Hearing Group	Impulsive	
	Peak (unweighted)	cSEL (weighted)
Low-frequency (LF) cetaceans	219	183
Mid-frequency (MF) cetaceans	230	185
High-frequency (HF) cetaceans	202	155
Phocid pinnipeds (PW) (underwater)	218	185
Otariid pinnipeds (OW) (underwater)	232	203

Source: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing, April 2018

Marine mammal disturbance thresholds (Level B) from underwater sound are based on RMS sound levels from previous guidance and are shown in Table 8.2.

Table 8.2 Disturbance Thresholds (RMS), dB re: 1 μPa

Marine Mammal	Impact Pile Driving Disturbance Threshold
Cetaceans	160
Pinnipeds	

Source: National Marine Fisheries Service

The practical spreading model, the highest 24-hour cSEL values, and the loudest average peak, and RMS_{90} sound levels recorded during pile driving were used to calculate the distances necessary for underwater sound to reach Level A and Level B thresholds. The resulting distances for impact pile driving distances are shown in Table 8.3.

Table 8.3 Distances to Marine Mammal Thresholds from Impact Pile Driving, Feet (Meters)

Hearing Group	Measured Sound Level			Marine Mammal Threshold			Distance to Threshold		
				Level A		Level B	Level A		Level B
	Peak	cSEL	RMS_{90}	Peak	cSEL	RMS_{90}	Peak	cSEL	RMS_{90}
LF Cetaceans	193	189	175	219	183	160	1.6 (0.5)	194 (59)	852 (260)
MF Cetaceans	193	189	175	230	185		0.3 (0.1)	150 (46)	807 (246)
HF Cetaceans	193	190	175	202	155		21.3 (6.5)	16,442 (5,011)	852 (260)
Pinnipeds (Phocids)	193	186	173	218	185		1.8 (0.5)	92 (28)	575 (175)
Pinnipeds (Otariids)	193	187	173	232	203		0.2 (0.1)	6 (1.8)	629 (192)

As shown in Table 8.3, the estimated distances required for sound produced by impact pile driving to reach the 160 dB marine mammal disturbance threshold is up to 852 feet (260 meters) from the pile. Approximately 16,442 feet (5,011 meters) may be required for sound to dissipate to below the Level A injury thresholds for high-frequency cetaceans, 194 feet (59 meters) for other cetaceans, and 92 feet (28 meters) for pinnipeds. Figure 8.1 illustrates the areas where underwater sound levels are expected to exceed the Level A and Level B thresholds for marine mammals. Descriptions of observed marine mammal behavior can be found in the marine mammal monitoring report.

Figure 8.1 Marine Mammal Disturbance and Injury Zones

8.2 Fish Threshold Distances

In 2008. The Fisheries Hydroacoustic Working Group, the Federal Highway Administration and Federal Agencies, including the National Marine Fisheries Service (NMFS), agreed upon dual sound level threshold criteria for the onset of injury to fish. These thresholds include peak sound pressure levels and cSEL levels for fish weighing more than 2 grams and fish weighing less than 2 grams. These thresholds as well as the threshold for “effective quiet” are shown in Table 8.4.

Table 8.4 Threshold Levels for Fish, dB re: 1 μPa

Effect	Metric	Fish Mass	Threshold
Physical Injury	Peak	N/A	206
	Daily cSEL	< 2 grams	183
		≥ 2 grams	187
Effective Quiet	Single Strike SEL	N/A	150

The distances for underwater sound levels to reach the threshold values listed in Table 8.4 were calculated using the practical spreading model and the highest mean peak and single strike SEL unweighted sound levels as well as the highest daily cSEL level measured by the far-field hydrophone. The resulting distances are provided in Table 8.5.

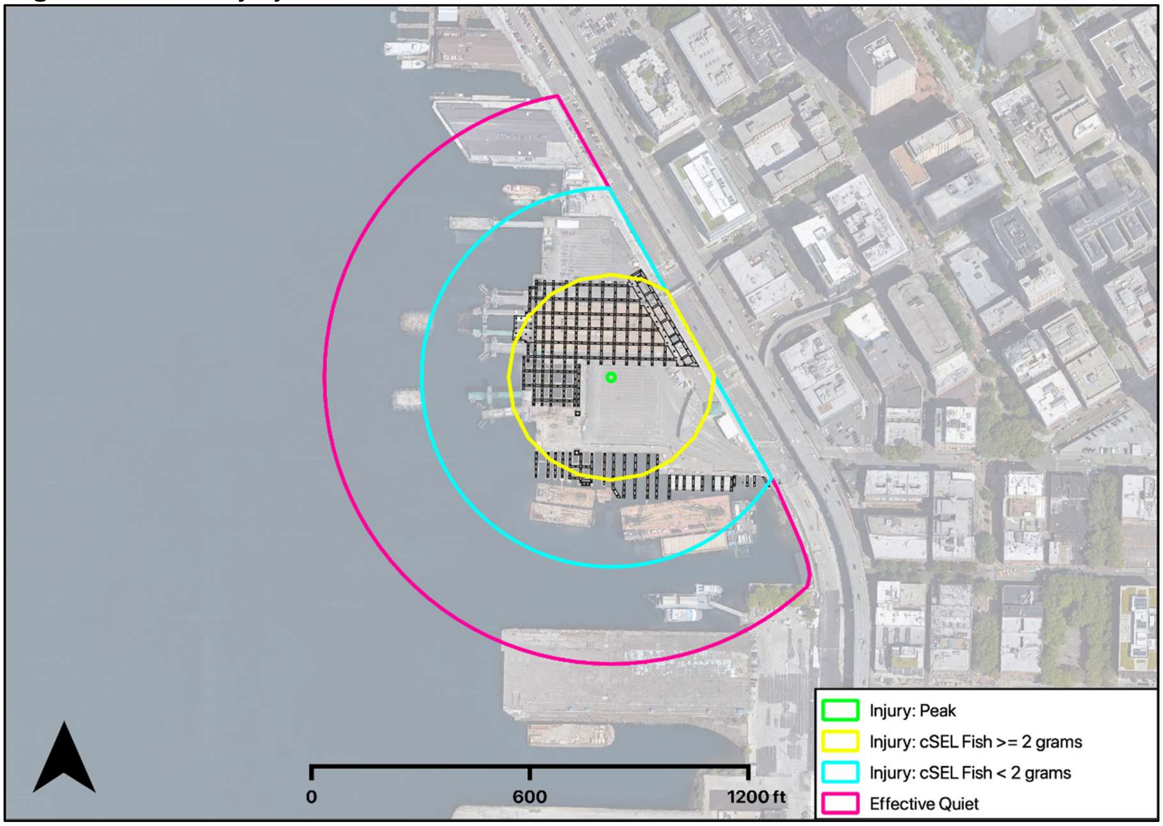
Table 8.5 Distances to Fish Thresholds, Feet (Meters)

Effect	Metric	Measured Sound Level	Fish Mass	Threshold	Distance
Physical Injury	Peak	193[1]	N/A	206	**12 (3.7)**
	Daily cSEL	195[2]	< 2 grams	183	**522 (159)**
			≥ 2 grams	187	**282 (86)**
Effective Quiet	Single Strike SEL	165[1]	N/A	150	**789 (241)**

1. The highest mean peak and singe strike SEL sound levels were measured during impact pile driving of Pile E3-5.
2. The highest daily unweighted cSEL sound level was measured by the far-field hydrophone on January 17, 2020.

Figure 8.2 illustrates the areas where underwater sound levels are expected to exceed the injury and effective quiet thresholds for fish.

Figure 8.2 Fish Injury and Effective Quiet Zones



9.0 PREDICTED AIRBORNE SOUND LEVELS AT NEARBY PROPERTIES

Airborne sound levels measured during Season 3 were used to predict sound levels at nearby residential properties.

Sound levels were predicted using a 3-D computer noise model. The computer noise model uses the acoustic modeling software Cadna/A. Cadna/A utilizes the CADNA (Control of Accuracy and Debugging for Numerical Applications) computation engine developed by the Pierre et Marie Curie University in Paris. The model accounts for the effects of distance, topography, and surface reflections on sound levels produced by impact pile driving.

The computer noise model was generated based on pile locations determined from project drawings and sound levels measured during Season 3. Elevation contours and locations and heights of nearby buildings were based on Geographic Information System (GIS) data downloaded from the Seattle Department of Construction and Inspections website.

Predicted sound levels at nearby residential properties are shown in Table 9.1. Sound contours predicted 5-feet (1.5 meters) above grade from the pile which produced the loudest predicted sound levels at nearby properties are shown in Figure 9.1.

Table 9.1 Predicted Airborne Sound Levels at Nearby Residential Properties

Property	Predicted 1-Second L_{eq} at Nearby Residential Use Properties, dBA										
	N12.5-NF	N12-NC.7	N11-NC.7	Pile 4	Pile 3	Pile 2	Pile 1	W1	E3-5	E1.1-10	E1.1-8
The Post at Pier 52	77	78	81	77	77	78	77	77	84	86	82
Waterfront Place	77	78	80	77	77	78	76	79	82	84	80
Alexis Hotel	71	72	72	71	71	72	71	72	65	66	63
Best Western Plus Pioneer Square Hotel	72	74	76	73	73	74	73	71	77	78	76
606 Post Condominium	69	70	72	69	69	70	69	67	73	74	72
Travelers Hotel the Post Condominium	59	68	70	65	66	68	67	68	74	75	73

Figure 9.1 Predicted Airborne Sound Levels 5-Feet Above Grade, L_{eq}, dBA

10.0 REFERENCES

California Department of Transportation. “Hydroacoustic Effects of Pile Driving on Fish.” November 2015.

Madsen, P.T., M. Johnson, P.J.O. Miller, N. Aguilar Soto, J. Lynch and P. Tyack. “Quantitative Measures of Air-Gun Pulses Recorded on Sperm Whales (Physeter macrocephalus) Using Acoustic Tags during Controlled Exposure Experiments.” October 2006.

NMFS Northwest Region and Northwest Fisheries Science Center. “Guidance Document: Data Collection Methods to Characterize Impact and Vibratory Pile Driving Source Levels Relevant to Marine Mammals.” January 31, 2012.

NOAA. “Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts.” April 2018.

NOAA Fisheries National Marine Fisheries Service “Marine Mammal and Fish Injury and Disturbance Thresholds for Marine Construction Activity.”

Seattle Multimodal Terminal at Colman Dock Project Drawings and Specifications. November 28, 2016

The Greenbusch Group, Inc. “Colman Dock Phase 3 Underwater Noise Monitoring Plan.” August 12, 2019.

Washington State Department of Transportation. “Seattle Multimodal Terminal at Colman Dock-Phase 1 Underwater Noise Monitoring Plan.” July 27, 2016

Washington State Department of Transportation. “Underwater Noise Monitoring Plan Template.” August 2013.