

APPENDIX A: NAVBASE KITSAP MARINE MAMMAL SURVEYS

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NAVBASE Kitsap Bangor Marine Mammal Surveys

Available data on marine mammal numbers in Hood Canal are sparse, with the exception of surveys of harbor seal haulouts (Jeffries et al. 2000) and recent surveys and monitoring efforts on NAVBASE Kitsap Bangor (Agness and Tannenbaum 2009; Tannenbaum et al. 2009, 2011; HDR 2012; Navy 2012; Hart Crowser 2013, Navy 2014a and c), some of which covered a very limited area.

NAVBASE Kitsap Bangor Pinniped Haulout Surveys

Beginning in April 2008, Navy personnel have recorded sightings of California sea lion, Steller sea lion, and harbor seal at known sea lion haulouts along the Bangor waterfront, including submarines and the nearshore pontoons of the floating security fence. Sightings of marine mammals within the waters adjoining these locations were also recorded. Sightings were attempted during a typical work week (i.e., Monday through Friday), but inclement weather, holidays, or security constraints often precluded surveys. Through 2012, these sightings took place frequently (average 14 per month) and only included haulouts. Surveys were minimal in 2013 due to budget reductions. During the surveys, staff visited each of the above mentioned locations and recorded observations of marine mammals on data collection forms, noting date, time, location, number, and species of marine mammals (by location), and other relevant notes. Surveys were conducted using binoculars and the naked eye from shoreline locations or the piers/wharves themselves. Data were compiled for the period from April 2008 through December 2013 for analysis in this IHA (Navy 2014a).

NAVBASE Kitsap Bangor Boat-Based Opportunistic and Marine Wildlife Surveys

Boat-based opportunistic sightings along portions of the Bangor waterfront during the course of beach seine fish surveys during the spring/summer of 2007 detected two marine mammal species (harbor seal and California sea lion) (Agness and Tannenbaum 2009). In these surveys, seals and sea lions were noted in a field notebook, as well as date, time, location, number of individuals, species, and other relevant notes.

Boat-based protocol marine wildlife surveys conducted during July through September 2008 (12 surveys) and November through May 2009/2010 (12 surveys) (Tannenbaum et al. 2009, 2011) detected four marine mammal species (harbor seal, California sea lion, harbor porpoise, and Dall's porpoise). These protocol surveys operated along pre-determined transects parallel to the shoreline from the nearshore out to approximately 1,800 feet from shoreline, at a spacing of 100 yards, and covered the entire Bangor waterfront (approximately 1.5 square miles) at a speed of 5 knots or less. Two observers recorded sightings of marine mammals both in the water and hauled out, including date, time, species, number of individuals, age (juvenile, adult), behavior (swimming, diving, hauled out, avoidance dive), and haulout location. Positions of marine mammals were obtained by recording distance and bearing to the animal with a rangefinder and compass, noting the concurrent location of the boat with Global Positioning System (GPS), and,

subsequently, analyzing these data with the coordinate geometry application available in ArcInfo to produce coordinates of the locations of all animals detected.

Construction Monitoring Surveys During Test Pile Program and EHW-2 Construction

Marine mammal monitoring was conducted in the EHW-2 project area in late 2011 during a test pile program (TPP) as mitigation for pile driving noise (HDR 2012). In addition, on days where no pile driving activities occurred the Navy conducted vessel-based line transect surveys in Hood Canal and Dabob Bay to collect additional density data for species present in Hood Canal. The primary impetus for the Hood Canal/Dabob Bay surveys was that observational data during pile driving monitoring indicated an unexpected abundance of harbor porpoise within Hood Canal. The surveys in Hood Canal were conducted in September and October and detected three marine mammal species (harbor seal, California sea lion, and harbor porpoise). The surveys operated along pre-determined transects that followed a double saw-tooth pattern to achieve uniform coverage of the entire Bangor waterfront. The vessel traveled at a speed of approximately 5 knots when transiting along the transect lines. Two observers recorded sightings of marine mammals both in the water and hauled out, including the date, time, species, number of individuals, and behavior (swimming, diving, etc.). Positions of marine mammals were obtained by recording the distance and bearing to the animal(s), noting the concurrent location of the boat with GPS, and subsequently analyzing these data with the coordinate geometry application available in ArcInfo to produce coordinates of the locations of all animals detected. Distance sampling methodologies were used to estimate densities of animals.

Marine mammal monitoring was conducted during construction on the EHW-2 from late September 2012 to mid-February 2014 (Hart Crowser 2013, Navy 2014x). Monitoring was conducted in several areas: (1) Primary Surveys within the behavioral monitoring and shutdown zones in the waterfront restricted area (WRA) (464-meter radius of the driven pile), (2) In the first construction year, Outside Boat Surveys within the larger Level B behavioral harassment zone due to vibratory pile driving but outside of the WRA, and (3) Delta Pier Surveys of marine mammals hauled out on submarines at Delta Pier and, in Year 2, Marginal Wharf. Monitoring of the first two areas was conducted in accordance with an approved Marine Mammal Monitoring Plan for the EHW-2 project and consisted of placing marine mammal observers on construction barges, the construction pier, and vessels located in near-field (within the behavioral monitoring zone in the WRA) and, in the first year of construction, far-field (outside the WRA but within the Level B harassment zone) locations. Marine mammal observers reported occurrences of marine mammals during actual construction (i.e., pile driving activity) and non-construction periods. The survey effort will continue for the third construction year (mid-July 2014 through mid-February 2015) with similar monitoring protocols.

The total number of marine mammals reported on construction days (including both pile-driving and non-pile driving activities) in first and second year surveys is summarized in Table A-1 (Hart Crowser 2013, Navy 2014c).

A subset of all marine mammal observations consisting of sightings that occurred during pile installation and removal was also reported (Table A-2). Two hundred nine sightings of 218

marine mammals were reported during primary surveys during construction monitoring of the buffer and shutdown zones (i.e., within a 464-meter radius) during impact and vibratory pile driving during the first in-water season (Table A–2) (Hart Crowser 2013). Six hundred ninety-seven sightings of 723 marine mammals were reported during primary surveys during construction monitoring of the buffer and shutdown zones (i.e., within a 464-meter radius) during impact and vibratory pile driving during the second in-water season (Table A–2) (Navy 2014c.). No observations were made at Delta Pier during pile installation or removal activities. During Year 1 (but not Year 2), additional sightings of marine mammals during pile installation and removal were reported from outside boat surveys (Table A–2).

Table A-1. Total Number of Unique Animals and Sightings by Species During EHW-2 Construction Days

Year	Species	Total # of Animals	Total # of Sightings	Mean Group Size	Min Group Size	Max Group Size
Year 1	Primary Surveys¹ Year 1 total monitoring time: 530 hours, 50 minutes of marine mammal surveys on 80 construction days					
	California sea lion	30	30	1	1	1
	Harbor Seal	984	939	1.05	1	4
	Delta Pier Surveys²					
	California sea lion	385	30	12.8	1	40
	Steller sea lion	4	3	1.3	1	2
	Outside Boat Surveys³					
	California sea lion	126	21	6.0	1	20
	Harbor seal	76	73	1.0	1	2
	Steller sea lion	3	3	1.0	1	1
Harbor Porpoise	57	10	5.7	1	10	
Year 2	Primary Surveys¹ Year 2 total monitoring time: 1,247 hours, 27 minutes of marine mammal surveys on 162 construction days.					
	California sea lion	83	77	1	1	3
	Harbor Seal	3,229	3,046	1	1	5
	Non-Primary Surveys⁴					
	California sea lion	917	32	29	1	96
	Harbor seal	9	2	5	1	8
	Steller sea lion	36	9	4	1	11
	Harbor Porpoise	0	0	0	0	0

Source: Hart Crowser 2013, Navy 2014c, in prep.

1. Primary Surveys occurred during monitoring of the shutdown zone and 464-meter buffer zone.
2. Delta Pier Surveys were sightings of animals hauled out on submarines at Delta Pier. These surveys typically occurred only at the end of daily construction monitoring.
3. Outside Boat Surveys were sightings of animals in the 41.4 sq km Level B harassment zone. These surveys occurred only during acoustic monitoring outside the WRA and therefore are a subset of all pile driving days.
4. Non-primary surveys were sightings of animals at Delta Pier, Marginal Wharf, and along the fence floats.

Table A-2. Summary of Unique Mammal Sightings during EHW-2 Pile Installation and Removal Activities

Year	Species	Total # of Animals	Total # of Sightings	Mean Group Size	Min Group Size	Max Group Size	Construction Type ¹			
							SSV	V	SSI	I
Year 1	Primary Surveys² Year 1 total monitoring time: 530 hours, 50 minutes of marine mammal surveys on 80 construction days									
	California sea lion	4	4	1.0	1	1	--	3	---	1
	Harbor seal	214	205	1.06	1	3	19	179	5	11
	Total	218	209	1.03			19	182	5	12
	Outside Boat Surveys³									
	California sea lion	22	4	4.0	1	20	--	21	1	--
	Harbor seal	22	21	1	1	2	11	17	1	4
Harbor porpoise	36	5	7.2	4	10	--	36	--	--	
Year 2	Primary Surveys² Year 2 total monitoring time: 1,247 hours, 27 minutes of marine mammal surveys on 162 construction days.									
	California sea lion	10	10	1.0	1	1	--	8	--	2
	Harbor seal	713	687	1.05	1	2	--	304	30	379
	Total	723	697	1.02	--	--	--	312	30	381

Source: Hart Crowser 2013, Navy 2014c, in prep.

1. SSV = Vibratory hammer soft start, V = Vibratory driving, SSI = Impact hammer soft start, I = impact hammer.
2. Primary Surveys occurred during monitoring of the shutdown zone and 464-meter buffer zone.
3. Outside Boat Surveys were sightings of animals in the 41.4 sq km Level B harassment zone. These surveys occurred only during acoustic monitoring outside the WRA, and therefore are a subset of all pile driving days. During Year 2, no outside boat surveys took place during pile installation or removal activities.

**APPENDIX B: Proxy Source Sound Levels and Potential
Bubble Curtain Attenuation for Acoustic Modeling of
Nearshore Marine Pile Driving at Navy Installations in
Puget Sound**

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Proxy Source Sound Levels and Potential Bubble Curtain Attenuation for Acoustic Modeling of Nearshore Marine Pile Driving at Navy Installations in Puget Sound



Final
September 2014

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1 Background

The National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) issue incidental take for Endangered Species Act (ESA)-listed species potentially adversely affected by the Navy's activities. This includes sound pressure levels (SPLs) produced from pile driving. Incidental take statements (ITS) are an outcome of Section 7 consultations and addressed in the Biological Opinions. The NMFS also issues authorizations for noninjurious take (Level B) for marine mammals for noise produced by pile driving. Such take provisions are authorized by the Marine Mammal Protection Act.¹

ITS often authorize incidental take by the area encompassed within zones above noise thresholds for ESA-listed fish. ITS for other animals such as marbled murrelets and marine mammals are based upon the number of animals anticipated to occur in the zones above the noise thresholds. For example, the peak SPL for the onset of injury threshold for fish is 206 dB referenced to 1 micropascal (μPa)². If actual project noise exceeds the extent of the modeled authorized area, the project would exceed authorized incidental take allotted in the ITS. Consequently, the project would be required to reinstate consultation under Section 7 of the ESA and a shut-down of impact pile driving would occur until a new ITS is issued. For marbled murrelets and marine mammals, injurious incidental take is avoided by monitoring areas exceeding the injury thresholds. If an animal enters this area, pile driving is shut down until it leaves. In addition, there can be provisions in an ITS or MMPA authorization allocating incidental take for potential behavioral disturbance. In this case, monitoring is required within the behavioral disturbance zones. Therefore, accurate establishment of the extent of the area exceeding established thresholds is essential to complying with the terms of an ITS or MMPA authorization.

When possible data obtained for a given site are used to predict expected source levels. However, for most project sites, prior measurements of the extent of pile driving noise have not been made. For these sites the extents of the areas where noise exceeds threshold values are modeled with an equation for sound propagation using proxy values for the source pile driving levels. Proxy source values are therefore either from prior measurements obtained on-site by installing the same type and size of piles or, when site specific information is lacking, obtained from the same or most similar type and size pile at locations with a similar sound environment. Other important factors include the type of equipment used to install the pile, substrate type, and water depth, all of which result in variations in pile driving noise levels. Detailed analyses of these factors are beyond the scope of this source document. The following section considers the rationale we used when reviewing proxy impact and vibratory pile driving source values for noise threshold metrics. We first discuss the available data included in the review. Second, we discuss the values for each threshold metric (peak SPL, root-mean-square [RMS], and sound

¹ New NMFS criteria using frequency weighted (filtered) responses are in development, with new standards anticipated. The current revision of this document does not include frequency weighted results; such results will be promulgated in a revised edition.

² All peak and root-mean-square (RMS) sound pressure levels in this document are referenced to 1 μPa . All sound exposure levels (SEL) in this document are referenced to 1 $\mu\text{Pa}^2\text{-second}$. All peak SPLs in this document refer to absolute peak overpressures or under pressures.

Proxy Source Sound Levels and Bubble Curtain Attenuation
September 2014

exposure level [SEL]) that will result in a high likelihood of encompassing the extent of actual project noise levels. Last, we review relevant data available for various types and sizes of piles typically used for pile driving and recommend proxy source values for Navy installations in Puget Sound.

Section 2 of this document is a review of attenuation levels reported for various impact pile driving projects.

2 Proxy Source Sound Levels for Acoustic Modeling of Nearshore Marine Pile Driving at Navy Installations in Puget Sound

2.1 Underwater Pile Driving Source Levels

2.1.1 Data Sources

Differences in underwater source levels for a given pile size and type will vary because of differences in geologic conditions, water depths where piles are installed, and pile driver type. In other words, the same size pile and type may generate different noise characteristics when installed in dissimilar environments. To obtain source values and model distances to the USFWS and NMFS thresholds for nearshore marine environments at Navy installations in Puget Sound, we reviewed available values from multiple nearshore marine projects obtained from the California Department of Transportation (CALTRANS), Washington State Department of Transportation (WSDOT), and Navy pile driving acoustic reports. Projects were located in California, Oregon, and Washington. Non-marine projects were excluded because of differences in substrate and/or acoustic conditions, and are not relevant herein due to the dissimilar nature from typical work performed at Navy marine facilities in Puget Sound. For example, a project located in Lake Washington and a freshwater bay (SR 520 Test Pile Project) was excluded due to very different substrate conditions present at those sites. Projects located in rivers were excluded because substrate characteristics, such as presence of bedrock, were not typical of Puget Sound. River projects also had different bathymetric profiles as well as increased current velocities. Of the projects reviewed, only measurements from unattenuated piles (e.g. a noise attenuation device was not operating³) were evaluated. Attachments 1 through 5 in Appendix A list the projects considered in this review.

All projects considered in the review had similar nearshore project depths from less than 5 m to approximately 15 m with the exception of Test Pile Program at Naval Base (NAVBASE) Kitsap Bangor where depths ranged from approximately 13 to 27 m. Impact pile driver type is listed in the attachments. Impact pile drivers can be drop, pneumatic, hydraulic, or diesel powered. With some exceptions at the Friday Harbor Ferry Terminal, all impact driven piles were installed with diesel powered drivers. Vibratory drivers vary only by size (energy) and type (variable moment/non-variable moment), but because of the limited data set, no attempt was made to distinguish between driver energies when reviewing noise levels produced from different impact or vibratory drivers.

Proxy values in similar marine sound environments can be challenging to obtain for pile driving because of variations in geologic conditions between projects and variability within project sites. Substrate types were not reported for most projects included in the review. Substrate types typical of Puget Sounds are sand/silt to sand/silt/cobbles overlying glacial till or hard clay layers. Therefore, projects located in the marine waters of Puget Sound, including the San Juan Islands, were considered more heavily because they would be more likely to share the

³ Pile caps are routinely placed on top of piles prior to driving to cushion equipment. While they are recognized as providing some sound attenuation, they are not considered in this analysis because they are part of baseline sound measurement presented in many reports.

same substrate characteristics than projects located in the San Francisco Bay area, the mouth of the Columbia River, or coastal bays. However, it should be noted that within Puget Sound a considerable variability in substrate conditions can exist between projects and within projects due to harder glacial layers and unforeseen encounters with glacial erratics (e.g. erratic rocks). Depending on the substrate type, piles may easily be advanced or, because of glacial till or submarine boulders, piles may require much more energy to drive. Piles driven to different tip elevations could also experience different driving conditions. For example, fender piles generally are not driven to the same depth as structural piles and may not encounter the same resistance during driving. Therefore, considerable variation in values is expected when looking from project to project or pile to pile within a project. To ensure proxy values are protective of species, conservative values were chosen to encompass regional and pile to pile variation. The following section considers the rationale we used when reviewing values for various sound metrics.

2.1.2 Other Considerations in Evaluation of Pile Driving Source Values

Proxy values need to be conservative. This ensures the area modeled above the injury thresholds is correctly assessed and remains within an ITS for fish. This approach will also preclude incidental take considered injurious based on the established injury criteria of marbled murrelets and marine mammals. In addition, proxy values are used to model the areas above the marbled murrelet and marine mammal behavioral thresholds or guidance values. Sound levels from pile driving are reported on either a per pile basis within a project, or per project summary basis. Summary data reported in acoustic reports varies, but can include one or more of the following:

- Per pile averages
- Ranges
- Minimum and maximum values
- Per project average
- Typical values
- Average range
- Minimum, maximum, average minimum
- Average maximum value
- Standard deviation.

Thus, interpretation of the reported levels may depend on the analytical methodology selected, which in turn can affect the proxy source level selected for modeling analysis. For example, one approach to choosing a source value is to pick the mean value from a number of projects reviewed. The results from the model utilizing this mean value will adequately characterize the estimated average extent of noise from pile driving. However, depending on the pile to pile variability it would only characterize the area for individual piles if the pile to pile variability in the source data were low. If the data were highly variable, the extent of the area above the threshold would be smaller or larger than described by the model on a per pile basis. Therefore, on-site monitoring of pile driving noise could exceed the modeled values on a

significant portion of the piles. Another, but more conservative approach is to select the proxy source value from the highest value of all values reported. This method would ensure that most, if not all, measured values on a pile by pile basis would be below the selected value, but could significantly overestimate the area or extent of biological impact.

In the section below we outline the rationale we used for selecting proxy values from the available data for each threshold metric. Values were chosen to ensure that a reasonable worst case scenario is modeled to estimate the extent of noise from pile driving.

2.1.2.1 Root Mean Square

The root-mean-square (RMS) value is the metric used to define the behavioral zones for fish, marbled murrelets, and marine mammals. For piles that are impact driven, RMS values are generally reported for individual piles over the duration of the driving of a given pile; often the number of strikes is also reported on a per-pile basis. Thus, in order to best characterize a broad-base proxy SPL, average RMS pressures were computed from the reported SPL (dB) values, and then weighted by the number of pile strikes for a given pile. This weighting methodology estimates proxy values across multiple projects with differing numbers of piles or strike counts, and the effect of using weighting values ensures that a single project or pile does not overtly bias the result high or low. This proxy value represents the most likely value expected for individual pile strikes for a typical project.

For piles that are vibratory driven, RMS values are typically computed over 10-second or 30-second averaging periods, and represent the most probable typical value over a long event. Thus, recommended proxy RMS values for vibratory and impact pile driving are computed using different techniques. For vibratory piles, reported values were selected on a pile-by-pile basis for a given pile type and size. An average value was computed by converting selected SPL values (dB) into pressure values, summing them together in linear space, dividing by the total number, n , of selected piles, and converting the result back to SPL (dB). In following this approach, the proxy value represents the arithmetic average value for each pile type and size from applicable projects. Thus, for vibratory driven piles averaged RMS values were used from all applicable projects as a representative average level of long-term pile driving events.

The following equations and calculations are used within this report and appendices to compute average values.

$$\text{Sound Pressure Level (SPL, dB)} = 10 \cdot \log_{10}(\text{Pressure, } \mu\text{Pa})$$

$$\text{Pressure } (\mu\text{Pa}), P = 10^{\left(\frac{\text{SPL, dB}}{10}\right)}$$

Weighted pressures are simply the linear product of the number of events, n , (such as pile strikes), multiplied by the average pressure for the pile, P :

$$\text{Weighted Pressure} = n \cdot P$$

Weighted SPL averages are computed by first converting all SPL values to linear pressure, weighting pressure (P) values by the number of events (for example, by number of strikes, n), normalizing by dividing by the number of events, and then converting back to SPL. Using k as an index counter for all piles, 1 = pile #1, 2 = pile #2, etc:

$$\text{Weighted SPL} = 10 \log_{10} \left[\frac{1}{n_{total}} \sum_{k=1}^{n_{total}} (n_k P_k) \right]$$

where

$$n_{total} = n_1 + n_2 + n_3 \dots$$

Charts depicting the behavior of the measured data used to prepare proxy values within this document are presented in Appendix B. Two types of charts are provided. First, for all data types, a sorted chart showing amplitude for all piles included, recommended proxy value, and when available, minimum and maximum levels observed. Next, the cumulative probability distribution function charts are provided for all pile sizes, with the recommended proxy value annotated on each chart.

2.1.2.2 Peak Sound Pressure Level

The peak sound pressure level (SPL) metric is used to evaluate the potential for injurious effects to fish. The barotrauma injury to fish due to peak over or under pressurization could result in instantaneous injury with a single strike. Average peak impact SPL values were selected from applicable projects, from which a weighted probability distribution function (PDF) was computed based on the number of pile strikes for each pile. To ensure a conservative proxy value, a value representing the ninetieth percentile of the PDF was selected, meaning that for a typical impact pile driving project, 90% of all pile strikes would typically occur below this proxy value. Use of this value ensures potentially injurious effects to fish would have a high likelihood of being within the area exempted for incidental take.

2.1.2.3 Sound Exposure Level

The sound exposure level (SEL) metric for impact driving is used to calculate the area of cumulative exposure potentially resulting in injury to fish or marbled murrelets over a daylong pile driving event (the accumulation of energy received from all pile strikes). To compute the cumulative SEL all single strike SEL energy in a workday is summed to calculate the overall SEL. However, modeling for the SEL “dosage” generally involves estimation of a typical single pile value logarithmically added to sum the expected energy over the day. While some strikes may be lower and some higher than the mean SEL value, use of the mean value would result in the best overall estimate of expected cumulative energy over the work day. In practice, the SEL value will vary on any given workday due to variability in the levels measured for each individual strike. The acoustic reports reviewed typically provided the mean single strike SEL per pile. Therefore, the most representative estimate of the single strike SEL for a proxy value is to use a mean SEL value from data from all piles in applicable projects. Furthermore, to avoid biasing the data high or low from a single pile or project, a weighted average was computed using the number of pile strikes, n , in the same manner as was followed for computation of

impact RMS values. This approach ensures that a single project or pile does not bias the result high or low. This proxy value represents the most likely value expected for individual pile strikes for a typical project.

2.1.3 Impact Driving Source Values

Table 2-1 summarizes projects from Attachment 1 in Appendix A that were considered in the final analysis and highlights proxy values. These highlighted proxy source values are reasonably conservative for modeling future Navy pile driving projects in Puget Sound. Detailed discussions of the projects considered and the values obtained for each pile type and size are provided below.

Table 2-1. Summary of Unattenuated Impact Pile Driving Levels Considered. Recommended Proxy Source SPLs at 10 m Bolded.

Pile Size	Number of Projects Considered ¹	Range of Average RMS (n-weighted pile average) dB re 1µPa	Range of Average Peak (90% PDF value) dB re 1µPa	Range of Average SEL (n-weighted pile average) dB re 1µPa
Steel				
24-inch	2	181-198 (193)	196-213 (210)	176-185 (181)
30-inch	3	192-196 (195)	203-217 (216)	182-187 (186)
36-inch (all projects)	3	185-196 (192)	202-211 (211)	173-186 (184)
36-inch (Bangor only)	1	185-196 (194)	Not reported ³	173-183 (181)
All 24/30/36-inch	7	181-198 (193)	196-217 (211)	173-193 (184)
Concrete				
≤18-inch	3	158-173 (170) ²	172-188 (184) ²	147-163 (159) ²
24-inch	7	167-179 (174) ²	180-191 (188) ²	158-167 (164) ²
¹ See Appendix A, Attachment 1 and 2 for projects reviewed. ² Number of pile strikes, <i>n</i> , was not available for any concrete projects; all piles were equally weighted. ³ Although absolute peak values were collected for TPP testing, average peak values were not reported; unattenuated data from EHW-2 was not collected.				

2.1.3.1 24-Inch Steel Pile Impact Driving Source Values

Attachment 1 in Appendix A lists six marine nearshore projects reviewed for possible inclusion in the analysis. Data for one 24-inch pile installed with an impact hammer in the Test Pile Project at NBK Bangor are listed in Attachment 1. However, only 7 pile strikes were reported and measurements from this pile are lower than all of the other five projects reviewed. Therefore, these data were not considered in the selection of the most conservative value. Of the remaining five projects reviewed, the Bainbridge Island Ferry Terminal Preservation Project and the Friday Harbor Restoration Ferry Terminal project were considered as the most representative of typical glacial till and erratics encountered in Puget Sound and were carried forward in the analysis. We based this on the assumption that substrate conditions are more similar than those found in San Francisco Bay or the mouth of the Columbia River.

For the two ferry terminal sites, five piles were driven at Bainbridge Island in substrate that consisted of a mix of sand and fist-sized rocks with occasional rocks one-foot in diameter. At Friday Harbor six piles were driven into a silty sand substrate approximately 9 meters thick and underlain by a hard clay lens. Three of the piles at this site encountered a large rock ledge approximately 10.7 meters below the mudline. One of the six piles in the project had the high end of the data clipped⁴ and therefore invalid, so this pile was excluded from the analysis. This project used different hammer types, but because the report noted little variation in the data, all five remaining piles were included in our review. Data from the two ferry projects only included values without a bubble curtain attenuator operating, i.e. no attenuation.

Source levels for each metric reviewed are discussed below. Table 2-1 summarizes unattenuated impact pile driving source data from Attachment 1 for the two ferry terminal projects.

RMS SPL

Weighted average proxy RMS source values for the two Puget Sound ferry terminal projects were 189 dB (range 181 dB to 193 dB) and 195 dB (range 193 dB to 198 dB) (Attachment 1), representing 1007 pile strikes. Therefore, actual RMS values would be expected to fall between 181 dB and 198 dB. The weighted average RMS value of 193 dB was chosen as a conservative value that likely encompasses the average extent of the area exceeding the injury thresholds for marine mammals and the behavioral thresholds for marine mammals, fish and marbled murrelets.

Peak SPL

Average peak SPLs reported for individual piles at the Bainbridge Island and Friday Harbor projects were 202 dB to 209 dB and 196 dB to 213 dB, with an average weighted value of 207 dB. Of the applicable projects, the 90% probability from the weighted cumulative distribution density function value of 210 dB was chosen as a conservative proxy value that likely encompasses the modeled extent of the area over the onset of injury threshold for fish. Table 2-1 summarizes the values from the two projects considered likely to be most representative.

SEL

Mean weighted SEL values for the two Puget Sound projects reviewed are each 181 dB for all piles. The mean SEL per any one pile for both projects ranged from 176 and 185 dB. These values are higher than the values reported for the other three projects reviewed (project SEL means that ranged from 168 to 177 dB). Therefore, the Washington projects were considered the most conservative and a mean weighted SEL of 181 dB was chosen as a reasonable proxy value of the overall SEL for 24-inch piles.

⁴ Clipping occurs when a signal exceeds the linear limits of an electronics system in essence the extreme levels of the signal are truncated or “clipped” off. For pile driving measurements, clipped data can produce results that are lower than the actual signal of interest, thus producing invalid results.

2.1.3.2 30-inch Steel Pile Impact Driving Source Values

Data for 30-inch steel pipe piles were available from three marine pile driving projects in Puget Sound, Washington and one project from San Francisco Bay, California. No projects from Bangor were available for analysis, and data from the California project provided only typical data, and did not provide per-pile SPL or number of strikes for each pile (see Attachment 1 in Appendix A). All available data in Attachment 1 were reviewed. However, as with the 24-inch pile source values, values from the Puget Sound projects were considered the most representative of source values because of similar substrate characteristics and are the only values considered in the Table 2-1 summary. Note that data from the Vashon Island project were acquired from 7m to 16m from the pile, and were normalized using a $15 \cdot \log_{10}(\text{range}/10\text{m})$ relationship.

RMS SPL

Average RMS source values for three Puget Sound projects ranged from 192 dB to 196 dB. The minimum average value reported for any one pile is 192 dB (Eagle Harbor Ferry Terminal) and a maximum average reported of 196 dB (Vashon Island Ferry Terminal, two piles). The RMS values from three Puget Sound projects were moderately higher than values measured from the California project considered, which reported a typical RMS value 190 dB. A conservative proxy RMS value is the weighted average value of 195 dB from the three projects in Puget Sound representing 263 pile strikes. This value would be a reasonable worst case ensuring that noise levels modeled would have a high likelihood of not exceeding this value.

Peak SPL

Average peak SPLs reported from the Puget Sound projects with available data ranged from 203 dB to 217 dB (n=3 projects) on a per-pile basis, with a computed weighted average of 214 dB. Levels from three piles at Eagle Harbor Ferry Terminal range from 7 to 11 dB quieter than those measured at two other Puget Sound sites, indicating a significant variability between sites. The typical peak SPL reported for the single California project was 205 dB, which was noted to be on the lower end of the range of data reported from Puget Sound, although the number of pile strikes was not reported, thus this data were not included in the weighted average for 30" peak values. The 90% weighted cumulative probability value of 216 dB was chosen as a reasonable and conservative proxy value.

SEL

Average per-pile SEL values were reported for the two Puget Sound Projects representing 214 pile strikes; the Eagle Harbor project did not report single strike SEL levels, and a California project did not report any SEL levels. SEL values from the two applicable projects ranged from 182 dB to 187 dB with an overall weighted average of 186 dB. Thus, a reasonable conservative SEL source value for future projects in Puget Sound is 186 dB derived from the weighted value of reported Puget Sound levels.

2.1.3.3 36-inch Steel Pile Impact Driving Source Values

Data for 36-inch steel pipe piles were available from three marine pile driving projects in Puget Sound, Washington and one project from Humboldt Bay along the California coast (Attachment 1 in Appendix A). All projects installed piles with a diesel hammer. The Humboldt Bay project did not report number of pile-strikes, and furthermore, this pile was only measured by re-striking a pile that had already been driven. Therefore, this project was excluded from the 36-inch average value computations. Data from two piles measured during the NBK Bangor Test Pile Program were at 11m and 20m from the pile, and were normalized using a $15 \cdot \log_{10}(\text{range}/10\text{m})$ relationship.

RMS SPL

Average RMS source values for the three Puget Sound projects ranged from 185 dB to 196 dB, representing 662 pile strikes, the full range of which were observed during the Test Pile Program at NBK Bangor project. The weighted average value for these projects was 192 dB, and represents a reasonable proxy RMS value for impact driven 36-inch piles. The average RMS value of 193 dB reported for the 36-inch pile from the Humboldt Bay Bridge project in California fell within the range of values for the three Washington 36-inch pile projects reviewed, although as previously discussed, this value was not included in the averaging calculations. Considering just the Test Pile Program at Bangor, 121 pile strikes produced a set of measurements ranging from 185 to 196 dB, with a weighted average value of 194 dB.

Peak SPL

Average peak SPLs reported from two Puget Sound projects ranged from 202 dB to 211 dB on a per-pile basis, representing 541 pile strikes. Average peak values were not reported for the NBK Bangor project. A proxy peak value of 211 dB was chosen representing the 90% cumulative probability SPL.

SEL

Average SEL values were reported for three Puget Sound projects, with 662 pile strikes measured. SEL values ranged from 173 dB to 186 dB with an overall weighted average of 184 dB, the recommended proxy value for piles driven in Puget Sound. Only one value was reported for the Humboldt Bay project, 183 dB, which was within the range of values reported in Puget Sound. A reasonable conservative SEL source value for future projects in Puget Sound is 184 dB derived from the weighted average of three Puget Sound projects. Analyzing data from just the NBK Bangor project resulted in a weighted average value of 181 dB, with a data range of 173 to 183 dB.

2.1.3.4 Combined Steel Pipe Impact Driving Source Values

Review of RMS, average peak, and SEL values for steel pipe piles of 24, 30, and 36-inches shows that often only slight differences are noted across the three sizes (see Table 2-1). In some cases, weighted average values for smaller piles are higher than for larger piles, even if by only

one or two decibels. For this reason a combined analysis was done for each of the metrics to investigate the potential value of preparing overall average values over multiple sizes of steel pipe piles. Each of the metrics is discussed in the following paragraphs.

RMS SPL

Average RMS values over 24, 30, and 36-inch piles ranged from 181 dB to 198 dB, although weighted averages were very close, 193, 195, and 192 dB, respectively, with an overall weighted average value of 193 dB. 30-inch piles (three projects located in Puget Sound, not including any NBK Bangor projects) produced average RMS levels of 195 dB, higher than both 24-inch and 36-inch average values. Even though few piles and a lower number of pile strikes were measured with 30-inch piles, the scatter in the points measured only ranged from 192 to 196 dB, without a large deviation. 24-inch and 36-inch piles have larger data sets, but nonetheless, the recommended proxy value for each of these sizes is only a few decibels different. Figure B-4 in Appendix B graphically shows how the scatter for each pile size compares with other pile sizes. While it is reasonable to assert that RMS impact values for steel pipe piles can be represented by a single, composite value of 193 dB, additional data is recommended to be collected to increase the size of the analysis sample set.

Peak SPL

Peak SPL values varied over a broader range than RMS values, although 24- and 36-inch 90% cumulative probability results were within 1 dB, representing 1,669 pile strikes. 30-inch results were measurably higher than either 24- or 36-inch data, represented by fewer piles, and fewer strikes (263 strikes). Furthermore, 30-inch pile data is somewhat bi-modal in behavior, with three values near 203 to 204 dB, and four in the 211 to 217 dB range, and nothing in between. Figure B-11 in Appendix B graphically shows the distribution of levels by pile size. Three piles represented in the 211 to 217 dB range were measured from distances other than the standard 10 meter de facto measurement range, which were corrected using the traditional practical spreading model. Although not necessarily incorrect, this serves to increase the uncertainty of those measurements. Since none of the 30-inch (nor 24-inch measurements) represent data acquired directly from NBK projects, it makes sense to prepare a broader analysis to consider different pile sizes for the purpose of increasing confidence in the estimated peak values. The 90% cumulative distribution value for all 24-, 30-, and 36-inch applicable projects is 211 dB, represented by 1,932 pile strikes, and is the recommended proxy value for NBK Bangor projects, especially those using 24-inch and 30-inch steel pipe piles, until such time that Bangor-specific data can be acquired using these pile sizes.

SEL

Weighted average SEL values for 24-, 30-, and 36-inch piles also resulted in somewhat anomalous data with 30-inch steel pipe piles, with both 24-inch and 36-inch data producing lower values. As described above, the 30-inch data set includes range corrected values, and furthermore, only represented 4 piles, since single strike SEL values were not reported for one of the Puget Sound projects (Eagle Harbor Ferry Terminal). Figure B-16 in Appendix B shows the data grouping by pile size. This gives rise to increased uncertainty in the 30-inch average values.

There is some evidence that SEL values for 36-inch piles at NBK Bangor (182 dB, weighted average) is lower than a proxy value including Puget Sound projects (184 dB). This conclusion is drawn from a modest sample size (4 piles, 121 strikes) of NBK Bangor measurements. Similar analyses could not be done with 24- and 30-inch piles, since these data did not exist for NBK Bangor projects.

Taken in summary, there is motivation to compute a single proxy value for all 24-, 30-, and 36-inch steel pipe piles, but this approach is not recommended at this time due to the uncertainty in the data scatter, and different results among RMS, SEL, and peak metrics. Additional data should be collected before using combined analyses.

2.1.3.5 18-Inch Concrete Pile Impact Driving Source Values

Attachment 2 in Appendix A lists three marine nearshore projects that monitored sound levels during installation of 18-inch or similar (16-inch) concrete piles, none of which were conducted in Puget Sound. Two projects were conducted at the Berkeley Marina in San Francisco Bay, California, one in 2007 and one in 2009 using 18-inch concrete piles. Acoustic measurements were only collected for four piles total for both projects. Water depth was fairly shallow ranging from 3 to 4 meters. Source levels for each metric reviewed are discussed below. Another project located near Concord, CA at the Naval Weapons Station (NWS) drove five 16-inch concrete piles, with water depth of 10 meters. Source values for this project were similar to those for the Berkeley Marina projects, and thus data from the Concord NWS were included in the analysis. Table 2-1 summarizes unattenuated impact pile driving source data from Attachment 2 and highlights recommended proxy source values. Since the number of pile strikes for all concrete projects were not reported, pile averages were computed.

RMS SPLs

Average RMS values for three projects using 16 or 18-inch concrete piles ranged from of 158-173 dB (Table 2-1), with an average RMS value of 170 dB over 9 piles, selected as a conservative value likely to encompass the maximum extent of the area exceeding the behavioral thresholds and guidance for marine mammals, fish and marbled murrelets. No concrete pile levels exceed the RMS injury thresholds established for marine mammals (180 dB RMS for cetaceans and 190 dB RMS for pinnipeds).

Peak SPLs

Average peak SPLs reported for all piles at the Berkeley Marina projects ranged from 172 dB to 188 dB. Because only three projects with relatively small samples sizes were available for review, a per-pile average value of 184 dB was chosen as the recommended SPL proxy value for all piles. This value is below the threshold for the onset of injury in fish (206 dB). Table 2-1 summarizes the values from these projects.

SEL

Two average SEL values of 155 and 159 dB were reported for the two Berkeley marina projects, both with very small sample sets ranging from 147 dB to 163 dB. SEL data were not acquired for the Concord NWS project. The per-pile average value of 159 dB SEL was selected as the most conservative proxy value available for 18-inch concrete piles until additional data are obtained.

2.1.3.6 24-Inch Concrete Pile Impact Driving Source Values

Only one value from a single 24-inch concrete pile was available for the Mukilteo Ferry Terminal in Puget Sound. Therefore, we reviewed seven additional marine projects: six in San Francisco Bay, California, and one in Humboldt Bay, California (Attachment 2 in Appendix A). Note that some of the San Francisco Bay projects included data from the same site in two different time periods. Two projects (Humboldt State Floating Dock and Pier 40 Marina) included piles that were driven using a jetting technique, often in combination with a reduced level of fuel to minimize driving energy. Piles driven under these circumstances were not included in the calculation of piles averages. Table 2-1 summarizes unattenuated impact pile driving source data from Attachment 2 and highlights recommended proxy source values.

RMS SPLs

The one pile in Puget Sound reported a maximum RMS value of 170 dB, with average values reported for the California projects ranging from 167 dB RMS to 179 dB RMS. The recommended proxy source value was chosen from the highest average pile value over all projects, 174 dB RMS (Table 2-1). No concrete pile noise levels exceed the RMS injury threshold established for pinnipeds (190 dB RMS), nor the RMS injury threshold for cetaceans (180 dB RMS).

Peak SPLs

Average Peak SPLs reported for projects ranged from approximately 180 dB to 191 dB. The per-pile 90% cumulative probability value of 188 dB was chosen as the recommended proxy peak SPL value. This value is below the peak threshold for the onset of injury in fish (206 dB). Table 2-1 summarizes the values from the two projects.

SEL

Sound exposure levels were only reported for six of the eight projects reviewed, with per-pile values ranging from 158 dB to 167 dB (Table 2-1). The pile SEL average over all projects of 164 dB was considered representative of a conservative average SEL source value for 24-inch piles.

2.1.4 Vibratory Pile Driving Source Values

NMFS has established non-impulsive injury thresholds (180 dB RMS for cetaceans, 190 dB RMS for pinnipeds) and a disturbance threshold (120 dB RMS) for marine mammals. Vibratory driving is considered a non-impulsive sound source. Attachment 3 in Appendix A contains a list of vibratory projects and derived proxy source values we reviewed in order to calculate how far sound from vibratory driving exceeds the thresholds discussed in Section 1.2.1. Table 2-2 presents the summary of vibratory pile driving data from the projects reviewed. Due to the similarity in levels across multiple projects, 16-inch and 24-inch piles were considered together, and 30-inch and 36-inch piles were considered together.

**Table 2-2. Vibratory Pile Driving SPLs.*
Recommended Proxy Source SPLs at 10 m Bolded.**

Pile Size and Type	Number of Projects Considered ¹	Range of Average RMS dB re 1µPa @ 10 meters	Reasonable Source Level dB re 1µPa dB @ 10 meters
Timber			
12-inch	1	152-155 ²	153²
Steel Pipe			
16-inch and 24-inch	4	Bangor 153-162 All projects 159-162	161
30-inch and 36-inch	7	Bangor 166 All projects 159-172	NBK Bangor 166 Other Puget Sound Locations 167
Steel Sheet			
24-inch	3	160-163**	163
¹ See Attachment 3 for projects reviewed. ² Data reported at 16m, converted to equivalent range of 10m using $15\text{Log}_{10}[16/10]$ range correction factor *Recommended values for 10 meters unless otherwise indicated. **Highest value for pile; value includes some averages from only top or bottom depth measurements and one from top and bottom averaged.			

2.1.4.1 Timber Pile Vibratory Driving Source Values

Only one timber pile study is available and only for noise measurements taken during extraction of one 12-inch diameter pile (see Attachment 3 in Appendix A). The highest RMS value was 152 dB measured at 16 meters (Table 2-2), with an average value of 150 dB reported at 16 meters.

2.1.4.2 24-Inch Diameter Steel Pipe Pile Vibratory Driving Source Values

Two projects in Washington and one in California were reviewed for 24-inch diameter steel pipe piles. The Washington marine projects at the Friday Harbor Terminal and NBK, Bangor waterfront, only measured one pile each, but reported similar sound levels of 162 dB RMS and 159 dB RMS (range 157 dB to 160 dB), respectively (see Attachment 3 in Appendix A). Because only two piles were measured in Washington, the California project was also included in the analysis. The California project was located in a coastal bay and reported a “typical” value

of 160 dB RMS with a range 158 to 178 dB RMS for two piles where vibratory levels were measured. Caltrans summarized the project's RMS level as 170 dB RMS (Table I.2-3 in Caltrans 2012), although most levels observed were nominally 160 dB. A fourth project at NBK, Bangor drove 16-inch hollow steel piles, and measured levels similar to those for the 24-inch piles; therefore these data were included in the 24-inch analyses. Although the data set is limited to these four projects, close agreement of the levels (average project values from 159 to 162 dB at 10 meters) indicate similar vibratory conditions at NBK, Bangor. The highest project average of 162 dB was selected as the most reasonable proxy for 24-inch steel pipe piles. This number is higher than the data from the Bangor Test Pile Program and is therefore conservative.

2.1.4.3 30-inch and 36-inch Diameter Steel Pipe Pile Vibratory Driving Source Values

Five projects were reviewed for 30-inch diameter piles and four projects were reviewed for 36-inch diameter piles, with a total sample set of seven projects since some projects used both 30-inch and 36-inch piles. All projects were located in Puget Sound. Because the 30-inch diameter pile average RMS measurements overlap (164 dB, 168 dB, 170 dB, and 171 dB) the measurements reported for 36-inch diameter piles at the Bangor waterfront, the Edmonds and Anacortes ferry terminals range (159 dB, 162.5 dB, 169 dB, respectively), the 30-inch and 36-inch pile data were combined for the review.

We reviewed data from Bangor waterfront projects for 30 and 36-inch piles, which were based on a large sample size relative to other projects (n~68 piles, Attachment 3). RMS vibratory average levels were consistently lower at Bangor than other Puget Sound locations. We recommend using the site-specific data average RMS level for modeling vibratory pile driving at NBK, Bangor, that is, the recommended RMS vibratory installation proxy source value 30-inch to 36-inch diameter piles is 166 dB. Because site specific data is unavailable for all other Navy installations in Puget Sound, we recommend the more conservative proxy value of 167 dB for other Puget Sound Navy sites, which represents the average level for all Puget Sound locations excluding NBK, Bangor for both 30-inch and 36-inch piles.

Table 2-2 summarizes the ranges for the combined size category. Table 2-2 presents reasonable proxy values expected from reviewing values taken from the highest average project SPL for all projects reviewed.

2.1.4.4 24-Inch Steel Sheet Pile Vibratory Driving Source Values

Sound levels for vibratory sheet pile driving were reported for three Caltrans projects at the Port of Oakland in San Francisco Bay (see Attachment 3 in Appendix A). No data were found for sheet pile driving in Puget Sound. RMS values were only available for one pile at one project and this had an average RMS value of 163 dB. The second project reported 1 sec SEL levels at 10 m for 5 vibratory driven sheet piles. The average per pile SEL ranged from 157 to 160 dB based on the average top and bottom depth measurements. Caltrans also reported 162 dB RMS as the highest average for a single depth for the same project. The third project reported 163 dB RMS (Table I.2-3 in Caltrans 2012). Caltrans reported 160 dB RMS as the typical sheet pile value for all three projects (Table I.2-2 in Caltrans 2012). Based on the levels from the three projects, 163 dB RMS value was used as a conservative proxy value.

2.2 Airborne Pile Driving Source Values

NMFS has established an in-air noise disturbance threshold of 90 dB RMS re 20 μ Pa (unweighted) for harbor seals, and 100 dB RMS re 20 μ Pa (unweighted) for all other pinnipeds. Attachment 4 and Attachment 5 in Appendix A list the impact and vibratory pile driving projects, respectively, that were reviewed. Most projects report A-weighted levels. For this review, however, only unweighted data were considered. Two airborne noise values are presented for most projects: L_{\max} and L_{eq} . The L_{\max} is the instantaneous highest sound level measured during a specified period, or maximum noise level. It typically represents a short duration average, usually 35 milliseconds. Because impact pile driving is an impulsive sound with short durations, the signal is most appropriately characterized by the L_{\max} value. Proxy values for impact driving are found in Attachment 4.

The L_{eq} is the equivalent steady-state noise level in a stated period of time. It contains the same acoustic energy as the time-varying noise level during the same period. L_{eq} is primarily used for a steadier, non-impulsive noise. The L_{eq} , which averages the source over a period of time, is a better descriptor for non-impulsive sound like vibratory pile driving. These values are listed in Attachment 5 for vibratory pile driving and Table 2-3 summarizes L_{\max} and L_{eq} data.

Review of the available literature provided two unweighted L_{\max} levels, both from the NBK Bangor Test Pile Program. A maximum level of 112 dB re 20 μ Pa was measured for 36-inch piles (n=9 piles), at the de facto measurement distance of 50 feet, and was therefore chosen as a conservative proxy value for piles 30 and 36-inches. A maximum level of 110 dB was measured for a single 24-inch pile, and was selected as the most representative value for modeling analysis.

Unweighted RMS L_{eq} values of 88 dB were obtained from vibratory pile driving 18-inch steel pipe piles. A single 30-second measurement was made for 24-inch piles during the Test Pile Program at NBK, Bangor. These data fit the overall trend of smaller and larger pile sizes. The limited data set for 24-inch steel pipe, supports a reasonable representative proxy value of 92 dB.

Limited data were available for 30 and 36-inch piles. One 30-inch pile measured at the Keystone ferry terminal fell within the range of 36-inch piles measured at Bangor., although the average value for this was 2 dB above the average value measured at Bangor. Levels measured at Vashon Island ferry terminal were made using A-weighted filters, and adjusted for range and filter type. Even after corrections were made observed levels were significantly lower than other sites, thus these data were not considered for further analysis. We therefore selected 95 dB (unweighted) as the representative L_{eq} average proxy value for 30-inch and 36-inch piles. Based on the limited data available, the RMS L_{eq} value for 18-inch steel pipe piles was chosen as the proxy source value for vibratory installation or removal of piles less than 24-inch regardless of pile type. The RMS L_{eq} value for 24-inch steel pipe piles was chosen as the best estimate for 24-inch sheet piles.

Table 2-3. Summary of Airborne Source Levels with Recommended Proxy Source Values Bolded¹

Pile Type	Size (diameter in inches)	Installation Method	
		Impact RMS L _{max} (Unweighted) Impact	Vibratory RMS L _{eq} (Unweighted) Vibratory
Timber	12-inch	---	---
Steel Pipe	18-inch	---	88
	24-inch	110²	92²
	30-inch	---	95
	36-inch	112	95
Steel Sheet	24-inch	---	---

Notes: All values relative to 20μPa and at 15 m (50 ft) from pile.
¹See Attachments 4 and 5 in Appendix A for projects reviewed. ²Limited data set

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3 Evaluation of Potential Bubble Curtain Sound Attenuation

To reduce noise produced from impact pile driving, bubble curtains are used around the pile as it is driven and can be confined or unconfined. Confined bubble curtains place a fabric shroud or rigid sleeve around the pile to hold air bubbles near the pile, ensuring they are not washed away by currents or tidal action. They are recommended when water velocities are 0.6 meters (1.6 feet per second) or greater (NMFS 2008).

None of the project locations at Naval Base Kitsap, Naval Magazine Indian Island, Naval Station Everett, Naval Air Station Whidbey Island Seaplane Base, Manchester Fuel Depot are in high current areas; therefore, this discussion focuses on unconfined bubble curtains. Unconfined bubble curtains involve use of pressurized air injected from an air compressor on the pile driving barge through small holes in aluminum or PVC pipe around the driven pile. Noise reduction results from unconfined bubble curtains were reported from several projects. There was a wide range of effectiveness from very little measurable attenuation in some cases to high attenuation in others (Illingworth and Rodkin 2001; WSDOT 2013). Caltrans (2009) summarized the application of unconfined bubble curtain systems in various California projects and reported from 1 to 5 dB of attenuation in high current situations and 5 to 15 dB of attenuation in low current situations. Application of a multiple-ring system in a deep water, strong current setting (Benicia-Martinez Bridge) achieved 15 to more than 30 dB attenuation when driving 8-foot diameter piles. Because some sound pressure waves also propagate from the pile through the substrate and reenter the water column, not all sound pressure waves will be attenuated by a bubble curtain (Reinhall and Dahl 2011). Variability in bubble curtain performance when measured at various distances out from the pile is likely explained by the sound propagation properties of various substrates, the localized bathymetry, as well as variances in embedment depths of piles.

3.1 Noise Attenuation Assumptions for Acoustic Modeling

The Navy conducted a Test Pile Program at Naval Base Kitsap, Bangor where attenuation of an unconfined bubble curtain was measured when driving 24-inch, 36-inch, and 48-inch steel pipe piles.⁵ It should be noted that attenuation measurements were not conducted at EHW-2, and are therefore excluded from calculations herein.⁶ Calculations for attenuation were made by calculating the amplitude ratio reduction of the pressure metric with the bubble curtain on compared to the bubble curtain off measurements, and then converting the ratio into a decibel value. Weighted values are computed for each metric based on the number of strikes measured. All measurements were taken from the nominal 10 meter de facto distance from the pile.

⁵ Illingworth and Rodkin, 2012

⁶ Attenuated measurements from pile installation at EHW-2 in 2012 were similar to nonattenuated measurements from test piles installed in 2011 at the project site, indicating a nonfunctional bubble curtain. Most commonly observed problems reported for non-functional bubble curtains reflect inadequate air-flow or poor seating of the bottom of the curtain at the water-sediment boundary resulting in a non-attenuated sound path.

The sole 24-inch pile in this project was struck a total of 3 times with the bubble curtain turned on. Therefore, the results are unlikely to be indicative of values that would be obtained on this site with more extensive measurements and are not considered further in this review. Piles for which fewer than 10 strikes were measured were also excluded. It is recommended to acquire a larger 24-inch data set to obtain a better synopsis for these results.

For 36-inch piles the weighted average peak, RMS, and SEL reduction with use of the bubble curtain was 10 dB, where the averages of all bubble-on and bubble-off data were compared (see Table 3-1 below). This data set represents 2 piles, for a total of 165 strikes. For 48-inch piles, the weighted average pressure reduction for RMS, peak, and SEL with use of a bubble curtain was 8 dB, representing 138 strikes. Across all piles (36" and 48") and all metrics (RMS, peak, SEL), the weighted average attenuation was 9 dB.

Table 3-1. Reduction (dB) in Weighted Average Noise Values for Impact Pile Driving of Steel Piles with a Bubble Curtain, Measured at 10 meters averaging mid-depth and deep-depth data. Measurements obtained during Bangor Naval Base Test Pile Program

Pile Size	Attenuation Level (RMS)		Attenuation Level (Peak)		Attenuation Level (SEL)		Weighted Average (all metrics)
	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted	
36-inch	9	9	11	11	10	10	10
48-inch	7	7	9	9	7	7	8
Overall weighted average							9
Source: Illingworth & Rodkin 2012							

We also reviewed unconfined bubble curtain attenuation rates from available reports from projects in Washington, California, and Oregon that impact drove steel pipe piles up to 48-inches in diameter. Table 3-2 contains a summary of the attenuation levels reported. Several studies were reviewed, but not included in the summary because they were not considered representative. Excluded studies were:

- Willamette River Bridge Project (Caltrans 2012). Bubble curtain was poorly designed and deployed in a river with a high current. No RMS SPLs reported.
- South Umpqua River (Caltrans 2012). Current conditions resulted in little coverage of piles by bubble curtain. No RMS SPLs reported.
- Ten Mile River Bridge Project (Caltrans 2012). 30-inch piles driven with bubble curtain, but inside of cofferdam.

Of the remaining studies reviewed, significant variability in attenuation occurred; however, an average of at least 8 dB of peak SPL attenuation was achieved on ten of the twelve projects (Table 3-2). Some of the lower attenuation levels reported were attributed to the bottom ring not

seated on the substrate, poor airflow, or currents that resulted in an uneven distribution of bubbles (WSDOT 2005a, WSDOT 2005b, Caltrans 2012).

Table 3-2. Summary of Attenuation Levels Reported with Unconfined Bubble Curtains During Impact Driving of Steel Pipe Piles up to 40-inches Diameter

Project/Location	Steel Pipe Pile Diameter	Range (dB)	Mean Peak dB re 1 μ Pa @ 10 m	Standard Deviation (dB)
Friday Harbor Ferry Terminal Restoration/ San Juan Island marine waters, WA ¹	24-inch 30-inch	0-5	2	2.2
Bainbridge Island Ferry Terminal Preservation/ Puget Sound marine waters, WA ¹	24-inch	3-14	7	4.7
Cape Disappointment Boat Launch Facility, Wave Barrier Project/ Columbia River, Ilwaco, WA ¹	12-inch (n=5*)	6-17	11	4.9
Mukilteo Ferry Terminal Test Pile/Puget Sound marine waters, WA ¹	36-inch (n=2)	7-22	15	10.6
Anacortes Ferry Terminal Dolphin Replacement/Puget Sound marine waters, WA ¹	36-inch (n=7)	3-11	8	3.1
SR 520 Test Pile Project/Lake Washington/Portage Bay (freshwater), WA ^{1,2}	24-inch (n=4) 30-inch (n=2)	3-32	20	11.1
Columbia River Crossing Test Pile Program/Columbia River, WA/OR ³	24-inch (n=1)	---	10	---
Tesoro's Amorco Wharf/San Francisco Bay, Martinez, CA ²	24-inch (n =18 battered and n =18 vertical)	---	~10 dB (not well seated, stated capable of up to 15 dB and strong currents present at times and poor positioning on some piles)*	---
Deep Water-tongue Point Facility Pier Repairs/Columbia River, Astoria, OR ²	24-inch (n = 10)	5-22	14	---
Portland-Milwaukie Light Rail Project/Willamette River, Portland, OR ²	24-inch (n=5)	8-27	---	---
Bay Ship and Yacht Dock/San Francisco Bay, Alameda, CA ²	40-inch (n = 2)	---	~10-15 (Not installed at the substrate at start of drive. Performance from part of drive when bubble curtain properly situated).*	---
Richmond-San Rafael Bridge Project/San Francisco Bay, CA ²	30-inch (n=2)	---	9	---

Sources: ¹WSDOT 2013, Also, see individual report references for WSDOT; ²Caltrans 2012; ³CRC 2011.
*As reported by Illingworth and Rodkin in Caltrans 2012.

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In summary, bubble curtain performance is highly variable. Effectiveness depends on the system design and on-site conditions such as water depth, water current velocity, substrate and underlying geology. Installation and how well the curtain is seated on the substrate at the bottom are also important factors. To avoid loss of attenuation from design and implementation errors, our project has specific bubble curtain design specifications, including testing requirements for air pressure and flow prior to initial impact hammer use, and a requirement for placement on the substrate.

While bubble curtain performance is variable, we believe that, based on information from the Bangor Naval Base Test Pile Program, an average peak SPL⁷ reduction of 8 dB to 10 dB at 10 meters would be an achievable level of attenuation for steel pipe piles of 36- and 48-inches in diameter. However, to be more conservative for 48 inch piles, use of 7 dB for both RMS and SEL metrics is justified.

⁷ For most of the studies reviewed, Peak SPLs were the only metric reported.

4 References

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Proxy Source Sound Levels and Bubble Curtain Attenuation
September 2014

Appendix A: Studies Reviewed for Evaluation of Underwater Pile Driving Sound

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Appendix A: Studies Reviewed for Evaluation of Underwater Pile Driving Sound

Attachment 1. Impact Pile Driving SPLs from Studies Utilizing Steel Pipe/CISS Piles.
Bolded values were considered for proxy source levels.

Project	Location	Number of Piles Measured	Hammer Type	Water Depth (m)	Distance (m)	RMS (dB re 1 μ Pa)	Peak (dB re 1 μ Pa)	SEL (dB re 1 μ Pa ² s)
24-inch Steel Pipe								
Bainbridge Island Ferry Terminal ¹	Bainbridge Island, WA	n=5	Diesel	2.1-3.4	10	Weighted Ave 195 Ave range 193-198	Weighted Ave 206 Ave range 202-209	Weighted Ave 181 Ave range 177-184
Friday Harbor Ferry Terminal ²	Friday Harbor, WA	n=5	Diesel, pneumatic, hydraulic	10-14.3*, **	10	Weighted Ave 189 Ave range 181-193	Weighted Ave 207 Ave range 196-213	Weighted Ave 181 Ave range 176-185
Bangor Test Pile Program ³	Bangor Naval Base, WA	† n=1	Impact	4.6	10	Max 180	Max 193	Ave 167
Conoco/Phillips Dock ⁴	Rodeo, San Francisco Bay, CA	n=2	Diesel	>5	10	Range 188-189	203 (unclear if this is average or ave max)	Typical 177 Range 177-178
Tesoro's Amorco Wharf- all values were attenuated- values reported are mostly unattenuated – strong currents present ⁴	San Francisco Bay; Martinez, CA	(1 st pile with poor attenuation)	Diesel	10-15	10	189	Max 209	174
Deep Water-Tongue Point Facility Pier Repairs ⁴	Mouth of Columbia River; Astoria, OR	n=10	Diesel	unknown	10	Ave 182 Ave range 178-189	Ave max 198 Range 193-206 Max 207	Ave 168 Ave range 160-175
30-inch Steel Pipe								
Richmond-San Rafael Bridge, CALTRANS ⁴	San Rafael, CA	n=4	Diesel	4-5	10	Typical 190 (max=192)	210 max (typical 205)	---
Eagle Harbor Maintenance Facility ⁵	Bainbridge Island, WA	n=3	Diesel	10	10 (n=2) 16 (n=1)	Weighted Ave 192 Ave range 192-193	Weighted Ave 204 Ave range 203-204	---***
Friday Harbor Ferry Terminal #8 ²	Friday Harbor, WA	n=1	Diesel	10.4*	10	196	211	187

Project	Location	Number of Piles Measured	Hammer Type	Water Depth (m)	Distance (m)	RMS (dB re 1 μ Pa)	Peak (dB re 1 μ Pa)	SEL (dB re 1 μ Pa ² s)
Vashon Ferry Terminal ^{6,#}	Vashon Island, WA	n=3	Diesel	11-12	10	Weighted Ave 195 Ave range 192-196	Weighted Ave 215 Ave range 212-217	Weighted Ave 186 Ave range 182-187
36-inch Steel Pipe****								
Humboldt Bay Bridge ⁴	Humboldt Bay – Eureka, CA	CISS n=1, restrikes	Diesel	10	10-	193 (max)	210 (max)	183 (max)
Mukilteo Test Piles ⁷	Mukilteo, WA	n=2	Diesel	7.3	10	Weighted Ave 190 Ave range 187-191	Weighted Ave 205 Ave range 202-207	Weighted Ave 183 Ave range 180-184
Anacortes Ferry ⁸	Anacortes, WA	n=7	Impact	12.8	10	Weighted Ave 192 Ave range 189-193	Weighted Ave 209 Ave range 205-211	Weighted Ave 185 Ave range 183-186
Bangor Test Pile Program ^{3,#}	Bangor Naval Base, WA	n=4	Diesel	13.7-26.8	10	Weighted Ave 194 Ave range 185-196	---^	Weighted Ave 181 Ave range 173-183

Notes: Ave = Average

* Substrate was sandy silt/clay

** Substrate was sandy silt/rock

*** Single strike SEL not reported.

****EHW-2 project at Bangor waterfront measured 24- and 36-inch piles; however, all piles were attenuated so they are not included in the table. 24-inch (n=41) averages were: average peak = 199 (s.d. 9.58), average RMS = 179 (s.d.=24.10), SEL = 170 dB (s.d.=7.48). 36-inch pile (n=26): average peak=205 (s.d.=4.33), average RMS = 188 (s.d.=5.01), average SEL=175 (s.d= 5.11) (Navy 2013).

† 24-inch piles were not hit very hard, so these are not representative of the levels that may occur in the future or elsewhere.

distance to pile ranged above and below 10m. Data normalized to 10m using $15\log_{10}(\text{range}/10\text{m})$ relationship.

^ Average peak values not reported.

Sources:

¹ WSDOT 2005a

² WSDOT 2005b

³ Navy 2012.

⁴ Caltrans 2012

⁵ JASCO Research. 2005, WSDOT 2008

⁶ WSDOT 2010b

⁷ WSDOT 2007a

⁸ WSDOT 2007b

Attachment 2. Impact Pile Driving SPLs from Studies Utilizing Concrete Piles.
Bolded values were considered for proxy source levels.

Project	Location	Number of Piles Measured	Hammer Type	Water Depth (m)	Distance (m)	RMS (dB re 1 µPa)	Peak (dB re 1 µPa)	SEL (dB re 1 µPa ² s)
16-inch and 18-inch Piles								
Pier 2 Concord NWS ¹ (16-inch square)	Concord, CA	n=5	Drop Steam Powered	7	10	Ave 171 Ave range 167-173	Ave max 183 Ave max range 182-184 Max 184	N/A
Berkeley Marina (2007) ¹ (18-inch octagonal)	Berkeley, CA	n=1	Diesel	2-3	10	Ave 159 Ave range 155-167	Ave max 172 Ave range 172-181 Max 181	Ave 155
Berkeley Marina (2009) ¹ (18-inch octagonal)	Berkeley, CA	n=3	Diesel	2-3	10	Ave 169 Ave range 165-178	Ave max 189 Ave max range 184-192 Max 192	Ave 159
24-inch Piles								
Mukilteo Ferry Terminal ² (octagonal)	Mukilteo, WA	n=1	Diesel	7-8	10	Ave 170 (single pile)	Ave max 184 Single pile	Ave 159 dB Range 159-170
Amports Pier 95 ¹ (octagonal)	Benicia, CA	Not provided	Diesel	3-7	10	Ave 170 Range 168-172	Ave max 184 Range 180-192 Max 192	N/A
Pier 40 Marina ¹ (square)	San Francisco, CA	n=7	Diesel	3-4	10	Ave 171 Ave range 167-174	Ave max 184 Ave range 180-186 Max 186	N/A
Berth 22 Port of Oakland (December 2004) ¹ (octagonal)	Oakland, CA	Several	Diesel	0-15 (dependent on row)	10 (mostly)	Ave 176*** Ave range*** 171-179 Max 181	Ave max 188*** Ave max range*** 183-191 Max 193	Ave 165*** Ave range** 162-167
Berth 22 Port of Oakland (August 2004) ¹ (octagonal)	Oakland, CA	n=4	Diesel	10-13	10	Ave 175 Ave range during loudest part of drive 174-176 Max 178	Ave max 187 Ave max range during loudest part of drive 186-188 Max 190	Ave 165 Ave range during loudest part of drive 164-166 Max 168
Berth 32 Port of Oakland (2005) ¹ (octagonal)	Oakland, CA	n=2	Diesel	3-7	10	Ave 174 Ave range 172-176	Ave max 186 Ave max range 185-187 Max 187	Ave 163 Ave range 158-165

Project	Location	Number of Piles Measured	Hammer Type	Water Depth (m)	Distance (m)	RMS (dB re 1 μ Pa)	Peak (dB re 1 μ Pa)	SEL (dB re 1 μ Pa ² s)
Berth 32 Port of Oakland (2004) ¹ (octagonal)	Oakland, CA	n=5	Diesel	>10	10	Ave 173 Ave range 173-174	Ave max 185 Ave max range 184-185 Max 185	Ave 162 Ave range 161-163
Humboldt State University Floating Dock**** ¹ (octagonal)	Humboldt Bay, Eureka, CA	n=3	Diesel	3-4	10	Ave 157 Ave range 156-158	Ave max 179 Ave max range 176-179 Max 179	Ave 148 Ave range 142-151

Notes: Ave = Average

* For piles with fuel setting on high, no jetting.

**Pile with fuel setting on low, no jetting.

*** Average for row, not pile. Sound levels varied by depth. Only in-water sound levels reported in table (unattenuated values from Row A-D in Table 1.5-4 in Caltrans 2013).

****Piles jetted, so project data is not included in analysis.

Sources:

¹ Caltrans 2012

² WSDOT 2007a

Attachment 3. Vibratory Pile Driving SPLs from Marine Projects.
Bolded values were considered for proxy source levels.

Project	Location	Number of Piles Measured	Water Depth (meters)	Distance (meters)	Mean RMS* dB re 1 µPa
12-inch Timber					
Port Townsend Dolphin Timber Pile Removal ¹	Port Townsend, WA	n=1	---	16	Average 150 Range 149-152
13-inch Steel Pipe					
Mad River Slough Pipeline Construction ²	Mad River Slough, Arcata, CA	n=3	4.5-5.5	10	155
16-inch Steel Pipe					
EHW-1 ³	Bangor, WA	n=8	9-12	10	162 Ave range 153-168
24-inch Steel Pipe					
Friday Harbor ⁴	Friday Harbor, WA	n=1	2.6	10	162
Trinidad Pier Reconstruction ²	Trinidad Bay, Humboldt County, CA	n=2	15.2	10	Typical 160 range 158-178
Bangor Test Pile Program ⁵	Bangor Naval Base, WA	n=2 (1 pile vibed in and out)	4.6	10	160 Ave range 157-160**
30-inch Steel Pipe					
Edmonds ⁶	Edmonds, WA	n=2	6.4	10	165-166
Keystone Ferry Terminal ⁷	Coupeville, WA	n=4	~9.4	10 11 6 11	Per pile values due to different distances (165 176 176 165) Ave 173 Ave range 165-176
Vashon Ferry Terminal ⁸	Vashon Island, WA	n=4	<6	11-16	167 Ave range 160 - 169
Port Townsend Test Pile Project ^{9,10}	Port Townsend, WA	n=1	8.8	10	170 Ave range 164-174
EHW-1 ³	Bangor, WA	n=35	9-12	10	168 Ave range 155-174
36-inch Steel Pipe					
Edmonds Ferry Terminal ⁶	Edmonds, WA	n=2	5.8	11	Ave range 162-163
Anacortes Ferry Terminal ¹¹	Anacortes, WA	n=2	12.7	11	Ave range 168-170
Port Townsend Test Pile Project ^{9,10}	Port Townsend, WA	n=1	9.5	10	172 159-177
Bangor Test Pile Program ⁵	Bangor Naval Base, WA	n=~33 ~33	13.7-26.8	10	164 ** Ave range 154-169
24-inch AZ25 Steel Sheet					
Berth 23, Port of Oakland ²	Oakland, CA	n=1	~12-14	10	163***
Berth 30, Port of Oakland ²	Oakland, CA	n = 5	~12	10	1-sec SEL **** = 159 Ave range 157-160 (162 highest ave from bottom depth)
Berth 35/37, Port of Oakland ²	Oakland, CA	---	15	10	163

Notes: Ave = Average.

*WSDOT typically reports average of 30-second RMS values calculated over the duration of a drive.

** Average of all pile driving events.

***Involved only stabbing. Average reported by Caltrans Table I-1.2-3

****RMS SPLs were not reported, but would be similar to SEL for 1 second. Average top and bottom depths.

Sources:

¹ WSDOT 2011a

² Caltrans 2012

³ Miner 2012

⁴ WSDOT 2010a

⁵ Navy 2012

⁶ WSDOT 2011b.

⁷ WSDOT 2010c

⁸ WSDOT 2010d

⁹ WSDOT 2010e

¹⁰ Laughlin 2010

¹¹ WSDOT 2012

* Sound attenuation used - water jetting and cushion blocks.

** Water jetting data were excluded from analysis data set

¹ Caltrans 2012

Attachment 4. Impact Pile Driving L_{max} Airborne SPL Studies.
Bolded projects were considered for proxy source levels.

Project	Location	Number of Piles Measured	Distance (meters/feet)	L_{max} dB re 20 μ Pa
12-inch Steel Pipe				
Cape Disappointment Boat Launch Facility, Wave Barrier Project ¹	Columbia River, Astoria, OR	1 at 50 m	50 m/164 ft	89 A-weighted
24-inch Steel Pipe				
Bangor Test Pile Program	Bangor Naval Base, WA	1	15.2 m/50 ft 121.9 m/400 ft	110 dB (109dBA) 95 dB (93 dBA)
SR 520 Bridge Replacement Test Pile ²	Portage Bay, Seattle, WA	2	11-15 m/ 36-49 ft	95-100 dBA
30-inch Steel Pipe				
Friday Harbor Ferry Terminal Restoration ³	San Juan Island Area, Friday Harbor, WA	1	49 m / 160 ft	---
SR 520 Bridge Replacement Test Pile ²	Union Bay, Lake Washington, Seattle, WA	4	11-15 m/ 36-49 ft	103-106 dBA
36-inch Steel Pipe				
Bangor Test Pile Program⁴	Bangor Naval Base, WA	---	15 m/ 50 ft	109 dB (sd=2.58) Range 106-112 dB

Notes: All values unweighted unless indicated. Only unweighted values were considered for proxy values.

Sources:

¹ WSDOT 2006

² WSDOT 2010f

³ WSDOT 2005b

⁴ Navy 2012

Attachment 5. Vibratory Pile Driving L_{eq} Airborne SPL Studies.
Bolded projects were considered for proxy source levels.

Project	Location	Number of Piles Measured	Distance (meters/feet)	Average RMS L_{eq} dB re 20 μ Pa*	Average RMS L_{eq} dBA re 20 μ Pa*
18-inch Steel Pipe					
Wahkiakum Ferry Terminal¹	Columbia River, WA	1	15.2 m/50 ft*	87.5	
24-inch Steel Pipe					
Bangor Test Pile Program	Bangor Naval Base, WA	1	15.2 m/50 ft 121.9 m/400 ft	92 78 dB	85 72
SR 520 Bridge Replacement Test Pile ²	Portage Bay, Seattle, WA	1	11 m/36 ft	88 dBA	---
30-inch Steel Pipe					
Keystone Ferry Terminal¹	Puget Sound, WA	1	15.2 m/50 ft*	95 Range 93-96	
Vashon Ferry Terminal Test Pile Project ^{1,3}	Puget Sound, Vashon Island, WA	2	15.2 m/50 ft*	~83-85**	~77-80 dBA*
36-inch Steel Pipe					
Bangor Test Pile Program⁴	Bangor Naval Base, WA	---	15 m/50 ft	93 (sd =3.08) Range 89-102	

Notes; All values unweighted unless indicated.

* Sound pressure levels standardized to 50 ft range. Measurements made at 11 meters

**Converted to C-weighted from A-weighted measurements to approximate unweighted sound level, reported at a distance of 26 to 36 feet.

Sources:

¹ WSDOT 2010g

² WSDOT 2010f

³ WSDOT 2010d

⁴ Navy 2012

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- 6) Navy (U.S. Department of the Navy). 2012. Acoustic monitoring report Test Pile Program. Prepared for Naval Base Kitsap at Bangor, WA. Prepared by Illingworth and Rodkin, Inc., April 27, 2012.
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- 15) WSDOT 2010c. Keystone Ferry Terminal – Vibratory pile monitoring. Technical Memorandum prepared by Jim Laughlin for John Callahan. Washington State Department of Transportation, Office of Air Quality and Noise, Seattle, Washington. May 4, 2010. Available at <http://www.wsdot.wa.gov/NR/rdonlyres/B42B02E3-713A-44E1-A4A6-B9DDD0C9D28A/0/KeystoneVibratoryPileReport.pdf>
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Appendix B: Data Charts for Measured Data and Cumulative Probability
Distribution Functions

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Appendix B: Data Charts for Measured Data and Cumulative Probability Distribution Functions

Impact RMS

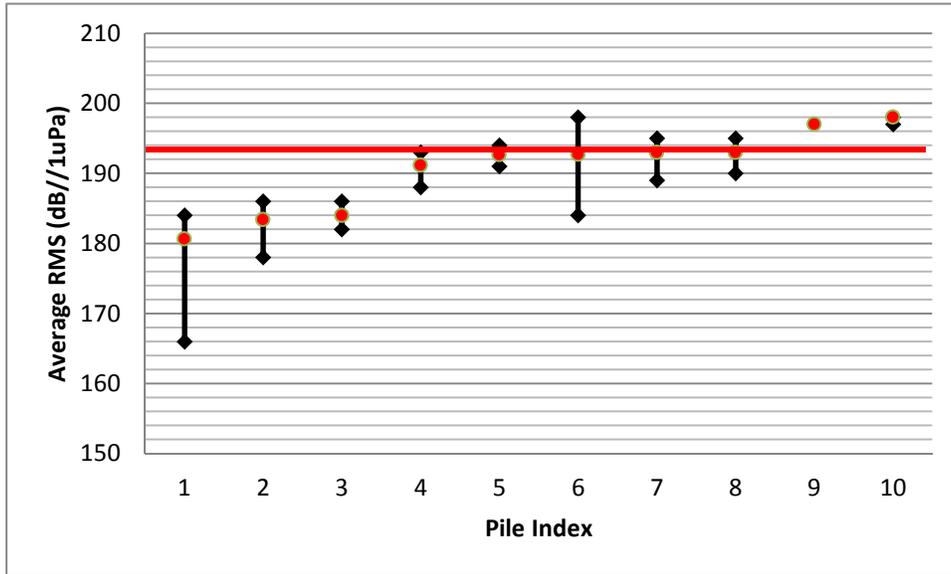


Figure B-1 – 24-inch RMS Measurements

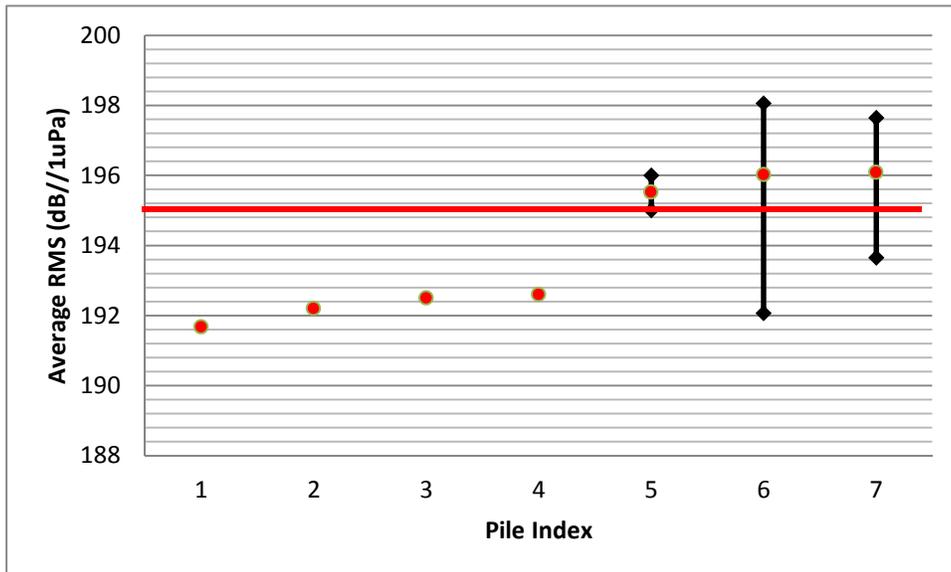


Figure B-2 - 30-inch RMS Measurements

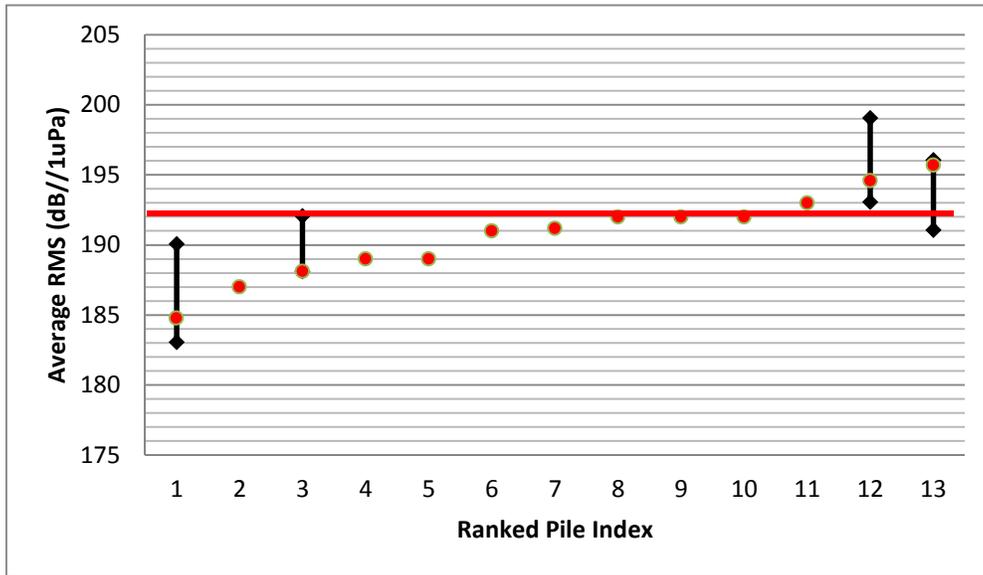


Figure B-3 – 36-inch RMS Measurements

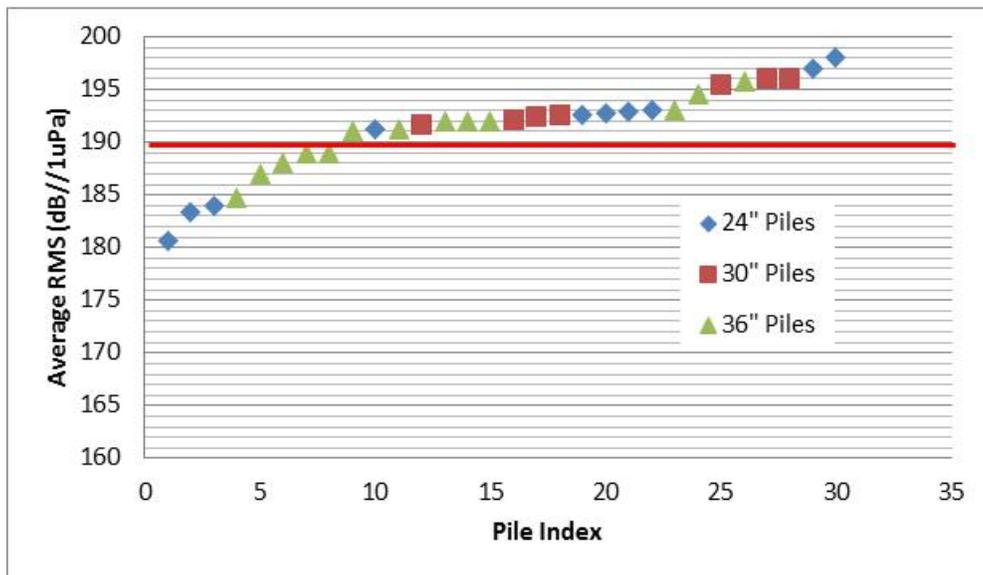


Figure B-4 – Combined Analysis: 24, 30, 36-inch RMS Measurements

Impact Average Peak

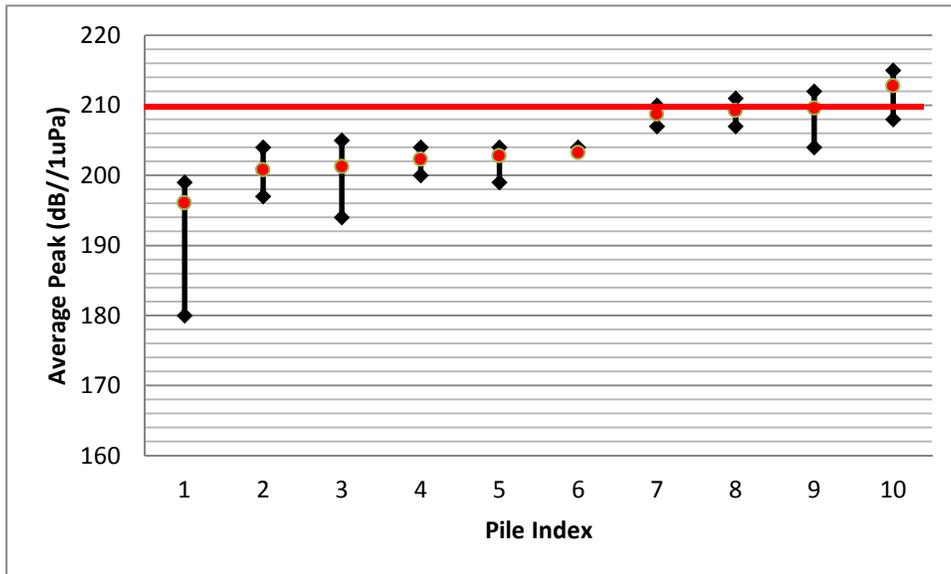


Figure B-5 – 24-inch Average Peak Measurements

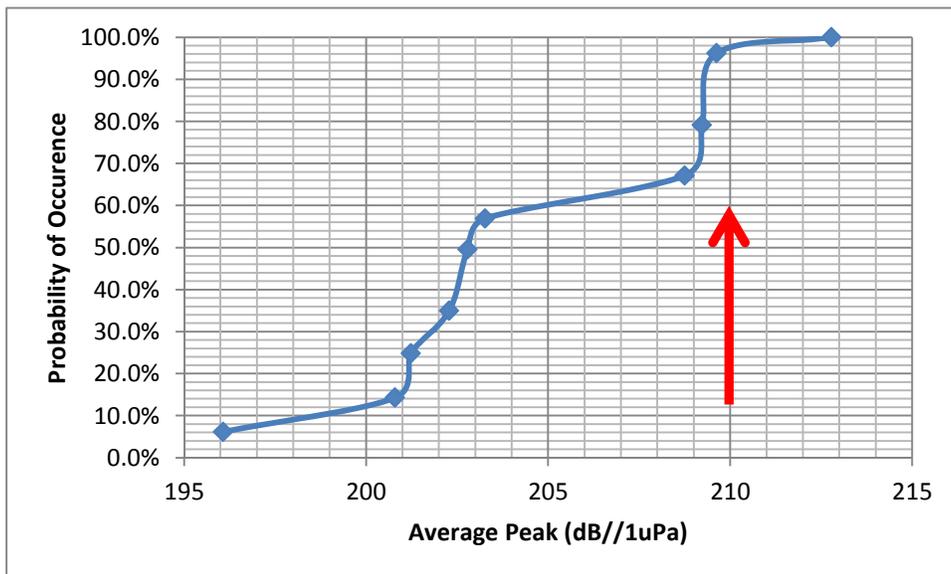


Figure B-6 – 24-inch Average Peak Cumulative Distribution Function

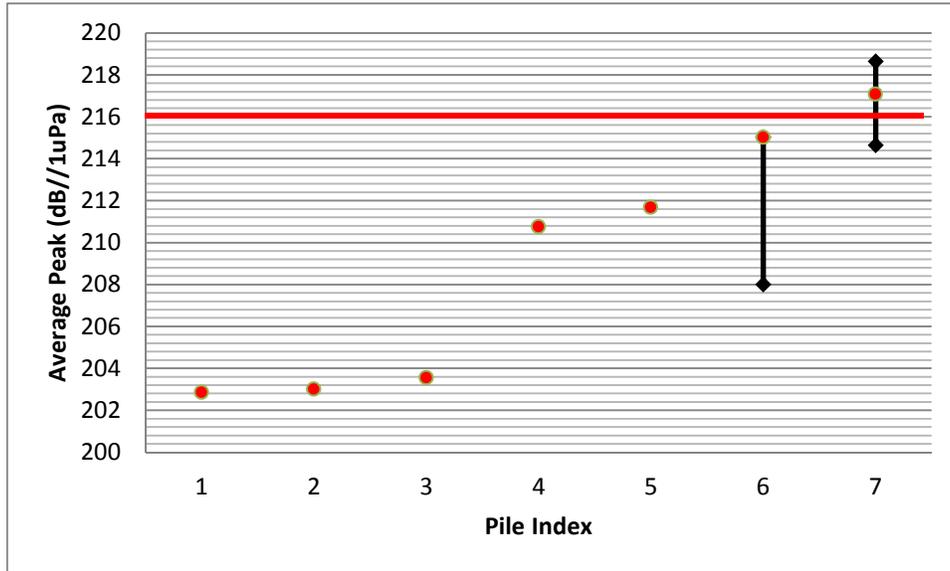


Figure B-7 – 30-inch Average Peak Measurements

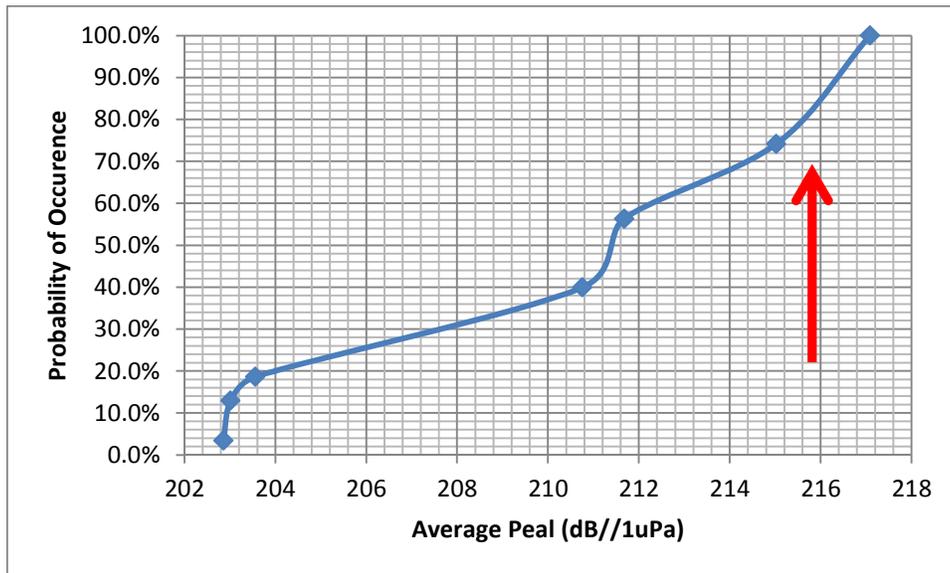


Figure B-8 – 30-inch Average Peak Cumulative Distribution Function

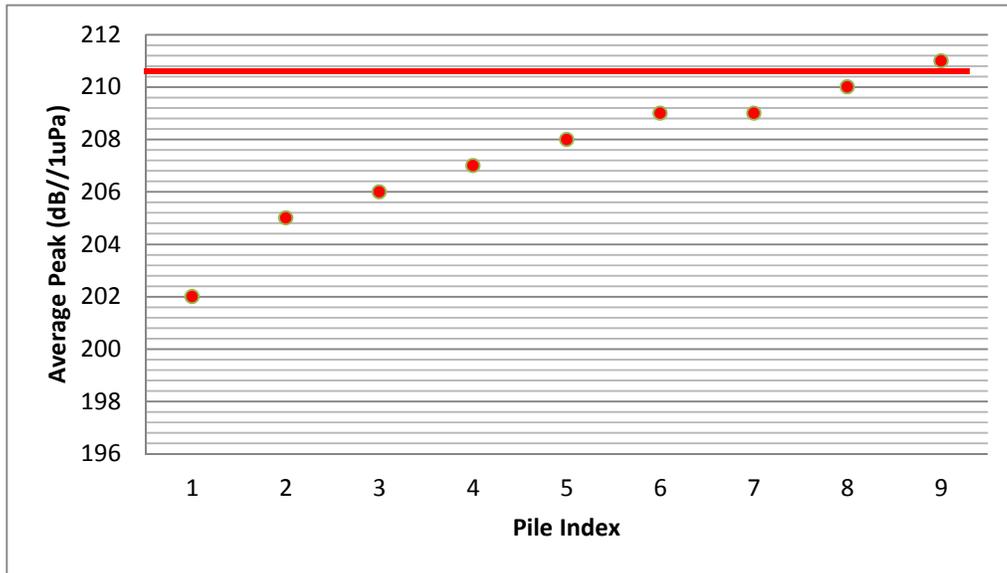


Figure B-9 – 36-inch Average Peak Measurements

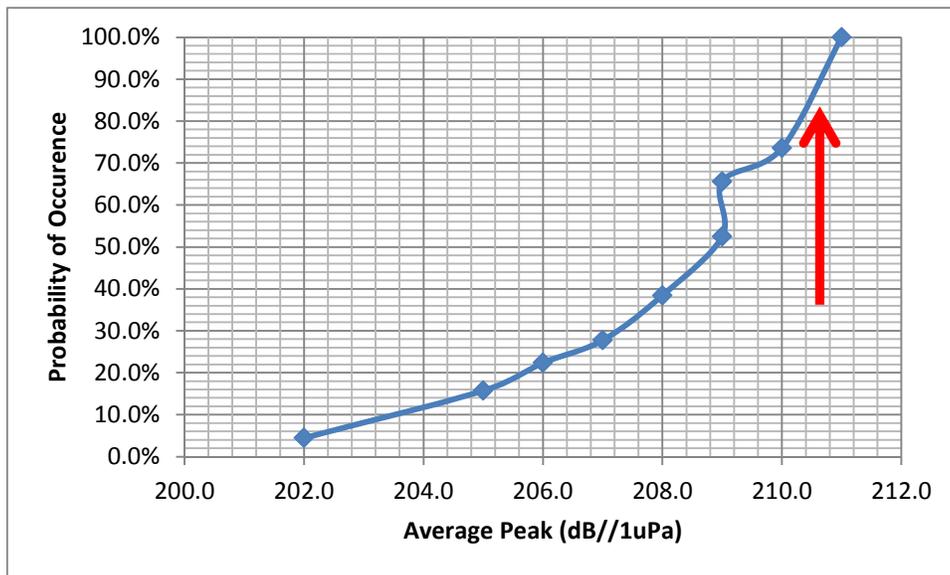


Figure B-10 – 36-inch Average Peak Cumulative Distribution Function

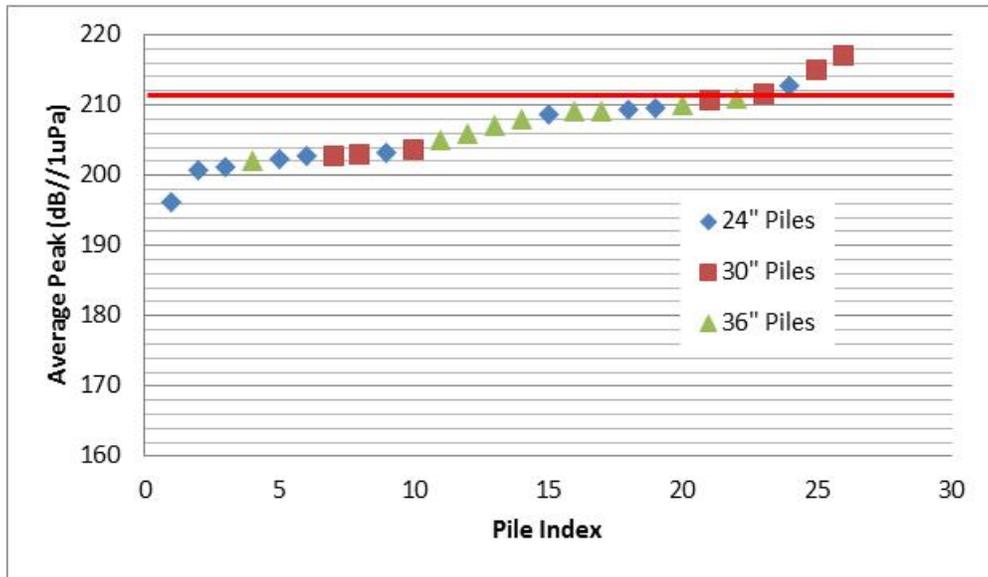


Figure B-11 – Combined Analysis: 24, 30, 36-inch Average Peak Measurements

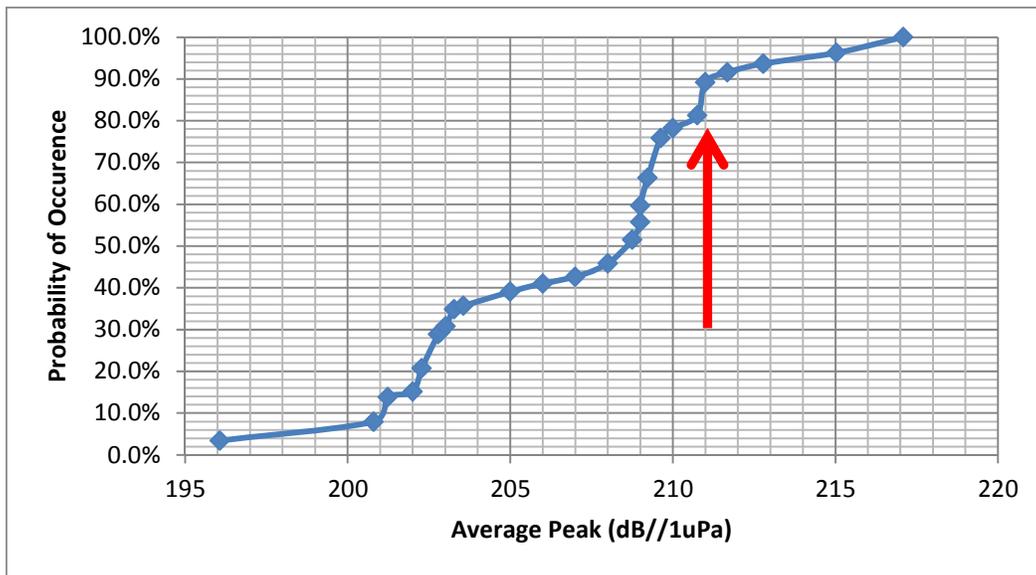


Figure B-12 – Combined Analysis: 24, 30, 36-inch Average Peak Cumulative Distribution Function

Impact SEL

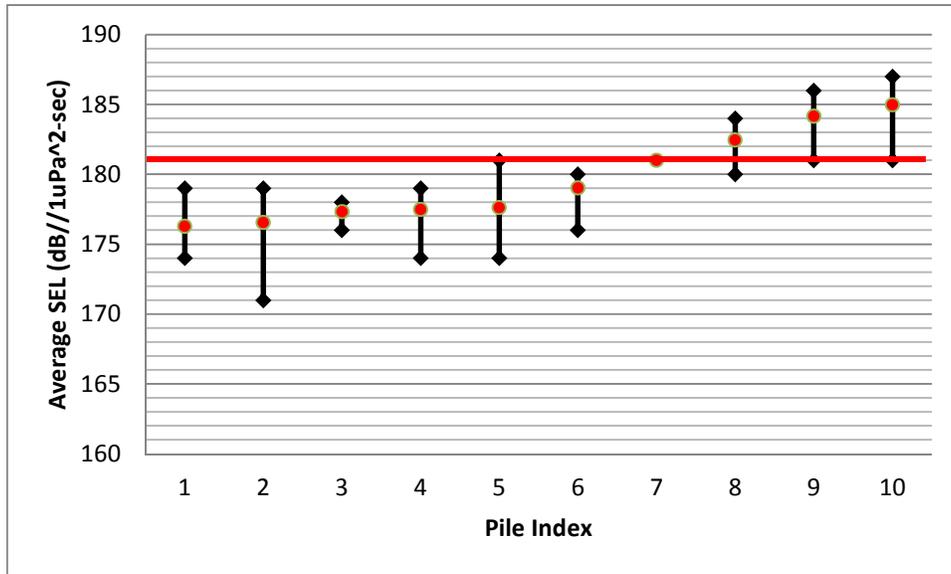


Figure B-13 – 24-inch SEL Measurements

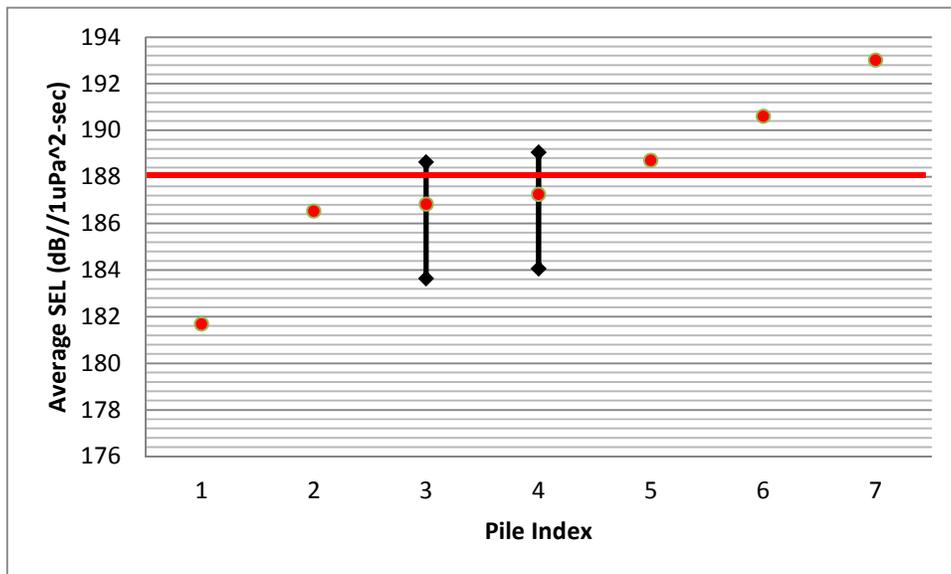


Figure B-14 - 30-inch SEL Measurements

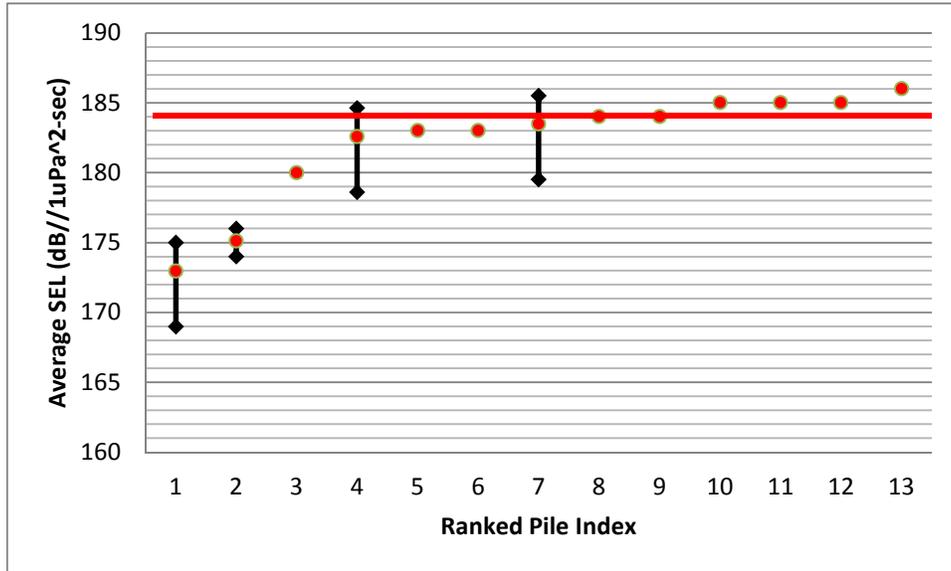


Figure B-15 – 36-inch SEL Measurements

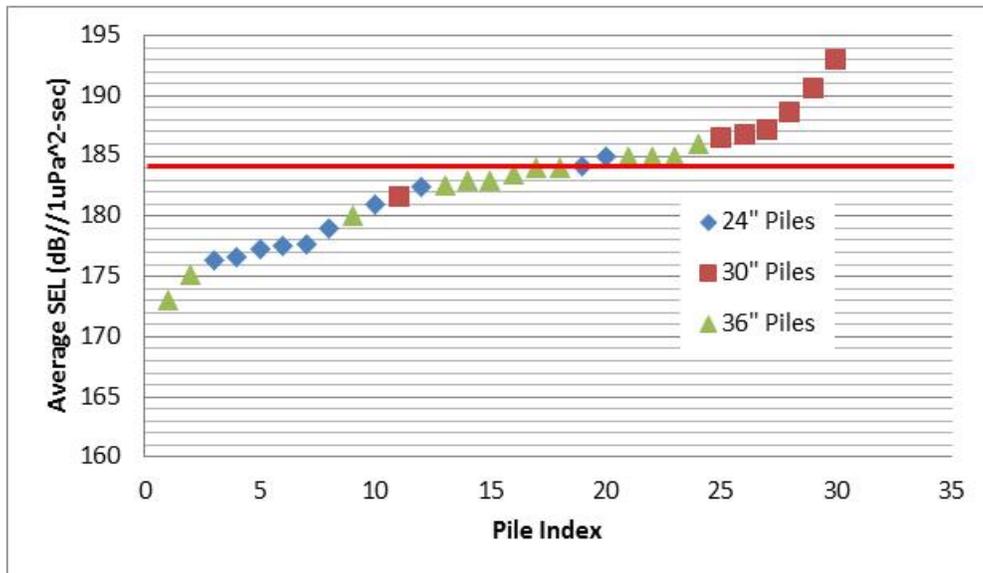


Figure B-16 - Combined Analysis: 24, 30, 36-inch SEL Measurements

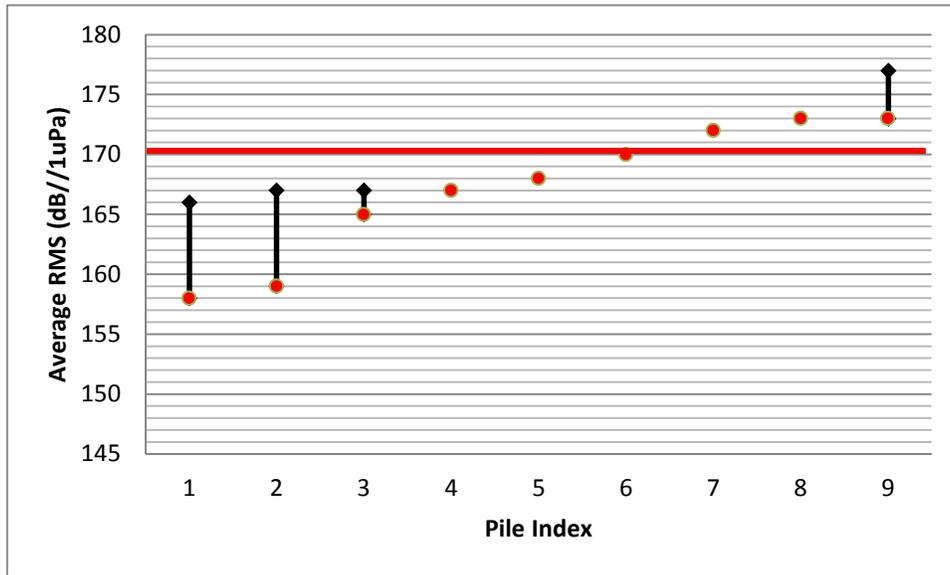


Figure B-17 – Concrete 16, 18-inch RMS Measurements

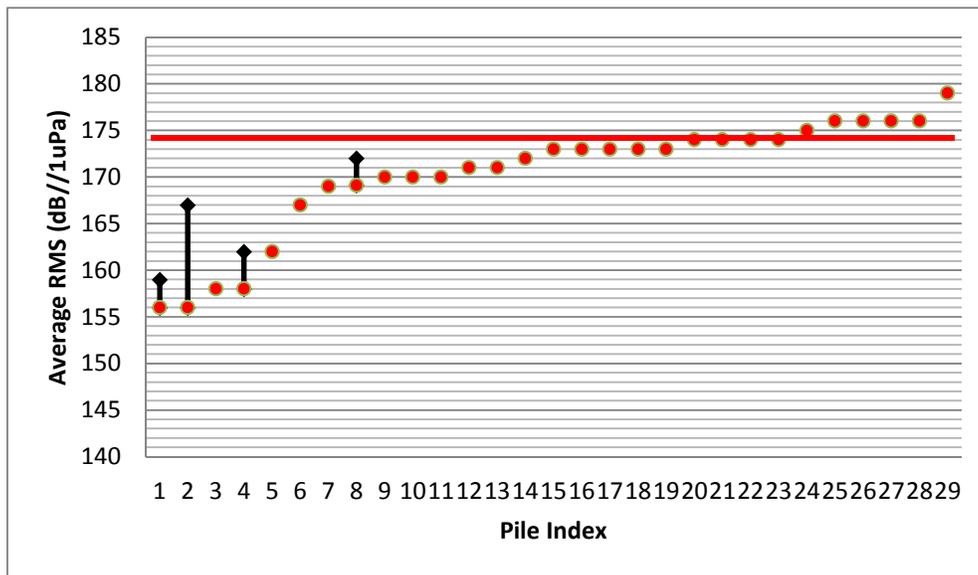


Figure B-18 – Concrete 24-inch RMS Measurements

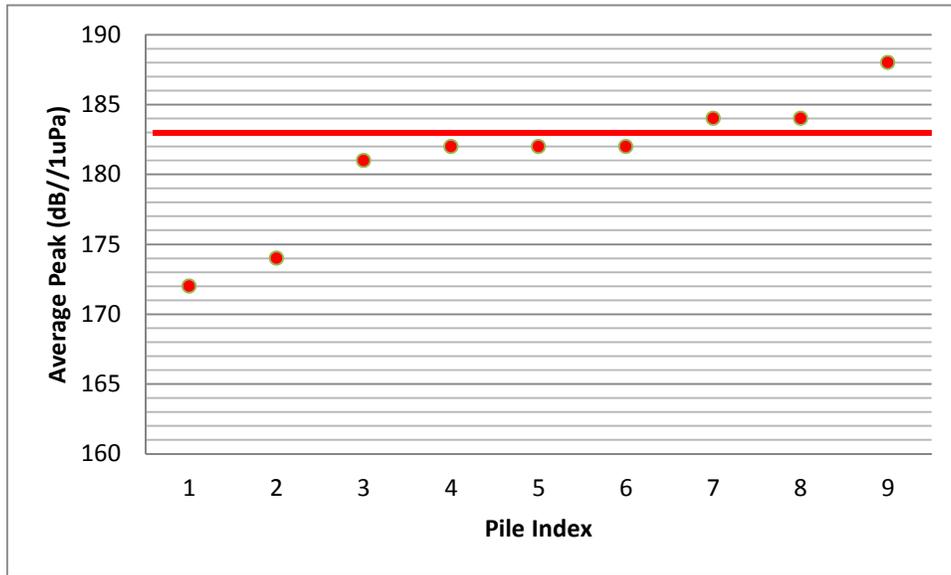


Figure B-19 – Concrete 16, 18-inch Average Peak Measurements

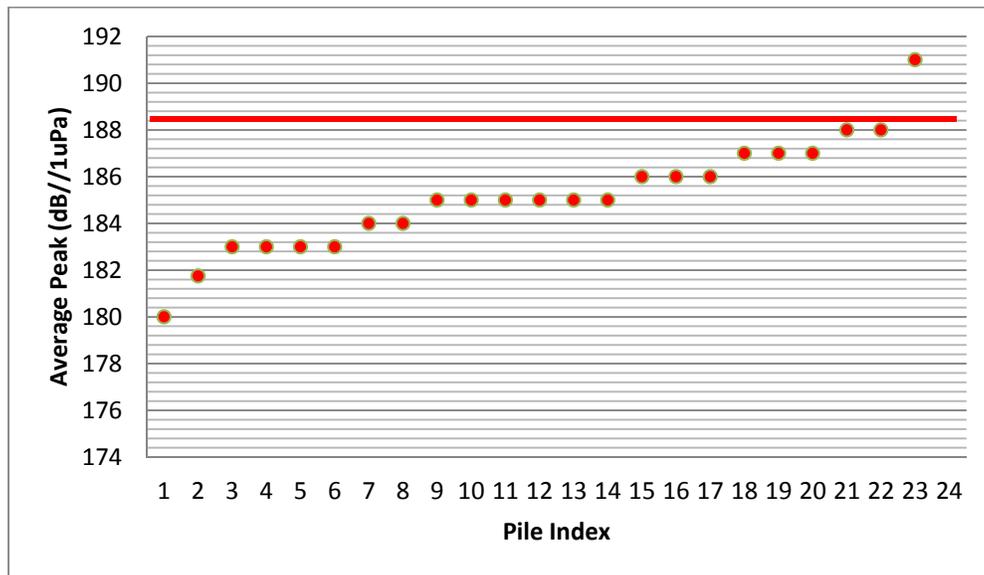


Figure B-20 – Concrete 24-inch Average Peak Measurements

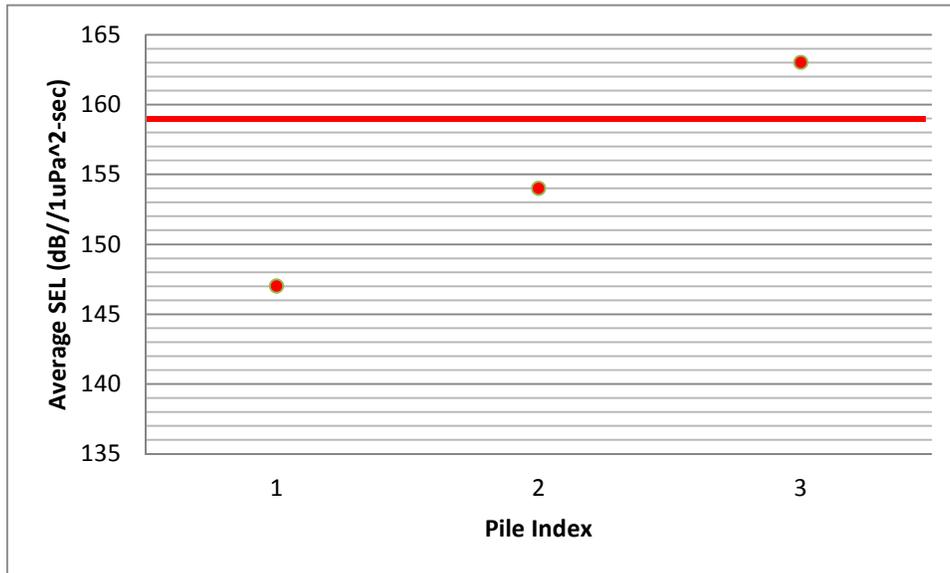


Figure B-21 – Concrete 16, 18-inch SEL Measurements

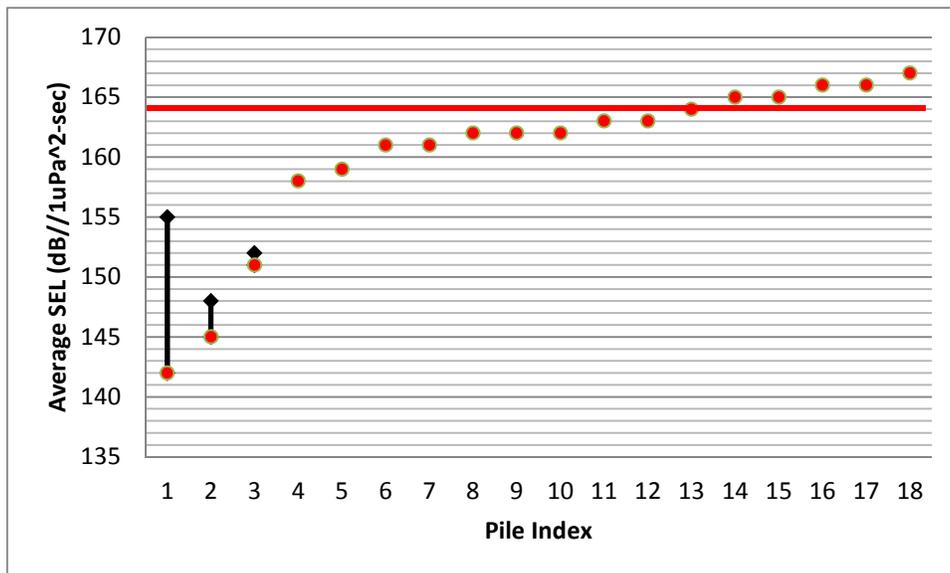


Figure B-22 – Concrete 24-inch SEL Measurements

Vibratory RMS

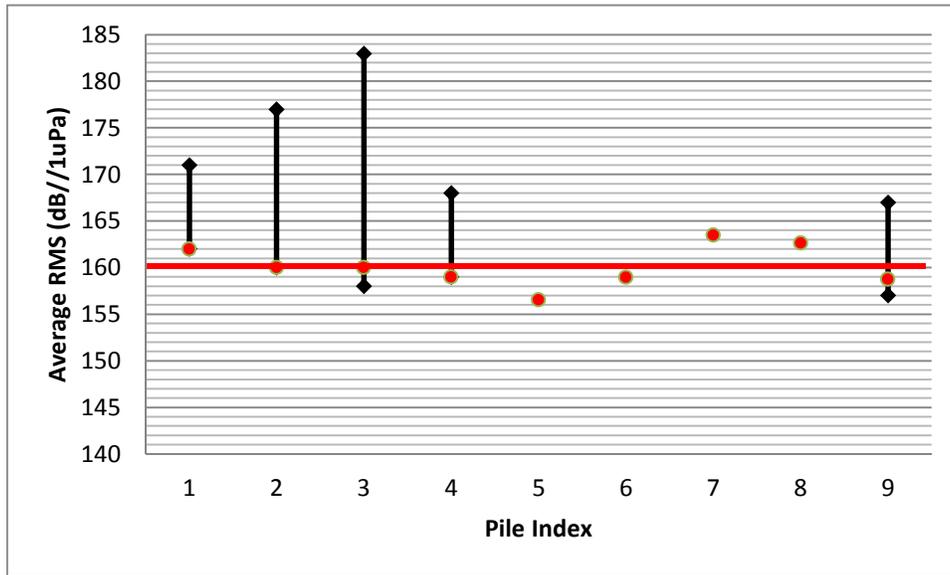


Figure B-23 –24-inch RMS Vibratory Measurements

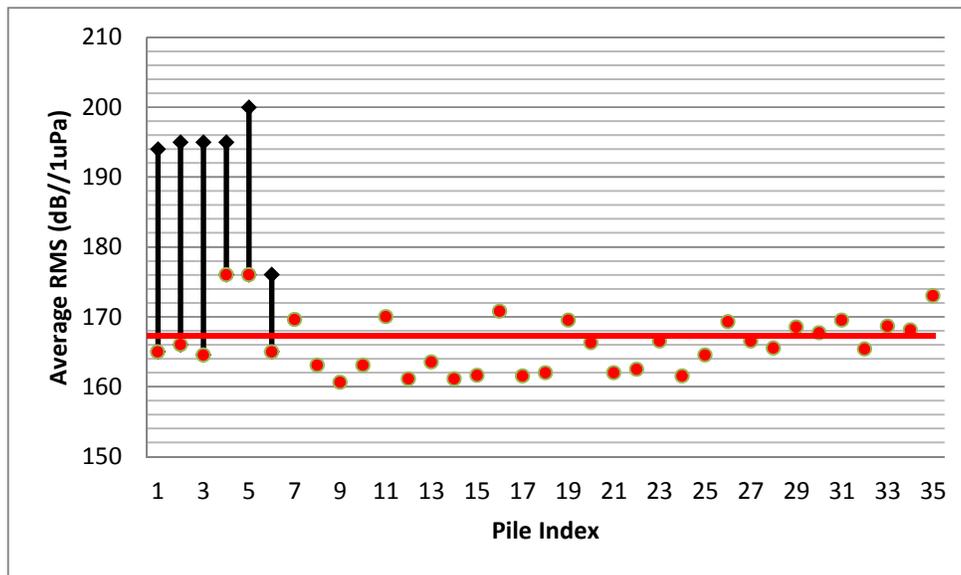


Figure B-24 –30-inch RMS Vibratory Measurements

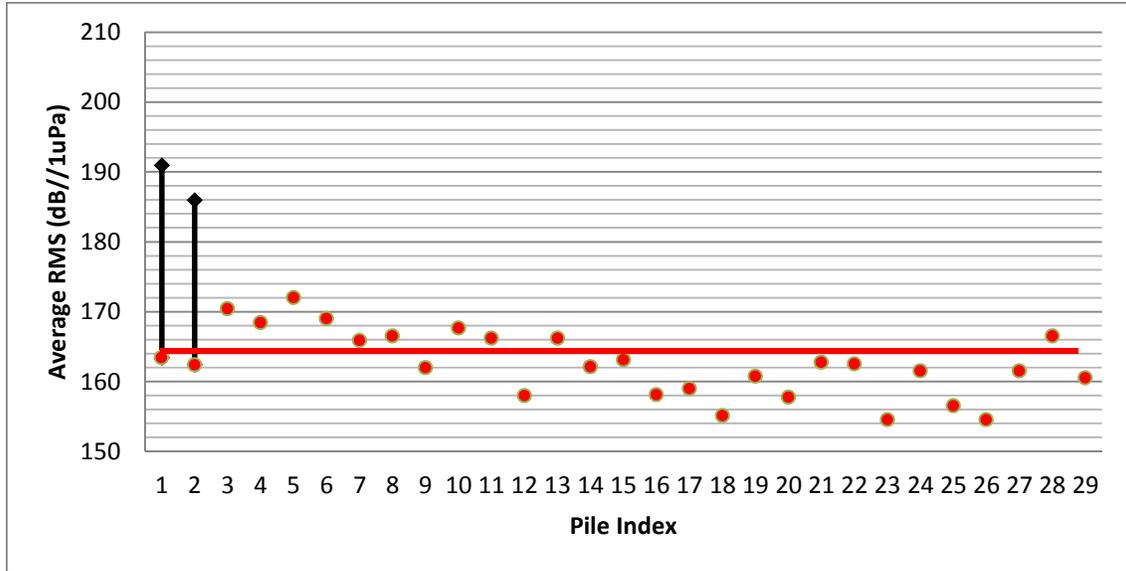


Figure B-25 –36-inch RMS Vibratory Measurement

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APPENDIX C: MARINE MAMMAL MONITORING PLAN

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Marine Mammal Monitoring Plan

TRIDENT SUPPORT FACILITIES
EXPLOSIVES HANDLING WHARF (EHW-1)



NAVAL BASE KITSAP at BANGOR
SILVERDALE, WA

October 2014

DEPARTMENT OF THE NAVY

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1.0 INTRODUCTION

The United States Navy (Navy) will complete necessary repairs and maintenance of the Explosive Handling Wharf #1 (EHW-1) facility at Naval Base Kitsap at Bangor. The purpose of this plan is to provide a protocol for marine mammal monitoring that will occur during in-water construction scheduled to begin July 16, 2015. Visual marine mammal monitoring will be conducted before, during, and after pile driving activities where noise levels may behaviorally disturb marine mammals. Noise levels from pile driving were determined to exceed the behavioral and injury thresholds for marine mammals. However, a zone will be visually monitored and pile driving will be shut-down if marine mammals are in the injury zone. This measure will preclude physical harm to marine mammals. This monitoring plan was developed to ensure compliance with the incidental harassment authorization issued for in-water construction from July 16, 2015 through January 15, 2013.

2.0 METHODS

2.1. OBSERVER QUALIFICATIONS

Monitoring will be conducted by qualified, trained marine mammal observers (hereafter, “observer”). An observer is a biologist with prior training and experience in conducting marine mammal monitoring or surveys, and who has the ability to identify marine mammal species and describe relevant behaviors that may occur in proximity to in-water construction activities. A trained observer will be placed at the best vantage point(s) practicable (e.g., from a small boat, the pile driving barge, on shore, or any other suitable location) to monitor for marine mammals and implement shutdown/delay procedures when applicable by calling for the shutdown to the hammer operator. The observers will have no other construction related tasks while conducting monitoring.

A dedicated monitoring coordinator will be on-site during all construction days. The monitoring coordinator will oversee marine mammal observers. The monitoring coordinator will serve as the liaison between the marine mammal monitoring staff and the construction contractor to assist in the distribution of information.

2.2. DATA COLLECTION

Observers will use the most current NMFS-approved Marine Mammal Sighting Form supplied by the Navy (see Appendix A for example) which will be completed by each observer for each survey day.

- Date and time that pile driving begins or ends;
- Construction activities occurring during each sighting;
- Weather parameters (e.g., percent cover, percent glare, visibility);
- Water conditions (e.g., Tidal state [incoming (flood), slack (neither direction), or outgoing (ebb)], and sea state). The Beaufort Sea State Scale (Appendix B) will be used to determine sea-state.
- Species, numbers, and if possible, sex and age class of marine mammals;
- Marine mammal behavior patterns observed, including bearing from observer and direction of travel. If possible, include the correlation to sound pressure levels for context;
- Distance from pile driving activities to marine mammals and distance from the marine mammal to the observation point;

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- Locations of all marine mammal observations;
- Other human activity in the area. Record the hull numbers of fishing vessels if possible.

The monitoring coordinator will complete a Marine Mammal Monitoring Summary Form (Appendix A) for each day of monitoring. The summary form compiles information collected on the individual sighting forms and provides additional details about construction activities during marine mammal monitoring. The summary form will be provided to the Navy each day following monitoring.

2.3. EQUIPMENT

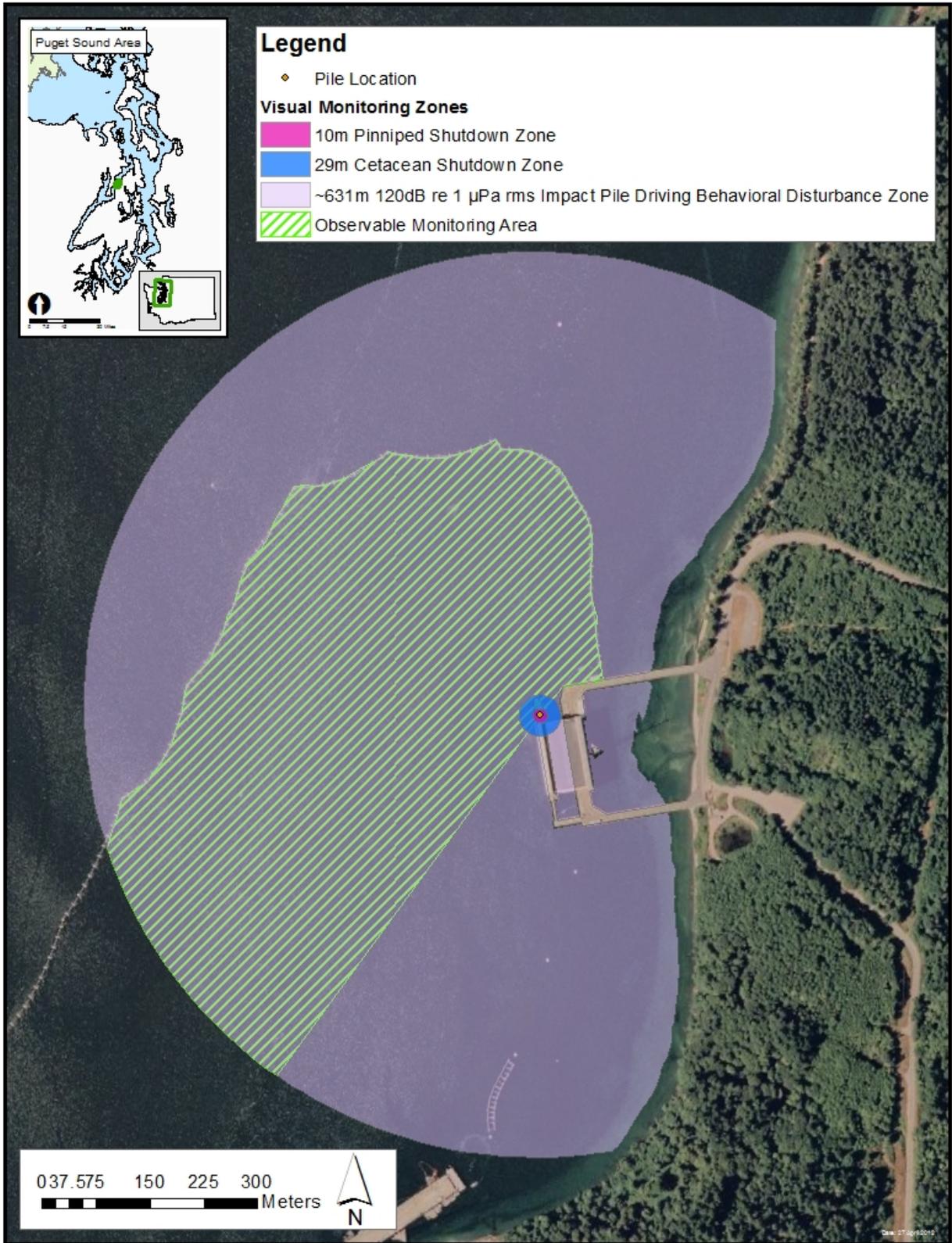
The following equipment will be required to conduct marine mammal monitoring:

- If boat based monitors are used, a survey boat (with flying bridge for elevated observations) will include: covered cabin areas to keep electrical equipment dry, a fixed marine radio for the Captain to communicate on Ch. 16 and other marine channels independent of observers communicating on a dedicated channel, depth finder, measuring tape, navigational plotting equipment, and both fixed and hand-held GPS Units. Vessels will comply with all Coast Guard regulations and be able to pass a Coast Guard safety inspection;
- Hearing protection for biologists and boat operators working near heavy construction equipment;
- Portable marine radios and headsets for the observers to communicate with the monitoring coordinator, construction contractor, and other observer(s);
- Cellular phones, without a camera (one per boat/observing location), and the contact information for the other observer(s), monitoring coordinator, and NMFS point of contact;
- Green flags (one per boat/observing location) as back-up for radio communication;
- Red flags (one per boat/observing location) as back-up for radio communication;
- Nautical charts;
- Daily tide tables for the project area within the Hood Canal;
- Watch or Chronometer;
- Binoculars with built-in rangefinder or reticles – (quality 7 x 50 or better);
- Monitoring plan, IHA permit, and/or other relevant permit requirement specifications in sealed clear plastic cover;
- Notebook with pre-standardized monitoring Marine Mammal Observation Record forms on non-bleeding paper (e.g Rite-in-the Rain);
- Marine mammal identification guides on waterproof paper
- Clipboard, pen / pencil

2.4. SHUTDOWN AND BEHAVIORAL VISUAL MONITORING ZONES

2.4.1 Behavioral Visual Monitoring Zone

The 631m behavioral zone for impact pile driving is the distance noise levels are estimated to be at or above 160 dB re 1 μ Pa Level B behavioral threshold (Figure 2-1). A larger Level B behavioral zone, estimated to extend 6.3 km during vibratory pile driving is also present. Because monitoring these two large zones is not practicable, a smaller monitoring zone depicted in Figure 2-1 will be monitored. This zone is based on visibility at the project site. Visibility is effectively limited within the Level B zones by the Port Security Barrier (PSB)



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Figure 2-1. Visual Marine Mammal Monitoring Zone with Representative Monitoring Locations Shown.

approximately 400 meters to the north, north east and west of the project site. In addition, the EHW-1 overwater building and the wharf structure effectively limit visibility. Not shown on the Figure is the EHW-2 which is currently in construction directly south of EHW-1. This new wharf will also block monitoring efforts to the south of the green hatched area on Figure 2-1. Therefore, even though the behavioral zones for impact and vibratory pile driving will extend beyond this area, monitoring will be effectively limited to the smaller zone (Figure 2-1). However, monitors will, where possible, report any marine mammals they are able to see outside the monitoring area depicted in Figure 2-1.

2.4.2 Visual Shutdown Zone

To preclude injury to pinnipeds, a 10 meter radius Shutdown Zone from a pile will be implemented during pile driving. The 10 m Shutdown Zone is based on encompassing the distance to the 190 dB RMS re 1 μ Pa impact pile driving injury zone (calculated at 6 m for pinnipeds). To preclude injury to cetaceans, a 29 meter radius Shutdown Zone will be implemented while pile driving is conducted. This zone is within the Waterfront Restricted Area (WRA) where cetaceans have never been observed.

Modeling does not predict sound levels at or above the criteria for injury from vibratory pile driving. If the Navy determines another activity may physically harm marine mammals then a 10 meter radius Shutdown Zone from the activity will be monitored.

Visual Monitoring and Shutdown:

- During impact and vibratory pile driving, a 10 meter pinniped Shutdown Zone and, during impact driving, a 29 meter cetacean Shutdown Zone shall be established and monitored to prevent injury to marine mammal species from pile driving noise and physical interaction with construction equipment. Modeling does not predict sound levels at or above the criteria for injury from vibratory pile driving.
- During pile driving, the Visual Monitoring Zone shall include all areas within the Port Security Barrier (PSB) fence or out to approximately 631 meters where practicable (e.g. equivalent to where pile driving noise levels are estimated to be at or above 160 dB re 1 μ Pa impact pile driving behavioral threshold) (Figure 2-1).
- The Shutdown and Visual Monitoring Zones will be monitored throughout the time required to install a pile. If a marine mammal enters the Visual Monitoring Zone, an exposure would be recorded and behaviors documented. However, that pile would be completed without cessation, unless the animal approaches or enters the Shutdown Zone, at which point all pile removal activities will be halted.

2.5. OBSERVER MONITORING LOCATIONS

In order to effectively monitor the Shutdown Zone, marine mammal observers will be positioned at the best practicable vantage points, taking into consideration security, safety, and space limitations at the waterfront. A minimum of three monitors will be present. Because of the difficulty of seeing harbor seals swimming underneath the wharf and approaching the shutdown zone, two observers will monitor the 10 m Shutdown Zone. Monitors will be stationed in small vessels, on the wharf, or on the pile driving barge in a location that will provide adequate visual coverage of the Shutdown Zones. One additional observer will be stationed to maximize observations in the behavioral Visual Monitoring Zone (not including boat operators if a boat is used).

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Security restrictions and operations inside the WRA as defined by the area inside the PSB fence line, may preclude the placement of boats/personnel at certain times and locations. If security restrictions result in movement of a monitoring location, an alternate location will be identified for monitoring by the monitoring coordinator in conjunction with the Navy. Additionally, security requires that all vessels maintain a minimum standoff distance of 25 feet from the PSB fence at all times.

2.6. MONITORING TECHNIQUES

The Navy will collect sighting data and behaviors of marine mammal species observed pre-, during, and post-driving period. The efficacy of visual detection depends on several factors including the observer's ability to detect the animal, the environmental conditions (visibility and sea state), and monitoring platforms. The following survey methodology will be implemented for all monitoring activities:

- Observers will survey the Shutdown and Visual Monitoring Zones. Monitoring of the Shutdown Zone will take place from 15 minutes prior to initiation through 30 minutes post-completion of pile driving to ensure there are no marine mammals present.
- Marine Mammal Observation Record forms (Appendix A) will be used to document observations.
- Any survey boats engaged in marine mammal monitoring will maintain speeds equal to or less than 10 knots.
- Observers will be trained and experienced marine mammal observers in order to accurately verify species sighted.
- Observers will use binoculars and the naked eye to search continuously for marine mammals.

2.6.1. Visual Survey Protocol – Pre-Activity Monitoring

The following survey methodology will be implemented prior to commencing pile driving:

- If marine mammal(s) are present within or approaching the Shutdown Zone prior to pile driving, the start of these activities will be delayed until the animal(s) leave the shutdown zone voluntarily and have been visually confirmed beyond the Shutdown Zone, or 15 minutes has elapsed without re-detection of the animal.
- If marine mammal(s) are not detected within the Shutdown Zone (i.e., the zone is deemed clear of marine mammals), the observers will raise a green flag and radio the monitoring coordinator/construction contractor that pile driving can commence.
- If marine mammal(s) are present within the Visual Monitoring Zone, pile driving would not need to be delayed, but observers would monitor and document, to the extent practical, the behavior of marine mammals that remain in the zone.
- In case of fog or reduced visibility, the observers must be able to see the Shutdown Zones or pile driving will not be initiated until visibility in these zones improves to acceptable levels.

2.6.2. Visual Survey Protocol – During Activity Monitoring

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The Shutdown and Visual Monitoring Zones will be monitored throughout pile driving. The following survey methodology will be implemented during pile driving:

- If a marine mammal is observed within or entering the Visual Monitoring Zone during pile driving, an exposure would be recorded, behaviors documented, and the Shutdown Zone monitor alerted to the position of the animal. However, that pile segment would be completed without cessation, unless the animal approaches or enters the Shutdown Zone, at which point all pile driving activities will be halted. The observers shall immediately radio to alert the monitoring coordinator/construction contractor and raise a red flag. This action will require an immediate “all-stop” on pile operations.
- Under certain construction circumstances where initiating the shutdown and clearance procedures (which could include a delay of 15 min or more) would result in an imminent concern for human safety, the shutdown provision may be waived.
- Once a shutdown has been initiated, pile driving and other in-water construction activities will be delayed until the animal has voluntarily left the Shutdown Zone and has been visually confirmed beyond the Shutdown Zone, or 15 minutes have passed without re-detection of the animal.
- Once marine mammals are no longer detected within the Shutdown Zone (i.e., the zone is deemed clear of marine mammals), the observer will raise a green flag and radio the monitoring coordinator/construction contractor that activities can re-commence;
- If marine mammals are detected outside the Shutdown Zone, the observers will continue to monitor these individuals and record their behavior, but pile driving and other in-water construction may proceed. Any marine mammals detected outside the Shutdown Zone after pile driving is initiated shall likewise continue to be monitored and their behaviors recorded.

2.6.3. Visual Survey Protocol – Post-Activity Monitoring

Monitoring of the Shutdown Zones will continue for 30 minutes following completion of pile driving. These surveys will record marine mammal observations, and will focus on observing and reporting unusual or abnormal behavior of marine mammals. During these surveys, if any injured, sick, or dead marine mammals are observed, procedures outlined below in Section 3.0 should be followed.

3.0 INTERAGENCY NOTIFICATION

In the event that the Navy needs to modify terms of this monitoring plan, the NMFS representative will be promptly contacted for discussion of the requested modification. In the unanticipated event that the specified activity clearly causes the take of a marine mammal in a manner prohibited by this IHA, such as an injury (Level A harassment), serious injury, or mortality, Navy shall immediately cease the specified activities and report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, and the Northwest Regional Stranding Coordinator, NMFS. The report must include the following information:

- Time and date of the incident;
- Description of the incident;
 - Environmental conditions (e.g., wind speed and direction, Beaufort sea state, cloud cover, and visibility);

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- Description of all marine mammal observations in the 24 hours preceding the incident;
- Species identification or description of the animal(s) involved;
- Fate of the animal(s); and
- Photographs or video footage of the animal(s).

Activities shall not resume until NMFS is able to review the circumstances of the prohibited take. NMFS will work with Navy to determine what measures are necessary to minimize the likelihood of further prohibited take and ensure MMPA compliance. Navy may not resume their activities until notified by NMFS.

In the event that Navy discovers an injured or dead marine mammal, and the lead observer determines that the cause of the injury or death is unknown and the death is relatively recent (e.g., in less than a moderate state of decomposition), Navy shall immediately report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, and the Northwest Regional Stranding Coordinator, NMFS. The report will include the same information as listed above. Activities may continue while NMFS reviews the circumstances of the incident. The Navy will work with NMFS to determine whether additional mitigation measures or modifications to the activities are appropriate.

In the event that Navy discovers an injured or dead marine mammal, and the lead observer determines that the injury or death is not associated with or related to the activities authorized in the IHA (e.g., previously wounded animal, carcass with moderate to advanced decomposition, or scavenger damage), the Navy shall report the incident to the Chief of Permits and Conservation Division, Office of Protected Resources, NMFS, and the Northwest Regional Stranding Coordinator, NMFS, within 24 hours of the discovery. Navy shall provide photographs or video footage or other documentation of the stranded animal sighting to NMFS.

Care should be taken in handling dead specimens to preserve biological materials in the best possible state for later analysis of cause of death, if that occurs. In preservation of biological materials from a dead animal, the finder (i.e., marine mammal observer) has the responsibility to ensure that evidence associated with the specimen is not unnecessarily disturbed.

Primary points of contact for the Navy are:

1. Tyler Yasenak - (360) 315-2452
2. Greg Leicht - (360) 315-5411

Primary points of contact at NMFS are:

1. Modification to protocol - (360) 753-5835
2. Chief of the Permits and Conservation Division (301-427-8425)
3. Northwest Regional Stranding Coordinator (206-526-6550)

4.0 MONITORING REPORTS

A draft report will be submitted to NMFS within 90 work days of the completion of marine mammal monitoring. A final report will be prepared and submitted to the NMFS within 30 days following receipt of comments on the draft report from the NMFS. At a minimum, the report shall include:

- General data:

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- Date and time of activities.
- Water conditions (e.g., sea-state, tidal state).
- Weather conditions (e.g., percent cover, visibility).

Specific pile data:

- Description of the pile driving activities including the size and type of pile,
- The installation methods used for each pile and the duration each method was used per pile
- Impact or vibratory hammer force used to drive/extract piles
- Detailed description of the sound attenuation system for impact driving, including the design specifications
- Depth of water in which the pile was driven
- Depth into the substrate that the pile was driven
- Pre-activity observational survey-specific data:
 - Dates and time survey is initiated and terminated.
 - Description of any observable marine mammal behavior in the immediate area during monitoring.
 - If possible, the correlation to underwater sound levels occurring at the time of the observable behavior.
 - Actions performed to minimize impacts to marine mammals.
- During-activity observational survey-specific data:
 - Description of any observable marine mammal behavior within monitoring zones or in the immediate area surrounding monitoring zones including the following:
 - Distance from animal to source.
 - Reason why/why not shutdown implemented.
 - If a shutdown was implemented, behavioral reactions noted and if they occurred before or after implementation of the shutdown.
 - If a shutdown is implemented, the distance from animal to source at the time of the shutdown.
 - Behavioral reactions noted during soft starts¹ and if they occurred before

¹ The objective of a soft-start is to provide a warning and/or give animals in close proximity to pile driving a chance to leave the area prior to a vibratory or impact driver operating at full capacity thereby, exposing fewer animals to loud underwater and airborne sounds.

- A soft start procedure will be used at the beginning of each day's in-water pile driving or any time pile driving has ceased for more than 1 hour.
- For impact pile driving, the following soft-start procedures will be conducted:
 - If a bubble curtain is used for impact pile driving, the contractor will start the bubble curtain prior to the initiation of impact pile driving.
 - The contractor will provide an initial set of strikes from the impact hammer at reduced energy, followed by a 30-second waiting period, then two subsequent sets. (The reduced energy of an individual hammer cannot be quantified because they vary by individual drivers. Also, the number of strikes will vary at reduced energy because raising the hammer at less than full power and then releasing it results in the hammer "bouncing" as it strikes the pile resulting in multiple "strikes").
- For vibratory pile driving, the contractor will initiate noise from vibratory hammers for 15 seconds at reduced

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- or after implementation of the soft start.
 - Distance to the animal from the source during soft start.
- If possible, the correlation to underwater or airborne sound levels occurring at the time of this observable behavior.
- Actions performed to minimize impacts to marine mammals.
- Times when pile driving is stopped due to presence of marine mammals within the Shutdown Zones and time when pile driving resumes.
- Post-activity observational survey-specific data:
 - Results, which include the detections of marine mammals, species and numbers observed, sighting rates and distances, behavioral reactions within and outside of monitoring zones.
 - A refined take estimate based on the number of marine mammals observed during the course of construction. The refined take estimate will use the most current guidelines. If a contractor is used for visual monitoring, the Navy will furnish the guidelines to the contractor with this monitoring plan.

energy followed by a 30-second waiting period. The procedure shall be repeated two additional times. If additional marine mammal monitoring data indicates that there is no change in behavior of pinnipeds during vibratory pile driving or soft start procedures and the NMFS concurs, then the soft start procedure would no longer be required. Additionally, if unsafe working conditions during soft starts are reported by the contractor and verified by an independent safety inspection, the Navy may elect to discontinue vibratory soft starts. The Navy will inform NMFS HQ if the soft start procedure is discontinued.

APPENDIX A

Example MARINE MAMMAL OBSERVATION RECORD FORM

APPENDIX A
MARINE MAMMAL OBSERVATION RECORD FORM

Project Name: _____

Monitoring Location _____
(Pier Location, Vessel based, Land Location, other)

Page _____ of _____

Date: _____

Vessel Name: _____

Time Effort Initiated: _____

Time Effort Completed: _____

Sighting Data

Event Code	Sighting Number (1 or 1.1 if resight)	Time/Duration watching sighting (Start/End time if continuous)	WP # (every time a sighting is made)	Observer	Sighting cue	Species	Dist/ Dir to Animal (from Observer)	Dist to Pile (btwn animal & pile)	# of Animals Group Size (min/max/best) # of Calves	Relative Motion/and Behavior Code (see code sheet)	Const Type During Sighting	Mitigation used during sighting?	Mitigation Type?	Visibility	% Glare	Weath Cond	Sea State and Wave Ht	Swell Dir	Behavior Change/ Response to Activity/Comments
		: : : :					m or km °	m or km	/ / ___ calves	opening closing parallel none	PRE POST SSV SSI V I PC DP ST NONE	Y N	DE SD	B P M G E			Light Mod Heavy	N or S W or E	
		: : : :					m or km °	m or km	/ / ___ calves	opening closing parallel none	PRE POST SSV SSI V I PC DP ST NONE	Y N	DE SD	B P M G E			Light Mod Heavy	N or S W or E	
		: : : :					m or km °	m or km	/ / ___ calves	opening closing parallel none	PRE POST SSV SSI V I PC DP ST NONE	Y N	DE SD	B P M G E			Light Mod Heavy	N or S W or E	
		: : : :					m or km °	m or km	/ / ___ calves	opening closing parallel none	PRE POST SSV SSI V I PC DP ST NONE	Y N	DE SD	B P M G E			Light Mod Heavy	N or S W or E	
		: : : :					m or km °	m or km	/ / ___ calves	opening closing parallel none	PRE POST SSV SSI V I PC DP ST NONE	Y N	DE SD	B P M G E			Light Mod Heavy	N or S W or E	
		: : : :					m or km °	m or km	/ / ___ calves	opening closing parallel none	PRE POST SSV SSI V I PC DP ST NONE	Y N	DE SD	B P M G E			Light Mod Heavy	N or S W or E	
		: : : :					m or km °	m or km	/ / ___ calves	opening closing parallel none	PRE POST SSV SSI V I PC DP ST NONE	Y N	DE SD	B P M G E				N or S W or E	

Sighting #=chronological number of sightings, if resight of same animal, then 1.1, 1.2, etc. WP (Waypoint)=GPS recording of lat/long, time/date stamp. Critical for vessel observers.

Sighting Codes (Sighting Cue & Behavior Codes)

Behavior codes

Code	Behavior	Definition
BR	Breaching	Leaps clear of water
CD	Change Direction	Suddenly changes direction of travel
CH	Chuff	Makes loud, forceful exhalation of air at surface
DI	Dive	Forward dives below surface
DE	Dead	Shows decomposition or is confirmed as dead by investigation
DS	Disorientation	An individual displaying multiple behaviors that have no clear direction or purpose
FI	Fight	Agonistic interactions between two or more individuals
FO	Foraging	Confirmed by food seen in mouth
MI	Milling	Moving slowly at surface, changing direction often, not moving in any particular direction
PL	Play	Behavior that does not seem to be directed towards a particular goal; may involve one, two or more individuals
PO	Porpoising	Moving rapidly with body breaking surface of water
SL	Slap	Vigorously slaps surface of water with body, flippers, tail etc.
SP	Spyhopping	Rises vertically in the water to "look" above the water
SW	Swimming	General progress in a direction. Note general direction of travel when last seen [Example: "SW (N)" for swimming north]
TR	Traveling	Traveling in an obvious direction. Note direction of travel when last seen [Example: "TR (N)" for traveling north]
UN	Unknown	Behavior of animal undetermined, does not fit into another behavior
Pinniped only		
EW	Enter Water (from haul out)	Enters water from a haul-out for no obvious reason
FL	Flush (from haul out)	Enters water in response to disturbance
HO	Haul out (from water)	Hauls out on land
RE	Resting	Resting onshore or on surface of water
LO	Look	Is upright in water "looking" in several directions or at a single focus
SI	Sink	Sinks out of sight below surface without obvious effort (usually from an upright position)
VO	Vocalizing	Animal emits barks, squeals, etc.
Cetacean only		
LG	Logging	Resting on surface of water with no obvious signs of movement

Marine Mammal Species

Code	Marine Mammal Species
CASL	California Sea Lion
HSEA	Harbor Seal
STSL	Steller Sea Lion
HPOR	Harbor Porpoise
DPOR	Dall's Porpoise
ORCA	Killer Whale
HUMP	Humpback Whale
UNLW	Unknown Large Whale
RIVO	River Otter (not a mammam)
OTHR	Other
UNKW	Unknown

Event

Code	Activity Type
E ON	Effort On
E OFF	Effort Off
PRE	Pre Watch
POST	Post Watch
SSV	Soft start-vibratory
SSI	Soft start-impact
WC	Weather Condition/Change
S	Sighting
M-DE	Mitigation Delay
M-SD	Mitigation Shutdown

Construction Type

Code	Activity Type
SSV	Soft Start (Vibratory)
SSI	Soft Start (Impact)
V	Vibratory Pile Driving (installation and extraction)
I	Impact Pile Driving
PC	Pneumatic Chipping
DP	Dead pull
ST	Stabbing
NONE	No Pile Driving

Mitigation Codes

Code	Activity Type
DE	Delay onset of Pile Driving
SD	Shut down Pile Driving

Visibility

Code	Distance Visible
B	Bad (<0.5km)
P	Poor (0.5 – 1.5km)
M	Moderate (1.5 – 10km)
G	Good (10 - 15km)
E	Excellent (>15km)

Glare

Percent glare should be total glare of observers' area of responsibility. Are they covering 90 degrees or 180 degrees? Total glare for that area and write that area down on the datasheet so we know later what percentage of the field of view was poor due to glare.

Weather Conditions

Code	Weather Condition
S	Sunny
PC	Partly Cloudy
L	Light Rain
R	Steady Rain
F	Fog
OC	Overcast

Sea State and Wave Height

Use Beaufort Sea State Scale for Sea State Code. This refers to the surface layer and whether it is glassy in appearance or full of white caps. In the open ocean, it also takes into account the wave height, but in inland waters the wave heights (swells) may never reach the levels that correspond to the correct surface white cap number. Therefore, include wave height for clarity.

Code	Wave Height
Light	0 – 3 ft
Moderate	4 – 6 ft
Heavy	>6 ft

Swell Direction

Swell direction should be where the swell is coming from (S for coming from the south). If possible, record direction relative to fixed location (pier). Choose this location at beginning of monitoring project.

APPENDIX B
BEAUFORT SEA STATE SCALE

APPENDIX B
BEAUFORT SEA STATE SCALE

US Navy and Beaufort Sea State Codes (<http://ioc.unesco.org> and <http://www.wrh.noaa.gov/pqr/info/beaufort.php>)

Beaufort SS	Wind speed (knots)	Wind description	Wave height (ft) Beaufort	Sea State – Beaufort	Notes specific to on-water seabird observations	Photos indicating Beaufort Sea State
0	<1	Calm	0	Calm; like a mirror	Excellent conditions, no wind, small or very smooth swell. You have the impression you could see anything.	 Force 0
1	1-3	Light air	¼ < ½	Ripples with appearance of scales; no foam crests	Very good conditions, surface could be glassy (Beaufort 0), but with some lumpy swell or reflection from forests, glare, etc.	 Force 1

Beaufort SS	Wind speed (knots)	Wind description	Wave height (ft) Beaufort	Sea State – Beaufort	Notes specific to on-water seabird observations	Photos indicating Beaufort Sea State
2	4-6	Light breeze	½ – 1 (max 1)	Small wavelets; crests with glassy appearance, not breaking	Good conditions, no whitecaps; texture/lighting contrast of water make murrelets hard to see. Surface could also be glassy or have small ripples, but with a short, lumpy swell, thick fog, etc.	
3	7-10	Gentle breeze	2 – 3 (max 3)	Large wavelets; crests begin to break; scattered whitecaps	Fair conditions, scattered whitecaps, detection of murrelets definitely compromised; a hit-or-miss chance of seeing them owing to water choppiness and high contrast. This could also occur at lesser wind with a very short wavelength, choppy swell.	

Beaufort SS	Wind speed (knots)	Wind description	Wave height (ft) Beaufort	Sea State – Beaufort	Notes specific to on-water seabird observations	Photos indicating Beaufort Sea State
4	11-16	Moderate breeze	3 ½ – 5 (max 5)	Small waves becoming longer, numerous whitecaps	Whitecaps abundant, sea chop bouncing the boat around, etc.	
5	17-20	Fresh breeze	6 – 8 (max 8)	Moderate waves, taking longer form; many whitecaps; some spray		

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APPENDIX C
CHAIN OF CUSTODY RECORD FORM



Chain of Custody Record				
Date and Time of Collection:	Duty Station:	Collection By:		
Source of Specimen (Person and/or Location) Found At:		Project Name:		
Item No:	Description of Specimen (include Species and Tag Number):			
Item No:	From: (Print Name, Agency)	Release Signature:	Release Date:	Delivered via: FEDEX U.S. Mail In Person Other:
	To: (Print Name, Agency)	Receipt Signature:	Receipt Date:	

*Appendix C
Wharf #1*

TRIDENT Support Facilities Explosives Handling

Item No:	From: (Print Name, Agency)	Release Signature:	Release Date:	Delivered via: FEDEX U.S. Mail In Person Other:
	To: (Print Name, Agency)	Receipt Signature:	Receipt Date:	
Item No:	From: (Print Name, Agency)	Release Signature:	Release Date:	Delivered via: FEDEX U.S. Mail In Person Other:
	To: (Print Name, Agency)	Receipt Signature:	Receipt Date:	
Item No:	From: (Print Name, Agency)	Release Signature:	Release Date:	Delivered via: FEDEX U.S. Mail In Person Other:
	To: (Print Name, Agency)	Receipt Signature:	Receipt Date:	
Item No:	From: (Print Name, Agency)	Release Signature:	Release Date:	Delivered via: FEDEX U.S. Mail In Person Other:
	To: (Print Name, Agency)	Receipt Signature:	Receipt Date:	
Item No:	From: (Print Name, Agency)	Release Signature:	Release Date:	Delivered via: FEDEX U.S. Mail In Person Other:
	To: (Print Name, Agency)	Receipt Signature:	Receipt Date:	

	To: (Print Name, Agency)	Receipt Signature:	Receipt Date:	
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