Appendix D. Cofferdam Installation and Removal Memorandum

8701 Georgia Avenue, Suite 410
Silver Spring, MD 20910 USA

Tel: +1-301-565-3500
www.jasco.com

Memo

DATE: 20 May 2022
FROM: Emma Ozanich and David Zeddies (JASCO Applied Sciences (USA) Inc.)
TO: Maria Hartnett (Epsilon)

Subject: Distance to regulatory thresholds and exposure estimation for vibratory pile driving of sheet piles

As part of the export cable landing, temporary cofferdams may be constructed at two locations using vibratory driving to install and remove steel sheet piles (see Figure 1). Vibratory pile driving produces non-impulsive sounds that may cause hearing damage or behavioral responses in marine mammals. The distances to potential injury and behavioral disruption of marine mammals are computed here by propagating measured source levels in the construction area and then comparing the resulting sound fields to regulatory thresholds. These distances are then used to estimate marine mammal takes that may occur as a result of the pile driving operations.

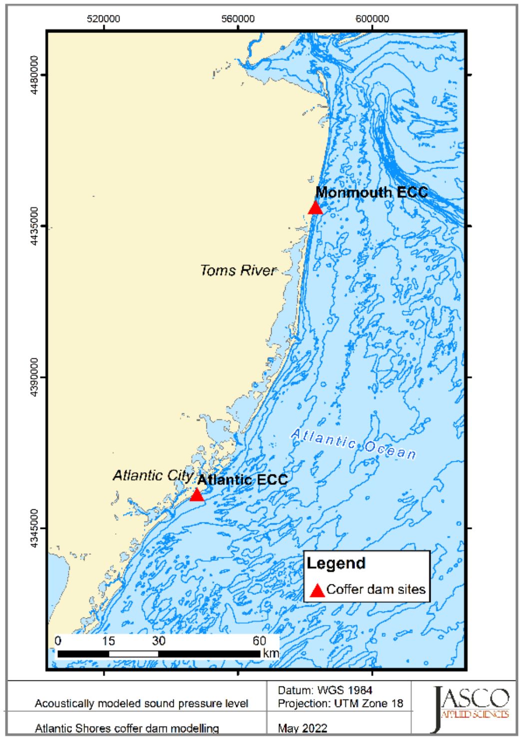

Figure 1. Proposed cofferdam locations (Atlantic ECC and Monmouth ECC). Acoustic modelling was conducted separately for each location

Evaluation Criteria

Injury to the hearing apparatus of a marine mammal may result from a fatiguing stimulus measured in terms of the sound exposure level (SEL), which considers the sound level and duration of the exposure signal. A permanent threshold shift (PTS) in hearing may be considered injurious but there are no published data on the sound levels that cause PTS in marine mammals. There are, however, data that indicate the received sound levels at which temporary threshold shifts (TTS) occurs, and PTS onset may be extrapolated from TTS onset level and an assumed growth function (Southall et al. 2007). In 2018, the National Oceanographic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) issued a Technical Guidance document (NMFS 2018) that incorporated the best available science to estimate PTS onset thresholds in marine mammals from sound energy, SEL, accumulated within 24 hrs. NMFS (2018) also provided guidance on the use of weighting functions to adjust the received sound levels according to the hearing sensitivity of the animals. Acoustic criteria and weighting function application are divided into functional hearing groups (low-, mid-, and high-frequency cetaceans and phocid pinnipeds) that species are assigned to based on their respective hearing frequency ranges. Hearing group frequency ranges that are used to define the auditory weighting function are shown in Table 1 and the hearing group thresholds are shown in Table 2.

Numerous studies on marine mammal behavioral responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioral reactions. NMFS currently uses behavioral response thresholds of 120 dB re 1 μPa for non-impulsive/continuous sounds for all marine mammal species (NMFS 2018), based on observations of mysticetes (Malme et al. 1983, 1984, Richardson et al. 1986, 1990).

Table 1 Marine mammal hearing groups and frequency ranges (Sills et al. 2014, NMFS 2018).

Faunal group	Generalized hearing range[a]
Low-frequency (LF) cetaceans (mysticetes or baleen whales)	7 Hz to 35 kHz
Mid-frequency (MF) cetaceans (odontocetes: delphinids, beaked whales)	150 Hz to 160 kHz
High-frequency (HF) cetaceans (other odontocetes)	275 Hz to 160 kHz
Phocid pinnipeds in water (PPW)	50 Hz to 86 kHz

[a] The generalized hearing range is for all species within a group. Individual hearing will vary.

Table 2 Summary of permanent threshold shift onset acoustic thresholds for marine mammals (NMFS 2018).

Faunal group	Non-impulsive signals: Frequency-weighted $L_{E,24h}$ (dB re 1 µPa²·s)
Low-frequency (LF) cetaceans	199
Mid-frequency (MF) cetaceans	198
High-frequency (HF) cetaceans	173
Phocid pinnipeds in water (PPW)	201

Source and Propagation modeling

Illingworth & Rodkin (2017) measured vibratory driving of four 12-in wide connected sheet piles (48 in/122 cm total width) using an APE Model 300 vibratory hammer (1842 kN centrifugal force). The sound exposure level (SEL) at 10 m from the pile was included in the frequency band 5–25,000 Hz. The Illingworth & Rodkin (2017) source spectrum of vibratory pile driving (Figure 2) was used here to define the source characteristics for acoustic propagation modeling.

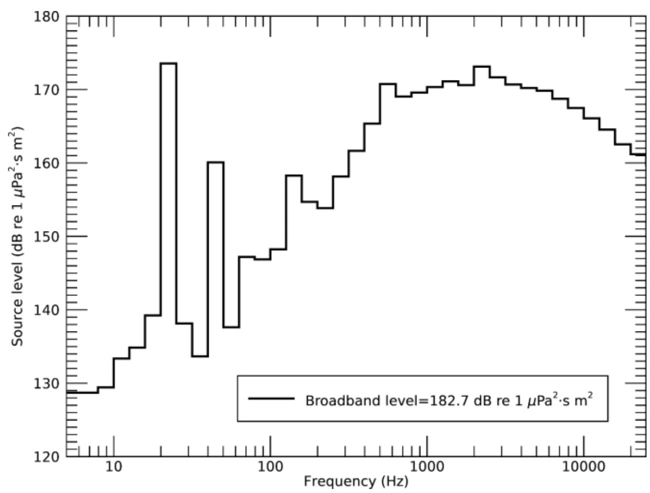

Figure 2. Decidecade-band spectral levels, at 10 m, for vibratory driving of sheet pile (Illingworth & Rodkin 2017).

JASCO's Marine Operations Noise Model (MONM) was used to predict SEL and SPL sound fields at a representative location near the proposed cofferdam sites considering the influence of bathymetry, seabed, water sound speed, and water attenuation. MONM uses a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). The sheet pile was represented as a point source at 2 m depth, and total sound energy transmission loss was computed at the center frequencies of decidecade bands as a function of range and depth from the source. The acoustic field in three dimensions was generated by modeling 2-D vertical planes radially spaced at 2.5° in a 360° swath around the source (N x 2-D). Composite broadband received SEL was computed by summing the received decidecade band levels across frequency and taking the maximum-over-depth. Major modeling assumptions are listed in Table 3.

Table 3 Major assumptions used in underwater acoustic modeling of vibratory driving of steel sheet piles.

Parameter	Value	Reference (if applicable)
Hammer	APE Model 300 (vibratory)	Illingworth & Rodkin (2017)
Pile type	Sheet pile	Illingworth & Rodkin (2017)
Bathymetry	NCEI Multibeam Bathymetry Database	National Center for Environmental Information (NCEI) (https://www.ngdc.noaa.gov/)
Sound speed	Mean seasonal profiles*	GDEM v-3.0
Geoacoustics	Medium sand	Ainslie (2010)

*Sound speed was converted to mean summer (June-August) and mean winter (December-February) profiles (NDBC(noaa.gov)).

Acoustic Ranges

The acoustic ranges to the SPL 120 dB re 1 µPa threshold (NMFS 2018), without frequency weighting, are summarized in Table 4 for the Atlantic and Monmouth locations. Assuming 8 hours of vibratory pile driving will occur in a 24-hour period, the frequency-weighted distances to potential injury for the marine mammal hearing groups are shown in Table 5.

The farthest range occurred where sound propagated offshore from the New Jersey coastline onto the continental shelf (Figure 3). Propagation extent and shoreline are determined by water depth at the time of measurement and may vary tidally and seasonally; however, this is not considered a significant contributor at the modeled locations.

Table 4. Distances to the unweighted SPL 120 dB re 1 µPa behavioral response threshold for summer and winter at both the Atlantic and Monmouth sites.

Season	Atlantic		Monmouth	
	R_{max} (m)	$R_{95\%}$ (m)	R_{max} (m)	$R_{95\%}$ (m)
Summer	5,490	5,076	5,834	5,412
Winter	8,260	7,546	12,960	11,268

Table 5. Distances to PTS onset for marine mammal hearing groups (NMFS 2018) exposed to non-impulsive sounds generated by vibratory driving of sheet piles assuming either summer or winter sound speed profiles.

Hearing group	Frequency-weighted $L_{E,24h}$ (dB re 1 µPa²·s)	Atlantic		Monmouth	
		R_{max} (m)	$R_{95\%}$ (m)	R_{max} (m)	$R_{95\%}$ (m)
Summer					
Low-frequency (LF) cetaceans	199	65	65	45	45
Mid-frequency (MF) cetaceans	198	0	0	0	0
High-frequency (HF) cetaceans	173	530	490	485	425
Phocid pinnipeds in water (PPW)	201	30	30	20	20
Winter					
Low-frequency (LF) cetaceans	199	70	65	60	60
Mid-frequency (MF) cetaceans	198	0	0	0	0
High-frequency (HF) cetaceans	173	585	540	545	450
Phocid pinnipeds in water (PPW)	201	30	30	20	20

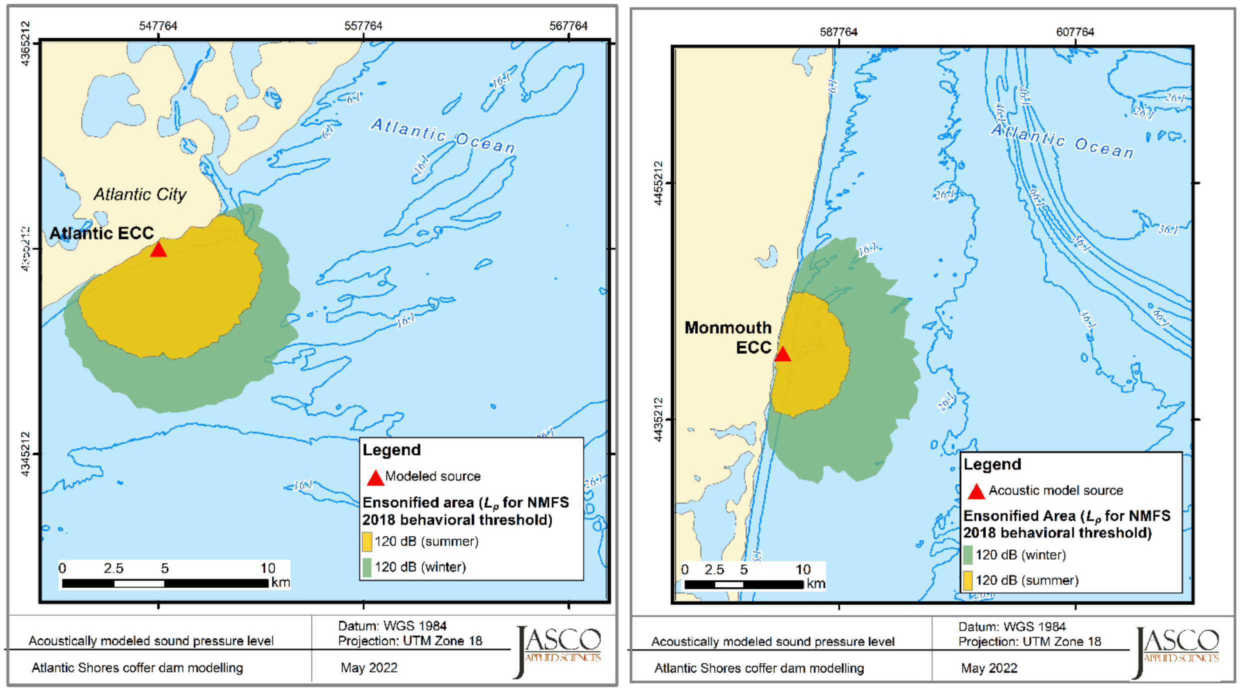

Figure 3. Modeled sound pressure level (SPL) at 120 dB re 1 μPa for two proposed cofferdam sites with sheet pile sources. The behavioral threshold for vibratory pile driving is SPL 120 dB re 1 μPa.

Exposure and Take Estimates for Marine Mammals

Exposure calculations assumed that impact from removal of cofferdam sheet piles would have the same impact as installation. It was assumed there would be 8 days of cofferdam installation and 8 days of removal at each of the two landing site locations (Atlantic and Monmouth), for a total of 16 days at each site. We assumed all four cofferdams would be installed and removed in Year 1. Construction will not occur during the summer months between Memorial Day and Labor Day each year, and exposures were estimated using the maximum animal density for the months from September to May, inclusive.

Density calculations

Marine mammal densities in the potential impact area were estimated using the Marine Geospatial Ecology Laboratory (MGEL)/Duke University Habitat-based Marine Mammal Density Models for the U.S. Atlantic (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b). Densities in the MGEL/Duke models are provided as the number of animals per 100 square kilometers (animals/100 km^2) and given for each 10 km x 10 km cell in the U.S. Atlantic for most species, with a cell size of 5 km x 5 km for the North Atlantic right whale (NARW).

To calculate marine mammal densities for the potential vibratory pile driving impact area, it was assumed that the surveys would occur in two areas of interest: the Atlantic export cable landing site and the Monmouth export cable landing site. The density buffers were determined using the longest 95th percentile acoustic range to threshold ($R_{95\%}$) at each location (see Tables 4 and 5; 7.546 km at the Atlantic site and 11.268 km at the Monmouth site). Monthly density was calculated for each area of interest and for each species as the average of the densities from all MGEL/Duke model grid cells that overlap partially or completely with each area of interest. Cells entirely on land were not included, but cells that overlap only partially with land were included.

There are two cases in this study wherein the MGEL/Duke model reports densities for species guilds, where the species were considered separately for exposure calculations: seals and pilot whales. In these cases, the densities were each scaled by their relative abundances. For example, the density for short-finned pilot whales is computed as:

$$d_{short-finned} = d_{both}\left(\frac{a_{short-finned}}{a_{short-finned} + a_{long-finned}}\right) \tag{1}$$

The maximum annual density was calculated over the possible construction months: September to May, inclusive. The resulting densities are included in Table 6.

Table 6. Maximum monthly density (animals per 100 km^2), estimated from September to May, at each of the two vibratory piling sites.

Species	Monmouth	Atlantic
Fin whale	0.073	0.046
Minke whale	0.014	0.009
Humpback whale	0.122	0.169
North Atlantic right whale	0.142	0.134
Sei whale	0.004	0.001
Atlantic spotted dolphin	0.016	0.004
Atlantic white-sided dolphin	0.133	0.065
Short-beaked common dolphin	1.797	0.657
Bottlenose dolphin, coastal	13.296	58.741
Bottlenose dolphin, offshore	0.000	0.000
Risso's dolphin	0.001	0.000
Long-finned pilot whale	0.003	0.001
Short-finned pilot whale	0.002	0.001
Sperm whale	0.004	0.001
Harbor porpoise	7.796	2.810
Gray seal	5.272	4.234
Harbor seal	11.845	9.513

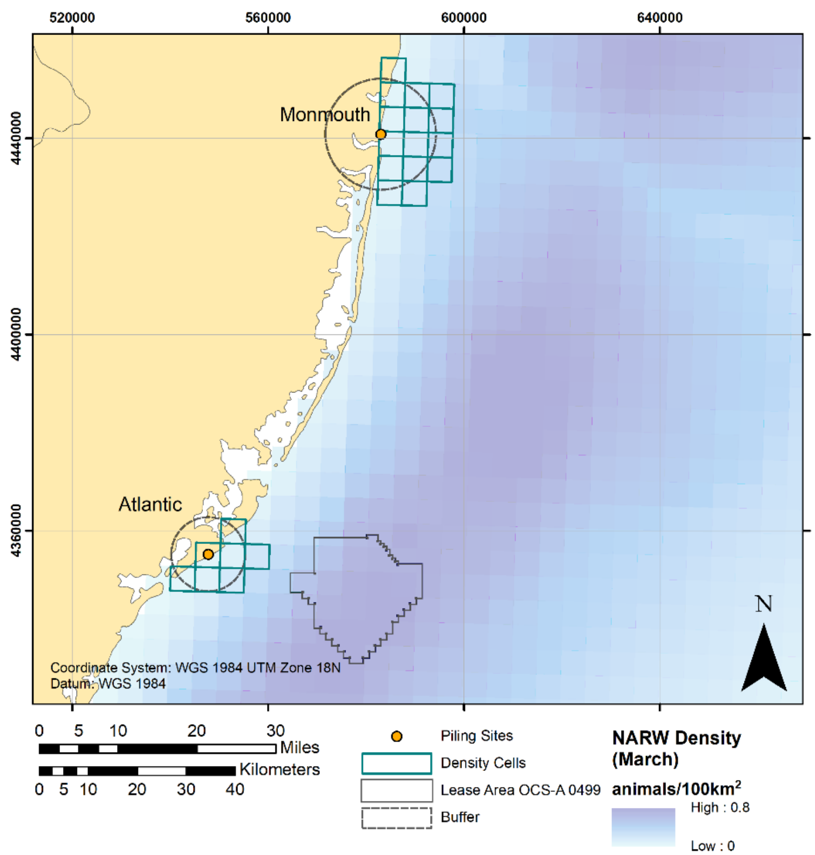

Figure 4. Marine mammal (e.g., NARW) density map showing highlighted grid cells used to calculate maximum seasonal species densities at each vibratory piling location (Roberts et al. 2016a, 2016b, 2017, 2018, 2021c, 2021b).

Exposure Estimation

The zone of influence (ZOI) is a representation of the maximum extent of the ensonified area around a sound source over a 24-hour period. The ZOI was calculated for each of the two locations (Atlantic and Monmouth), for each season, and for both Level A and Level B. The ZOI for stationary sources is a circle centered on the source location, with a radius equal to the acoustic range to threshold ($R_{95\%}$). Because the sources were located along the coastline, the ZOI area was partially on land. To correct for this, the ZOI was clipped by the coastline so that land areas were not included in the exposure calculation:

$$\mathrm{ZOI} = \pi r^2 - A_{land} \ , \tag{2}$$

where r is the acoustic range to threshold for the metric of interest and A_{land} is the portion of the circle that is over land. Exposures above Level A and B acoustic thresholds were estimated at each location and for all species using:

$$\mathrm{Exposures} = \mathrm{ZOI} \times (\mathrm{days}) \times \mathrm{density}\,, \tag{3}$$

where ZOI is defined in Equation 2, days = 16, and density is from Table 6, below. An annual maximum exposure was calculated, conservatively assuming that construction will occur during winter months only. The resulting maximum yearly exposures for all cofferdam installation and removal activities are provided in Table 7 for Level A and Table 8 for Level B.

Table 7. Maximum predicted Level A exposures resulting from cofferdam installation and removal at the Monmouth and Atlantic sites.

Species	Atlantic	Monmouth	Maximum Total Exposures
Fin whale	<0.01	<0.01	<0.01
Minke whale	<0.01	<0.01	<0.01
Humpback whale	<0.01	<0.01	<0.01
North Atlantic right whale	<0.01	<0.01	<0.01
Sei whale	<0.01	<0.01	<0.01
Atlantic spotted dolphin	0	0	0
Atlantic white-sided dolphin	0	0	0
Short-beaked common dolphin	0	0	0
Bottlenose dolphin, coastal	0	0	0
Bottlenose dolphin, offshore	0	0	0
Risso's dolphin	0	0	0
Long-finned pilot whale	0	0	0
Short-finned pilot whale	0	0	0
Sperm whale	0	0	0
Harbor porpoise	0.40	0.79	1.19
Gray seal	<0.01	<0.01	<0.01
Harbor seal	<0.01	<0.01	<0.01

Table 8. Maximum predicted Level B exposures resulting from cofferdam installation and removal at the Monmouth and Atlantic sites.

Species	Atlantic	Monmouth	Maximum Total Exposures
Fin whale	0.77	2.58	3.35
Minke whale	0.16	0.49	0.65
Humpback whale	2.81	4.32	7.14
North Atlantic right whale	2.23	5.02	7.26
Sei whale	0.01	0.16	0.17
Atlantic spotted dolphin	0.06	0.58	0.64
Atlantic white-sided dolphin	1.09	4.74	5.83
Short-beaked common dolphin	10.96	63.75	74.71
Bottlenose dolphin, coastal	980.53	471.78	1452.31
Bottlenose dolphin, offshore	0	0	0
Risso’s dolphin	<0.01	0.02	0.03
Long-finned pilot whale	0.02	0.10	0.13
Short-finned pilot whale	0.02	0.07	0.09
Sperm whale	0.02	0.14	0.15
Harbor porpoise	46.91	276.64	323.55
Gray seal	70.67	187.06	257.74
Harbor seal	158.79	420.28	579.07

Take Estimation

Maximum takes per project year were calculated for Level B. It is assumed that there will be no Level A takes because of mititgation, and the animals are not likely to remain in the area for the duration of time it would take to reach the SEL threshold. In cases where the predicted number of Level B exposures was less than the estimated group size for that species (Table 9), the number of takes was adjusted upward to equal the group size.

Table 9. Mean group size of modeled marine mammal species that could be present in the Atlantic Shores Project Area.

Species	Group Size
Fin whale	1.3
Minke whale	1.1
Humpback whale	1.8
North Atlantic right whale	3.8
Sei whale	2.1
Atlantic spotted dolphin	100
Atlantic white-sided dolphin	21.4
Short-beaked common dolphin	1.55
Bottlenose dolphin, coastal	13.1
Bottlenose dolphin, offshore	30
Risso’s dolphin	20
Long-finned pilot whale	6.0
Short-finned pilot whale	1.8
Sperm whale	1.8
Harbor porpoise	1.3
Gray seal	1.2
Harbor seal	1.3

Table 10. Maximum total Level B takes calculated for vibratory pile driving.

Species		Maximum total
LF	Fin whale[a]	4
	Minke whale[b]	2
	Humpback whale	8
	North Atlantic right whale[a, b]	8
	Sei whale[a, b]	3
MF	Atlantic spotted dolphin[b]	100
	Atlantic white-sided dolphin[b]	22
	Short-beaked common dolphin	75
	Bottlenose dolphin, coastal[b]	1453
	Bottlenose dolphin, offshore	0
	Risso's dolphin[b]	30
	Pilot whale, long-finned[b]	20
	Pilot whale, short-finned[b]	6
	Sperm whale[a,b]	2
HF	Harbor porpoise	324
PPW	Gray seal	258
	Harbor seal	580

[a] Listed as Endangered under the ESA.
[b] Adjusted to average group size.

Literature cited

[NMFS] National Marine Fisheries Service (US). 2018. *2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. US Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59. 167 p. https://www.fisheries.noaa.gov/webdam/download/75962998.

[NOAA] National Oceanic and Atmopsheric Administration National Centers for Environmental Information. 2004: Multibeam Bathymetry Database (MBBDB). NOS Hydrographic surveys. NOAA National Centers for Environmental Information. https://doi.org/doi:10.7289/V56T0JNC. Accessed May 5, 2022.

Ainslie, M.A. 2010. *Principles of Sonar Performance Modelling*. Praxis Books. Springer, Berlin. https://doi.org/10.1007/978-3-540-87662-5.

Carnes, M.R. 2009. Description and Evaluation of GDEM-V 3.0. Document Number NRL Memorandum Report 7330-09-9165. US Naval Research Laboratory, Stennis Space Center, MS. 21 pp.

Collins, M.D. 1993. A split-step Padé solution for the parabolic equation method. *Journal of the Acoustical Society of America* 93(4): 1736-1742. https://doi.org/10.1121/1.406739.

Illingworth & Rodkin, Inc. 2017. *Pile-Driving Noise Measurments at Atlantic Fleet Naval Installations: 28 May 2013-28 April 2016*. Report by Illingworth & Rodkin, Inc. under contract with HDR Environtmental for NAVFAC. 152 p. https://www.navymarinespeciesmonitoring.us/files/4814/9089/8563/Pile-driving_Noise_Measurements_Final_Report_12Jan2017.pdf.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. Tyack, and J.E. Bird. 1983. *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior. Final Report for the Period of 7 June 1982 - 31 July 1983*. Report Number 5366. Report by Bolt Beranek and Newman Inc. for US Department of the Interior, Minerals Management Service, Alaska OCS Office, Cambridge, MA, USA. https://www.boem.gov/sites/default/files/boem-newsroom/Library/Publications/1983/rpt5366.pdf.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. Tyack, and J.E. Bird. 1984. *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior. Phase II: January 1984 Migration*. Report Number 5586. Report by Bolt Beranek and Newman Inc. for the US Department of the Interior, Minerals Management Service, Cambridge, MA, USA. https://www.boem.gov/sites/default/files/boem-newsroom/Library/Publications/1983/rpt5586.pdf.

Richardson, W.J., B. Würsig, and C.R. Greene, Jr. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. *Journal of the Acoustical Society of America* 79(4): 1117-1128. https://doi.org/10.1121/1.393384.

Richardson, W.J., B. Würsig, and C.R. Greene, Jr. 1990. Reactions of bowhead whales, *Balaena mysticetus*, to drilling and dredging noise in the Canadian Beaufort Sea. *Marine Environmental Research* 29(2): 135-160. https://doi.org/10.1016/0141-1136(90)90032-J.

Teague, W.J., M.J. Carron, and P.J. Hogan. 1990. A comparison between the Generalized Digital Environmental Model and Levitus climatologies. Journal of Geophysical Research 95(C5): 7167-7183.

Sills, J.M., B.L. Southall, and C. Reichmuth. 2014. Amphibious hearing in spotted seals (*Phoca largha*): Underwater audiograms, aerial audiograms and critical ratio measurements. *Journal of Experimental Biology* 217(5): 726-734. https://doi.org/10.1242/jeb.097469.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, et al. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals* 33(4): 411-521. https://doi.org/10.1578/AM.33.4.2007.411.

Zhang, Z.Y. and C.T. Tindle. 1995. Improved equivalent fluid approximations for a low shear speed ocean bottom. *Journal of the Acoustical Society of America* 98(6): 3391-3396. https://doi.org/10.1121/1.413789.