East Tongue Point Fast Response Cutter Homeport Project

Acoustic Assessment

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ACRONYMS AND ABBREVIATIONS

dB	decibel
dB re 1 μPa	decibels referenced at one micropascal
dB re 1 $\mu Pa^2 \cdot s$	decibels referenced at one squared micropascal-second
dB/km	decibels per kilometer
ETP	East Tongue Point
HF	high-frequency
Hz	Hertz
kHz	kilohertz
km	kilometers
LF	low-frequency
L_{PK}	peak sound pressure
m	meter
m/s	meters per second
MF	mid-frequency
MMPA	Marine Mammal Protection Act
MWD	Maintenance and Weapons Division
NOAA Fisheries	National Oceanic and Atmospheric Administration's National Marine Fisheries Service
OHWM	ordinary high water mark
Project	Fast Cutter Response Homeport
PTS	permanent threshold shift
RMS	root-mean-square
SEL	sound exposure level
SEL_{cum}	cumulative sound exposure level
SPL	sound pressure level
SPL RMS	sounds pressure level root mean square
TSHD	Trailer Suction Hopper Dredger
TTS	temporary threshold shift
U.S.	United States
USFWS	United States Fish and Wildlife Service
USCG	United States Coast Guard
μPa	micropascal
λ	wavelength

A.1 INTRODUCTION

The U.S. Coast Guard (USCG) intends to construct the Fast Cutter Response Homeport Project (Project) to homeport two 154-foot Fast Response Cutters (FRCs) in Tongue Point Job Corps Center in Astoria, Oregon. The existing Pier 6 will be removed and a new 320-foot by 60-foot, pile-supported pier with 200 feet by 15 feet of floating dock on each side will be constructed. The Project will require dredging of approximately 90,000 cubic yards to provide a depth of 18 feet below mean lower low water plus 2 feet over-depth. The proposed dredging area is approximately 1,380 feet by 250 feet. In addition, the landside-side improvements involve the demolition of existing facilities, construction of a new 21,000 square feet, single-story Maintenance and Weapons Division (MWD) building, and associated utility work.

The Project site is located within the Tongue Point Job Corps Center on Tongue Point along the Columbia River in Astoria, Oregon (Figure 1). Tongue Point is located approximately 4 miles upstream from downtown Astoria, at approximately Columbia RM 18, within Clatsop County, Oregon.

This acoustic assessment report includes an analysis of both the in-air and underwater acoustic impacts associated with the waterside and landside construction and operations of the Project. In-air acoustic impacts associated with the Project that have been assessed include pile driving during waterside construction and phased construction activities during landside improvements. Underwater acoustic impacts were also evaluated for pile driving and dredging activities, which have the potential to cause acoustic harassment to marine species. Relevant regulatory criteria are presented as well as acoustic modeling inputs and methodologies. The objectives of this modeling study are the following:

1. Predict ranges to in-air acoustic thresholds for harbor seals and other pinnipeds; and
2. Predict the ranges to acoustic thresholds that could result in injury (Level A Take) or behavioral disruption (Level B Take) of marine mammals, sea turtles, and fish during construction and operations of the Project.

Those ranges were determined and are presented both in tabular format and graphically in the form of sound contour figures.

U.S. Coast Guard FRC Homeporting Project

Astoria, OR

Background: NAIP 2016
Coordinate System: NAD 1983 Oregon State Plane North
Date Created: 8/19/2020

Figure 1: Project Location Vicinity

A.1.1 Acoustic Concepts and Terminology

A.1.1.1 In-air Acoustics

All sounds originate with a source, such as motor vehicles on a roadway or lawn mowers. Energy is required to produce sound and this sound energy is transmitted through the air in the form of sound waves—tiny, quick oscillations of pressure just above and just below atmospheric pressure. These oscillations, or sound pressures, impinge on the ear, creating the sound we hear. A sound source is defined by a sound power level (abbreviated "L_W"), which is independent of any external factors. By definition, sound power is the rate at which acoustical energy is radiated outward and is expressed in units of watts.

A source sound power level cannot be measured directly. It is calculated from measurements of sound intensity or sound pressure at a given distance from the source outside the acoustic and geometric near-field. A sound pressure level (abbreviated "L_P") is a measure of the sound wave fluctuation at a given receiver location and can be obtained through the use of a microphone or calculated from information about the source sound power level and the surrounding environment. The sound pressure level in decibels (dB) is the logarithm of the ratio of the sound pressure of the source to the reference sound pressure of 20 microPascals (μPa), multiplied by 20. The range of sound pressures that can be detected by a person with normal hearing is very wide, ranging from about 0 decibels on the A-weighted scale (dBA) (or 20 μPa) for very faint sounds at the threshold of hearing, to nearly 120 dBA (or 20 million μPa) for extremely loud sounds such as a jet during takeoff at a distance of 200 feet.

Broadband sound includes sound energy summed across the entire audible frequency spectrum. In addition to broadband sound pressure levels, analysis of the various frequency components of the sound spectrum can be completed to determine tonal characteristics. The unit of frequency is Hertz (Hz), measuring the cycles per second of the sound pressure waves. Typically, the frequency analysis examines 11 octave bands ranging from 16 Hz (low) to 16,000 Hz (high). Because the human ear does not perceive every frequency with equal loudness, spectrally varying sounds are often adjusted with a weighting filter. The A-weighted filter is applied to compensate for the frequency response of the human auditory system and is represented in dBA.

Sound levels can be measured, modeled and presented in various formats. The sound metrics that were employed in the following noise assessment have the following definitions:

- L_{eq}: Conventionally expressed in dBA, the L_{eq} is the energy-averaged, A-weighted sound level for the complete time period. It is defined as the steady, continuous sound level over a specified time, which has the same total sound energy as the actual varying sound levels over the specified period;

- L_n: This descriptor identifies the sound level that is exceeded "n" percent of the time over a measurement period (e.g., L_{90} = sound level exceeded 90 percent of the time). The sound level exceeded for a small percent of the time, L_{10}, closely corresponds to short-term, higher-level, intrusive noises (such as vehicle pass-by noise near a roadway). The sound level exceeded for a large percent of the time, L_{90}, closely corresponds to continuous, lower-level background noise (such as continuous noise from a distant industrial facility). L_{50} is the level exceeded 50 percent of the time and is typically referred to the median sound level over a given period;

- L_{max}: The maximum sound level (L_{max}) can be used to quantify the maximum instantaneous sound pressure level over a given measurement period or maximum sound generated by a source.

Table 1 presents estimates of noise sources and outdoor acoustic environments, and the comparison of relative loudness. Table 2 presents additional reference information on terminology used in the report.

Table 1. Sound Pressure Levels and Relative Loudness of Typical Noise Sources and Soundscapes

<table>
<tr><th>Noise Source or Acoustic Environment</th><th>Sound Level (dBA)</th><th>Subjective Impression</th></tr>
<tr><td>Garbage disposal, food blender (2 feet), or Pneumatic drill (50 feet)</td><td>80</td><td>Loud</td></tr>
<tr><td>Vacuum cleaner (10 feet)</td><td>70</td><td rowspan="3">Moderate</td></tr>
<tr><td>Passenger car at 65 mph (25 feet)</td><td>65</td></tr>
<tr><td>Large store air-conditioning unit (20 feet)</td><td>60</td></tr>
<tr><td>Light auto traffic (100 feet)</td><td>50</td><td rowspan="2">Quiet</td></tr>
<tr><td>Quiet rural residential area with no activity</td><td>45</td></tr>
<tr><td>Bedroom or quiet living room or Bird calls</td><td>40</td><td rowspan="2">Faint</td></tr>
<tr><td>Typical wilderness area</td><td>35</td></tr>
<tr><td>Quiet library, soft whisper (15 feet)</td><td>30</td><td>Very quiet</td></tr>
<tr><td>Wilderness with no wind or animal activity</td><td>25</td><td rowspan="2">Extremely quiet</td></tr>
<tr><td>High-quality recording studio</td><td>20</td></tr>
<tr><td>Acoustic test chamber</td><td>10</td><td>Just audible</td></tr>
<tr><td></td><td>0</td><td>Threshold of hearing</td></tr>
</table>

Table 2. Acoustic Terms and Definitions

Term	Definition
Noise	Typically defined as unwanted sound. This word adds the subjective response of humans to the physical phenomenon of sound. It is commonly used when negative effects on people are known to occur.
Sound Pressure Level (L_P)	Pressure fluctuations in a medium. Sound pressure is measured in decibels referenced to 20 microPascals, the approximate threshold of human perception to sound at 1,000 Hz.
Sound Power Level (L_W)	The total acoustic power of a noise source measured in decibels referenced to picowatts (one trillionth of a watt). Noise specifications are provided by equipment manufacturers as sound power as it is independent of the environment in which it is located. A sound level meter does not directly measure sound power.
Equivalent Sound Level (L_{eq})	The L_{eq} is the continuous equivalent sound level, defined as the single sound pressure level that, if constant over the stated measurement period, would contain the same sound energy as the actual monitored sound that is fluctuating in level over the measurement period.
A-Weighted Decibel (dBA)	Environmental sound is typically composed of acoustic energy across all frequencies. To compensate for the auditory frequency response of the human ear, an A-weighting filter is commonly used for describing environmental sound levels. Sound levels that are A-weighted are presented as dBA in this report.
Unweighted Decibels (dBL)	Unweighted sound levels are referred to as linear. Linear decibels are used to determine a sound's tonality and to engineer solutions to reduce or control noise as techniques are different for low and high frequency noise. Sound levels that are linear are presented as dBL in this report.

Table 2. Acoustic Terms and Definitions

Term	Definition
Propagation and Attenuation	Propagation is the decrease in amplitude of an acoustic signal due to geometric spreading losses with increased distance from the source. Additional sound attenuation factors include air absorption, terrain effects, sound interaction with the ground, diffraction of sound around objects and topographical features, foliage, and meteorological conditions including wind velocity, temperature, humidity, and atmospheric conditions.
Octave Bands	The audible range of humans spans from 20 to 20,000 Hz and is typically divided into center frequencies ranging from 31 to 8,000 Hz.
Broadband Noise	Noise which covers a wide range of frequencies within the audible spectrum, i.e., 200 to 2,000 Hz.
Frequency (Hz)	The rate of oscillation of a sound, measured in units of Hz or kilohertz (kHz). For example, 100 Hz is a rate of one hundred times (or cycles) per second. The frequency of a sound is the property perceived as pitch: a low-frequency sound (such as a bass note) oscillates at a relatively slow rate, and a high-frequency sound (such as a treble note) oscillates at a relatively high rate. For comparative purposes, the lowest note on a full range piano is approximately 32 Hz and middle C is 261 Hz.

A.1.1.2 Underwater Acoustics

This section outlines some of the relevant concepts in acoustics to help the non-specialist reader best understand the modeling assessment and results presented in this report. Sound is the result of mechanical vibrations traveling through a fluid medium such as air or water. These vibrations constitute waves that generate a time-varying pressure disturbance oscillating above and below the ambient pressure.

It is important to note that underwater sound levels are not equivalent to in-air sound levels, with which most readers would be more familiar. An underwater sound pressure level (SPL or L_p) of 150 decibels (dB) referenced to 1 micropascal (re 1 µPa) is not equivalent to an in-air sound pressure level of 150 dB re 20 µPa due to the differences in density and speed of sound between water and air, and the different reference pressures that are used to calculate the dB levels, i.e., 1 µPa for water and 20 µPa for air. Underwater sound levels can be presented either as overall broadband levels or as frequency-dependent levels showing the frequency content of a source. Broadband values present the total sound pressure level of a given sound source within a specified frequency bandwidth. Sometimes it is preferable to use frequency-dependent sound levels to characterize spectral content of a sound source and/or identify narrowband sources such as one-third octave band levels, which are one-third of an octave wide, wherein octave refers to a factor 2 increase in sound frequency.

The sound level estimates presented in this modeling study are expressed in terms of several metrics and apply the use of exposure durations to allow for interpretation relative to potential biological impacts on marine life. The National Oceanic and Atmospheric Administration National Marine Fisheries Service ("NOAA Fisheries") issued a Technical Guidance that provides acoustical thresholds and defines the threshold metrics (NOAA Fisheries 2018). The ISO 18405 Underwater Acoustics – Terminology (ISO 2017) provided a dictionary of underwater bioacoustics for standardized terminology. Table Error! **No text of specified style in document.**-1 provides a summary of the relevant metrics from both NOAA Fisheries (2018) and ISO (2017) that are used within this report.

Table Error! No text of specified style in document.**-1. Summary of Acoustic Terminology**

Metric	NOAA Fisheries (2018)	ISO (2017)		Reference Value
		Main Text	Equations and Tables	
Sound Pressure Level	SPL	SPL	L_p	dB re 1 μPa
Peak Sound Pressure Level	PK	Lpk	$L_{p,pk}$	dB re 1 μPa
Cumulative Sound Exposure Level	SEL_{cum} [1]	SEL	L_E	dB re 1 μPa²·s

Note:
1 NOAA Fisheries (2018) describes the cumulative sound exposure level ("SEL_{cum}") metric over an accumulation period of 24-hour period. Following the ISO standard, this will be identified as SEL in the text and LE will be used in tables and equations of this report with the accumulation period identified.

This report follows the ISO (2017) standard terminology and symbols for the sound metrics unless stated otherwise. Below are descriptions of the relevant metrics and concepts that should help frame the discussion of acoustics in this document. The majority of the information in the following sections provides further insight into how data and modeling results have been presented in accordance with regulatory reporting requirements and established criteria.

Peak sound pressure (Lpk or $L_{p,pk}$; dB re 1 μPa) is the maximum instantaneous noise level over a given event and is calculated using the level of the squared sound pressure from zero-to-peak within the wave. The peak sound pressure level is commonly used as a descriptor for impulsive sound sources. At high intensities, the Lpk can be a valid criterion for assessing whether a sound is potentially injurious; however, since it does not take into account the pulse duration or bandwidth of a signal, it is not a good indicator of loudness or potential for masking effects. The Lpk can be calculated using the formula below. Impulses are characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a decay period that may include a period of diminishing, oscillating maximal and minimal pressures.

$$L_{p,pk} = 10\,log_{10}\left[\frac{max(|p^2(t)|)}{p_0^2}\right]\;dB \quad (1)$$

Sound pressure level ("SPL or L_p"; dB re 1 μPa) is the root-mean-square (rms) sound pressure level in a stated frequency band over a specified time window. It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure. The SPL is calculated by taking the square root of the average of the square of the pressure waveform over the duration of the time period. The SPL is also known as the quadratic mean and is a statistical measure of the magnitude of a varying quantity. Given a measurement of the time-varying sound pressure from a given sound source, the SPL is computed according to the following formula where p^2 is the mean squared sound pressure and p_0^2 is the reference value of mean-square sound pressure, which is 1 μPa².

$$L_p = 10\,log_{10}\left(\frac{1}{T}\int_T p^2(t)dt/p_0^2\right)\;dB \quad (2)$$

Sound exposure level ("SEL or L_E"; dB re 1 μPa²·s) is similar to the SPL but further specifies the sound pressure over a specified time interval or event, for a specified frequency range. The SEL for a single event is calculated by taking the time-integral of the squared sound pressure, E_p, over the full event duration:

$$L_E = 10\,log_{10}\left(\int_{T_{100}} p^2(t)dt/T_0 p_0^2\right)\;dB \quad (3)$$

The SEL represents the total acoustic energy received at a given location. Unless otherwise stated, SELs for impulsive noise sources presented in this report, i.e., impact hammer pile-driving, refer to a single pulse. In addition, SEL can be calculated as a cumulative metric over periods with multiple acoustic events. In the case of impulsive sources like impact piling, SEL describes the summation of energy for the entire impulse normalized to 1 second and can be expanded to represent the summation of energy from multiple pulses. The latter is written SEL_{cum} denoting that it represents the cumulative sound exposure level. Sound exposure level is often used in the assessment of marine mammal and fish injury/physiological impacts over a 24-hour time period. The SEL_{cum} (dB re 1 μPa²·s) can be computed by summing (in linear units) the SEL of N individual events:

$$L_{E,N} = 10\, log_{10}\left(\sum_{i=1}^{N} 10^{\frac{\mathrm{SEL}_i}{10}}\right)\ dB \tag{4}$$

A.1.1.3 Sound Propagation in Shallow Waters

Seawater Absorption

Absorption in the underwater environment involves the process of converting acoustic energy into heat which represents the true loss of acoustic energy to the water. The primary causes of absorption have been attributed to several processes, including viscosity, thermal conductivity, and chemical reactions involving ions in the seawater. The absorption of sound energy by water contributes to the attenuation (or reduction) in sound linearly with range and is given by an attenuation coefficient in units of decibels per kilometer (dB/km). This absorption coefficient is computed from empirical equations and increases with the square of frequency. For example, for typical open-ocean values (temperature of 10° Celsius, pH of 8.0, and a salinity of 35 practical salinity units), the equations presented by Francois and Garrison (1982a and 1982b) yield the following values for seawater absorption: 0.001 dB/km at 100 Hz, 0.06 dB/km at 1 kHz, 0.96 dB/km at 10 kHz, and 33.6 dB/km at 100 kHz. Thus, low frequencies are favored for long-range propagation. Seawater absorption was accounted for in the acoustic modeling according to the Fisher and Simmons (1977) calculation methodology. Site-specific sound speed profile information was input, resulting in a site-specific sound attenuation rate per kilometer.

Scattering and Reflection

Scattering of sound, from the surface and bottom boundaries and from other objects, is important in characterizing and understanding the received sound field. Reflection, refraction, and diffraction from gas bubbles and other inhomogeneities in the propagating medium serve to scatter sound and affect propagation loss. If boundaries are present, whether they are “real” like the surface of the sea or “internal” like changes in the physical characteristics of the water, they affect sound propagation. The acoustic intensity received depends on the losses due to the path length as well as the amount of energy reflected from each interface. Multiple reflections may occur as the sound reflects alternately from the bottom and the sea surface resulting in constructive and/or destructive interference patterns. Reflections occurring between the sea floor and surface are accounted for in this acoustic modeling analysis. The model is described further in Section A.4.2. Two solvers were used to calculate underwater received sound levels. The parabolic equation solver extends to three times the depth of the water column. For the ray-tracing solver, a complex reflection coefficient was calculated based on frequency, incidence angle, and sediment layers.

Changes in direction of the sound due to changes of sound velocity are known as refraction. The speed of sound depends on water temperature, pressure, and salinity. Of the three factors, the largest impact on sound velocity is temperature. The change in the direction of the sound wave, with changes in velocity, can produce many complex sound paths. When there is a negative temperature gradient, sound speed decreases with depth and sound rays bend sharply downward. This condition is common near the surface of the sea. A shadow zone, the horizontal distance from the sound source beyond where the rays bend downward, is a region in which sound intensity is negligible. The shadow zone may also produce sound channels that can trap the sound and allow a signal to travel great distances with minimal loss in energy. These underwater channels, known as the Sound Fixing and Ranging channel or deep sound channel, allows marine mammal communications to travel great distances.

Interaction with bathymetry and the subsurface seafloor properties significantly affect sound propagation. The sound signal is also influenced differently depending on its frequency characteristics. For variable bathymetries, the calculation complexity increases as individual portions of the signal are scattered differently. However, if the acoustic wavelength is much greater than the scale of the seabed non-uniformities, as is most often the case for low-frequency sounds, then the effect of scattering on propagation loss becomes somewhat less important than other factors. Also, scattering loss occurring at the surface due to wave action will increase at higher sea states. For reflection from the sea-surface, it is assumed that the surface is smooth. While a rough sea surface would increase scattering (and hence transmission loss) at higher frequencies, the scale of surface roughness is insufficient to have a significant effect on sound propagation in the near-field relative to the source.

Seabed Absorption

Seabed sediment characteristics influence propagation loss in shallow water due to the repeated reflections and scattering at the water/seafloor interface. For underwater acoustic analysis, shallow water is typically defined as water depths less than 200 meters (m). Depending on the sediment properties, sound may be absorbed or reflected. For example, fine-grained silt and clay absorb sound efficiently, while sand, gravel, and bedrock are more reflective. To model these effects, the most important parameters to consider are the sediment density, sound speed, and acoustic attenuation.

The acoustic properties of different sediment types display a much greater range of variation than the acoustic properties of seawater. A good understanding of these properties and their spatial variation is useful for accurate modeling. Oftentimes it is challenging to obtain site-specific data characterizing the seafloor; however, geotechnical reports were available and reviewed for the offshore Project Area and expected geophysical parameters of the seabed were incorporated into the modeling analysis up to a depth of 50 m below the survey of the seabed. The geoacoustic parameters of the seabed materials, including but not limited to compressional speed, density, attenuation rates, and shear speed, were assigned using the empirical model based on measurements developed by Hamilton over many years; this method has been widely used for practical modeling purposes (Farcas et al. 2016). Further details pertaining to sediment characteristics are given in Section A.4.3.2.

Cut-off Frequency

Sound propagation in shallow water (i.e., less than 200 m) is essentially a normal mode where a sound wave moves sinusoidally and has its own frequency and the sound channel is an acoustic waveguide. Each mode is a standing wave in the vertical direction that propagates in the horizontal direction at a frequency-dependent speed. Each mode has a cut-off frequency, below which no sound propagation is possible. The cut-off frequency is determined based on the type of bottom material and water column depth. This limiting frequency (f_c) can also be calculated if the speed of sound in the sediment ($C_{sediment}$) is known (Au and Hastings 2008) and seasonal temperature variation of the speed of sound of the seawater (C_{water}) is known using the following equation:

$$f_c = \frac{C_{water}}{4h} / \sqrt{1 - (C_{water})^2/(C_{sediment})^2} \qquad (8)$$

Where: f_c = critical frequency
C_{water} = speed of sound of water
$C_{sediment}$ = speed of sound in sediment
h = water depth in the direction of sound propagation

The speed of sound in sediment is higher than in water. In water, it is approximated at 1,500 meters per second (m/s). Values for speed of sound in sediment will range from 1,605 m/s in sand-silt sediment to 1,750 m/s in predominantly sandy areas. In addition, the equation for critical frequency indicates that, as water column depth increases, the cut-off frequency and corresponding sound attenuation rate will decrease

Figure 2 graphically presents the cut-off frequency for different bottom material types (represented as separate lines on the figure) plotted as a function of water depth (x-axis) and cut-off frequency (y-axis). As shown, at an approximate water depth of 42 m and a seabed consisting of predominantly sand, which represents the deeper region of the Lease Area, the cut-off frequency would be expected to occur at approximately 0.03 kHz. Greater low-frequency attenuation rates would occur at shallower locations within the Lease Area. For the Project acoustic modeling analysis, the concept of cut-off frequency is incorporated into the modeling calculations through the characterization of sediment properties within the seabed.

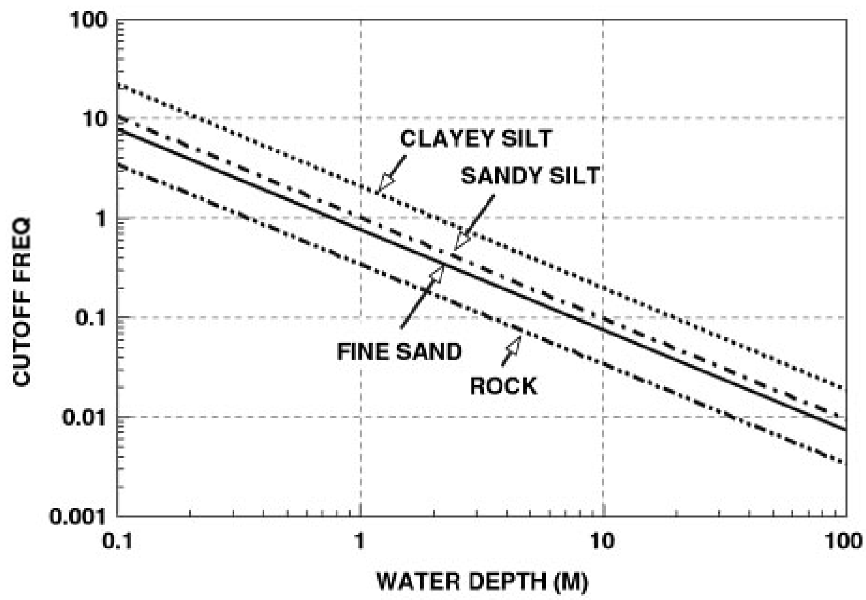


Figure 2 Cut-off Frequencies for Different Bottom Materials (AU and Hastings 2008)

A.2 REGULATORY CRITERIA AND SCIENTIFIC GUIDELINES

A.2.1 In-air Acoustic Criteria

There are no in-air regulations at the local, state, or federal level that are applicable to the Project. However, noise thresholds for the behavioral disturbance of harbor seals at 90 dB rms and all other pinnipeds at 100 dB rms have been identified by NOAA Fisheries and those thresholds are considered in this analysis.

A.2.2 Underwater Acoustic Criteria

The Marine Mammal Protection Act (MMPA) of 1972 provides for the protection of all marine mammals. The MMPA prohibits, with certain exceptions, the “take” of marine mammals. The term “take,” as defined pursuant to the MMPA (16 United States [U.S.] Code section 1362 [13]), means “to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.” NOAA Fisheries has jurisdiction for overseeing the MMPA regulations as they pertain to most marine mammals and is responsible for issuing take permits under MMPA, upon a request, for authorization of incidental but not intentional “taking” of small numbers of marine mammals by U.S. citizens or agencies who engage in a specified activity (other than commercial fishing) within a specified geographical region. USFWS issues take permits for manatees but criteria evaluating potential acoustic impacts to manatees has not yet been developed by the agency. “Harassment” was further defined in the 1994 amendments to the MMPA, with the designation of two levels of harassment: Level A and Level B. By definition, Level A harassment is any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock, while Level B harassment is any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering. NOAA Fisheries defines the threshold level for Level B harassment at 160 dB SPL re 1μPa for impulsive sound, averaged over the duration of the signal and at 120 dB re 1μPa for non-impulsive sound, with no relevant acceptable distance specified.

NOAA Fisheries provided guidance for assessing the impacts of anthropogenic sound on marine mammals under their regulatory jurisdiction, which includes whales, dolphins, porpoises, seals, and sea lions, which was updated in 2018 (NOAA Fisheries 2018). The guidance specifically defines marine mammal hearing groups, develops auditory weighting functions, and identifies the received levels, or acoustic threshold levels, above which individual marine mammals are predicted to experience changes in their hearing sensitivity (permanent threshold shift [PTS] or temporary threshold shift [TTS]) for acute, incidental exposure to underwater sound. Under this guidance, any occurrence of PTS constitutes a Level A, or injury, take. The sound emitted by man-made sources may induce TTS or PTS in an animal in two ways: (1) peak sound pressure levels (L_{PK}) may cause damage to the inner ear, and (2) the accumulated sound energy the animal is exposed to (SEL_{cum}) over the entire duration of a discrete or repeated noise exposure has the potential to induce auditory damage if it exceeds the relevant threshold levels.

Research showed that the frequency content of the sound would play a role in causing damage. Sound outside the hearing range of the animal would be unlikely to affect its hearing, while the sound energy within the hearing range could be harmful. Under the NOAA Fisheries (2018) guidance, recognizing that marine mammal species do not have equal hearing capabilities, five hearing groups of marine mammals are defined as follows:

- *Low-frequency (LF) Cetaceans*—this group consists of the baleen whales (mysticetes) with a collective generalized hearing range of 7 Hz to 35 kHz.
- *Mid-frequency (MF) Cetaceans*—includes most of the dolphins, all toothed whales except for Kogia spp., and all the beaked and bottlenose whales with a generalized hearing range of approximately 150 Hz to 160 kHz (renamed High-frequency cetaceans by Southall et al. (2019) because their best hearing sensitivity occurs at frequencies of several tens of kHz or higher).
- *High-frequency (HF) Cetaceans*—incorporates all the true porpoises, the river dolphins, plus Kogia spp., Cephalorhynchid spp. (genus in the dolphin family Delphinidae), and two species of Lagenorhynchus (Peale's and hourglass dolphins) with a generalized hearing range estimated from 275 Hz to 160 kHz (renamed very high-frequency cetaceans by Southall et al. (2019) since some species have best sensitivity at frequencies exceeding 100 kHz).
- *Phocids Underwater*—consists of true seals with a generalized underwater hearing range from 50 Hz to 86 kHz (renamed Phocids carnivores in water by Southall et al. [2019]).
- *Otariids Underwater*—includes sea lions and fur seals with a generalized underwater hearing range from 60 Hz to 39 kHz (termed Other marine carnivores in water by Southall et al. [2019] and includes otariids, as well as walrus [Family *Odobenide*], polar bear [*Ursus maritimus*], and sea and marine otters [Family *Mustelidae*]).

Within these generalized hearing ranges, the ability to hear sounds varies with frequency, as demonstrated by examining audiograms of hearing sensitivity (NOAA Fisheries [2018]; Southall et al. [2019]). To reflect higher noise sensitivities at particular frequencies, auditory weighting functions were developed for each functional hearing group that reflected the best available data on hearing ability (composite audiograms), susceptibility to noise-induced hearing loss, impacts of noise on hearing, and data on equal latency (NOAA Fisheries 2018). These weighting functions are applied to individual sound received levels to reflect the susceptibility of each hearing group to noise-induced threshold shifts, which is not the same as the range of best hearing (Figure 3).

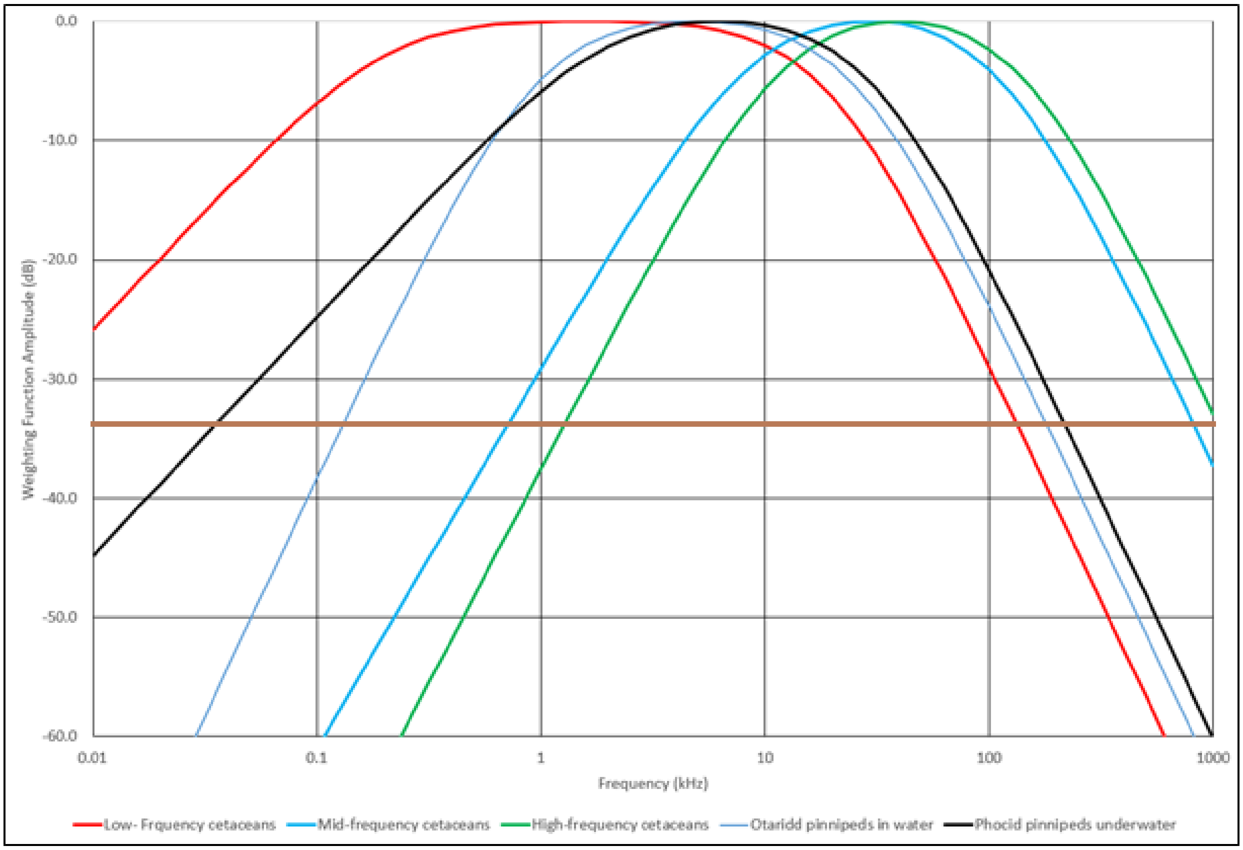


Figure 3. Auditory Weighting Functions for Cetaceans (LF, MF, and HF Species) and Pinnipeds in water from NOAA Fisheries (2018)

NOAA Fisheries (2018) defined acoustic threshold levels at which PTS and TTS are predicted to occur for each hearing group for impulsive and non-impulsive signals (Table), which are presented in terms of dual metrics; SEL_{cum} and L_{PK}. The Level B harassment thresholds are also provided in Table .

Table 3. Acoustic Threshold Levels for Marine Mammals

Hearing Groups	Impulsive Sounds			Non Impulsive Sounds		
	PTS Onset	TTS Onset	Behavior	PTS Onset	TTS Onset	Behavior
Low-frequency cetaceans	219 dB ($L_{p,pk}$) 183 ($L_{E, LF, 24h}$)	213 dB ($L_{p,pk}$) 168 dB ($L_{E, LF, 24h}$)	160 dB (L_p)	199 dB ($L_{E, LF, 24h}$)	179 dB ($L_{E, LF, 24h}$)	120 dB (L_p)
Mid-frequency cetaceans	230 dB ($L_{p,pk}$) 185 dB ($L_{E, MF, 24h}$)	224 dB ($L_{p,pk}$) 170 dB ($L_{E, MF, 24h}$)		198 dB ($L_{E, MF, 24h}$)	178 dB ($L_{E, MF, 24h}$)	
High-frequency cetaceans	202 dB ($L_{p,pk}$)	196 dB ($L_{p,pk}$)		173 dB ($L_{E, HF, 24h}$)	153 dB ($L_{E, HF, 24h}$)	

Hearing Groups	Impulsive Sounds			Non Impulsive Sounds		
	PTS Onset	TTS Onset	Behavior	PTS Onset	TTS Onset	Behavior
	155 dB ($L_{E, HF, 24h}$)	140 dB ($L_{E, HF, 24h}$)				
Phocid pinnipeds underwater	218 dB ($L_{p,pk}$) 185 dB ($L_{E, PW, 24h}$)	212 dB ($L_{p,pk}$) 170 dB ($L_{E, PW, 24h}$)		201 dB ($L_{E, PW, 24h}$)	181 dB ($L_{E, PW, 24h}$)	
Otariid pinnipeds underwater	232 dB ($L_{p,pk}$) 203 dB ($L_{E, OW, 24h}$)	226 dB ($L_{p,pk}$) 188 dB ($L_{E, OW, 24h}$)		219 dB ($L_{E, PW, 24h}$)	199 dB ($L_{E, PW, 24h}$)	
Sources: Southall et al. 2019; NOAA Fisheries 2018 $L_{E, 24h}$ = cumulative sound exposure over a 24-hour period (dB re 1 μPa^2·s); $L_{p,pk}$ = peak sound pressure (dB re 1 μPa); L_p = root mean square sound pressure (dB re 1 μPa)						

In a cooperative effort between federal and state agencies, interim criteria were developed to assess the potential for injury to fish and sea turtles exposed to pile driving sounds. These noise injury thresholds have been established by the Fisheries Hydroacoustic Working Group, which was assembled by NOAA Fisheries with thresholds subsequently adopted by NOAA Fisheries. NOAA Fisheries' Greater Atlantic Regional Fisheries Office has applied these standards for assessing the potential effects of Endangered Species Act-listed fish specie exposed to elevated levels of underwater sound produced during pile driving, which were updated in 2019 (NOAA Fisheries 2020) These noise thresholds are based on sound levels that have the potential to produce injury or illicit a behavioral response from fish (Table).

Table 4. Acoustic Threshold Levels for Fish, Injury and Behavior

Hearing Group	Injury	Behavior
Fish	206 dB ($L_{p,pk}$) 187 dB ($L_{E, 24h}$) (Fish mass ≥ 2g) 183 dB ($L_{E, 24h}$) (Fish mass < 2g)	150 dB (L_p)
Sources: NOAA Fisheries 2020; Stadler and Woodbury 2009.Department of the Navy 2017. $L_{E, 24h}$ = cumulative sound exposure over a 24-hour period (dB re 1 μPa^2·s); $L_{p,pk}$ = peak sound pressure (dB re 1 μPa); L_p = root mean square sound pressure (dB re 1 μPa)		

A Working Group organized under the American National Standards Institute-Accredited Standards Committee S3, Subcommittee 1, Animal Bioacoustics, also developed sound exposure guidelines for fish (Table ; Popper et al. 2014). They identified three types of fish depending on how they might be affected by underwater sound. The categories include fish with no swim bladder or other gas chamber (e.g., dab and other flatfish); fish with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g., salmonids); and fish with a swim bladder that is involved in hearing (e.g., channel catfish).

Table 5. Acoustic Threshold Levels for Fish, Impulsive and Non-Impulsive

Hearing Groups	Impulsive Sounds			Non Impulsive Sounds	
	Mortality and Potential Mortal Injury	Recoverable Injury	TTS	Recoverable Injury	TTS
Fishes without swim bladders	> 213 dB ($L_{p,pk}$) > 219 dB ($L_{E, 24h}$)	> 213 dB ($L_{p,pk}$) > 216 dB ($L_{E, 24h}$)	> 186 dB ($L_{E, 24h}$)	--	--
Fishes with swim bladder not involved in hearing	207 dB ($L_{p,pk}$) 210 dB ($L_{E, 24h}$)	207 dB ($L_{p,pk}$) 203 dB ($L_{E, 24h}$)	>186 dB ($L_{E, 24h}$)	--	--
Fishes with swim bladder involved in hearing	207 dB ($L_{p,pk}$) 207 dB ($L_{E, 24h}$)	207 dB ($L_{p,pk}$) 203 dB ($L_{E, 24h}$)	186 dB ($L_{E, 24h}$)	170 dB (L_p)	158 dB (L_p)
Eggs and larvae	207 dB ($L_{p,pk}$) 210 dB ($L_{E, 24h}$)	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	--	--

Sources:
Popper et al. 2014, Department of the Navy 2017.
$L_{E, 24h}$ = cumulative sound exposure over a 24-hour period (dB re 1 μPa^2·s);
$L_{p,pk}$ = peak sound pressure (dB re 1 μPa);
L_p = root mean square sound pressure (dB re 1 μPa)
PTS = permeant threshold shift;
N = near (10s of meters);
I = intermediate (100s of meters);
F = far (1000s of meters);
-- = not applicable

A.3 EXISTING AMBIENT CONDITIONS

Primary sources of in-air noise within the community are the industrial areas and their land uses, harbor uses and infrastructure, waterfront industrial uses, and traffic along Route 30. There are no applicable noise regulations that require collection of ambient sound data to demonstrate Project compliance.

Underwater noise in the ocean associated with natural sources is generated by physical and biological processes and non-natural sources. Examples of physical noise sources are tectonic seismic activity, wind, and waves; examples of biological noise sources are the vocalizations of marine mammals and fish. There can be a strong minute-to-minute, hour-to-hour, or seasonal variability in sounds from biological sources. The ambient noise for frequencies above 1 kHz is due largely to waves, wind, and heavy precipitation (Simmonds et al. 2004). Surface wave interaction and breaking waves with spray have been identified as significant sources of noise. Wind induced bubble oscillations and cavitation are also near-surface noise sources. At areas within distances of 8 to 10 km of the shoreline, surf noise will be prominent in the frequencies ranging up to a few hundred Hz (Richardson et al. 2013).

A considerable amount of background noise may also be caused by biological activities. Aquatic animals generate sounds for communication, echolocation, prey manipulation, and as by-products of other activities such as feeding. Biological sound production usually follows seasonal and diurnal patterns, dictated by variations in the activities and abundance of the vocal animals. The frequency content of underwater biological sounds ranges from fewer than 10 Hz to beyond 150 kHz. Source levels show a great variation, ranging from below 50 dB to more than 230 dB SPL RMS re 1 μPa at 1 m. Likewise, there is a significant variation in other source characteristics such as the duration, temporal amplitude, frequency patterns, and the rate at which sounds are repeated (Wahlberg 2012). Typical underwater noise levels show a frequency dependency in relation to different noise sources; the classic curves are given in Wenz (1962).

Anthropogenic noise sources can consist of contributions related to industrial development, offshore oil industry activities, naval or other military operations, and marine research. A predominant contributing anthropogenic noise source is generated by commercial ships and recreational watercrafts. Noise from these vessels dominates coastal waters and emanates from the ships' propellers and other dynamic positioning propulsion devices such as thrusters. The sound generated from main engines, gearboxes, and generators transmitted through the hull of the vessel into the water column is considered a secondary sound source to that of vessel propulsion systems, as is the use of sonar and depth sounders which occur at generally high frequencies and attenuate rapidly. Typically, shipping vessels produce frequencies below 1 kHz, although smaller vessels such as fishing, recreational, and leisure craft may generate sound at somewhat higher frequencies (Simmonds et al. 2004).

There is limited publicly available site-specific ambient sound information collected within the Project Area. NOAA's SoundMap, which is a mapping tool that provides maps of the temporal, spatial, and frequency characteristics of man-made underwater noise resulting from various activities, was consulted. Pressure fields associated with different contributors of underwater sound (i.e., shipping and passenger vessels) were summed and the sound pressure level values at frequencies ranging from 50 to 800 Hz were presented for various water column depths. Within the lower 50 Hz frequency range, underwater sound pressure levels were greatest, varying between approximately 80 to 100 dB depending on water depth and proximity to the coastline. The sound contribution and magnitude decrease with increasing frequency, indicating that the noise from shipping and passenger vessels is largely focused within the low frequency range.

A.4 ACOUSTIC MODELING METHODOLOGY

In-air and Underwater acoustic model simulations were conducted for primary noise-generating activities occurring during Project construction and operations. The following subsections describe the modeling calculations approach, modeled scenarios, and model input values.

A.4.1 In-air Acoustic Modeling Methodology

A.4.1.1 In-air Acoustic Modeling Software

The Cadna-A® computer noise model was used to calculate sound pressure levels associated with Project construction activities. An industry standard, Cadna-A® was developed by DataKustik GmbH to provide an estimate of sound levels at distances from sources of known emission. It is used by acousticians and acoustic engineers because it has the capability to accurately describe noise emission and propagation from complex facilities and developments consisting of various equipment, and it in most cases yields conservative sound pressure level results.

The current International Organization for Standardization (ISO) standard for outdoor sound propagation, ISO 9613 Part 2, "Attenuation of Sound during Propagation Outdoors," was used within Cadna-A®. The method described in this standard calculates sound attenuation under weather conditions that are favorable for sound propagation, such as for downwind propagation or atmospheric inversion, conditions that are typically considered worst case. The calculation of sound propagation from source to receiver locations consists of full octave-band sound frequency algorithms that incorporate the following physical effects:

- Geometric spreading wave divergence
- Reflection from surfaces
- Atmospheric absorption at 10 degrees Celsius and 70 percent relative humidity
- Screening by topography and obstacles
- Effects of terrain features including relative elevations of noise sources
- Sound power levels from stationary and mobile sources
- Locations of noise-sensitive land use types
- Intervening objects including buildings and barrier walls to the extent included in a project's design
- Ground effects due to areas of pavement and unpaved ground
- Sound power at multiple frequencies
- Source directivity factors
- Multiple noise sources and source type (point, area, and/or line

Topographical information was imported into the acoustic model using the official U.S. Geological Survey digital elevation dataset to accurately represent terrain in three dimensions. Terrain conditions, vegetation type, ground cover, and the density and height of foliage can also influence the absorption that takes place when sound waves travel over land. The ISO 9613-2 standard accounts for ground absorption rates by assigning a numerical coefficient of G=0 for acoustically hard, reflective surfaces and G=1 for absorptive surfaces and soft ground. If the ground is hard-packed dirt, which is typically found in industrial complexes, pavement, bare rock or for sound traveling over water, the absorption coefficient is defined as G=0 to account for reduced sound attenuation and higher reflectivity. In contrast, ground covered in vegetation, including suburban lawns and agricultural fields (both fallow with bare soil and planted with crops), will be acoustically absorptive and aid in sound attenuation (i.e., G=1.0). A mixed (semi-reflective) ground factor of G=0.5 was used in the Project acoustic modeling analysis. In addition to geometrical divergence, attenuation factors include topographical features, terrain coverage, and/or other natural or anthropogenic obstacles that can affect sound attenuation and result in acoustical screening. To be conservative, sound attenuation through foliage and diffraction around and over existing anthropogenic structures such as buildings was ignored.

A.4.2 Underwater Acoustic Modeling Methodology

A.4.2.1 Underwater Acoustic Modeling Software

Underwater sound propagation modeling was completed using dBSea, a software developed by Marshall Day Acoustics for the prediction of underwater noise in a variety of environments. The model is built by importing bathymetry data and placing noise sources in the environment. Each source can consist of equipment chosen from either the standard or user-defined databases. Noise mitigation methods may also be included. The user has control over the seabed and water properties including sound speed profile, temperature, salinity, and current. Noise levels are calculated to the extent of the bathymetry area. To examine results in more detail, levels may be plotted in cross sections, or a detailed spectrum may be extracted at any point in the calculation area. Levels are calculated in third octave bands from 12.5 Hz to 20 kHz. Please refer to Appendix A for additional details on the modeling principles and assumptions.

A.4.3 Modeling Environment

The accuracy of underwater noise modeling results is largely dependent on the sound source characteristics and the accuracy of the intrinsically dynamic data inputs and assumptions used to describe the medium between the path and receiver, including river surface conditions, water column, and riverbed. Depending on the sound source under review, it was approximated as a point source or a line source, composed of multiple points, extending downward into the water column. Furthermore, determining sound emissions for the various sources are based on a combination of factors, including known properties (e.g., hammer strength) as well as consulting empirical data. Model input variables incorporated into the calculations are further described as follows.

A.4.3.1 Bathymetry

For geometrically shallow water (i.e., less than 200 m), sound propagation is dominated by boundary effects. Bathymetry data represent the three-dimensional nature of the subaqueous land surface and were obtained from the National Geophysical Data Center 2003 U.S. Coastal Relief Model Volume 8. (NOAA Satellite and Information Service 2003); the horizontal resolution of this dataset has an approximate grid spacing of 73 meters. National Geophysical Data Center's U.S. Coastal Relief Model provides the first comprehensive view of the U.S. coastal zone, integrating offshore bathymetry with land topography into a seamless representation of the coast. The U.S. Coastal Relief Model spans the U.S. east and west coasts, the northern coast of the Gulf of Mexico, Puerto Rico, and Hawaii, reaching out to, and in places even beyond, the continental slope. The Geophysical Data System is an interactive database management system developed by the National Geophysical Data Center for use in the assimilation, storage and retrieval of geophysical data. Geophysical Data System software manages several types of data including marine trackline geophysical data, hydrographic survey data, aeromagnetic survey data, and gridded bathymetry/topography.

The bathymetric data were sampled by creating a fan of radials at a given angular spacing. This grid was then used to determine depth points along each modeling radial transect. The underwater acoustic modeling takes place over these radial planes in set increments depending on the acoustic wavelength and the sampled depth. These radial transects were used for modeling underwater acoustic impacts during both the construction and operations of the Project, with each radial centered on the given Project sound source or activity.

A.4.3.2 Sediment Characteristics

Sediment type (e.g., hard rock, sand, mud, clay) directly impacts the speed of sound as it is a part of the medium in which the sound propagates. The geoacoustic properties with information on the compositional data of the surficial sediments were informed by site-specific geophysical and geotechnical data presented in the sediment characterization report (Shannon & Wilson 2021). The sediment layers used in the modeling and the main geoacoustic properties are defined in Table . The term “compressional” refers to the fact that particle motion of the sound wave is in the same direction as propagation. The term “compressional sound speed” refers to the speed of sound in the sediment along the direction of acoustic propagation. The term “compressional attenuation” refers to how much sound (dB) is lost per wavelength (λ) of the signal. Lastly, density (ρ) is the physical density of the sediment.

Table 6 provides geoacoustic properties for compressional waves. Acoustical parameters of shear waves are not included in the acoustical modeling. Bottom reflection loss occurs when sound energy interacts with the sediment at the bottom and therefore, dependent on the geoacoustic properties of the sediments and water column. Shear wave speed and attenuation can be important parameters for bottom loss based on the depth, but typically negligible since they are small as compared to the water column sound speed, and compressional wave speed and attenuation parameters (Jensen 2011). By no including acoustic parameters of shear waves, the acoustic modeling results are expected to be more conservative and representative of the propagation conditions in the Project area.

Table 6. Geoacoustic Properties of Sub-bottom Sediments as a Function of Depth

Seabed Layer (m)	Material	Geoacoustic Properties
0 to 4	Silt	Cp = 1575 m/s αs (dB/λ) = 1.0 dB/ λ ρ = 1700 kg/m^3
4 to 8	Sand-silt	Cp = 1612 m/s αs (dB/λ) = 0.9 dB/ λ ρ = 1800 kg/m^3
8 to 15	Sand	Cp = 1650 m/s αs (dB/λ) = 0.8 dB/ λ ρ = 1900 kg/m^3
15 to 50	Clay	Cp = 1500 m/s αs (dB/λ) = 0.2 dB/ λ ρ = 1500 kg/m^3
Sources: Shannon & Wilson 2021 and Jensen 2011		

A.4.3.3 Seasonal Sound Speed Profiles

The speed of sound in sea water depends on the temperature T (˚ Celsius), salinity S (parts per thousand), and depth D (m) and can be described using sound speed profiles. Typically, a homogeneous or mixed layer of constant velocity is present in the first few meters. It corresponds to the mixing of superficial water through surface agitation. There can also be other features such as a surface channel, which corresponds to sound velocity increasing from the surface down. This channel is often due to a shallow isothermal layer appearing in winter conditions but can also be caused by water that is very cold at the surface. In a negative sound gradient, the sound speed decreases with depth, which results in sound refracting downwards which may result in increased bottom losses with distance from the source. In a positive sound gradient, as is predominantly present in the winter season, sound speed increases with depth and the sound is, therefore, refracted upwards, which can aid in long distance sound propagation. The construction timeframe is expected to occur from November 1st to February 28th. A sensitivity analysis was completed evaluating the sound propagation during the construction months. Based on the sensitivity analysis, the January sound speed profile was selected since applying it resulted in sound propagating furthest from the source. **Error! Reference source not found.** displays the monthly sound speed profiles for the Project Area for the months when Project construction may occur.

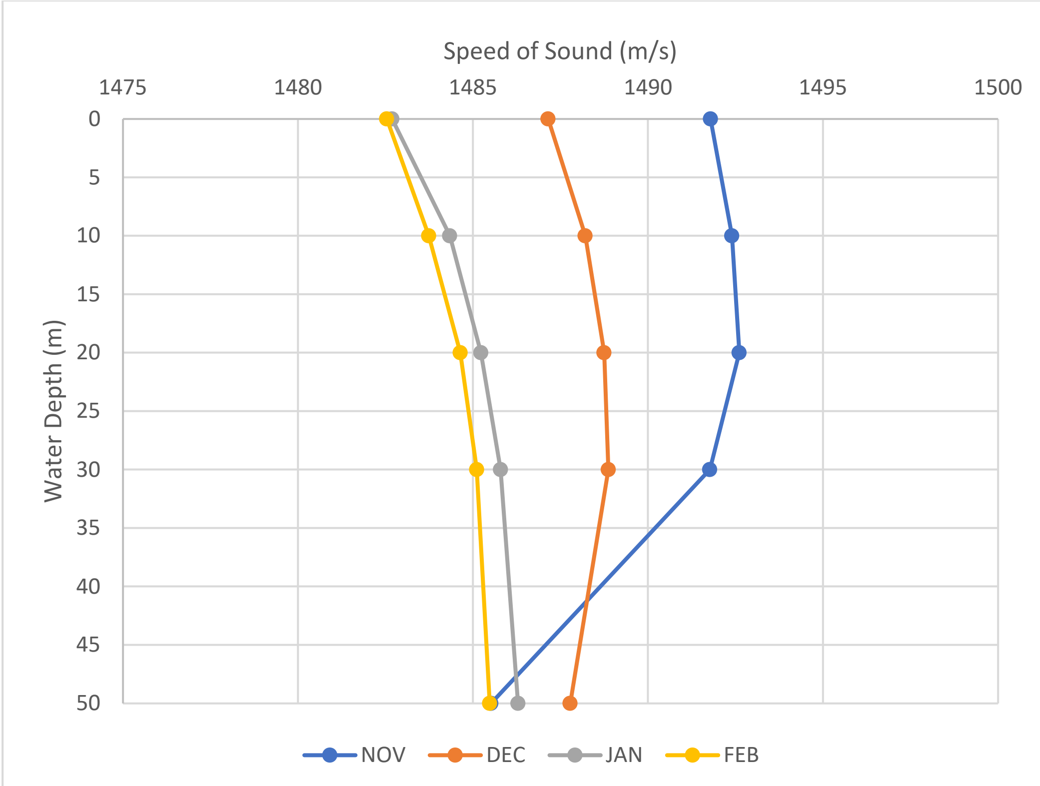


Figure 4 Monthly Sound Speed Profile as a Function of Depth

A.4.3.4 Threshold Range Calculations

To determine the ranges to the defined threshold isopleths, a maximum received level-over-depth approach was used. This approach uses the maximum received level that occurs within the water column at each horizontal sampling point. Both the R_{max} and the $R_{95\%}$ ranges were calculated foreach of the regulatory thresholds. The R_{max} is the maximum range in the model at which the sound level is calculated. The $R_{95\%}$ is the maximum range at which a sound level was calculated excluding 5% of the R_{max}. The $R_{95\%}$ excludes major outliers or protruding areas associated with the underwater acoustic modeling environment. Regardless of shape of the calculated isopleths the predicted range encompasses at least 95% of the horizontal area that would be exposed to sound at or above the specified level. All ranges to injury thresholds are presented in terms of the $R_{95\%}$ range.

A.4.3.5 Calculation Methodology for the Removal of the Timber Piles

Because of the short duration and low noise level modeling of the removal of the existing timber piles was conducted following prescriptive guidance provided by NOAA Fisheries. The Level A harassment cumulative PTS criteria were applied to the formulaic spreadsheet provided by NOAA Fisheries, which has been updated to reflect NOAA Fisheries' 2018 Revisions to Technical Guidance (NOAA Fisheries 2018). PTS onset acoustic thresholds estimated in the NOAA Fisheries User Spreadsheets rely on overriding default values, calculating individual adjustment factors, and using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The adjustment factors in the spreadsheets allow for the calculation of SEL_{cum} and PK distances and account for the accumulation using the source characteristics (duty cycle and speed) after Silve et al. (2014). The vibratory hammer evaluated was input using the vibratory pile driving specific tab within the NOAA Fisheries User Spreadsheet as appropriate.

The Level B harassment distance was calculated using a simple spread calculation to estimate the horizontal distance to Level B isopleth:

$$\mathrm{SPL}(r)=\mathrm{S}L-PL(r) \qquad (9)$$

Where:

SPL = sound pressure level (dB re 1 μPa),
r = range (m),
SL = source level (dB re 1 μPa m), and
PL = propagation loss as a function of distance.

Propagation loss is calculated using:

$$PL(r)=\mathrm{F}\ \mathrm{Log}_{10}(r) \qquad (10)$$

Where:

F = Tranmission loss coefficient (15 was used to calculate all Level B thresholds.),

Note that the calculation methodologies do not allow for inclusion of site-specific environmental parameters. For the vibratory hammer it is assumed that the SPL is equal to the 1 second SEL. To calculate the cumulative SEL distances the 1 second SEL is adjusted to incorporate the total duration of the vibratory hammer that would operation for a 24-hour period.

A.5 ACOUSTIC MODELING SCENARIOS

Construction of the proposed project landside and waterside improvements necessary to homeport the new FRCs at East Tongue Point (ETP) is anticipated to occur over a 36-month construction schedule, depending on environmental and regulatory requirements and timing for the various work types. Any work below the ordinary high water mark (OHWM) will occur during the in-water work window of November 1 to February 28.

A.5.1 In-air Acoustics

Project construction is expected to include the following phases:

1. Demolition and clearing of existing facilities and utilities;
2. Ground improvements at the proposed Project location;
3. New site work for landside improvements and supporting infrastructure for the newly homeported FRCs;
4. Construction of new MWD building; and
5. Pile driving pier piles.

Acoustic emission levels for activities associated with Project construction were based upon typical ranges of energy equivalent noise levels at construction sites, as documented by the Federal Highway Administration (FHWA 2004) and the Department for Environment, Food, and Rural Affairs (Defra 2005). Typically, construction activity is also characterized by usage load rating, which is the fraction of time the equipment is operated over the specified working timeframe; however, for the purposes of this assessment the usage load rating was assumed to be 100 percent for all equipment. Therefore, the acoustic analysis conservatively assumes that all construction equipment will operate continuously and concurrently at their maximum sound levels throughout construction.

Received sound levels will fluctuate, depending on the construction activity, equipment type, and distance between noise source and receiver. Construction sound will be attenuated as distance from the source increases. Other factors, such as vegetation, terrain, and obstacles such as buildings will act to further limit the impact of construction noise levels, but they were not considered in the analysis. Information pertaining to construction schedule and numbers of equipment and equipment type was obtained by USCG. Table 7 presents the types of construction equipment and corresponding maximum sound level (L_{max}) used in the model.

Table 7. Construction Equipment Source Levels, L_{max}

Phase	Construction Equipment[1]	Quantity	Octave Band Sound Pressure Level (Hz) dB[2]								Equipment Noise Level at 50 ft. L_{max}
			63	125	250	500	1,000	2,000	4,000	8,000	
Demolition	Excavator	2	81	84	80	80	81	78	75	70	89 dB / 85 dBA
	Hoe Ram	2	95	86	84	85	84	85	80	75	97 dB / 90 dBA
	Front-end Loader	2	92	84	83	77	76	74	71	62	93 dB / 82 dBA
	Bulldozer	2	85	83	78	79	84	72	67	60	89 dB / 85 dBA
	Dump Truck	2	89	91	81	79	80	77	73	66	93 dB / 84 dBA
Ground Improvements	Cement Truck	2	88	89	71	74	75	83	65	60	92 dB / 85 dBA
	Excavator	1	81	84	80	80	81	78	75	70	89 dB / 85 dBA
	Dump Truck	2	89	91	81	79	80	77	73	66	93 dB / 84 dBA
	Front-end Loader	2	92	84	83	77	76	74	71	62	93 dB / 82 dBA
	Grader	2	88	87	83	79	84	78	74	65	92 dB / 86 dBA
New Site Works	Excavator	2	81	84	80	80	81	78	75	70	89 dB / 85 dBA
	Front-end Loader	2	92	84	83	77	76	74	71	62	93 dB / 82 dBA
	Bulldozer	2	85	83	78	79	84	72	67	60	89 dB / 85 dBA
	Compactor	2	85	80	76	77	76	76	72	67	88 dB / 82 dBA
	Dump Truck	2	89	91	81	79	80	77	73	66	93 dB / 84 dBA
	Cement Truck	2	88	89	71	74	75	83	65	60	92 dB / 85 dBA
	Cement Pump	2	88	80	74	75	77	77	70	62	90 dB / 82 dBA
MWD Building	Lift	2	87	84	81	81	81	78	72	70	97 dB / 85 dBA
	Crane	1	95	90	86	82	79	75	68	63	97 dB / 85 dBA
	Forklift	1	64	64	65	65	63	61	59	52	72 dB / 68 dBA
	Air Compressor	2	99	88	79	74	72	70	73	62	99 dB / 80 dBA
	Welding Equipment	2	67	68	69	68	69	66	61	56	76 dB / 73 dBA
Pile Driving	Impact Hammer	1	118	110	89	93	90	96	95	97	119 dB / 103 dBA

[1]Equipment usage percentage was assumed 100% for all equipment.

[2]Octave band data is based on Defra 2005 and adjusted to the broadband levels provided by FHWA 2004.

A.5.2 Underwater Acoustics

The representative acoustic modeling scenarios were derived from descriptions of the expected construction activities through consultations between the Project design and engineering teams. The scenarios modeled were ones where potential underwater noise impacts of marine species were anticipated and included impact pile driving associated pier installation. All modeling scenarios occur at a representative location. This location was selected so that the effects of sound propagation at the range of water column depths occurring within the project area could be observed.

A summary of construction and operational scenarios included in the underwater acoustic modeling analysis is provided in Table . The pile diameters selected for the impact pile driving modeling scenarios were based on maximum Project design considerations provided by the Company. The subsections that follow provide more detailed information about the parameters used to model the noise sources associated with each scenario.

Table 8. Underwater Acoustic Modeling Scenarios

Scenario	Description	Location (UTM Coordinates)	Hammer Energy (kilojoule) a/	Total Hammer Blows / Duration	Apparent Source Level (at 10 meter)[2]
1	Impact pile driving, diameter: 36-inch	441340 m, 5116945 m	118	45 blows per minute for 9 minutes (1,203 total blows)[1]	208 dB $L_{p,pk}$ 180 dB $L_{E,ss}$ 190 L_p
2	Impact pile driving, Diameter: 30-inch	441340 m, 5116945 m	118	45 blows per minute for 9 minutes (1,203 total blows)[1]	210 dB $L_{p,pk}$ 177 dB $L_{E,ss}$ 190 L_p
3	Dredging	441340 m, 5116945 m	N/A	N/A	186 dB $L_{E,\ 1sec}$[3] 191 L_p[3]
4	Vibratory Timber Pile Removal	Representative Location	N/A	20 minutes[4]	152 dB $L_{E,\ 1sec}$

[1] The total number of blows and duration represents the installation of three piles per day. The duration provided in minutes has been rounded to the nearest whole number.

[2] Source levels were based on similar pile installations published by CALTRANS (CALTRANS 2020)

[3] The apparent source level is at 1 meter.

[4] A total of 20 piles per day with a duration of 1 minute each.

A.5.3 Impact Pile Driving of Pier Foundations

Impact pile driving involves weighted hammers that pile into the river floor. Different methods for lifting the weight include hydraulic, steam, or diesel. The acoustic energy is created upon impact; the energy travels into the water along different paths (1) from the top of the pile where the hammer hits, through the air, into the water; (2) from the top of the pile, down the pile, radiating into the air while traveling down the pile, from air into water; (3) from the top of the pile, down the pile, radiating directly into the water from the length of pile below the waterline; and (4) down the pile radiating into the ground, traveling through the ground and radiating back into the water. Near the pile, acoustic energy arrives from different paths with different associated phase and time lags, which creates a pattern of destructive and constructive interference. Further away from the pile, the water and seafloor born energy are the dominant pathways. The underwater noise generated by a pile-driving strike depends primarily on the following factors:

1. The impact energy and type of pile driving hammer;
2. The size and type of the pile;

3. Water depth; and
4. Subsurface hardness in which the pile is being driven.

The acoustic energy radiated into the aquatic environment by a struck pile is directly correlated to the kinetic energy that the impact hammer imparts to it. Engineering considerations about pile penetration and load bearing capacity dictate that the impact hammer energy must be matched to the pile and to the resistance of the underlying substrate (Parola 1970). Greater hammer impact energy is required for larger diameter piles to achieve the desired load bearing capacity. The water depth also has a strong influence. As more of the surface area is exposed at deeper depths, a greater percentage of sound energy is introduced into the aquatic environment. The site selected presented in Table 8 has a depth of 3 meters, which is representative of the project area where pile driving will occur.

The 36-inch pile and 30-inch pile driving scenarios were both modeled using a vertical array of sources spaced at a 0.5-meter array, distributing the sound emissions from pile driving throughout the water column. The vertical array was assigned third-octave band sound characteristics adjusted for site-specific parameters discussed above including expected hammer energy and number of blows. Third octave band center frequencies from 12.5 Hz up to 20 kHz were used in the modeling. The spectra used in the modeling is shown below in Figure 5. This spectrum is based on the empirical model (see Appendix B) and is scaled to the broadband source levels presented in Table 8.

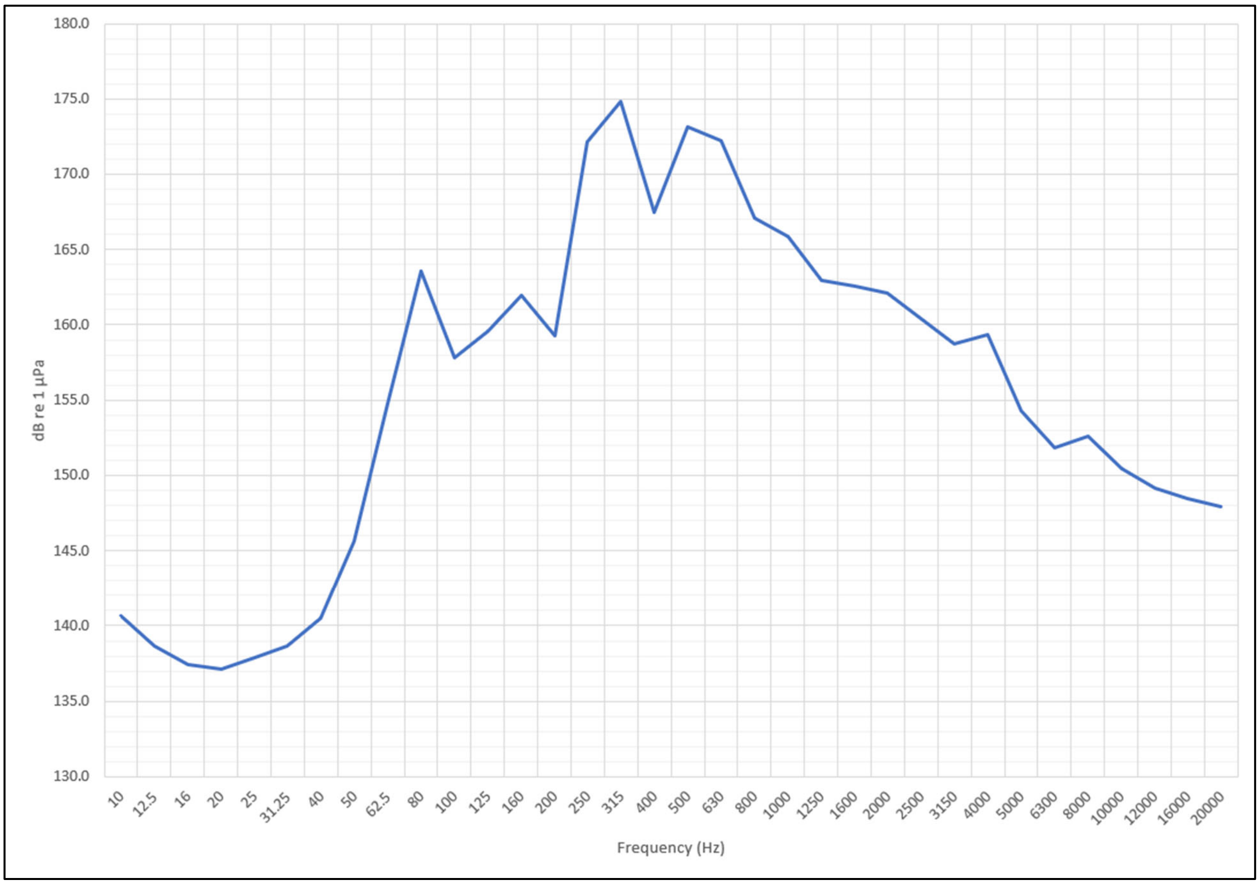


Figure 5 Impact Pile Driving Spectral Source Level

A.5.4 Dredging Operations

It is anticipated that dredging will occur during the first in-water window (November 1, 2022 – February 28, 2023). The hydrographic survey completed in July of 2020 indicated that the current water depth in the vicinity of Pier 6 range from 9 to 10 feet. In order to achieve a draft of 18.5 feet at the berth and navigation channel within the proposed dredging area, approximately 131,000 cubic yards will be removed and disposed of. The source level of the dredging activity is variable and can be affected by the type of dredger used and the sediment type. During the completion of this study the type of dredger proposed to be used has not been determined. Therefore, a conservative assumption was made to evaluate a Trailer Suction Hopper Dredger (TSHD). Based on literature review TSHDs have been monitored more than any other type of dredger. TSHDs also tend to generate higher levels than backhoe or bucker/clamshell dredgers. Modeling of the TSHD was completed using one-third-octave band TSHD source levels from measurements of a similar type of equipment (Connel Wagner 2008). The assumed sound source level for the dredger corresponds to a 191 dB SPL RMS. The frequency distribution of the dredger sound source is displayed in Figure 6. This spectrum was scaled to the broadband levels presented in Table 8 within the underwater noise model.

A.5.5 Vibratory Pile Removal Operations

The existing timber piles will be removed using a vibratory hammer. Vibratory hammers install/remove piles by applying a rapidly alternating force to the pile. This is generally accomplished by rotating eccentric weights about shafts. Each rotating eccentric produces a force acting in a single plane and directed toward the centerline of the shaft. The weights are set off-center of the axis of rotation by the eccentric arm. If only one eccentric is used, in one revolution a force will be exerted in all directions, giving the system a good deal of lateral whip. To avoid this problem the eccentrics are paired so the lateral forces cancel each other, leaving only axial force for the pile.

In general, vibratory pile driving is less noisy than impact pile driving. Impact pile driving produces a loud impulse sound that can propagate through the water and substrate whereas vibratory pile driving produces a continuous sound with peak pressures lower than those observed in pulses generated by impact pile driving. For estimating source level, the vibratory pile hammer was estimated based on measurement data from similar types of operation (CALTRANS 2020). It was assumed that the vibratory hammer would be used for 1 minute per pile removal for a total of 20 piles per day.

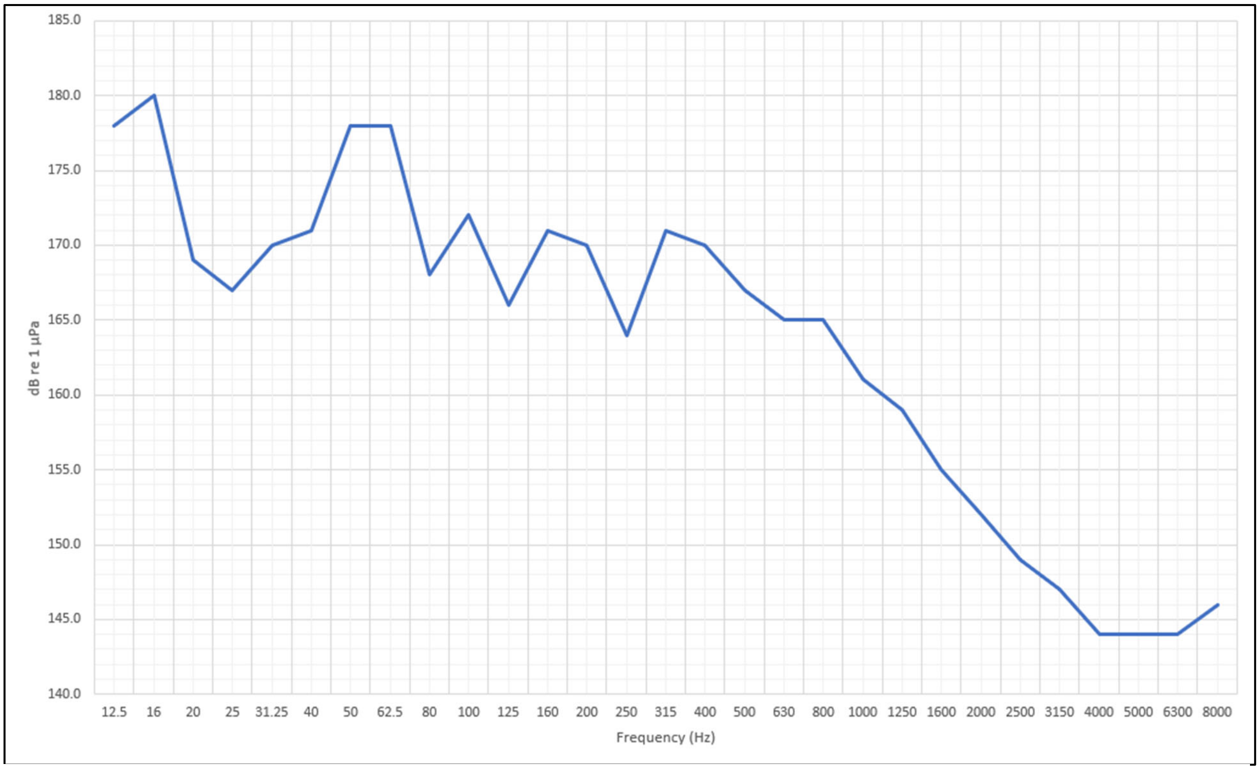


Figure 6 Dredging Spectral Source Level (Connell Wagner 2008)

A.6 NOISE MITIGATION

Devices may be considered to mitigate pile driving sound levels. There are several types of sound attenuation devices including bubble curtains, cofferdams, isolation casings (also called temporary noise attenuation piles), and cushion blocks. The most commonly considered mitigation strategy is the use of bubble curtains. Bubble curtains create a column of air bubbles rising around a pile from the substrate to the water surface. Because air and water have a substantial impedance mismatch, the bubble curtain acts as a reflector. In addition, the air bubbles absorb and scatter sound waves emanating from the pile, thereby reducing the sound energy. Bubble curtains may be confined or unconfined. These systems may be deployed in series, such as a double bubble curtain with two rings of bubbles encircling a pile. Attenuation levels also vary by type of system, frequency band, and location. Small bubble curtains have been measured to reduce sound levels from 5 dB to more than 10 dB but are highly dependent on depth of water and current, and configuration and operation of the curtain (Koschinski and Lüdemann 2013, Bellmann 2014, Austin et al. 2016, Caltrans 2020).

Effectiveness of bubble curtains is variable and depends on many factors, including the bubble layer thickness, the total volume of injected air, the size of the bubbles relative to the sound wavelength, and whether the curtain is completely closed. High current conditions can limit the effectiveness of bubble curtains by sweeping the air bubbles away from the pile (Elmer et al. 2006). As water depth increases, the opportunity for current-based disruption of the bubble curtain increases. In general, bubble curtain effectiveness decreases as the water depth increases (Bellmann et al. 2017).

With studies reporting variable achievable attenuation rates for bubble curtains, to represent the use of bubble curtains as a mitigation option in the modeling, a range of potential sound reduction was applied to the modeled sound fields associated with impact pile driving. Attenuation factors of 6 dB and 10 dB were applied to all modeled scenarios to evaluated potential mitigated underwater noise impacts. This is a reasonable range based on the bubble curtains used for similar types of projects providing 5 to 10 dB of reduction (CALTRANs 2020). The results for the mitigation factors are provided for informational purposes only and the take calculations will be based on unmitigated results.

A.7 RESULTS

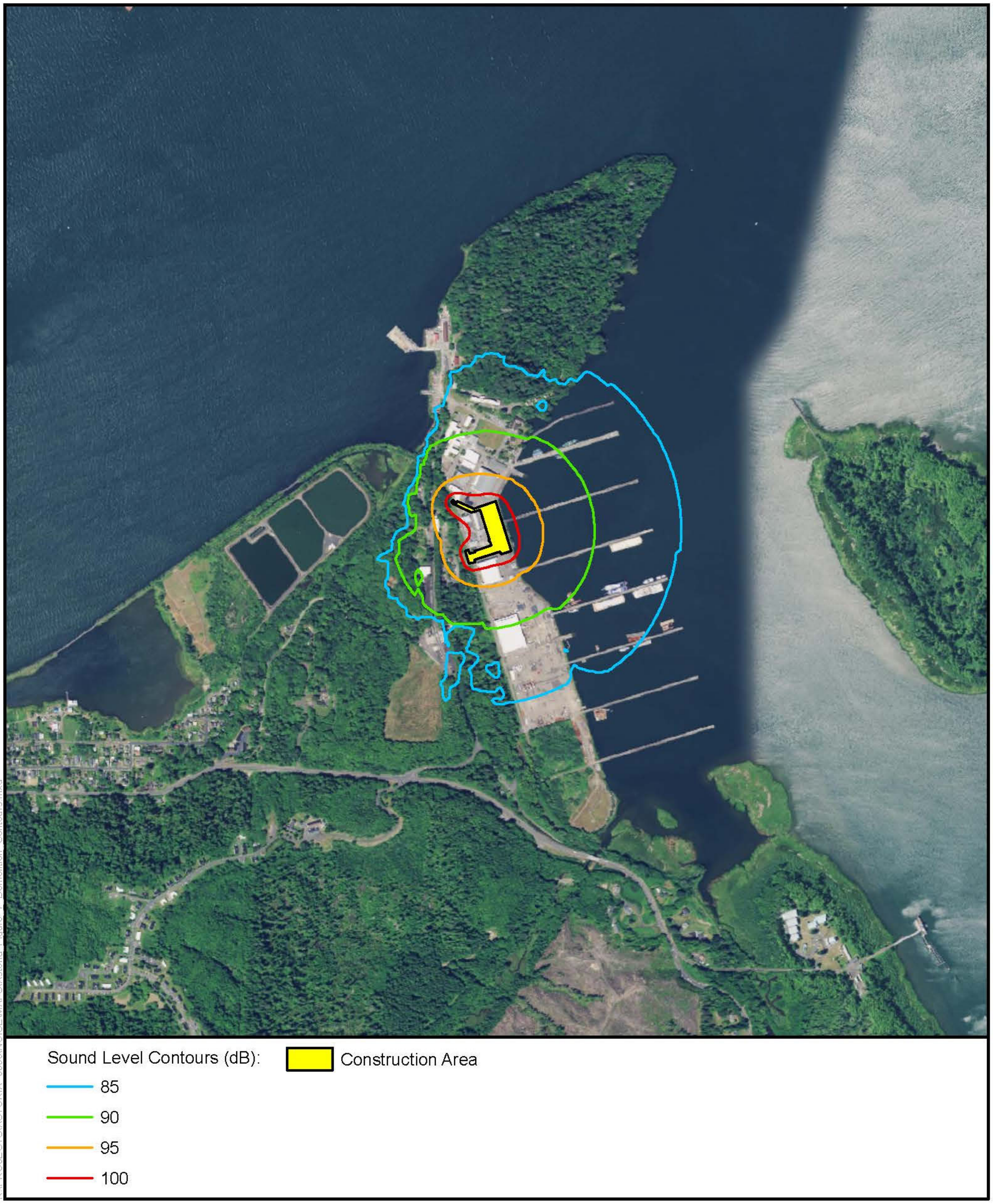
A.7.1 In-air Acoustics

The equipment from Table 7 and corresponding sound information was entered into the CadnaA® model and received sound levels associated with each location were evaluated. Table 9 shows the maximum distance of disturbance to the 90 dB rms and 100 dB rms contours for the different phases of construction.

Figures 7 through 12 show potential noise impacts to harbor seals and other pinnipeds at each construction location in sound contour plots displaying broadband sound levels as color-coded noise isopleths at 90 dB and 100 dB intervals. The noise contours are graphical representations of the cumulative noise associated during normal construction of the equipment components operating simultaneously and shows how the maximum construction noise will be distributed over the surrounding area. The contour lines shown are analogous to elevation contours on a topographic map, i.e., the noise contours are continuous lines of equal noise level around some source, or sources, of noise. Table 9 presents the predicted distances to the relevant 90 dB rms in-air acoustic threshold for harbor seals and 100 dB rms in-air acoustic threshold for other pinnipeds. The tabulated results and sound contour plots are independent of the existing acoustic environment and are representative of expected Project construction sound levels only.

Table 9. In-air Acoustic Modeling Results - Distances of Maximum Disturbance, dB

Construction Phase	Harbor Seals 90 dB rms	Other Pinnipeds 100 dB rms
Demolition	942 ft (287 m)	115 ft (35 m)
Ground Improvements	837 ft (255 m)	82 ft (25 m)
New Site Works	900 ft (275 m)	100 ft (30 m)
MWD Building	315 ft (95 m)	0 ft (0 m)
Pile Driving (Closest to shore)	6,560 ft (2000 m)	2,560 ft (780 m)
Pile Driving (Furthest from shore)	6,560 ft (2000 m)	2,560 ft (780 m)



USCG Fast Response Cutter Homeport Project

Date: 5/12/2023
Map Sources: ESRI

Figure 7: In-air Received Sound Levels: Demolition

N

0 500 1,000 2,000 Feet

1:16,000

USCG Fast Response Cutter Homeport Project

Date: 5/12/2023
Map Sources: ESRI

Figure 8: In-air Received Sound Levels: Ground Improvements

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Date: 5/12/2023
Map Sources: ESRI

Figure 9: In-air Received Sound Levels: New Site Works

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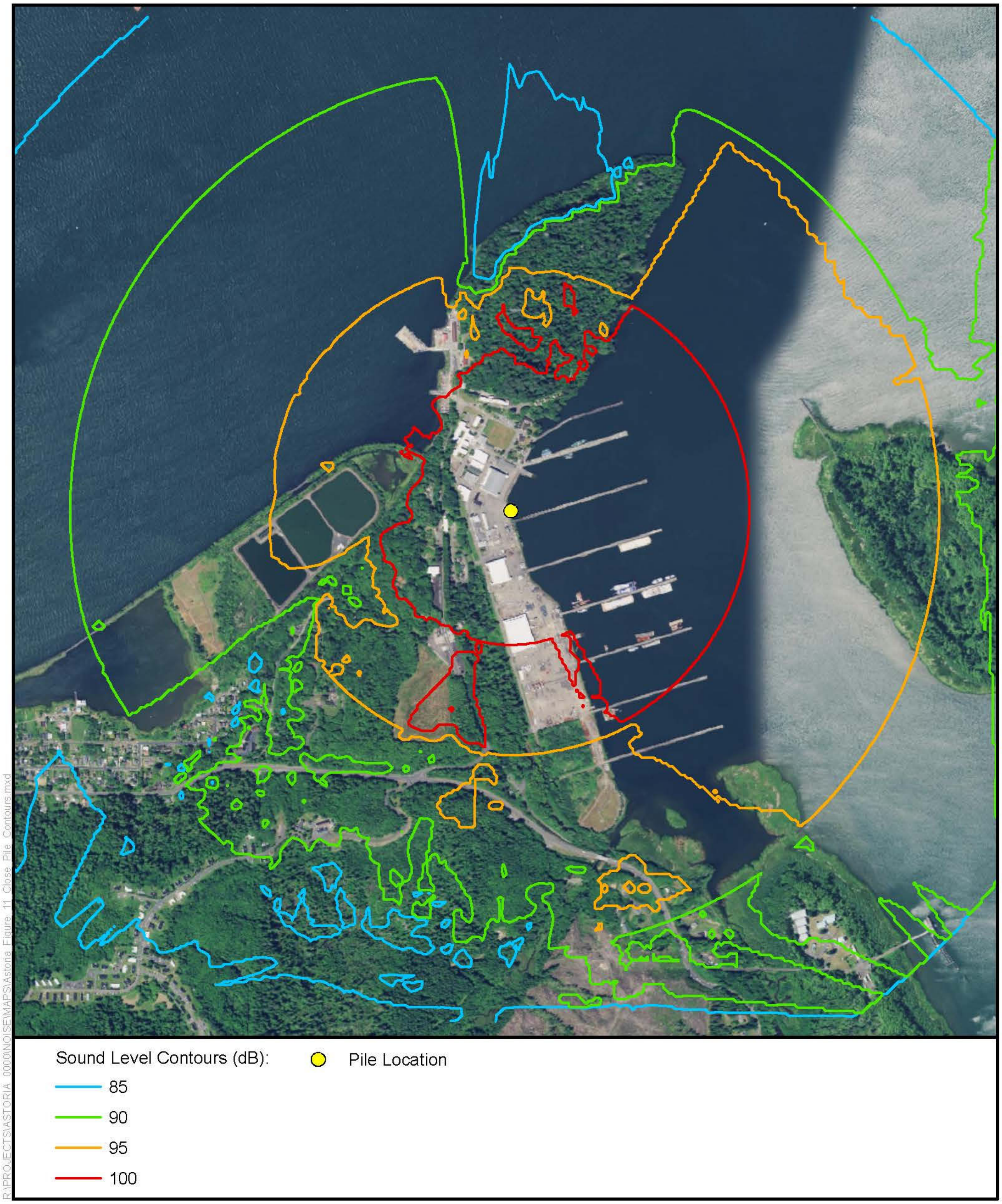
Date: 5/12/2023
Map Sources: ESRI

Figure 10: In-air Received Sound Levels: MWD Building

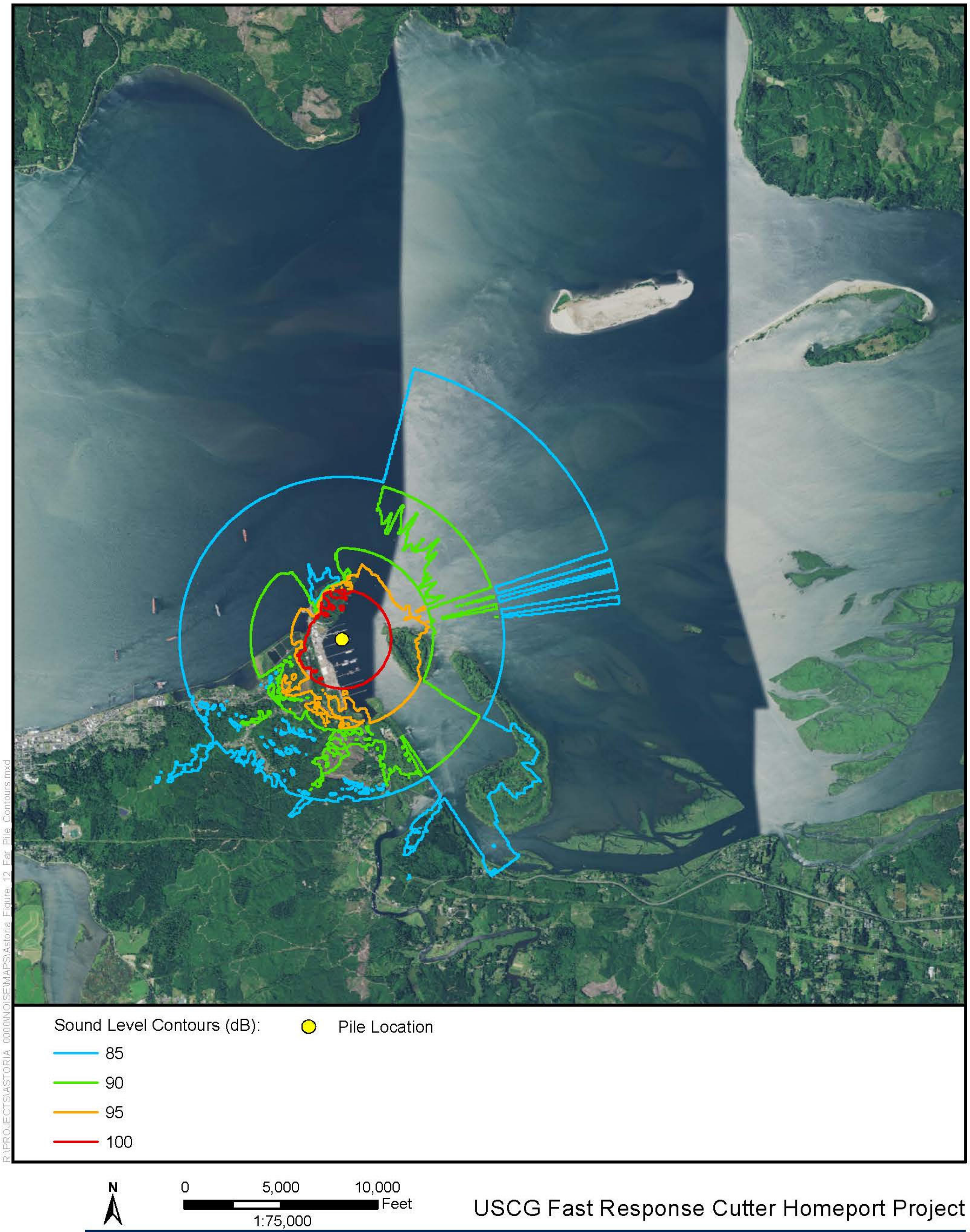


N
0 500 1,000 2,000 Feet
1:16,000

USCG Fast Response Cutter Homeport Project

Date: 5/12/2023
Map Sources: ESRI

Figure 11: In-air Received Sound Levels: Pile Driving (Closest to Shore)



Date: 5/12/2023
Map Sources: ESRI

Figure 12: In-air Received Sound Levels: Pile Driving (Furthest from shore)

A.7.2 Underwater Acoustics

As indicated earlier, using dBSea and site-specific parameters related to the marine environment and Project sound source characteristics, acoustic modeling was completed to assess distances to the various acoustic threshold levels identified in Section A.2.2. The modeling scenarios analyzed are described in Table and include impact pile driving activities for a 36-inch pile diameter and 30-inch pile diameter, and dredging. All those activities may occur at a representative location within the Project Area. The results for impact pile driving (36-inch and 30-inch piles) for the representative location, are shown in Tables 10 through 13. Results are presented without mitigation and with two different levels of mitigation: a 6-dB reduction and a 10-dB reduction. Noise mitigation requirements and methods have not been finalized at this stage of permitting; therefore, these two levels of reduction were applied to potentially mimic the use of noise mitigation options such as bubble curtains. The results in Table 10 indicate that the unmitigated distances to the L_{PK} thresholds are below 100 m. Thresholds to the PTS onset thresholds in terms of SEL are also provided. Similar results are given for fish, with ranges to applicable thresholds varying depending on the threshold value and sound level weighting. Expectedly, the largest ranges to thresholds are the ones for the marine mammal and fish behavioral response, which are 160 dB SPL and 150 dB SPL, respectively. **Error! Reference source not found.** shows the unweighted and unmitigated underwater received SPL for the 36-inch pile and 30-inch pile impact pile driving scenarios. Underwater SPL ranges are displayed in 10 dB increments and sound propagation characteristics are shown throughout the Project Area and beyond, as applicable.

Potential sound impacts were also evaluated for dredging at a representative location. Results are given in Tables 14 through 16. Due to the low sound source level associated with dredging, distances to the applicable acoustic thresholds in most cases are less than 700 m; however, the distance to the 120 SPL RMS threshold is approximately 3,700 m. Figure 14 shows the unweighted and unmitigated underwater received SPL for the dredging operation.

Potential sound impacts were also evaluated for vibratory hammer pile removal operations at a representative location. Results are given in Tables 17 through 19. Due to the low sound source level associated with the vibratory hammer, distances to the applicable acoustic thresholds in most cases are less than 20 m; however, the distance to the 120 SPL threshold is approximately 1,359 m.

The results of the underwater acoustic modeling analysis will be used to inform development of evaluation and mitigation measures that will be applied during construction of the Project, in consultation with NOAA Fisheries and any additional appropriate regulatory agencies. The Project will obtain necessary permits to address potential impacts to marine mammals and fisheries resources from underwater noise and will establish appropriate and practicable mitigation and monitoring measures through discussions with regulatory agencies.

Table 10. Marine Mammal PTS Onset Criteria Threshold Distances (meters) for Impact Pile Driving

Pile Type	Scenario	Hearing Group									
		LF cetaceans		MF cetaceans		HF cetaceans		Phocid pinnipeds		Otariid pinnipeds	
		219 dB $L_{p,pk}$ [1,2]	183 dB $L_{E,24hr}$ [1,2]	230 dB $L_{p,pk}$ [1,2]	185 dB $L_{E,24hr}$ [1,2]	202 dB $L_{p,pk}$ [1,2]	155 dB $L_{E,24hr}$ [1,2]	218 dB $L_{p,pk}$ [1,2]	185 dB $L_{E,24hr}$ [1,2]	232 dB $L_{p,pk}$ [1,2]	203 dB $L_{E,24hr}$ [1,2]
36-inch Pile	Unmitigated	--	485	--	--	75	287	--	197	--	--
	Mitigation (-6 dB)	--	374	--	--	17	160	--	101	--	--
	Mitigation (-10 dB)	--	271	--	--	---	101	--	72	--	--
30-inch Pile	Unmitigated	--	427	--	--	86	213	--	130	--	--
	Mitigation (-6 dB)	--	319	--	--	57	111	--	79	--	--
	Mitigation (-10 dB)	--	179	--	--	--	80	--	56	--	--

[1] NOAA Fisheries 2018

[2] Level A Injury PTS

Table 11. Fish Onset of Injury Threshold Distances (meters) for Impact Pile Driving

Pile Type	Scenario	Hearing Group							
		Fish: No Swim Bladder		Fish: Swim bladder not involved in hearing		Fish: Swim bladder involved in hearing		Eggs and Larvae	
		213 dB $L_{p,pk}$ [1,2]	219 dB $L_{E,24hr}$ [1,2]	207 dB $L_{p,pk}$ [1,2]	210 dB $L_{E,24hr}$ [1,2]	207 dB $L_{p,pk}$ [1,2]	207 dB $L_{E,24hr}$ [1,2]	207 dB $L_{p,pk}$ [1,2]	210 dB $L_{E,24hr}$ [1,2]
36-inch Pile	Unmitigated	--	--	34	21	34	62	34	21
	Mitigation (-6 dB)	--	--	--	--	--	--	--	--
	Mitigation (-10 dB)	--	--	--	--	--	--	--	--
30-inch Pile	Unmitigated	--	--	61	--	61	21	61	--
	Mitigation (-6 dB)	--	--	--	--	--	--	--	--
	Mitigation (-10 dB)	--	--	--	--	--	--	--	--

[1] Popper et al. 2014

[2] Mortality and Potential Mortal Injury

Table 12. Fish Acoustic Injury Threshold Distances (meters) for Impact Pile Driving

Pile Type	Scenario	Hearing Group			
		Small Fish		Large Fish	
		206 dB $L_{p,pk}$ [1,2]	183 dB $L_{E,24hr}$ [1,2]	206 dB $L_{p,pk}$ [1,2]	187 dB $L_{E,24hr}$ [1,2]
36-inch Pile	Unmitigated	57	496	57	420
	Mitigation (-6 dB)	--	384	--	302
	Mitigation (-10 dB)	--	302	--	170
30-inch Pile	Unmitigated	65	438	65	366
	Mitigation (-6 dB)	--	329	--	193
	Mitigation (-10 dB)	--	193	--	44

[1] Stadler and Woodbury 2009

[2] Small fish are fish less than 2 grams in weight. Large fish are 2 grams or larger.

Table 13. Marine Mammals and Fish Behavioral Response Criteria Threshold Distances (meters) for Impact Pile Driving

Pile Type	Scenario	Hearing Group	
		Fish	Marine Mammals
		150 dB L_p [1]	160 dB L_p [1]
36-inch Pile	Unmitigated	1202	602
	Mitigation (-6 dB)	712	444
	Mitigation (-10 dB)	572	367
30-inch Pile	Unmitigated	1202	602
	Mitigation (-6 dB)	712	444
	Mitigation (-10 dB)	572	367

[1] GARFO 2016

Table 14. Marine Mammal PTS Onset Criteria Threshold Distances (meters) for Dredging

Activity	Scenario	Hearing Group				
		LF cetaceans	MF cetaceans	HF cetaceans	Phocid pinnipeds	Otariid pinnipeds
		199 dB $L_{E,24hr}$ [1,2]	198 dB $L_{E,24hr}$ [1,2]	173 dB $L_{E,24hr}$ [1,2]	201 dB $L_{E,24hr}$ [1,2]	219 dB $L_{E,24hr}$ [1,2]
Dredging	Unmitigated	40	--	24	--	--
	Mitigation (-6 dB)	21	--	5	--	--
	Mitigation (-10 dB)	14		--	--	--

[1] NOAA Fisheries 2018

[2] Level A Injury PTS

Table 15. Fish Acoustic Injury Threshold Distances (meters) for Dredging

Activity	Scenario	Hearing Group	
		Small Fish	Large Fish
		183 dB $L_{E,24hr}$ [1,2]	187 dB $L_{E,24hr}$ [1,2]
Dredging	Unmitigated	676	590
	Mitigation (-6 dB)	383	124
	Mitigation (-10 dB)	143	49

[1] Stadler and Woodbury 2009

[2] Small fish are fish less than 2 grams in weight. Large fish are 2 grams or larger.

Table 16. Marine Mammals and Fish Behavioral Response Criteria Threshold Distances (meters) for Dredging

Activity	Scenario	Hearing Group	
		Fish	Marine Mammals
		150 dB L_p [1]	120 dB L_p [1]
Dredging	Unmitigated	88	3701
	Mitigation (-6 dB)	39	2504
	Mitigation (-10 dB)	26	1520

[1] GARFO 2016

Table 17. Marine Mammal PTS Onset Criteria Threshold Distances (meters) for Vibratory Hammer Pile Removal

Activity	Scenario	Hearing Group				
		LF cetaceans	MF cetaceans	HF cetaceans	Phocid pinnipeds	Otariid pinnipeds
		199 dB $L_{E,24hr}$ [1,2]	198 dB $L_{E,24hr}$ [1,2]	173 dB $L_{E,24hr}$ [1,2]	201 dB $L_{E,24hr}$ [1,2]	219 dB $L_{E,24hr}$ [1,2]
Vibratory Hammer	Unmitigated	0.8	0.1	1.2	0.5	--
	Mitigation (-6 dB)	0.3	--	0.5	0.2	--
	Mitigation (-10 dB)	0.2	--	0.3	0.1	--

[1] NOAA Fisheries 2018

[2] Level A Injury PTS

Table 18. Fish Acoustic Injury Threshold Distances (meters) for Vibratory Hammer Pile Removal

Activity	Scenario	Hearing Group	
		Small Fish	Large Fish
		183 dB $L_{E,24hr}$ [1,2]	187 dB $L_{E,24hr}$ [1,2]
Vibratory Hammer	Unmitigated	10	5
	Mitigation (-6 dB)	2	4
	Mitigation (-10 dB)	1	2

[1] Stadler and Woodbury 2009

[2] Small fish are fish less than 2 grams in weight. Large fish are 2 grams or larger.

Table 19. Marine Mammals and Fish Behavioral Response Criteria Threshold Distances (meters) for Vibratory Hammer Pile Removal

Activity	Scenario	Hearing Group	
		Fish	Marine Mammals
		150 dB L_p [1]	120 dB L_p [1]
Vibratory Hammer	Unmitigated	14	1359
	Mitigation (-6 dB)	5	541
	Mitigation (-10 dB)	3	293

[1] GARFO 2016

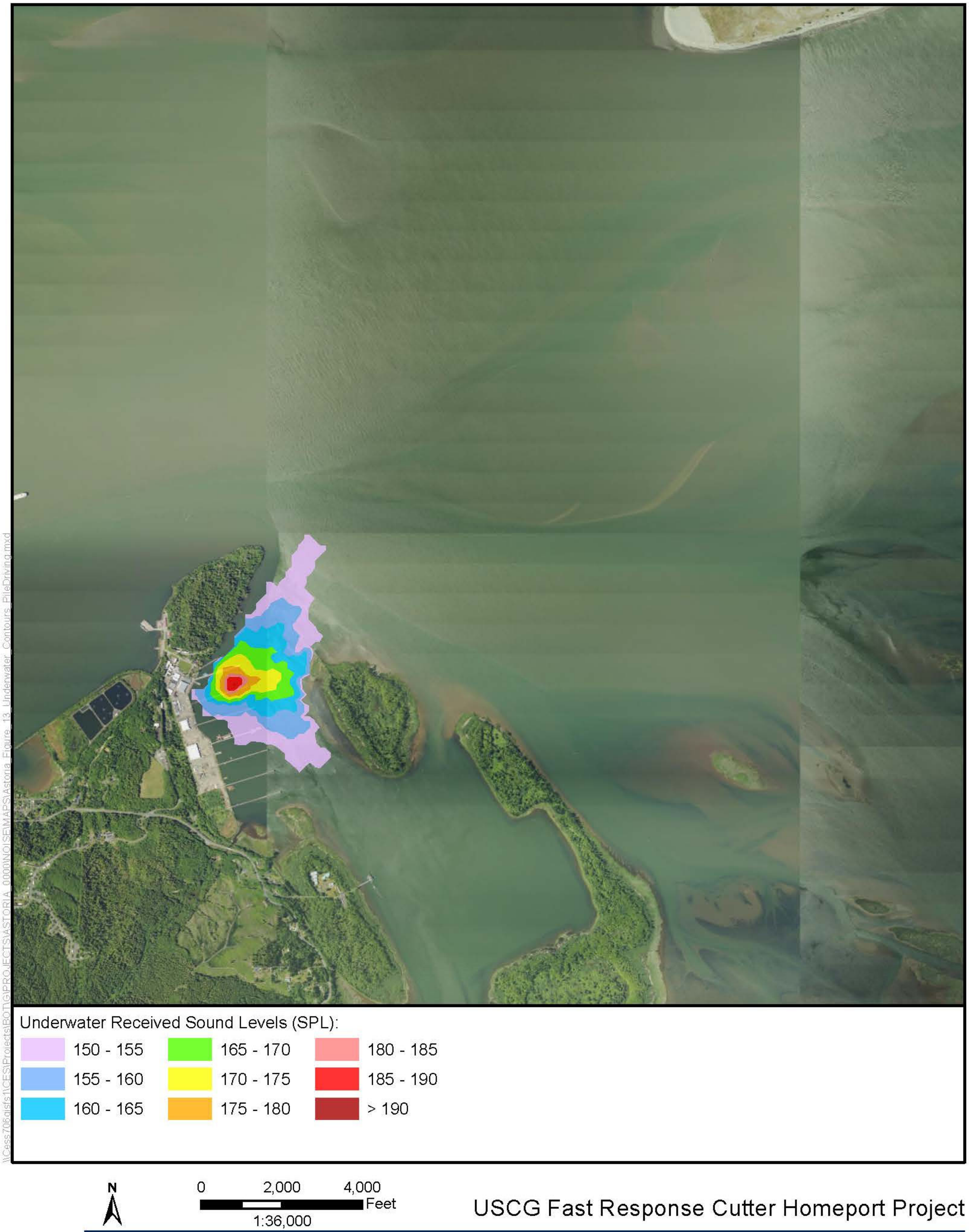


Figure 13: Underwater Received Sound Levels (SPL RMS): Impact Pile Driving (36-inch pile and 30-inch pile), Unmitigated

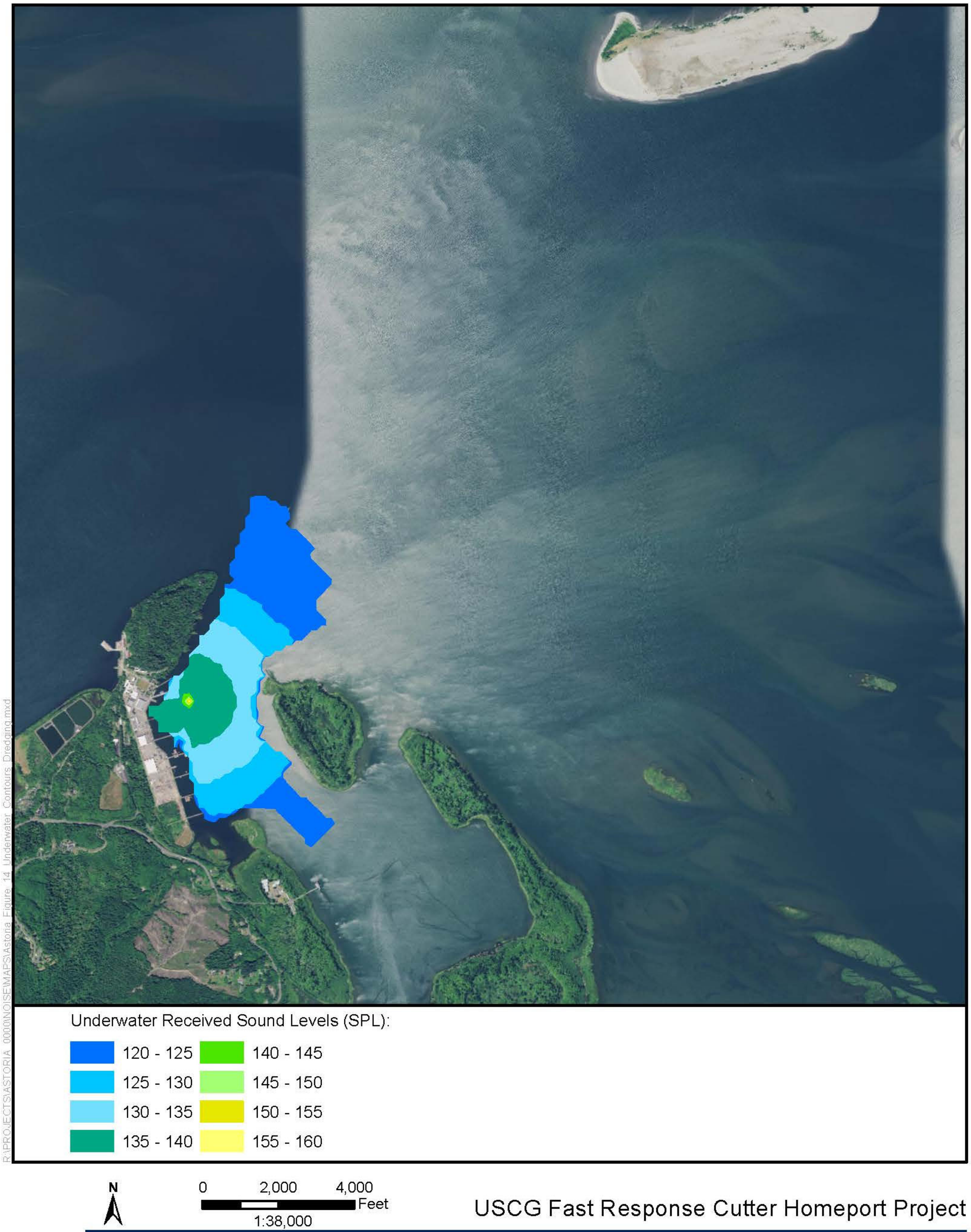


Figure 14: Underwater Received Sound Levels (SPL RMS): Dredging Operations

A.8 REFERENCES

Au, Whitlow W.L., and M. Hastings. 2008. *Principles of Marine Bioacoustics*. Springer Science & Business Media, New York, New York.

Austin, M., S. Denes, J. MacDonnell, and G. Warner. 2016. *Hydroacoustic Monitoring Report: Anchorage Port Modernization Project Test Pile Program. Version 3.0.* Technical report by JASCO Applied Sciences for Kiewit Infrastructure West Co.

Bellmann, Michael. 2014. *Overview of existing Noise Mitigation Systems for Reducing Pile-Driving Noise.* Inter-noise 2014. Melbourne, Australia. 16-19 Nov 2014. Available online at: https://www.acoustics.asn.au/conference_proceedings/INTERNOISE2014/papers/p358.pdf. Accessed 02 Dec 2020.

Bellmann, M., J. Schuckenbrock, S. Gündert, M. Müller, H. Holst, and P. Remmers. 2017. *Is There a State-of-the-Art to Reduce Pile-Driving Noise? Wind Energy and Wildlife Interactions* (pp. 161-172): Springer. Available online at: https://tethys.pnnl.gov/publications/there-state-art-reduce-pile-driving-noise. Accessed 02 Dec 2020.

Blackstock, S.A., J.O. Fayton, P.H. Hulton, T.E. Moll, K.K. Jenkins, S. Kotecki, E. Henderson, S. Rider, C. Martin, and V. Bowman. 2017. *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing*. Available online at: https://apps.dtic.mil/sti/citations/AD1046606. Accessed 02 Dec 2020.

California Department of Transportation (CALTRANS). 2020. Technical Guidance for the Assessment of Hydroacoustic Effects of Pile Driving on Fish.

Connell Wagner Pty Ltd. 2008. Adelaide Desalination Project Technical Report – Underwater Noise & Vibration.

Department of the Navy. 2017. Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). U.S. Navy SSC Pacific.

Elmer, K.H., K. Betke, T. Neumann et al. 2006. "Standard Procedures for the Determination and Assessment of Noise Impact on Sea Life by Offshore Wind Farms (German)." *Offshore Wind Energy pp 255-279.* Available online at: https://link.springer.com/chapter/10.1007%2F978-3-540-34677-7_16. Accessed 02 Dec 2020.

Elmer, K.H., and J. Savery. 2014. *New Hydro Sound Dampers to reduce piling underwater noise.* Inter-noise 2014. Melbourne, Australia. 16-19 Nov 2014. Available online at: https://tethys.pnnl.gov/sites/default/files/publications/Elmer_and_Savery_2014.pdf. Accessed 02 Dec 2020.

Farcas, Adrian, P.M. Thompson, and N.D. Merchant. 2016. "Underwater noise modelling for environmental impact assessment." *Environmental Impact Assessment Review, 57, pp.114–122.*

Fisher F.H and V.P. Simmons. 1977. "Sound absorption in seawater." *Journal of the Acoustical Society of America, 1977, vol. 62 3(pg. 558 -564).*

Francois, R. E., and G.R. Garrison. 1982a. "Sound absorption based on ocean measurements. Part I: Pure water and magnesium sulphate contributions." *Journal of the Acoustical Society of America, 72(3): 896–907.*

Francois, R. E., and G.R. Garrison. 1982b. "Sound absorption based on ocean measurements. Part II: Boric acid contribution and equation for total absorption." *Journal of the Acoustical Society of America, 72: 1879–1890.*

Hamilton, E.L. 1976. 'Geoacoustic modeling of the sea floor', Journal of the Acoustical Society of America, 68, 1313-1340.

Hamilton, E.L. 1982. 'Compressional Waves in marine sediments', Geophysics, 37 620-646.

Hamilton, E.L. and Bachman, R.T. 1982. 'Sound velocity and related properties of marine sediments', Journal of the Acoustical Society of America, 72, 1891-1904.

Koschinski, Sven and K. Lüdemann. 2013. *Development of noise mitigation measures in offshore wind farm construction.* Federal Agency for Nature Conservation.

Nedwell, Jeremy R., J. Langworthy, and D. Howell. 2004. *Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise.* Subacoustech Report Reference: 544R0424, November 2004, to COWRIE. Available online at: https://tethys.pnnl.gov/sites/default/files/publications/Noise_and_Vibration_from_Offshore_Wind_Turbines_on_Marine_Wildlife.pdf. Accessed 02 Dec 2020.

NOAA Fisheries (National Oceanic and Atmospheric Administration's National Marine Fisheries Service). 2018. 2018 Revisions 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.* U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p.

NOAA Fisheries. 2020. "NOAA Fisheries Greater Atlantic Regional Fisheries Office. GARFO Acoustics Tool: Analyzing the effects of pile driving on ESA-listed species in the Greater Atlantic Region." Available online at: https://www.fisheries.noaa.gov/new-england-mid-atlantic/consultations/section-7-consultation-technical-guidance-greater-atlantic. Accessed 02 Dec 2020.

NOAA Satellite and Information Service. 2005. NGDC. U.S. Coastal. Relief Model. 1999 to 2005. Available online at: https://www.ngdc.noaa.gov/mgg/coastal/crm.html**.** Accessed 02 Dec 2020.

Parola, J.F. 1970. *Mechanics of Impact Pile Driving*. Ph.D. Thesis, University of Illinois at Urbana-Champaign.

Popper, A.N., A.D. Hawkins, R.R. Fay, D. Mann, S. Bartol, T. Carlson, S. Coombs, W.T. Ellison, R. Gentry, M.B. Halvorsen, S. Lokkeborg, P. Rogers, B.L. Southall, D.G. Zeddies, and W.N. Tavolga. 2014. *ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*, pp. 33-51. Springer. Available online at: https://www.springer.com/us/book/9783319066585. Accessed 02 Dec 2020.

Richardson, W. J., C. R. Jr., Greene, C. I. Malme, C. I., and D. H. Thomson. 2013. *Marine Mammals and Noise.* Academic Press, New York. Available online at: https://www.elsevier.com/books/marine-mammals-and-noise/richardson/978-0-08-057303-8. Accessed 02 Dec 2020.

Silve, L.D., P.H. Kvadsheim, and M.A. Ainslie. 2014. "Potential for population-level disturbance by active sonar in herring." *ICES Journal of Marine Science* 72: 558-567.

Simmonds, M., S. Dolman, and L. Weilgart, eds. 2004. *Oceans of Noise - A WDCS Science Report. Chippenham, UK: Whale and Dolphin Conservation Society.* Available online at: https://whales.org/wp-content/uploads/2018/08/Oceans-of-Noise.pdf. Accessed 02 Dec 2020.

Southall, B. L., Finneran, J. J., Reichmuth, C., Nachtigall, P. E., Ketten, D. R., Bowles, A. E., Ellison, W. T., Nowacek, D. P., and Tyack, P. L. 2019. "Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects." *Aquatic Mammals 45, 125-232.*

Stadler, John H. and D.P. Woodbury. 2009. *Assessing the effects to fish from pile driving: Application of new hydroacoustic criteria.* 38th International Congress and Exposition on Noise Control Engineering 2009, Inter-noise 2009. Available online at: https://www.researchgate.net/publication/266212932_Assessing_the_effects_to_fishes_from_pile_driving_Application_of_new_hydroacoustic_criteria. Accessed 02 Dec 2020.

Wahlberg, M. 2012. "Contribution of Biological Sound Sources to Underwater Ambient Noise Levels." *Bioacoustics* 17(1-3):30-32. Available online at: https://doi.org/10.1080/09524622.2008.9753754. Accessed 02 Dec 2020.

Wenz, G. 1962. "Acoustic ambient noise in the ocean: Spectra and Sources." *Journal of Acoust. Soc. Am.*, Vol 34, p 1936.

APPENDIX A: Underwater Noise Model Methodology

TETRA TECH

Underwater Sound Propagation Modeling Methodology

Tetra Tech has developed a reliable and effective approach to evaluating underwater acoustic impacts from pile driving as well as other in-water activities. The underwater noise modeling methodology used to evaluate the Project pile driving activities is described below.

Underwater Sound Propagation Modeling

Tetra Tech uses dBSea for underwater sound propagation modeling. dBSea is a software program developed by Marshall Day Acoustics for the prediction of underwater noise. The three-dimensional model is built by importing bathymetry data and placing noise sources in the environment. Each source can consist of equipment chosen from either the standard or user-defined databases. Noise mitigation methods may also be included. The user has control over the seabed and water properties including sound speed profile ("SSP"), temperature, salinity, and current.

Noise levels are calculated throughout the entire Project Area and displayed in three dimensions. Levels are calculated in third octave bands. For the Project, two different solvers are used for the low- and high-frequency ranges:

- dBSeaPE (Parabolic Equation Method): The dBSeaPE solver makes use of the parabolic equation method, a versatile and robust method of marching the sound field out in range from the sound source. This method is one of the most widely used in the underwater acoustics community and offers excellent performance in terms of speed and accuracy in a range of challenging scenarios.
- dBSeaRay (Ray Tracing Method): The dBSeaRay solver forms a solution by tracing rays from the source to the receiver. Many rays leave the source covering a range of angles, and the sound level at each point in the receiving field is calculated by coherently summing the components from each ray. This is currently the only computationally efficient method at high frequencies.

The specific parameters used in the modeling analysis are described below.

Calculation Grid and Source Solution Setup

The calculation grid and source solution setup are based on the resolution and extents of the bathymetry data. The calculations within dBSea are made along each radial for each range point and depth point. Radials are generated from the source location out to the extent of the bathymetry area. The range points are generated along each radial and are evenly spaced out (range step). However, this spacing does not change if the source is moved. The number of "Radial slices" and "Range points" are entered, which represents the number of radial solution slices for each source and the evaluation range points along those slices (Figure B-1). The range points are determined based on the width and length of the modeled area as well as the required range step resolution (Equation 1).

$$Range\ Points = \frac{\sqrt{Width^2 + length^2}}{\text{Range Step}} \quad (1)$$

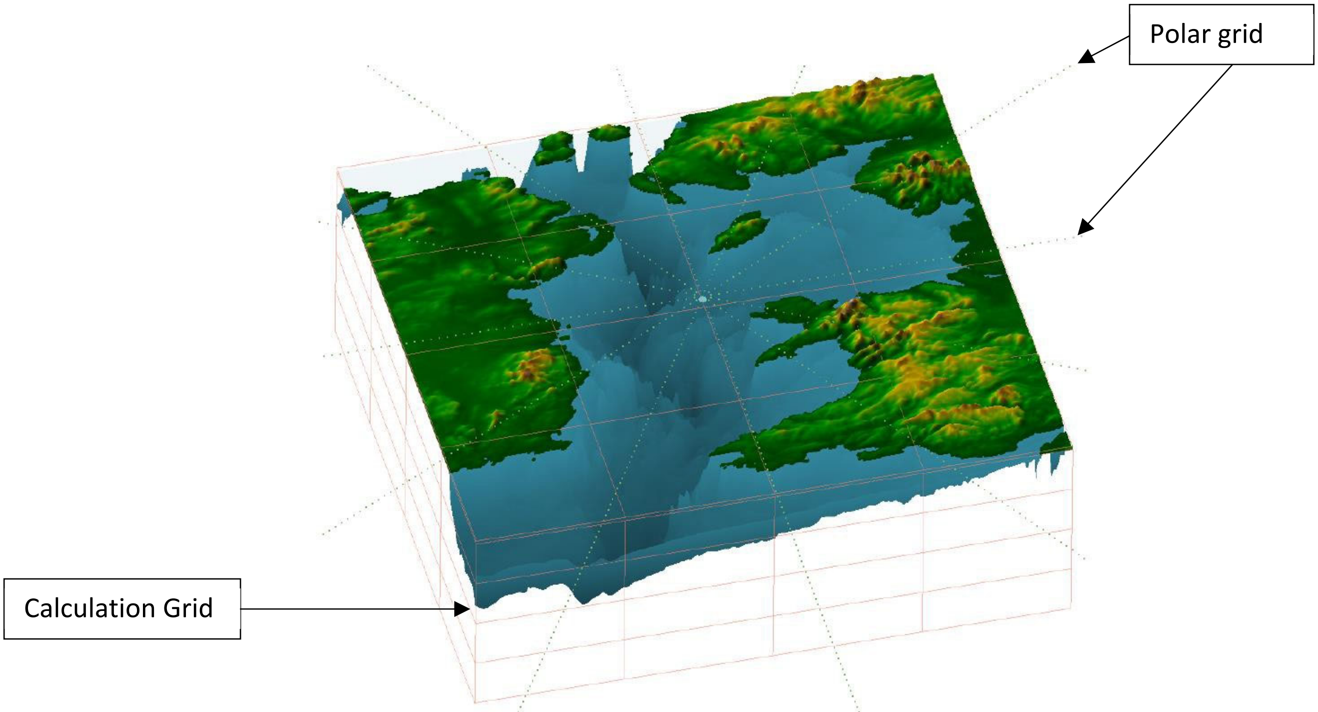


Figure B-1 Example Radial Solution Points

dBSea source solution calculations are completed along the radials (polar grid) based on the defined range and depth points. The calculation grid (cartesian) is filled from the polar grid using the nearest neighbor sampling, i.e., a point in the calculation results grid takes the value of the closest point in the polar grid. The calculation steps in dBSea are summarized below:

- Calculations are done in the polar grid (radials) at multiple depths, which are the same depths as the (cartesian) calculation grid.
- The calculation of the polar grid is smoothed with a triangular kernel, the width of which is selected by the user.
- The results of the cartesian grid is filled by the nearest neighbor sampling from the calculated polar grid using an inverse distance.

The more radials and range points used, the less interpolation needed for the cartesian grid. Because the calculation happens in the polar grid, while the results grid is cartesian, every point in the cartesian grid is "filled" depending on what point of the polar grid it is closest to (Figure B-2).

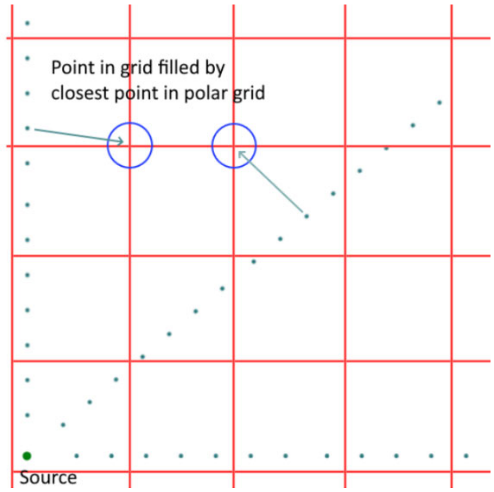
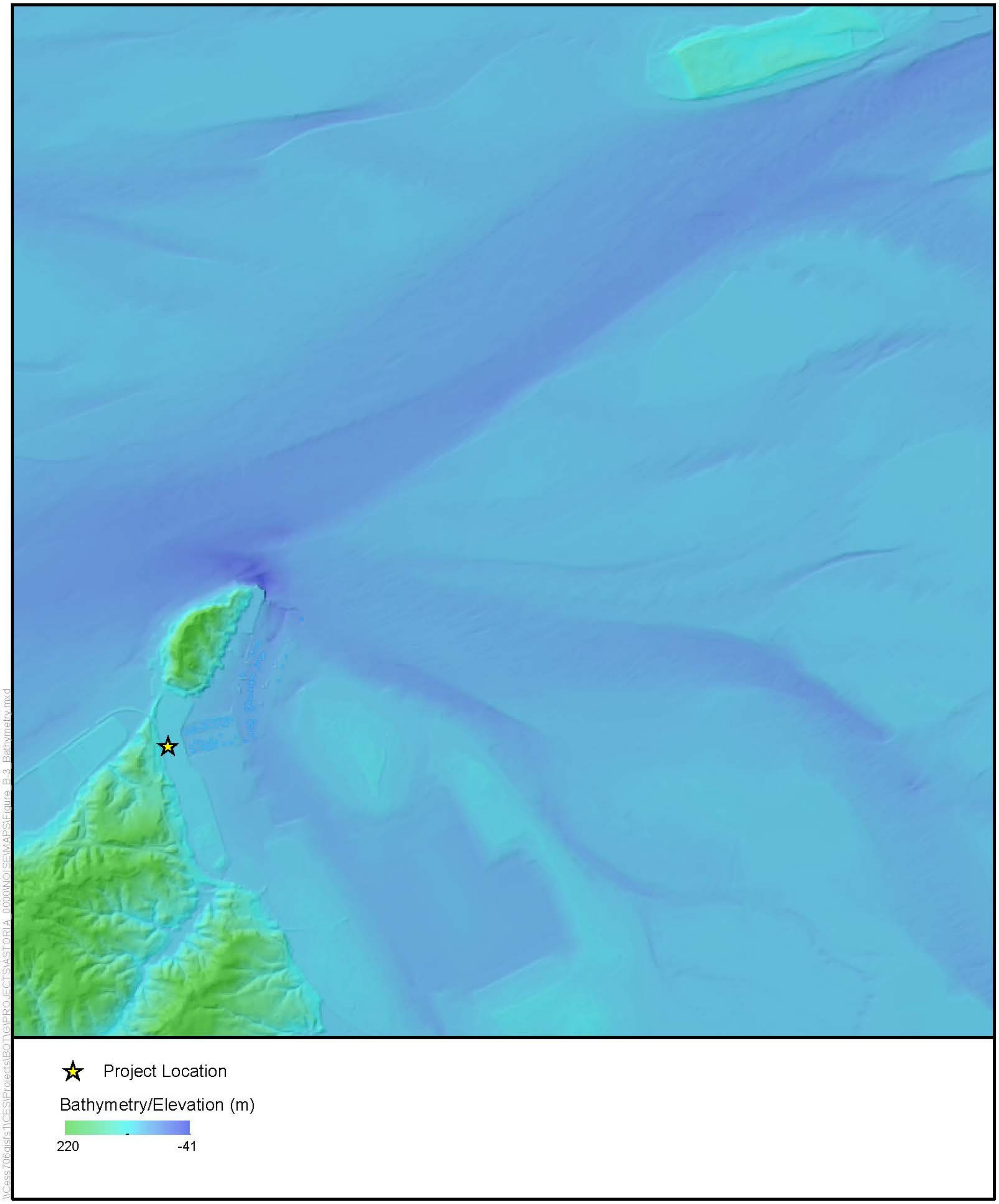


Figure B-2 Example Cartesian Grid Calculation

The underwater acoustic modeling analysis for the Project used a split solver, with dBSeaPE evaluating the 12.5 Hz to 800 Hz range and dBSeaRay addressing the 1 kHz to 20 kHz range. The radial resolution was 10-degree intervals to the extent of the bathymetry. The specific parameters used in the modeling analysis are described below.

Bathymetry

Bathymetry data for the Project was obtained from the National Geophysical Data Center 2003 U.S. Coastal Relief Model Volume 8. (NOAA Satellite and Information Service 2003); the horizontal resolution of this dataset has an approximate grid spacing of 73 meters. National Geophysical Data Center's U.S. Coastal Relief Model provides the first comprehensive view of the U.S. coastal zone, integrating offshore bathymetry with land topography into a seamless representation of the coast. The bathymetry for the project area is shown in Figure B-3.



N
0 2,000 4,000
Feet
1:38,000

USCG Fast Response Cutter Homeport Project

Date: 7/20/2023
Map Sources: ESRI

Figure B-3: Project Bathymetry

The geoacoustic properties including compositional data of the surficial sediments were informed by site by site-specific geophysical and geotechnical data presented in the sediment characterization report (Shannon & Wilson 2021). The sediment profile is presented in Table 1. The geoacoustic properties given in Table 1 were directly input into dBSea for each defined sediment layer. Each sediment layer is entered directly into dBSea. The parameters entered for each sediment layer is bulleted below:

- Sediment layer depth (provided by the client)
- Material name (provide by the client)
- Speed of sound (meters/second)
- Density (kilograms per cubic meter)
- Attenuation (dB/wavelength)

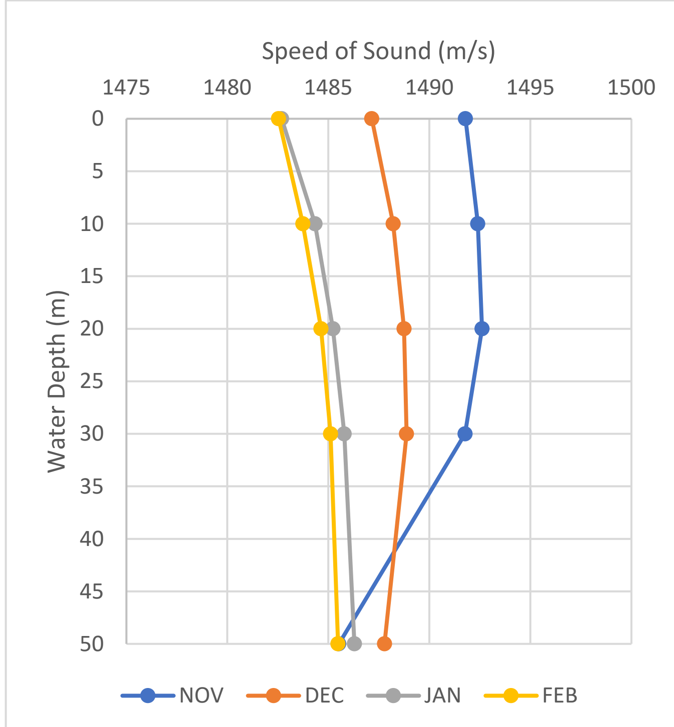
The acoustic parameters (speed of sound, density, and attenuation) are typically taken from Jensen et al. (2011), Hamilton (1976, 1982), and Hamilton and Bachman (1982).

Table 1. Geoacoustic Properties of Sub-bottom Sediments as a Function of Depth

Depth	Speed of Sound	Geoacoustic Properties
0 to 4	Silt	Cp = 1575 m/s αs (dB/λ) = 1.0 dB/ λ ρ = 1700 kg/m^3
4 to 8	Sand-silt	Cp = 1612 m/s αs (dB/λ) = 0.9 dB/ λ ρ = 1800 kg/m^3
8 to 15	Sand	Cp = 1650 m/s αs (dB/λ) = 0.8 dB/ λ ρ = 1900 kg/m^3
15 to 50	Clay	Cp = 1500 m/s αs (dB/λ) = 0.2 dB/ λ ρ = 1500 kg/m^3
Sources: Shannon & Wilson 2021 and Jensen 2011		

Speed of Sound Profile

Sound speed profile information for the year was obtained per month for the construction period. The speed of sound profile was obtained using the NOAA Sound Speed Manager software incorporating the World Ocean Atlas 2009 extension algorithms. Pile-driving will take place from November to February, and only taking place in the daytime. A sensitivity analysis was completed evaluating the sound propagation during the construction months. Based on the sensitivity analysis, the January sound speed profile was selected since applying it resulted in sound propagating furthest from the source., and the input is shown in Figure B-3.



Pile Driving Sound Source Characterization

The pile-driving sound source level was represented using three different metrics: peak sound level ("Lpk"), sound exposure level ("SEL"), and sound pressure level ("SPL"). The sound source spectrum is entered for each one-third octave band from 12.5 Hz to 20kHz.

For the Lpk underwater acoustic modeling scenario, the pile-driving sound source was represented as a point source at mid-water depth. The Lpk scenario evaluates a single pile-driving strike.

For the SEL underwater acoustic modeling scenario, the pile-driving sound source was represented by a moving source, which accounts for the speed of sound of steel for the pile itself. The pile-driving scenarios were modeled using a vertical array of point sources spaced at 0.5-meter intervals. Using the SEL level calculated by the empirical model, the SEL sound source is calculated using the following equation to distribute the sound emissions across the vertical array:

$$L_{E,N} = L_{E,\,1\,strike} + 10Log(N) \qquad (2)$$

Where: N is the number strikes

$L_{E,\,1\,strike}$ is obtained from CALTRANS published data (CALTRANS 2020)

The SPL underwater acoustic modeling scenario is set up identical to the SEL underwater acoustic modeling scenario. The difference regarding the SPL underwater acoustic modeling scenario is that the total number of anticipated pile-driving blows in the 24-hour assessment period is not incorporated into the calculation. For the SPL underwater acoustic modeling scenario, only a single pile-driving strike is evaluated.

Dredging Sound Source Characterization

The dredging source was modeled as a point source at mid-water depth. The dredging source spectrum was entered for each one-third octave band from 12.5 Hz to 20 kHz.

Time Domain Considerations

Tetra Tech also recognizes the effect time has on pile driving sound. As Bellman (2020) reports, the noise of a single strike is thus temporally stretched with increasing distance. Additionally, the amplitude decreases steadily with the distance to the source, so that the signal-to-noise-ratio continuously decreases. Figure 5 from Bellman (2020) illustrates the change in signal over time.

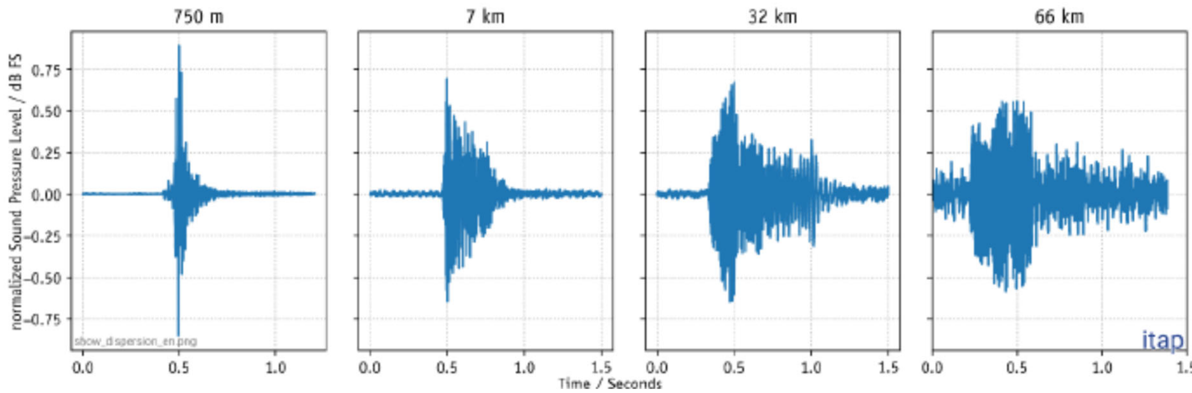


Figure 5. Time signal of a single strike, measured in different distances to the pile-driving activity (Bellman 2020)

The L_{PK} levels tend to decrease faster than the SEL sound levels as the propagation occurs. There are mixed views on whether the impulsivity of signals decrease over time, suggesting that non-impulsive limits should be applied to assess underwater acoustic impacts. While impulsivity may decrease, it is still observed that the rise times associated with impulsive signals are maintained (Martin et al. 2020). This is especially true when considering the narrow temporal windows (high temporal resolution) of many cetaceans and after application of weightings, excluding lower frequencies.

dBSea can account for the effects of the time domain using two different mechanisms. If time series information is available for use in the modelling analysis, it can be directly loaded into dBSea and used as sound source. The gaussian beam raytracer (dBSeaRay) will calculate the paths and arrival times from the source to all receiver points in the scenario for all the rays emitted from the source. At every receiver point, the transmission loss, phase inversion from the surface, loss to the sediment, and time of arrival is stored. This information is used to convolve all ray-arrivals into a single signal at that point. This means that each receptor point will receive a signal from many perceived origins and at various arrival times (depending on the length of the path travelled). This tends to “smooth” out and stretch the received signal at greater ranges or with more reflections.

Alternatively, if time series data are not known or available, dBSea can include a crest factor, which is a way to incorporate impulsiveness information into the source. The crest factor indicates the dB level above the rms level of the highest peak in the signal. It is applied when assessing peak levels and is applied to all frequency bands. Application of the crest factor is generally expected to yield more conservative results relative to using a time series for characterizing pile-driving sound source levels. Since time series data for the Project’s pile-driving activities were not available at the time of the modelling analysis, Tetra Tech used the conservative crest application methodology.

References

Bellman, M.A., A. May,, T. Wendt, S. Gerlach, P. Remmers, and J. Brinkmann. 2020. Underwater noise during percussive pile driving: Influencing factors on pile-driving noise and technical possibilities to comply with noise mitigation values. ERa Report.

California Department of Transportation (CALTRANS). 2020. Technical Guidance for the Assessment of Hydroacoustic Effects of Pile Driving on Fish.

Hamilton, E.L. 1976. Geoacoustic modeling of the sea floor. *Journal of the Acoustical Society of America*, 68, 1313-1340.

Hamilton, E.L. 1982. Compressional Waves in marine sediments. *Geophysics*, 37 620-646.

Hamilton, E.L. and Bachman, R.T. 1982. Sound velocity and related properties of marine sediments. Journal of the Acoustical Society of America, 72, 1891-1904.

Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. 2011. Computational Ocean Acoustics, 2nd edition, Springer.

Martin, B., K. Lucke, and D. Barclay. 2020. Techniques for distinguishing between impulsive and non-impulsive sound in context of regulating sound exposure for marine mammals. *The Journal of the Acoustical Society of America* 147, 2159.

NOAA Satellite and Information Service. 2020. U.S. Coastal Relief Model. 1999 to 2005. Available online at: https://www.ngdc.noaa.gov/mgg/coastal/crm.html. Accessed December 13, 2020.

Shannon & Wilson, Inc. 2021. Geotechnical Engineering Report Correct Shoreline Erosion United States Coast Guard Station Florence, Oregon.

World Ocean Atlas. 2009. NOAA Atlas NESDIS 68, U.S. Government Printing Office, Washington, D.C. *Available online at:* https://www.ngdc.noaa.gov/mgg/coastal/crm.html*.*

APPENDIX B: Pile Driving Sound Source Spectrum Development

Pile Driving Sound Source Spectrum Development

Tetra Tech has developed a reliable and effective approach to evaluating sound source levels for impact pile driving operations. In-water construction pile driving is typically the loudest activity and therefore analysis of pile driving impacts is critical during the permitting process. The development of the impact pile driving source levels is described below.

Pile Driving Sound Source Spectrum Development

Tetra Tech has developed an empirical modeling approach where source spectrum levels are derived based on published data from measurement studies that incorporated similar pile diameters (see references). The spectrum for the pile is based on pile diameters ranging from 0.61 m to 4 m. The reference spectrum for the impact piling is presented in Figure 1. This spectrum is then scaled to match the broadband levels presented in Table 8 of the report.

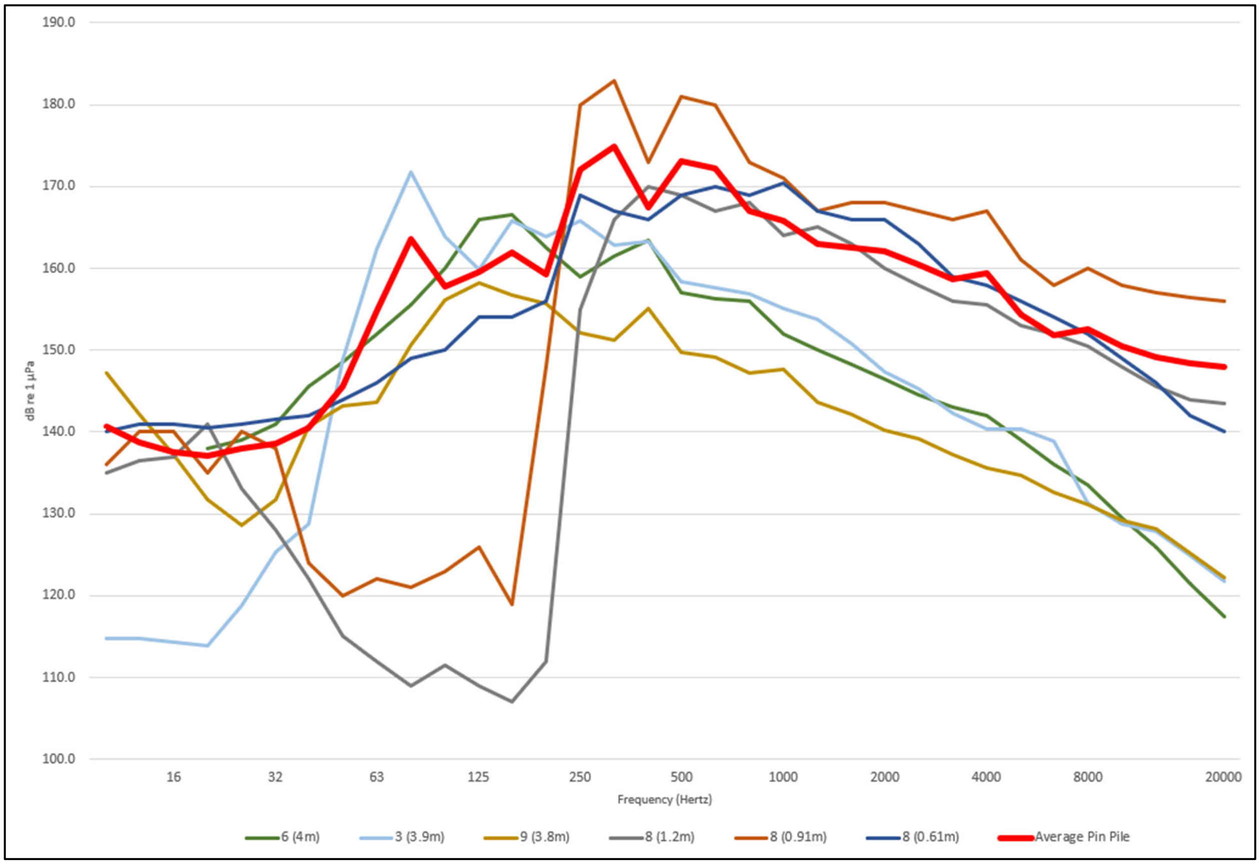


Figure 1. Impact Pile Driving Spectrum (Red)

Please refer to the references section for the supporting documentation that has been used to support the development of the pile driving sound source empirical model. The references used to develop the spectrum can be referenced based on the numbering of the references.

Source References

1. Bailey, H., Senior, B., Simmons, D., Rusin, J., Picken, G., Thompson, P.M. (2010). Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Marine Pollution Bulletin 60:888-897.
2. Blackwell, S.B. 2005. Underwater measurements of pile driving sounds during the Port Mackenzie dock modifications, 13-16 August 2004. Report from Greeneridge Sciences
3. Brandt, M.J., Diederichs, A., Betke, K., Nehls, G. 2011. Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Marine Ecology Progress Series 421:205-216.
4. Caltrans. 2015. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish.
5. Dawoud, W. Negm, A., Saleh, N., Bady, M. 2016. Impact Assessment of Offshore Pile Driving Noise on Red Sea Marine Mammals.
6. De Jong, C.A.F. & Ainslie, M.A. 2008. Underwater radiated noise due to the piling for the Q7 Offshore Wind Park. Journal of the Acoustical Society of America, 123:2987.
7. itap Gmbh. Offshore Wind Farm "Baltic Eagle" Prognosis of the expected underwater sound emissions during pile-driving work. January 2019
8. NAVFAC. 2017. Pile Driving Noise Measurements at Atlantic Fleet Naval Installations: 28 May 2013 – 28 April 2016.
9. Norro, A., Haelters, J., Rumes, B., Degraer, S. 2010. Underwater noise produced by the piling activities during the construction of the Belwin offshore wind farm.
10. Stephen P. Robinson, Peter D. Theobald, and Paul A. Lepper. 2012. Underwater sound from marine pile driving
11. Yang, L., Xu, X., Huang, Z., & Tu, X. 2015. Recording and Analyzing Underwater Noise During Pile Driving for Bridge Construction. Acoustics Australia, 43:159-167.