Request for Incidental Harassment Authorization
Biorka Island Dock Replacement

Sitka, Alaska

Federal Aviation Administration (FAA)
Alaskan Region
Anchorage, Alaska 99513

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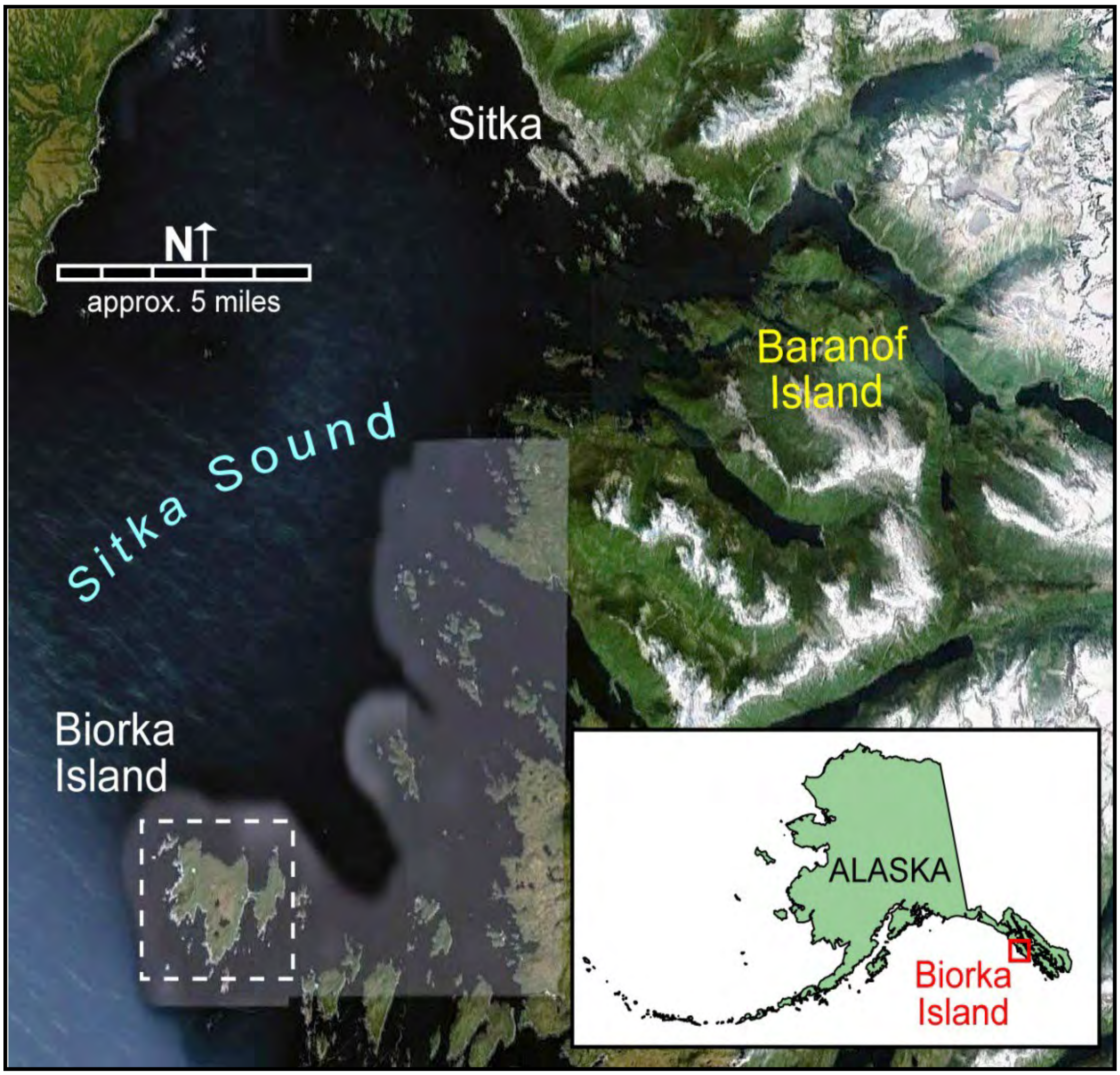
1. DESCRIPTION OF THE ACTIVITY

1.1. Introduction

The Federal Aviation Administration (FAA) is proposing to construct a replacement dock on Biorka Island in Symonds Bay near Sitka, Alaska (hereafter referred to as the Project). The Project is located approximately 15 miles (24 kilometers [km]) southwest of Sitka on the northern shore of Biorka Island on land owned by the FAA (Figure 1-1). Biorka Island is the most westerly and largest of the Necker Island group on the west coast of Baranof Island (Figure 1-2). Figure 1-3 provides a view from the dock location to the mouth of Symonds Bay.

FIGURE 1-1. PROJECT LOCATION



Source: USACE 2013

FIGURE 1-2. BIORKA ISLAND DOCK LOCATION

Source: USACE 2013

FIGURE 1-3. VIEW OF SYMONDS BAY FROM THE DOCK LOCATION

Source: R&M 2016

The FAA navigational aids located on Biorka Island are critical in supporting the main north-south air routes and international routes from the Seattle Tacoma International Airport. In addition to supporting major air routes to Alaska from Seattle, the Next Generation Weather Radar (NEXRAD) system for southeast Alaska is located on Biorka Island. This system provides weather data to the National Weather Service and FAA Automated Flight Service Station located in Juneau, Alaska.

As a federally funded project, the Biorka Island dock replacement is subject to review and the requirements of federal environmental statutes and regulations including the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). The MMPA prohibits the taking[1] of marine mammals except under certain situations. Sections 101 (a) (5)(D) of the MMPA allows for the issuance of an Incidental Harassment Authorization (IHA), provided an activity results in negligible impacts on marine mammals and would not adversely affect subsistence use of these animals.

The proposed Project would occur in marine waters that support several marine mammal species. The timing and duration of specific Project-related activities may result in the incidental taking by acoustic harassment of marine mammals protected under the MMPA. Incidental take is an unintentional, but not unexpected, take of a marine mammal. The demolition and replacement of the Biorka Island dock would be accomplished using a variety of pile removal and installation methods including a combination of vibratory hammers, impact hammers, and drilling methods that may result in the incidental take of marine mammals by acoustic harassment. Therefore, the FAA is requesting an IHA from the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) for the take by harassment of five marine mammal species under their jurisdiction that may occur in the vicinity of the Project including harbor seals, Steller sea lions, humpback whales, killer whales and harbor porpoise.

While the demolition and reconstruction of the dock has the potential to take marine mammals by harassment, it is not expected to result in serious injury or mortality of any marine mammal. Specifically, the FAA is requesting that NMFS issue an IHA in October 2017, effective for a 12-month period, allowing for the non-lethal taking of small numbers of marine mammals by acoustic harassment incidental to the proposed activities that would be conducted during all demolition and re-construction phases of the Project. This request is submitted pursuant to Section 101 (a) (5)(D) of the MMPA, 16 USC 1371.101 (a) (5), and 50 CFR 216, Subpart I.

1.2. Purpose and Need for Action

The purpose of the Project is to improve and maintain the sole point of access to Biorka Island and the navigational and weather facilities located on the island. The existing dock is deteriorated and has reached the end of its useful life (Figure 1-4). Regular and repetitive heavy surging seas, along with constant use have destroyed the face of the existing floating marine dock. Cleats have been broken by heavy seas and it is difficult to tie a vessel to the existing dock. In its present condition, small vessels cannot use the dock to provide supplies to facilities on the island (E. Majeski, pers. comm.). The existing barge landing area is reinforced seasonally by adding fill to the landing at the shoreline, which is periodically washed away by

[1] "Take" is defined under the MMPA (16 USC 1362) and further defined by regulation (at 50 CFR 216.3) as "to harass, hunt, capture, collect, or kill, or attempt to harass, hunt, capture, collect, or kill any marine mammal. Take is further defined under the ESA as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."

storms and wave action. The Project would reconstruct the deteriorated existing dock and construct an improved barge landing area.

FIGURE 1-4. EXISTING DOCK AT BIORKA ISLAND

The Project is needed to address safety issues associated with continued use of the existing dock. Replacing the dock and barge landing with modern infrastructure is necessary to provide continued reliable and safe access to Biorka Island.

1.3. Proposed Action

The Proposed Action consists of removing the existing dock and associated infrastructure and constructing a new, modern structure to provide continued safe access to Biorka Island facilities. The existing barge landing would be improved to minimize seasonal maintenance and to provide a structurally sufficient landing area.

1.3.1. Demolition of Existing Dock and Pile Removal

The existing dock is a T-shaped, pile-supported structure consisting of a 170-foot (ft) long by 16-ft wide approach trestle with a 51-ft wide by 35-ft long end section. The existing infrastructure also includes a 30-ft by 32-ft floating dock that is accessed by a 5-ft wide by 50-ft long steel gangway, a small 10-ft by10-ft pre-fabricated building, and an electric hydraulic pedestal crane.

A total of 46 existing piles would be removed (Table 1-1). The steel and timber piles would be pulled out of the substrate directly with a crane and sling, by using a vibratory hammer, or with a clamshell bucket. The three concrete piles that are located above the high tide were cast in place. The concrete piles are set in bedrock and will be removed at low tide using standard excavation equipment. Therefore, removal of these piles will not produce underwater noise. The construction contractor would determine the exact method for concrete pile removal.

TABLE 1-1. EXISTING PILES TO BE REMOVED

Pile Type	Quantity	Size *(in.)*
Concrete	3	24
Steel	14	8
	8	10
	14	12.75
Timber	7	14 tapering to 8

The existing deck and other associated infrastructure would also be disassembled and removed. The existing 4-ton pedestal crane would be salvaged for relocation on the new dock. As necessary, portions of the existing rubble mound/breakwater would be removed to provide enough clearance for construction and then replaced once the dock has been constructed.

1.3.2. Construction of New Dock and Barge Landing

Facilities for the new dock consist of three main structures: a barge landing platform, a dock/trestle, and two dolphin fenders located near the dock outer corners (Figure 1-5). For these structures, temporary piles would be installed to form a scaffold system (i.e., a template) that permits the permanent piles to be aligned and controlled. With the exception of the temporary piles which are driven exclusively by vibratory pile driving, the installation of all permanent piles requires a combination of pile driving methods.

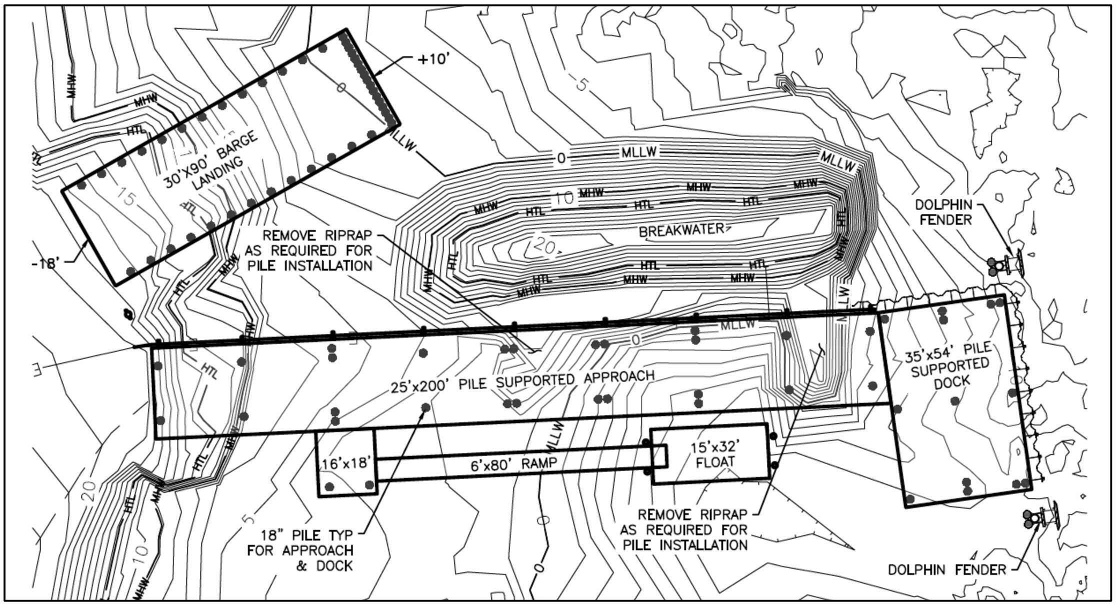
1.3.2.1. Template Piles

Construction of the new dock would begin with the erection of a temporary template. The construction contractor would determine the specific type and size of template piles based on site conditions and availability of materials. The template piles would be driven into the overburden by vibratory hammer and removed after the permanent piles are installed. Table 1-2 shows the anticipated number of template piles for the Project.

1.3.2.2. New Dock and Dolphin Moorings

The new trestle approach would be up to 25 ft wide. An 80-ft aluminum gangway connecting to a 15-ft wide by 32-ft long small craft berthing float would also be constructed (see Figure 1-5). The face of the dock would be approximately 54-ft long and 35-ft wide. Similar to the trestle, steel pipe pilings would support a precast concrete deck. Two berthing dolphin fenders would be installed, one at each end section of the new dock. These dolphins each consist of one 30-inch (in.). diameter plumb pile and two 18-in. diameter batter piles. Some piles would require internal tension anchors for increased support. A wave barrier, consisting of Z-sheet piles in between steel H piles, would be installed at the face of the dock. Pile counts, sizes, and other details are shown in Table 1-2.

FIGURE 1-5. MAIN STRUCTURES FOR THE BIORKA DOCK REPLACEMENT PROJECT



Source: Appendix A (Quijano and Austin 2017)

TABLE 1-2. TEMPORARY AND PERMANENT PILE DETAILS

Component	Stage	Type	Quantity	Size
Dock[1,2]	Template[3]	Steel H or Pipe	60	12 in.
	Permanent	Steel Pipe	43	18 in.
Wave Barrier	Permanent	Sheet	32	NZ26
	Permanent	Steel H	16	W40x199
Dolphin Fenders[4]	Template[3]	Steel H or Pipe	4	12 in.
	Permanent	Steel Pipe	4	18 in.
	Permanent	Steel Pipe	2	30 in.
Barge Landing	Template[3]	Steel H or Pipe	20	12 in.
	Permanent	Steel Pipe	35	18 in.
	Permanent	Sheet	34	NZ26
Total	Template[3]		84	
	Permanent		166	

[1]Includes piles for the approach, end section, platform, and floating dock.
[2]Number of piles for dock is based on 25-ft approach trestle width.
3Noise from installation and removal of the template piles is considered in the analysis, therefore template pile count equates to two times 84 or 168 but the actual number of piles to be installed is 84. Template piles were assumed to be 12-in. diameter for modeling.
[4]For two dolphin fender systems.

Permanent Piles

All permanent pipe piles would be installed using a combination of vibratory and impact hammering methods to drive the pile into the overburden. Pipe piles would then be drilled and socketed into the underlying bedrock using down-the-hole (DTH) hammering/drilling techniques. DTH equipment breaks up the rock below the pile while simultaneously installing the pile through rock formation. The pile is then set/confirmed with a few strikes of an impact hammer. Sheet piles would be driven into the overburden and set into the top layer of bedrock using a combination of vibratory and impact hammering.

Tension Anchors

Certain piles would require internal tension anchors. Up to eight of the dock piles and all six piles for the dolphins would require these internal tension anchors. Each pile with a tension anchor would first be drilled, socketed into bedrock, and proof driven with an impact hammer as described above for permanent piles. Then a separate smaller drill would be used to complete an approximately 5-in. diameter hole extending about 30 to 40 ft into bedrock below the tip of the pile. A steel bar would be grouted into this hole. Once the grout sets, a jack would be applied to the top of the bar and the tensioned rod would be locked off to plates at the top of the pile.

Permanent Wave Barrier

The wave barrier consisting of steel H piles with Z sheets in between is located at the face of the dock. The H piles and Z sheets would be initially driven through overlying sediment with a vibratory hammer, and set into the bedrock with an impact hammer. The wave barrier sheet piling would be driven either singly or in preassembled pairs.

1.3.2.3. Improved Barge Landing

The current barge landing is located northwest of the existing dock and is comprised of gravel and cobbles with no formal structure. The uplands area on the west end of the trestle would be slightly graded into the existing terrestrial approach. The existing barge landing would be upgraded to a 30-ft by 90-ft precast concrete plank landing placed over fill, with a perimeter constructed of concrete, sheet piles, and 18-in. steel piles (see Table 1-2). Similar to the wave barrier, the sequence for installing the permanent barge ramp pipe piles would begin with advancement through overlying sediment with a vibratory hammer, followed by use of an impact hammer to drive the piles into bedrock.

1.4. Description of the Action Area

The FAA considers the Action Area for this Project distinct from, and larger than, the immediate footprint of the dock and barge landing (see Figure 1-2) because some of the noise-producing elements of the Project may affect marine mammal species at a distance. Therefore, for purposes of this IHA application, the Action Area is defined consistent with ESA regulations[2] as the area within which all direct and indirect effects of the Project could occur. Thus, the Action Area extends out to a point where no measurable effects from the Project are expected to occur. This includes the zone radiating from the noise source at the dock out to a distance where marine mammals are no longer affected by the underwater and

[2] 50 CFR 402.02

in-air sounds produced by the actions that might result in Level A (potential injury) and Level B takes (behavioral disturbance or harassment) to marine mammals as defined in the MMPA, and consistent with NMFS acoustic injury guidelines (NMFS 2016)[3]. Because of the configuration of Symonds Bay (see Figure 1-2), the distance at which sound might impact marine mammals would be truncated in all directions except north from the mouth of the bay into Sitka Sound.

1.5. Project Elements that May Result in the Incidental Take of Marine Mammals

Elements of the proposed Action that generate noise that may impact marine mammals include vibratory pile driving, impact pile driving, and DTH drill/hammer driving. Each of these elements generates in-water and in-air noise (R&M Consultants, Inc. 2016). Durations per method is described in Section 2.1

Vibratory pile driving and DTH drilling/hammering are considered continuous or non-pulsed sound sources, while impact pile-driving is considered impulse sound. It is important to distinguish between these two sound types because they have different potential to cause physical effects, particularly with regard to hearing (Southall *et al.* 2007).

Non-pulsed sounds may be either continuous or non-continuous. Some of the non-pulsed sounds can be transient signals of short duration, but without the essential properties of pulses (e.g., rapid rise time). The duration of such sounds, as received at a distance, can be greatly extended in a highly reverberant environment. However, it is expected that ambient underwater noise levels in Symonds Bay would be variable but low given the relatively shallow depth and other conditions as described in Section 2.2.2.

Pulsed sound sources produce signals that are brief, typically less than one second, and occur either as isolated events or repeated in succession. Pulsed sounds are all characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a rapid decay period that may include a period of diminishing, oscillating pressures; they generally have an increased capacity to induce physical injury as compared with sounds lacking these features.

1.5.1.1. Vibratory Hammer

Vibratory hammers are commonly used in steel pile driving or removal where sediments allow. Generally, the pile is placed into position using a choker and crane, and then vibrated between 1,200 and 2,400 vibrations per minute. The vibrations liquefy the sediment surrounding the pile allowing it to penetrate to the required seating depth, or to be removed.

1.5.1.2. Impact Hammer

Impact hammers are used to install plastic/steel core, wood, concrete, or steel piles. An impact hammer is a steel device that works like a piston. The pile is first moved into position and set in the proper location using a choker cable or vibratory hammer. The impact hammer is held in place by a guide (lead) that aligns the hammer with the pile. A heavy piston moves up and down, striking the top of the pile and driving it into the substrate. Once the pile is set in place, pile installation with an impact hammer can take less than 15 minutes under good substrate conditions. However, under poor conditions, such as glacial till and bedrock or exceptionally loose material, piles can take longer to set.

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[3] The NMFS acoustic injury guidelines are located at (http://www.nmfs.noaa.gov/pr/acoustics/guidelines.htm)

1.5.1.3. DTH Drill/Hammer

The DTH drill/hammer acts on a shoe at the bottom of the pile and uses a pulsing mechanism to break up rock below the pile while simultaneously installing the pile through the rock formation. Rotating bit wings extend below the pile and remove the broken rock fragments as the pile advances. The pulsing sounds produced by the DTH hydro-hammer method reduces sound attenuation because the noise is primarily contained within the steel pile and below ground rather than impact hammer driving methods which occur at the top of the pile (R&M 2016). Therefore, the pulsing sounds produced by this method are considered less harmful than those produced by impact hammer driving.

2. DATES, DURATION, AND SPECIFIED GEOGRAPHIC REGION

2.1. Dates and Durations of Activities

The proposed date for the issuance of the IHA is approximately October 2017. Construction would occur from approximately May through mid-September 2018.

Based on the sequence of pile driving activities and the duration per method required to install piles, six construction steps or scenarios were identified as representing the largest acoustic footprints of construction activities at the Biorka Island Project site over any 24-hour period (Table 2-1). These construction scenarios are described in detail in Appendix A.

TABLE 2-1. PILE DRIVING MODELING SCENARIOS FOR THE BIORKA PROJECT

			Vibratory		DTH		Impact		
Scenario	**Description**	**Piles installed[1]**	**Hrs per pile**	**Total hrs[1]**	**Hours per pile**	**Total hours[1]**	**Hours per pile**	**Total strikes[1]**	**Shift (hr)**
S1	Removal of existing piles and installation/removal of temporary piles	21		6.93	NA[2]		NA		6.93
S2	Installation of 18-inch pipe piles (dock and dolphin)	3	0.33	0.99	2	6	0.17	15	7.49
S3	Installation of 18-inch pipe piles (barge	4		1.32	NA		0.33	2720	2.65
S4	Installation of 30-inch pipe piles (dolphins)	2		0.66	2	4	0.17	10	4.99
S5	Installation of H piles (dock wave barrier)	8		2.64	NA		0.33	5440	5.31
S6	Installation of sheet piles (dock wave barrier and barge landing)	12		3.96	NA		0.25	6120	6.96

Source: Appendix A (Quijano and Austin 2017)
[1]Refers to the number of piles, hours of operation of hammer strikes within a 24-hr period.
[2]NA indicates when a pile driving method was not required in a given scenario.

Table 2-2 provides the duration of activities in number of days (see Appendix A for details). The estimated number of days required to complete each scenario is provided in Table 2-3. The total number of weighted days is not additive and does not represent the total duration of pile driving. There may be more than one pile driving method used over the course of a single construction day.

TABLE 2-2 DURATION OF ACTIVITIES BY SCENARIO

	Duration (days)					
Structure	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Barge Landing	5	-	9	-	-	8
Wave Barrier	-	-	-	-	5	8
Dock	15	14	-	-	-	-
Dolphins	2	2	-	2	5	-
Total Days[1]	**22**	**16**	**9**	**2**	**5**	**16**

Source: Appendix A (Quijano and Austin 2017).
[1]Total project duration is 70 days.

TABLE 2-3. ESTIMATED DAYS TO COMPLETE EACH PILE DRIVING SCENARIO

			Weighted Days per Method[1]		
Scenario	**Number of Piles**	**Duration of Scenario (days)[2]**	**Vibratory (Non-impulsive)**	**DTH (Non-impulsive)**	**Impact (Impulsive)**
S1	21	22	22	0	0
S2	3	16	16	16	16
S3	4	9	9	0	9
S4	2	2	2	2	2
S5	8	5	5	0	5
S6	12	16	16	0	16

Source: R&M 2016
Note: The total number of weighted days per method is not additive and does not represent the actual project duration. The contractor will likely utilize more than one pile driving method over the course of a single day, with down time in between to mobilize equipment. because more than one activity may occur in a day.
[1]Number of days each pile driving method may occur during a scenario)
[2]From Table 2-2.

2.2. Geographic Setting

2.2.1. Physical Environment

Symonds Bay is approximately 0.4 miles (0.6 km) wide (east to west direction). Water depths are less than 66 ft (20 meters [m]) within 1,300 ft (400 m) of the dock (see Figure 1-2). The outer dolphin (see Figure 1-5) would be located in about 20 ft (6 m) of water at mean high water. This is the deepest water depth for all piles and, as a precautionary measure, was used as the water depth input for acoustic modeling described in Section 6.2.

On shore at the Project site, bedrock is exposed in many places. The overburden varies from 0 to about 15 ft (4.6 m) deep and consists of highly fractured weathered bedrock and includes seams of very soft rock or soil. Due to the fractures and seams, it is possible to drive piles into this top layer “Category 1 intensely fractured bedrock.” Beneath the top layer, the rock becomes more intact “Category II intensely to moderately fractured bedrock.” The seabed composition is important in this Project because it determines the pile-driving methods needed to achieve the required pile penetration.

2.2.2. Acoustic Environment

While there are no current measurements of ambient noise levels at the Project site, it is expected that ambient underwater noise levels in the immediate area would be variable and low.

3. SPECIES AND ABUNDANCE OF MARINE MAMMALS IN THE ACTION AREA

3.1. Marine Mammal Species of Sitka Sound

Nine marine mammal species under NMFS jurisdiction are known to occur, at least seasonally, in waters of Sitka Sound, in the immediate vicinity of Biorka Island, and in adjacent shelf and shelf-edge/slope waters of the Gulf of Alaska (Allen and Angliss 2013, 2014, 2015; Caretta *et al*. 2016; Muto *et al.* 2016; NMFS 1995, 2008, 2013). Several of these species occur in the area in response to seasonal influxes of forage fish. The nine species reviewed for consideration in this application are listed below:

- Harbor seals (*Phoca vitulina*) are considered common in the region and occur in coastal and nearshore habitats of Sitka Sound where several haulouts are located. They are year-round residents of the area but increase in abundance during the spring when seasonal spawning period of herring (*Clupea harengus*) occurs. They also occur during the winter when adult herring overwinter in Sitka Sound.
- Steller sea lions (*Eumetopias jubatus*) occur in coastal and nearshore habitats of Sitka Sound, and forage on herring and salmon throughout the Sound. A Steller sea lion haulout/rookery is located on Kaiuchali Island, a 3-acre rocky islet less than one mile southwest of Biorka Island (see Figure 1-2). Steller sea lions are divided into two distinct population segments (DPSs[4]) in Alaska, an endangered western DPS and an eastern DPS that is not listed under the ESA. Both DPSs occur in the Action Area on a year-round basis. Kaiuchali Island is used as a sea lion rookery in spring-summer and as a haulout during the non-breeding seasons (Fritz *et al*. 2016).
- Humpback whales (*Megaptera novaeangliae*) are found in Sitka Sound throughout much of the year; seasonal increases in abundance are observed consistent with forage fish spawning runs. The abundance of humpbacks in the Action Area is closely tied to the Pacific herring spring pre-spawning and spawning period, and again during late-fall and winter when adult herring are present in Sitka Sound. Humpback whales in the Action Area are most likely from the Hawaii DPS which is part of the Central North Pacific (CNP) stock.
- Gray whales (*Eschrichtius robustus*) are observed in and outside of Sitka Sound during their northward spring migration. Gray whales migrate from their winter feeding grounds in Baja California in late February and move up the Pacific coastline to Alaska. They have been known to travel 10,000 miles to reach the Bering Sea in May or June. Gray whales are most common in the Sitka Sound area during April and May; however they occur generally north and west of the Action Area in outer shelf waters of Sitka Sound near Kruzof Island (see Section 3.2).
- Transient killer whales (*Orcinus orca*) are sporadically observed in Sitka Sound on a year-round basis. These animals are primarily attracted to Steller sea lions found in the Action Area.

[4] A distinct population segment or DPS is the smallest division of a taxonomic species permitted to be protected under the ESA recognized as a taxonomic species or subspecies of plant or animal, or in the case of vertebrate species (61 FR 4722: February 7, 1996).

- Harbor porpoise (*Phocoena phocoena*) are observed in coastal and near-shore waters of the Action Area throughout the year. They forage almost exclusively on herring. They have been infrequently observed in small numbers near Biorka Island.
- Dall's porpoise (*Phocoenoides dalli*) are observed in mid- to outer-shelf coastal waters of Sitka Sound ranging to the Gulf of Alaska (see Section 3.2)
- The Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) also occurs in Sitka Sound (see Section 3.2)
- Sperm whales (*Physeter macrocephalus*) occur in the eastern Gulf of Alaska, outside of Sitka Sound (Mathias *et al*. 2012) and interactions between sperm whales and the regional longline fishery for sablefish (*Anoplopoma fimbria*) have been well documented (Straley *et al.* 2005, 2014; Thode *et al.* 2007).

Abundance estimates of all marine mammal species, densities and seasonal trends and occurrences in the Action Area have been determined by using best available data for this specific area, including but not limited to:

- Over two decades of NMFS-funded research on seasonal occurrence, abundance, behavior and status/trends of the western and eastern DPSs of Steller sea lions throughout Alaska;
- Knowledge of marine mammal occurrence during the summer months, based on multiple years of whale-watching and opportunistic observations from charter vessel operations (E. Majerski, pers. comm.);
- Research conducted and published in peer-reviewed manuscripts on humpback whales in Sitka Sound and southeast Alaska for the past several decades, including specific research and a doctoral dissertation on the relationship between humpback whale abundance and Pacific herring biomass in Sitka Sound;
- Information provided in previously published Environmental Assessments and Environmental Impact Statements conducted on federal projects in Sitka Sound and adjacent areas in southeast Alaska;
- The NMFS Marine Mammal Laboratory (MML) multi-year database of Steller sea lion counts (Fritz *et al*. 2015; 2016). This database contains annual survey counts for Steller sea lions by month and location; counts of sea lion pups, juveniles and adults; movements of branded animals from the western DPS of Steller sea lions into Southeast Alaska; and movements of sea lions from the eastern DPS into the Central Gulf of Alaska and Prince William Sound (the latter two regions belong to the western DPS);
- An active database maintained by MML of all harbor seals counts from aerial surveys, and locations throughout Alaska by stock. These data were provided for the Sitka/Chatham Strait stock (data provided by Josh London, NMFS, MML);
- Species background, abundance estimates and population trends, and status by species and stock taken from several Marine Mammal Stock Assessment Reports drafted by researchers at MML; and

- Additional information on the distribution and occurrence of marine mammals in Sitka Sound provided by Ms. Jan Straley, University of Alaska Southeast, Sitka, Alaska (personal communication).

3.2. Species Potentially Affected by the Proposed Project

Based on review of the available information on the occurrence of marine mammal species during the duration of the proposed Project (approximately May through September 2018), five of the nine species discussed in Section 3.1 could be encountered in the Action Area and potentially impacted during Project construction activities. Based on the available data, four species - sperm whales, Dall's porpoise, Pacific white-sided dolphin, and gray whales - would not likely be impacted by proposed Project activities due to the: (1) timing and duration of the Project relative to the occurrence of the species in Sitka Sound; (2) limited number of individuals found in the Sitka Sound and the Action Area during summer months; and (3) fact that the area potentially ensonified by the proposed activities would not extend into the preferred marine habitats of these species during summer months. These assumptions are based on the following observations:

- Interaction studies between sperm whales and the longline fishery have been focused along the continental slope of the eastern Gulf of Alaska in water depths between about 1970 and 3280 ft (600 and 1000 m) (Straley *et al.* 2005, 2014). Tagging studies show that sperm whales use the deepwater slope habitat extensively for foraging (Mathias *et al*. 2012). The shelf-edge/slope waters of the Gulf of Alaska are far outside of the Action Area. Therefore, sperm whales are not be considered further in this application.
- Dall's porpoise are observed throughout southeast Alaska to the Gulf of Alaska (Dahlheim *et al*. 2009). However, during the summer months between the herring pre-spawning and spawning season, and when adult herring school during late fall and winter, Dall's porpoise are found further offshore in outer Sitka Sound waters ranging to the Gulf of Alaska. Generally, this species is considered absent from Sitka Sound during mid-summer (E. Majeski, pers. comm.). This is consistent with results of survey by Piatt and Dragoo (2005) who observed Dall's porpoises in waters outside the Action Area during a July 2000 survey. Therefore, the likelihood that this species would be affected by the proposed activities at the Project is minimal. Dall's porpoise are not considered further in this application.
- Pacific white-sided dolphins are observed in the outer shelf-slope waters of the Gulf of Alaska outside of the Action Area. During the summer months between the herring pre-spawning/spawning season and when adult herring re-appear to overwinter in Sitka Sound, white-sided dolphin have been observed offshore along outer Sitka Sound and outside of Kruzof Island in the Gulf of Alaska. They are considered to be rare in waters of Sitka Sound in summer (E. Majeski, pers. comm.). This observation is consistent with results of the surveys by Piatt and Dragoo (2005) who observed white-sided dolphin in slope waters outside the Action Area during a July 2000 survey. The likelihood that this species would be affected by the proposed activities at the Project site is minimal. Therefore, white-sided dolphins are not considered further in this application.

- Gray whales in the North Pacific fall into two genetically distinct populations: eastern North Pacific (ENP) and western North Pacific (WNP) (LeDuc *et al.* 2002, Lang 2010, Weller *et al*. 2013).
  - Some WNP gray whales observed feeding off Sakhalin and Kamchatka have migrated during the winter to the west coast of North America in the eastern North Pacific (Weller *et al.* 2012, Urbán *et al*. 2013). However, they are unlikely to be found in the waters of Sitka Sound, the Project vicinity or Action Area. Therefore, the WNP stock of gray whales is not considered further in this application.
  - The ENP stock migrates from winter feeding grounds in Baja California in late February to reach the Bering Sea in May or June (Muto *et al*. 2016). The most likely months to observe gray whales in offshore waters adjacent to Sitka Sound would be April and May. Since the mid-1990s, approximately 30 to 50 gray whales have been observed in the summer months feeding along the outer coast of Southeast Alaska (reported in Moore *et al.* 2007, based on J. Straley pers. comm.). A few individual gray whales have been observed during most years in coastal waters of western Sitka Sound. They arrive during the spring migration and enter the shallow waters of Sitka Sound inside Kruzof Island, concurrent with spawning herring in April. The whales generally leave Sitka Sound by June (E. Majeski, pers. comm.). While gray whales enter the outside of Sitka Sound, it is highly unlikely that a gray whale from the ENP stock would occur within the Action Area and be affected by the proposed Project activities. Therefore, gray whales are not considered further in this application.

Based on these observations and data, this IHA application is requesting incidental take for potential underwater acoustic disturbance from Project activities for the following five species: harbor seals, Steller sea lions (Eastern and Western DPS), humpback whales, (Hawaii and Mexico DPS), transient killer whales and harbor porpoise. Abundance estimates for these five marine mammal species are shown in Table 3-1. Abundance estimates are presented at the stock or population level, and may exceed the numbers of animals found in Sitka Sound, and especially the Project site, at any time of the year. Additional information on the status and distribution of these species is provided in Section 4.

3.3. Influence of Prey Species in the Action Area on the Distribution and Abundance of Marine Mammals

In Southeast Alaska, marine mammal distributions and seasonal increases in their abundance are strongly influenced by seasonal pre-spawning and spawning aggregations of forage fish, especially Pacific herring (*Clupea pallasii*), eulachon (*Thaleichthys pacificus*) and Pacific salmon (*Onchorynchus spp.*) (Marston *et al.* 2002, Sigler *et al.* 2004, Womble *et al.* 2005; USACE 2013). All five species of salmon are found in Sitka Sound and are preyed upon by Steller sea lions, harbor seals and killer whales. However, there are no salmon spawning streams in the vicinity of the Project that would tend to aggregate foraging marine mammals. As described in Wombel *et al*. (2005), while eulachon are likely to be an important prey

TABLE 3-1. MARINE MAMMAL SPECIES POTENTIALLY PRESENT IN ACTION AREA

Common Name	Scientific Name	Stock Name	Stock Abundance	ESA Status	MMPA Status	Frequency of Occurrence in Project Area[2]
Harbor seal	*Phoca vitulina*	Sitka/Chatham	14,855	Not listed	Not Strategic, Non-depleted	Likely
Steller sea lion	*Eumetopias jubatus*	Western	49,497, (western DPS)	Western DPS-Endangered	Endangered, Strategic, Depleted	Likely
		Eastern	60,131 (eastern DPS)	Eastern DPS-Not listed		Likely
Harbor porpoise	*Phocoena phocoena*	Southeast Alaska	11,146	Not listed	Strategic, Non-depleted	Likely
Humpback whale[3]	*Megaptera novaeangliae*	Central North Pacific (CNP)	10,103 (CNP stock)	Hawaii DPS - Not Listed	Not Strategic, Non-depleted	Likely
		Mexico	3,264 (Mexico (DPS)	Mexico DPS - Threatened	Strategic, Depleted	Rare
Killer whale	*Orcinus orca*	Eastern North pacific Gulf of Alaska, Aleutian Island, and Bering Sea Transient	587	Not listed	Not strategic, Non-depleted	Infrequent (transient stocks only)
		West Coast Transient	243 830 Total	Not Listed		

[1] NMFS marine mammal stock assessment reports at Allen and Angliss (2014, 2015), Muto *et al.* (2016) and http://www.nmfs.noaa.gov/pr/sars/species.htm.

[2]Rare: Few confirmed sightings, or the distribution of the species is near enough to the area that the species could occur there; Infrequent: Confirmed, but irregular sightings; Likely: Confirmed and regular sightings of the species in the area at least seasonally.

[3]The Central North Pacific (CNP) stock of humpback whales is discussed in Section 4.3.1

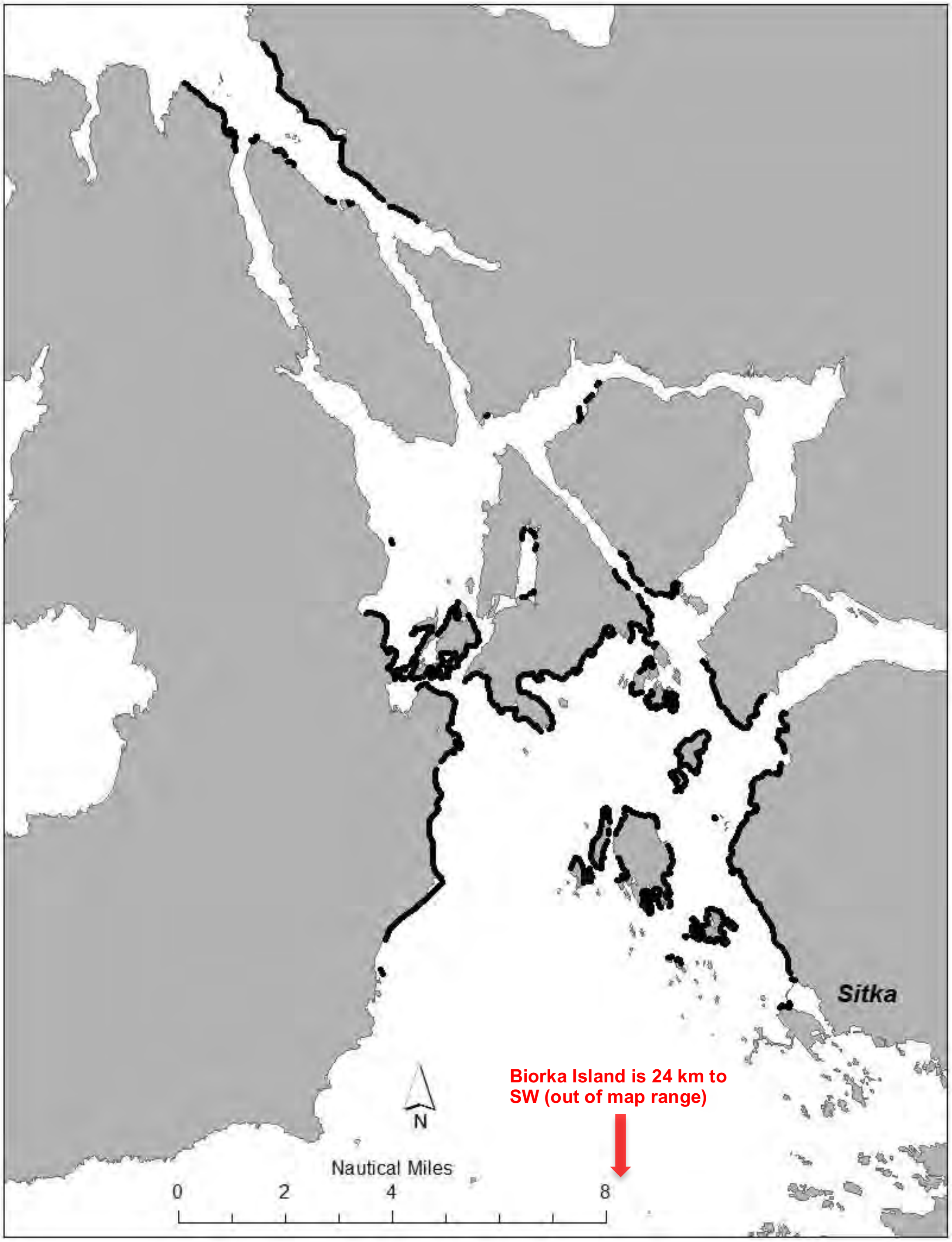
species for sea lions, they are not commonly found in scat analyses during breeding season. Other studies summarized by Wombel *et al*. determined that the frequency of eulachon occurrence in scat samples from a location in Lynn Canal was greatest in April. Herring are the keystone species in Southeast Alaska, especially Sitka Sound, serving as a vital link between lower trophic levels, including crustaceans and small fish, and higher trophic levels (NMFS 2014a).

Pacific herring are a small, planktivorous forage fish whose range includes coastal regions along the eastern and western Pacific (Hart 1973, Mecklenburg *et al.* 2002). They are found in numerous large and small aggregations throughout the Action Area (NMFS 2014a). Habitat requirements for pacific herring in Southeast Alaska are diverse and partially a function of life stage. Preferred habitat for adult and juvenile herring includes a variety of nearshore habitat types, such as bedrock outcrops, eelgrass, kelp beds, and sand-gravel beaches (Carlson 1980, Johnson and Thedinga 2005, NMFS 2014a). During the fall and winter months, Pacific herring exhibit a behavioral change; they switch from smaller, dispersed, mobile, foraging schools found throughout the water column and form large, dense shoals in the deeper trenches of bays and fjords, where little feeding takes place (Heintz *et al.* 2010).

The most visible and crucial event in the herring life cycle is spawning, which generally occurs at predictable times (typically in the spring/early summer) and in predictable locations (Hay and Outram 1981). During spawning events, adult herring congregate along shorelines protected from ocean surf. Within these established spawning grounds, female herring deposit eggs onto a variety of different substrate types, including eelgrass, kelp, rockweed and other seaweed as well as on inorganic material such as rocks or pilings (Hart 1973). Male herring then fertilize the eggs externally. In 2016, there were two spawning events in the Sitka Sound area (ADFG 2016). The first event occurred from March 18 to 28 and the second event began on April 1 and ended on April 8. About 63 nautical miles (nm) (117 km)of shoreline was used for spawning, primarily located in bays, and along the shoreline of northern and northeastern Sitka Sound (see Figure 3-1). These predominant spawning areas occurred over 15 miles (24 km) from the Project site in Symonds Bay. This spawning season and extent of spawning areas in Sitka Sound are consistent with previous spawning seasons; the long-term average spawning area is 61 nm (113 km) of shoreline and the recent ten-year average is 65 nm (120 km) (ADFG 2016).

Foraging studies of Steller sea lions suggest that during their non-breeding season, they forage on seasonally densely aggregated prey (Sinclair and Zepplin 2002). In southeast Alaska, Pacific herring typically spawn from March to May and attract large numbers of predators (Marston *et al* 2002, Womble 2003). The relationship between humpback whales and Steller sea lions and these ephemeral fish runs is so strong in Sitka Sound that the seasonal abundance and distribution of marine mammals reflects the distribution of pre-spawning and spawning herring, and overwintering aggregations of adult herring in Sitka Sound. The largest aggregations of several species of marine mammals in the Action Area target Pacific herring during spring and again in late fall through the winter. Pacific herring are largely absent from Sitka Sound and the Action Area from May, following spawning season, until at least October, prior to adult overwintering in Sitka Sound (NMFS 2014a).

Figure 3-1. Spawning Locations of Pacific Herring in Sitka Sound 2016



Source: ADFG 2016

Note: Bolded coastline indicates spawning areas, grey is land, white is water.
Biorka Island is out of the map range, approximately 24 km (15 miles) to the southwest of Sitka.

4. AFFECTED SPECIES STATUS AND DISTRIBUTION

This IHA application is requesting incidental take for potential underwater acoustic disturbance from pile installation activities at the Project site for the following five species: harbor seals, Steller sea lions (eastern and western DPS), humpback whales, (Hawaii DPS of the CNP stock), transient killer whales (potentially two stocks) and harbor porpoise.

4.1. Harbor Seal

4.1.1. Distribution and Status

Harbor seals inhabit coastal and estuarine waters off Alaska. They haul out on rocks, reefs, beaches, and drifting glacial ice, and feed in marine, estuarine, and occasionally fresh waters (Allen and Angliss 2014, 2015). Harbor seals in Southeast Alaska are considered non-migratory with local movements attributed to factors such as prey availability, weather, and reproduction.

In 2010, NMFS identified 12 stocks of harbor seals in Alaska based on genetic structure (Allen and Angliss 2015). The Sitka/Chatham (S/C) stock is genetically distinct and believed to be year-round residents of the region; therefore, estimates of abundance are considered reliable for this stock. During the 2011 range-wide survey, there were approximately 325 haulout locations identified within the range of the S/C stock[5]. Based on aerial survey data, the current abundance estimate for the S/C stock is 14,855 individuals (Allen and Angliss 2014) (see Table 3-1). The population trend for the S/C harbor seal stock is positive (Muto *et al.* 2016).

Harbor seals are not considered depleted under the MMPA, they are not listed under the ESA, and none of the stocks are classified as strategic (Muto *et al.* 2016).

4.1.2. Presence in Sitka Sound and the Action Area

Harbor seals are opportunistic feeders that forage on fish and invertebrates and often adjust their distribution to take advantage of locally and seasonally abundant prey. Aggregations of adult herring during spring pre-spawning and spawning runs, and again from October throughout the winter, are a very important seasonal prey species for harbor seals in Sitka Sound.

The minimum count of harbor seals within Sitka Sound during the 2011 aerial survey was approximately 900 individuals occupying 25 haulout locations (unpublished data from MML dataset). The largest count of seals in Sitka Sound (n = 745) during the 2011 survey occurred at several adjacent rocky outcroppings and islands (Vitskari Rocks, Vitskari Island and Low Island) located approximately 15 miles (24 km) north of the Project site in northcentral Sitka Sound inside Kruzof Island. This is outside of the Action Area. Prey species moving into Sitka Sound from the Gulf of Alaska move past these islands so pinnipeds aggregate at these rocks to forage. There are six haulout locations identified in the extreme southern portion of the Sitka Sound, and potentially in the Action Area, including rocky outcroppings near Biorka Island, where seals have been observed in low numbers. Prey resources inside Symonds Bay are limited, particularly when compared to the northern coastal areas of Sitka Sound (see Figure 3-1).

[5] The observed haulout locations of harbor seals in coastal Alaska can be located at the following MML dataset: http://afsc.noaa.opendata.arcgis.com/datasets?g=Harbor%20Seal

While individual seals may occur in Symonds Bay, it is unlikely that seals would be attracted to Symonds Bay to forage. While their occurrence in the Action Area is possible it is infrequent to uncommon.

4.1.3. Acoustics

According to Kastak and Schusterman (1995), harbor seals respond to underwater sounds below 180 kHz. Their functional high frequency limit is about 60 kHz and peak sensitivity is around 32kHz. Harbor seals have reduced hearing ability for in air sounds, as they respond to sounds from 1-22 kHz with a peak sensitivity of 12 kHz.

4.2. Steller Sea Lion

4.2.1. Distribution and Status

Steller sea lions have been studied throughout their range for the past several decades (Calkins and Pitcher 1982; Fritz *et al.* 1995, 2008, 2013, 2016; Loughlin *et al.* 1984, 1987, 1990, 1992; Loughlin and York 2000; Merrick *et al.* 1987; Merrick and Loughlin 1997; NMFS 1995, 2008, 2013; Sease *et al.* 2001). Their range includes the North Pacific Rim from northern Japan to California, with centers of abundance located in the Gulf of Alaska and Aleutian Islands. Large numbers of individuals disperse widely outside of the breeding season (late May to early July), thus potentially intermixing with animals from other areas to access seasonally important prey resources (Allen and Angliss 2014).

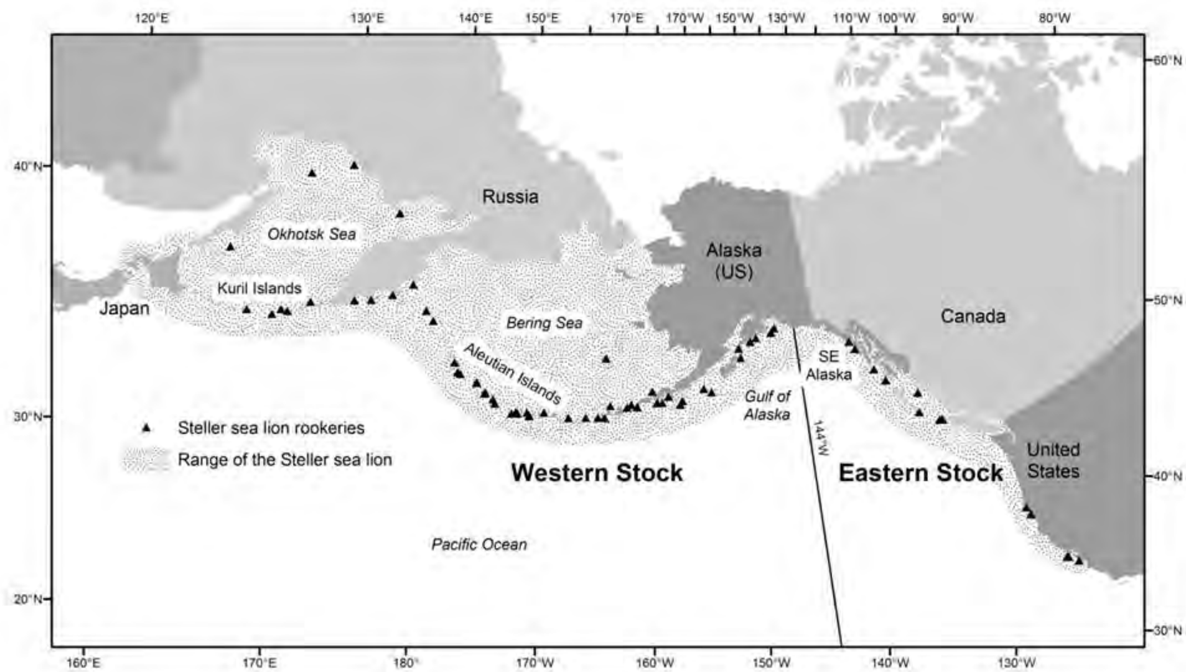
In 1997, based on demographic and genetic dissimilarities, NMFS identified two DPSs of Steller sea lions under the ESA: a western DPS and an eastern DPS[6,7]. The western DPS breeds on rookeries located west of 144°W in Alaska and Russia, whereas the eastern DPS breeds on rookeries in southeast Alaska through California. The majority of Steller sea lions are part of the eastern DPS (Jemison *et al.* 2013). In recent years, there has been an increasing trend of western DPS animals occurring and breeding in Southeast Alaska (NMFS 2013; Fritz *et al.* 2015). Figure 4-1 depicts the geographical delineation of these two DPSs.

4.2.1.1. Western DPS

The current minimum population of western DPS sea lions in Alaska is estimated at 49,497 based on 2014 survey results (DeMaster 2014; Fritz *et al.* 2015; Muto *et al.* 2016). For this estimate, pups were counted during the breeding season, and the numbers of births were estimated from the pup count. Because of uncertainties regarding the use of pup data, this estimate is also considered the minimum population estimate. During the 1980s, counts of western Steller sea lions declined approximately 15 percent per year (NMFS 2008), which prompted the threatened listing under the ESA. Continued declines in the 1990s resulted in listing the species as endangered in 1997 (NMFS 2008). Survey data in 2002 and subsequent surveys suggest that the overall decline stopped between 2000 and 2002 (Sease and Gudmundson 2002). Trend data collected through 2014 suggest there is strong evidence that the population has increased between 2000 and 2014; however, there are also strong regional differences across the range in Alaska (Muto *et al.* 2016). Therefore, the western DPS remains listed as endangered under the ESA, and depleted under the MMPA. As a result, the DPS is classified as a strategic stock.

[6] 62 *FR* 24345
[7] 50 CFR 226.202 a and b

FIGURE 4-1. STELLER SEA LION RANGE AND ROOKERY LOCATIONS WITH DESIGNATION BETWEEN THE WESTERN AND EASTERN DPS



Source: NMFS 2008

4.2.1.2. Eastern DPS

Steller sea lions occurring in Southeast Alaska are dominated by individuals from the eastern DPS. The current total population estimate for eastern DPS Steller sea lions is estimated at 60,131 based on counts made between 2009 and 2013 (Allen and Angliss 2014; Muto *et al*. 2016). This estimate is also considered the minimum population estimate. The best available information indicates the eastern DPS has increased at a rate of 4.18 percent per year between 1979 and 2010 based on an analysis of pup counts in California, Oregon, British Columbia, and Southeast Alaska (Allen and Angliss 2014). The increase in the eastern DPS has been driven by growth in pup counts in all regions (NMFS 2013). As a result of the sustained increase in abundance (Pitcher *et al*. 2007), the eastern DPS of Steller sea lions has been de-listed under the ESA[8], but is still considered depleted and strategic under the MMPA.

4.2.1.3. Overlap between the Eastern and Western DPS

Movement between the western and eastern DPS of Steller sea lions occurs, and increasing numbers of individuals from the western DPS have been seen in Southeast Alaska in recent years (NMFS 2013, Fritz *et al.* 2013, 2016; DeMaster 2014). This DPS-exchange is especially evident in the outer Southeast coast of Alaska including Sitka Sound. The distribution of marked animals (along with other demographic

[8] 78 *FR* 66139.

data) indicates that movements of Steller sea lions during the breeding season result in a small net annual movement of animals from southeast Alaska (eastern DPS) to the western DPS (approximately 80 sea lions total) but a much larger inter-regional movement between the western DPS and the eastern DPS (approximately 1,000 sea lions per year; Fritz *et al.* 2016). DNA analyses of pup tissue samples demonstrate that recently-established rookeries in northern southeast Alaska have been partially to predominately formed by western DPS females (Gelatt *et al.* 2007, Jemison *et al.* 2013).

4.2.2. Critical Habitat

NMFS designated critical habitat for Steller sea lions on August 27, 1993[9]. At the time of designation, Steller sea lions were listed as a single species (not two DPSs). Although the eastern DPS is no longer protected under the ESA, it remains protected under the MMPA and the designated critical habitat remains unchanged because it was established for the entire population. Thus, the designation includes sites within the breeding range of both the eastern DPS and the western DPS.

Critical habitat for Steller sea lions includes designated haulouts within the range of the eastern DPS, and all marine waters within 20 nautical miles of rookeries and haulouts within the breeding range of the western DPS and within three special aquatic foraging areas in Alaska[10]. In identifying aquatic habitats as part of critical habitat, NMFS specifically highlighted several components of such habitats: nearshore waters around rookeries and haulouts; traditional rafting sites; food resources; and foraging habitats. Adequate food resources are an essential feature of the Steller sea lion's aquatic habitat (58 FR 45269).

The closest haulout/rookery to the Project site that has been designated as a Steller sea lion critical habitat is listed as "Biorka Island" in the critical habitat descriptions at 50 CFR 226.202. However, the haulout is actually on Kaiuchali Island, a three-acre rocky islet located slightly less than one mile southwest of Biorka Island (see Figure 1-2).

4.2.3. Presence in Sitka Sound and the Action Area

The Steller sea lions that inhabit Sitka Sound are considered part of the eastern DPS but some interchange between the western and eastern DPS seems likely given recent overlap between the two groups (see Section 4.2.1.3). Based on results of recent aerial surveys, there has been an increase of sea lions that use Kaiuchali Island during both the breeding and non-breeding seasons. In June 2013, Fritz *et al.* (2016) documented 22 individuals, none of which were pups. In June 2015, the same study recorded 77 Steller sea lions, including one pup. This limited information shows an increase in the numbers of animals at this location and indicates that the site has become a recently-established eastern DPS rookery. The breeding season for Steller sea lions does not overlap with proposed summer construction activity at the Project site, and the location of the rookery at Kaiuchali Island is outside the Action Area, opposite Biorka Island (see Figure 1-2).

Observations of animals now using this haulout in winter (non-breeding season) have exceeded 400 in recent years. Based on the percentage of animals from the western DPS found on recently established rookeries north and south of Kaiuchali Island (Jemison *et al.* 2013), it is likely that the observed increases in Steller sea lions have been due, in part, to an influx of the western DPS into the region. Although the

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[9] 58 *FR* 45269.
[10] 50 CFR 226.202, a and c, respectively.

distinction between western and eastern DPS individuals cannot be confirmed unless an animal has been marked, for this IHA application it is assumed that at least 50 percent of the Steller sea lions observed in the Action Area are from the western DPS.

Kaiuchali Island is also used as a haulout during the non-breeding season. The utilization of adult, over-wintering herring in Sitka Sound by Steller sea lions has a substantial seasonal significance on the energy budget of sea lions at this time because herring are energy-rich (Iverson *et al.* 2002) and the overwintering aggregation occurs during a period of high-energetic demands for Steller sea lions (Winship *et al.* 2002; Winship and Trites 2003; Sigler *et al.* 2004). The late fall and overwintering aggregation of adult herring results in hundreds of animals using Kaiuchali Island as a haulout during this period. However, the construction period for the proposed Project would not overlap with the overwintering aggregations of sea lions.

Steller sea lions are present in Sitka Sound in very low numbers over the summer months when construction is planned, during the interval between herring spawning and the return of adult herring to Sitka Sound (E. Majeski, pers. comm.). Prey availability for Steller sea lions in Sitka Sound is limited during this period as compared to other seasons, and they are generally only observed as individuals or in small groups of three to five animals (E. Majeski, pers. comm.). During this period, sea lions tend to forage in the vicinity of recreational and commercial fishing vessels, or scavenging in very shallow waters near the Sitka town docks when the vessels return from fishing.

4.2.4. Acoustics

Hearing capacity for Steller sea lions is thought to be similar to the hearing range of California Sea lions ranging from 1-80 kHz in water and less than 30 kHz in air (Nedwell *et al*. 2004). Kastelein *et al*. (2005) documented that the best hearing range for Steller sea lions was 1-16 kHz.

4.3. Humpback Whale

4.3.1. Distribution and Status

Humpback whales are the most commonly observed baleen whale in Sitka Sound and generally throughout Southeast Alaska. The humpback whales of Southeast Alaska and Northern British Columbia form a genetically discrete feeding aggregation, migrating seasonally between lower latitude mating and calving areas to high latitude feeding areas (Gaskin 1982; Baker *et al* 1986; Calambokidis *et al.* 2001). While a very small degree of interchange has been documented, these feeding aggregations are generally isolated from each another (Witheveen *et al.* 2011).

The humpback whale population was considerably reduced due to intensive commercial exploitation during the 20th century (Perry *et al.* 1999). In 1970, the humpback whale was listed as endangered under the ESA[11]. As a result of the ESA listing, the central North Pacific Stock of humpback whale was also designated as depleted under the MMPA. The humpback whale is also considered a strategic stock under the MMPA. In 1991, NMFS published a Final Recovery Plan for Humpback Whales (NMFS 1992).

A large-scale study of humpback whales throughout the North Pacific was conducted between 2004 and 2006 (the Structure of Populations, Levels of Abundance, and Status of Humpbacks [SPLASH] project).

[11] 35 *FR* 18319

Initial results from this project including abundance estimates and movement information have been reported in Calambokidis *et al.* (2008), Barlow *et al.* (2011), and Baker *et al*. (2008). Abundance estimates for Hawaii show an annual increase that ranged from 5.5 to 6.0 percent 1991-1993 (Calambokidis *et al.* 2008), and a population that is doubling approximately every 15 years (Heintz *et al*. 2010). It is also clear that the abundance of humpback whales has increased in Southeast Alaska (*Muto et al.* 2016).

On February 26, 2014, the State of Alaska submitted a petition to delineate the CNP stock of the humpback whale as a DPS and subsequently remove that DPS from the ESA List of Endangered and Threatened Species. NMFS conducted a review of the humpback whale DPS designation and ESA listings to prepare a status report[12]. Based on information presented in the status report, NMFS proposed a revised species-wide listing of the humpback whale in 2015[13]. A revision to the status of humpback whale DPSs was finalized by NMFS on September 8, 2016[14], effective October 11, 2016. In the final decision, NMFS recognized the existence of 14 DPSs, classified four of those as endangered and one as threatened, and determined that the remaining nine DPSs do not warrant protection under the ESA. Three DPSs of humpback whales occur in waters off the coast of Alaska: the Western North Pacific (WNP) DPS, an endangered species under the ESA; the Mexico DPS, listed as threatened under the ESA; and Hawaii DPS, which is not listed under the ESA. Wade *et al*. (2016) determined that humpback whales from the endangered WNP DPS are uncommon in waters off Alaska and are only likely to be encountered in the Aleutian Islands and Bering Sea region. Mexico DPS whales occur in the Gulf of Alaska with a 10.5 percent probability of occurrence. Humpback whales in Southeast Alaska are most likely to be from the Hawaii DPS (93.9 percent probability) (Wade *et al*. 2016).

Under the MMPA, humpback whale DPSs are considered to be depleted based solely on their ESA listing status. Therefore, humpback whale DPSs that are listed as threatened or endangered would retain depleted status under the MMPA, and DPSs that are not listed as threatened or endangered would not be considered depleted under the MMPA. NMFS would conduct a review of humpback whale stock delineations in waters under the jurisdiction of the U.S. to determine whether any stocks should be realigned in light of the ESA. Until such time as the MMPA stock delineations are reviewed, NMFS would treat existing MMPA stocks that fully or partially coincide with a listed DPS as depleted and stocks that do not fully or partially coincide with a listed DPS as not depleted for management purposes. Therefore, as shown in Table 3-1, the Hawaiian DPS is considered as Not Strategic, Non-depleted under the MMPA, while the Mexico DPS is considered Strategic, Depleted. As noted above, humpback whales in southeast Alaska, including Sitka Sound, are most likely to be from the CNP stock/Hawaii DPS. However, for this application, based on NMFS recommendation for proposed actions off Southeast Alaska, 6.1 percent of humpback whales has been apportioned to the Mexico DPSs (Wade *et al*. 2016).

4.3.2. Critical Habitat

Critical habitat has not been designated for the humpback whale.

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[12] Status Review available at *http://www.fisheries.noaa.gov/pr/species/mammals/whales/humpback-whale.html*.
[13] 80 FR 22304, 21 April 2015
[14] 81 FR 62259, Endangered and Threatened Species; Identification of 14 Distinct Population Segments of the Humpback Whale (*Megaptera novaeangliae*) and Revision of Species-Wide Listing

4.3.3. Presence in Sitka Sound and the Action Area

In Southeast Alaska, humpback whale numbers have been monitored since the 1970s (Straley 1994; Straley *et al*; 2002, 2009, 2014). The humpback whales of Southeast Alaska and Northern British Columbia form a genetically discrete feeding aggregation and return to specific feeding locations in southeast Alaska including Sitka Sound.

Humpback whale abundance in Sitka Sound has increased in recent years (Straley *et al*. 2009; Hendrix *et al.* 2012; Liddle *et al.* 2015a). The population estimate during the period 1986 to 1992 ranged from 60 to 272 whales (Straley 1994). From 1995 to 2000 the abundance estimate was updated to range from 261 to 491 (Straley *et al*. 2009). Five hundred and fifty-seven whales were uniquely photo-identified in Sitka Sound from 1989 to 2008. By 2008, the number of unique whales (557) fell comfortably within the confidence interval for the abundance estimate (321 - 643) (Liddle *et al*. 2015a) and showed a population rate of increase of 5.1 percent (Hendrix *et al*. 2012). This suggests that the size of the marked population is very nearly the same as the humpback whale abundance.

Humpback whale seasonal distribution varies from infrequent (very low in number during summer), to common (very abundant during late fall through spring). Humpback whales are most abundant in Sitka Sound from late fall through April when they forage on large densities of herring (Liddle *et al.* 2015a). The seasonal increase in whale abundance corresponds to increases in Pacific herring biomass during pre-spawning, spawning and overwintering periods (Liddle *et al.* 2015b). Whales feed on large schools of adult, over-wintering herring throughout winter, and on pre-spawning and spawning aggregations of herring in spring. Sitka Sound is believed to be a last feeding stop for humpback whales as they migrate to winter breeding and calving waters in Hawaii. During winter, groups of 30 to 40 humpback whales have been observed from the coastline of Sitka Sound (E. Majesi, pers. comm.). However, humpback whales stagger their departure from the feeding grounds, suggesting they also stagger their return. This could create the impression that whales had been present throughout the entire winter in the sound when it is unlikely that any individual whale remains in Sitka Sound throughout the entire winter (Heintz *et al.* 2010).

During mid-summer, tour boat operators generally observe four to five whales per day near rocky islets in the middle of Sitka Sound. As noted previously, the abundance of forage fish and particularly herring is reduced during mid-summer as compared to other times of the year. The abundance of humpbacks in Sitka Sound changes by several orders of magnitude from one season to another in response to dense schools of herring in the sound (Liddle *et al*. 2015b). They are generally present in large numbers from late fall-early winter through mid- to late spring, but are infrequent to uncommon during the mid-summer months when herring are absent (E. Majeski, pers. Comm.).

4.3.4. Acoustics

Southall *et al*. (2007) categorized humpback whales in the low frequency functional hearing group, with and estimated auditory bandwidth of 7 to 22 kHz.

4.4. Killer Whale

4.4.1. Distribution and Status

Killer whales are found throughout the North Pacific. Along the west coast of North America, killer whales occur along the entire Alaskan coast, in British Columbia and Washington inland waterways, and along the outer coasts of Washington, Oregon, and California (Allen and Angliss 2014). Seasonal and year-round occurrence has been documented for killer whales throughout Alaska and in the intra-coastal waterways of British Columbia and Washington State.

Killer whales that are observed in Southeast Alaska could belong to one of three different stocks: Eastern North Pacific Northern Resident Stock (Northern residents); Gulf of Alaska, Aleutian Islands, and Bering Sea Transient Stock (Gulf of Alaska transients); or West Coast Transient Stock. The Gulf of Alaska Transient Stock occupies a range that includes southeastern Alaska. Photo-identification studies have identified 587 individual whales in this stock (Table 3-1). A total of 219 killer whales from the West Coast Transient Stock have also been identified between Southeast Alaska and British Columbia (Allen and Angliss 2013). More recent analyses of photographic data identified 243 individual transient killer whales in this stock (Allen and Angliss 2013). From 1991 to 2007, an increasing population trend of 5.2 percent annually has been documented for transient killer whales in Southeast Alaska (Dahlheim *et al*. 2009).

All killer whale stocks in Southeast Alaska are protected under the MMPA. However, none of them are designated as depleted or listed as threatened or endangered under the ESA (Allen and Angliss 2014). Therefore, none of the three stocks of killer whales are classified as strategic.

4.4.2. Presence in Sitka Sound and the Action Area

There are no resident killer whales in Sitka Sound (E. Majeski, pers. comm.). However, transient killer whales from either the Gulf of Alaska transient group or West Coast Transient Stock have been observed in the sound. These whales are observed infrequently during summer months with five to six sightings noted throughout the summer by the whale-watching industry (E. Majeski, pers. comm.). Dahlheim *et al.* (2009) found that transient killer whale mean group size ranged from four to six individuals in Southeast Alaska.

Generally, transient killer whales follow movements of, and prey on, Steller sea lions and harbor seals. Killer whales have been observed in the waters outside of Sitka Sound near the haulouts at Kaiuchali Island and outside of Kruzof Island when sea lions are present. This behavioral distribution is characteristic of killer whales and consistent with killer whale sightings around other Steller sea lion haul-out locations in southeast Alaska (Dahlheim *et al*. 2009). Given the low numbers of Steller sea lions in Sitka Sound during summer, it is consistent that transient killer whales would be considered infrequent to uncommon in the Action Area during these months.

4.4.3. Acoustics

Killer whales have a well-developed sense of hearing and are able to respond to sounds between 1 and 120 kHz, with the most sensitive range between 18 and 42 kHz (Szymanski *et al.* 1999). Their greatest sensitivity is approximately 20 kHz, lower than many other toothed whales.

4.5. Harbor Porpoise

4.5.1. Distribution and Status

Harbor porpoise are common in coastal waters. In the Gulf of Alaska and Southeast Alaska they are observed most frequently in waters less than 350 ft (107 m) deep (Dahlheim *et al*. 2009). Within the inland waters of Southeast Alaska, the harbor porpoise distribution is patchy and clumped.

There are three harbor porpoise stocks in Alaska: the Bering Sea Stock; the Southeast Alaska Stock; and the Gulf of Alaska Stock (Angliss and Allen 2015). Only the Southeast Alaska stock occurs in the Action Area (Muto *et al.* 2016). Harbor porpoise numbers for the Southeast Alaska stock are estimated at 11,146 animals (Allen and Angliss 2014). The abundance estimates for harbor porpoise occupying the inland waters of Southeast Alaska was 1,081 in 2012. However, this number may be low due to survey methodology (Allen and Angliss 2014). The mean group size of harbor porpoise in Southeast Alaska is estimated at two to three individuals (Dahlheim *et al.* 2009).

Information on harbor porpoise abundance and relative abundance has been collected by NMFS MML using both aerial and shipboard surveys. Aerial surveys of this stock were conducted in June and July 1997 and resulted in an observed abundance estimate of 3,766 (CV = 0.162) porpoise (Hobbs and Waite 2010); the surveys included a subset of smaller bays and inlets. Correction factors for observer perception bias and porpoise availability at the surface were used to develop an estimated corrected abundance of 11,146 (3,766 × 2.96; CV = 0.242) harbor porpoise in the coastal and inside waters of Southeast Alaska (Hobbs and Waite 2010, reported in Muto *et al*. 2016).

Harbor porpoise are not designated as depleted under the MMPA or listed as threatened or endangered under the ESA. However, because the abundance estimates are 12 years old and the frequency of incidental mortality in commercial fisheries is not known, the Southeast Alaska Stock of harbor porpoise is classified as a strategic stock under the MMPA (Muto *et al.* 2016).

4.5.2. Presence in Sitka Sound and the Action Area

This species can be found in Sitka Sound throughout the year but individuals are infrequently observed during the summer months (E. Majeski, pers. comm.). Harbor porpoise are infrequently observed in nearshore Sitka Sound areas in summer by hikers on the coastal trails that parallel the coastline near Sitka. At times throughout the year, they likely forage exclusively on herring and may be more abundant when herring are present. During surveys for seabirds, marine mammals and forage fish conducted in Sitka Sound during July 2000, relatively few marine mammals were observed during this period. However, one harbor porpoise was observed in coastal/shelf waters of northeast Sitka Sound (Piatt and Dragoo 2005.

4.5.3. Acoustics

The harbor porpoise has the highest upper-frequency limit of all odontocetes investigated. Kastelein *et al.* (2002) found that the range of best hearing was from 16 to 140 kHz, with a reduced sensitivity around 64 kHz. Maximum sensitivity (about 33 dB referenced to 1 micropascal (dB re 1 μPa) occurred between 100 and 140 kHz. This maximum sensitivity range corresponds with the peak frequency of echolocation pulses produced by harbor porpoises (120–130 kHz).

5. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

The demolition and re-construction work at the dock in Symonds Bay, Biorka Island, has the potential to take by Level A or Level B[15] acoustic harassment up to five species of marine mammals.

Construction activities are not expected to result in serious injury or mortality of any marine mammal, and are planned to be completed within a 12-month period of time. Therefore, the FAA, Alaskan Region, is applying for an IHA, pursuant to Section 101(a)(5)(D) of the MMPA, 16 USC Section 1371.101 (a)(5), and 50 CFR Section 216, Subpart I, effective approximately February 2018, for incidental take of up to five species of marine mammals.

5.1. Methods of Incidental Taking

The actions outlined in Section 2 have the potential to take marine mammals by exposure to underwater sound. Level A and Level B takes could potentially result from waterborne noise generated from vibratory methods to remove piles, and from impact, vibratory and DTH hydro hammering to place new piles. It is anticipated that the marine mammals found in the Action Area during Project construction activities (i.e., the summer months) may be briefly subjected to noise levels that exceed thresholds established by NMFS (2016) for Level A and Level B harassment (unless mitigated) from pile removal and driving noise as they move throughout the area. However, neither serious injury nor mortality are expected from activities within the Biorka Island Action Area.

In July 2016, NMFS published revised acoustic Level A injury criteria based on frequency-weighted sound exposure levels. JASCO Applied Sciences (JASCO) performed an underwater acoustic modeling study of pile installation and removal activities planned for the Project which has been included as Appendix A. To assess potential underwater noise exposure of marine mammals during construction activities, Quijano and Austin (2017) determined source levels for six different construction scenarios (see Table 2-1). The source levels are frequency-dependent and suitable for modeling underwater acoustic propagation using JASCO's Marine Operations Noise Model (MONM). The modeling predicted the extent of ensonification and the acoustic footprint from construction activities, taking into account the effects of pile driving equipment, bathymetry, water sound speed profile, and seabed geoacoustic parameters. Auditory weighting was applied to the modeled sound fields to estimate received levels relative to hearing sensitivities of five marine mammal hearing groups following NMFS 2016 guidance.

The goal of this study was also to define zones of potential effects on marine mammals. The results are based on currently adopted sound level thresholds for auditory injury (Level A) expressed as peak pressure level (PK) and 24-hr sound exposure level (SEL), and behavioral disturbance (Level B) expressed as sound pressure level (SPL). Using these guidelines, Quijano and Austin (2017) calculated the maximum extent (distance and ensonified areas) of the Level A and Level B exposure zones for each marine mammal functional hearing group. This was calculated for both impact and vibratory pile driving of 18- and 30-in. piles for each of the following six Project scenarios:

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[15] Level A harassment may result in injury or death, whereas Level B only results in disturbance without the potential for injury. However, authorization of a Level A harassment take does not automatically imply that serious-injury to an animal has occurred.

- Scenario 1 – Removal of existing piles and installation/removal of temporary piles;
- Scenario 2 - installation of 18-in. piles (docks and dolphins);
- Scenario 3 - installation of 18-in. piles (barge landing);
- Scenario 4 - installation of 30-in. piles (dolphins);
- Scenario 5 - installation of H piles (dock barrier);
- Scenario 6 - and installation of sheet piles (dock barrier and barge landing).

Analyses of these scenarios were used to estimate potential takes for each of the five marine mammal species potentially impacted by the proposed Project activities (See Section 6.5).

Based on the revised NMFS guidelines, Level A thresholds consider cumulative sound exposure over a 24-hour period. Level B thresholds continue to be based on a single hammer strike event. Therefore, it may be necessary to request Level A incidental take in this IHA application for several of the species found within the Project area. This is especially true during impact pile driving of 30-in. diameter piles. However, authorization of Level A take does not automatically imply that serious injury to an animal has occurred. Many animals may not necessarily experience sound exposure levels that exceed the injury threshold if the exposure is temporary or of very short duration. If a marine mammal enters the Level A zone during pile driving and quickly leaves, it is unlikely that the animal experienced long-term adverse impact because the exposure would not result in serious injury. This is a possible conclusion for several of the species in the area.

5.2. Compliance with 'Small Numbers' and 'Negligible Impact' Requirements of MMPA

Upon request, Section 101(a) (5)(d) of the MMPA allows the incidental but not intentional taking of small numbers of marine mammals if certain findings are made (16 U.S.C. 1361 et seq.). NMFS authorizes incidental takes under the MMPA if the taking would: (1) be of small numbers; (2) have no more than a negligible impact on those marine mammal species or stocks; and (3) not have an immitigable adverse impact on the availability of the species or stocks for subsistence uses[16].

The estimate of takes requested relative to these requirements is included in Section 7 of this application.

[16] See http://www.nmfs.noaa.gov/pr/permits/incidental/

6. TAKE ESTIMATES FOR MARINE MAMMALS

Modeled results are presented as tables of distances at which sound pressure levels (SPLs) or sound exposure levels (SELs) fell below thresholds defined by criteria. For marine mammal injury, the Level A thresholds considered here follow the NMFS guidelines (NMFS 2016). Results are also presented as sound field isopleth maps, which show the planar distribution of sound levels with range and azimuthal direction (see Appendix A).

6.1. Threshold Criteria for Injury (Level A) and Behavioral (Level B) Disturbance

The criteria for sound exposure threshold levels as applied in this study are based on references that represent the current best available science, and require computing PK, SPL[17], and SEL. Appendix A describes these metrics and provides formulae. Results of the modeling study are presented in terms of the following noise criteria:

- Dual criteria (Auditory-weighted SEL and PK) Level A thresholds for marine mammals, based on NMFS (2016) for sound sources; and
- Level B thresholds for marine mammals of 120dB re 1 μPa SPL for non-impulsive and 160 dB re 1 μPa SPL for impulsive sound sources.

Maps depicting sound level contours that correspond to Level A and Level B criteria are presented in Appendix A.

6.1.1. Auditory Weighting Functions for Marine Mammals

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell *et al.* 2007). These frequency-dependent scaling functions are known as auditory weighting functions.

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \quad (1)$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2015). In July 2016, NMFS

[17] SPL refers to the root-mean-square sound pressure level. It is measured in dB re 1 μPa, which is a ratio of the time-mean-square sound pressure to the square of a standard reference sound pressure.

published its revised acoustic injury criteria that are based on PK and frequency-weighted SELs (NMFS 2016). The criteria depend on the hearing sensitivity of five marine mammal hearing groups as characterized in Southall *et al.* (2007): low-frequency cetaceans (LFC), mid-frequency cetaceans (MFC), high-frequency cetaceans (HFC), phocid pinnipeds in water (PPW), and otariid pinnipeds in water (OPW). The parameters are defined uniquely for each functional hearing group (Table 6-1). Of the five marine mammal species (four cetaceans and two pinnipeds) that may occur in the Action Area, humpback whales are classified as LFC, killer whales are MFC and harbor porpoise are classified as HFC (Southall *et al.* 2007). Harbor seals are members of the PPW group, while Steller sea lions are grouped under the OPW.

TABLE 6-1. PARAMETERS FOR THE RELEVANT AUDITORY WEIGHTING FUNCTIONS

Hearing Group	*a*	*b*	f_1 (kHz)	f_2 (kHz)	*K* (dB)
Low-frequency cetaceans	1	2	0.20	19	0.13
Mid-frequency cetaceans	1.6	2	8.8	110	1.20
High-frequency cetaceans	1.8	2	12	140	1.36
Otariids and other non-phocid marine carnivores	2	2	0.94	25	0.64
Phocids in water	1	2	1.9	30	0.75

Source: NMFS 2016

6.1.2. Auditory Injury (Level A) Threshold Criteria for Marine Mammals

This application applies the specific methods and Level A thresholds summarized by NMFS (2016, Table 6-2). The Level A criteria provide cautionary estimates of levels above which acoustic exposure may lead to loss of hearing, a process known as permanent hearing threshold shift (PTS).

TABLE 6-2. ACOUSTIC THRESHOLDS FOR LEVEL A INJURY

Hearing Group	Impulsive source		Non-impulsive source
	Peak Pressure Level (dB re 1 μPa)	Auditory-weighted SEL_{24h} (dB re 1 μPa²·s)	Auditory-weighted SEL_{24h} (dB re 1 μPa²·s)
Low-frequency cetaceans	219	183	199
Mid-frequency cetaceans	230	185	198
High-frequency cetaceans	202	155	173
Phocid pinnipeds in water	218	185	201
Otariid pinnipeds in water	232	203	219

Source: NMFS 2016

6.1.3. Disturbance (Level B) Threshold Criteria for Marine Mammals

Level B Harassment is defined as sound levels that exceed those that could disturb a marine mammal. For impulsive sounds, the threshold for Level B Harassment is an SPL of 160 dB re 1 μPa for pinnipeds and cetaceans (NMFS 2014b). NMFS has implemented a lower threshold of 120 dB re 1 μPa rms SPL for animals exposed to non-impulsive sources.

6.2. Modeling Methodology

Modeling of the six construction scenarios described in Section 5.1 at the Project site on Biorka Island followed three steps (Appendix A):

1. Piles driven into the sediment by impact, vibratory, or DTH hydro-hammering were characterized as sound-radiating sources. Source levels in 1/3-octave-bands were obtained by modeling (using JASCO's PDSM) or by adjusting source levels found in the literature. The exact method to obtain the 1/3-octave-band levels depends on the pile geometry and pile driving equipment, and it is described on a case-by-case basis (Appendix A);

2. The theory of underwater sound propagation was applied to predict how sound propagates from the pile into the water column as a function of range, depth, and azimuthal direction. Propagation depends on several conditions including the frequency content of the sound, the bathymetry, the sound speed in the water column, and sediment geoacoustics; and

3. The propagated sound field was used to compute received levels over a grid of simulated receivers, from which distances to criteria thresholds and maps of ensonified areas were generated.

The underwater sound fields predicted by the propagation models were sampled so that the received sound level at each geographic location (horizontal plane) was set to the maximum value of all modeled depths at that location. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths; and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded.

The $R_{95\%}$ is used to develop exposure maps because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases, $R_{95\%}$ neglects to account for significant protrusions in the footprint. Such cases are usually associated with bathymetric features affecting propagation and R_{max} might better represent the region of effect in specific directions. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

6.3. Acoustic Source Parameters

All environmental and sound source parameters used to model sound fields, including references for each data set from which the parameters were derived, and all related assumptions made are provided in Appendix A.

Where uncertainties in operating conditions existed, the models were parameterized to yield realistically conservative noise levels. Several such conservative assumptions were applied to the methods used in this study so that the results would not underestimate potential effects on marine life including:

- All the distances to thresholds (R_{max}, $R_{95\%}$) and the noise level contour maps represent the maximum sound levels over all depths because marine mammals swim through a wide depth range;

- The spectral content from pile driving activities of H piles, sheet piles, and cylindrical piles (impact driving) either modeled by PDSM or obtained from the literature, was extended in frequency to account for energy contributions up to 25 kHz, using measurement-based spectral decay factors;
- The location selected for modeling corresponded to the pile in the deepest water, for which coupling of sound into the water column is higher than shallower locations. In addition, the bathymetry used for modeling was also adjusted to represent mean high water;
- Modeling was carried out using the August sound speed profile, which exhibits the most pronounced surface channel over all other months for this geographic area; and
- The spectral content for vibratory pile driving of cylindrical piles was obtained from measured levels, which exhibit large energy contributions at high-frequency harmonics.

Source levels for impact pile driving testing in scenarios 2 and 4 were adjusted to reflect the higher SEL commonly observed in measurements obtained when piles are being driven to near refusal.

6.4. Distances to Level A and Level B Sound Thresholds

This section presents the distances in meters to marine mammal Level A and Level B thresholds for impulsive sources and vibratory sources (Table 6-3). The distances are based on NMFS (2016) for Level A and generally-accepted criteria for Level B. Acoustic contour maps, which show the directivity and range to various sound level isopleths, are presented in Appendix A. The reported radii for 24-hr SEL (Level A) thresholds are based on the assumption that marine mammals remain stationary or at a constant exposure range during the entire 24-hr period, which is an extremely unlikely scenario. These estimated distances for Level A represent an unlikely worst-case scenario.

TABLE 6-3. MODELED DISTANCES TO LEVEL A AND LEVEL B EXPOSURE THRESHOLDS FROM VIBRATORY AND IMPULSIVE SOURCES MODELED DISTANCES TO EXPOSURE THRESHOLDS FROM NON-IMPULSIVE SOURCES

Functional Hearing Group	Level A Vibratory Threshold *(dB re1 $\mu Pa^2 \cdot s$)*	Level A Impulse Threshold *(dB re1 $\mu Pa^2 \cdot s$)*	Distance to Level A Threshold (m)[1]											
			S1[2]		S2		S3		S4		S5		S6	
			Vibratory	Impulse	Vibratory	Impulse	Vibratory	Impulse	Vibratory	Impulse	Vibratory	Impulse	Vibratory	Impulse
LFC[3]	199	183	10	NA	350	30	10	630	260	80	-	670	40	1,360
MFC[4]	198	185	-	NA	10	-	-	10	10	-	-	130	<10	220
HFC[5]	173	155	-	NA	510	50	-	770	360	90	10	2,050	10	2,930
PPW[6]	201	185	-	NA	80	<10	-	200	60	10	-	290	10	770
OPW[7]	219	203	-	NA	-	-	-	10	-	-	-	<10	-	80
	Level B Vibratory Threshold *(dB re1 $\mu Pa^2 \cdot s$)*	Level B Impulse Threshold *(dB re1 $\mu Pa^2 \cdot s$)*	Distance to Level B Threshold (m)[1]											
All marine mammals	120	160	1,800	NA	10,002	710	4,270	550	10,002	1,250	790	430	4,720	790

[1] $R_{95\%}$ as modeled in Appendix A (Quijano and Austin 2017).
[2] Scenario 1 does not include impulsive sources.
[3] Low-frequency cetaceans, humpback whales.
[4] Mid-frequency cetaceans, killer whales.
[5] High-frequency cetaceans, harbor porpoise.
[6] Phocid pinnipeds in water, harbor seals.
[6] Otariid pinnipeds in water, Steller sea lions.

6.5. Estimated Takes

The potential for incidental take is estimated for each species by determining the likelihood that a marine mammal would be present within a Level A or Level B Zone of Influence (ZOI) during active pile driving for each of the construction scenarios shown in Table 2-1. This method is consistent with an approach used for SAC (2016) for the Kodiak Harbor replacement project. Pinnipeds (Steller sea lions and harbor seals) are present throughout the summer, as are harbor porpoise, and it is assumed that take requests could include multiple encounters of the same individual(s). Humpback whales and killer whales are expected to be in the Action Area only occasionally.

6.5.1. Incidental Take Estimates Assumptions

Incidental take estimates assume:

- Animals occurring within the Level A and Level B ensonified zones are considered to be in each zone simultaneously, but would only be counted as one Level A take;
- Exposures are based on total number of days that pile driving could occur and that animals might occur in the ensonified Action Area;
- One day equates to any length of time that piles are driven whether it is a partial day or a 24-hour period;
- All marine mammals occurring in the Action Area are assumed to be incidentally taken;
- An individual animal can only be taken once during a 24-hour period;
- For animals that may occur in small groups, each individual in the group would be considered taken;
- Exposures to sound levels at or above the relevant thresholds equate to take, as defined by the MMPA; and
- Level B take estimates are unmitigated and do not take into account monitoring and mitigation efforts to reduce take as described in Chapters 11 and 13.

Based on the available population data and modeled threshold areas or zones, potential take estimates are overestimations of the actual number of individuals exposed or “taken” by activities at the Project site. For example, in the absence of specific density estimates for Symonds Bay, it is assumed that the output of the calculation represents the maximum number of individuals that may be taken by the specified activity. In consideration of resident animals that may be present, the exposure estimate represents the number of instances a take may occur to a small number of individuals. It is assumed a notably smaller number of animals would actually be exposed more than once per individual. While pile driving can occur any day throughout the in-water work period, the calculations are on a per day basis. However, due to the time required for set up and movement of equipment only a fraction of that time (typically a matter of hours on any given day) would actually be spent pile driving. Vibratory and impulse driving would not happen simultaneously. Also, animals are assumed to be stationary and remain in the area of ensonification. This is unlikely as animals would be expected to move away from the noise source before the exposure would result in a meaningful impact that might affect the individual or populations.

Therefore, equating exposure to an actual "take" results in an overestimate of takes as defined in the MMPA.

The potential effectiveness of mitigation measures for Level A take is accounted for in the take requests presented in Section 6.5.4. Therefore, exposure estimates for Level A are overly precautionary and do not represent the take request.

6.5.2 Vibratory and Impact Pile Driving Airborne Noise

Airborne noises could also affect pinnipeds. However, noise generated during vibratory pile driving would reach the harbor seal in-air threshold (90 db) at approximately 112 ft (34 m) and is below the threshold for other pinnipeds. The in-air threshold for driving 30 in. diameter pipe (110 dB at 50 ft) would reach the harbor seal threshold (90 dB) at approximately 500 ft (152 m), and the threshold for other pinnipeds (Steller sea lions) (100 dB) at approximately 158 ft (48 m).

Pile driving will not exceed in-air disturbance thresholds for hauled-out pinnipeds and there are no haulout sites close enough that sound at the site could be detected. Therefore, during impact pile driving, temporary in-air disturbance would be limited to harbor seals and sea lions swimming on the surface through the immediate Action Area near the dock (approximately 500 ft (152 m), and within 158 ft (48 m), respectively. At this distance, any animal swimming would already have been taken by the in-water noise levels; therefore, in-air disturbance is generally not considered for pinnipeds swimming near the Project site. Further, proposed mitigation would prevent a take from occurring at these distances (see Section 11) or cause serious injury. For these reasons, in-air noise is not considered further in this document.

6.5.3 In-Water Incidental Take Exposure Calculations

Expected marine mammal presence is determined by past observations and general abundance in the Project area during construction. The take requests for this IHA application were estimated using information from several marine mammal data sets and counts, including observations from biologists, peer-reviewed literature, and information obtained from personal communication with researchers (i.e., J. Straley of University of Alaska Southeast) and state and federal biologists, as described in Chapter 4. Information obtained from local charter boat operators with Allen Marine Tours, Sitka, Alaska, was also used to document seasonal marine mammal occurrence as these charter vessels operate on a daily-basis in Sitka Sound and parts of the Action Area throughout the summer.

As described in Sections 3 and 4, the abundance of marine mammals in the Action Area correlates with the presence or absence of herring; the densities of the five marine mammals of concern are an order of magnitude greater when herring are abundant in the Sound (October through April) as compared to when they are less abundant or absent (May through September, corresponding with proposed Project activities). Marine mammal numbers are fairly consistent from month to month within each of these periods. Since Project construction activities would only occur during the summer months (May to September), incidental takes for each marine mammal species were estimated only for this period when marine mammals are present in numbers representing their lowest density throughout the year.

Additionally, these estimates assume that all five species could occur within the Action Area each day during construction activities (see Tables 2-2 and 2-3), thereby representing a maximum estimate of exposure to the noise sources. The take estimates also do not assume that animals would move away from the noise source. These assumptions provide a conservative estimate exposures to noise levels that may exceed thresholds for incidental take and therefore, provide an overestimate of potential takes. The following subsections describe the methods used to calculate estimates of the potential exposures to noise levels per day for each species.

6.5.3.1 Harbor Seals

As described in Section 4.1.2, harbor seals are present in Sitka Sound and potentially the Action Area throughout the year but their local abundance is defined by the presence of available prey. The seasonal pre-spawning and spawning runs of herring in Sitka Sound during April and the overwintering aggregations of adult herring are a very important seasonal forage resource for harbor seals in Sitka Sound. The largest counts of seals within the sound were made during the spring herring spawn at several adjacent rocky outcroppings and islands located approximately 24 km (15 miles) north of the Project site in northcentral Sitka Sound (see Figure 3-1). This location is beyond the greatest Level B threshold distance or ZOI from the activities at the Project site under any of the six construction scenarios (see Table 6-3). However, there are several smaller haulouts much closer to the Project location, including Biorka Island. Seals generally forage near the shoreline or in coastal waters as individuals rather than in groups. The animals with the greatest potential to be impacted by the activities at the Project are those individual seals that may forage near Biorka Island or possibly venture inside Symonds Bay while foraging, or individual animals that could be attracted to Project activities due to their curious behavior.

Therefore, harbor seals could be encountered in low numbers within the Action Area every day during construction activities (Tables 2-2 and 2-3). An estimate of five harbor seals could be present on any given day during the 70 days of pile installation and removal occurring from May through September, and therefore could be exposed to noise above the Level B threshold:

> *Underwater Level B exposure estimate: 5 animals/day × 70 days total of pile driving activity for all scenarios (vibratory, DTH, and impulse) = 350 potential harbor seal exposures to noise levels that may exceed the Level B threshold.*

During Scenario 6, the Level A ensonified area for harbor seals approaches 1 km so any animals within Symonds Bay may be temporarily exposed to these noise levels. However, Marine Mammal Observers (MMOs) would monitor the Level A ensonified areas at all times during construction activities (see Section 11.2.1). It is possible that one or two harbor seals could quickly approach and enter the mouth of Symonds Bay or the ensonified area outside the bay even as impulse pile driving activity is being shut down. For this reason, the Level A take request (see Section 6.5.4) allows for the potential that 2 animals might not be detected and enter the Level A zone. No Level A takes are anticipated as a result of vibratory pile driving for any species.

6.5.3.2 Steller Sea Lions

Steller sea lion abundance was estimated from NMFS MML surveys taken during pupping season, and from observations taken by charter whale-watching and fishing boats that operate from spring throughout the summer season in Sitka Sound (see Section 4.2.3). As expected, the abundance of Steller sea lions at the Project site fluctuates seasonally with prey abundance.

Similar to harbor seals, sea lions focus on seasonal prey resources which occur in the northcentral Sitka Sound area. The center of herring spawning distribution is north of calculated ZOIs for activities at the Project site (See Table 6-3). Herring do not spawn in Symonds Bay and prey resources inside Symonds Bay are limited, especially as compared to the northern coastal areas of Sitka Sound. Therefore, while individual sea lions may occur outside Symonds Bay it is unlikely that they would be attracted to Symonds Bay to forage. In addition, the distance to the OPW Level A threshold for impulsive noise is only 80 m (see Table 6.3). During the construction period of May through September, sea lion numbers near Biorka Island are likely to be at their lowest. However, to be precautionary for purposes of this application, it is assumed that Steller sea lions may be present outside Symonds Bay every day during construction, and that take estimates include multiple harassment of the same individuals. Exposure of 5 animals to noise levels that may exceed Level B thresholds could occur each day of the Project (a total of 70 days):

> *Underwater Level B exposure estimate: 5 animals/day × 70 days of pile driving activity = 350 potential Steller sea lion exposures to noise levels that may exceed the Level B threshold.*

No Level A takes are expected for Steller sea lions. The linear distance (from the noise source) to the threshold for a Level A take for sea lions (OPW) is less than 10 m (Table 6-3). However, to be precautionary for purpose of this application, it is assumed that a Steller sea lion could approach the construction site and become exposed to noise levels that exceed Level A thresholds during impact pile driving.

As described in Section 4.2.3, there has been an influx of western DPS animals into the Action Area. For this application, it is assumed that at least 50 percent of the animals in the Action Area could be from the western DPS. Therefore, potential Level B takes are apportioned appropriately to each DPS. Level A takes were calculated considering that one group of 5 animals could be exposed. This number (5) was split between the two DPSs and rounded up to 3 Level A takes from each DPS for a total of 6 Steller sea lion level A takes.

6.5.3.3 Humpback Whales

As described in Section 4.3.3. the seasonal abundance of humpback whales in Sitka Sound varies from very low numbers during summer to very abundant between late fall and the spring herring spawning cycle. During mid-summer, tour boats generally see four to five whales per day, sometimes in small groups, in the middle of Sitka Sound (see Section 4.3.3; E. Majeski, pers. comm.). Therefore, a count of 5 humpback whales per day was used to estimate takes per day.

Individual whales may be exposed to increased noise from the Project only when they are directly north of Symonds Bay, and when noise propagates out of Symonds Bay into the sound. During the intended construction period of May through September, the most likely scenario where a whale may be exposed to noise from the Project would be during Scenarios 2 and 4 when distances to the Level B exposure thresholds from non-impulsive DTH methods could exceed 10 km from the noise source (see Table 6-3 and Appendix A). Therefore, to be precautionary for the purpose of this application, it is assumed that humpback whales may be exposed to noise levels exceeding Level B thresholds during any scenario when vibratory or DHT drilling is occurring. It is likely that this will include multiple harassment of the same individuals.:

Underwater Level B exposure estimate: 5 animals/day × 70 days of activity = 350 humpback whales potentially exposed to noise levels that exceed the Level B threshold.

All humpback whales potentially encountered are assumed to be from the Hawaii DPS and CNP stock (see Section 4.3.1). No takes from the Mexico DPS are requested.

Level A takes are considered highly improbable for humpback whales. The maximum distance at which a humpback whale may be exposed to noise levels that exceed Level A thresholds is 1.4 km during Scenario 6. Even though the ensonified area extends outside of the entrance to Symonds Bay (see Appendix A), an MMO stationed near the mouth of the bay (see Figure 1-3) would be able to see a humpback whale outside Symonds Bay before it enters the area ensonified above the Level A threshold and could shut down the noise producing activity to avoid Level A take. In the unlikely event a whale would go undetected and enter the Level A zone, 3 Level A takes are requested as shown in Table 6-5. All level A takes would be from the Hawaii DPS.

6.5.3.4 Killer Whales

Small groups of 5 to 6 transient killer whales per day could be observed throughout the summer months (see Section 4.4.2; E. Majeski, pers. comm.). Generally, transient killer whales follow movements of Steller sea lions and harbor seals on which they prey. Given the low numbers of Steller sea lions in Sitka Sound during summer, it is consistent that transient killer whales would also be rare or infrequent in the Action Area. Killer whales do frequent sea lion haulouts as described in Section 4.4.2, but these haulouts and rookeries are well outside of the Level A and Level B ZOIs calculated for this Project (see Table 6-3). It is unlikely that killer whales would be impacted by proposed activities at the Project site. However, because they have been observed in low numbers in or near the Action Area during summer, occurrence outside of Symonds Bay is possible and, as a result, killer whales may be encountered as they transit Sitka Sound searching for prey. Therefore, this application assumes that a group of up to 6 killer whales could pass through the area north of Symonds Bay that is ensonified by proposed construction activities up to six times during the 70 days of noise generating activities. It is assumed that exposure could include multiple harassments of the same few individuals:

Underwater Level B exposure estimate: 6 animals/day × 6 days = 36 potential killer whale exposures to noise levels that may exceed Level B thresholds.

Level A takes of killer whales are not expected during this Project, and no Level A takes are requested. The maximum linear distance to the Level A threshold for killer whales (classified as MFCs) is less than 250 m from the source (Table 6-3). It is assumed an MMO would be able to observe animals at this distance and shut down pile driving activities in time to avoid Level A takes.

6.5.3.5 Harbor Porpoise

As described in Section 4.5.2, harbor porpoise have been observed in Symonds Bay during summer months and could be encountered in low numbers within the Action Area.

The mean group size of harbor porpoise in Southeast Alaska was estimated to be 2 to 3 individuals (Dahlheim *et al.* 2009). Small groups of 2 to 3 animals (consistent with two adults and a calf in summer) were also reported in Alaska DOT&PF (2016). Six sightings of individuals or pairs were observed during 110 days of monitoring of the Kodiak Ferry Terminal and Dock Improvements Project (SAC 2016).

Using this as the best estimate of harbor porpoise in the Action Area at any time, 3 animals per day is used to estimate the number of animals that could be exposed to noise levels that exceed threshold criteria for either Level A or Level B takes during the summer months. Since harbor porpoise have been observed in summer in Symonds Bay, it is assumed that 3 harbor porpoises could be present at least every other day during project construction. The distances to Level A thresholds for harbor porpoise (HFC) are largest during impulse driving under Scenarios 5 and 6 (see Table 6-3), and extend beyond the entrance to Symonds Bay. The duration of Scenarios 5 and 6 is expected to be 21 days (see Tables 2-2 and 2-3); therefore half that number or 10.5 days of exposure is used to estimate the Level A takes:

> *Underwater Level A exposure estimate: 3 animals/day × 10.5 days exposure = 31.5 harbor porpoise (rounded up to 32) potentially exposed to noise levels that may be above the Level A threshold*.

If a harbor porpoise is observed by an MMO, it will be counted as a Level A take. This is considered an exceptionally precautionary approach to estimating the number of animals that might be exposed to increased noise levels from the construction activities at the Project site.

Due to the size of the Level B exposure area, especially under Scenarios 2 and 4 (see Table 6-3), it is possible that 3 harbor porpoise could approach quickly during half of the project days (35) without being detected by an MMO and enter the Level B ensonified area. Therefore, for purposes of this application, Level B takes are estimated as an extrapolated number based on the potential for undetected harbor porpoise to be exposed above threshold levels, especially during Scenarios 2 and 4. Therefore, the number of Level B takes that might occur is:

> *Underwater extrapolated Level B exposure estimate: 3 animals/day × 35 days of non-impulsive and impulse pile driving activity (from Table 2-3) = 105 harbor porpoise potentially exposed to noise levels that may be above the Level B threshold*.

Extrapolated takes will be recorded and reported weekly as described in section 13.4.

6.5.4 Level A and Level B Take Requests Relative to Abundance of Stock or DPS

The total number of Level A and Level B takes requested for the duration of this Project are presented in Table 6-4. The table also includes the take estimates as a percentage of abundance for each species or DPS as appropriate.

Given the precautionary approach to estimating Level B exposures described in Section 6.5.3, the numbers provided in Table 6-4 overestimate what could be actual takes. Being exposed to noise at or slightly above Level B thresholds does not automatically imply that a take by harassment has occurred. There is general recognition that minor and brief changes in behavior generally do not have biologically significant consequences for marine mammals and do not “rise to the level of taking” (NRC 2005). The biological relevance of a behavioral response to noise exposure depends, at least in part, on how long it persists. Southall *et al*. (2007) noted that “a reaction lasting less than 24 hrs is not regarded as particularly severe unless it could directly affect survival or reproduction.” Based on these considerations, it is highly unlikely that the potential behavioral effects from this project would result in anything more than minor, biologically insignificant consequences for any individual animal or for the populations. Takes are likely overestimated for each species because simple exposures to the Level B threshold of 120 dB without behavior changes would not constitute a "take". However, for the purposes of this application, the FAA is assuming that an exposure to Level B thresholds equates to a take. The Level B Harassment authorization requested for the species shown in Table 6-4 covers any unexpected circumstances throughout the Project that might lead to a "take".

TABLE 6-4. ACOUSTIC HARASSMENT LEVEL A AND LEVEL B TAKE REQUESTS AND PERCENTAGE OF ABUNDANCE

Species	Stock or DPS Abundance[1]	Level A Take Request	Level A Take Request Percent of Abundance	Level B Take Request	Level B Take Request Percent of Abundance
Harbor Seal (S/C stock)	14,855	2	0.013	350	2.35
Steller Sea Lion (eastern DPS)[2]	60,131	3	0.005	175	0.29
Steller Sea Lion (western DPS)[2]	49,497	3	0.006	175	0.35
Humpback Whale (CNP stock)[3]	10,103	3	0.030	350	3.46
Killer Whale[4]	830	0	NA	36	4.34
Harbor Porpoise (SEAK stock)	11,146	32	0.287	105	0.942

[1]From Table 3-1.
[2]Steller sea lion take is apportioned by DPS assuming 50 percent of sea lions at Kaiuchali rookery are from the western DPS.
[3]All humpback whale takes are from Hawaii DPS.
[4]Transients only.

Level A takes would be reduced when considering mitigation measures described in Section 11.2.1 and the monitoring plan in Section 13.1. The entrance to Symonds Bay is narrow and could be easily monitored. The 24-hr SEL (Level A) thresholds are based on the assumption that marine mammals remain stationary or at a constant exposure range during an entire 24-hr period (Quijano and Austin 2017). Pile driving activities would be shut down by MMOs before this could occur. Generally, a Level A take would only occur if an animal enters the Bay, goes undetected by two observers, and remains there for a considerable amount of time without mitigation or in the case of Harbor porpoise, the zone cannot be fully monitored.

7. ANTICIPATED IMPACT OF THE ACTIVITY ON SPECIES AND STOCKS

The FAA Alaskan Region is requesting authorization for Level A and Level B takes by acoustic harassment of marine mammals. Any incidental take would likely consist of multiple takes of the same individual, rather than single takes of unique individuals. This is especially valid for the requested number of Level B takes. The take calculations by stock assume takes of individual animals, instead of repeated takes of a smaller number of individuals. Therefore, the take/stock percentage calculations are very conservative.

A review of Table 6-4 indicates:

- Exposure estimates described in Section 6.5.3 are considered worst-case;
- Based on the analysis, requesting Level A incidental take in the IHA application is a precautionary measure. A minimal number of Level A takes is being requested in case an animal unexpectedly enters the ensonified area or the zones cannot be monitored due to size or visibility issues. Serious injury or mortality is not expected for any of the five species;
- The estimated Level B take levels are also considered negligible (<5 percent of estimated stock size for any species or DPS).

7.1 Hearing Impairment and Non-Auditory Injury

Permanent or temporary hearing impairment or threshold shifts (PTS or TTS) could occur when marine mammals are exposed to very loud noise for short periods or to quieter noise over a prolonged period. When animals are in close proximity to the sound source there is a potential for PTS or TTS.

NMFS revised acoustic guidelines (2016), take into account the most recent scientific data on TTS (NMFS 2014). Hearing impairment and non-auditory physical effects (e.g., stress) might occur in marine mammals exposed to strong, pulsed underwater sounds. However, the limited data available from captive marine mammals do not provide definitive evidence that any of these effects occur, even for marine mammals in close proximity to sound sources. In addition, the planned monitoring and mitigation measures include shutting down equipment should animals enter specified exclusion zones to prevent Level A takes of most species (see Section 11). Given the brief duration of exposure of any marine mammal, in combination with the proposed monitoring and mitigation measures, auditory impairment or other non-auditory physical effects are unlikely to occur during the proposed Project.

7.2 Masking

Natural and artificial sounds can disrupt behavior by masking. The masking of communication signals by anthropogenic noise may reduce the communication space of animals (Clark *et al.* 2009). The frequency range of the potentially masking sound is important in determining any potential behavioral impacts. Because sound generated from in-water pile driving is mostly concentrated at low frequency ranges, it may have less effect on high frequency sounds made by porpoises. The most intense underwater sounds of the proposed Project are those produced by impact pile driving. Given that the energy distribution of pile driving covers a broad frequency spectrum, sound from these sources would likely be within the audible range of marine mammals present in the Action Area.

The impact pile driving activity proposed for this Project is relatively short duration. The probability that impact pile driving associated with the proposed Project would result in masking acoustic signals important to the behavior and survival of marine mammal species is low. Vibratory pile driving is also expected over a relatively short duration, with rapid oscillations occurring for approximately twenty minutes per pile. It is possible that noise generated during vibratory pile driving may mask acoustic signals important to the behavior and survival of marine mammal species in the Project Area, but the short-term duration and limited ensonified area would result in insignificant impacts from masking. Any masking event that could possibly rise to Level B harassment under the MMPA would occur concurrently within the zones of behavioral harassment already estimated for vibratory and impact pile driving, and which have already been taken into account in the exposure analysis. Therefore, it is unlikely that sounds produced by the pile driving described here would mask marine mammal communications.

7.3 Disturbance Reactions

Responses to continuous sound such as those generated during vibratory pile installation, are not as well documented as compared to those for pulsed sounds. For both types of pile driving, it is likely that the onset of pile driving could result in temporary, short-term changes in an animal's typical behavior or avoidance of the affected area (Richardson *et al.* 1995). The biological significance of many of these behavioral disturbances is difficult to predict, especially if the detected disturbances seem to be minor. However, behavioral modification could be expected to be biologically significant if the change affects an individual’s growth, survival, or reproduction.

7.4 Small Numbers Consideration

Table 6-4 presents the number of animals potentially exposed to elevated noise levels from the Project that could result in a Level B or Level A take by harassment. For all species, less than 0.3 percent of total stock would be potentially affected by noise levels that exceed the threshold that for Level A acoustic harassment due to activities at the Project site. Estimates of Level B, non-injurious take, are less than 4.5 percent of stock size for all species.

Also, it is very unlikely there would be multiple takes of a smaller percentage of individuals. The numbers of animals authorized to be taken for all species is considered negligible or very small relative to their stocks size even if each take occurred to a new individual which is very unlikely. In all cases, the take request is less than one percent of the estimated size of the stock and for several species evaluated, is at least an order of magnitude less than that. These estimates are considered “small numbers” pursuant to NMFS guidance. Further, potential take at these levels would not have any effect on populations, population recruitment or survival, and the effect of such take would be considered insignificant.

Based on this analysis of effects, and taking into consideration the implementation of the mitigation and monitoring measures (see Section 11), only small to very small numbers of marine mammals are likely to be taken relative to the populations of the affected species or stocks.

7.5 Negligible Impact Consideration

Negligible impact is "an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival"[18]. A negligible impact finding is based on the lack of likely adverse effects on annual rates of recruitment or survival (i.e., population-level effects). An estimate of the number of Level A or Level B harassment takes alone is generally not enough information on which to base an impact determination. In addition to considering estimates of the number of marine mammals that might be "taken" through behavioral harassment, other factors were considered including: the nature of responses (intensity and duration); the context of responses (critical reproductive time or location, migration, etc.); number and nature of estimated Level A takes; number of estimated mortalities; effects on habitat; and the status of the species. These considerations apply to the five species listed in Table 3-1.

Pile driving activities associated with the proposed Project have the potential to temporarily disturb or displace marine mammals. Specifically, the specified activities may result in Level A or Level B harassment (behavioral disturbance) for all species authorized for take, from underwater sound generated from pile driving. Potential takes could occur if individuals of these species are present in the ensonified zone when pile driving is underway.

The takes from Level A harassment would be due to potential behavioral disturbance. While Level A takes have been requested for this Project, serious injury, PTS, or death would be extremely unlikely for all authorized species. The request for these potential takes is considered precautionary to prevent an unnecessary work stoppage due to an accidental take. The precautionary numbers help to determine the appropriate level of mitigation and monitoring, which would further ensure that a Level A take is avoided. Therefore, the exposure would occur in a very short time-frame or the Project activity would be stopped until the animal had moved out of the Level A threshold zone.

The takes from Level B harassment would be due to potential behavioral disturbance and potential TTS. Injury is unlikely for all species exposed, as the FAA would enact several required mitigation measures to prevent animals from entering the Level A serious injury zone (see Section 11). The FAA would ensure that prior to pile driving operations, there would be no marine mammals in Symonds Bay, or they would allow marine mammals to vacate the area prior to commencement of pile driving. The FAA would establish and monitor a shutdown zone within Symonds Bay for authorized species, which would prevent or significantly reduce the likelihood of injury to these species. The FAA would also record all occurrences of marine mammals and any behavior or behavioral reactions observed, any observed incidents of behavioral harassment, and any required shutdowns. The FAA would also submit a report upon completion of the Project. The FAA believes that proposed mitigation measures are sufficient to reduce the effects of specified activities such that the least practicable adverse impact upon the affected species, as required by the MMPA.

The FAA's proposed activities are localized and of short duration, spread out over a 5-month period (May to September). The entire Project Area is limited to the Symonds Bay and its immediate surroundings. While impact driving does have the potential to cause injury to marine mammals, mitigation in the form of shutdown zones should eliminate or minimize exposure to Level A thresholds. Vibratory driving does

[18] Definition at 50 CFR 216.103

not have significant potential to cause injury to marine mammals due to the relatively low source levels produced and the lack of potentially injurious source characteristics. Additionally, FAA intends to conduct pile driving during months when marine mammal densities are lower than during peak foraging months, thereby minimizing noise exposure.

Based on current literature as well as monitoring from other similar activities, effects on marine mammals that are taken by either Level A or Level B harassment could result in reactions such as increased swimming speeds or increased surfacing time (Lerma 2014). Most individuals would simply move through or away from the sound source and be temporarily displaced from the areas of pile driving. This reaction has been observed primarily in association with impact pile driving. In response to vibratory driving, pinnipeds (which may become somewhat habituated to human activity in industrial or urban waterways) have been observed to orient towards and sometimes move towards the sound. Noise anticipated during Project construction activities would be similar to or lower than that produced during construction activities conducted in similar locations where no serious injuries, mortality or long-term adverse consequences from behavioral harassment of marine mammals were reported. Repeated exposures of individuals to levels of sound that may cause Level B harassment would be unlikely to result in hearing impairment or to significantly disrupt foraging behavior. Thus, even repeated Level B harassment of some small subset of the overall stock would be unlikely to result in any significant realized decrease in fitness for the affected individuals and would not result in any adverse impact to the individual or the stock as a whole.

In summary, the takes requested for this activity would result in no more than a negligible impact to any of the marine mammal species that may be taken during this Project. This is based on: 1) the overall effectiveness of proposed mitigation measures at minimizing the effects of pile driving and associated construction activities; 2) the low probability of serious injury or mortality to species; and 3) the anticipated incidents of Level B harassment likely consisting of, at worst, temporary modifications in behavior. Further, the results of recent studies at similar, adjacent locations demonstrate that the potential effects of the specified activity would have only short-term effects on individuals. The specified activity is not expected to impact rates of recruitment or survival and would therefore not result in population-level impacts.

8. ANTICIPATED IMPACTS ON SUBSISTENCE USE

The Alaska Department of Fish and Game (Wolfe *et al.* 2013) has regularly conducted surveys of harbor seal and Steller sea lion subsistence harvest in Alaska. During 2012, the estimated subsistence take of harbor seals in southeast Alaska was 595 seals with 49 of these taken near Sitka (Wolfe *et al.* 2013). This is the lowest number of seals taken since 1992 (Wolfe *et al.* 2013) and is attributed to the decline in subsistence hunting pressure over the years as well as a decrease in efficiency per hunter (Wolf *et al.* 2013).

Significantly, the peak hunting season in southeast Alaska occurs during the month of November and again over the March to April time frame (Wolfe *et al.* 2013). This corresponds to times when seals are aggregated in shoal areas as they prey on forage species such as herring, making them easier to find and hunt.

The proposed Project is in an area where subsistence hunting for harbor seals or sea lions could occur (Wolfe *et al.* 2013), but the location is not preferred for hunting. There is little to no hunting documented in the vicinity and there are no harvest quotas for non-listed marine mammals. For these reasons and the fact that Project activities would occur outside of the primary subsistence hunting seasons, there would be no impact on subsistence activities or on the availability of marine mammals for subsistence use.

To satisfy requirements under Section 106 of the National Historic Preservation Act (NHPA), R&M Consultants, Inc. reached out to the Sitka Tribe of Alaska, Central Council of the Tlingit and Haida, and Sealaska regarding cultural resources in 2016. No issues or concerns with the project were raised during this effort. R&M also consulted Jeff Feldpausch, tribal biologist for the Sitka Tribe of Alaska, on potential impacts to subsistence activities and/or the stock from which these activities rely on. Mr. Feldpausch represents subsistence on the Sitka Regional Advisory Committee and has staffed the Sitka Tribe of Alaska’s Cultural, Customary, and Traditional Committee for several years. He did not bring forward any concerns regarding potential impacts to the subsistence stock in the area around Biorka Island.

9. ANTICIPATED IMPACT ON HABITAT

Construction activities could generate temporary impacts on marine mammal habitat due to increased in-water sound pressure levels from pile driving and removal activities. Other potential temporary impacts on habitat include changes in water quality (increases in turbidity levels) and disturbance to prey species. Best management practices (BMPs) and minimization practices used by the FAA to minimize potential environmental effects from project activities are outlined in Section 11 Mitigation Measures.

9.1. Underwater Noise Disturbance

NMFS is currently using an in-water noise disturbance threshold of 120 dB re 1 μPa for pinnipeds and cetaceans for continuous noise sources, unless the site-specific background noise is higher than 120 dB re 1 μPa. In that case, the higher background becomes the threshold.

There are several short-term and long-term effects from noise exposure that may occur to marine mammals, including impaired foraging efficiency and its potential effects on movements of prey, harmful physiological conditions, energetic expenditures, and TTS or PTS shifts due to chronic stress from noise (Southall *et al.* 2007). Regarding foraging, there is minimal foraging by marine mammals inside Symonds Bay. Therefore, it is highly unlikely that foraging or forage species would be impacted by the proposed activities.

Pile driving would expose marine mammals to potential noise harassment but in-water noise impacts are localized and of short duration. Therefore, any impact on individual cetaceans and pinnipeds would be limited.

9.2. Water and Sediment Quality

Short-term turbidity increases would likely occur during in-water construction work, including pile driving, and pile removal. The physical resuspension of sediments could produce localized turbidity plumes that could last from a few minutes to several hours. Contaminated sediments are not expected at the Project site but any that do occur would be tightly bound to the sediment matrix. Because of the relatively small work area, any increase in turbidity would be limited to the immediate vicinity of the Project site and adjacent portion of the bay. There is little potential for pinnipeds to be exposed to increased turbidity during construction operations. Therefore, exposure to re-suspended contaminants is expected to be negligible since sediments would not be ingested and any contaminants would be tightly bound to them.

Considering local currents, tidal action and implementation of BMPs, any potential water quality exceedances would likely be temporary and highly localized. The local tides and currents would disperse suspended sediments from pile driving and dredging operations at a moderate to rapid rate depending on tidal stage.

Cetaceans are not expected to come close enough to the Biorka Dock site to encounter increased turbidity from construction activities. Any pinnipeds would avoid the short-term, localized areas of turbidity. Therefore, the impact from increased turbidity levels would be negligible to marine mammals.

9.3. Passage Obstructions

Pile driving and structure removal at the Project location would not obstruct movements of marine mammals. Construction activities at the Project site would occur within 500 ft of the shoreline. Similarly, vessel strikes are unlikely for the proposed Project.

9.4. Construction Effects on Potential Prey

Construction activities would produce continuous and pulsed sounds. Fish react to sounds that are especially loud or are intermittent, low-frequency sounds. Short duration, sharp sounds can cause overt or subtle changes in fish behavior and local distribution. Popper (2003) found that the process of hearing across fishes is quite variable, ranging from species that only hear up to 100 or 200 Hz to others that hear to well over 180 kHz. Hastings and Popper (2005) identified several studies that suggest fish may relocate to avoid certain areas of sound energy. Additional studies have documented effects of pile driving on fish, although several are based on studies in support of large, multiyear construction projects (Scholik and Yan 2001, 2002; Popper and Hastings 2009).

Generally, the most likely impact to fish from construction activities at the Project site would be temporary behavioral avoidance of the area. However, there are no salmon spawning streams in the vicinity of the Project, and Symonds Bay does not support large aggregations of pre-spawning or spawning herring. Prey are largely absent from the Project site during the duration of the Project activities (mid-summer) as the activities would occur outside the spawning season for herring. Any impacts to marine mammal prey species are expected to be minor and temporary due to the short timeframe for the Project.

Increased turbidity would be expected in the immediate vicinity (within 25 ft [7.6 m]) of construction activities. Suspended sediments and particulates would dissipate quickly within a single tidal cycle. Given the limited area affected and high tidal dilution rates any effects on fish would be minor or negligible. In addition, BMPs would be in effect which would limit the extent of turbidity to the immediate Project Area.

9.5. Construction Effects on Potential Foraging Habitat

Pile installation may suspend sediments and increase turbidity. Any increases in turbidity would be temporary, localized, and minimal (see Section 9.2). The FAA must comply with state water quality standards during construction operations by limiting the extent of turbidity to the immediate Project area. In general, turbidity associated with pile installation is expected to be localized to about a 25 ft radius around the pile (Everitt *et al.* 1980). Cetaceans are not expected to be close enough to the project pile-driving areas to experience effects of turbidity, and any pinnipeds would be transiting the area and could avoid localized areas of turbidity. Therefore, the impact to marine mammals from increased turbidity levels during construction would be negligible. Furthermore, pile driving and pile removal at the project site would not obstruct movements or migration of marine mammals.

10. ANTICIPATED EFFECTS OF HABITAT IMPACTS ON MARINE MAMMALS

This section includes a summary and discussion of the ways that the specified activity (e.g. pile driving), associated with the reconstruction of the dock at Biorka Island may impact marine mammals due to impacts on their habitat. Mitigation measures would reduce impacts to marine mammals from the Project activities (see Section 11).

As described in Section 9, the proposed activities would not result in a significant adverse or permanent loss or modification of habitat for marine mammals or their prey. The most likely effects on marine mammal habitat due to the proposed Project would be temporary, short duration in-water noise, temporary prey (fish) disturbance, and localized, temporary water quality effects. Because of the short duration of the activities and the relatively small area of the habitat that may be affected, as well as the availability of other nearby suitable habitat, the impacts to marine mammal habitat would not be expected to cause significant or long-term negative consequences. Additionally, no physical damage to habitat is anticipated as a result of Project activities at Biorka Island. Therefore, the potential impacts to marine mammal habitat is expected to be negligible.

11. MITIGATION MEASURES

FAA activities are subject to federal, state and local permit regulations, and routinely use the best guidance available (e.g., BMPs and mitigation measures) to avoid and minimize (to the greatest extent possible) impacts on the environment, ESA species, designated critical habitats and species protected under the MMPA.

Mitigation for noise would occur throughout all construction activities and mitigation measures to reduce total takes (e.g., monitoring, shutdown periods) would be employed throughout all phases of construction at the Project site. General mitigation measures used for all construction practices are listed first (Section 11.1), followed by specific mitigation measures for pile driving-related activities (Section 11.2)

11.1. Construction Activities

The FAA performs construction in accordance with the best guidance available (e.g., BMPs and mitigation measures) to avoid and minimize (to the greatest extent possible) impacts on the environment, ESA species, designated critical habitats and species protected under the MMPA. Some general BMPs include:

- The dock would be maintained in a manner that does not introduce any pollutants or debris into the harbor or cause a migration barrier for fish;
- Fuels, lubricants, and other hazardous substances would not be stored below the ordinary high water mark;
- Properly sized equipment would be used to drive piles;
- Oil booms would be readily available for containment should any releases occur;
- The contractor would check for leaks regularly on any equipment, hoses, and fuel storage that occur at the project site;
- All chemicals and petroleum products would be properly stored to prevent spills; and
- No petroleum products, cement, chemicals, or other deleterious materials would be allowed to enter surface waters.

11.2. Pile Installation Activities

The following subsections describe mitigation measures proposed by the FAA to reduce impacts on marine mammals to the lowest extent practicable.

11.2.1. Marine Mammal Monitoring and Shutdown Procedures

Marine mammal monitoring would be employed during all pile-driving and removal scenarios.

11.2.1.1. Level A Shutdown Zones

Current NMFS guidelines recommend that noise-producing activities should be shut down prior to reaching the PTS threshold (NMFS 2016). This would occur at a noise level lower than that which would result in injury (Level A). MMOs would be used to monitor Zones of Exclusion (ZOEs) and would stop work before an animal enters the Level A threshold zone to the extent possible, thereby preventing the potential onset of PTS. A primary MMO would be placed at a vantage point (e.g., at Hanus Point or across the bay from Hanus Point, Figures 1-2 and 1-3) that allows monitoring across the mouth of Symonds Bay, a width of about 0.6 miles (1 km). Hanus Point is slightly elevated (see Figure 1-3). The MMO will observe the areas from an elevated location if it is determined accessible and safe to do so. The area potentially ensonified above Level A thresholds during pile driving would be truncated by the location of the dock on the western shore near the head of the bay. By placing a primary MMO approximately 0.5 mile (800 m) from the Project site at the mouth of Symonds Bay, the maximum distance required to observe the Level A ensonified zone would be reduced, and the area of water ensonified at or above Level A threshold zones for most cetaceans and pinnipeds could be visually monitored. Table 11-1 summarizes the distance to Level A shutdown zones (in meters) for each scenario and each functional hearing group. Vibratory and impulse hammering during any scenario would not happen simultaneously; there will be sufficient time tor MMOs to be notified and to adjust the focus of monitoring as needed. Pink shading in Table 11-1 indicates monitoring and shutdown for marine mammal presence outside of the bay is required; as shown in the table, this is necessary for two species, harbor porpoise and humpback whales during Scenarios 5 and 6. Green shading indicates monitoring for shutdown within the bay, facilitated by having an observer at the mouth of the bay and another at the dock:

- *Harbor Porpoise (HFCs)*: The largest Level A ZOEs are seen for HFCs in any scenario, with nearly 1.8 miles (3,000 m) in Scenario 6 being the largest distance for Level A exposures (Table 6-3). A reasonable monitoring zone of 1 mile (1,600 m) is recommended as shown in Table 11-1. This worst-case Level A harassment zone would be monitored during all pile removal and installation activities. Because the distance to the Level A threshold is large for HFCs, if a harbor porpoise is observed by the MMO, especially during Scenarios 5 or 6, it is likely to already be inside the Level A ZOE for HFCs. The animal would be recorded as a Level A take.

- *Humpback Whales (LFCs)*: Any large whale observed approaching the visible limit for MMOs during impulse pile driving activities would be assumed to be a humpback and would be continually monitored to ensure that it does not enter the Level A ZOE for LFCs (~ 0.9 mile [1,400 m]; Table 11-1). If the whale does approach or enter the ZOE, it will be monitored for one hour before shut down of work is initiated. This is because the Level A thresholds are based on the whale remaining in the ensonified area for an extended period of time. If the whale moves away in less than one hour, mitigation will not be required. If the whale remains in the Level A zone for one hour, or enters the ~1,400 m Level A zone, then Project activities will be halted and restarted as described in Section 13.1.

- *Killer whales (MFCs), Harbor seals (PPWs) Steller sea lions (OPWs)*: If any of these animals are observed immediately outside of, or inside the mouth of Symonds Bay during pile driving or removal activities, MMOs would closely monitor animal movements to ensure that the animals do not approach closely enough to be exposed to noise above Level A noise thresholds (distances shown in Table 11-1). All activities would be shut down until the animal moves out of the bay, following monitoring and restart protocols in Section 13.1.

TABLE 11-1. DISTANCES TO LEVEL A SHUTDOWN AND LEVEL B EXPOSURE ZONES

	Distance to Level A Shutdown zone (m)[1]											
	Scenario 1[2] Removal of existing piles and installation/removal of temporary piles		**Scenario 2**[3] Installation of 18-inch pipe piles (dock and dolphin)[1]		**Scenario 3** Installation of 18-inch pipe piles (barge landing)		**Scenario 4**[3] Installation of 18-inch pipe piles (barge landing)		**Scenario 5** Installation of H piles (dock wave barrier)		**Scenario 6** Installation of sheet piles (dock wave barrier and barge landing)	
	22 days		16 days		9 days		2 days		5 days		16 days	
Species	Vibratory	Impulse	Vibratory	Impulse	Vibratory	Impulse	Vibratory	Impulse	Vibratory	Impulse	Vibratory	Impulse
Harbor Porpoise	-	-	600	50	-	800	400	100	10	1,600[4]	80	1,600[4]
Humpback whales	10	-	400	30	10	700	300	80	-	700	40	1,400
Harbor Seals	-	-	80	<10	-	200	60	10	-	300	10	800
Killer whales	-	-	10	-	-	10	10	-	-	150	<10	250
Steller sea lions	-	-	-	-	-	10	-	-	-	10	-	80
	Distance to Level B Exposure Zones (m)[1]											
All marine mammals	1,800	-	10,100[5]	800	5000	600	10,100[5]	1300	800	430	5000	800

NOTE: Vibratory and impulse hammering will not happen simultaneously; there will be sufficient time tor MMOs to be notified and to adjust monitoring as needed. An MMO will be stationed at the mouth of the bay about 800 m from the noise source. Pink shading indicates monitoring and potential shutdown for presence outside of the bay is required. Green shading indicates monitoring for shutdown or counting as a Level B take if an animal enters the bay.

[1]From Table 6-3 rounded up as appropriate.

[2]Scenario 1 does not include impulse hammering

[3]Includes DTH drilling (non-impulsive).

[4]Actual Level A zone is larger (see Table 6-3), but 1.6 km (1 mile) is considered to be a reasonable distance to monitor.

[5]Takes will be extrapolated due to these large monitoring zones.

The FAA recognizes that animals might not be detected by the primary MMO if they enter Symonds Bay, and for that reason a second MMO would be placed at the dock construction site. Pile driving activities occurring under Scenarios 2 through 6 would be halted if an animal is observed by the primary MMO approaching the Level A harassment zones and remaining within the bay, or if an animal is observed by the second MMO inside of the these zones because it was missed by the primary MMO.

11.2.1.2. Level B Monitoring and Recording Zones

Level B exposure zones are also depicted in Table 11-1. Generally, any marine mammal observed by the MMO stationed at the at the mouth of the bay during all scenarios except Scenario 5 would be monitored and recorded as a potential Level B take (if not already recorded as a Level A take), and animal behaviors would be documented (see Chapter 13.4). As shown in Table 11-1, the Level B ensonified areas extend past the entrance to the bay (+800 m) during vibratory drilling under all scenarios except Scenario 5, and during impulse drilling under Scenario 4. During Scenario 5 work any animal entering the bay would be closely monitored to determine if it approaches closely enough to be considered a Level B take.

11.2.2. Soft Start

The FAA would use the soft-start technique at the beginning of impact pile driving each day, or if pile driving has ceased for more than 30 minutes. Soft-start procedures would be used prior to impact pile removal or pile installation to allow marine mammals to leave the area prior to exposure to maximum noise levels. The requirements for soft start for impact driving are:

> *Initiating sound from impact driving with an initial set of three strikes from the impact hammer at reduced energy, followed by a 1-minute waiting period, then two subsequent three strike sets. Soft start will be required at the beginning of each day's impact pile driving work and at any time following a cessation of pile driving of 30 minutes or longer*.

11.2.3. Noise Attenuating Devices

Noise sources have been modeled without noise attenuation devices and the IHA application has been prepared on the premise that noise attenuating devices such as use of a bubble curtain or a pile cap/cushion during impact pile driving will not be used. Therefore noise attenuation devices have not been proposed and are not being considered at this time.

11.3. Mitigation Summary

The FAA has developed the proposed mitigation measures to ensure the least practicable impact on affected marine mammal species and stocks, and their habitat. Potential measures include consideration of the following factors: 1) the degree to which, the successful implementation of the measure is expected to minimize adverse impacts to marine mammals; 2) the proven efficacy of the specific measure to minimize adverse impacts as planned based on monitoring plans from previous, similar IHA applications incorporating pile driving; and 3) the practicability of the measure for implementation. Based on these factors, the FAA believes the mitigation measures being considered accomplish the following required objectives:

- Avoidance or minimization of injury or death of marine mammals;
- Avoidance of activities at biologically important times or locations to reduce the total number of marine mammals exposed to received levels of pile driving, or other activities expected to result in the take of marine mammals;
- A reduction in the number of times (total number or number at biologically important time or location) individuals would be exposed to stimuli expected to result in incidental take of marine mammals;
- Avoidance or minimization of adverse effects to marine mammal habitat paying particular attention to the prey base, activities that block or limit passage to or from biologically important areas, permanent destruction of habitat, or temporary destruction/disturbance of habitat during the biologically important winter foraging; and
- For monitoring directly related to mitigation—an increase in the probability of detecting marine mammals, thus allowing for more effective implementation of the mitigation.

Based on results of previous monitoring programs similar to the Biorka Island Project, the proposed mitigation measures provided would result in the least practicable impact on marine mammal species or stocks, and their habitat.

12. ARCTIC PLAN OF COOPERATION

This section is not applicable to this application. The proposed activity would take place off Biorka Island in southeast Alaska. Therefore, no activities would take place in or near a traditional Arctic subsistence hunting area. There are no relevant subsistence uses of marine mammals implicated by this action. Further, as stated in Section 8, based on the information provided in this application, the proposed activities at the Project site in Symonds Bay would have no impact on the abundance or availability of marine mammals to subsistence hunters in the region. Therefore, no further measures to reduce impacts to subsistence are being considered.

13. MONITORING AND REPORTING

In order to issue an IHA for an activity, Section 101(a)(5)(D) of the MMPA states that NMFS must set forth “requirements pertaining to the monitoring and reporting of such taking.” The MMPA implementing regulations at 50 CFR 216.104 (a)(13) indicate that requests for incidental take authorizations must include the suggested means of accomplishing the necessary monitoring and reporting that would result in increased knowledge of the species and the level of taking or impacts on populations of marine mammals that are expected to be present in the Action Area.

The FAA recognizes that monitoring requirements should be designed that improve the understanding of one or more of the following:

- Occurrence of marine mammal species in the Action Area (e.g., presence, abundance, distribution, density);
- Nature, scope, or context of likely marine mammal exposure to potential stressors/impacts (individual or cumulative, acute or chronic), through better understanding of: 1) action or environment (e.g., source characterization, propagation, ambient noise); 2) affected species (e.g., life history, dive patterns); 3) co-occurrence of marine mammal species with the action; or 4) biological or behavioral context of exposure (e.g., age, calving or feeding areas);
- Individual responses to acute stressors, or impacts of chronic exposures (behavioral or physiological);
- How anticipated responses to stressors impact either: 1) long-term fitness and survival of an individual; or 2) population, species, or stock;
- Effects on marine mammal habitat and resultant impacts to marine mammals; and
- Mitigation and monitoring effectiveness.

13.1. Visual Marine Mammal Observation

The FAA would collect marine mammal behavioral response and other observation data related to construction for species observed in the region of activity during the construction period. All MMOs would be trained in marine mammal identification and behaviors, would be required to have no other construction-related tasks while conducting monitoring. The MMOs would monitor the shutdown and disturbance zones before, during, and after pile driving, with MMOs located at the best practicable vantage points. The FAA would determine the most appropriate observation platform(s) for monitoring during pile installation and extraction.

The FAA would implement the following procedures for pile driving:

- MMOs would monitor Level A and Level B harassment zones during pile driving and extraction activities. Generally, monitoring would occur for all of Symonds Bay during pile driving as a potential shutdown zone for impact driving by appropriately stationed MMOs;
- Any marine mammal documented within the Level B harassment zone during impact driving would constitute a Level B take (harassment), and would be recorded and reported;

- The waters would be scanned 15 minutes prior to commencing pile driving at the beginning of each day or after any stoppage of 30 minutes or greater. Pile installation would not commence if any marine mammals were observed within or approaching the Level A harassment zone or the Project site;
- If marine mammals enter or were observed within the designated marine mammal shutdown zone during or 15 minutes prior to pile driving, the MMOs would notify the on-site construction manager to not begin until the animal has moved outside the designated radius.
- If a marine mammal is observed approaching the Level A harassment zone or Project site after pile driving has commenced, pile installation would be would be suspended until the animal has been visually confirmed beyond the shutdown zone, or fifteen minutes have passed without re-detection of small cetaceans and pinnipeds, and thirty minutes for large whales.
- MMOs would scan the waters using binoculars, spotting scopes, and unaided visual observation;
- MMOs would use a hand-held GPS or range-finder device to verify that no marine mammals were in the areas ensonified as a result of activities at the Project site;
- If poor environmental conditions restrict MMO ability to see within the marine mammal shutdown zone (e.g. excessive wind or fog, high Beaufort state), pile installation would cease;
- Pile driving activities would only be conducted during daylight hours when it is possible to visually monitor marine mammals; and
- The waters would continue to be scanned for at least 30 minutes after pile driving has completed each day, and after each stoppage of 30 minutes or greater.

13.2. MMO Requirements

MMO requirements are as follows:

- Independent observers (i.e., not construction personnel) are required.
- At least one observer must have prior experience working as an observer.
- Other observers may substitute education (undergraduate degree in biological science or related field) or training for experience.
- Where a team of three or more observers are required, one observer should be designated as lead observer or monitoring coordinator. The lead observer must have prior experience working as an observer.
- Observer resume’s must be submitted to and approved by NMFS.

Other standard qualifications are:

- Ability to conduct field observations and collect data according to assigned protocols.
- Experience or training in the field identification of marine mammals, including the identification of behaviors.
- Sufficient training, orientation, or experience with the construction operation to provide for personal safety during observations.
- Writing skills sufficient to prepare a report of observations including but not limited to the number and species of marine mammals observed; dates and times when in-water construction

activities were conducted; dates and times when in-water construction activities were suspended to avoid potential incidental injury from construction sound of marine mammals observed within a defined shutdown zone; and marine mammal behavior.

- Ability to communicate orally, by radio or in person, with project personnel to provide real-time information on marine mammals observed in the area as necessary.

13.3. Data Collection

The FAA would require that MMOs use approved data forms developed for this Project. Among other pieces of information, the MMOs would record detailed information about any implementation of shutdowns, including the distance of animals to the pile, description of specific actions that ensued and resulting behavior of the animal, if any. In addition, the MMOs would attempt to distinguish between the number of individual animals taken and the number of incidents of take. At a minimum, the following information would be collected on the observer forms:

- Date and time that monitored activity begins or ends;
- Construction activities occurring during each observation period;
- Weather parameters (e.g., percent cover, visibility);
- Water conditions (e.g., sea state, tide state);
- Species, numbers, and, if possible, sex and age class of marine mammals;
- Description of any marine mammal behavior patterns, including bearing and direction of travel and distance from pile driving activity;
- Distance from pile driving activities to marine mammals and distance from the marine mammals to the observation point;
- Description of implementation of mitigation measures (e.g., shutdown or delay);
- Locations of all marine mammal observations; and
- Other human activity in the area.

13.4. Reporting

13.4.1. Interim Reports

Brief, weekly summaries of MMO observations and recorded takes will be provided to NMFS during construction. The frequent reports will allow NMFS to track takes (including extrapolated takes) so that authorized take numbers are not exceeded.

13.4.2. End-of-Project Report

A draft report would be submitted to NMFS within 90 days of the completion of marine mammal monitoring, or 60 days prior to the requested date of issuance of any future IHAs for projects at the same location, whichever comes first. The report would include marine mammal observations pre-activity, during-activity, and post-activity during pile driving days, and would also provide descriptions of any behavioral responses to construction activities by marine mammals. It would include a complete description of all work shutdowns and total takes based on the number of marine mammals observed during construction. A final report would be submitted within 30 days following resolution of comments on the draft report.

In the unanticipated event that the specified activity clearly causes the take of a marine mammal in a manner prohibited by the IHA, such as serious injury or mortality (e.g., ship-strike), the observer would immediately cease the specified activities and immediately report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS. The report would include:

- Time, date, and location (latitude/longitude) of the incident;
- Name and type of vessel involved (if applicable);
- Vessel's speed during and leading up to the incident (if applicable);
- Description of the incident;
- Status of all sound source use in the 24 hours preceding the incident;
- Water depth;
- Environmental conditions (e.g., wind speed and direction, Beaufort sea state, cloud cover, and visibility);
- Description of all marine mammal observations in the 24 hours preceding the incident;
- Species identification or description of the animal(s) involved;
- Fate of the animal(s); and
- Photographs or video footage of the animal(s) (if equipment is available).

Activities would not resume until NMFS is able to review the circumstances of the prohibited take. NMFS would work with the MMOs to determine actions necessary to minimize the likelihood of further prohibited take and ensure MMPA compliance. The MMOs would not be able to resume activities until notified by NMFS via letter, email, or telephone.

In the event that the observer discovers an injured or dead marine mammal, the cause of the injury or death is unknown, and the death is relatively recent (i.e., in less than a moderate state of decomposition), the observer would immediately report the incident to the NMFS Chief of the Permits and Conservation Division, Office of Protected Resources in Silver Spring, Maryland and the Alaska Stranding Coordinator in Juneau, Alaska.

The report would include the same information identified in the paragraph above. Activities would be allowed to continue while NMFS reviews the circumstances of the incident. NMFS would work with the observer to determine whether modifications in the activities are appropriate.

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

14. SUGGESTED MEANS OF COORDINATION

Project activities would be conducted in accordance with all federal, state, and local regulations. This would minimize the likelihood that impacts could occur to the species, stocks, and subsistence use of marine mammals in Sitka Sound. The FAA would continue to cooperate with NMFS, other appropriate federal agencies, and the State of Alaska throughout all phases of the Project.

The FAA would also cooperate with any other marine mammal monitoring and research programs that may take place in Sitka Sound including reporting marine mammal sightings to the Sitka Science Center. If requested, the FAA would provide any marine mammals monitoring data and behavioral observations collected during construction of the Project to other researchers. Results of monitoring efforts would be provided to NMFS in a draft summary report within 90 calendar days of the conclusion of monitoring (see Section 13). This information could be made available to regional, state, and federal resource agencies, universities, and other interested private parties upon written request to NMFS.

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APPENDIX A

Biorka Island Dock Replacement:

Modeling Pile Installation Footprints

Biorka Island Dock Replacement

Modeling Pile Installation Sound Footprints

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Executive Summary

JASCO Applied Sciences, under contract to R&M Consultants, Inc., performed an underwater acoustic modeling study of pile installation activities for the construction of a new dock at Biorka Island, which will replace the existing dock. Various simulated scenarios were considered to investigate the potential acoustic effects created by installing cylindrical steel pipe piles, sheet piles, and H-profile steel piles using a combination of down the hole (DTH) hydro-hammering, and impact and vibratory pile driving.

To assess potential underwater noise exposure of marine mammals during construction activities, we determined source levels for the different combinations of types of piles and how each was installed, a process from which we obtained frequency-dependent source levels suitable for modeling underwater acoustic propagation using JASCO's Marine Operations Noise Model (MONM). The modeling predicted the acoustic footprint from construction activities taking into account the effects of pile driving equipment, bathymetry, water sound speed profile, and seabed geoacoustic parameters to. Auditory weighting was applied to the modeled sound fields to estimate received levels relative to hearing sensitivities of five marine mammal hearing groups.

The goal of this study was to model the extent of ensonification and to define zones of potential effects on marine mammals. The results are based on currently adopted sound level thresholds for auditory injury (Level-A), expressed by peak pressure level and 24-hr sound exposure level (SEL), and behavioral disturbance (Level-B) expressed as sound pressure level (SPL). The loudest 24-hr SEL for impulsive sounds corresponded to impact pile driving of sheet and H-profile steel piles with auditory-weighting applied for high-frequency cetaceans, due to generation of acoustic noise at high frequencies (above 1 kHz) which exceeded all other sources considered in this study. DTH hydro-hammering was the loudest non-impulsive noise source when it was used to advance the pile through the bedrock.

Summarized threshold criteria and results:

- Impact pile driving (impulsive sounds): The maximum distance to peak pressure Level-A thresholds was 0.05 km. The 95th percentile distances to 24-hr auditory-weighted Level-A SEL thresholds (when reached) ranged from < 0.01 km to 2.93 km. The 95th percentile distances corresponding to Level-B thresholds ranged from 0.43 km to 1.25 km.
- Vibratory pile driving and DTH hydro-hammering (non-impulsive sounds): The 95th percentile distances to 24-hr auditory-weighted Level-A SEL thresholds (when reached) ranged from < 0.01 km to 0.51 km from a combination of vibratory pile driving and DTH hydro-hammering. The 95th percentile distances corresponding to Level-B thresholds ranged from < 0.79 km to 6.07 km for vibratory pile driving, and 10.02 km for DTH hydro-hammering.

1. Introduction

In July 2016, the Federal Aviation Administration (FAA) contacted the National Marine Fisheries Service to propose constructing a replacement dock at Symonds Bay (Biorka Island) near Sitka, Alaska. JASCO Applied Sciences Ltd., under contract to R&M Consultants, Inc., performed an underwater acoustic modeling study to predict underwater sound levels generated during the installation of cylindrical, sheet, and H-profile steel piles (H piles) using down the hole (DTH) hydro-hammering, vibratory, and impact pile driving. The goal of this study was to predict the extent of ensonification from these activities and to define zones of potential effects on marine fauna based on sound level thresholds for Level-A (auditory injury) and Level-B (behavioral disturbance).

The seabed at the construction site consists of a layer of sand and gravel mixed with cobbles and boulders, laying on top of intensely fractured bedrock. Beneath the fractured bedrock, the rock is generally more intact. The seabed composition is important in this project because it determines the methods needed to achieve the required pile penetration.

The project site is made up of three main structures located within a few meters of one other (Figure 1): a barge landing platform, a dock/trestle, and two dolphin fenders near the dock outer corners. In all cases, temporary piles will also be installed to form a scaffold system (i.e., a template) that permits the permanent piles to be aligned and controlled. With the exception of the temporary piles, which are driven exclusively by vibratory pile driving, installing all other piles requires a combination of pile driving methods (Section 1.1).

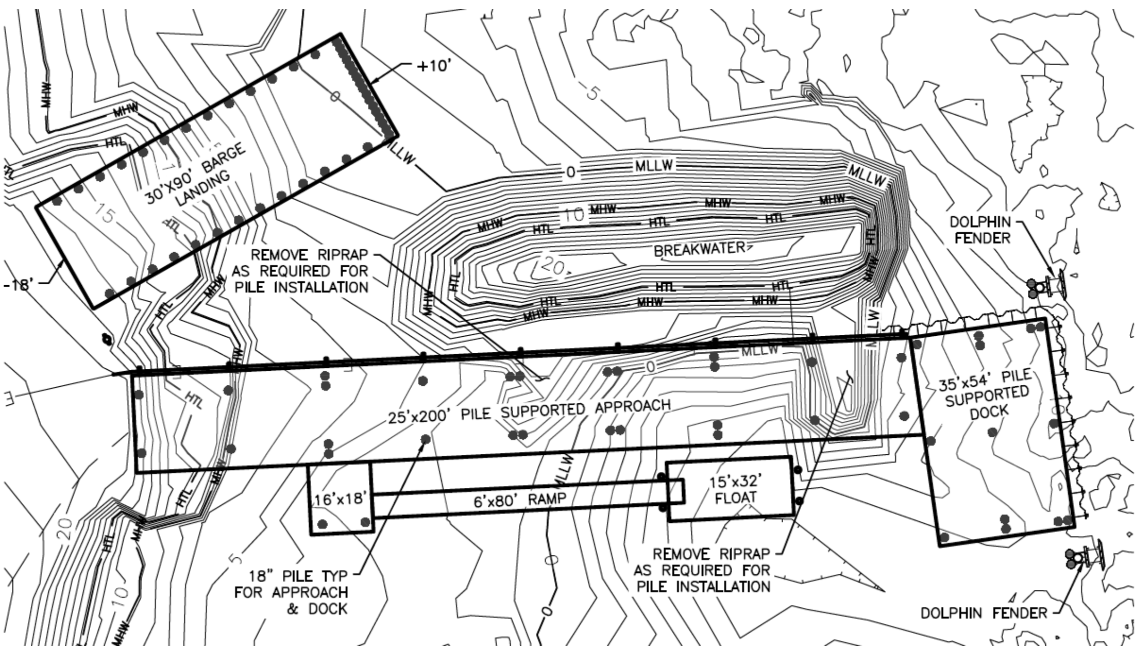


Figure 1. Diagram of the main structures for the Biorka Dock Replacement project, showing the barge landing platform, the dock/trestle, and the dolphin fenders. A wave barrier will also be installed around two sides of the dock (Pers comm 2016).

Acoustic modeling was performed by estimating frequency-dependent source levels for different combinations of pile geometry and pile driving approach, and by applying JASCO's Marine Operations Noise Model (MONM) to model acoustic propagation through the ocean waveguide. In most cases, source levels were obtained from representative published measurements (Section 3.2). For impact pile driving of cylindrical piles, source levels and spectra were obtained by applying JASCO's Pile Driving Source Model (PDSM). For vibratory pile driving of cylindrical piles, spectra were obtained from measurements, and adjusted to have broadband SEL levels according to simulations using PDSM.

Modeled results are presented as tables of distances at which sound pressure levels or sound exposure levels fell below certain thresholds defined by criteria. For marine mammal injury, the Level-A thresholds (Section 1.2.2) considered here follow the National Marine Fisheries Service (NMFS) guidelines (NMFS 2016). Marine mammal disturbance is assessed relative to the Level-B thresholds (Section 1.2.3) based on the interim NMFS criteria (NMFS 2013). Results are also presented as sound field isopleth maps, which show the planar distribution of sound levels with range and azimuthal direction.

Section 1 of this report describes the modeled scenarios, introduces the acoustic metrics used in the study, and presents the impact criteria applied for assessing noise levels. Section 2 outlines the acoustic modeling approach and the procedure used to compute distances for a given threshold. Section 3 describes the parameters used in the models to define the acoustic environment. Tables of distances to the various sound level thresholds and ensonified areas are provided in Section 4. Section 5 discusses and interprets the results. A glossary of acoustic terminology is included. Appendix A details acoustic terminology and the applied modeling approach. Appendix B provides the modeled sound field isopleth maps.

1.1. Modeled Scenarios

Symonds Bay, Biorka Island, the proposed location for construction activities, is approximately 700 m wide (east to west direction), with water depths below 20 m at ranges within 400 m from the dock (Figure 2). The acoustic modeling assumed all construction activities occurred at the location of the outer dolphin, which is in the deepest water (6.2 m at mean high water) among all piles. This assumption was done intentionally as a precautionary measure, since noise generation at the pile and its subsequent propagation along the water column is generally enhanced in deeper water, as a result of a larger portion of the pile being in the water, as well as better sound propagation characteristics in deeper water.

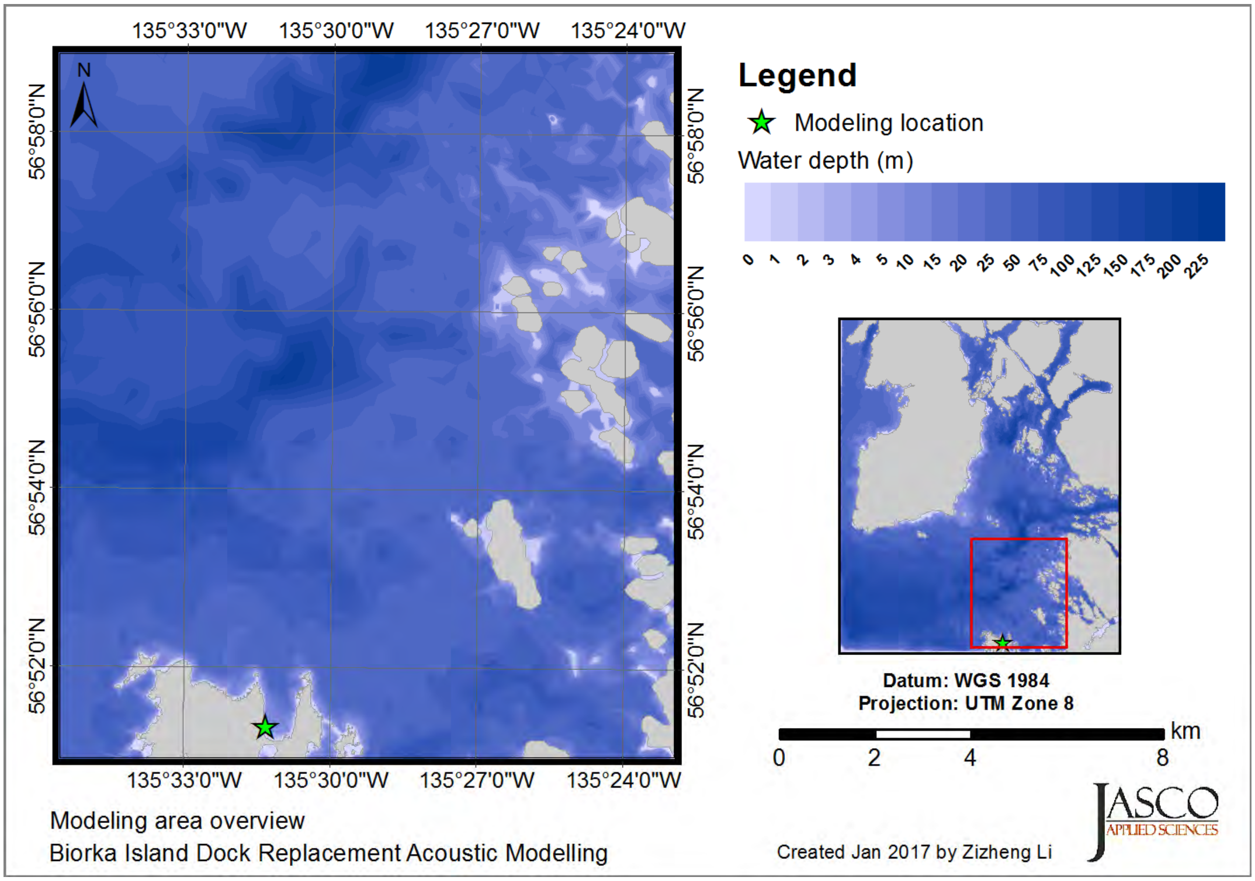


Figure 2. Study area showing the modeling location of pile driving activities at Biorka Island. Details about the bathymetry data are provided in Section 3.1.1.

Prior to construction, the existing dock structure will be removed through use of a crane and sling and potentially also using the vibratory hammer. Construction of the barge landing platform (Figure 1) begins with erecting the temporary template using cylindrical piles (12 inch diameter), which are driven through the top sediment layer by vibratory pile driving. The barge structure itself consists of permanent cylindrical piles (18 inch diameter) supporting sheet piles. To achieve the required pile penetration, both types of piles are installed by going through the sediment layer using vibratory pile driving, followed by impact pile driving. The cylindrical piles will by driven through the sediment layer as well as through the intensely fractured bedrock, while the sheet piles will be driven only through the top sediment.

Similar to the barge platform, construction of the dock/trestle begins with erecting a temporary template. The permanent dock/trestle consists of 18 inch diameter cylindrical piles distributed along its perimeter. The procedure to install these piles consists of advancing through the sediment layer by vibratory pile driving. Next, a hole is drilled in the underlying fractured bedrock by DTH hydro-hammering until the piles reach the required penetration seating on top of the consolidated bedrock. Finally, impact pile driving will be applied to test whether the piles are firmly set onto the bedrock.

As part of the dock structure, a permanent wave barrier consisting of H piles with sheet piles in between will also be installed. The H piles will be advanced through the sediment using vibratory pile driving, and driven through the intensely fractured bedrock by impact pile driving. The sheet piles will be driven through the sediment by vibratory pile driving, and to their final position on top of the intensely fractured bedrock by impact pile driving.

The dolphins consist of 30 inch diameter steel piles driven vertically into the sediment, and 18 inch diameter batter piles. Only the 30 inch diameter piles are considered for acoustic modeling, since 18 inch piles are already considered when modeling the acoustic footprint corresponding to the dock/trestle.

Based on a preliminary assessment provided by R&M Consultants, Inc. of the sequence of pile-driving activities and the amount of time per method required to install piles, six scenarios (Table 1) were identified as representing the largest acoustic footprints of construction activities at Biorka over any 24-hour period. We assume that sound generated during vibratory removal of both the existing piles and the temporary template piles will be similar to that generated during installation of the temporary template piles (Scenario S1).

Table 1. Pile driving modeling scenarios for the Biorka Dock Replacement project. All scenarios assume piles are 20 m (66 ft) long. For acoustic modeling purposes, all piles were modeled as being installed at 56.85568063° N latitude and,135.52176946° W longitude.

Scenario	Description	Number of Piles per Day*	Vibratory		DTH		Impact		Total Number of Piles to Install/Remove
			Hours per pile	Total hours*	Hours per pile	Total hours*	Hours per pile	Total strikes*	
S1	Installation/removal of temporary piles and Removal of existing piles	21	0.33	6.93	NA		NA		84 temporary 43 existing
S2	Installation of 18 inch pipe piles (dock and dolphin)	3		0.99	2	6	0.17	15	47
S3	Installation of 18 inch pipe piles (barge landing)	4		1.32	NA		0.33	2720	35
S4	Installation of 30 inch pipe piles (dolphins)	2		0.66	2	4	0.17	10	2
S5	Installation of H piles (dock wave barrier)	8		2.64	NA		0.33	5440	16
S6	Installation of sheet piles (dock wave barrier and barge landing)	12		3.96	NA		0.25	6120	66

* Refers to the number of piles, hours of operation, or hammer strikes within 24 hr.
NA stands for "Not applicable" to indicate when a pile driving method was not required in a given scenario.

1.2. Threshold Criteria for Marine Mammal Injury (Level-A) and Behavioral Disturbance (Level-B)

Determining standards to quantify the way in which underwater noise can affect marine fauna is an active research topic. There are different views among bioacousticians about the best method to estimate injury and disturbance effects on animals, and because evaluating chronic effects is even more complex and harder to quantify, there is little consensus at the moment on how to perform those assessments. The criteria applied in this study are based on references that represent the current best available science, and require computing peak pressure level (PK), sound pressure level (SPL), and sound exposure level (SEL). Appendix A.1 describes these metrics and provides formulae. Since 2007, several expert groups have investigated an SEL-based assessment approach for injury, publishing some key papers on the topic; the number of studies investigating the level of disturbance to marine animals by underwater noise has also increased substantially.

Results of this modeling study are presented in terms of the following noise criteria:

- Dual criteria (Auditory-weighted SEL and PK) Level-A thresholds for marine mammals, based on NMFS (2016) for all sound sources.

- Level-B thresholds for marine mammals, based on the interim NMFS criteria (NMFS 2013) of 120dB re 1 μPa SPL for non-impulsive and 160 dB re 1 μPa SPL for impulsive sound sources.

Maps that correspond to Level-A and Level-B criteria are presented in Appendix B.

1.2.1. Auditory weighting functions for marine mammals

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a \left[1+(f/f_{hi})^2\right]^b}\right)\right] \quad (1)$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses noise impacts on marine mammals (NMFS 2016). Table 2 lists the frequency-weighting parameters for each hearing group; Figure 3. shows the resulting frequency-weighting curves.

Table 2. Parameters for the auditory weighting functions recommended by NMFS (2016).

Hearing group	*a*	*b*	f_{lo} (Hz)	f_{hi} (kHz)	*K* (dB)
Low-frequency cetaceans	1.0	2	200	19,000	0.13
Mid-frequency cetaceans	1.6	2	8,800	110,000	1.20
High-frequency cetaceans	1.8	2	12,000	140,000	1.36
Phocid pinnipeds in water	1.0	2	1,900	30,000	0.75
Otariid pinnipeds in water	2.0	2	940	25,000	0.64

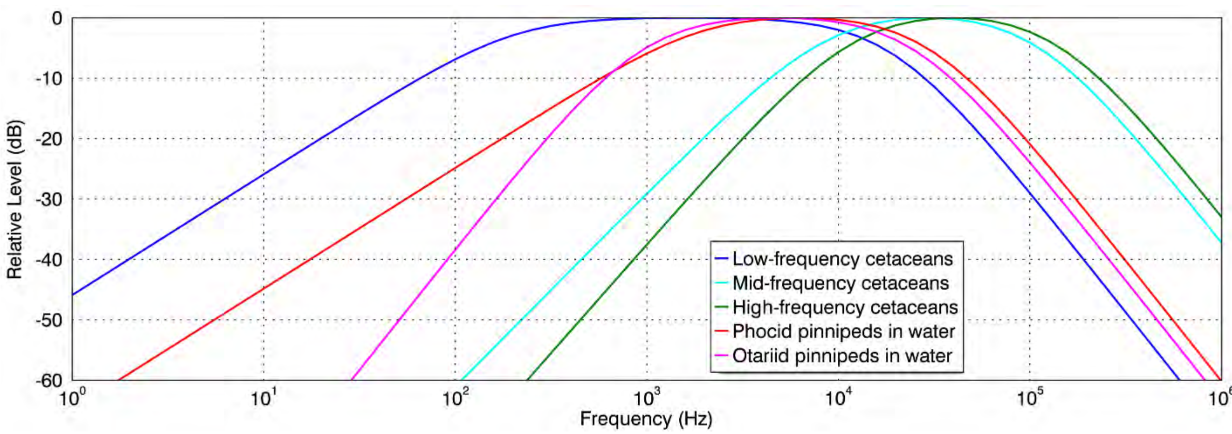


Figure 3. Auditory weighting functions for functional marine mammal hearing groups as recommended by NMFS (2016).

1.2.2. Auditory injury (Level-A) threshold criteria for marine mammals

The latest National Oceanic and Atmospheric Administration (NOAA) criteria for injury (NMFS 2016) and its earlier iterations (NOAA 2013, 2015) have been scrutinized by the public, industrial proponents, and academics. This study applies the specific methods and Level-A thresholds summarized by NMFS (2016, Table 3). The Level-A criteria provide cautionary estimates of levels above which acoustic exposure may lead to loss of hearing, a process known as permanent hearing threshold shift (PTS).

Table 3. Marine mammal Level-A thresholds based on NMFS (2016) peak pressure level in dB re 1 µPa, and auditory-weighted SEL (24 h) in dB re 1 µPa²·s.

Hearing group	Impulsive source		Non-impulsive source
	Peak pressure level (dB re 1 µPa)	Auditory-weighted SEL_{24h} (dB re 1 µPa²·s)	Auditory-weighted SEL_{24h} (dB re 1 µPa²·s)
Low-frequency cetaceans	219	183	199
Mid-frequency cetaceans	230	185	198
High-frequency cetaceans	202	155	173
Phocid pinnipeds in water	218	185	201
Otariid pinnipeds in water	232	203	219

1.2.3. Disturbance (Level-B) threshold criteria for marine mammals

In this assessment we apply the interim NMFS criteria (NMFS 2013) because these are the most recently published disturbance criteria for marine mammals (Table 4).

Table 4. Marine mammal Level-B thresholds (SPL, dB re 1 µPa).

Impulsive source	Non-impulsive source
160	120

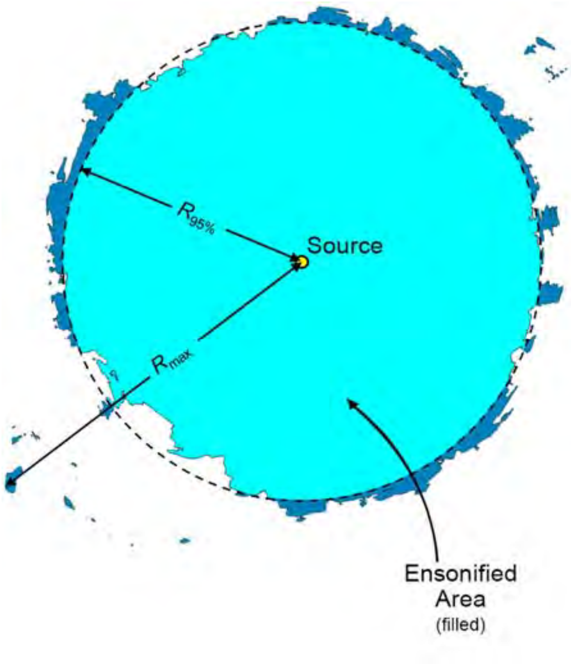
2. Modeling Methodology

The following three steps comprised the general approach applied to modeling construction activities at Biorka:

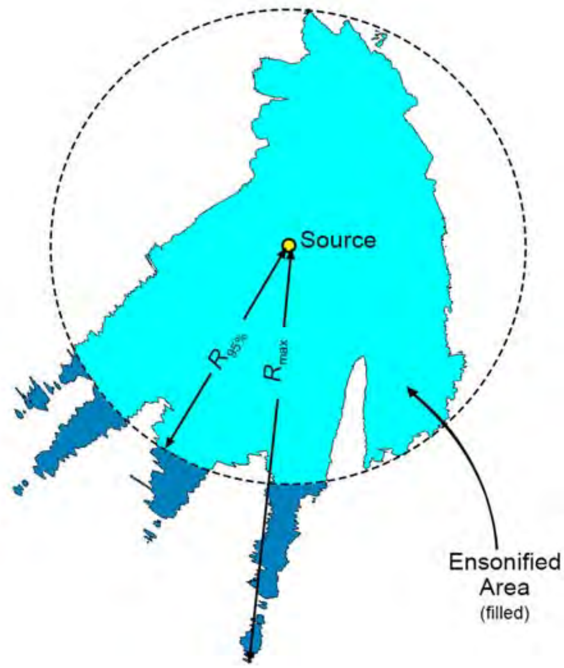
1. Piles driven into the sediment by impact, vibratory, or DTH hydro-hammering were characterized as sound-radiating sources. To this end, source levels in 1/3-octave-bands were obtained by modeling (using JASCO's PDSM) or by adjusting source levels found in the literature. The exact method to obtain the 1/3-octave-band levels depends on the pile geometry and pile driving equipment, and it is described on a case-by-case basis (Section 3.2).
2. The theory of underwater sound propagation was applied to predict how sound propagates from the pile into the water column as a function of range, depth, and azimuthal direction. Propagation depends on several conditions including the frequency content of the sound, the bathymetry, the sound speed in the water column, and sediment geoacoustics. For computational efficiency, sound propagation was modeled at the 1/3-octave band center frequencies.
3. The propagated sound field was used to compute received levels over a grid of simulated receivers, from which distances to criteria thresholds and maps of ensonified areas were generated. The marine mammal frequency-weighting function values at the 1/3-ocatve band center frequencies were applied to calculate frequency-weighted sound fields for the Level A criteria threshold calculations.

The underwater sound fields predicted by the propagation models were sampled so that the received sound level at each geographic location (horizontal plane) was set to the maximum value of all modeled depths at that location. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure 4).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure 4(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure 4(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.



(a)



(b)

Figure 4. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

3. Model Parameters

This section describes all environmental and sound source parameters used to model sound fields, including references for each data set from which the parameters were derived, and all related assumptions made.

3.1. Environmental Parameters

The sound propagation model, MONM, requires inputs to describe the underwater environment because that is the medium through which sound from pile driving operations propagates. The parameters input to the models are listed below and described in following subsections.

3.1.1. Bathymetry

The bathymetry describes the water depths throughout the modeled area. For this project, bathymetry data were compiled from NOAA Nav (S-57) Charts US1WC02M, US3AK3BM, US5AK3FM, US5AK3GM, US5AK3HM, US5AK3VM, and US5AK3YM (NOAA Electronic Navigational Chart 2016). In addition, client-supplied high resolution data at the modeling location were also included (TerraSond Precision Geospatial Solutions 2015). The final bathymetry grid (Figure 2) has a 4 m cell size and was adjusted to represent mean high water (MHW).

3.1.2. Sound speed profile

The sound speed profile (SSP) provides the values of sound speed as a function of water depth representing the mean conditions throughout the modeled area. For this report, the SSP was obtained as an average of two profiles derived from historical temperature and salinity data obtained from the U.S. Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009) for August. The averaged profiles corresponded to locations at 260 m and 12.5 km range from the pile, where GDEM provided data up to 15 m depth at the first location and 110 m depth at the second. To extend the SSP to the largest water depth of 230 m within the modeled area, we extrapolated the sound speed to depths from 180 to 230 m using this empirical formula (Medwin and Clay 1997):

$$c = 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3 + (1.34 - 0.01T)(S - 35) + 0.016z \tag{2}$$

where T is the temperature (°C), S is the salinity (parts per thousand), and z is the depth (m). The formula was applied assuming constant temperature and salinity at depths beyond 180 m.

To account for the effect of sound absorption in water, S = 30.2 PSU and T = 12.25°C were used to correct sound propagation results obtained from MONM. These values correspond to the salinity and temperature obtained from the SSP profile closer to the average SSP (Figure 5), at a depth of 2 m. We chose this shallow depth because near-surface sound propagation is expected as a result of the surface channel created by the SSP local maximum near 4 m depth (Figure 5).

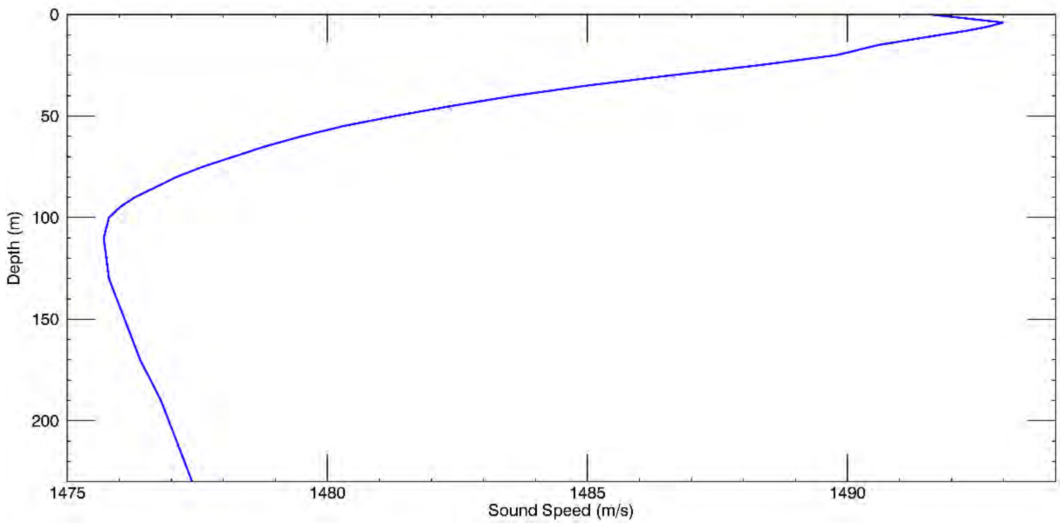


Figure 5. August sound speed profile (SSP) used for acoustic modeling.

3.1.3. Geoacoustic profile

Seafloor properties influence underwater sound propagation because they affect energy transmission at the water-bottom interface and through underlying sediment layers. Seabed geoacoustic properties in this study are based on a preliminary assessment of the soil structure at the construction site, as indicated by information provided to JASCO by R&M Consultants, Inc., which suggests a top layer of unconsolidated sediment approximately 5 m thick. Sediment samples collected at shallow waters around Biorka Island (Hoskin and Sundeen 1975) suggest that this sediment is mainly sandy gravel of 2.83 mm grain size. A sediment grain-shearing model (Buckingham 2005) with an input porosity of 60-50% between 0-5 m depth, was used to estimate the density, compressional-wave speed, shear-wave speed, and compressional-wave attenuation for the sandy gravel layer (Table 5). Hoskin and Sundeen (1975) suggest that the predominant type of bedrock at Biorka Island is tonalite granite. Geoacoustics for the underlying bedrock (Table 5) were determined based on depth-dependent measurements of compressional sound speed (Jensen et al. 1994, Brocher 2005), and estimates of density and attenuation in granite (Hughes et al. 1991).

Table 5. Geoacoustic properties used for pile driving acoustic modeling in this report. Within each depth range, each parameter varies linearly within the stated range.

Depth below seafloor (m)	Material	Density (g/cm³)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–5	Sandy gravel	1.70-1.87	1719–2118	1.06-1.83	350	3.653
5–500	Intensely fractured tonalite bedrock	2.6	2500-3700	0.25-0.37		
> 500	Fractured tonalite bedrock	2.6	3700	0.37		

3.2. Acoustic Source Parameters

This section describes pile geometry and pile driving equipment parameters relevant to the acoustic modeling scenarios (see Table 1). For this project, five types of steel piles were considered:

- Cylindrical piles, 12 in diameter, 0.5 in pile wall thickness.
- Cylindrical piles, 18 in diameter, 0.625 in pile wall thickness.
- Cylindrical piles, 30 in diameter, 0.75 in pile wall thickness.
- H piles model W40, 38.7 in deep with flanges of 15.8 in width.
- Sheet piles model NZ19, with a profile 27.56 in width by 17.32 in height. Sheet piles model NZ26 were used at the barge landing; however, because profile height of the two pile models differed by only 1.2 in , the models' source levels differed by just 0.08 dB, and thus only the piles corresponding to the wave barrier were modeled.

Three different pieces of pile driving equipment have been proposed for the construction of the dock at Biorka Island: the diesel impact hammer ICE I-36V2 for impact operations, the ICE-44B vibratory driver for vibratory, and the Numa Patriot 180 for DTH hydro-hammering. Table 6 lists relevant parameters for the acoustic modeling in this report. For impact pile driving, the rated energy was used to adjust the source levels obtained from measurements noted in the literature (for H and sheet piles), and as input to model pile driving source levels in the case of cylindrical piles. The rated striking frequency was used to estimate the total number of strikes in Scenarios S3 and S5 (see Table 1). The centrifugal force for the vibratory hammer was used to adjust the source levels obtained from measurements. Finally, we point out that although DTH hydro-hammering is classified as an impulsive source, the high frequency of 1100 blows/minute combined with long continuous operation intervals of several minutes make its signature noise more like a non-impulsive source and therefore we treat it as such in this report.

Table 6. Properties of pile driving equipment used for modeling the acoustic footprint from construction activities at Biorka Island.

Driving mechanism	Pile driver	Properties
Impact	ICE I-36V2	127.1 kNm rated energy, 34 strikes/minute
Vibratory	ICE-44B	1789 kN centrifugal force
DTH hydro-hammering	Numa Patriot 180	1100 blows/minute

Source levels input to MONM correspond to SEL in 1/3-octave-bands. The frequency content of such sources strongly depends on the pile type and driving equipment. The following sub-sections describe the procedure used to obtain source levels for each scenario (Table 1).

3.2.1. Source levels for DTH hydro-hammering

In this project, the DTH hydro-hammer operates in vertical piles that have been partially driven by vibratory means. Before it begins operating, the DTH hydro-hammer is installed within the hollow pipe pile at the bottom of the pile. Piles are advanced by applying a pulsating mechanism to break the underlying bedrock while simultaneously removing broken rock fragments. We have assumed that the interaction between the rock and the DTH hydro-hammer is what generates noise, therefore sound levels do not depend on pile diameter (Pers comm 2016). In May 2016, a Numa Patriot 180 hammer was used to drive 24 in diameter piles at a ferry terminal at Kodiak, AK (Denes et al. 2016). Acoustic signatures for DTH hydro-hammering were recorded at ranges of 10–30 m from the pile. The measured source levels at each 1/3-octave-band from these measurements were adjusted by $20\log_{10}$(range) (i.e., back propagated assuming spherical spreading) and averaged to provide the representative 1/3-octave-band SEL (Figure 6), which we used for acoustic modeling in Scenarios S2 and S4 (see Table 1).

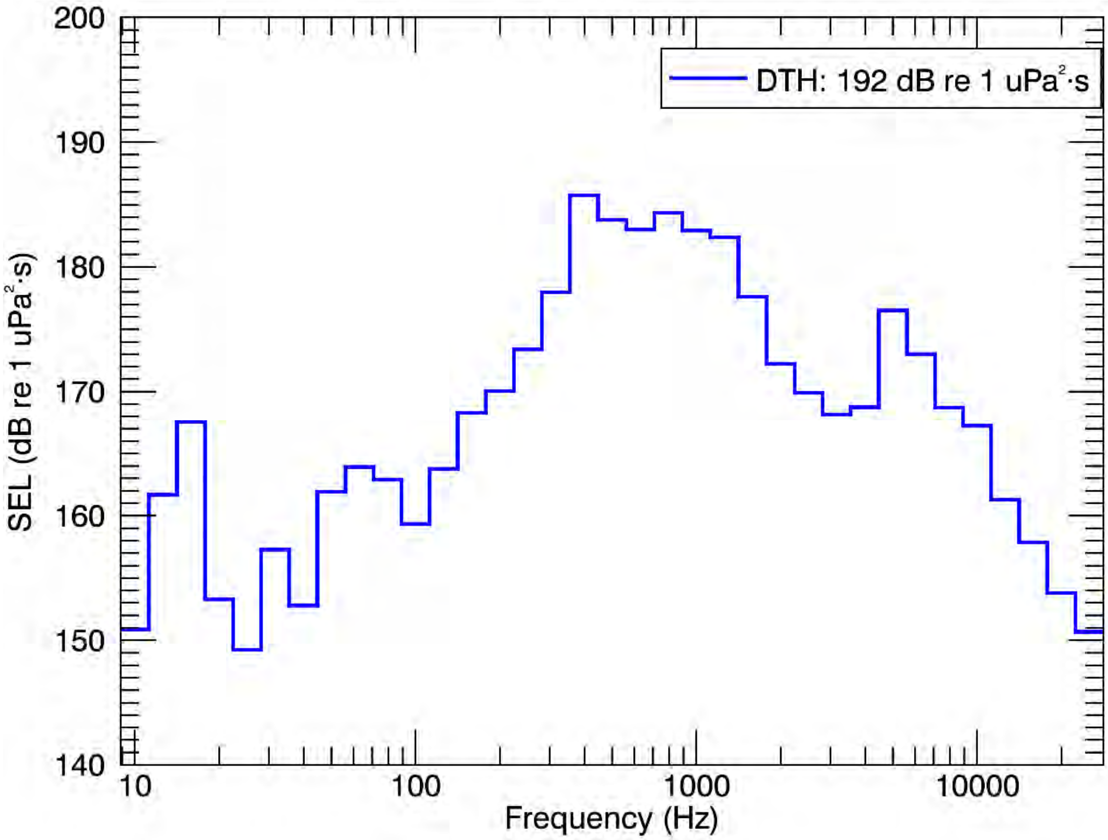


Figure 6. One-third-octave-band source levels for DTH hydro-hammering. Broadband SEL is indicated in the inset legend.

3.2.2. Source levels for impact and vibratory driving of sheet piles

Spectral acoustic measurements from impact driving of sheet piles 24 in wide by 50 feet long (Buehler et al. 2015) were used to estimate source levels for the present study. Measurements in the frequency band 10–5000 Hz were obtained at 10 m range in water depth of 13 m, when an ICE60S impact hammer (rated energy of 81.4 kJ) was in its final stage of driving these sheet piles.

The measured data were digitalized and processed in 1/3-octave-bands, yielding a broadband per-strike SEL reaching 180 dB re 1 μPa²·s. This can be considered high when compared to the typical broadband SEL for cylindrical pipes of similar dimensions (28 in diameter/ 50 feet long). Such elevated levels, as well as long pulse duration of ~50 ms observed in the measured time-domain signature and the fact that measurement was taken during the final minute of pile installation, are evidence of pile driving in soil with high mechanical resistance (as would be the case near pile refusal at the end of the pile driving event, for which pile penetration per hammer strike is minimal). The radiated noise footprint resulting from such levels would be unusually large and not representative of a typical operation. Furthermore, the 24-h SEL, being cumulative over the duration of a piling, should be based on the prevailing levels per strike and not on the extreme. For this reason, simulations were performed to correct suitably the measured broadband SEL so it would reflect a typical pile driving operation.

The simulated study used a cylindrical pile of 83.5 cm diameter as a surrogate to determine how soil resistance impacts broadband SEL, SPL (rms), and peak pressure levels (Section 3.2.4 describes the simulation process for pile driving of cylindrical piles). This diameter was selected to approximate the width of an AZ25 sheet pile. A cylindrical pile was used here as a surrogate of the sheet pile because GRLWEAP and JASCO's PDSM modelling approach (as described in Section 3.2.4. below) can be used to investigate the effect of soil resistance. Results corresponding to high soil resistance (i.e., pile penetration rates of ~2.5 mm/strike) yield SEL~178.1 dB re μPa²·s, SPL~191.1 dB re 1 μPa, and peak pressure level of 200.2 dB re 1 µPa at 10 m distance. These values are close to the Buehler et al. sheet pile measurements and therefore are considered here as a suitable surrogate of the sheet piles. Next, a new simulation was run using a soil resistance in agreement with the value used for all other modeling for cylindrical piles in this study. The result for low soil resistance suggests a broadband SEL of 174 dB re 1 µPa²·s measured at 10 m (i.e., 6 dB less than the SEL near refusal indicated by the atypical measurement).

One-third-octave-band source levels for impact sheet pile driving (Figure 7) have also been corrected to account for the higher energy of the ICE I-36V2 relative to the ICE60S; 20 dB were also added to account for the spherical spreading loss from the pile to the 10 m range where measurements were taken. No experimental data were available for frequencies higher than 5 kHz but the levels are expected to decrease with frequency, so the measurements were extrapolated to 25 kHz according to a decay rate of 14.1 dB/decade as suggested by the trend observed in the 1/3-octave-band levels from the measured data between 2000 and 5000 Hz.

For vibratory pile driving of 24 in wide sheet piles, we used spectral measurements in the frequency band 10–4000 Hz from the literature (Buehler et al. 2015). In this case, the pile was driven using an APE 400 King Kong hydraulic vibratory hammer (3200 kN centrifugal force). These measurements were corrected for spherical spreading by +20 dB (corresponding to 10 m range) and by −2.5 dB (the logarithm of the ratio of the centrifugal force of the modeled to the measured hammer) to account for the smaller driving force of the ICE44B hammer. One-third-octave-band SEL were obtained from the measured spectra up to 2500 Hz. At higher frequencies no experimental data were available, so the measurements were extrapolated to ~25 kHz according to a decay rate of 19 dB/decade as suggested by the trend observed in the 1/3-octave-band levels from the measured data between 1000-4000 Hz.

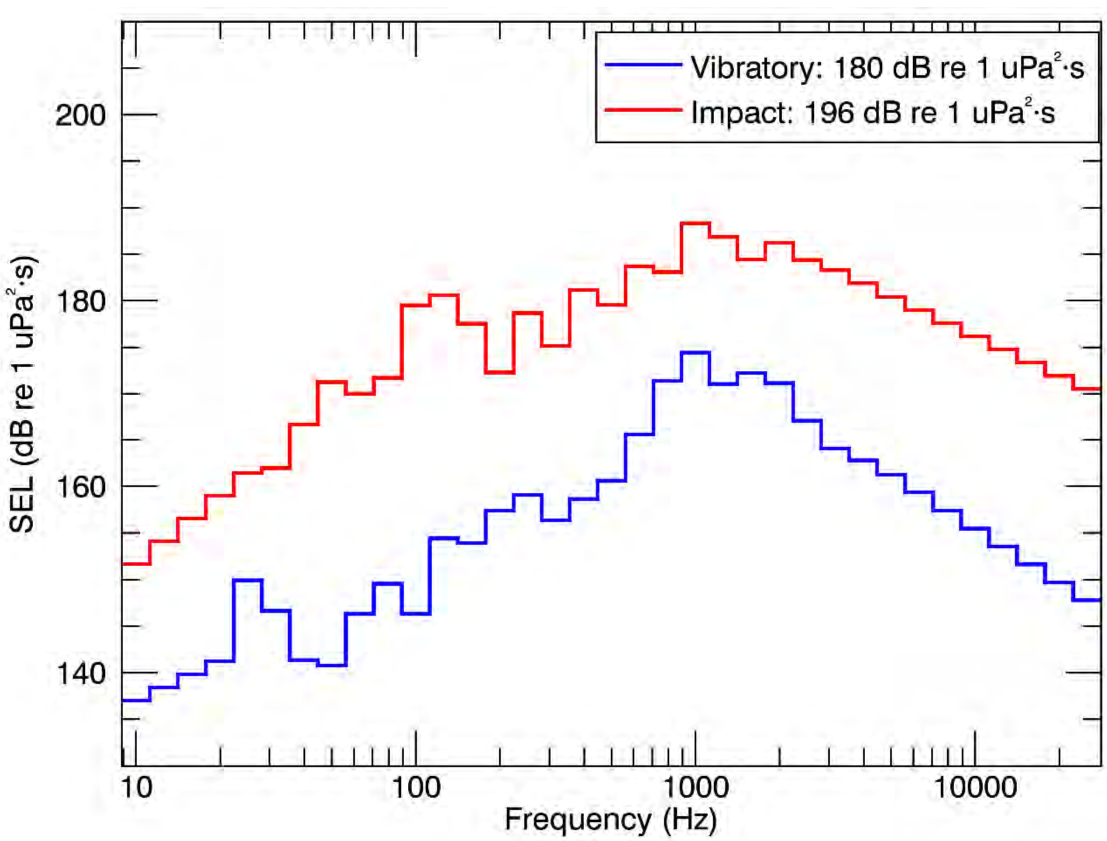


Figure 7. One-third-octave-band source levels for impact and vibratory pile driving of sheet piles. Broadband SEL is indicated in the inset legend.

3.2.3. Source levels for impact and vibratory driving of H piles

For impact pile driving of H piles, spectral measurements in the frequency band 10–4000 Hz for 12 × 12 in H piles were available from the literature (Buehler et al. 2015). The pile was driven using an APE D-19-42 diesel impact hammer (63.63 kN·m energy). These measurements were corrected for spherical spreading by +20.0 dB (corresponding to 10 m range of the measurement) and by +3 dB to account for the higher energy of the ICE I-36V2 hammer. One-third-octave-band SEL were obtained from the measured spectra up to 4000 Hz. The measurements were extrapolated to ~25 kHz according to a decay rate of 2.6 dB/decade as suggested by the trend observed in the 1/3-octave-band levels from the measured data between 1000-4000 Hz, resulting in the 1/3-octave-band SEL (Figure 8).

For vibratory pile driving of H piles, spectral measurements in the frequency band 10–10000 Hz for 14 × 14 in H piles were available from the literature (Burgess et al. 2005). In this case, the pile was driven using an APE 200 hydraulic vibratory hammer (1797 kN centrifugal force). These measurements were corrected for spherical spreading by +22.9 dB (corresponding to 14 m range) and by −0.02 dB to account for the slightly smaller driving force of the ICE44B hammer. One-third-octave-band SEL were obtained from the measured spectra up to 10000 Hz. The measurements were extrapolated to ~25 kHz according to a decay rate of 20.2 dB/decade as suggested by the trend observed in the 1/3-octave-band levels from the measured data between 4000-10000 Hz.

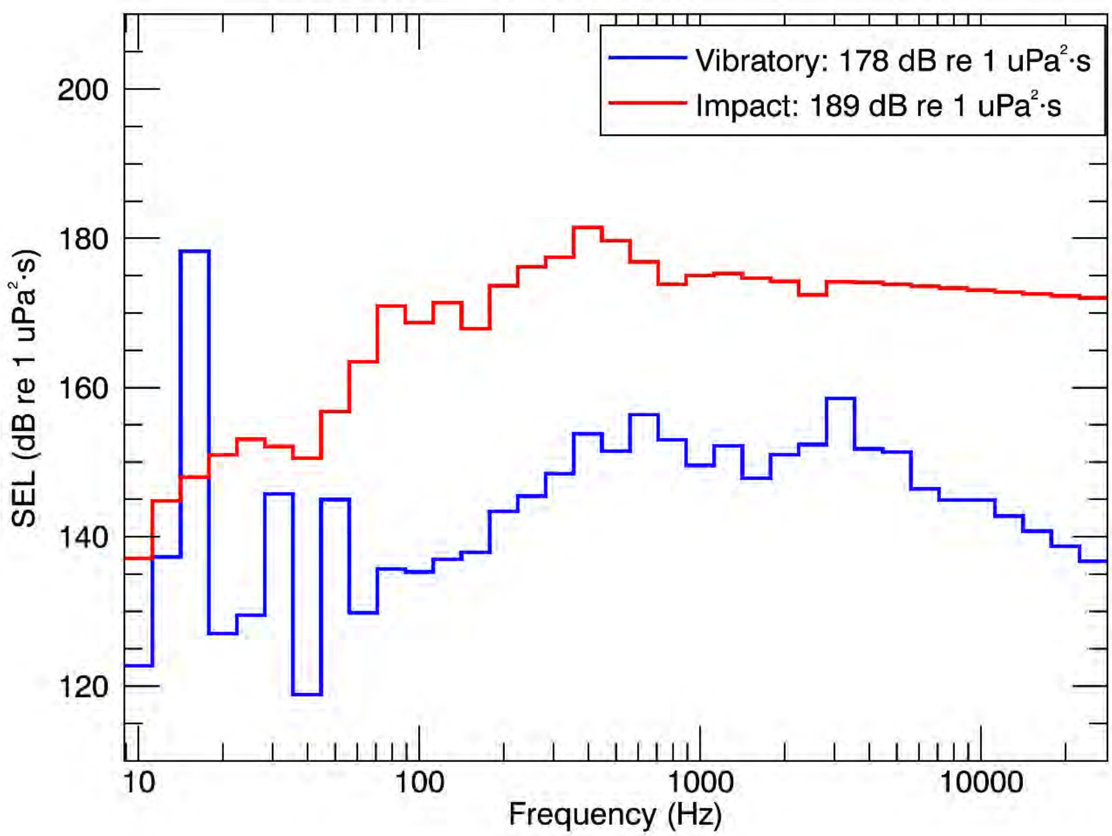


Figure 8. One-third-octave-band source levels for impact and vibratory pile driving of H piles. Broadband SEL is indicated in the inset legend.

3.2.4. Source levels for impact pile driving of cylindrical piles

To model sounds resulting from impact pile driving of cylindrical pipes, JASCO's Pile Driving Source Model (PDSM), a physical model of pile vibration and near-field sound radiation (MacGillivray 2014), was used in conjuction with the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010). Once the impact pile driver model and the pile dimensions were input into GRLWEAP, we were able to compute the force at the top of the pile generated by the driver (Figure 9) and then input that into JASCO's PDSM.

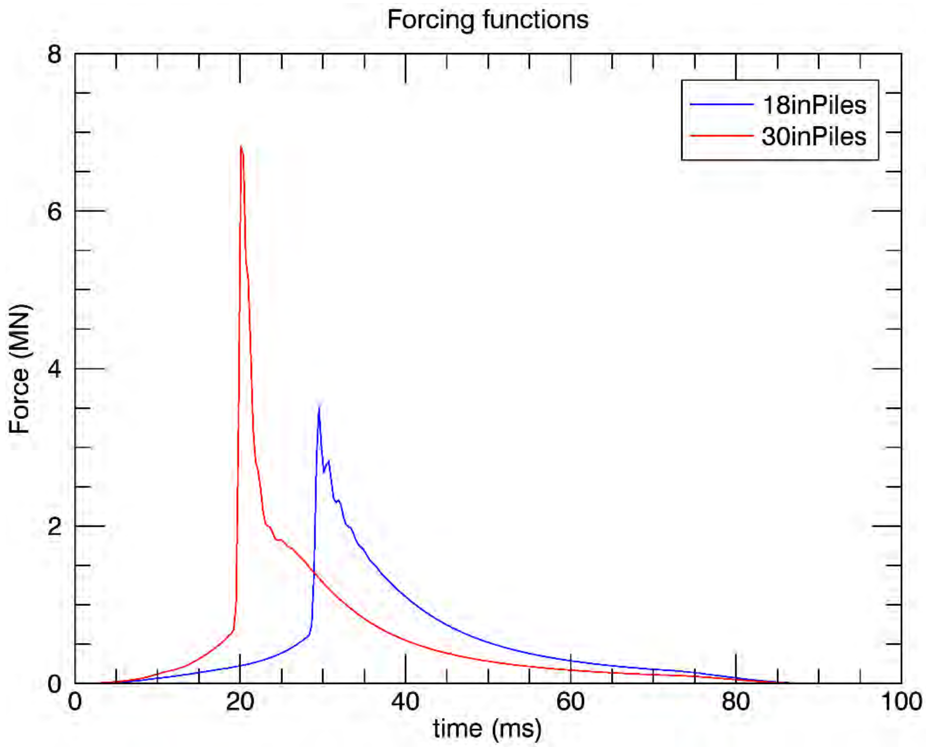


Figure 9. Force at the top of the pile corresponding to impact pile driving of 18 in and 30 in diameter piles, computed using the GRLWEAP 2010 wave equation model for the ICE I-36V2 impact hammer.Forcing functions (Figure 9) were input to JASCO's PDSM to obtain equivalent pile driving signatures consisting of a vertical array of discrete point sources (Appendix A.2.1), which provide a representation of the pile as an acoustic source and account for several parameters that describe the operation: pile type, material, size, and length; the pile driving equipment; and approximate pile penetration rate. The amplitude and phase of the point sources along the array were computed so that they collectively mimicked the time-frequency characteristics of the acoustic wave at the pile wall that results from a hammer strike or from forced vibration (vibratory driving) at the top end of the pile. This approach accurately estimates spectral levels within the band 10–800 Hz where most of the energy from impact pile driving is concentrated.

For consistency with the modeling approach used for all other piles (in which SEL 1/3-octave-band levels are input to MONM to determine received levels at given ranges and depths), the pile driving source signature obtained from PDSM was further converted into an equivalent single monopole source at the middle of the water column, suitable for MONM. To achieve such conversion, the PDSM signature was input to JASCO's Full Waveform Range-dependent Acoustic Model (FWRAM), which is a time-domain acoustic model that accepts as input a PDSM-generated array of point sources representing the pile and computes synthetic pressure waveforms via Fourier synthesis, from which several metrics—SPL, PK, and SEL—can be obtained. SEL was determined along a 20 km radial from the pile, and far-field point source representations of the acoustic signatures from the piles (Figure 10) were then determined by back-propagating the received sound levels from FWRAM using the transmission loss calculated with MONM.

Impact pile driving in Scenarios 2 and 4 (see Table 1) is used to confirm that the pile is firmly positioned on the bedrock (i.e., pile near refusal). Pile refusal results in elevated SEL compared to normal pile driving conditions (Section 3.2.2). For this reason, impact pile driving source levels for Scenarios 2 and 4 were obtained by specifying a high soil resistance input parameter in the PDSM model, which mimics the condition of low penetration rates during refusal. Figure 10 shows the two levels adjusted to account for the use of the impact hammer at pile refusal in Scenarios 2 and 4.

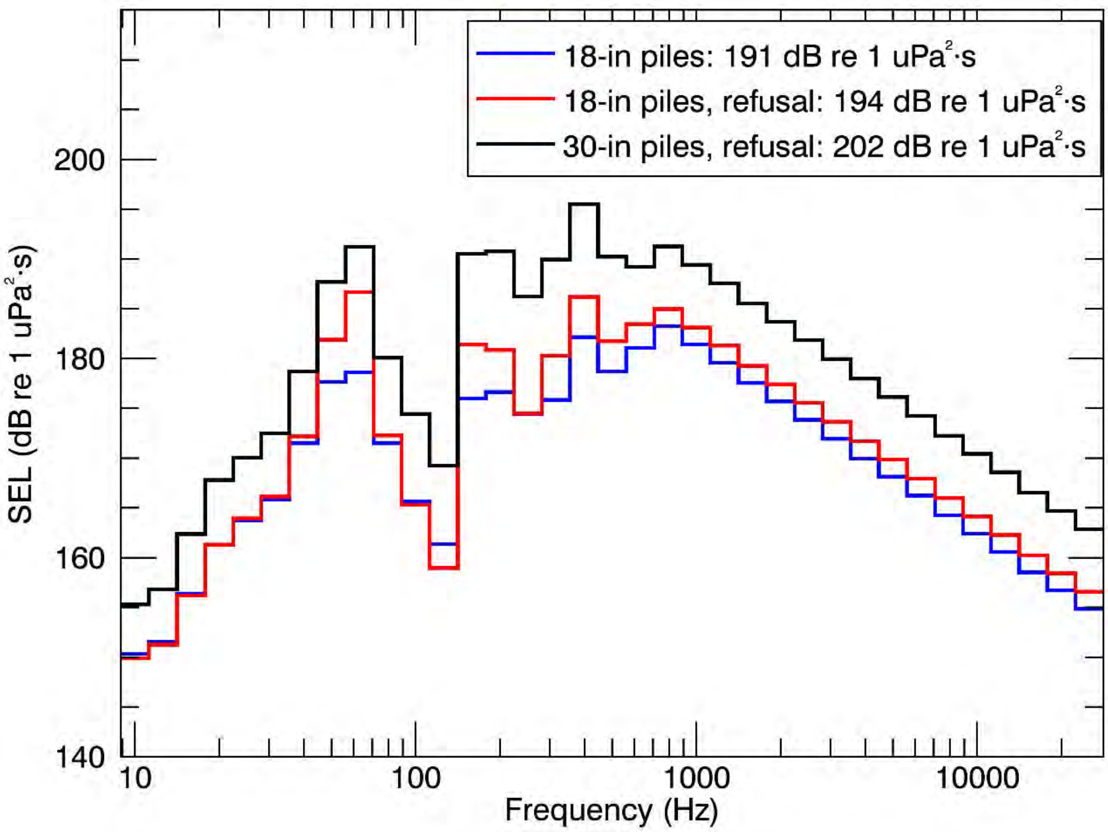


Figure 10. One-third-octave-band source levels for impact pile driving of cylindrical piles.Broadband SEL is indicated in the inset legend. The label "refusal" refers to Scenarios 2 and 4, for which the impact hammer was used to test the pile once it has been driven to consolidated bedrock.

3.2.5. Source levels for vibratory pile driving of cylindrical piles

Source levels that correspond to vibratory pile driving of cylindrical pipes were first modeled with the same approach described for impact pile driving (see Section 3.2.4). However, since the PDSM model is linear and the GRLWEAP forcing function for vibratory pile driving is a periodic signal with its frequency determined by the pile driver, the resulting source levels are mostly concentrated at the single band that includes the hammer's oscillation frequency. While this method is correct in principle, field measurements for vibratory pile driving often exhibit energy at multiple harmonics of the hammer's fundamental frequency. To account for this effect, 1/3-octave-band levels from measurements of vibratory pile driving of 30 in diameter piles obtained at Ketchikan, AK (Denes et al. 2016), were adjusted to match the broadband SEL obtained by the preliminary model using GRLWEAP and PDSM. The resulting 1/3-octave-band levels (Figure 11) exhibit peaks over multiple bands.

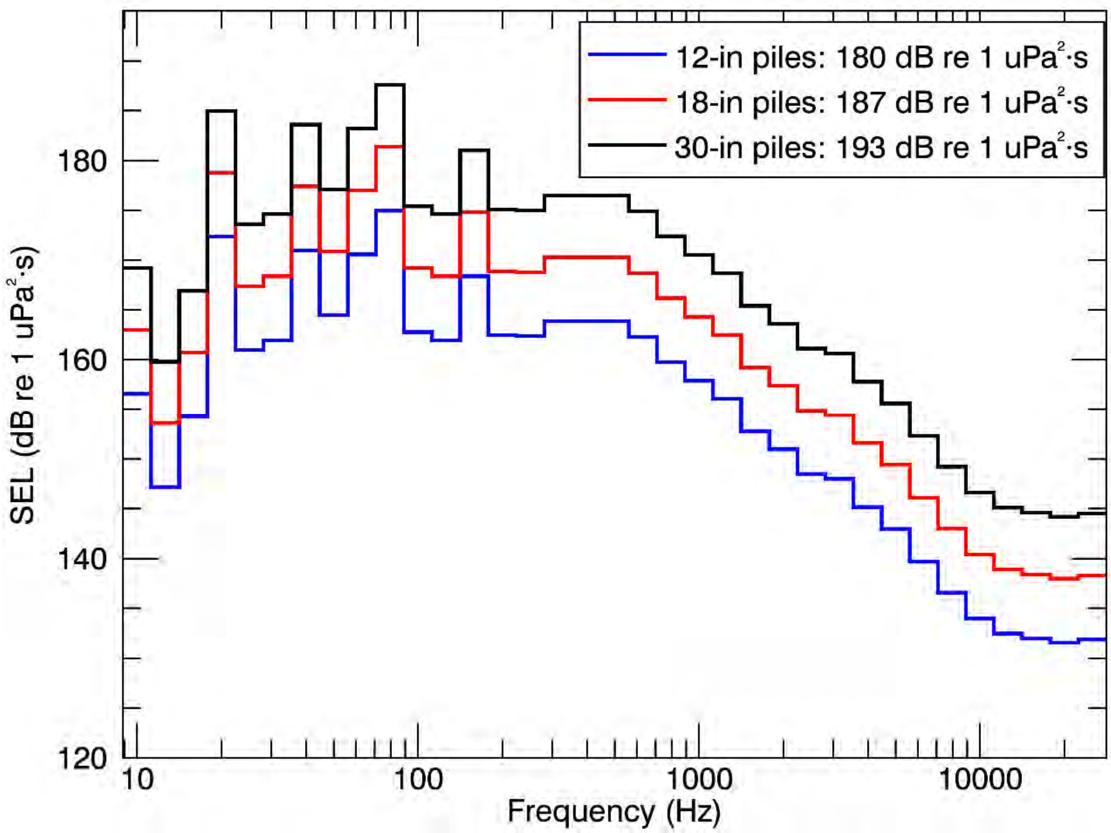


Figure 11. One-third-octave-band source levels for vibratory pile driving of cylindrical piles. Broadband SEL is indicated in the inset legend.

3.3. Sound Pressure Level and Peak Pressure Level

The SPL for impulsive sources is related to the SEL of a single pulse and the pulse length (Appendix A.1). For this reason, the SPL over a wide area can be estimated from the single-pulse SEL values generated by MONM. The required conversion factor depends on the pulse length, which typically increases in duration as pulses propagate away from their source due to reverberation from seabed and sea-surface reflections as well as from in-water refractive effects. To investigate how pulse length depends on range and depth, FWRAM (Appendix A.3.2) was used to model synthetic impact pile driving pulses along a 20 km radial extending from the modeling location for cylindrical piles of 12 in, 18 in, and 30 in diameter. The synthetic pulses were analyzed to determine pulse length versus receiver depth and distance from the source. Conversion factors from single-pulse SEL to SPL (rms) were derived in two steps: first, the average pulse duration over depth at each modeled range was obtained by including only depth points with high SEL (i.e., within 3 dB from the largest SEL at each range); second, averaging was applied in range for 1 km radial steps. The averaged conversion factor was similar for the three pile sizes. At all ranges, the SEL-to-SPL conversion factor for 18 in diameter piles was the largest and differed from the conversion factors for the other two piles by less than 2 dB at ranges greater than 1 km. This suggests strong independence of the conversion factor with respect to pile size. In this work, the range-dependent conversion offset factor for 18 in cylindrical piles (Figure 12) was applied to the modeled SEL from MONM to calculate SPL (rms) values over a 360 degree area for all scenarios with impact pile driving.

A similar analysis of the range dependency on the difference between SEL and peak values using cylindrical piles of 12 in, 18 in, and 30 in diameter shows that the SEL-to-Peak conversion factor for 18 in diameter piles is the largest, and differs from the conversion factors for the other two piles by less than

0.7 dB at all ranges. The SEL-to-Peak conversion factor applied to the modeled SEL from MONM for all scenarios involving impact pile driving is shown in Figure 12.

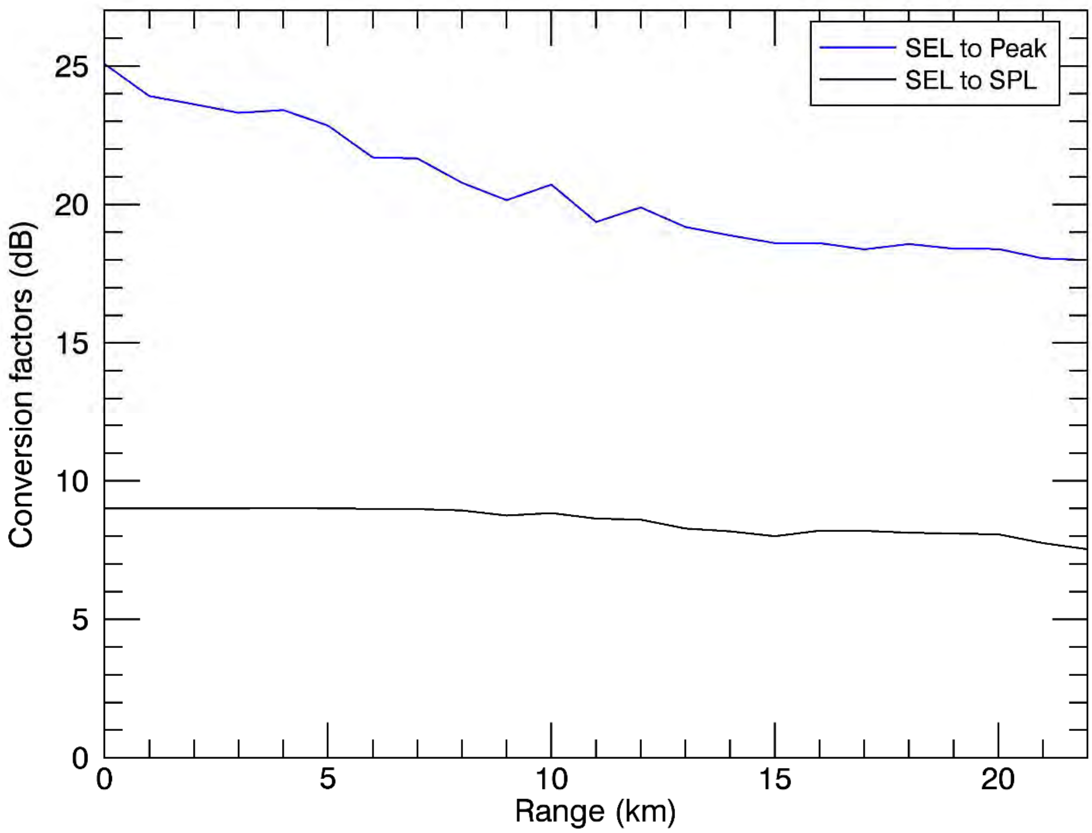


Figure 12. Range-dependent conversion offset factors for converting SEL-to-SPL and SEL-to-Peak.

3.4. Cumulative Criteria Based on 24-hr Periods

The modeling approach outlined in Section 2 provides per-pulse SEL for impulsive sources or per-second SEL for non-impulsive sources. Information on the total number of strikes (impact) or the total number of seconds (vibratory and DTH hydro-hammering) required to install a pile (Table 1) was used in this report to obtain SEL over 24 hours for impulsive sources by applying Equation 3:

$$\text{24-hr SEL} = \text{per-blow SEL} + 10 \times \log_{10} N_{24h} \quad (3)$$

where N_{24h} represents the total number of hammer blows for impact pile driving.

For non-impulsive sources, the SEL over 24 hours was computed by applying Equation 4:

$$24 - \text{hr SEL} = 10\log_{10}\left(V_{24}10^{\text{SEL}_V/10} + D_{24}10^{\text{SEL}_D/10}\right) \quad (4)$$

where SEL_V and SEL_D, correspond to the per-second SEL for vibratory or DTH hydro-hammering, respectively, while V_{24} and D_{24} are the total number of seconds of operation for the vibratory hammer and the DTH hydro-hammer, respectively.

4. Results

This section presents the distances to marine mammal Level-A and Level-B thresholds for non-impulsive sources (Table 7) and impulsive sources (Table 8). The distances are based on NMFS (2016) and the interim NMFS (2013) criteria for Level-A and Level-B, respectively. Acoustic contour maps, which show the directivity and range to various sound level isopleths, are presented in Appendix B. The reported radii for 24-hr SEL (Level-A) thresholds are based on the assumption that marine mammals remain stationary or at a constant exposure range during the entire period, which for the relatively short estimated distances, in practical terms represents an unlikely worst-case scenario. This is discussed further in (Section 5).

Table 7. Threshold distances based on NMFS (2016) Level-A, and NMFS (2013) Level-B interim criteria for non-impulsive sources. A dash in table cells indicates that threshold was not reached. LFC = Low-frequency cetaceans. MFC = Mid-frequency cetaceans. HFC = High-frequency cetaceans. PPW = Phocid pinnipeds in water. OPW = Otariid pinnipeds in water.

Criteria	Functional hearing group	Threshold	S1			S2			S3			S4			S5			S6		
			R_{max} (km)	$R_{95\%}$ (km)	Area (km^2)	R_{max} (km)	$R_{95\%}$ (km)	Area (km^2)	R_{max} (km)	$R_{95\%}$ (km)	Area (km^2)	R_{max} (km)	$R_{95\%}$ (km)	Area (km^2)	R_{max} (km)	$R_{95\%}$ (km)	Area (km^2)	R_{max} (km)	$R_{95\%}$ (km)	Area (km^2)
Level-A (NMFS 2016)	SEL_{24h}																			
	LFC	199 dB re 1 µPa²·s	0.01	0.01	< 0.01	0.40	0.35	0.19	0.01	0.01	< 0.01	0.30	0.26	0.12	-	-	-	0.04	0.04	< 0.01
	MFC	198 dB re 1 µPa²·s	-	-	-	0.01	0.01	< 0.01	-	-	-	0.01	0.01	< 0.01	-	-	-	< 0.01	< 0.01	< 0.01
	HFC	173 dB re 1 µPa²·s	-	-	-	0.63	0.51	0.30	-	-	-	0.53	0.36	0.19	0.01	0.01	< 0.01	0.09	0.08	0.01
	PPW	201 dB re 1 µPa²·s	-	-	-	0.09	0.08	0.02	-	-	-	0.07	0.06	0.01	-	-	-	0.01	0.01	< 0.01
	OPW	219 dB re 1 µPa²·s	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Level-B (NMFS 2013)	SPL																			
	All marine mammals	120 dB re 1 µPa	2.03	1.80	1.38	4.94/ 12.17*	4.27/ 10.02*	3.77/ 21.60*	4.94	4.27	3.77	6.89/ 12.17*	6.07/ 10.02*	9.70/ 21.60*	0.98	0.79	0.60	5.74	4.72	4.56

*Level-B thresholds corresponding to DTH hydro-hammering.

Table 8. Threshold distances based on NMFS (2016) Level-A criteria, and NMFS (2013) Level-B interim criteria for impulsive sources. A dash in table cells indicates that threshold was not reached. LFC = Low-frequency cetaceans. MFC = Mid-frequency cetaceans. HFC = High-frequency cetaceans. PPW = Phocid pinnipeds in water. OPW = Otariid pinnipeds in water.

Criteria	Functional hearing group	Threshold	S2			S3			S4			S5			S6		
			R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)	R_{max} (km)	$R_{95\%}$ (km)	Area (km²)
Level-A (NMFS 2016)	SEL_{24h}																
	LFC	183 dB re 1 µPa²·s	0.03	0.03	< 0.01	0.83	0.63	0.43	0.08	0.08	0.02	0.89	0.67	0.47	1.69	1.36	1.04
	MFC	185 dB re 1 µPa²·s	-	-	-	0.01	0.01	< 0.01	-	-	-	0.14	0.13	0.04	0.25	0.22	0.09
	HFC	155 dB re 1 µPa²·s	0.05	0.05	< 0.01	1.03	0.77	0.57	0.10	0.09	0.02	2.47	2.05	1.85	3.79	2.93	2.84
	PPW	185 dB re 1 µPa²·s	< 0.01	< 0.01	< 0.01	0.22	0.20	0.08	0.01	0.01	< 0.01	0.33	0.29	0.15	0.95	0.77	0.60
	OPW	203 dB re 1 µPa²·s	-	-	-	0.01	0.01	< 0.01	-	-	-	0.01	0.01	<0.01	0.08	0.08	0.01
	PK																
	LFC	219 dB re 1 µPa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MFC	230 dB re 1 µPa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	HFC	202 dB re 1 µPa	0.01	0.01	< 0.01	0.01	0.01	< 0.01	0.05	0.05	< 0.01	0.01	0.01	< 0.01	0.01	0.01	< 0.01
	PPW	218 dB re 1 µPa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	OPW	232 dB re 1 µPa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Level-B (NMFS 2013)	SPL																
	All marine mammals	160 dB re 1 µPa	0.89	0.71	0.49	0.67	0.55	0.36	1.67	1.25	0.98	0.50	0.43	0.24	0.96	0.79	0.60

5. Conclusion

The purpose of this study was to assess the extent over which marine mammal species could be affected by pile driving activities at the Biorka Dock Replacement Project site. Acoustic models were used to predict noise levels from impact, vibratory and DTH hydro-hammering pile installations and the results were compared with various metrics for acoustic impacts.

Acoustic footprints were modeled by considering several combinations of pile geometries (H piles, sheet piles, and cylindrical piles of 12,18, and 30 in diameter), driving mechanisms, and specific characteristics of pile driving equipment (impact hammer, vibratory hammer and down the hole hydro-hammering). Noise characterization corresponding to several combinations of pile geometry and pile driving equipment was achieved in most cases by adjusting spectral measurements under similar operational conditions. In the case of impact and vibratory pile driving of cylindrical piles, source levels were obtained by applying JASCO's Pile Driving Source Model (PDSM). Sound propagation was carried out using JASCO's Marine Operations Noise Model (MONM) to obtain range- and depth-dependent SEL (sound exposure levels) from six construction scenarios.

Modeling results were processed to obtain distances to various marine mammal impact thresholds. These distances are presented in tables of maximum (R_{max}) ranges, the maximum distances at which thresholds are exceeded, and 95% ranges ($R_{95\%}$), the maximum range at which the given sound level was encountered after excluding 5% of the farthest such points to provide an estimate less affected by sound field outliers (see Tables 7 and 8).

Where uncertainties in operating conditions existed, the models were parametrized to yield realistically conservative noise levels. We applied several such conservative assumptions to the methods used in this study so the results would not underestimate potential effects on marine life:

- Because marine mammals swim through a wide depth range, all the distances to thresholds (R_{max}, $R_{95\%}$) and the noise level contour maps represent the maximum sound levels over all depths.
- The spectral content from pile driving activities of H piles, sheet piles, and cylindrical piles (impact driving) either modeled by PDSM or obtained from the literature, was extended in frequency to account for energy contributions up to 25 kHz, using measurement-based spectral decay factors.
- The location selected for modeling corresponded to the pile in the deepest water, for which coupling of sound into the water column is higher than shallower locations). In addition, the bathymetry used for modeling was also adjusted to represent mean high water.
- Modeling was carried out using the August sound speed profile, which exhibits the most pronounced surface channel over all other months for this geographic area.
- The spectral content for vibratory pile driving of cylindrical piles was obtained from measured levels, which exhibit large energy contributions at high-frequency harmonics.
- Source levels for impact pile driving testing in scenarios S2 and S4 were adjusted to reflect the higher SEL commonly observed in measurements obtained when piles are being driven near refusal.

For impact pile driving, PK level criteria for marine mammal injury were not reached beyond $R_{95\%}$ =50 m from the pile for any scenario. The maximum range for marine mammal disturbance, based on the 160 dB re 1 µPa SPL threshold, was $R_{95\%}$=1.25 km. The largest $R_{95\%}$ distance to 24-hr auditory weighted SEL injury thresholds was 2.93 km for the high-frequency cetacean hearing group for scenario S6, due to the large number of cumulative hammer strikes (N_{24h} =6120) required to install 12 sheet piles, as well as energy contributions at frequencies above 1 kHz. Similar conditions are observed for the installation of H piles in scenario S5 (N_{24h} = 5440), for which the impact pile driving source levels in Figure 8 exhibit a slow decay rate at frequencies higher than 1 kHz, resulting in $R_{95\%}$=2.05 km distance to the 24-hr auditory weighted SEL injury threshold for the high-frequency cetacean hearing group.

As mentioned in Section 4, understanding the assumptions that played a role in obtaining each metric is crucial when comparing SEL_{24h} and peak pressure Level-A thresholds radii. PK thresholds reflect the potential range at which an animal could be injured if it were exposed to a single loud, short-duration noise such as impact pile driving, and is usually limited to a short distance (i.e., within meters) from the pile. SEL_{24h} is a cumulative metric, reflecting the dosimetric impact of noise levels within 24 hours, under the assumption that an animal is consistently exposed to such noise levels. For estimated Level-A ranges not exceeding a few kilometers it can be assumed that within 24 hours marine mammals would, realistically, swim outside the potential harm zone at least some of the time, and would thus receive a lower exposure than the Level-A threshold.

For non-impulsive sources, the largest $R_{95\%}$ distances to 24-hr auditory weighted SEL injury thresholds were 0.51 km and 0.36 km for Scenarios S2 and S4, respectively, which correspond to the high-frequency cetacean hearing group. The increased radii in these two scenarios (compared to S3, S5, and S6) are due to the addition of DTH hydro-hammering. The maximum disturbance range based on the 120 dB re 1 µPa SPL threshold was $R_{95\%}$=6.07 km for vibratory pile driving of the 30” dolphin pipe piles (Scenario S4) and 10.02 km for DTH hydro-hammering.

Glossary

1/3-octave-band
Non-overlapping passbands that are one-third of an octave wide (where an octave is a doubling of frequency). Three adjacent 1/3-octave-bands make up one octave. One-third-octave-bands become wider with increasing frequency. See also octave.

90%-energy time window
The time interval over which the cumulative energy rises from 5% to 95% of the total pulse energy. This interval contains 90% of the total pulse energy. Symbol: T_{90}.

90% sound pressure level (90% SPL)
The sound pressure levels calculated over the 90%-energy time window of a pulse. Used only for pulsed sounds.

attenuation
The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

auditory weighting
The process of band-pass filtering loud sounds to reduce the importance of inaudible or less-audible frequencies for broad classes of marine mammals. "Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterizing auditory effects of strong sounds" (Southall et al. 2007).

bandwidth
The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).

bar
Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 bar is equal to $10^{6\ \mathrm{Pa}}$ or $10^{11\ \mu\mathrm{Pa}}$.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

Down the hole (DTH) hydro-hammering
Hammering device used to break rock underwater and install piles using a percussion action.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

functional hearing group
Grouping of marine mammal species with similar estimated hearing ranges. Southall et al. (2007) proposed the following functional hearing groups: low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seabed.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency cetacean
The functional hearing group that represents odontocetes specialized for using high frequencies.

HHWMT (higher high water mean tide)
The average from all the higher high waters from 19 years of predictions.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency cetacean
The functional hearing group that represents mysticetes (baleen whales).

marine mammal disturbance
Behavioral disruption in marine mammals exposed to underwater noise.

marine mammal injury
Direct physical injury (including permanent auditory threshold shift (PTS) and trauma in lungs) in marine mammals exposed to underwater noise.

mid-frequency cetacean
The functional hearing group that represents some odontocetes (dolphins, toothed whales, beaked whales, and bottlenose whales).

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and the grey whale (*Eschrichtius robustus*).

non-impulsive sound
Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have (ANSI/ASA S3.20-1995 R2008). Marine vessels, aircraft, machinery, construction, and vibratory pile driving are examples.

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The toothed whales' skulls

are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

parabolic equation method
A computationally-efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

peak pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak sound pressure level. Unit: decibel (dB).

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

pinniped
A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

power spectrum density
The acoustic signal power per unit frequency as measured at a single frequency. Unit: $\mu Pa^2/Hz$, or $\mu Pa^2 \cdot s$.

power spectrum density level
The decibel level ($10\log_{10}$) of the power spectrum density, usually presented in 1 Hz bins. Unit: dB re 1 $\mu Pa^2/Hz$.

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: *p*.

received level
The sound level measured at a receiver.

shear wave
A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves traveling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A measure related to the sound energy in one or more pulses. Unit: dB re 1 $\mu Pa^2 \cdot s$.

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 μPa) and the unit for SPL is dB re 1 μPa:

$$\mathrm{SPL} = 10\log_{10}\left(p^2/p_0^2\right) = 20\log_{10}\left(p/p_0\right)$$

Unless otherwise stated, SPL refers to the root-mean-square (rms) sound pressure level.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound pressure level measured 1 meter from a theoretical point source that radiates the same total sound power as the actual source. Unit: dB re 1 μPa @ 1 m.

spectrum
An acoustic signal represented in terms of its power (or energy) distribution versus frequency.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

transmission loss (TL)
Also called propagation loss, this refers to the decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment.

wavelength
Distance over which a wave completes one oscillation cycle. Unit: meter (m). Symbol: λ.

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Appendix A. Underwater Acoustics Theory and Formulae

A.1. Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Because the perceived loudness of sound, especially impulsive noise such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate noise and its effects on marine life. We provide specific definitions of relevant metrics used in the accompanying report. Where possible we follow the ANSI and ISO standard definitions and symbols for sound metrics, but these standards are not always consistent.

The zero-to-peak sound pressure level, or peak sound pressure level (PK; dB re 1 μPa), is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,pk} = 20\log_{10}\left[\frac{\max(|p(t)|)}{p_0}\right] \quad \text{(A-1)}$$

$L_{p,pk}$ is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of a noise event, it is generally a poor indicator of perceived loudness.

The sound pressure level (SPL; dB re 1 μPa) is the rms pressure level in a stated frequency band over a specified time window (T, s) containing the acoustic event of interest. It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) \quad \text{(A-2)}$$

The SPL represents a nominal effective continuous sound over the duration of an acoustic event, such as the emission of one acoustic pulse, a marine mammal vocalization, the passage of a vessel, or over a fixed duration. Because the window length, T, is the divisor, events with similar sound exposure level (SEL) but more spread out in time have a lower SPL.

In studies of impulsive noise, the time window T is often defined as the "90% time window" (T_{90}): the period over which cumulative square pressure function passes between 5% and 95% of its full per-pulse value. The SPL computed over this T_{90} interval is commonly called the 90% SPL (SPL(T_{90}); dB re 1 μPa):

$$L_{p90} = 10\log_{10}\left(\frac{1}{T_{90}}\int_{T_{90}} p^2(t)dt \Big/ p_0^2\right) \quad \text{(A-3)}$$

The sound exposure level (SEL, dB re 1 μPa²·s) is a measure related to the acoustic energy contained in one or more acoustic events (N). The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)dt \Big/ T_0 p_0^2\right) \quad \text{(A-4)}$$

where T_0 is a reference time interval of 1 s. The SEL continues to increase with time when non-zero pressure signals are present. It therefore can be construed as a dose-type measurement, so the integration time used must be carefully considered in terms of relevance for impact to the exposed recipients.

SEL can be calculated over periods with multiple acoustic events or over a fixed duration. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the *N* individual events:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right) \quad \text{(A-5)}$$

Because the SPL(T_{90}) and SEL are both computed from the integral of square pressure, these metrics are related by the following expression, which depends only on the duration of the time window *T*:

$$L_p = L_E - 10\log_{10}(T) \quad \text{(A-6)}$$

$$L_{p90} = L_E - 10\log_{10}(T_{90}) - 0.458 \quad \text{(A-7)}$$

where the 0.458 dB factor accounts for the 10% of SEL missing from the SPL(T_{90}) integration time window.

A.1.1. 1/3-Octave-Band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analyzing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into 1/3-octave-bands, which are one-third of an octave wide; each octave represents a doubling in sound frequency. The center frequency of the *i*th 1/3-octave-band, $f_c(i)$, is defined as:

$$f_c(i) = 10^{i/10}, \quad \text{(A-8)}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the *i*th 1/3-octave-band are defined as:

$$f_{lo} = 10^{-1/20} f_c(i) \text{ and } f_{hi} = 10^{1/20} f_c(i) \; . \quad \text{(A-9)}$$

The 1/3-octave-bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced.

The sound pressure level in the *i*th 1/3-octave-band $(L_b^{(i)})$ is computed from the power spectrum $S(f)$ between f_{lo} and f_{hi}:

$$L_b^{(i)} = 10\log_{10}\left(\int_{f_{lo}}^{f_{hi}} S(f)df\right) \quad \text{(A-10)}$$

Summing the sound pressure level of all the 1/3-octave-bands yields the broadband sound pressure level:

$$\text{Broadband SPL} = 10\log_{10}\sum_i 10^{L_b^{(i)}/10} \tag{A-11}$$

A.2. Modeling Methods

A.2.1. Pile Driving Source Model

A physical model of pile vibration and near-field sound radiation is used to calculate source levels of piles. The physical model employed in this study computes the underwater vibration and sound radiation of a pile by solving the theoretical equations of motion for axial and radial vibrations of a cylindrical shell. These equations of motion are solved subject to boundary conditions, which describe the forcing function of the hammer at the top of the pile and the soil resistance at the base of the pile (Figure A-1). Damping of the pile vibration due to radiation loading is computed for Mach waves emanating from the pile wall. The equations of motion are discretized using the finite difference (FD) method and are solved on a discrete time and depth mesh.

To model the sound emissions from the piles, the force of the pile driving hammers also had to be modeled. The force at the top of each pile was computed using the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010), which includes a large database of simulated hammers—both impact and vibratory—based on the manufacturer's specifications. The forcing functions from GRLWEAP were used as inputs to the FD model to compute the resulting pile vibrations.

The sound radiating from the pile itself is simulated using a vertical array of discrete point sources. The point sources are centred on the pile axis. Their amplitudes are derived using an inverse technique, such that their collective particle velocity—calculated using a near-field wave-number integration model—matches the particle velocity in the water at the pile wall. The sound field propagating away from the vertical source array is then calculated using a time-domain acoustic propagation model (Section A.3.2). MacGillivray (2014) describes the theory behind the physical model in more detail.

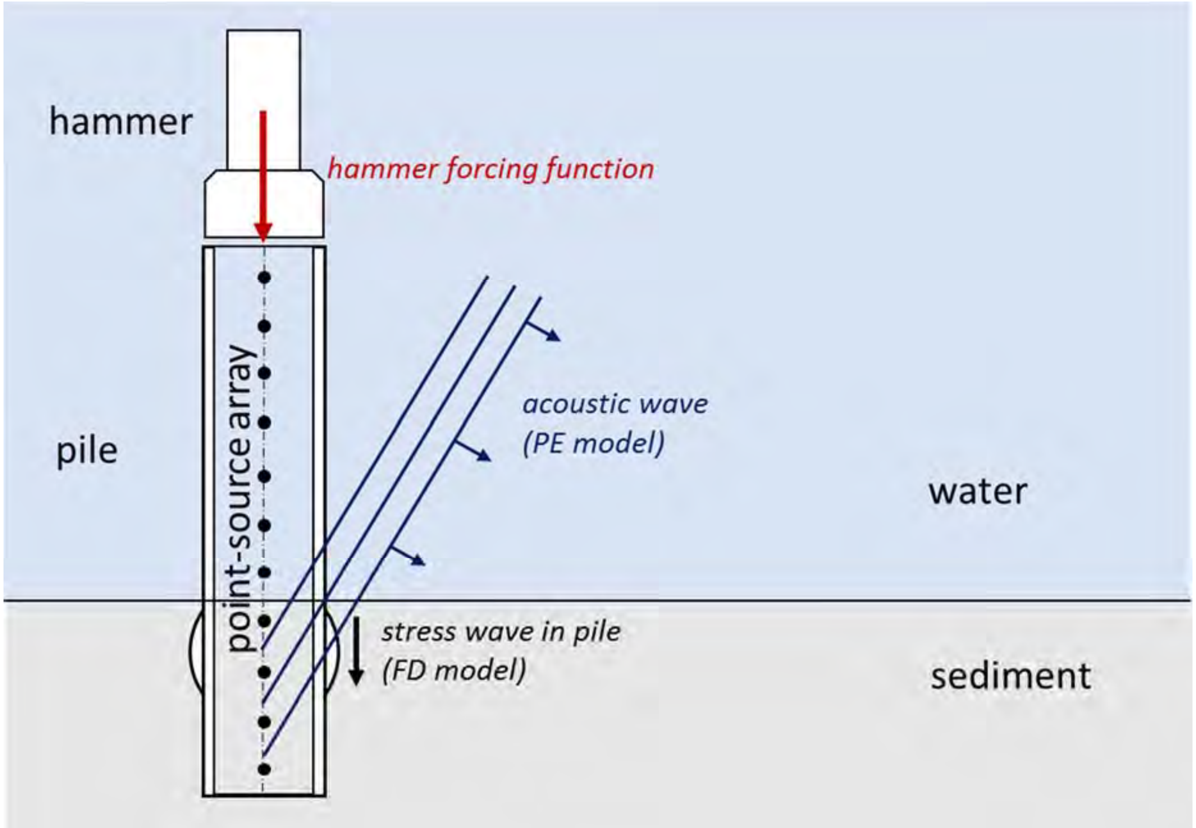

Figure A-1. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). The hammer forcing function is used with the finite difference (FD) model to compute the stress wave vibration in the pile. A vertical array of point sources is used with the parabolic equation (PE) model to compute the acoustic waves that the pile wall radiates.

A.3. Sound Propagation Models

A.3.1. Noise Propagation with MONM

Underwater sound propagation (i.e., transmission loss) at frequencies of 10 Hz to 5 kHz was predicted with JASCO's Marine Operations Noise Model (MONM). MONM computes received per-pulse SEL for directional impulsive sources, and SEL over 1 s for non-impulsive sources, at a specified source depth.

MONM computes acoustic propagation via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modeled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

MONM computes acoustic fields in three dimensions by modeling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure A-2).

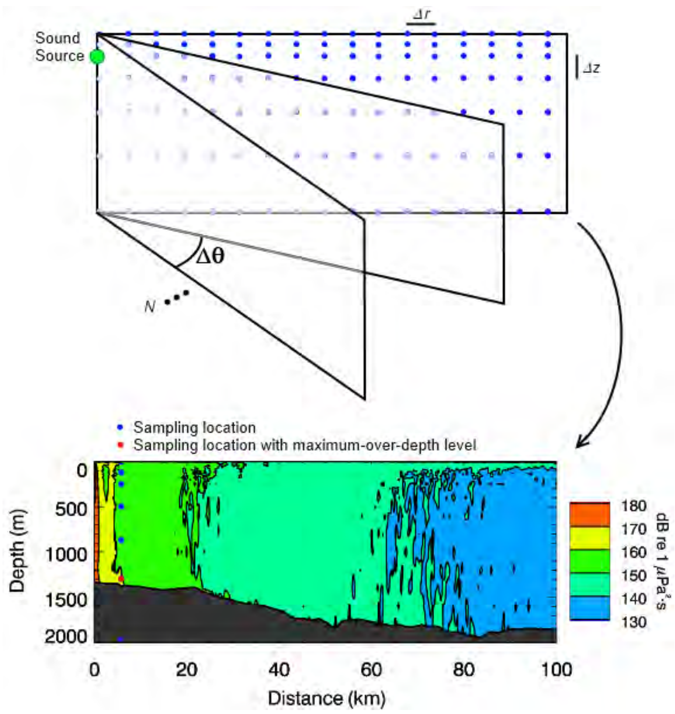

Figure A-2. The N×2-D and maximum-over-depth modeling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the center frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, starting at 10 Hz, are modeled to include the majority of acoustic energy emitted by the source. At each center frequency, the transmission loss is modeled within each of the N vertical planes as a function of depth and range from the source. The 1/3-octave-band received per-pulse SELs are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received SELs are then computed by summing the received 1/3-octave-band levels.

The received per-pulse SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. The received per-pulse SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-pulse SELs are presented as color contours around the source.

MONM's predictions have been validated against experimental data from several underwater acoustic measurement programs conducted by JASCO (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Martin et al. 2015).

A.3.2. Noise Propagation with FWRAM

For impulsive sounds from impact pile driving, time-domain representations of the pressure waves generated in the water are required to calculate SPL and peak pressure level. Furthermore, the pile must be represented as a distributed source to accurately characterise vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seabed geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modeled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Besides providing direct calculations of the peak pressure level and SPL, the synthetic waveforms from FWRAM can also be used to convert the SEL values from MONM to SPL.

Appendix B. Modeled Sound Fields

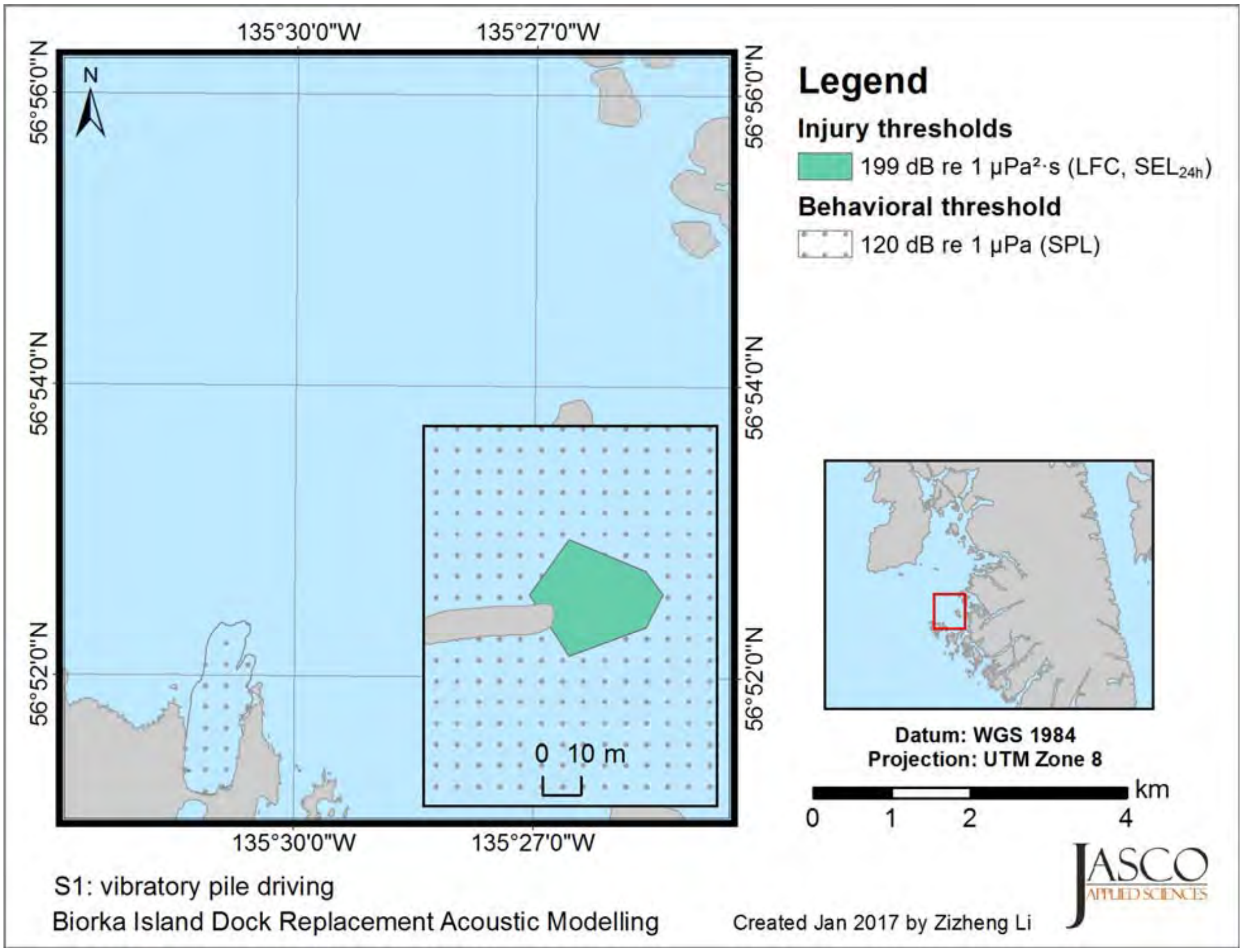

Figure B-1. Thresholds to selected impact criteria for non-impulsive sources in the modeling Scenario S1. The inset shows a close-up of sound fields around the pile location.

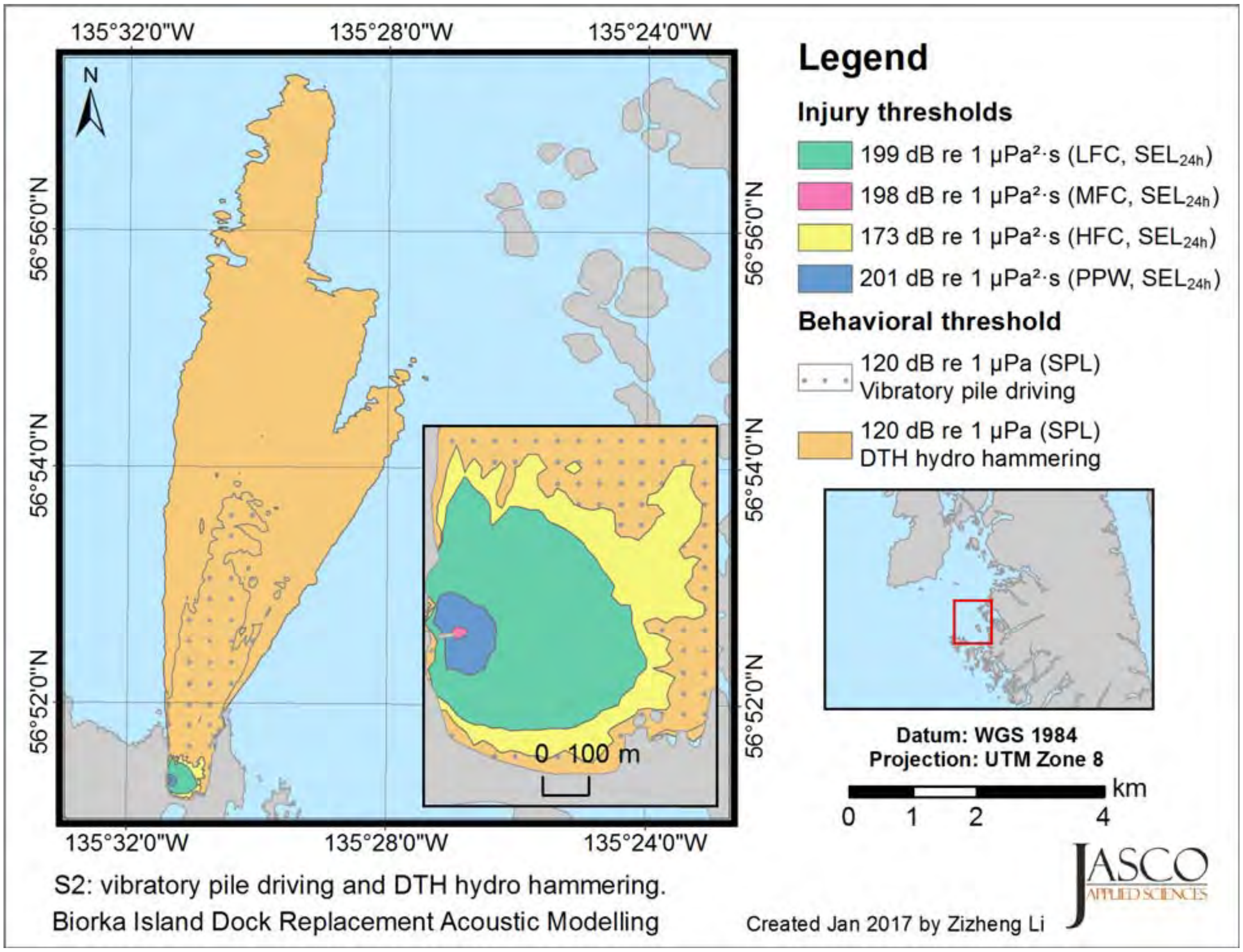

Figure B-2. Thresholds to selected impact criteria for non-impulsive sources in the modeling Scenario S2. The inset shows a close-up of sound fields around the pile location.

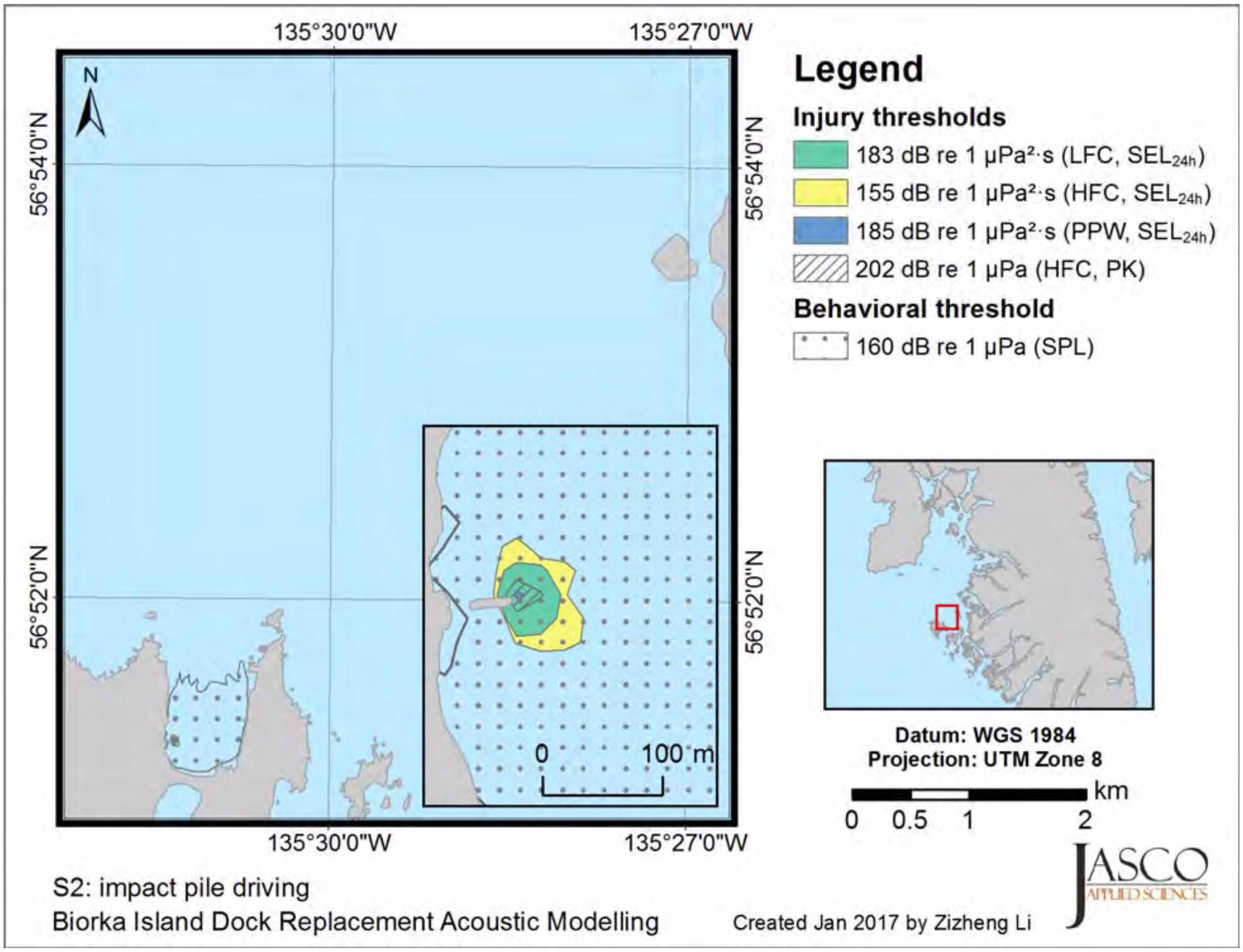

Figure B-3. Thresholds to selected impact criteria for impulsive sources in the modeling Scenario S2. The inset shows a close-up of sound fields around the pile location.

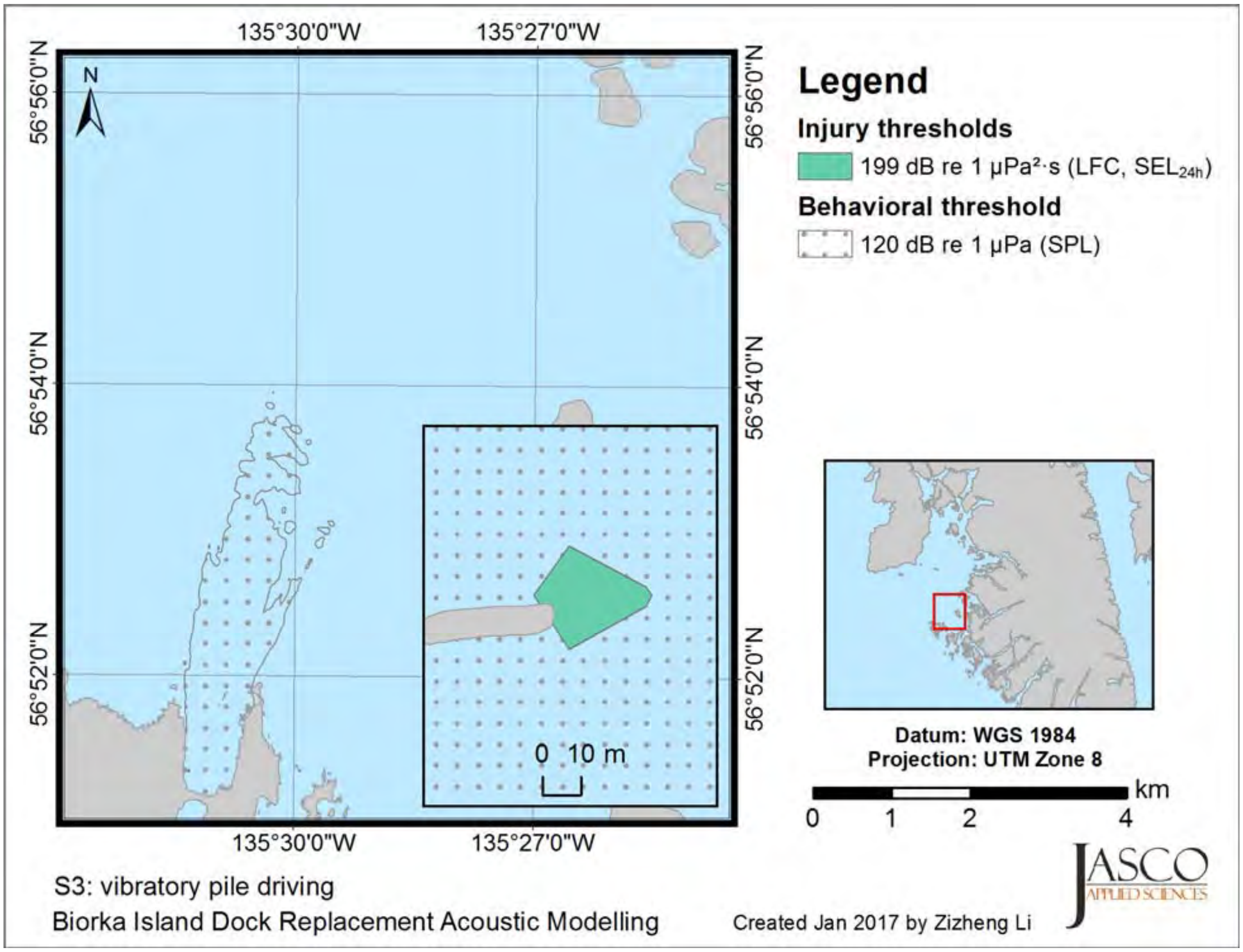

Figure B-4. Thresholds to selected impact criteria for non-impulsive sources in the modeling Scenario S3. The inset shows a close-up of sound fields around the pile location.

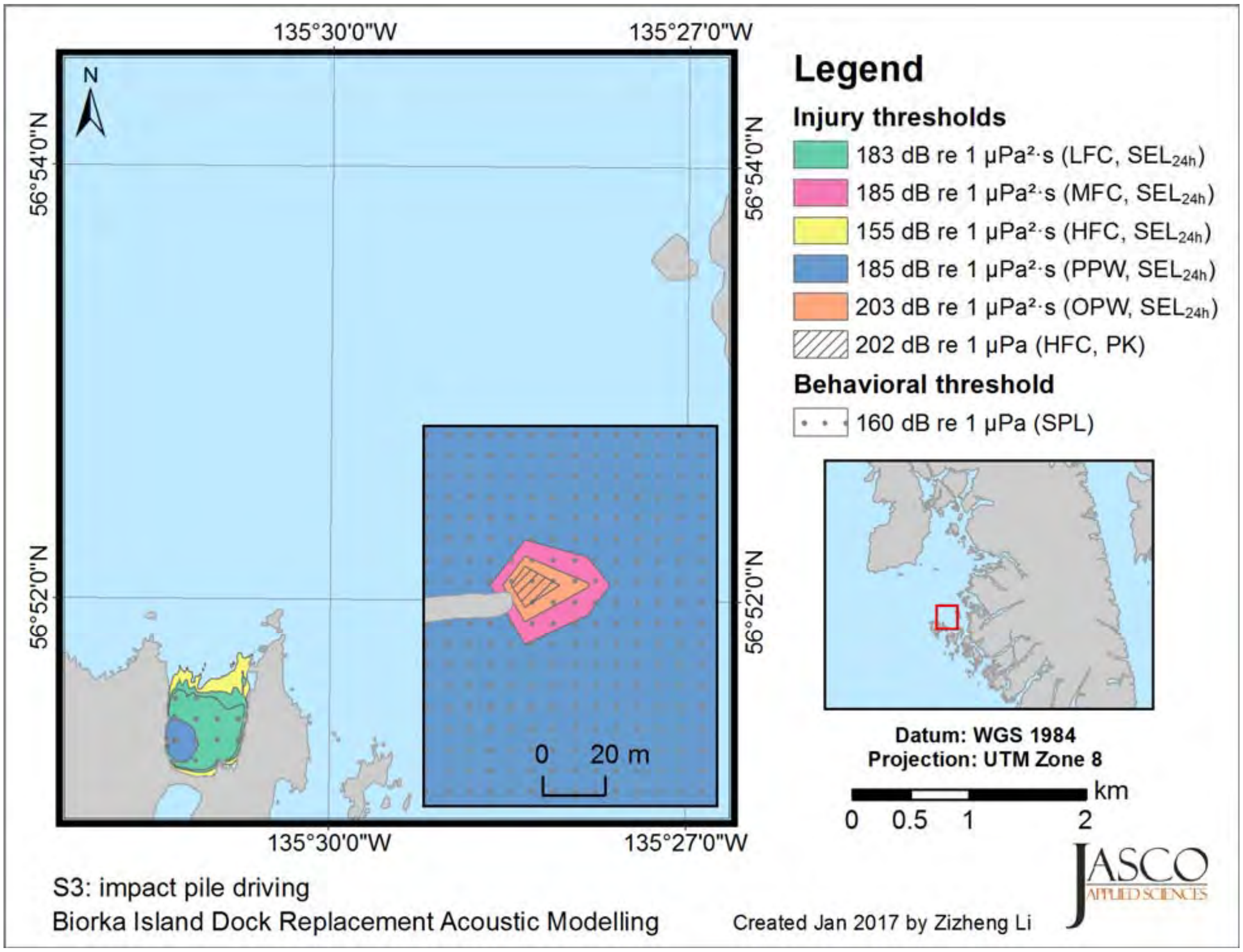

Figure B-5. Thresholds to selected impact criteria for impulsive sources in the modeling Scenario S3. The inset shows a close-up of sound fields around the pile location.

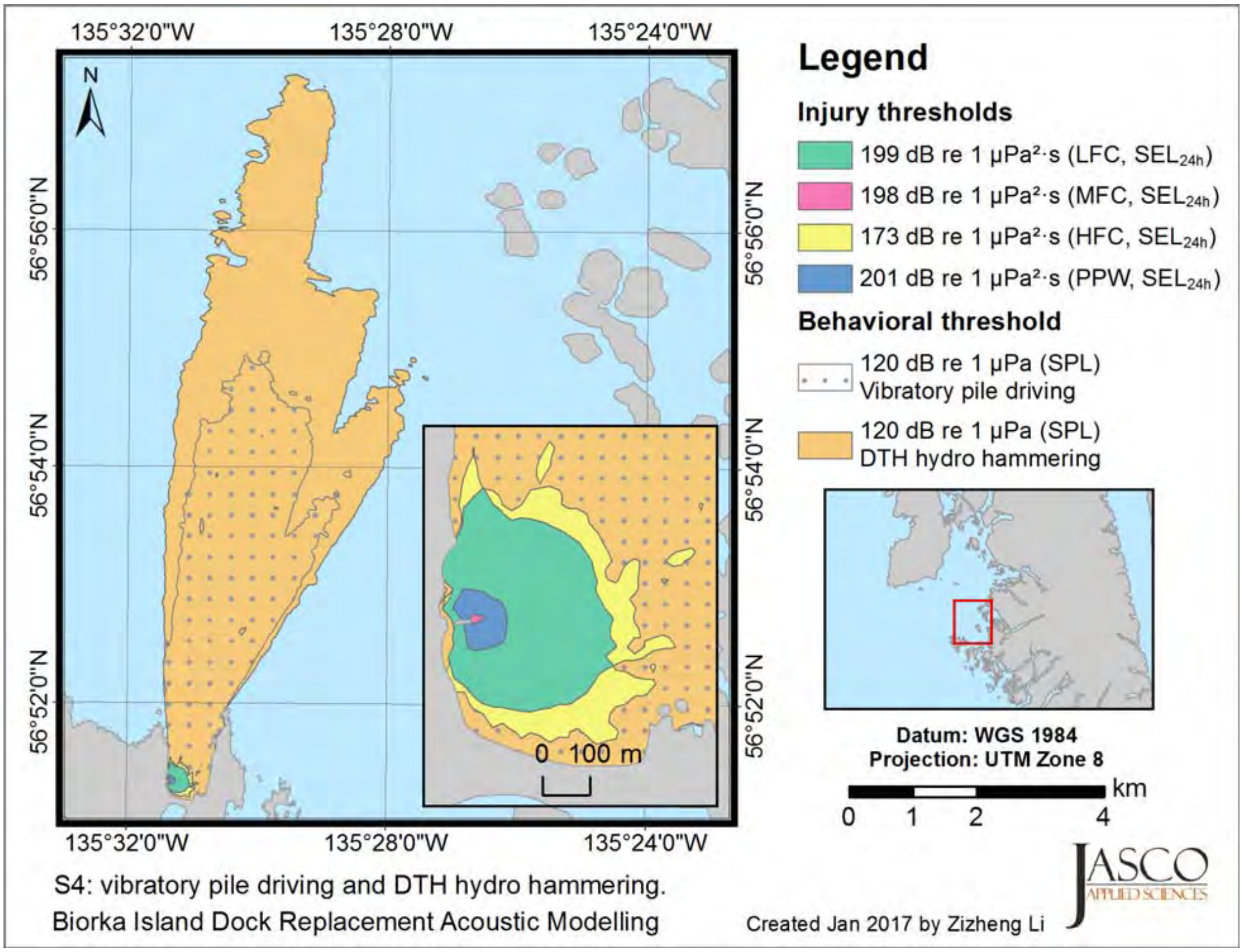

Figure B-6. Thresholds to selected impact criteria for non-impulsive sources in the modeling Scenario S4. The inset shows a close-up of sound fields around the pile location.

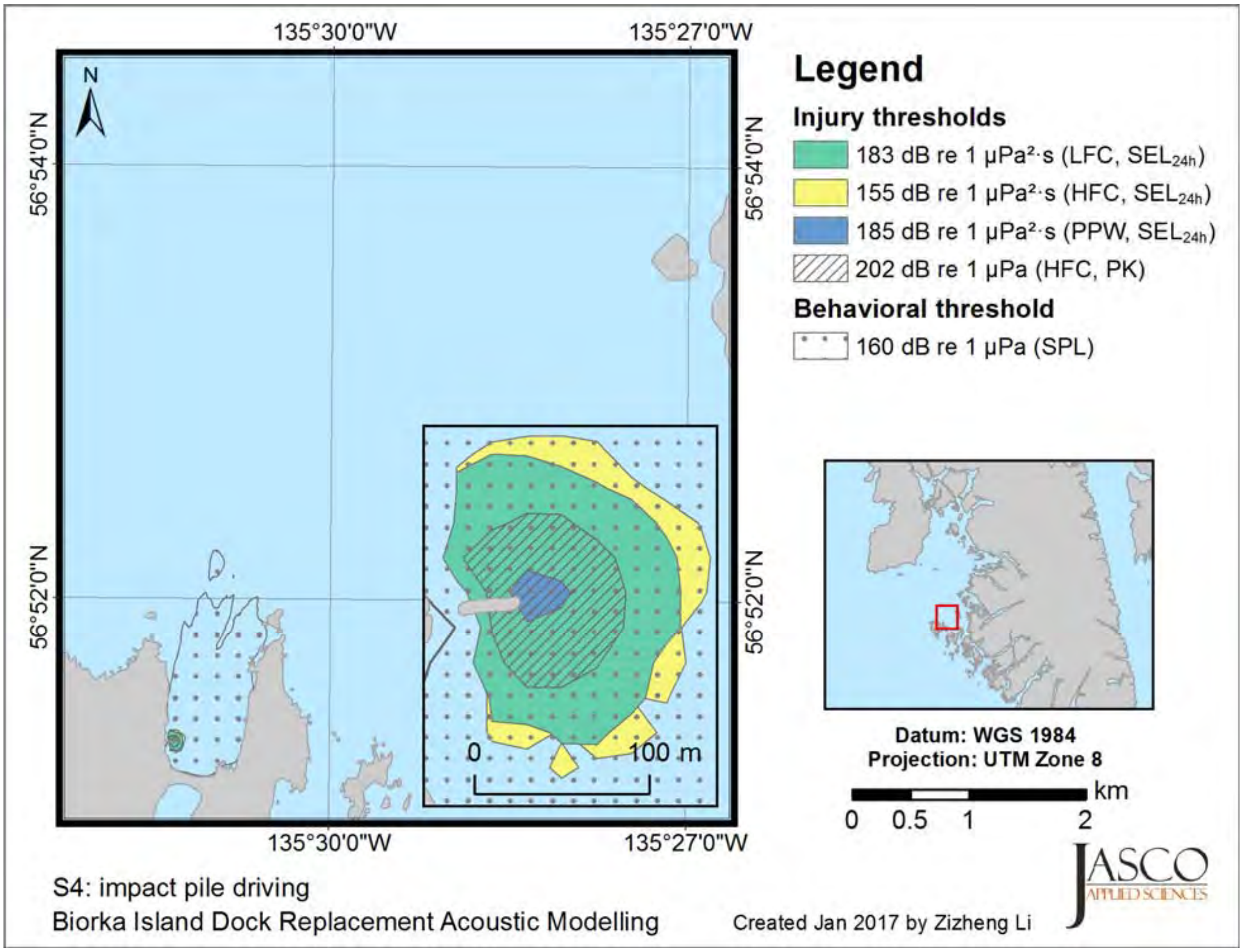

Figure B-7. Thresholds to selected impact criteria for impulsive sources in the modeling Scenario S4. The inset shows a close-up of sound fields around the pile location.

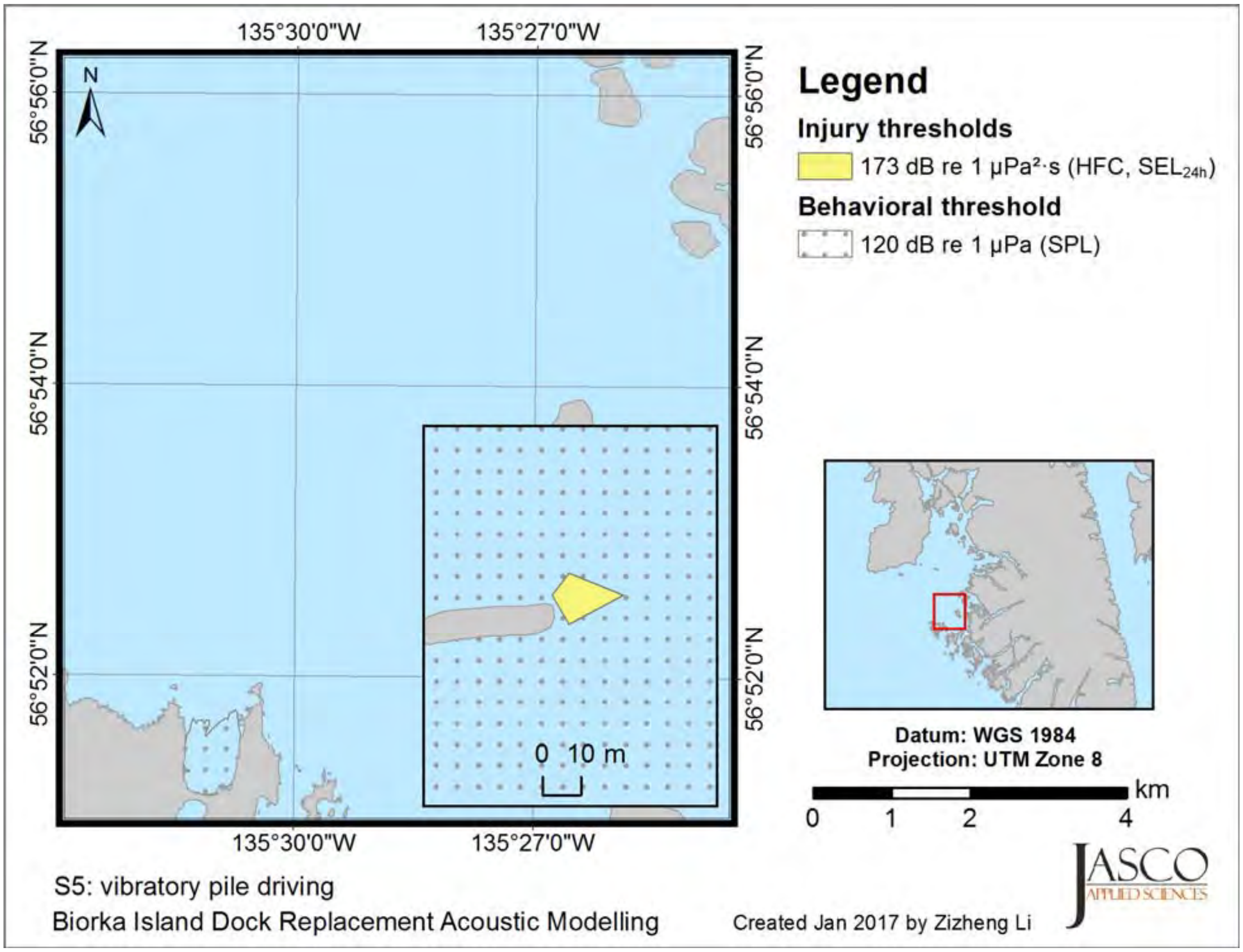

Figure B-8. Thresholds to selected impact criteria for non-impulsive sources in the modeling Scenario S5. The inset shows a close-up of sound fields around the pile location.

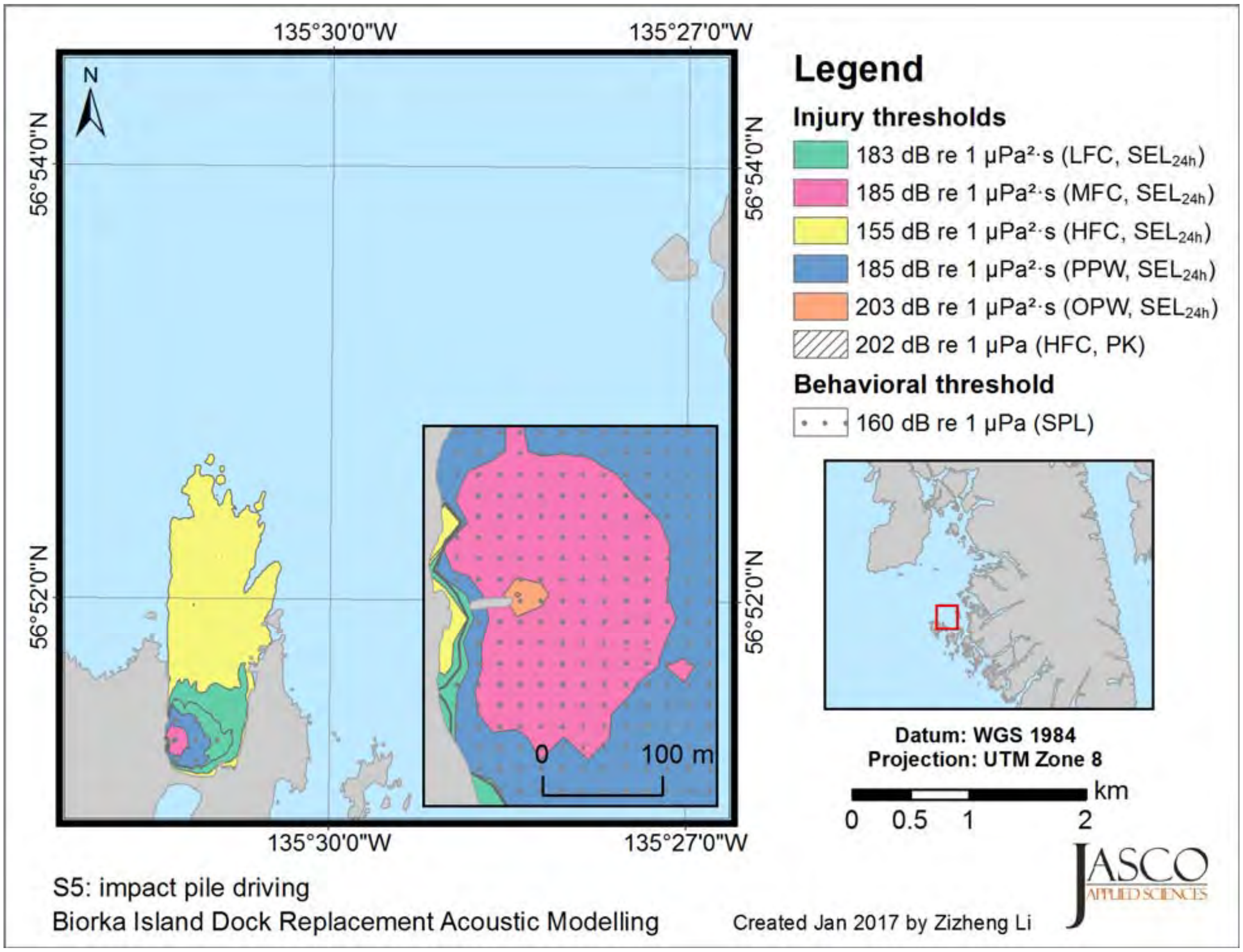

Figure B-9. Thresholds to selected impact criteria for impulsive sources in the modeling Scenario S5. The inset shows a close-up of sound fields around the pile location.

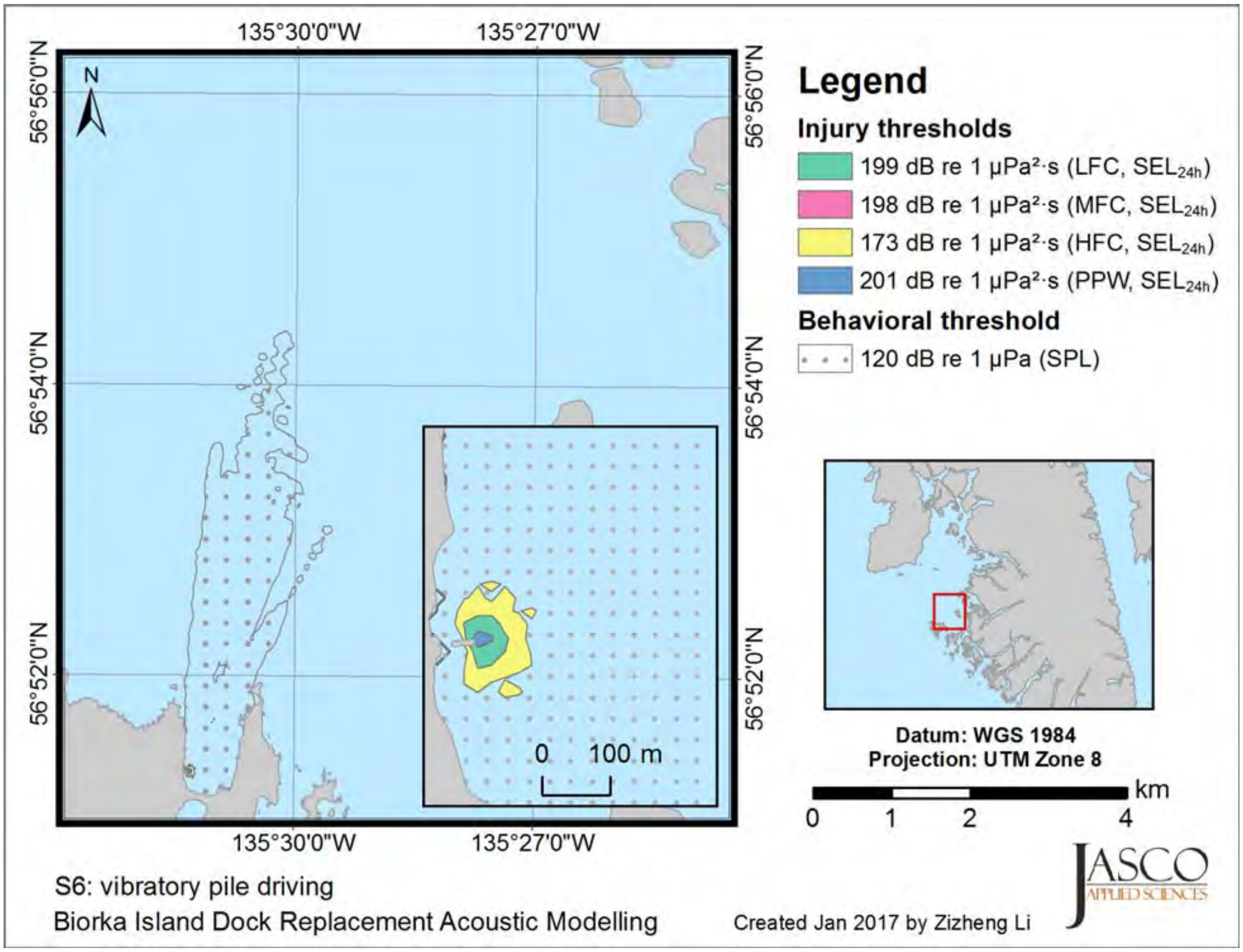

Figure B-10. Thresholds to selected impact criteria for non-impulsive sources in the modeling Scenario S6. The inset shows a close-up of sound fields around the pile location.

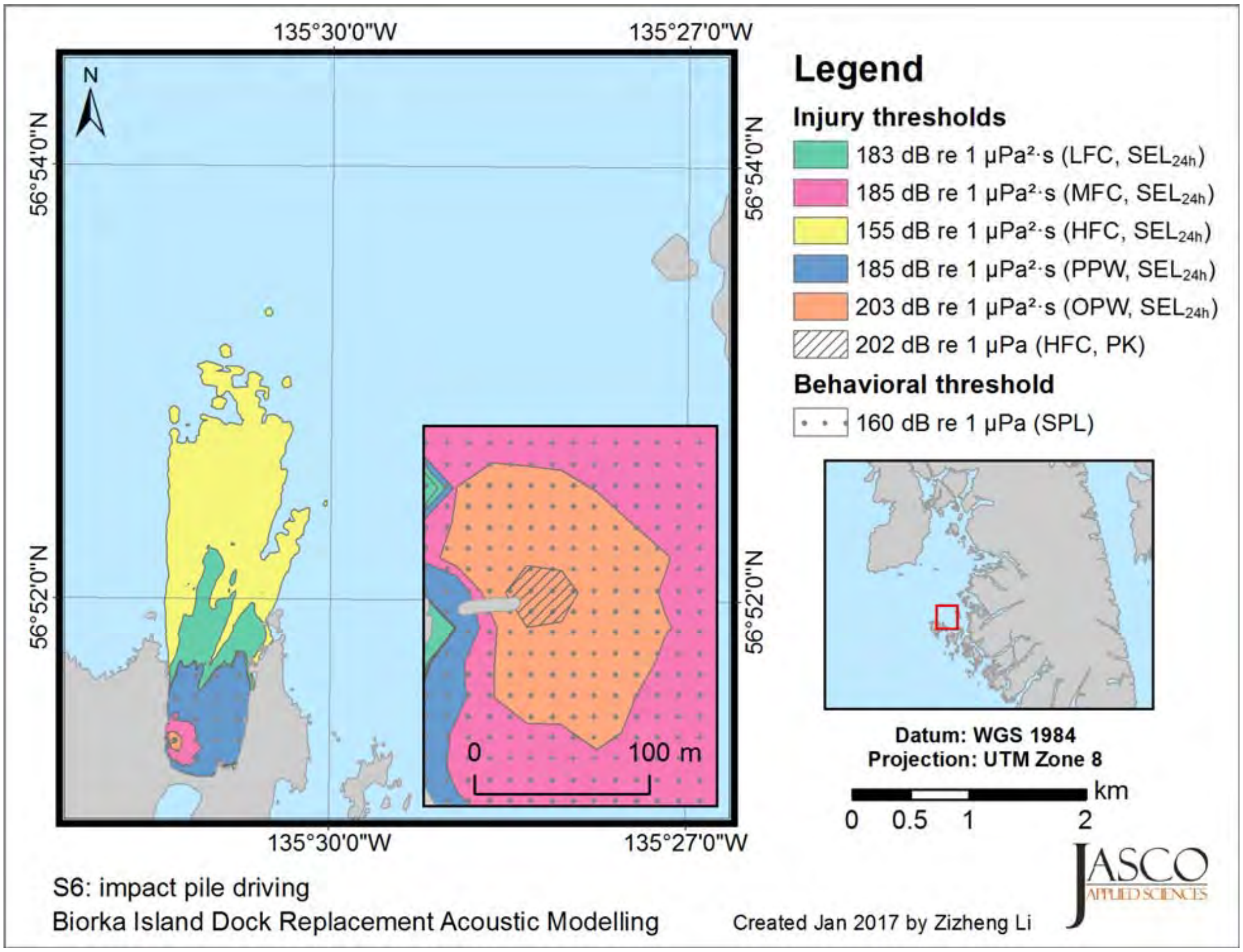

Figure B-11. Thresholds to selected impact criteria for impulsive sources in the modeling Scenario S6. The inset shows a close-up of sound fields around the pile location.